

Periphytic algal flora of the low Doce river, Espírito Santo State, Brazil, after ore tailings flow, 2: ornamented cell-wall *Cosmarium* (Zygnematophyceae, Desmidiaceae)¹

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ABSTRACT – (Periphytic algal flora of the bow Doce river, Espírito Santo State, Brazil, after ore tailings flow, 2: ornamented cell-wall *Cosmarium* (Zygnematophyceae, Desmidiaceae). Present study aimed at carrying out the taxonomic survey of the ornamented cell-wall *Cosmaria* from the low Doce river region, Espírito Santo State. Material studied was collected between months October 2018 and February 2020. Thirty-three taxa were identified, from which 32 are new additions to the Espírito Santo State desmid flora, five are new records for Brazil (*C. blyttii* cf. var. *basior natum*, *C. cf. dentiferum*, *C. monomazum* var. *polymazum*, *C. sphagnicola* var. *pachygonum*, and *C. subcostatum* var. *subcostatum*), and one for South America (*C. isthmochondrum* cf. var. *biseriatum*). Present study increased the knowledge on the genus *Cosmarium* in Espírito Santo State by adding both taxonomic and ecological information.

Keywords: algae, desmids, periphyton, taxonomy

RESUMO – (Ficoflórula perifítica do baixo rio Doce, Espírito Santo, Brasil, após o fluxo de rejeitos de minério, 2: *Cosmarium* de parede celular ornamentada (Zygnematophyceae, Desmidiaceae). O estudo objetivou realizar o levantamento taxonômico dos *Cosmarium* com parede celular ornamentada coletados na região do baixo rio Doce, Estado do Espírito Santo. O material foi coletado durante os meses outubro de 2018 e fevereiro de 2020. Trinta e três táxons entre espécies e variedades taxonômicas foram identificados, dos quais 32 são adições para a desmidioflórula do Estado do Espírito Santo, dos quais cinco são registros pioneiros para o Brasil (*C. blyttii* cf. var. *basior natum*, *C. cf. dentiferum*, *C. monomazum* var. *polymazum*, *C. sphagnicola* var. *pachygonum* e *C. subcostatum* var. *subcostatum*) e um para a América do Sul (*C. isthmochondrum* cf. var. *biseriatum*). O estudo aumentou o conhecimento sobre o gênero *Cosmarium* no Estado do Espírito Santo a partir de informação taxonômica e ecológica.

Palavras-chave: algas, desmídias, perifíton, taxonomia

Introduction

Brazilian desmids have been investigated since the 19th century (Ramos *et al.* 2021, Bicudo *et al.* 2014). Such studies are not, however, equally distributed throughout the country,

but concentrated in its southeast region, and mostly in the State of São Paulo. Among this region States, Espírito Santo certainly is the most neglected in terms of desmids floristic studies, which are represented to date only by two taxonomic surveys (Delazari-Barroso *et al.* 2007, Fadul-Souza *et al.*

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2022). Knowledge of aquatic biodiversity in that State is still worse when one considers that it has been under anthropogenic impacts for decades (Barroso *et al.* 2012) and, more recently by a massive 43 million cubic meters of ore tailings discharge on the important watershed, and that the Doce river basin is located in the Atlantic Forest biome, a Brazilian hotspot area. Considering that the freshwater habitats are extremely important for the society by being one of the most important natural resources on Earth (Shetty & Gulimane 2022), and that desmids are key organisms for water quality evaluation and biomonitoring studies (Coesel 2001, Shetty & Gulimane 2022), it becomes eloquent that floristic studies are important for environmental conservation efforts, especially in historically degraded areas.

Present study aimed at carrying out a taxonomic survey of the *Cosmarium* taxa with ornamented cell wall from the Low Doce river region three years after some ore tailings input and including some ecological data about each species in order to contribute to the knowledge on the desmids from the Espírito Santo State. This study is the second one of the series “Periphytic algal flora of the low Doce river”.

Material and methods

Details on the study area and the sampling design are in Zorzal-Almeida *et al.* (2021). Material studied was observed and photographed using, respectively, a binocular microscope and a portable digital camera. Specimens were investigated to recognize the important taxonomic features used for the taxonomic identification of the ornamented cell wall *Cosmarium*, such as granules, denticles, punctuations, and scrobicules. Furthermore, measurements of the cell such as length (L), width (W) and isthmus breadth (I) were taken using the Motic Image Plus 3.0 software. Specimens identifications were based on the specialized literature (*e.g.* Ralfs 1848, Scott & Grönblad 1957, Förster 1964, Krieger & Gerloff 1965, Ramos *et al.* 2018, Bicudo *et al.* 2019). First records of occurrence in Espírito Santo State are marked with one asterisk [*] and the ones for Brazil with double asterisk [**].

Results and discussion

Thirty-three cell wall ornamented *Cosmarium* taxa were identified in the present study. Thirty-two are cited for the first time for the Espírito Santo State, five for Brazil, and one for South America. Complete list of taxa identified, their geographical distribution in the area studied and environmental preferences are in Table 1.

* *Cosmarium amoenum* Brébisson *ex* Ralfs *cf. var. constrictum* A.M.Scott & Grönblad, Acta Societatis Scientiarum Fennicae 2(8): 15, pl. 5, fig. 18. 1957.

Figures 1, 2

Cell ca. 1.6 times longer than broad, median constriction deep, sinus closed, linear; semicells subsemicircular, apex

rounded, basal and apical angles rounded; cell wall granulate, granules in horizontal series; chloroplasts and pyrenoid not observed. L: c. 42.5 µm; W: c. 27.2 µm; I: c. 9.8 µm.

Notes: According to Scott & Grönblad (1957), *Cosmarium amoenum* var. *constrictum* differs from the nominate variety in having broader and deep linear sinus, basal granules sometimes arranged in a double row, and less pronounced granules at the semicell central area.

Present material was found living in lentic environment, under eutrophic and alkaline conditions.

Material examined: BRDE19A14.

* *Cosmarium binum* Nordstedt, Algae aquae dulcis exsiccatae 21: 39. 1880.

Figures 3-5

Cells 1.3-1.5 times longer than broad, median constriction deep, sinus closed, linear; semicells subsemicircular, apex round to slightly truncate, basal and apical angles rounded; cell wall granulate, double granules in 3-4 concentric series close to the margins, 1 horizontal series with 7 granules just above the sinus; chloroplasts 2, pyrenoids 2; semicell apical view elliptical, inflated at the mid region; side view not observed. L: 37.1-51.2 µm; W: 26-38.3 µm; I: 9.9-12 µm.

Notes: According to Bicudo *et al.* (2019), *Cosmarium binum* is morphologically similar to *C. subspeciosum* Nordstedt, but the latter is different in having truncate-pyramidal semicells, simple granules, and smaller cell dimensions.

Present material was found in lotic environments, under ultraoligotrophic to eutrophic and circumneutral to alkaline conditions.

Material examined: BRDE26A01 BRDE22A04, BRDE26A05, BRDE21A06, BRDE22A05, BRDE00A07, BRDE21A07, BRDE00A08, BRDE21A08, BRDE22A07, BRDE17A09, BRDE21A09, BRDE26A09, BRDE19A09, BRDE00A10, BRDE21A10, BRDE22A09, BRDE26A10, BRDE17A11, BRDE00A11, BRDE21A11, BRDE22A10, BRDE26A11, BRDE26A12, BRDE24A11, BRDE22A12, BRDE26A13, BRDE22A14, BRDE26A15, BRDE21A16.

** *Cosmarium blyttii* Wille *cf. var. basiornatum* C-C.

Jaø, Botanical Bulletin of Academia Sinica 3: 48, pl. 2, fig. 15. 1949.

Figures 6, 7

Cells as broad as long to 1.2-1.3 times longer than broad, median constriction deep, sinus closed, linear; semicells trapezoidal, apex truncate, margins crenate, 10-12 crenations along the semicell margin, each with 2 divergent small granules; cell wall granulate, granules arranged in 3 concentric series, 1 horizontal series of granules just above the isthmus; chloroplast 1, pyrenoid 1; semicell lateral view elliptical, 1 median swelling. L: 16.6-29.2 µm; W: 17.2-26.8 µm; I: 6.5-8.9 µm.

Table 1. Distribution, frequency occurrence and environmental conditions of the ornamented *Cosmarium* taxa in low Doce river, Espírito Santo State, Brazil. RF: relative frequency. C: categorization – R: rare. LF: little frequent. Trophic State – ult: ultraoligotrophic, oli: oligotrophic, mes: mesotrophic, eu: eutrophic, sup: supereutrophic, hyp: hypereutrophic, ac: acid, neu: circumneutral, alk: alkaline. Fe: total iron.

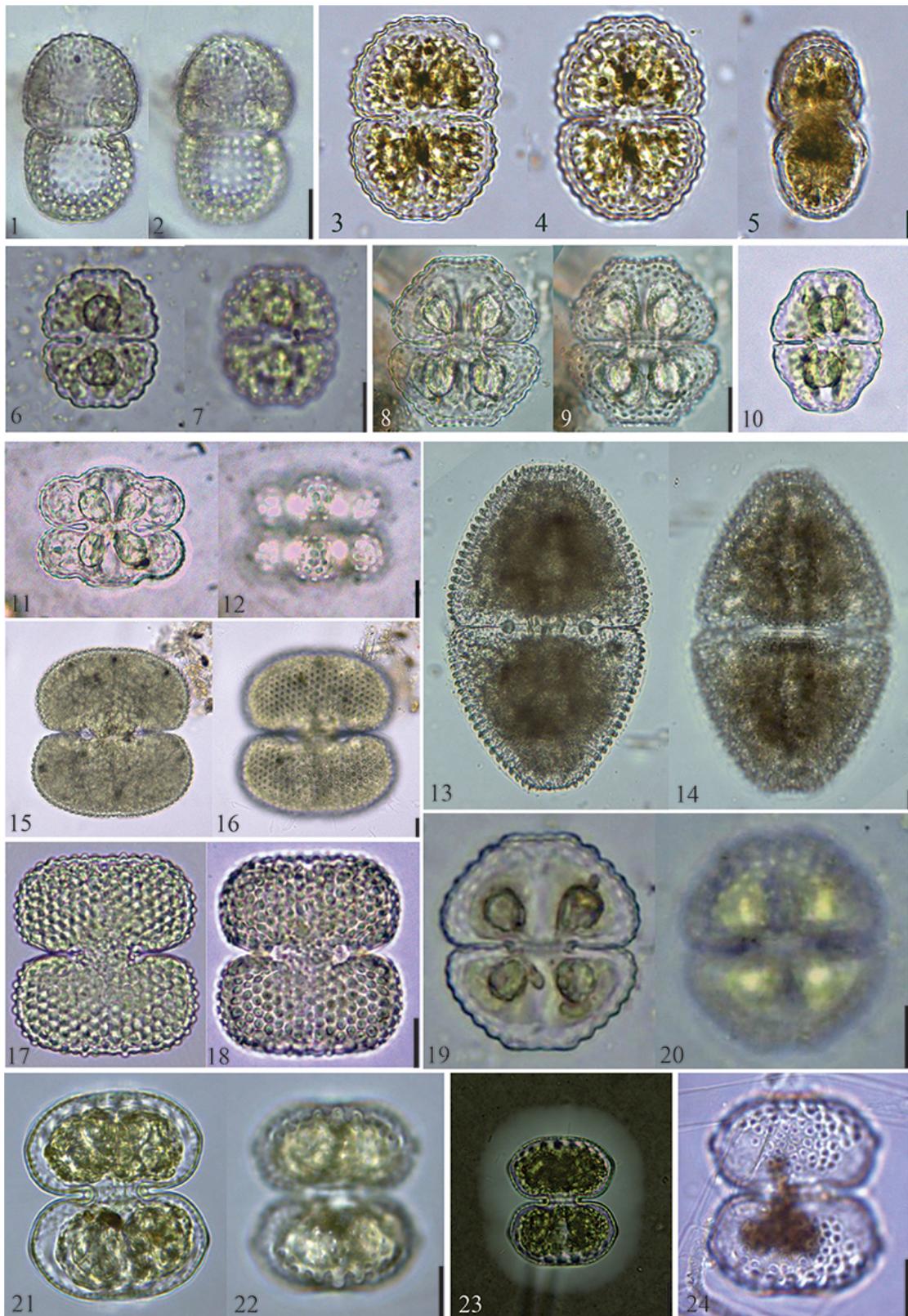
Taxa	Rivers		Lagoons			Lakes		Frequency		Environmental Conditions			
	Doce	Guandu	Areal	Areão	Monsarás	Limão	Nova	Juparanã	RF (%)	C	Trophic State	pH	Fe (mg L-1)
<i>Cosmarium amoenum</i> cf. var. <i>constrictum</i> A.M.Scott & Grönblad	-	-	-	-	-	-	x	-	0.4	R	eu	alk	0.5
<i>Cosmarium binum</i> Nordstedt	x	x	x	-	-	-	-	-	23.3	LF	ult-eu	neu-alk	0.1-5.8
<i>Cosmarium blyttii</i> cf. var. <i>basiornatum</i> C.-C.Jao	x	x	-	x	x	x	x	x	29.0	LF	ult-eu	ac-alk	0.2-4.9
<i>Cosmarium</i> cf. <i>botrytis</i> Meneghini ex Ralfs	x	-	-	-	-	-	-	-	0.4	R	mes	alk	1.6
<i>Cosmarium</i> cf. <i>columbianum</i> G.S.West	-	-	-	-	-	x	-	-	1.5	R	oli-eu	neu-alk	0.6-1.3
<i>Cosmarium</i> <i>commissurale</i> var. <i>crassum</i> Nordstedt	-	-	-	-	-	x	-	-	0.4	R	mes	neu	0.8
<i>Cosmarium</i> <i>denticulatum</i> var. <i>ovale</i> Grönblad	x	-	-	-	-	x	x	-	1.1	R	oli-mes	neu-alk	0.1-2.7
<i>Cosmarium</i> cf. <i>dentiferum</i> Corda ex Nordstedt	-	-	-	-	-	x	-	-	0.4	R	mes	alk	0.7
<i>Cosmarium</i> cf. <i>favum</i> West & G.S.West	-	-	-	-	-	x	-	-	0.4	R	mes	alk	0.7
<i>Cosmarium</i> <i>formosulum</i> Hoffman	x	x	-	-	x	x	x	-	13.4	LF	ult-eu	ac-alk	0.1-3.7
<i>Cosmarium</i> <i>hexagonum</i> Nordstedt	-	-	-	-	x	x	-	-	2.3	R	oli-eu	neu-alk	0.6-3.4

Table 1 (continued)

Taxa	Rivers		Lagoons			Lakes			Frequency		Environmental Conditions		
	Doce	Guandu	Areal	Areão	Monsarás	Limão	Nova	Juparanã	RF (%)	C	Trophic State	pH	Fe (mg L-1)
<i>Cosmarium isthmochondrum</i> cf. var. <i>biseriatum</i> West & G.S.West	-	-	-	-	x	x	x	x	9.5	R	oli-sup	ac-alk	0.01-3.4
<i>Cosmarium lagoense</i> (Nordstedt) Nordstedt	-	-	-	-	-	x	-	-	0.8	R	mes	neu-alk	0.6-0.8
<i>Cosmarium margaritatum</i> (P.Lundell) J.Roy & Bisset	-	-	-	-	x	x	x	-	2.3	R	mes-eu	neu-alk	0.6-1.3
<i>Cosmarium monomazum</i> var. <i>polymazum</i> Nordstedt	-	-	-	-	-	x	-	-	1.9	R	oli-eu	alk	0.6-1.3
<i>Cosmarium</i> cf. <i>obtusatum</i> (Schmidle) Schmidle	x	-	-	-	x	-	-	-	0.8	R	mes-sup	alk	1.3-2.1
<i>Cosmarium porteanum</i> var. <i>nephroideum</i> Wittrock	-	-	-	-	-	x	-	-	1.1	R	oli-eu	neu-alk	0.7-1.3
<i>Cosmarium porteanum</i> W.Archer var. <i>porteanum</i>	-	-	x	-	-	x	x	-	6.1	R	oli-sup	ac-alk	0.4-3.0
<i>Cosmarium pseudobroomei</i> Wolle var. <i>pseudobroomei</i>	x	-	x	-	x	x	x	-	12.6	LF	oli-eu	ac-alk	0.1-4.1
<i>Cosmarium quadrum</i> P.Lundell var. <i>quadrum</i>	x	x	-	-	-	-	-	-	12.2	LF	ult-eu	neu-alk	0.9-3.1
<i>Cosmarium quadrum</i> var. <i>sublatum</i> (Nordstedt) West & G.S.West	x	x	-	-	-	-	-	-	4.2	R	ult-eu	neu-alk	1.7-3.4

Table 1 (continued)

Taxa	Rivers		Lagoons			Lakes			Frequency		Environmental Conditions		
	Doce	Guandu	Areal	Areão	Monsarás	Limão	Nova	Juparanã	RF (%)	C	Trophic State	pH	Fe (mg L-1)
<i>Cosmarium regnesi</i> Reinsch	x	-	-	-	x	-	-	-	0.8	R	mes-eu	alk	2.7-4.9
<i>Cosmarium reniforme</i> var. <i>reniforme</i> (Ralfs) W.Archer	x	x	x	-	x	x	x	-	15.6	LF	ult-sup	ac-alk	0.1-3.1
<i>Cosmarium scabrum</i> W.B.Turner	-	-	-	-	-	x	-	-	1.5	R	mes	ac-alk	0.4-2.3
<i>Cosmarium scrobiculosum</i> O.Borge	x	-	-	-	x	x	-	-	4.6	R	oli-sup	ac-alk	0.4-3.4
<i>Cosmarium sphagnicola</i> var. <i>pachygonum</i> Skuja	x	-	x	-	x	x	x	-	2.3	R	oli-eu	neu-alk	0.7-3.8
<i>Cosmarium subcostatum</i> Nordstedt var. <i>subcostatum</i>	-	x	-	-	-	-	-	x	1.1	R	mes-eu	alk	0.5-3.6
<i>Cosmarium subhammeri</i> var. <i>italicum</i> Grönblad	-	-	x	-	-	x	x	-	2.7	R	mes-sup	ac-alk	0.2-2.9
<i>Cosmarium subspeciosum</i> Nordstedt	x	x	-	-	-	-	-	-	1.9	R	mes	alk	1.6-2.6
<i>Cosmarium vitiosum</i> A.M.Scott & Grönblad	-	-	-	-	-	x	-	-	1.5	R	oli-eu	ac-alk	0.4-1.3
<i>Cosmarium</i> sp.1	x	-	-	-	-	-	-	-	0.8	R	oli-eu	alk	2.1-2.4
<i>Cosmarium</i> sp.2	-	-	-	-	-	x	-	-	0.4	R	eu	alk	0.6



Figures 1, 2. *Cosmarium amoenum* cf. var. *constrictum* A.M.Scott & Grönblad; 3-5. *Cosmarium binum* Nordstedt; 6-7. *Cosmarium blyttii* cf. var. *basiornatum* C.-C.Jao; 8, 9. *Cosmarium* cf. *botrytis* Meneghini ex Ralfs; 10. *Cosmarium* cf. *columbianum* G.S.West; 11, 12. *Cosmarium commissurale* var. *crassum* Nordstedt; 13, 14. *Cosmarium denticulatum* var. *ovale* Grönblad; 15, 16. *Cosmarium* cf. *dentiferum* Corda ex Nordstedt; 17, 18. *Cosmarium* cf. *favum* West & G.S.West; 19, 20. *Cosmarium formosulum* Hoffman; 21-24. *Cosmarium hexagonum* Nordstedt. Scale bar = 10 µm.

Notes: *Cosmarium blyttii* var. *basior natum* differs from the type variety in having one horizontal series of granules just above the isthmus. This is the first record of the occurrence of the variety in Brazil.

Material studied was gathered from lentic and lotic environments, under ultraoligotrophic to eutrophic and acid to alkaline conditions.

Material examined: BRDE17A01, BRDE00A01, BRDE19A01, BRDE21A02, BRDE17A04, BRDE00A04, BRDE21A05, BRDE22A04, BRDE26A05, BRDE25A09, BRDE00A06, BRDE21A06, BRDE22A05, BRDE26A06, BRDE17A07, BRDE00A07, BRDE21A07, BRDE22A06, BRDE26A07, BRDE17A08, BRDE00A08, BRDE21A08, BRDE22A07, BRDE20A08, BRDE17A09, BRDE00A09, BRDE21A09, BRDE22A08, BRDE26A09, BRDE17A10, BRDE00A10, BRDE21A10, BRDE22A09, BRDE26A10, BRDE18A10, BRDE17A11, BRDE00A11, BRDE21A11, BRDE22A10, BRDE26A11, BRDE17A12, BRDE22A11, BRDE26A12, BRDE23A11, BRDE25A24, BRDE22A12, BRDE17A14, BRDE26A14, BRDE17A15, BRDE00A15, BRDE21A15, BRDE22A14, BRDE26A15, BRDE17A16, BRDE00A16.

* *Cosmarium* cf. *botrytis* Meneghini ex Ralfs, British Desmids. 99, pl. 16, fig. 1. 1848.
Figures 8, 9

Cells 1.1-1.2 times longer than broad, median constriction deep, sinus closed, linear; semicells trapezoidal, apex retuse, lateral margins crenate, granulate, basal and apical angles rounded; cell wall granulate, granules in 5 concentric series, except for above the isthmus where they are in a single horizontal series, mid region with sparse granules; chloroplasts 2, pyrenoids 2. L: 40-52.3 μm ; W: 42.8-44.2 μm ; I: 13.5-14.8 μm .

The species occurred in a lotic system, under mesotrophic and alkaline conditions.

Material examined: BRDE22A10.

* *Cosmarium* cf. *columbianum* G.S.West, Mémoires de la Société des Sciences Naturelles de Neuchâtel 5(2): 1036, pl. 23, fig. 68, 69. 1914.
Figure 10

Cells c. 1.3 times longer than broad, median constriction deep, sinus closed, linear; semicells subtrapezoidal, apex truncate, upper lateral margins slightly convex, lower lateral margins granulate, apical and basal angles rounded; cell wall punctate, granulate, sparse granules near the basal angles, 4 larger subapical granules; chloroplasts 2, pyrenoids 2. L: 26-30 μm ; W: 19.8-23.3 μm ; I: 5.7-6.5 μm .

Notes: *Cosmarium columbianum* G.S.West and *C. corumbense* Borge are very similar species, a revision of

these species being absolutely needed due to the difficulty in differing them. Ramos *et al.* (2021) commented that *C. corumbense* differs from *C. columbianum* by having the cell lower lateral sides with few granules and granules in the apical view arranged along the margins, not in a circle as in *C. columbianum*.

Cosmarium cf. *columbianum* was found in a lentic environment, under oligotrophic to eutrophic and circumneutral to alkaline conditions.

Material examined: BRDE18A11, BRDE18A13, BRDE18A14, BRDE18A16.

* *Cosmarium commissurale* Brébisson ex Ralfs var. *crassum* Nordstedt, Videnskabelige Meddelelser fra Dansk naturhistorisk forening i København 21(14-15): 213, pl. 3, fig. 19. 1870.

Figures 11, 12

Cell ca. 1.2 times broader than long, median constriction deep, sinus open, U-shaped close to the isthmus, linear at the apex; semicells elliptical, apex truncate, slightly protuberant; cell wall granulate, granules in concentric series; chloroplasts with 2 pyrenoids. L: c. 22.4 μm ; W: c. 26.2 μm ; I: c. 8.5 μm .

Notes: According to Felisberto & Rodrigues (2004), this variety resemble *Cosmarium ornatum* Ralfs ex Ralfs, but the latter differs by having a linear sinus at the apex, and the cell wall a parallel series of granules.

This variety was recorded from a lentic environment, under mesotrophic and circumneutral conditions.

Material examined: BRDE18A04.

* *Cosmarium denticulatum* O.Borge var. *ovale* Grönblad, Acta Societatis Scientiarum Fennicae, ser. B, 2(6): 17, pl. 5, fig. 98-100, 103. 1945.

Figures 13, 14

Cell ca. 1.7 times longer than broad, median constriction deep, sinus closed, linear; semicells oval-pyramidate, apex rounded, basal angles rounded; cell wall granulate, granules approximately spine-shaped, in concentric series near the margins and above the sinus; chloroplasts 2, pyrenoid not observed. L: c. 160 μm ; W: c. 95 μm ; I: c. 33 μm .

Notes: *Cosmarium denticulatum* var. *ovale* differs from the typical variety in having oval-pyramidate semicells and rounded apex.

This variety was recorded in lentic and lotic environments, under oligotrophic to mesotrophic and circumneutral to alkaline conditions.

Material examined: BRDE21A03, BRDE19A09, BRDE18A13.

** *Cosmarium cf. dentiferum* Corda ex Nordstedt, Videnskabelige Meddelelser Dansk Naturhistorisk Forening 1888: 192, pl. 6, fig. 4, 5. 1888.

Figures 15, 16

Cell ca. 1.1 times longer than broad, median constriction deep, sinus V-shaped, closed near the isthmus; semicells subelliptical, apex slight truncate, lateral margins rounded, granulate, apical and basal angles rounded; cell wall granulate, granules in 16 obliquely decussating series; chloroplasts 2, pyrenoid not observed. L: c. 76.9 μm ; W: c. 71.2 μm ; I: c. 19 μm .

Notes: Present material was smaller than the ones described by West & West (1908: length 92-104 μm , breadth 89-100 μm , breadth of isthmus 28-37 μm), but matched the description of the present species in all other morphological features, such as the arrangement and number of granules along the margins.

Present material occurred in a lentic environment, under mesotrophic and alkaline conditions.

Material examined: BRDE18A13.

* *Cosmarium favum* West & G.S. West, Transactions of the Linnean Society of London, bot. 2, 5(5): 250, pl. 15, fig. 5, 6. 1896.

Figures 17, 18

Cell ca. 1.1 times longer than broad, median constriction deep, sinus open, V-shaped; semicells subrectangular, apex slightly truncate, lateral margins rounded, granulate, apical and basal angles rounded; cell wall granulate, granules in obliquely decussating series, each granule surrounded by 6 punctae; chloroplasts 2, pyrenoid not observed. L: c. 44 μm ; W: c. 40 μm ; I: c. 14 μm .

Notes: The main diagnostic feature of *Cosmarium favum* is its pattern of punctuations round each granule, which forms a hexagon (Bicudo *et al.* 2019). The specimen currently examined has a V-shaped open sinus that was not mentioned in the species original description, but all other features of the species matched adequately the current material.

The species was collected from a lentic environment, under mesotrophic and alkaline conditions.

Material examined: BRDE18A13.

* *Cosmarium formosulum* Hoff, Videnskabelige Meddelelser Naturhistorisk Forening i Kjøbenhavn 1888: 194, pl. 6, fig. 6, 7. 1888.

Figures 19, 20

Cells c. 1.1 times longer than broad to as long as broad, median constriction deep, sinus closed, linear; semicells

trapezoid, apex truncate, margins crenate, basal angles rounded; cell wall granulate, granules in concentric series close to the margins, midregion inflated, with granules arranged in a circle; chloroplasts 2, pyrenoids 2; semicell side view subcircular. L: 26.7-34 μm ; W: 24.7-33.2 μm ; I: 6.6-9.8 μm .

Notes: Current specimens were smaller when compared to those from the type material in Hoff (Nordstedt 1888: 40-50 x 34-40 μm), but all other species diacritic morphological features were present in our material. Furthermore, population of *C. formosulum* with smaller dimensions were also mentioned in other Brazilian floristic studies (Silva & Cecy 2004, Menezes *et al.* 2011, Bicudo *et al.* 2019).

Current specimens were gathered from lotic and lentic environments, under ultraoligotrophic to eutrophic and acid to alkaline conditions.

Material examined: BRDE21A01, BRDE26A01, BRDE22A01, BRDE22A02, BRDE22A04, BRDE18A05, BRDE00A06, BRDE22A05, BRDE26A06, BRDE26A07, BRDE19A08, BRDE21A09, BRDE22A08, BRDE00A10, BRDE22A09, BRDE17A11, BRDE00A11, BRDE21A11, BRDE22A10, BRDE25A24, BRDE22A12, BRDE26A13, BRDE18A13, BRDE22A13, BRDE26A14, BRDE18A14, BRDE22A14.

* *Cosmarium hexagonum* Nordstedt, Videnskabelige Meddelelser fra den naturhistoriske Forening i Kjøbenhavn 14-15: 208, pl. 3, fig. 18. 1870.

Figures 21-24

Cells c. 1.2 times longer than broad, median constriction deep, sinus open, linear; semicells elliptic-hexagonal, apex round or truncate, lateral margins with round papillae; cell wall scrobiculate, scrobicules varying from circular to triangular, irregularly distributed, single series of 6-8 large granules near the apex; chloroplasts 2, pyrenoids 2; mucilage little conspicuous; semicell lateral view circular. L: 33.3-38.3 μm ; W: 28.3-33.2 μm . I: 7.7-9 μm .

Notes: Population examined showed smaller individual specimens when compared to the type described by Nordstedt (1870: length 43-50 μm ; width 40-43 μm), but all other morphological features, such as hexagonally disposed scrobicules and subapical granules were present in the Espírito Santo material.

Present material was recorded in lentic environments, under oligotrophic to eutrophic and circumneutral to alkaline conditions.

Material examined: BRDE18A11, BRDE18A13, BRDE18A15, BRDE18A16, BRDE25A32.

**** *Cosmarium isthmochondrum* Nordstedt cf. var. *biseriatum* West & G.S.West**, Transactions of the Linnean Society of Botany 5(2): 63, pl. 7, fig. 14. 1895. Figures 25-27

Cells as long as broad to 1.2 times longer than broad, median constriction deep, sinus closed, linear; semicells oblong, apex round to truncate, lateral and basal margins rounded; cell wall granulate, 4 prominent subapical granules, smaller granules irregularly spread over the cell wall; chloroplasts 2, pyrenoids 2; semicell side view circular, apical view elliptical. L: 18.3-27.8 μm ; W: 16.8-23.5 μm ; I: 5.8-7.7 μm .

Notes: This variety differs from the typical by having smaller cell dimensions, narrower isthmus, semicells granulate at the margins, four granules within the margin and two smaller ones at the isthmus (West & West 1895). Current specimens had smaller dimensions when compared to the type in West & West (1895: length 23 μm ; width 20 μm ; isthmus 5-7 μm), but all other morphological features, such as granules arrangement and semicell shape fitted well with that material. The variety was previously recorded only from its type locality, Madagascar.

This taxon was presently recorded in lentic environments, under oligotrophic to hypertrophic and acid to alkaline conditions.

Material examined: BRDE18A01, BRDE25A02, BRDE18A02, BRDE18A03, BRDE18A04, BRDE20A05, BRDE19A07, BRDE20A07, BRDE18A08, BRDE18A09, BRDE25A18, BRDE18A10, BRDE25A20, BRDE18A11, BRDE20A11, BRDE25A24, BRDE18A13, BRDE25A26, BRDE18A14, BRDE25A28, BRDE20A15, BRDE25A29, BRDE18A16, BRDE19A16, BRDE25A32.

*** *Cosmarium lagoense* (Nordstedt) Nordstedt var. *amoebum* Kurt Förster & Eckert**, Hydrobiologia 23(3-4): 394, pl. 24, fig. 10-13. 1964. Figures 28, 29

Cells 1.1-1.2 times broader than long, median constriction deep, sinus open, U-shaped internally, closed externally; semicells oblong, apex inflated, with spines, lateral margins convex, with spines; cell wall granulate, spine-shaped granules forming a circle at the mid of semicells and near the margins; chloroplasts 2, pyrenoid not observed. L: 28.8-30.8 μm ; W: 34.3-35 μm ; I: 8.8-10.3 μm .

Notes: According to Bicudo *et al.* (2019), this variety differs from the typical in having larger dimensions, more

granules, longer spines at the margins, and one big granule right above the isthmus. Present Espírito Santo specimens were smaller when compared to the original description (Förster 1964: 44-60 x 52-63 μm without spines), however, other Brazilian floristic studies also observed specimens with smaller dimensions (Bicudo *et al.* 2019, Felisberto & Rodrigues 2004, 2010, Camargo *et al.* 2009, Oliveira *et al.* 2010, Estrela *et al.* 2011).

Present material was recorded in a lentic environment, under mesotrophic and circumneutral to alkaline conditions.

Material examined: BRDE18A04, BRDE18A15.

*** *Cosmarium margaritatum* (P.Lundell) J.Roy & Bisset**, Journal of Botany 24: 194. 1885. Figures 30, 31

Cells 1.1-1.3 times longer than broad, median constriction deep, sinus closed, linear; semicells subrectangular, apex truncate, apical and basal angles rounded, lateral margins granulate, straight to slightly convex; cell wall granulate, granules in oblique decussating series; chloroplasts 2, pyrenoids 2. L: 38.7-60.4 μm ; W: 33-50.2 μm ; I: 10.3-16.2 μm .

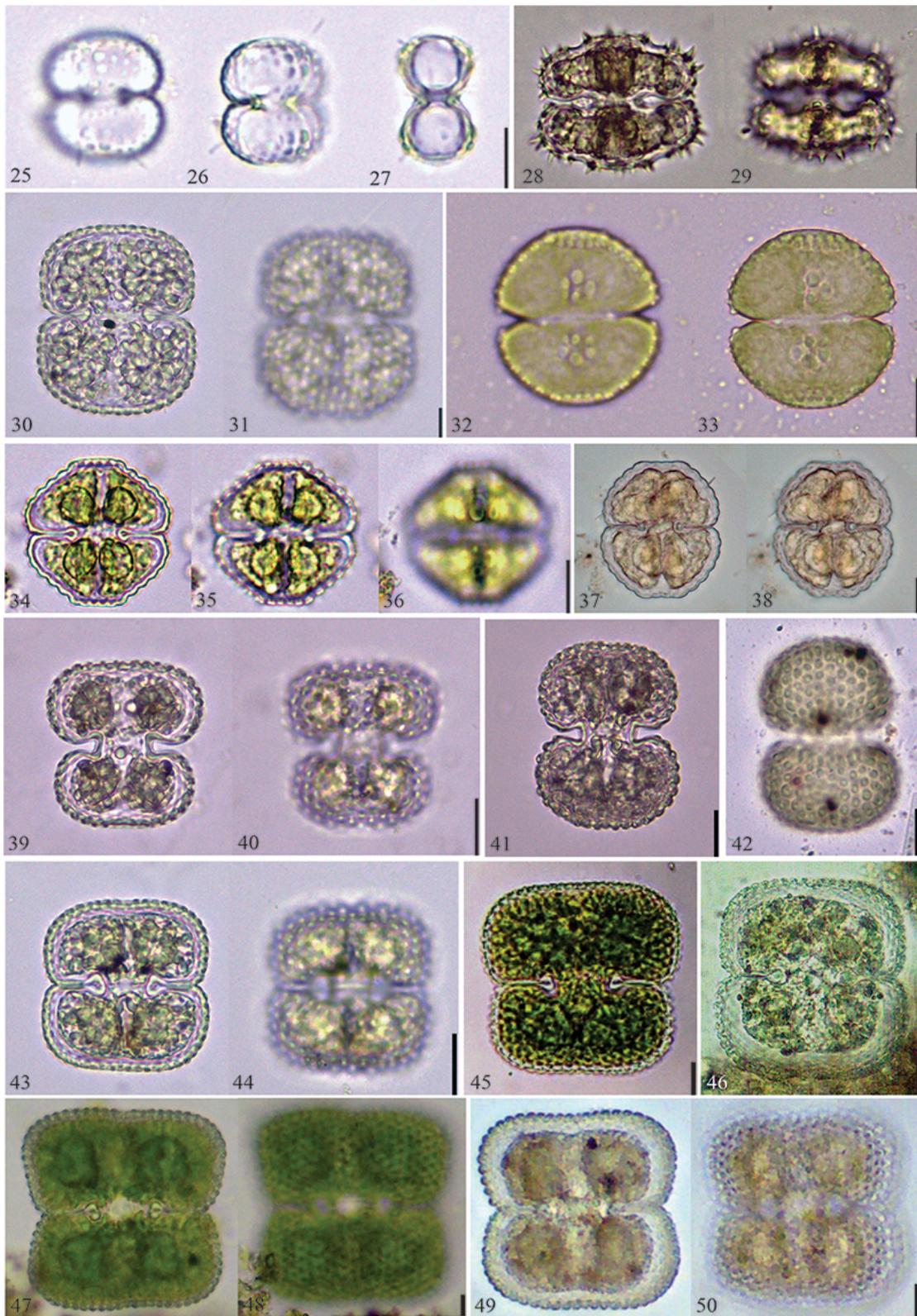
Notes: According to Bicudo *et al.* (2019), *Cosmarium margaritatum* is similar to *C. quadrum* P.Lundell, but differs by having not divergent lateral margins, as well as in the number of granules on the margins.

Present material was recorded in lentic environments, under mesotrophic to eutrophic and circumneutral to alkaline conditions.

Material examined: BRDE18A12, BRDE18A13, BRDE18A14, BRDE18A15, BRDE25A29, BRDE18A16.

*** *Cosmarium monomazum* P.Lundell var. *polymazum* Nordstedt**, Lund Universitets Årsskrift 9: 14, pl. 1, fig. 3. 1873. Figures 32-36

Cells as long as broad, median constriction deep, sinus closed, linear; semicells trapezoid, apex truncate, crenate, lateral margin 4-5-crenate, basal angles rounded; cell wall granulate, punctate, 4-5 double granules arranged along the lateral margins, midregion with (1-)5-6 large granules cruciate or circular arranged; apical view ellipsoid, c. 14 square shaped apical granules forming a crown, midregion inflated; chloroplasts 2, pyrenoid 2. L: 15-28.8 μm ; W: 13.5-26.6 μm ; I: 4-8.3 μm .



Figures 25-27. *Cosmarium isthmochondrum* cf. var. *biseriatum* West & G.S.West; 28, 29. *Cosmarium lagoense* (Nordstedt) Nordstedt; 30, 31. *Cosmarium margaritatum* (P.Lundell) J.Roy & Bisset; 32-36. *Cosmarium monomazum* var. *polymazum* Nordstedt; 37, 38. *Cosmarium* cf. *obtusatum* (Schmidle) Schmidle; 39, 40. *Cosmarium porteanum* W.Archer var. *nephroideum* Wittrock; 41, 42. *Cosmarium porteanum* W.Archer var. *porteanum*; 43, 44. *Cosmarium pseudobroomei* Wolle var. *pseudobroomei*; 45, 46. *Cosmarium quadrum* P.Lundell var. *quadrum*; 47-50. *Cosmarium quadrum* var. *sublatum* (Nordstedt) West & G.S.West Scale bar = 10 µm

Notes: *Cosmarium monomazum* var. *polymazum* differs from the typical variety by having three large granules (the middle one sometimes larger) forming a transverse series across the mid of the semicell, and one large granule immediately above the isthmus (West & West 1908), whereas the typical variety shows only a single granule in the mid-region. The present variety showed polymorphism, especially regarding the number, size and disposition of granules. Some variation may be detected in the West & West (1908: pl. 76, figs. 13, 14) illustrations, one specimen having larger granules than the other, their shapes being also slightly distinct. Current material varied a great deal in its ornamentation. Population studied showed what we considered two different patterns of ornamentation: one with four granules cruciately disposed, and the other one with six granules disposed in a subcircular shape. Further investigation needs to be done to ensure that both forms actually belongs to the same taxonomic variety, and that *C. monomazum* is indeed a polymorphic species. Present investigation is the first official record of the occurrence of this variety in Brazil. However, it is possible that some records of *C. formosulum* in Brazilian floristic studies may actually refer to this variety.

Present material was recorded in a lentic environment, under oligotrophic to eutrophic and alkaline conditions.

Material examined: BRDE18A11, BRDE18A13, BRDE18A14, BRDE18A15, BRDE18A16.

* *Cosmarium obtusatum* (Schmidle) Schmidle, Engler's Botanische Jahrbücher 26(1): 38. 1898. Figures 37, 38

Cells c. 1.1 times longer than broad, median constriction deep, sinus closed, linear; semicells trapezoid, apex truncate, lateral margins undulate, basal angles rounded; cell wall granulate, granules in 2 concentric intramarginal series; chloroplasts 2, pyrenoids 2. L: 21.5-37.7 µm; W: 19.9-34.2 µm; I: 5.6-11.7 µm.

Notes: According to Bicudo *et al.* (2019), *Cosmarium obtusatum* is morphologically close to *C. subochthodes* Schmidle, but the latter is distinct in having larger cells, a fully closed median sinus, and three series of granules around each semicell margin.

Present material was recorded in lentic and lotic environments, under mesotrophic to hypertrophic and alkaline conditions.

Material examined: BRDE22A09, BRDE25A28.

* *Cosmarium porteanum* W.Archer var. *nephroideum* Wittrock, Bihang till Kungliga Svenska Vetenskaps-Akademiens Handlingar 1(1): 57. 1872. Figures 39, 40

Cells as broad as long to 1.2 times longer than broad, median constriction deep, sinus broadly open; semicells

reniform to elliptical, lateral margins rounded, apex truncate; cell wall granulate, granules in obliquely decussating series; chloroplast 2, pyrenoids 2. L: 29.1-36 µm; W: 28-30.2 µm; I: 8.9-10.7 µm.

Notes: According to Bicudo *et al.* (2019), *Cosmarium porteanum* var. *nephroideum* differs from the type of variety in having smaller cell dimensions and subreniform to semicircular-elliptical semicells.

Present material was recorded in lentic environments, under oligotrophic to eutrophic and circumneutral to alkaline conditions.

Material examined: BRDE18A11, BRDE18A13, BRDE18A16.

* *Cosmarium porteanum* W.Archer var. *porteanum*, Proceedings of the Natural History Society of Dublin 3: 49, pl. 1, fig. 8-9. 1860. Figures 41, 42

Cells 1.4-1.5 times longer than broad, median constriction deep, sinus broadly open; semicells spherical to oblong, apex rounded, lateral margins rounded; cell wall granulate, each granule surrounded by 5-6 pores, granules in obliquely decussating series; chloroplast 2, pyrenoids 2; semicell apical view spherical. L: 35.4-42 µm; W: 25.8-30.5 µm; I: 10-10.5 µm.

Notes: Brazilian floristic studies reported significant polymorphism in the semicell shape of *Cosmarium porteanum* var. *porteanum*, including elliptic to subreniform semicells (Bicudo *et al.* 2019).

Present material was recorded from lentic environments, under oligotrophic to hypertrophic and acid to alkaline conditions.

Material examined: BRDE24A01, BRDE18A05, BRDE18A07, BRDE18A08, BRDE18A09, BRDE18A10, BRDE24A09, BRDE18A11, BRDE24A11, BRDE18A13, BRDE24A12, BRDE18A14, BRDE19A14, BRDE24A13, BRDE18A15, BRDE24A14.

Cosmarium pseudobroomei Wolle var. *pseudobroomei*, Bulletin of the Torrey Botanical Club 11(2): 16, pl. 44, fig. 36, 37. 1884. Figures 43, 44

Cells as broad as long, median constriction deep, sinus closed, linear, dilated near the isthmus; semicells subelliptical to subrectangular, apex truncate to slightly rounded; cell wall granulate, granules in obliquely decussating series; chloroplasts 2, pyrenoids 2; semicell apical view elliptical, lateral view spherical. L: 28.2-40.1 µm; W: 27.3-38 µm; I: 9.4-14.7 µm.

Notes: Bicudo *et al.* (2019) commented on the difficulty to distinguish *Cosmarium pseudobroomei* from *C. quadrum*

P.Lundell var. *minus* Nordstedt due to their very close similarity. According to those authors, the first species differs from the latter in having smaller cell dimensions (31-38 x 27-45 µm), smaller number of granules round the semicell margin (23-32), and oblong-elliptical semicell in apical view.

Present material was recorded inhabiting lentic and lotic environments, under oligotrophic to eutrophic and acid to alkaline conditions.

Material examined: BRDE18A01, BRDE00A02, BRDE18A02, BRDE18A03, BRDE24A02, BRDE19A04, BRDE24A04, BRDE18A06, BRDE19A06, BRDE24A05, BRDE18A08, BRDE18A09, BRDE19A09, BRDE24A08, BRDE18A10, BRDE18A11, BRDE19A11, BRDE24A10, BRDE24A11, BRDE00A13, BRDE18A13, BRDE19A13, BRDE21A14, BRDE22A13, BRDE18A14, BRDE19A14, BRDE24A13, BRDE00A15, BRDE18A15, BRDE19A15, BRDE25A29, BRDE18A16, BRDE19A16.

* *Cosmarium quadrum* P.Lundell var. *quadrum*, Nova Acta Regiae Societatis Scientiarum Upsaliensis, ser. 3, 8(2): 25, fig. 11. 1871.

Figures 45, 46

Cells as broad as long to 1.1 times longer than broad, median constriction deep, sinus closed, linear, dilated near the isthmus; semicells subrectangular, apex straight to slightly retuse, lateral margins straight to slightly rounded, basal and apical angles rounded; cell wall granulate, granules in obliquely decussating series; chloroplasts 2, pyrenoids 2. L: 47-81 µm; W: 43-76.4 µm; I: 15.9-25.3 µm.

Notes: This species resembles *Cosmarium margaritatum* (P.Lundell) J.Roy & Bisset and *C. conspersum* Ralfs, but it is different in its almost rectangular cell outline, truncate apical margins, lateral margins divergent towards the apex, and the semicell lateral view oblong. Furthermore, *C. quadrum* presents smaller length:width ratio than *C. margaritatum* (Bicudo *et al.* 2019).

Present material was gathered from lotic environments, under ultraoligotrophic to eutrophic and acid to alkaline conditions.

Material examined: BRDE00A01, BRDE21A01, BRDE22A01, BRDE00A03, BRDE26A03, BRDE21A04, BRDE21A05, BRDE22A04, BRDE00A06, BRDE21A06, BRDE00A07, BRDE21A07, BRDE26A07, BRDE21A08, BRDE21A09, BRDE17A10, BRDE22A09, BRDE17A11, BRDE00A11, BRDE21A11, BRDE22A10, BRDE17A13, BRDE21A13, BRDE26A13, BRDE21A14.

* *Cosmarium quadrum* P.Lundell var. *sublatum* (Nordstedt) West & G.S.West, A monograph of the British Desmidiaceae 4: 21, pl. 100, fig. 2. 1912.

Figures 47-50

Cells as broad as long to 1.1 times longer than broad, median constriction deep, sinus closed, linear; semicells subrectangular, apex straight, retuse in the midregion, lateral margins straight, divergent, basal and apical angles rounded; cell wall granulate, punctate, granules in obliquely decussating series; chloroplasts 2, pyrenoids 2. L: 58.7-96.3 µm; W: 56.9-94 µm; I: 15-29.7 µm.

Notes: *Cosmarium quadrum* var. *sublatum* is typical by having lateral margins divergent towards the semicell apex, somewhat dilated apical angles, and the apical margin broader than the semicell base (Bicudo *et al.* 2019).

Present material was recorded in lotic environments, under ultraoligotrophic to eutrophic and neutral to alkaline conditions.

Material examined: BRDE21A02, BRDE22A01, BRDE00A10, BRDE26A10, BRDE26A11, BRDE17A12, BRDE17A13, BRDE22A12, BRDE26A13, BRDE22A13.

* *Cosmarium regnesi* Reinsch, Abhandlungen der Naturhistorischen Gesellschaft zu Nürnberg 6(2): 112, pl. 8, fig. 8. 1866.

Figure 51

Cells as broad as long to 1.2 times broader than long, median constriction deep, sinus broadly open; semicells oblong, apex concave, lateral margins rounded, granulate; cell wall partially granulate, 4-6 granules near the margins; chloroplasts 2, pyrenoids 2. L: 11.3-12.8 µm; W: 13.1 µm; I: 5.2-5.9 µm.

Present material was recorded in lentic and lotic environments, under mesotrophic to eutrophic and alkaline conditions.

Material examined: BRDE17A15, BRDE25A29.

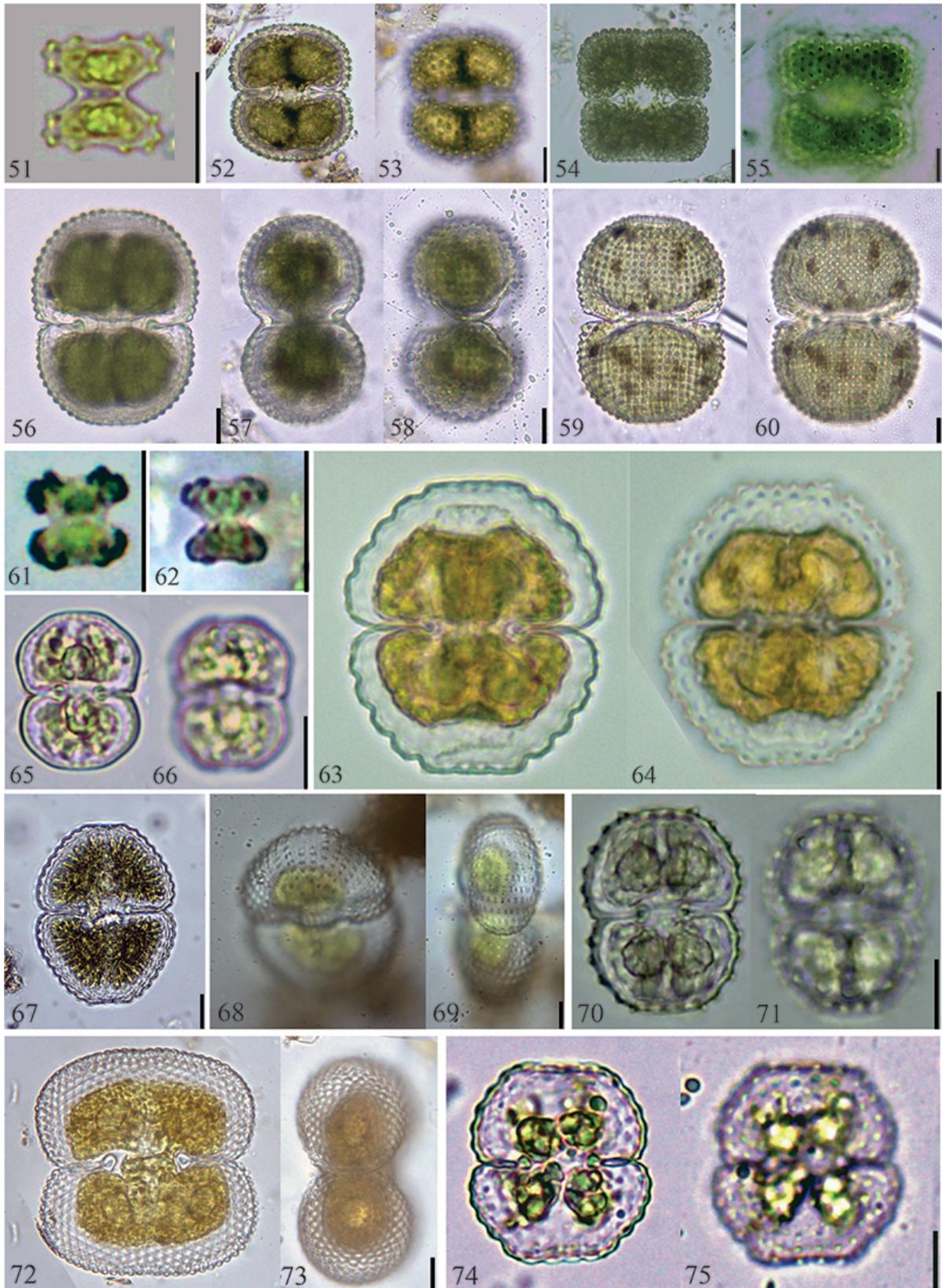
* *Cosmarium reniforme* (Ralfs) W.Archer var. *reniforme*, Journal of Botany 12: 92. 1874.

Figures 52, 53

Cells 1.1-1.3 times longer than broad, median constriction deep, sinus closed, linear, dilated near the isthmus; semicells reniform to subreniform, apex convex, lateral margins rounded to slightly straight; cell wall granulate, granules in obliquely decussating series, granules surrounded by 6 punctuations; chloroplasts 2, pyrenoids 2. L: 41.3-68.2 µm; W: 35-59.8 µm; I: 10.2-15.4 µm.

Notes: This species is very common in Brazil and shows considerable polymorphism (Bicudo *et al.* 2019). Current material showed variation in the semicell shape, mainly due to the lateral margins variation from rounded to slightly straight.

Present material was collected from lotic and lentic environments, under ultraoligotrophic to hypertrophic and acid to alkaline conditions.



Figures 51. *Cosmarium regnesi* Reinsch; 52, 53. *Cosmarium reniforme* var. *reniforme* (Ralfs) W.Archer; 54, 55. *Cosmarium scabrum* W.B.Turner; 56-60. *Cosmarium scrobiculosum* O.Borge; 61, 62. *Cosmarium sphagnicola* var. *pachygonum* Skuja; 63, 64. *Cosmarium subcostatum* Nordstedt var. *subcostatum*; 65, 66. *Cosmarium subhammeri* var. *italicum* Grönblad; 67-69. *Cosmarium subspeciosum* Norstedt; 70, 71. *Cosmarium vitiosum* A.M.Scott & Grönblad; 72, 73. *Cosmarium* sp.1; 74, 75. *Cosmarium* sp.2. Scale bar = 10 μ m.

Material examined: BRDE21A01, BRDE18A01, BRDE00A02, BRDE22A01, BRDE22A02, BRDE18A04, BRDE22A04, BRDE26A05, BRDE00A06, BRDE18A08, BRDE17A09, BRDE21A09, BRDE18A09, BRDE19A09, BRDE25A18, BRDE17A10, BRDE18A10, BRDE19A10, BRDE17A11, BRDE18A11, BRDE19A11, BRDE24A10, BRDE17A12, BRDE00A12, BRDE21A12, BRDE22A11, BRDE00A13, BRDE22A12, BRDE18A13, BRDE25A25, BRDE26A14, BRDE18A14, BRDE19A14, BRDE25A28, BRDE18A15, BRDE19A15, BRDE25A29, BRDE18A16, BRDE19A16.

* *Cosmarium scabrum* W.B.Turner, Kungliga Svenska Vetenskaps-Akademiens Handlingar 25(5): 65, pl. 9, fig. 32. 1892.
Figures 54, 55

Cells as long as broad to 1.1 times broader than long, median constriction deep, sinus closed, linear, dilated near the isthmus; semicells subrectangular, apex truncate, sometimes slightly retuse, lateral margins straight, apical angles dilated, basal angles rounded; cell wall granulate, punctate, granules in obliquely decussating series, granules surrounded by 6 pores; chloroplasts 2, pyrenoids 2. L: 36.2-38.4 µm; W: 33.8-39.5 µm; I: 11-12.9 µm.

Notes: *Cosmarium pardalis* Cohn and *C. scabrum* W.B.Turner are morphologically very close similar species, which led to different interpretations by distinct authors. We first considered that the latter would be different by having granules somewhat radially located close to the margins, arranged in clusters towards the sides to form rosettes. However, Scott & Prescott (1961) commented that *C. scabrum* is different in having 8-9 obliquely decussating series of 20-22 granules each, the series being slightly convex upwards at the upper semicell, but they did not comment on the rosettes. They have also pointed out that the material identified as *C. pardalis* by West & West (1902) would actually be *C. scabrum*. Furthermore, the same authors suggested that all material similar to theirs and to West & West's (1902) should be identified as *C. scabrum*. We have currently decided to follow Scott & Prescott (1961) suggestion, considering that the present material is too similar to theirs, but we would recommend that the two species under discussion should be revised, preferably using SEM and molecular data.

Present material was recorded in a lentic environment, under mesotrophic and acid to alkaline conditions.

Material examined: BRDE18A08, BRDE18A09, BRDE18A13, BRDE18A15.

* *Cosmarium scrobiculosum* O.Borge, Arkiv für Botanik 1: 107, pl. 2, fig. 12. 1903.
Figures 56-60

Cells 1.4-1.5 times longer than broad, median constriction deep, sinus sometimes closed, linear, dilated close to the isthmus, sometimes V-shaped; semicells subsemicircular, apex rounded, lateral margins rounded, basal angle obtuse-angular; cell wall granulate, scrobiculate, granules in vertical series between scrobicules; chloroplasts 2, pyrenoids 2, semicell side view circular. L: 55.5-67.7 µm; W: 38.6-46 µm; I: 14.3-22.7 µm.

Notes: *Cosmarium scrobiculosum* O.Borge is often mistaken for *C. logiense* Bisset and *C. decoratum* West & G.S.West (Ramos *et al.* 2018). Present material showed phenotypic plasticity in their sinus shape and in the magnitude of the semicell inflation.

Present material was recorded in lentic and lotic environments, under oligotrophic to hypertrophic and acid to alkaline conditions.

Material examined: BRDE18A05, BRDE18A06, BRDE18A08, BRDE18A09, BRDE18A10, BRDE18A11, BRDE18A12, BRDE21A13, BRDE18A13, BRDE18A15, BRDE18A16, BRDE25A32.

** *Cosmarium sphagnicola* West & G.S.West var. *pachygonum* Skuja, Nova Acta Regiae Societatis Scientiarum Upsaliensis, ser. 4, 16(3): 212, pl. 35, fig. 18. 1956.
Figures 61, 62

Cells as broad as long to 1.1 times broader than long, median constriction deep, sinus broadly open; semicells subtrapezoid, apex concave, lateral margins thickened, granulate; cell wall partially granulate; chloroplasts 2, pyrenoids 2. L: 4.6-7.8 µm; W: 4.4-8.3 µm; I: 2.5-4.3 µm.

Notes: According to Skuja (1956), *Cosmarium sphagnicola* var. *pachygonum* differs from the type variety by having trapezoidal semicells, a very open sinus, and the cell wall extremely thickened at the corners. The variety is also similar to *C. pygmaeum* W.Archer var. *perornatum* Skuja, but the latter is more deep constricted and has a closed sinus. Present study is the first record of the occurrence of the type-variety in Brazil.

Present material was recorded in lentic and lotic environments, under oligotrophic to eutrophic and circumneutral to alkaline conditions.

Material examined: BRDE18A13, BRDE24A12, BRDE25A26, BRDE19A14, BRDE25A27, BRDE17A16.

** *Cosmarium subcostatum* Nordstedt var. *subcostatum*, Öfversigt af Kongliga Vetenskaps-akademiens förhandlingar 33(6): 37, pl. 12, fig. 13. 1876.
Figures 63, 64

Cells 1.2-1.3 times longer than broad, median constriction deep, sinus closed, linear; semicells subtrapezoid, apex

truncate, 4-crenate, lateral margins 5-crenate, double granules on each crenation, basal angles rounded; cell wall granulate, double granules in 2 concentric series, granulate intumescence at the mid of the semicell just above the isthmus; chloroplasts 2, pyrenoids 2; cell apical view elliptical, a protuberance in both sides, semicell side view oblong. L: 29.7-31.8 μm ; W: 23.6-26.8 μm ; I: 8.3-9.5 μm .

Present material was collected from lentic and lotic environments, under mesotrophic to eutrophic and alkaline conditions. This is the first record of this variety occurrence in Brazil.

Material examined: BRDE26A05, BRDE26A15, BRDE20A16.

* *Cosmarium subhammeri* M.F.Rich var. *italicum* Grönblad, Acta Societatis Scientiarum Fennicae 22(4): 42, pl. 4, fig. 82-84. 1960.
Figures 65, 66

Cells 1.3-1.4 times longer than broad, median constriction deep, sinus closed, linear; semicells subhexagonal to oblong, apex rounded, or slightly truncate, lateral margins rounded, basal angles obtuse; cell wall mostly smooth, 2 large granules near the apex; chloroplasts 2, pyrenoids 2. L: 20-26 μm ; W: 14-19.5 μm ; I: 4.3-7.1 μm .

Notes: According to Bicudo *et al.* (2019), this variety differs from the typical by lacking the prominent apex and having subhexagonal-oblong semicells.

Present material was recorded in lentic environments, under mesotrophic to hypertrophic and acid to alkaline conditions.

Material examined: BRDE18A03, BRDE19A03, BRDE24A02, BRDE18A06, BRDE18A08, BRDE18A13, BRDE18A14.

* *Cosmarium subspeciosum* Nordstedt var. *validius* Nordstedt, Bihang till Kungliga Svenska Vetenskapsakademiens handlingar 22(8): 49, pl. 5, fig. 10. 1888.
Figures 67-69

Cells 1.3-1.5 times longer than broad, median constriction deep, sinus closed, linear; semicells subpyramidal, apex truncate, lateral margins straight, convergent, crenulate, apical and basal angles rounded; cell wall granulate, granules in 5-6 concentric series, mid semicell protrusion granulate; chloroplast with 2 pyrenoids per semicell. L: 62.2-75.6 μm ; W: 48.5-58.4 μm ; I: 12.9-18 μm .

Notes: According to Bicudo *et al.* (2019), *Cosmarium subspeciosum* var. *validius* differs from the typical by having greater cell dimensions (68-84 x 47-53 μm , ist. c. 22 μm) and a more prominent mid semicell protrusion.

Present material was found in a lotic environment, under mesotrophic and alkaline conditions.

Material examined: BRDE21A11, BRDE22A10, BRDE26A11, BRDE22A11.

* *Cosmarium vitiosum* A.M.Scott & Grönblad, Acta Societatis Scientiarum Fennicae: ser. 2, 8: 24, pl. 9, fig. 1-3. 1957.
Figures 70, 71

Cells 1.1-1.2 times longer than broad, median constriction deep, sinus closed, linear; semicells semicircular, apex rounded, 2 cone-shaped denticules, lateral margins rounded, 5 denticules, basal angles rounded, 1 denticule; cell wall partially granulate, 4 round granules horizontally disposed just below the apex, 2 larger round granules below, 4 denticules near the lateral margins, midregion of the semicell usually smooth, few punctuations; chloroplasts 2, pyrenoids 2; L: 25-28.2 μm ; W: 21.9-23.2 μm ; I: 5.3-6.1 μm .

Notes: The individual specimens described by Scott & Grönblad (1957) showed a few differences compared to the present ones, such as the trapezoid-pyramidal semicells, presence of 5-6 granules and between them 3-5 scrobicules in the central area of the semicells, and greater cell dimensions (37-44 x 32-34 μm). Despite of these differences, we considered the current specimens representatives of *C. vitiosum*, mostly because the number and arrangement of granules and scrobicules are too variable according to the above mentioned authors.

Present material was recorded in a lentic environment, under oligotrophic to eutrophic and acid to alkaline conditions.

Material examined: BRDE18A08, BRDE18A11, BRDE18A15, BRDE18A16.

Cosmarium sp. 1
Figures 72, 73

Cells as broad as long, median constriction deep, sinus closed, linear, dilated internally; semicells subelliptical, apex mostly round, slightly retuse, lateral margins rounded, basal and apical angles rounded; cell wall granulate, granules in obliquely decussating series; chloroplasts 2, pyrenoids 2; semicell apical view elliptical, side view circular. L: 42.2-87.9 μm ; W: 42.3-81.5 μm ; I: 12.2-22.3 μm .

Present material was collected in a lotic environment, under oligotrophic to eutrophic and alkaline conditions.

Material examined: BRDE00A05, BRDE22A12.

Cosmarium sp. 2
Figures 74, 75

Cell ca. 1.1 times longer than broad, median constriction deep, sinus closed, linear; semicells subtrapezoid, apex truncate, crenate, lateral margins undulate, basal angles rounded; cell wall granulate, granules in 3 concentric

series, semicell midregion with no granules; chloroplast and pyrenoids not observed. L: c. 29.7 μm ; W: c. 27.3 μm ; I: c. 10 μm .

Present material was collected in a lentic environment, under eutrophic and alkaline conditions.

Material examined: BRDE18A14.

Final remarks

The most frequent *Cosmarium* species in the study area was *Cosmarium blyttii* cf. var. *basiornatum*, followed by *Cosmarium binum*. The first one was also the species with the greatest distribution, being absent only at the Areal Lagoon. Most species were found in lentic environments, and just six in lotic ones. Limão lake was the most diverse environment studied, presenting 22 species followed by the Doce river with 15 ones. Concerning pH preference, most species occurred under circumneutral to alkaline and 10 under acidic conditions. Regarding the trophic state preference, most species occurred under eutrophic conditions, but five showed preference for the mesotrophic ones (table 1). Total iron values varied during the present study from 0.01 to 5.8 mg L^{-1} . Values of total iron for each sample is found in the first fascicle of this series (Zorzal-Almeida *et al.* 2021). Most species occurred under conditions bellow 4 mg L^{-1} , whereas *C. binum* was the only one occurring in the highest registered level of this study, followed by *Cosmarium regnesi* and *C. blyttii* cf. var. *basiornatum* that occurred under the second highest level (4.9 mg L^{-1}). Current study contributed to the desmid flora of Espírito Santo State with taxonomic, geographic distribution, and ecologic information about the *Cosmarium* with ornamented cell wall, and highlighted the relevance of floristic studies for the Brazilian less explored regions, especially the ones with environmental degradation history.

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Author contributions

Bruna Fadul-Souza: Substantial contribution to the concept and design of the study; contribution to data collection, analysis and interpretation; contribution to manuscript preparation.

Carlos Eduardo de Mattos Bicudo: Critical revision.

Geraldo José Peixoto Ramos: Data analysis and interpretation; critical revision adding intellectual content.

Mateus Sardi Trancoso: Data collection; critical revision.

Stéfano Zorzal-Almeida: Conceptualization and design of the study; manuscript preparation; critical revision.

Valéria de Oliveira Fernandes: Critical revision.

Conflicts of interest

There is no conflict of interest.

Literature cited

- Barroso, G.F., Garcia, F.D.C., Gonçalves, M.A., Martins, F.D.O., Venturini, J.C., Sabadini, S. & Bertoldi, L.** (2012). Estudos integrados no sistema lacustre do baixo rio Doce (Espírito Santo). Anais do 1º Seminário Nacional de Gestão Sustentável de Ecossistemas Aquáticos: Complexidade, Interatividade e Ecodesenvolvimento, Arraial do Cabo, pp. 126-132.
- Bicudo, C.E.M., Araújo, A. & Biolo, S.** (2019). Flora Ficológica do Estado de São Paulo, 4(3): Zygnemaphyceae. Editora RiMa, São Carlos.
- Bicudo, C.E.M., Azevedo, M.T.P, Castro A.A.J.** (2014). Flora Ficológica do Estado de São Paulo, 4(1): Zygnemaphyceae. Editora RiMA, São Carlos.
- Camargo, J.C., Loverde-Oliveira, S.M., Sophia, M.G. & Nogueira, F.M.B.** (2009). Desmídias perifíticas da baía do Coqueiro, Pantanal Matogrossense-Brasil. Iheringia, Série Botânica 64(2): 25-41.
- Coesel, P.F.** (2001). A method for quantifying conservation value in lentic freshwater habitats using desmids as indicator organisms. Biodiversity & Conservation 10(2): 177-187.
- Delazari-Barroso, A., Sant'Anna, C.L. & Senna, P.A.C.** (2007). Phytoplankton from Duas Bocas Reservoir, Espírito Santo State, Brazil (except diatoms). Hoehnea 34(2): 211-229.
- Estrela, L.M.B, Fonseca, B.M. & Bicudo, C.E.M.** (2011). Desmídias perifíticas de cinco lagoas do Distrito Federal, Brasil: I – Gênero *Cosmarium* Corda ex Ralfs. Hoehnea 38: 527-552.
- Fadul-Souza, B., Souza, K.B.D., Trancoso, M.S., Zorzal-Almeida, S., Bicudo, C.E.M., Ramos, G.J.P. & Fernandes, V.D.O.** (2022). Periphytic algal flora of the low Doce River, Espírito Santo State, Brazil, after ore tailings flow, 1: smooth cell walled *Cosmarium* Corda (Zygnematophyceae, Desmidiaceae. Hoehnea 49: e222022.

- Felisberto, S.A. & Rodrigues, L.** (2004). Periphytic desmids in Corumbá reservoir, Goiás, Brazil: genus *Cosmarium* Corda. *Brazilian Journal of Biology* 64(1): 141-150.
- Felisberto, S.A. & Rodrigues, L.** (2010). *Cosmarium* (Desmidiaceae, Zygnemaphyceae) da ficoflórula perifítica do reservatório de Rosana, bacia do rio Paranapanema, Paraná/São Paulo, Brasil. *Hoehnea* 37: 267-292.
- Förster, K.** (1964). Desmidiaceen aus Brasilien, 2: Bahia, Goyaz, Piauhy und Nord-Brasilien. *Hydrobiologia* 22(3-4): 321-505.
- Grönblad, R.** (1945). De algis brasiliensibus: praecipue Desmidiacius, in regione inferiore fluminis Amazonas. *Acta Societatis Scientiarum Fennica: ser. B*, 2(6): 1-43.
- Krieger, W. & Gerloff, J.** (1965). Die Gattung *Cosmarium*, 2. Verlag von J. Cramer. Weinheim.
- Menezes, V.C.D., Bueno, N.C., Bortolini, J.C., Biolo, S. & Siqueira, N.S.** (2011). O gênero *Cosmarium* Corda ex Ralfs (Desmidiaceae) no Reservatório de Itaipu, PR, Brasil. *Hoehnea* 38: 483-493.
- Nordstedt, C.F.O.** (1870). Symbolae ad floram Brasiliae centralis cognoscendam. *Videnskabelige Meddelelser fra Dansk naturhistorisk Forening i Kjøbenhavn* 21(14-15): 195-234.
- Nordstedt, C.F.O.** (1888). Freshwater algae collected by Dr. S. Berggren in New Zealand and Australia. *Kungliga Svenska Vetenskapsakademiens Handlingar* 22(8): 1-98.
- Oliveira, I.B.D., Bicudo, C.E.M. & Moura, C.W.N.** (2010). Contribuição ao conhecimento de *Cosmarium* Corda ex Ralfs (Desmidiaceae, Zygnemaphyceae) para a Bahia e o Brasil. *Hoehnea* 37: 571-600.
- Prescott, G.W., Croasdale, H.T., Vinyard, W.C. & Bicudo, C.E.M.** (1981). A synopsis of North American desmids, 2. Desmidiaceae: Placodermatae Section 3. University of Nebraska Press. Lincoln & London.
- Ralfs, J.** (1848). *The British Desmidiae*. Reeve, Benham and Reeve. London.
- Ramos, G.J.P., Bicudo, C.E.M. & Moura, C.W.N.** (2018). Some new, rare and interesting desmids from bromeliad phytotelmata in Brazil. *Phytotaxa* 346(1): 59-77.
- Ramos, G.J.P., Santos, M.A. & Moura, C.W.N.** (2021). How hidden is the diversity of the genus *Cosmarium* (Desmidiaceae) in the Brazilian Caatinga? *Acta Botanica Brasilica* 35(2): 188-214.
- Ramos, G.J.P., Santos, M.A., Oliveira, I.B. & Moura, C.W.N.** (2020). Taxonomic and nomenclatural notes on five taxa of *Cosmarium* (Desmidiaceae, Zygnemaphyceae) from Brazil. *Notulae Algarum* 146: 1-5.
- Scott, A.M. & Grönblad, R.** (1957). New and interesting desmids from the southeastern United States. *Acta Societatis Scientiarum Fennicae. ser. B*, 2: 3-62.
- Scott, A.M. & Prescott, G.W.** (1961). Indonesian desmids. *Hydrobiologia* 17(1-2): 1-132.
- Shetty, K. & Gulimane, K.** (2022). Biomonitoring of freshwater lentic habitats using desmids. *Limnology* 23(1): 245-251.
- Silva, S.R.V.F. & Cecy, I.I.T.** (2004). Desmídias (Zygnemaphyceae) da área de abrangência da Usina Hidrelétrica de Salto Caxias, Paraná, Brasil, I: Gênero *Cosmarium*. *Iheringia, Série Botânica* 59(1): 13-26.
- Skuja, H.** (1956). Taxonomische und biologische Studien über das Phytoplankton schwedischer Binnengewässer. *Nova Acta Regiae Societatis Scientiarum Upsaliensis: ser. 4*, 16(3): 1-404.
- West, W. & West, G.S.** (1895). A contribution to our knowledge of the freshwater algae of Madagascar. *Transactions of the Linnean Society of Botany* 5: 41-90.
- West, W. & West, G.S.** (1902). A contribution to the freshwater algae of Ceylon. *Transactions of the Linnean Society of London: ser. 2*, 6: 123-215.
- West, W. & West, G.S.** (1908). A monograph of the British Desmidiaceae. Vol. 3. The Ray Society. London.
- Zorzal-Almeida, S., Souza, K.B.D., Santana, L.M., Endlich, B.G., Fadul-Souza, B., Jesus, D.B.D. & Fernandes, V.D.O.** (2021). Flora de algas perifíticas da bacia do baixo rio Doce, após a passagem de rejeitos de minério, Estado do Espírito Santo, Brasil: Delineamento amostral e métodos. *Hoehnea* 48: e182021.

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