SCIENTIFIC NOTE

A dune pond and the first records of Desmidiaceae (Zygnematophyceae) in Sergipe, Brazil

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Abstract: Desmidiaceae (Zygnematophyceae) is represented in Brazil by 27 genera and about 485 species. Studies which complement taxonomic information and geographic distribution of desmids have advanced in the country; however, six states, including Sergipe, have no information about this family. Hence, this study carried out a checklist of Desmidiaceae on a dune pond in the South part of Aracaju city, state of Sergipe. Samples were collected from October 2014 to April 2015 through a usual qualitative method in three points in the selected pond. Materials in semi-permanent slides were compared with specialized bibliographic databases for identification. It was registered 29 taxa belonging to five genera of Desmidiaceae [*Actinotaenium* (Nägeli) Teiling, *Cosmarium* Corda ex Ralfs, *Euastrum* Ehrenberg ex Ralfs, *Micrasterias* C.Agardh ex Ralfs and *Staurastrum* Meyen ex Ralfs]. The information presented here increases the distribution of Desmidiaceae in Brazil, and two taxa may be new records to science. We consider that Sergipe is a species rich area to this family and need more ecological and taxonomic studies to contribute to the composition of the phycoflora of the state and Brazil.

Keywords: algae, Atlantic Forest, Conjugatophyceae, desmids, Northeast Brazil.

Uma lagoa dunar e os primeiros registros de Desmidiaceae (Zygnematophyceae) em Sergipe, Brasil

Resumo: Desmidiaceae é representada no Brasil por 27 gêneros e cerca de 485 espécies. Estudos que complementam informações taxonômicas e de distribuição geográfica de desmídias têm avançado no país; no entanto, seis estados, incluindo Sergipe, não possuem informações sobre esta família. Assim, este estudo realizou um levantamento de Desmidiaceae em uma lagoa dunar localizada no sul da cidade de Aracaju, estado de Sergipe. Amostras foram coletadas de outubro de 2014 a abril de 2015 através de método usual qualitativo, em três pontos pré-definidos na lagoa. Para identificação, materiais em lâminas semipermanentes foram comparados com dados em bibliografias especializadas. Foram registrados 29 táxons pertencentes a cinco gêneros de Desmidiaceae [*Actinotaenium* (Nägeli) Teiling, *Cosmarium* Corda ex Ralfs, *Euastrum* Ehrenberg ex Ralfs, *Micrasterias* C.Agardh ex Ralfs e *Staurastrum* Meyen ex Ralfs]. As informações aqui apresentadas ampliam a distribuição das Desmidiaceae no Brasil, e dois táxons podem ser novos para a ciência. Consideramos que Sergipe é uma área rica para esta família e que necessita de mais estudos ecológicos e taxonômicos que contribuam para a composição da ficoflora do Estado e do Brasil.

Palavras-chave: algas, Conjugatophyceae, desmídias, Mata Atlântica, Nordeste brasileiro.

The class Zygnematophyceae represents an important group in phycoflora of the continental aquatic environments compared to other groups of green algae (Wehr & Sheath, 2003). Their representatives are popularly known as desmids, and they may be found floating freely in the water column as part of the phytoplankton, or attached to substrate composing the periphyton, or living among substrates as part of the metaphyton (Parra & Bicudo, 1996; Šťastný, 2010).

The order Desmidiales comprehends the families Gonatozygaceae, Peniaceae, Closteriaceae and Desmidiaceae (McCourt, 2001). The last cited family has the largest representation in comparison to other Zygnematophyceae families (Gerrath, 2003), comprising around 2,500 species (Gontcharov & Melkonian, 2011; Hall et al., 2008; McCourt et al., 2001). A particular feature of this group is a complex cell wall punctured by a pore system linking two semi cells (Brook, 1981; Gerrath, 2003; Gontcharov, 2008; Gontcharov et al., 2003).

However, classical taxonomy has been insufficient to explain phylogenetic relationships into interfamilial levels, and nomenclatural changes based on molecular and morphological data are considered necessary for better delimitation (Gontcharov & Melkonian, 2011; McCourt, 2001). This family has a widespread distribution in the world, but displays higher concentrations close to the tropics, and in oligotrophic to lightly mesotrophic environments with temperatures among 25-30°C (Coesel & Wardenaar, 1990; Coesel & Wardenaar, 2006).

There are about 27 genera and 485 species in the family Desmidiaceae in Brazil (Flora do Brasil 2020 under construction, 2020). Taxonomy and geographical distribution of the family were first studied by Forster (1964). Since then, studies have been carried out in the country, especially in the Southeast (Araújo, 2006; Felisberto & Rodrigues, 2011; Soares et al., 2007; Sophia, 1999), North (Martins, 1980; Melo & Souza, 2009; Souza et al., 2007), Northeast (Burack et al., 2016; Costa et al., 2018; Fonseca & Estrela, 2015; Oliveira, 2008; Oliveira et al., 2010; Oliveira, 2011; Oliveira et al., 2016; Oliveira et al., 2017; Ramos et al., 2020), and Midwest regions (Camargo et al., 2009; De-Lamonica-Freire, 1985; Estrela et al., 2011; Fonseca et al., 2014; Forster, 1964). Indeed, despite projects such as the List of Species of the Brazilian Flora (Forzza et al., 2012), six states from Brazil, do not have records for Desmidiaceae, including the state of Sergipe (Flora do Brasil 2020 under construction, 2020; Oliveira, 2011).

In the coastal region of Sergipe, dunes are frequent and covered by herbaceous vegetation (Prata et al., 2013), which are also found surrounding dune pond formation in Aracaju (Alves com. pess.). Dune pounds are environments rich in organic matter and are suitable to phytoplankton development in water surface or tied in macrophytes (Mulderij et al., 2006). Although there are efforts of the city's government to preserve areas of biological interest (Semarh, 2020), the city has suffered intense mischaracterization of their natural environments (Prata et al., 2013).

Due to its biological importance and the lack of information about this family in the state of Sergipe, this work aimed to present a checklist of the family Desmidiaceae on a permanent dune pond in the Southern part of Aracaju. We believe that it will contribute to the knowledge of continental algae in the state and, consequently, in Brazil.

The study area chosen was the city of Aracaju. Aracaju is the capital of the state of Sergipe (Fig. 1A) and its most populous city, with about 650,000 inhabitants in an area of 181,857 km^2 (IBGE, 2019). The annual temperature and rainfall averages of Aracaju are expected not to exceed 26 °C and 1,600 mm, respectively (França & Cruz, 2007). Anthropogenic pressures such urbanization have also contributed to the reduction of the area occupied by forests, mangroves and "restingas", which resist only in small vegetation fragments in the coastal zone (França & Cruz, 2007; Prata et al., 2013). To perform the present research, a permanent dune pond located in the southern part of Aracaju in Aruanda suburb was chosen. The dune pond presented riparian vegetation and has area of 1,26 ha and 482 m of perimeter.

Along the permanent dune pond, three fixed points of sampling were determined (Fig. 1B), near places with high water transparency and presence of floating macrophytes from the families Cyperaceae and Poaceae. Samples were collected five times during October 2014 to April 2015, twice in each point (one sample to desmids presence in water surface and the another to desmids presence into squeezed macrophytes), following a qualitative method described by Bicudo & Menezes (2018). This method consists in using a plankton net with mesh size of 20 micrometers to drag repeatedly over the surface of the water until a significant amount of material is achieved. We also used squeezed macrophytes sampling (Fig. 2A-D). To remove alkali, the pots were washed three times with local water. After, samples were fixed according to Bicudo & Menezes (2018) and the glass pots were deposited in the liquid collection of the Herbarium Tiradentes (AJU).

Taxa identification was done in sampling units mounted on a series of semi-permanent glass slides. This step was repeated until there were no more different taxa after three slides

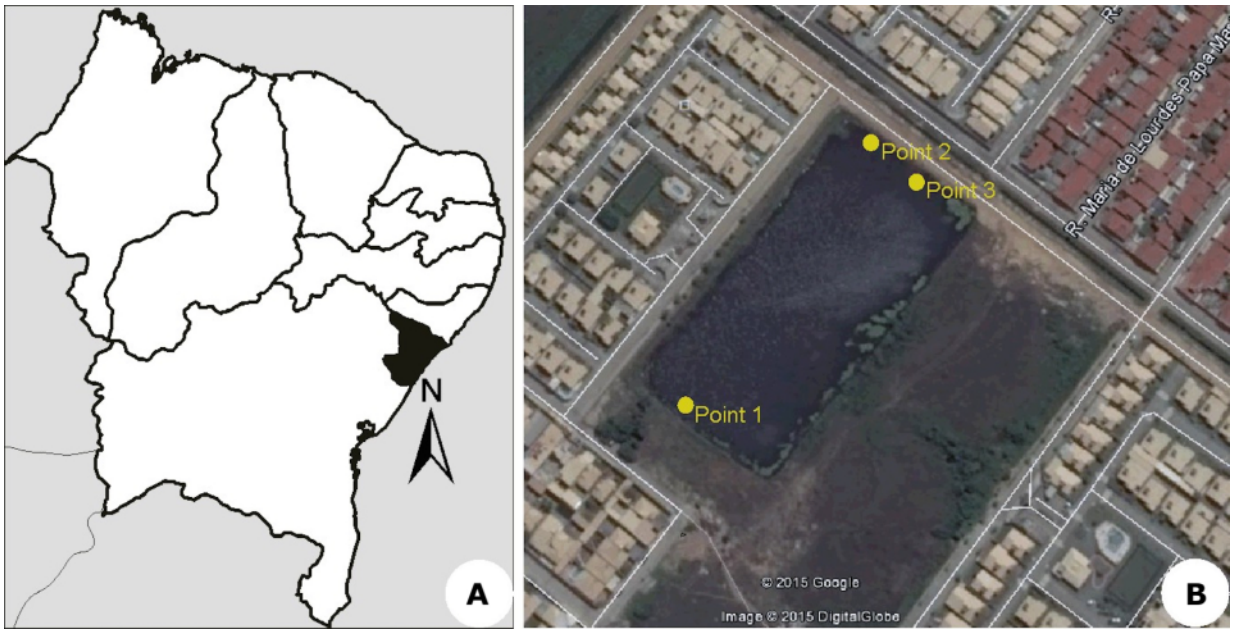

Fig. 1. Study area. A. Geographic localization from state of Sergipe, Brazil. B. Details for permanent dune pond studied, with emphasis on collection points.

Fig. 2. Study area characterization. A. Dune pond in which the study was conducted. B. Collecting made with the plankton net. C. Plankton's net details. D. Details of the squeezed's collection area.

(Oliveira, 2011). The main diagnostic characters of sample populations were observed in frontal, lateral or apical views in an optical microscope using a micrometric ruler.

The identification was based on comparisons to specialized bibliography [especially Araújo (2006) and Oliveira (2011)]. The classification system adopted was Guiry (2013). Geographical distribution of species in Brazil was according to literature (Araújo, 2006; Flora do Brasil 2020 under construction, 2020; Oliveira, 2011) and according to periodic found in Google Scholar using specific terms or key-words. The artworks of all figures were made using the Corel Craw X3® graphic program.

The present study found 29 taxa of Desmidiaceae family, which were found distributed in five genera (Tab. 1). Six taxa were only found in samples of water surface or squeezed macrophytes, and the remaining 20 taxa were re-

Tab. 1. List of species and occurrence of them in the three points in Aruanda dune pond, Aracaju, Sergipe, Brazil. (S) Squeezed samples; (W) water surface samples; (B) Both samples.

Species/collecting stations	2014		2015		
	OUT	NOV	JAN	FEV	ABR
Actinotaenium globosum var. *globosiforme* f. *minus* (Boldt) Kurt		S	S		W
Actinotaenium subglobosum (Nordstedt) Teiling		W			
Cosmarium angulosum Brébisson				S	
Cosmarium bireme var. huzelii Kurt Först	S				
Cosmarium connatum var. *connatum* (Brébisson) Ralfs	W	B	S	B	W
Cosmarium contractum cf. var. *ellipsoideum* (Elfving) West & G.S.West	W				
Cosmarium depressum var. *planctonicum* Reverdin	W			S	B
Cosmarium exiguum W.Archer		W		B	
Cosmarium formosulum Hoff		S			B
Cosmarium furcatospermum West & G.S.West	W	S	B	B	B
Cosmarium impressulum var. *impressulum* Elfving				B	
Cosmarium margaritatum var. *margaritatum* (Lundell) Roy & Bisset	W	B	W		W
Cosmarium cf. *moniliforme* Ralfs		W		S	W
Cosmarium portianum W.Archer	B	B	B	B	B
Cosmarium pseudoexiguum. var. *pseudoexiguum* Racib.	B	B	S	B	S
Cosmarium punctulatum var. *punctulatum* Brébisson				S	B
Cosmarium quardrum var. *quadrum* Lundell	W	W		W	
Cosmarium reniforme W.Archer	W	B		B	
Cosmarium tinctum var. globosiforme Willi Krieger & Gerloff	B	B	B	B	B
Cosmarium sp.				S	S
Euastrum evolutum var. *integrius* f. *integrius* West & G.S.West	W	B	S		W
Micrasterias truncata var. *truncata* f. *gibbosa* Thomasson		S			
Staurastrum chaetoceras var. *convexum* Gronblad		B			
Staurastrum dilatatum var. *dilatatum* f. *dilatatum* Ehrenberg ex Ralfs		S	B		
Staurastrum punctulatum Bréb. *ex* Ralfs	W	B	S	S	B
Staurastrum excavatum West & G.S.West		S	S		B
Staurastrum gracile var. *coronulatum* Boldt	W	B	B	B	S
Staurastrum muticum var. *muticum* Ralfs	W			B	S
Staurastrum tetracerum Ralfs ex Ralfs	W	S		S	B

corded on both types of sampling. The richest genera of water surface or squeezed macrophytes were *Cosmarium* Corda ex Ralfs, with 18 species and *Staurastrum* Meyen ex Ralfs, with seven species. The species of *Euastrum evolutum* var. *integrius* f. *integrius* West and G.S.West and *Micrasterias truncata* var. *truncata* f. *gibbosa* Thomasson were the only taxa of their genera.

The genus *Actinotaenium* (Nägeli) Teiling was represented by *A. globosum* var. *globosum* f. *minus* (Boldt) Kurt and *A. subglobosum* (Norderstedt) Teiling. Morphologically, populations of *A. globosum* var. *globosiforme* f. *minus* and *A. subglobosum* followed the descriptions, measurements and pictures in literature (Bortolini et al., 2010; Felisberto & Rodrigues, 2010; Oliveira, 2011). These two taxa are morphologically similar, but *A. subglobosum* differ by presenting an isthmus slightly marked. *A. globosum* occurs in the states of Amazonas, Pará and Bahia, and *A. subglobosum* is distributed in the states of Bahia, Goiás and Rio de Janeiro (Flora do Brasil 2020 under construction, 2020).

Cosmarium angulosum Brébisson occurs in the Distrito Federal and in the states of São Paulo and Paraná (Araújo, 2006; Flora do Brasil 2020 under construction, 2020). It is an extremely variable species (Araújo, 2006; Biolo et al., 2013; Estrela et al., 2011), which is distributed among four distinct varieties (Estrela et al., 2011; Prescott et al., 1981). The taxon sampled match with no typical variety and probably represents a new one. However, taxonomic studies are necessary to confirm this new identification in variety level.

Specimens of *Cosmarium bireme* var. *huzelii* Kurt Först sampled showed the diagnostic feature of a lateral margin markedly concave on the semicell (Biolo et al., 2013; Felisberto & Rodrigues, 2010; Oliveira, 2011; Silva & Cecy, 2004). Distribution of this taxon in Brazil is reported to the states of Amazonas, Mato Grosso, Bahia and Paraná (Flora do Brasil 2020 under construction, 2020; Oliveira et al., 2016; Silva & Cecy, 2004).

Cosmarium connatum var. *connatum* (Brébisson) Ralfs and *C.* cf. *moniliforme* Ralfs followed their descriptions and measurements (Araújo, 2006); however, illustrations are insufficient for precise identification of both taxa. *C. connatum* var. *connatum* may be confused with *Staurastrum muticum* var. *muticum* Ralfs, although they could be distinguished by apical view (Oliveira, 2011; Oliveira et al., 2016). The first taxon was recorded in the states of Mato Grosso, Rio de Janeiro and São Paulo (Flora do Brasil 2020 under construction, 2020), and *S. muticum* can be found in the states of Amazonas, Pará, Mato Grosso, Distrito Federal, Maranhão, Bahia, São Paulo, Paraná and Rio Grande do Sul (Flora do Brasil 2020 under construction, 2020; Oliveira, 2011).

Cosmarium cf. *moniliforme* occurs in the states of Amazonas, Distrito Federal, Goiás, Mato Grosso, Minas Gerais, Rio de Janeiro and Paraná (Araújo, 2006; Flora do Brasil 2020 under construction, 2020) and it is morphologically similar to *C. tinctum* var. *globosiforme* Willi Krieger & Gerloff (Fig. 3A-B). However, the latter presents lower cell measures and elliptical semicell (Oliveira, 2011). According to the last author, it was previously only found in the state of Bahia, but now also known in Sergipe.

Cosmarium contractum var. *ellipsoideum* (Elfving) West & G.S.West and *C. depressum* var. *planctonicum* Reverdin followed previous description and illustration. This species occurs in the states of Amazonas, Bahia and Minas Gerais, respectively (Oliveira, 2011). *C. formosulum* Hoff (Fig. 3C) followed the description made by Silva & Cecy (2004), and it can be confused with *C. monomazum* var. *brasiliense* (Kurt Forster & Eckert) G.J.P.Ramos & I.B.Oliveira (Ramos et al., 2020). Though, the latter shows rows of warts on the margin, only visible in apical view, while *C. formosulum* presents undulating margins (Araújo, 2006). It occurs in the states of Goiás, Paraná and Rio Grande do Sul (Flora do Brasil 2020 under construction, 2020).

Cosmarium furcatospermum West & G.S.West has a deep median constriction, elliptical semicell, with slightly undulation, approximately straight in the upper margin, and lateral margins widely concave (Oliveira, 2011; Oliveira et al., 2010). In this research, this taxon resembles *C. punctulatum* var. *punctulatum* Brébisson, however they differ by the presence of shallow median constriction, trapezoidal semicell and the lateral margins slightly to moderately concave in *C. punctulatum* var. *punctulatum* (Oliveira, 2011). There are records of these taxa in the states of Amazonas, Mato Grosso, Goiás, Bahia, São Paulo and Paraná, and *C. furcatospermum* occurs in the states of Bahia, Minas Gerais and São Paulo (Flora do Brasil 2020 under construction, 2020; Oliveira, 2011).

Cosmarium impressulum var. *impressulum* Elfving occurs in the states of Pará, Mato Grosso, Bahia, São Paulo and Paraná (Flora do Brasil 2020 under construction, 2020). Althought *C. impressulum* was described as presenting six undulations along the margin (Araújo, 2006; Oliveira, 2011), it was first mentioned as baring margin of semicell with eight undulations (Felisberto & Rodrigues, 2010; Silva & Cecy, 2004), and this feature was observed in our sampling. *C. impressulum* var. *alpicolum* Schmdle differs from the typical variety by having less length/width ratio (Prescott et al. 1981). This statement indicates that studies cited before found only one of the two varieties of *C. impressulum*.

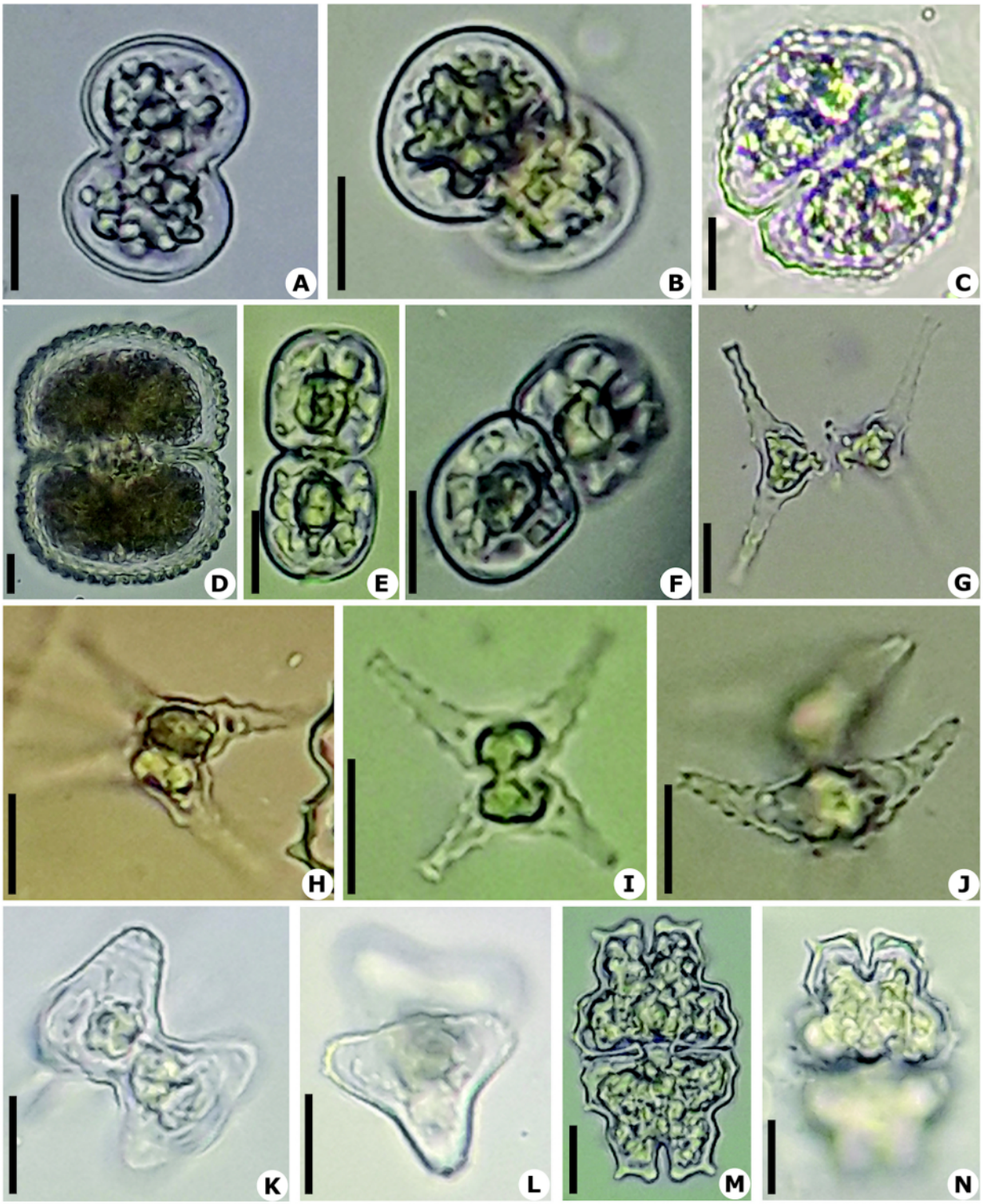

Fig. 3. Desmids found in a dune pond in Sergipe, Brazil. A-B. *Cosmarium tinctum* var. *globosiforme* Willi Krieger & Gerloff. A. Front view. B. Apical view. C. Front View of *Cosmarium formosulum* Hoff. D. Front View of *Cosmarium margaritatum* var. *margaritatum* (Lundell) Roy & Bisset. E-F. *Cosmarium pseudoexiguum* var. *pseudoexiguum* Racib. E. Front view. F. Apical view. G-H. *Staurastrum excavatum* West & G.S.West. G. Front view. H. Apical view. I-J. *Staurastrum tetracerum* Ralfs ex Ralfs. I. Front view. J. Apical view. K-L. *Staurastrum dilatatum* var. *dilatatum* f. *dilatatum* Ehrenberg ex Ralfs. K. Front view. L. Apical view. M-N. *Euastrum evolutum* var. *integrius* f. *integrius* West & G.S.West. M. Front View. N. Apical view. Bar = 1µm (A-B, E-F, I-J e M-N by *Gondra & Burle 28*, D, G-H, K-L by *Burle & Gondra 29*, C by *Gondra & Burle 37.*

Cosmarium margaritatum var. *margaritatum (*Lundell) Roy & Bisset (Fig. 3D) and *C. quadrum* var. *quadrum* Lundell are morphologically similar in form. However, *C. quadrum* differs for presenting sub-rectangular semicells. Both species have agreed with the illustrations and descriptions of Araújo (2006). *C. margaritatum* var. *margaritatum* occurs in the states of Amazonas, Pará, Mato Grosso, Bahia, São Paulo and Paraná, and *C. quadrum* occurs in the states of Amazonas, Bahia, Distrito Federal, Mato Grosso, Paraná, Rio de Janeiro, São Paulo and Rio Grande do Sul (Flora do Brasil 2020 under construction, 2020; Oliveira, 2011).

Cosmarium portianum W.Archer and C. reniforme W.Archer followed previous descriptions and illustrations (Camargo et al., 2009; Estrela et al., 2011; Oliveira, 2011). The first can be easily confused with *C. reniforme*, but this one differs by presenting semicells fully reniform and a less elongated isthmus than *C. portianum. C. reniforme* occurs in Amazonas, Bahia, Distrito Federal, Goiás, Mato Grosso, Paraná, and São Paulo, while *C. portianum* occurs in the states of Bahia, Goiás, Minas Gerais, São Paulo and Paraná (Flora do Brasil 2020 under construction, 2020; Oliveira, 2011).

Cosmarium exiguum W.Archer and *C. pseudoexiguum* var. *pseudoexiguum* Racib. (Fig. 3E-F) followed previous descriptions and illustrations by Araújo (2006) and Oliveira (2011). However, *C. pseudoexiguum* showed cell wall without the presence of hyaline (versus strongly punctuated hyaline cell wall). *C. tinctum* var. *globosiforme* followed previous descriptions (Eterovick & Giani, 1996; Oliveira, 2011), but it was found insufficient specimens for full taxon identification.

Cosmarium sp. presents cell 1,2 times longer than wide, deep median constriction, median sinus closed along its entire length, subrectangular semicells, parallel side margins slightly concave, apical margin flattened, basal and apical rounded angles, cell surface ornamented with grains, hyaline finely punctuated cell wall, and a central pyrenoid in semicell. These characteristics did not follow any previous descriptions in the genus, which may indicate the existence of a new record for science. However, a depth investigation of this taxon is necessary.

The genus *Staurastrum* was the second richest genera in this study, and *S. chaetoceras* var. *convexum* Grönblad had only been registered previously in the state of Bahia, therefore the samplings from Sergipe were in accordance with the descriptions of Oliveira (2011). Specimens of *S. punctulatum* Bréb ex. Ralfs did not show the granulated hyaline cell wall described by Felisberto & Rodrigues (2013), Oliveira et al. (2008), Oliveira (2011) and Oliveira et al. (2016).

Staurastrum excavatum West & G.S.West (Fig. 3G-H) and *S. tetracerum* Ralfs ex Ralfs (Fig. 3I-J) followed previous descriptions and illustrations (vide Barroso et al., 2007; Islam & Akter, 2006; Oliveira, 2011; Oliveira et al., 2016). This species presents diagnostic characteristics: the isthmus in form of "U", long processes and a small depression in the apical margin of the semicell (Oliveira, 2011).

Populations in the studies of Barroso et al. (2007) and Oliveira (2011) differ on the length/width ratio from the present taxon. In Barroso et al. (2007), cell ratio ranges from 1.3 to 1.4 times longer than wide. However, specimens studied by Oliveira (2011) had as long as wide measures; here, the length/width ratio was 1.2 to 1.4. These differences show that the relationship of cell measures of *Staurastrum excavatum* is not a determining factor for this species identification. The geographical distribution in Brazil is located in the states of Bahia, Espírito Santo and Rio de Janeiro, while *S. tetracerum* is in the states of Amazonas, Bahia, Espírito Santo, Maranhão, Mato Grosso, Minas Gerais, São Paulo and Paraná (Flora do Brasil 2020 under construction, 2020; Oliveira, 2011).

Staurastrum gracile var. *coronulatum* Boldt followed previous description and illustration (Oliveira 2011). The striking feature of this variety is the triangular apical view. According to Oliveira (2011), this taxon was previously only found in the states of Bahia and Rio de Janeiro, but it is now also known in Sergipe. *Staurastrum dilatatum* var. *dilatatum* f. *dilatatum* Ehrenberg ex Ralfs (Fig. 3K-L) followed the descriptions from Bortolini et al. (2010) and Oliveira (2011). This taxon is distributed in the states of Amazonas, Bahia, Maranhão and Paraná (Flora do Brasil 2020 under construction, 2020; Oliveira, 2011).

Euastrum evolutum var. *integrius* f. *integrius* West & G.S.West (Fig. 3M-N) and *Micrasterias truncata* var. *truncata* f. *gibbosa* Thomasson followed descriptions and illustrations in Oliveira (2011) and Oliveira et al. (2011). *E. evolutum* var. *integrius* f. *integrius* occur in the states of Amazonas, Bahia and São Paulo, and *M. truncata* var. *truncata* f. *gibbosa* is distributed in the states of Amazonas and Bahia (Oliveira, 2011; Oliveira et al., 2017).

Finally, as a pioneering work, all studied taxa represent new records in the state of Sergipe, which represents almost 6% of Brazilian desmids taxa (Flora do Brasil 2020 under construction, 2020) and two new possible species varieties of this family in Brazil. Despite the lack of data about this family in the state of Sergipe, results obtained from this project could provide precious information about distribution and richness of this family in Brazil. Due to the recent pressures of urban growth, a part of the information about Sergipe's phycoflora diversity has

probably been lost. Encouraging studies involving the diversity of species that occurs in these environments are essential, specially related to the family Desmidiaceae, whose representatives serve as biological indicators of water quality (Coesel, 1996; Gerrath, 2003; Prescott, 1948).

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