



Taxonomic diversity of Hydrodictyaceae (Sphaeropleales, Chlorophyceae) in Goiás state, Brazil

Yris Nara da Silva Santos^{1,2,4} & Ina de Souza Nogueira^{1,3}

Key words:

- Floristic survey
- *Pediastrum argentinense*
- *Pediastrum duplex* var. *duplex* f. *cohaerens*
- Unialgal culture

Palavras-chave:

- Florística
- *Pediastrum argentinense*
- *Pediastrum duplex* var. *duplex* f. *cohaerens*
- Cultura unialgal

Abstract

The Hydrodictyaceae family comprises unicellular to colonial organisms found mainly in lentic freshwater, oligotrophic or eutrophic freshwater environments. We investigated and documented the occurrence, frequency, and geographical distribution of Hydrodictyaceae in Goiás state, Brazil. A total of 14 infrageneric taxa were identified there, including 10 species, 3 varieties, and 1 taxonomic form, all of which were rare. *Pediastrum duplex* var. *duplex* f. *cohaerens* and *Pediastrum argentinense* were observed in oligo- or mesotrophic aquatic environments, while *Sorastrum americanum* was found in eutrophic waters. Notably, taxa such as *Lacunastrum gracillimum*, *Parapediastrium biradiatum* var. *biradiatum*, and *P. duplex* var. *duplex* f. *cohaerens* demonstrated significant plasticity both in their natural habitats and under laboratory conditions. We discuss here the taxonomic implications of findings concerning these species as well as others within the family Hydrodictyaceae.

Resumo

A família Hydrodictyaceae compreende organismos unicelulares a coloniais, registrada principalmente em ambientes de água doce, oligotrófico ou eutrófico. Investigamos e documentamos a ocorrência, frequência e distribuição geográfica de Hydrodictyaceae no estado de Goiás, Brasil. Um total de 14 táxons infragenéricos foram identificados, incluindo 10 espécies, 3 variedades e 1 forma taxonômica, todos raros. *Pediastrum duplex* var. *duplex* f. *cohaerens* e *Pediastrum argentinense* foram observados em ambientes aquáticos oligotróficos ou mesotróficos, enquanto *Sorastrum americanum* foi encontrado em águas eutróficas. Notavelmente, táxons como *Lacunastrum gracillimum*, *Parapediastrium biradiatum* var. *biradiatum* e *P. duplex* var. *duplex* f. *cohaerens* demonstraram plasticidade significativa tanto em seus habitats naturais quanto em condições de laboratório. Discutimos aqui as implicações taxonômicas das descobertas relacionadas a essas espécies, bem como outras dentro da família Hydrodictyaceae.

Original Papers

¹ Universidade Federal de Goiânia, Goiânia, GO, Brazil.

² ORCID: 0000-0002-1377-8837

³ ORCID: 0000-0003-4908-6442

⁴ Author for correspondence: yrisnara@gmail.com
Cite as: Santos YNS & Nogueira IS (2025) Taxonomic diversity of Hydrodictyaceae (Sphaeropleales, Chlorophyceae) in Goiás state, Brazil. Rodriguésia 76: e00382024. DOI: 10.1590/2175-7860202576021

Area Editor: Dr. Paulo Guimarães

Received on May 26, 2024. Accepted on February 25, 2025.

Rodriguésia

Revista do Instituto de Pesquisas Jardim Botânico do Rio de Janeiro
<<http://rodriguesia.jbrj.gov.br>>.

This is an open-access article distributed under the terms of the Creative Commons Attribution License.



Introduction

The Hydrodictyaceae family includes taxa ranging from unicellular to coenobial forms, widely distributed globally. The main diacritical characteristics of this family are detailed in Loaiza-Restano & Bicudo (2014) and Krienitz & Bock (2012). This family is commonly observed in many oligotrophic to eutrophic aquatic environments (Komárek & Fott 1983; Comas 1996). The geographical distribution of Hydrodictyaceae can be further categorized based on latitude, reflecting the cladogenesis of taxa in temperate and tropical zones and indicating recent in the family's phylogenetic history (McManus & Lewis 2011).

The Hydrodictyaceae family consists of 15 genera (Guiry & Guiry 2021), whose cytomorphological characteristics, as well as their vegetative and reproductive stages, have been described by Parra (1979), Komárek & Fott (1983), Loaiza-Restano & Bicudo (2014), Garduño-Solórzano *et al.* (2016), and Ramos *et al.* (2016). The molecular characteristics of the family have also been studied by Buchheim *et al.* (2005), McManus & Lewis (2005, 2011), and McManus *et al.* (2011), supporting the monophyly of Hydrodictyaceae.

Taxonomy within Hydrodictyaceae is primarily based on the analysis of vegetative stages and diacritical characters, with phylogenetic analysis providing additional support for some taxa. However, evolutionary convergence and phenotypic plasticity may introduce classification errors, resulting in ongoing discussions and revisions (*e.g.*, Buchheim *et al.* 2005).

The first records of Hydrodictyaceae in Brazil date to the late 19th century (Bohlin 1897), and its taxa have since been documented in all regions of that country, particularly in floristic inventories (Silva *et al.* 2001; Paiva *et al.* 2006; Perbiche-Neves *et al.* 2007; Monteiro *et al.* 2009; *e.g.*, Rodrigues *et al.* 2010; Silva *et al.* 2023). Recent studies focusing exclusively on the family notably include those by Loaiza-Restano & Bicudo (2014) and Ramos *et al.* (2016). Hydrodictyaceae was reported in the central region of Brazil in studies conducted by Bohlin (1897), Borge (1925), De-Lamônica-Freire (1989), De-Lamônica-Freire & Sant'Anna (1993), Nogueira & Leandro-Rodrigues (1999), Oliveira & Calheiros (2000), Felisberto *et al.* (2001), Silva *et al.* (2001), Nogueira *et al.* (2008), Freitas & Loverde-Oliveira (2013), D'Alessandro & Nogueira (2017) and Dunck *et al.* 2018, focusing primarily on inventories and taxonomy.

Although taxa within Hydrodictyaceae are common, some representatives can be difficult to differentiate at the species level, as noted by Loaiza-Restano & Bicudo (2014). Therefore, further taxonomic studies across different locations in

Brazil are essential for a deeper understanding of the family's diacritical characteristics.

While a few publications have mentioned the presence of this family in Goiás state, only a limited number of areas have been surveyed. The present study, therefore, inventoried and documented the occurrence and frequency of Hydrodictyaceae in diverse aquatic environments in Goiás State. To better understand the morphology of certain some taxa within of the family, they were cultivated.

Material and Methods

Goiás state is located in the central-western region of Brazil (16°00'23"S, 49°29'08"W) and covers a total area of 340,087 km², with elevations ranging from 186 to 1,670 m (IBGE 2010). The state experiences a wide range of climatic conditions, including types Am, Aw, Cwa, and Cwb according to the Köppen classification, with the Aw classification being the most prevalent. The mean regional temperature is 23.4 °C, with an annual rainfall rate of approximately 1,500 mm, with distinct dry (May to September) and wet seasons (October to April) (Cardoso *et al.* 2014). The aquatic environments in the state are distributed across three hydrographic basins: the Paraná, Tocantins-Araguaia, and São Francisco (Fig. 1), with the sampling points being found in the first two river basins. The majority of the study area consists of neotropical savanna vegetation and forests, characteristic of the Brazilian *Cerrado*, which is being impacted by ongoing deforestation and degradation of its water resources related to agricultural activities (Bayma & Sano 2015; Latrubesse *et al.* 2019). The environments studied and their characteristics are mentioned in Tables 1 and 2.

A total of 425 samples were collected from 82 municipalities during this study, although with Hydrodictyaceae being recorded only in 10 municipalities and 38 localities (Tab. 2). The data sampling and analysis were conducted between 2000 and 2018 and represent two of the state's three hydrographic regions (Paraná, Tocantins-Araguaia). Phytoplankton samples were collected using a 20 µm mesh plankton net, and phycoperiphyton samples were obtained by scraping various substrates. All samples were fixed in Transeau solution (1:1) in transparent glass flasks (Bicudo & Menezes 2017) and subsequently stored in the Herbarium UFG.

In 2018, material collected from the municipality of Britânia was cultivated in ASM1 culture medium (Jacinavicius *et al.* 2013) and *Lacunastrum gracillimum* (West & G.S. West) H.A. McManus, *Pediastrum duplex* Meyen var. *duplex* f. *coharens* Bohlin, and *Parapediastrium biradiatum* (Meyen) E. Hegewald in Buchheim *et al.* were

subsequently isolated into unialgal cultures (Anderson & Kawachi 2005). Lago dos Tigres was selected to study the Hydrodictyaceae taxa due to the greater occurrence of species from this family.

Part of the algae culture was set aside for ultrastructural analysis of the sporopollenin layer. That material was fixed in 2% glutaraldehyde, dehydrated in an increasing alcohol series (20, 40, 50, 60, 80, 100%), and then gold-coated for Scanning Electron Microscopy (SEM - JSM 6610, JEOL Ltd., Tokyo, Japan), following the method adapted from Buchheim *et al.* (2005). The SEM analysis was conducted using an electrical potential of 7 to 10 KV, at a distance of 11 mm, with a spot size of 25-40 mm.

The taxonomic identification of Hydrodictyaceae taxa was based on the works of

Komárek & Fott (1983), Parra (1979), and Buchheim *et al.* (2005), using both fixed and live material. Approximately 10 slides were prepared from each sample and subsequently examined under a optical microscope (OM - Zeiss Axioskop 40) equipped with a Zeiss Axiocam 350 color digital camera (at magnifications of 400 or 1,000). Microphotographs and morphometric analyses were performed via Zen blue lite 2.5 software. Nomenclatural updates and classification followed Krienitz & Bock (2012) and the Algaebase system (Guiry & Guiry 2021). The terminology recommended by Komárek & Jankovská (2001) was used to describe the algae observed under SEM. Taxa descriptions included metric, morphological, and meristic characteristics, and Figures were prepared from both optical and

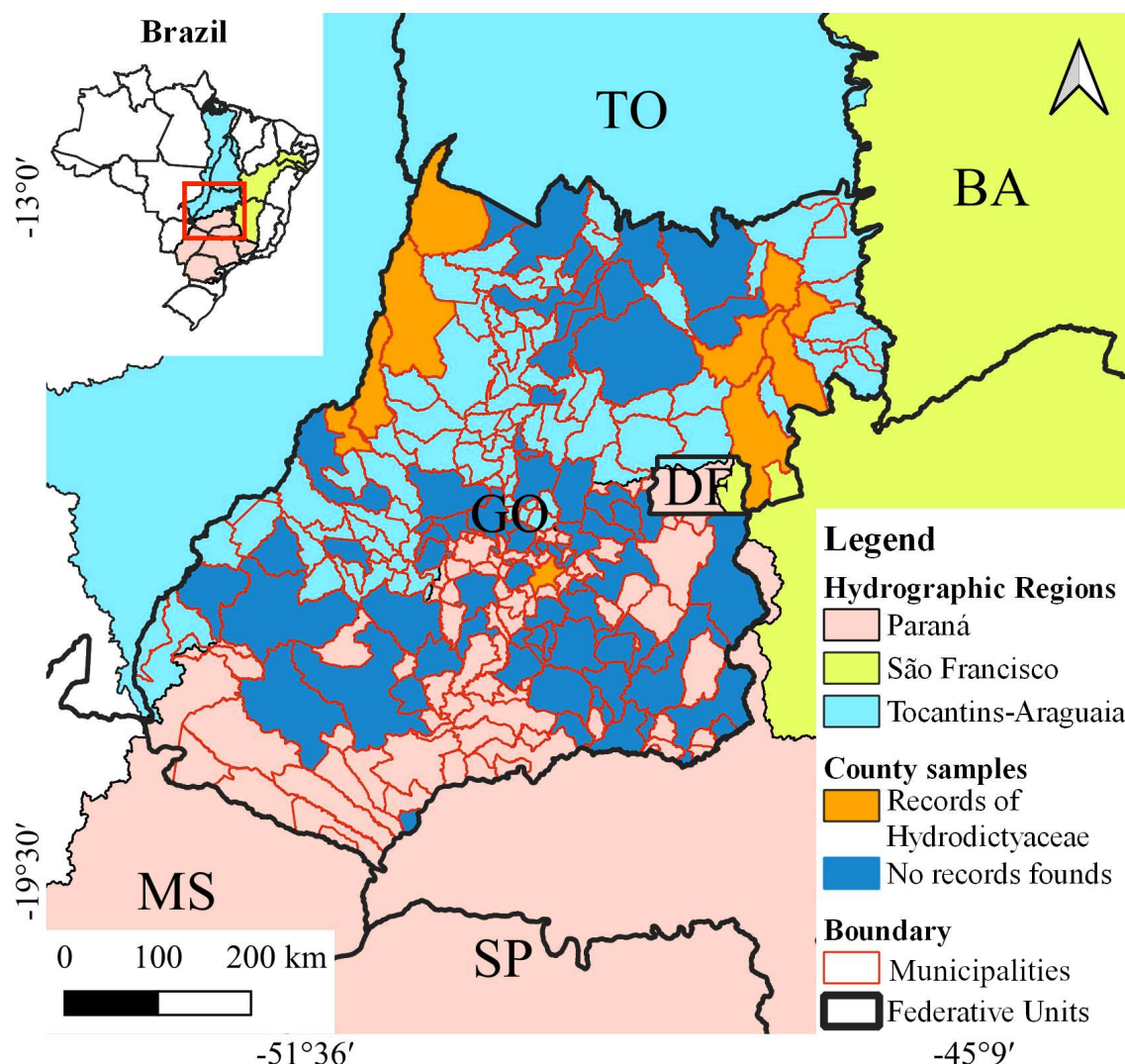


Figure 1 – Map showing the the hydrographic regions of Goiás state, along with all sampled municipalities and those surveyed in the literature.

Table 1 – Frequency of occurrence (expressed as percentages) of the taxa in each municipality of Goiás state, Brazil (n = 425), along with the number of samples collected per municipality. Abbreviations of the municipalities sampled in Goiás state, Brazil: Aru = Aruanã; Bri = Britânia; For = Formosa; FG = Flores de Goiás; Goi = Goiânia; Iac = Iaciara; NC = Nova Crixás; NR = Nova Roma; SJA = São João da Aliança; SMA = São Miguel do Araguaia.

Taxa / Municipalities	Aru	Bri	For	FG	Goi	Iac	NC	NR	SJA	SMA	Total
<i>L. gracillimum</i>	0,0	14	0,0	0,0	21,5	0,0	0,0	0,0	0,0	0,0	9
<i>M. simplex</i>	7,1	3	3,3	7,1	31	0,0	5,0	0,0	0,0	0,0	7,1
<i>P. biradiatum</i>	0,0	13	0,0	0,0	3,1	0,0	0,0	0,0	0,0	0,0	5,6
<i>P. biradiatum</i> var. <i>longicornutum</i>	0,0	2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,7
<i>P. argentinense</i>	0,0	0,0	3,3	21,4	1,5	0,0	20	5	0,0	0,0	2,4
<i>P. duplex</i> var. <i>duplex</i>	0,0	21,6	0,0	0,0	29,2	0,0	35	5	0,0	29,3	18
<i>P. duplex</i> f. <i>Cohaerens</i>	18	9,4	3,3	14,3	3,1	6	15	0,0	0,0	14,6	8,5
<i>P. cornutum</i>	0,0	1,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5
<i>S. americanum</i>	0,0	4,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2
<i>S. tetras</i>	0,0	23	3,3	0,0	15,4	0,0	0,0	0,0	0,0	7,3	12,5
<i>T. regurare</i> var. <i>bifurcatum</i>	3,6	0,0	0,0	7,1	1,5	0,0	0,0	0,0	0,0	2,4	1
<i>T. caudatum</i>	0,0	0,0	0,0	0,0	7,7	0,0	0,0	0,0	0,0	0,0	1,2
<i>T. minimum</i>	0,0	1,8	0,0	0,0	6,2	0,0	0,0	0,0	5,6	0,0	2
<i>T. triangulare</i>	0,0	1,2	0,0	0,0	7,7	0,0	0,0	0,0	0,0	0,0	1,6
N sample	28	171	30	14	65	17	20	21	18	41	425

Table 2 – Characteristics of the environments studied in the state of Goias with occurrence of Hydrodictyaceae.

Municipalities	Localities	Type of environment	Water flow	Trophic level of environments	Communities
Aruanã	Azul Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
Aruanã	Campos Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
Aruanã	Cangas Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
Aruanã	Dumbazinho Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
Britânia	Tigres Lake	Lake	Lentic	Oligo-mesotrophic (Nabout & Nogueira 2007; D'Alessandro & Nogueira 2018)	Plankton, Epiphyton and Epiendron
Britânia	Tigrinho Lake	Lake	Lentic	No information	Plankton and Epiphyton
Flores de Goiás	Correntes River	River	Lotico	Mesotrophic (Boaventura <i>et al.</i> 2007)	Plankton and Epiphyton
Flores de Goiás	Irrigation dam	Dam	Lentico	Mesotrophic (Boaventura <i>et al.</i> 2007)	Plakton
Flores de Goiás	Paraná River	River	Lotic	Mesotrophic (Boaventura <i>et al.</i> 2007)	Plankton
Goiânia	Beija-flor Lagoon	Lagoon	Lentic	No information	Plankton
Goiânia	Bosque dos Buritis Lagoon	Lagoon	Lentic	Eutrophic (Nogueira <i>et al.</i> 2008)	Plankton
Goiânia	Jardim Botânico Lagoon	Lagoon	Lentic	Eutrophic (Nogueira <i>et al.</i> 2008)	Plankton

Municipalities	Localities	Type of environment	Water flow	Trophic level of environments	Communities
Goiânia	Parque Vaca Brava Lagoon	Lagoon	Lentic	Eutrophic (Nogueira <i>et al.</i> 2008)	Plankton
Goiânia	Rosas Lagoon	Lagoon	Lentic	Eutrophic (Nogueira <i>et al.</i> 2008)	Plankton
Goiânia	Samambaia Dam	Dam	Lentic	Oligo-mesotrophic (Nogueira, 1999)	Plankton
Formosa	Jataí River	River	Lotic	Mesotrophic (Boaventura <i>et al.</i> 2007)	Periphyton
Formosa	Swamp	Swamp	Lentic	Mesotrophic (Boaventura <i>et al.</i> 2007)	Plankton
Iaciara	Paraná River	River	Lotic	Mesotrophic (Boaventura <i>et al.</i> 2007)	Periphyton
Nova Crixas	Bandeirantes Lagoon	Lagoon	Lentic	Mesotrophic (Boaventura <i>et al.</i> 2007)	Plankton
Nova Crixás	Cocal Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
Nova Crixás	Dumbá Grande Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
Nova Crixás	Fuzil Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
Nova Crixás	Landi Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
Nova Crixás	São Joaquim Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
Nova Crixás	São José dos Bandeirantes Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
Nova Roma	São Bartolomeu River	River	Lotic	Mesotrophic (Boaventura <i>et al.</i> 2007)	Epiphyton
Nova Roma	Forquilha River	River	Lotic	Mesotrophic (Boaventura <i>et al.</i> 2007)	Epiphyton
S. João da Aliança	Macacão River	River	Lotic	Mesotrophic (Boaventura <i>et al.</i> 2007)	Epiphyton
S. Miguel do Araguaia	Bandeirantes Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
S. Miguel do Araguaia	Brito Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
S. Miguel do Araguaia	Barra Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
S. Miguel do Araguaia	Japonês Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
S. Miguel do Araguaia	Luís Alves Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
S. Miguel do Araguaia	Montaria Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
S. Miguel do Araguaia	Piedade Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton
S. Miguel do Araguaia	Ribeirão Dantas Lagoon	Lagoon	Lentic	Mesotrophic (Nabout <i>et al.</i> 2006)	Plankton

SEM observations. Geographic distributions and additional comments are provided when necessary.

Ecological information concerning the recorded taxa was based on Komárek & Fott (1983), Sant'Anna (1984), Comas (1996), Nogueira (1999), Nabout *et al.* (2007), Boaventura *et al.* (2007), Nogueira *et al.* (2008), D'Alessandro & Nogueira (2017, 2018), and Guiry

& Guiry (2021), with consideration given to the continent when multiple countries were involved.

Frequencies of occurrence were determined following Guille (1970) Frequency up to 10% were considered rare, between 10% and 50%, inclusive, were considered common, and higher than 50% were considered constant. The distribution of the

family in Goiás State was plotted using Las Palmas QGIS 2.18 software. The material examined was categorized into two groups: new records for taxa not previously recorded, and additional records for municipalities cited in previous studies.

Results

The following key can be used to identify the eight genera, ten species, three varieties, and one taxonomic form recorded totaling 14 infrageneric taxa.

Identification key for Hydrodictyaceae in Goiás state, Brazil

1. Isolated cells, 3–5-angular.
 2. Cells 3-angular 14. *Tetraedron triangulare*
 - 2'. Cells 4-angular.
 3. Cells subquadratic, with rounded corners, with or without 1 papilla 12. *Tetraedron minimum*
 - 3'. Cells tetrahedral, corners with 2 spines 13. *Tetraedron regulare* var. *bifurcatum*
 - 2''. Cells 5-angular 11. *Tetraedron caudatum*
- 1'. Cells arranged in coenobia.
 4. Coenobium spherical, with pyramidal cells with 4 narrow processes, cells radially disposed, converging on a central body 9. *Sorastrum americanum*
 - 4'. Coenobium circular, flat to slightly concave, cells not pyramidal, with concentric dispositions.
 5. Marginal cells 1-lobed 2. *Monactinus simplex*
 - 5'. Marginal cells 2-lobed.
 6. Marginal cells longer than wide, with 1 pair of narrow and equal lobes, extending 3/5 of the cell length 1. *Lacunastrum gracillimum*
 - 6'. Marginal cells with different constitutions.
 7. Marginal cells with bifurcate lobes.
 8. Marginal cells, with median incision extending 2/3 of the cell length 10. *Stauridium tetras*
 - 8'. Marginal cells with a medium incision extending 1/2 of the cell length *Parapediastrium biradiatum*
 9. Lobules the same length 3. *Parapediastrium biradiatum* var. *biradiatum*
 - 9'. Lobules of differing lengths 4. *Parapediastrium biradiatum* var. *longecornutum*
 - 7'. Marginal cells with non-bifurcated lobes.
 10. Conic lobes truncate, extending 1/5–1/2 of the cell length.
 11. Lobes extending 1/5 of the cell length 5. *Pediastrium argentinense*
 - 11'. Lobes extending 1/2 of the cell length *Pediastrium duplex*
 12. One pair of long, non-divergent lobes, marginal cells with a U-shaped external incision 6. *Pediastrium duplex* var. *duplex*
 - 12'. One pair of short divergent lobes, marginal cells with a broad V-shaped external incision 7. *Pediastrium duplex* var. *duplex* f. *cohaerens*
 - 10'. Lobes extending 2/3 of the cell length 8. *Pseudopediastrium cornutum*

Taxa recorded in Goiás state, Brazil

Chlorophyta

Chlorophyceae

Hydrodictyaceae

1. *Lacunastrum gracillimum* (West & GS West) HA McManus 2011. Fig. 2a-i

Coenobium rounded, flat, 16–32 cells, 2–3 concentric cell layers, intercellular spaces present. Outer pole asymmetrical H-shaped, interconnected along 1/3 of the lower portion, the base of the cell concave, 1 pair of narrow lobes, elongated, of the same size, 3/5 of the cell size, ending in

short-cylindrical processes, apex truncate, ring thickenings, outer incision V-shaped, inner cells H-shaped, biconcave, smooth cell walls. Parietal chloroplast accompanying the cell shape, 1 central pyrenoid. SEM: cell surface smooth, edges of the processes with a thickened ring. Coenobium 23.5–133 μm , outer cells 6–26 $\times$ 3.5–19 μm , inner cells 3.5–18 $\times$ 4–18 μm , intercellular spaces 2.2–8.9 μm .

Material examined - new records: Britânia, Tigres Lake, 15°15'12"S, 51°09'56"W, 13.VII.2004, I.S. Nogueira 903 (UFG). 15°13'18"S, 51°10'06"W, 14.VII.2004, I.S. Nogueira 907 (UFG). 15°14'17"S, 51°08'59"W, 19.VIII.2004, I.S.

Nogueira 951 (UFG). 15°16'47"S, 51°09'44"W, 16.X.2004, I.S. *Nogueira* 1025 (UFG). 15°15'46"S, 51°08'41"W, 16.X.2004, I.S. *Nogueira* 1027 (UFG). 15°15'12"S, 51°08'33"W, 16.X.2004, I.S. *Nogueira* 1028 (UFG). 15°13'43"S, 51°09'14"W, 17.X.2004, I.S. *Nogueira* 1031 (UFG). 15°13'18"S, 51°10'06"W, 17.X.2004, I.S. *Nogueira* 1032 (UFG). 15°15'46"S, 51°08'41"W, 5.XI.2004, I.S. *Nogueira* 1119 (UFG). 15°16'47"S, 51°09'44"W, 17.VII.2008, I.S. *Nogueira* 1228 (UFG). 15°15'12"S, 51°08'33"W, 17.VII.2008, I.S. *Nogueira* 1231 (UFG). 15°14'09"S, 51°09'27"W, 17.VII.2008, I.S. *Nogueira* 1233 (UFG). 15°16'47"S, 51°09'44"W, 19.VIII.2008, I.S. *Nogueira* 1241 (UFG). 15°13'43"S, 51°09'14"W, 19.VIII.2008, I.S. *Nogueira* 1247 (UFG). 15°15'12"S, 51°08'33"W, 19.X.2008, I.S. *Nogueira* 1270 (UFG). 15°14'09"S, 51°09'27"W, 19.X.2008, I.S.

Nogueira 1272 (UFG). 15°16'47"S, 51°09'44"W, 15.XI.2008, I.S. *Nogueira* 1280 (UFG). 15°16'17"S, 51°09'10"W, 15.XI.2008, I.S. *Nogueira* 1281 (UFG). 15°15'12"S, 51°08'33"W, 15.XI.2008, I.S. *Nogueira* 1283 (UFG). 15°14'09"S, 51°09'27"W, 15.XI.2008, I.S. *Nogueira* 1285 (UFG). 15°13'43"S, 51°09'14"W, 16.XI.2008, I.S. *Nogueira* 1286 (UFG). 15°15'12"S, 51°08'33"W, 11.XII.2008, I.S. *Nogueira* 1296 (UFG). 15°13'43"S, 51°09'14"W, 12.XII.2008, I.S. *Nogueira* 1299 (UFG). 15°15'46"S, 51°08'41"W, 21.I.2009, I.S. *Nogueira* 1308 (UFG).

Additional material examined - previously recorded: BRAZIL. GOIÁS: Goiânia, Beija-flor Lake, E.B. D'Alessandro (UFG 40241). 16°39'11"S, 49°13'87"W, 26.VIII.2007, I.S. *Nogueira* 1146 (UFG). 16°39'11"S, 49°13'87"W, 26.VIII.2007, I.S. *Nogueira* 1147 (UFG).

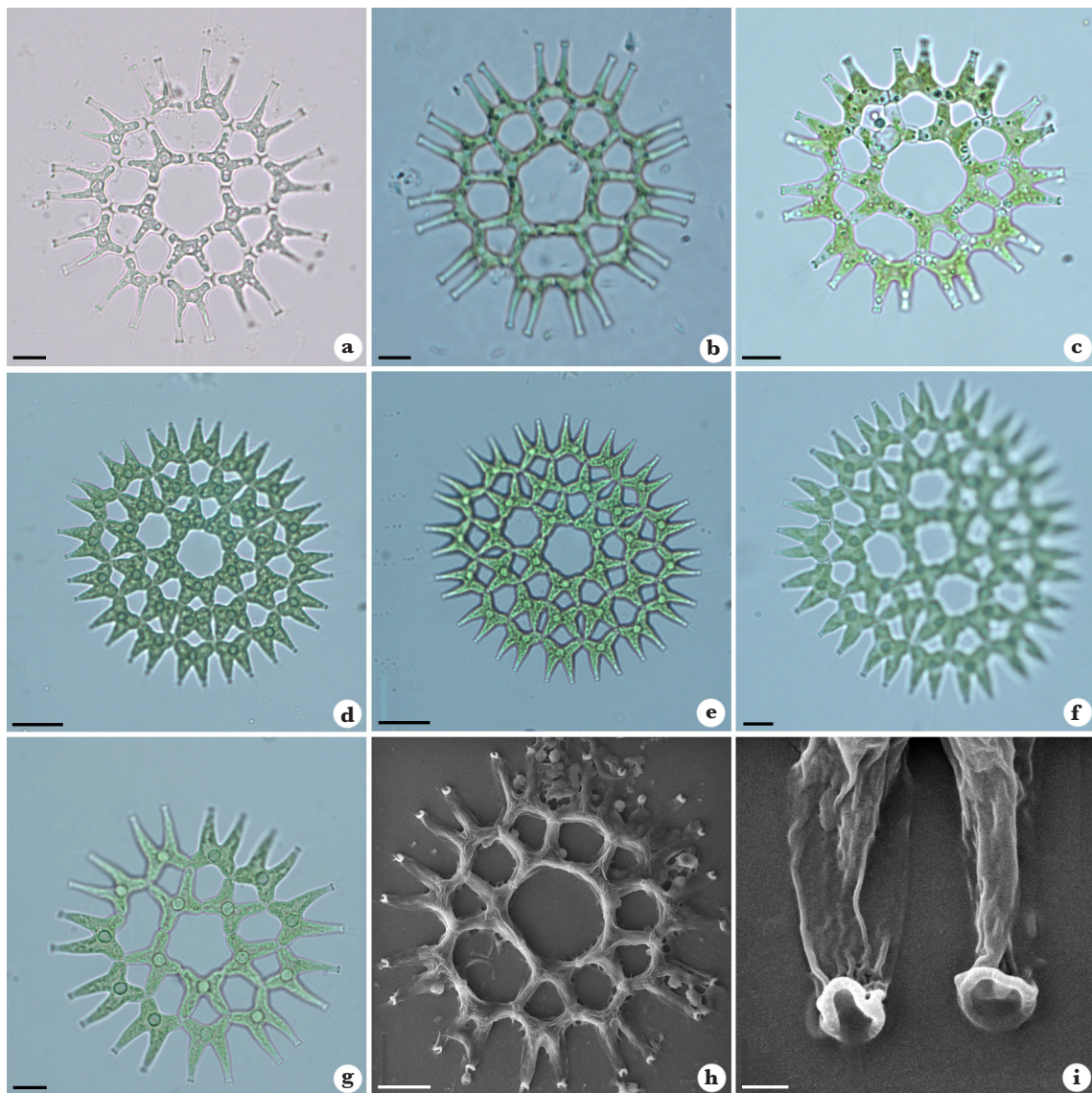


Figure 2 – a-i. Figures of in situ and cultivated material of *Lacunastrum gracillimum* via OM (Optical Microscopy) and SEM (Scanning Electron Microscopy) – a. *In situ*. b-i. cultivated. a-g. OM, scale bar = 10 µm. h-i. SEM, scale bar = 1 µm. (fixed replica, IS Nogueira).

16°39'11"S, 49°13'87"W, 2.IX.2007, I.S. Nogueira 1150 (UFG). 16°39'11"S, 49°13'87"W, 9.IX.2007, I.S. Nogueira 1152 (UFG 40249). 16°39'11"S, 49°13'87"W, 9.IX.2007, I.S. Nogueira 1153 (UFG). 16°39'11"S, 49°13'87"W, 16.IX.2007, I.S. Nogueira 1155 (UFG). 16°39'11"S, 49°13'87"W, 16.IX.2007, I.S. Nogueira 1156 (UFG 40252). 16°39'12"S, 49°13'85"W, 30.IX.2007, I.S. Nogueira 1159 (UFG 40256). 16°39'11"S, 49°13'87"W, 17.I.2008, I.S. Nogueira 1161 (UFG 40258). 16°39'11"S, 49°13'87"W, 24.I.2008, I.S. Nogueira 1164 (UFG 40261). 16°39'11"S, 49°13'87"W, 24.I.2008, I.S. Nogueira 1165 (UFG 40262). 16°39'11"S, 49°13'87"W, 31.I.2008, I.S. Nogueira 1167 (UFG 40264). 16°39'11"S, 49°13'87"W, 7.II.2008, I.S. Nogueira 1171 (UFG 40268). D'Alessandro & Nogueira 2017.

This species is recorded in plankton, periphyton, and metaphyton of oligotrophic and eutrophic environments. Cosmopolitan, with records from the United States, South America, Europe, and Oceania.

2. *Monactinus simplex* (Meyen) Corda 1839.

Fig. 3a

Coenobium rounded, planar to slightly concave, 16–32 cells, 2–3 concentric layers, intercellular spaces present. Marginal cells conical with trapezoidal base, 1/3 laterally joined at the base, base straight, 1 straight lobe, long, 2/3 of the

cell length, ending in a long process, 1/2 of the cell length, inner cells subtriangular, sides concave, joined at their corners. Chloroplast parietal, accompanying the cell shape, 1 central pyrenoid. Coenobium 55–98.1 µm, outer cells 15–17 × 7–9 µm, inner cells 8–9 µm, intercellular spaces 2–5 µm.

Material examined - new records: Aruanã, Azul Lagoon, 14°46'65"S, 51°01'82"W, 1.VIII.2000, I.S. Nogueira 672 (UFG). Campos Lagoon, 14°47'93"S, 51°01'90"W, 1.III.2001, I.S. Nogueira 713 (UFG). Britânia, Tigrinho Lake, 15°12'51"S, 51°10'22"W, 14.VII.2004, I.S. Nogueira 943 (UFG). 15°12'51"S, 51°10'22"W, 20.VIII.2004, I.S. Nogueira 979 (UFG). 15°14'17"S, 51°8'59"W, 16.X.2004, I.S. Nogueira 1029 (UFG). 15°13'18"S, 51°10'6"W, 17.X.2004, I.S. Nogueira 1032 (UFG). 15°11'47"S, 51°9'57"W, 20.VIII.2004, I.S. Nogueira 955 (UFG). Nova Crixás, Dumbá Grande Lagoon, 13°42'79"S, 50°48'63"W, 1.II.2002, I.S. Nogueira 649 (UFG).

Additional material examined - previously recorded: BRAZIL. GOIÁS: Goiânia, Bosque dos Buritis Lake, 16°40'83"S, 49°15'68"W, 25.VIII.2000, I.S. Nogueira 615 (UFG). 16°40'83"S, 49°15'68"W, 15.IX.2000, I.S. Nogueira 624 (UFG). 16°40'83"S, 49°15'68"W, 8.II.2001, I.S. Nogueira 659 (UFG). 16°40'83"S, 49°15'68"W, 8.III.2001, I.S. Nogueira 665 (UFG). 16°40'83"S, 49°15'68"W, 8.VI.2001, I.S. Nogueira 699 (UFG). 16°40'83"S, 49°15'68"W, 23.VIII.2001, I.S. Nogueira 707 (UFG). 16°40'83"S, 49°15'68"W, 4.X.2001, I.S. Nogueira 711 (UFG). 16°40'83"S, 49°15'68"W, 9.XI.2001, I.S. Nogueira 765 (UFG). Jardim Botânico Lake,

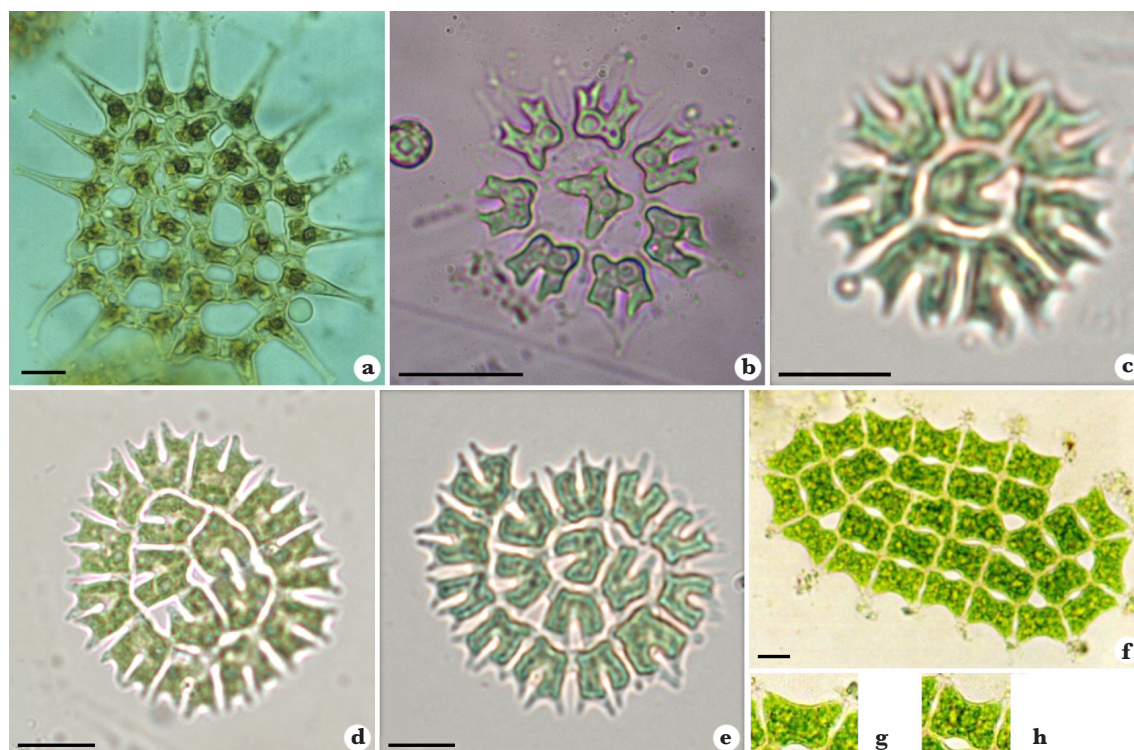


Figure 3 – a-h. Figure of in situ and cultivated material via OM (optical microscopy) – a. *Monactinus simplex*; b. *Parapedastrum biradiatum* var. *biradiatum*. c-e. *P. biradiatum* var. *biradiatum*. f-h. *P. argentinense*. In situ: a-b, f-h; cultivated: c-e. Scale bar = 10 µm (a. IS Nogueira 617; b. IS Nogueira 1119; c. IS Nogueira; d. IS Nogueira 1280; e. IS Nogueira 656).

16°43'48"S, 49°15'16"W, 25.VIII.2000, *I.S. Nogueira* 618 (UFG). 16°43'48"S, 49°15'16"W, 8.II.2001, *I.S. Nogueira* 655 (UFG). Parque Vaca Brava Lake, 16°42'54"S, 49°16'25"W, 8.II.2001, *I.S. Nogueira* 656 (UFG). 16°42'54"S, 49°16'25"W, 23.VIII.2001, *I.S. Nogueira* 705 (UFG). Rosas Lake, 16°40'78"S, 49°16'46"W, 25.VIII.2000, *I.S. Nogueira* 617 (UFG). 16°43'48"S, 49°15'16"W, 15.IX.2000, *I.S. Nogueira* 621 (UFG). 16°40'78"S, 49°16'46"W, 15.IX.2000, *I.S. Nogueira* 622 (UFG). 16°40'78"S, 49°16'46"W, 8.II.2001, *I.S. Nogueira* 657 (UFG). 16°40'78"S, 49°16'46"W, 8.III.2001, *I.S. Nogueira* 663 (UFG). 16°40'78"S, 49°16'46"W, 8.VI.2001, *I.S. Nogueira* 698 (UFG). 16°40'78"S, 49°16'46"W, 23.VIII.2001, *I.S. Nogueira* 706 (UFG). 16°40'78"S, 49°16'46"W, 9.XI.2001, *I.S. Nogueira* 764 (UFG). *Nogueira et al.* 2008. Flores de Goiás, Correntes River, 14°18'18"S, 46°55'58"W, IX.2004, *I.S. Nogueira* 1076 (UFG). Formosa, Swamp, 15°09'32"S, 47°28'04"W, IX.2004, *I.S. Nogueira* 1095 (UFG). Silva 2007.

This species is recorded in plankton, periphyton, and metaphyton of mesotrophic to eutrophic environments. Cosmopolitan, with records from Australia, the Americas, Europe, Asia, Africa, Arctic, and Antarctic.

3. *Parapediastrum biradiatum* (Meyen) E Hegewald 2005 var. *biradiatum*. Fig. 3b-e

Coenobium circular or a flat spiral, 8–32 cells, 2–3 concentric cell layers, no spacing between cells. Marginal cells polygonal, joined by their bases along 1/3 of the cell length, base straight, 2 lobes of the same size, elongated, 1/2 of the cell length, each one bifurcated into 2 lobules of the same size, short, 1/10 of the cell length, with ending processes, short-cylindrical, sometimes in a different plane of coenobium, apices abrupt-truncate, with a U-shaped external incision, inner cells polygonal, with a deep central U-shaped incision, joined together along their entire extension, cell wall smooth. Chloroplast parietal, 1 central pyrenoid. Coenobium 25–40 µm, outer cells 7–13 × 6–8 µm, inner cells 6–7 µm.

Material examined - new records: Britânia, Tigres Lake, 15°17'57"S, 51°10'07"W, 4.VI.2004, *I.S. Nogueira* 876 (UFG). 15°15'12"S, 51°08'33"W, 4.VI.2004, *I.S. Nogueira* 878 (UFG). 15°14'09"S, 51°09'27"W, 5.VI.2004, *I.S. Nogueira* 892 (UFG). 15°15'46"S, 51°08'41"W, 9.IX.2004, *I.S. Nogueira* 989 (UFG). 15°15'46"S, 51°08'41"W, 16.X.2004, *I.S. Nogueira* 1027 (UFG). 15°15'12"S, 51°08'33"W, 16.X.2004, *I.S. Nogueira* 1028 (UFG). 15°16'17"S, 51°09'10"W, 17.VII.2008, *I.S. Nogueira* 1229 (UFG). 15°15'12"S, 51°08'33"W, 19.VIII.2008, *I.S. Nogueira* 1244 (UFG). 15°14'09"S, 51°09'27"W, 19.VIII.2008, *I.S. Nogueira* 1246 (UFG). 15°15'12"S, 51°08'33"W, 16.IX.2008, *I.S. Nogueira* 1257 (UFG). 15°14'17"S, 51°08'59"W, 19.X.2008, *I.S. Nogueira* 1271 (UFG). 15°14'09"S, 51°09'27"W, 19.X.2008, *I.S. Nogueira* 1272 (UFG). 15°13'43"S, 51°09'14"W, 20.X.2008, *I.S. Nogueira* 1273 (UFG). 15°16'17"S, 51°09'10"W, 15.XI.2008, *I.S. Nogueira* 1281 (UFG). 15°14'17"S, 51°08'59"W, 15.XI.2008, *I.S. Nogueira* 1283 (UFG). 15°14'09"S, 51°09'27"W, 15.XI.2008, *I.S. Nogueira* 1285 (UFG). 15°15'12"S, 51°08'33"W, 11.XII.2008, *I.S. Nogueira* 1296 (UFG). 15°14'17"S, 51°08'59"W, 11.XII.2008, *I.S. Nogueira* 1297 (UFG). 15°13'43"S, 51°09'14"W, 12.XII.2008, *I.S. Nogueira* 1299 (UFG). 15°11'47"S, 51°09'57"W, 12.XII.2008, *I.S.*

Nogueira 1301 (UFG). 15°16'47"S, 51°09'44"W, 21.I.2009, *I.S. Nogueira* 1306 (UFG). 15°14'09"S, 51°09'27"W, 21.I.2009, *I.S. Nogueira* 1311 (UFG).

Additional material examined - previously recorded: BRAZIL. GOIÁS: Goiânia, Parque Vaca Brava Lake, 16°42'54"S, 49°16'25"W, 8.II.2001, *I.S. Nogueira* 656 (UFG). Jardim Botânico Lake, 16°43'48"S, 49°15'16"W, 23.VIII.2001, *I.S. Nogueira* 704 (UFG). *Nogueira et al.* 2008.

This species is recorded in plankton. Cosmopolitan, with records from the Americas, Asia, and Europe.

When *Parapediastrum biradiatum* var. *biradiatum* was collected and isolated for unialgal cultivation, it was observed that the cells of the coenobium exhibited morphological variability. In the unialgal culture medium, morphotypes displaying coenobium disconfigurations were frequently observed it was possible to record morphotypes with disconfigurations of the coenobium, transitioning from a concentric configuration (Fig. 4d-e) to a spiral configuration (Fig. 4f). These morphological changes were more pronounced in cultivated specimens compared to those in natural populations.

4. *Parapediastrum biradiatum* var. *longicornutum* (Gutwinski) PMT Sarenko 2011. Fig. 5a

Differs from the typical variety by having lobes in the same plane, with primary and secondary processes, primary processes 1/4 of the cell length, secondary processes 1/8 of the cell length. Coenobium 30.1 µm, marginal cells 9.7–10 × 5.2–5.8 µm.

Material examined - new records: Britânia, Tigres Lake, 15°14'09"S, 51°09'27"W, 13.VII.2004, *I.S. Nogueira* 904 (UFG). 15°13'43"S, 51°09'14"W, 18.VII.2008, *I.S. Nogueira* 1234 (UFG). 15°14'09"S, 51°09'27"W, 15.XI.2008, *I.S. Nogueira* 1285 (UFG).

This species is recorded in plankton from oligotrophic to mesotrophic environments in the Americas, and Europe.

5. *Pediastrum argentinense* Bourrelly & Tell 1979. Fig. 3f-h

Coenobium oblong to elliptic, flat, 32 cells, 2–3 concentric and compact layers, spacing between cells present, irregular. Marginal cells sub-rectangular to trapezoidal, joined 1/3 from the upper portion and 1/3 from the lower portion, external margins concave, inner margin slightly concave to straight, 1 pair of short lobes, 1/5 of the cell length, both the same size, truncate, lobes with slightly granulate surfaces, ending processes short-cylindrical, 1/6 of the cell length, inner cells sub-rectangular, concave in the median portion, joined together at their corners. Chloroplast parietal, accompanying the cell shape, 1 central pyrenoid. Coenobium 120 µm, cells 13–22 × 9–26 µm, intercellular spaces 1.4–3.6 µm.

Material examined - new records: Aruanã, Azul lagoon, 14°46'65"S, 51°01'82"W, 1.VIII.2001, *I.S. Nogueira* 739 (UFG). Formosa, Swamp, 15°09'32"S, 47°28'05"W, III.2003, *I.S. Nogueira* 830 (UFG). Flores de Goiás, irrigation dam, 14°32'12"S, 47°01'51"W, III.2003, *I.S. Nogueira* 847 (UFG). Irrigation dam, 14°32'12"S, 47°01'51"W, IX.2003, *I.S. Nogueira* 1080 (UFG). Marsh, 14°19'30"S, 46°59'26"W, III.2003, *I.S. Nogueira* 841 (UFG). Goiânia, Samambaia Dam, 16°35'71"S, 49°16'84"W, 5.IV.2000, *I.S. Nogueira* (UFG 11332). Nova Crixás, Bandeirantes Lagoon, 13°44'56"S, 50°52'99"W, 1.VIII.2000, *I.S. Nogueira* 682 (UFG). Cocal Lagoon, 13°44'56"S, 50°52'99"W, 1.II.2000, *I.S. Nogueira* 648 (UFG). 13°44'56"S, 50°52'99"W, 1.III.2001, *I.S. Nogueira* 725 (UFG). 13°44'56"S, 50°52'99"W, VIII.2001, *I.S. Nogueira* 750 (UFG). Nova Roma, São Bartolomeu River, 14°05'14"S, 47°07'33"W, IX.2003, *I.S. Nogueira* 1069 (UFG).

This species is recorded in plankton and periphyton. Oligo- or mesotrophic environments. Neotropical taxon, there are records from the Americas.

Pediastrum argentine was described based on the net-like arrangement of its marginal cells and reticulate cell walls. This species is a neotropical taxon first recorded for Argentina by Tell (1979) and subsequently recorded for Paraguay, Brazil, and Cuba (Bohlin 1897; Comas 1996; Komárek & Fott 1983; Parra 1979; Komárek & Jankovská 2001; Ramos *et al.* 2016).

There is some confusion concerning this species, as there it shows morphological overlapping with two taxonomic forms of *P. duplex* var. *duplex* f. *coharens* and f. *rectangularis*. These taxa will require additional studies, however, to be considered a taxonomic synonym, or not, of *P. argentine*. Although this is a tropical and subtropical species, Lenarczyk *et al.* (2015) recorded fossils of this taxon in Europe, and considered the current specimens of *P. argentine* to be morphologically closer to *P. duplex* var. *rugulosum* than to f. *coharens*.

6. *Pediastrum duplex* Meyen 1829 var. *duplex*.

Fig. 4a

Coenobium circular, planar to slightly concave, 8–16 cells, 2–3 concentric layers of cells, intercellular spaces present. Marginal cells polygonal, H-shaped, asymmetric, joined for 1/3 of their lower portion, base of the cell straight to discreetly concave, 1 pair of lobes narrowing to the apex, 1/2 of the cell length, of equal size, conical-truncate ending processes, 1/3 of the cell length, apices with delicate thickenings, base of the lobe bloated, external incision U-shaped, inner cells polygonal to sub-rectangular, at least one of their sides concave, joined together at their corners.

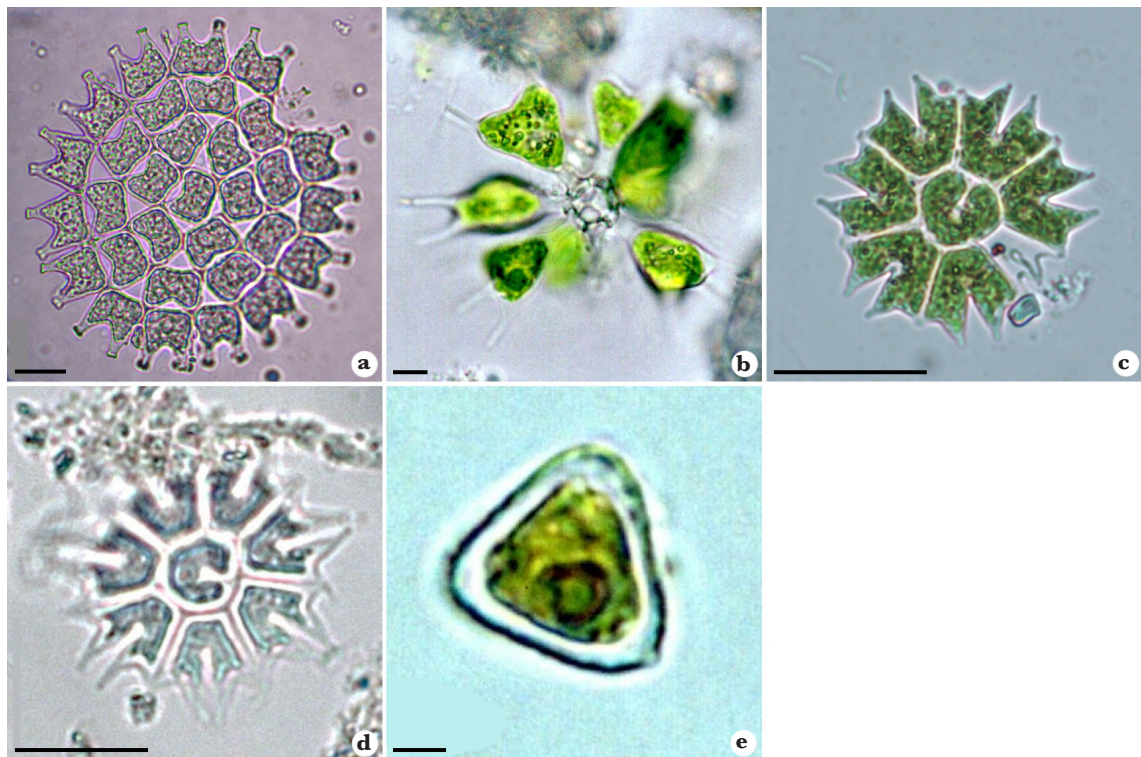


Figure 4 – a-e. Figure of *in situ* and cultivated material via OM (optical microscopy) – a. *Pediastrum duplex* var. *duplex*; b. *Sorastrum americanum*; c-d. *Stauridium tetras*; e. *Tetraedron triangulare*. Scale bar = 10 μm (Fixed replica, IS Nogueira).

Chloroplast parietal, accompanies the cell shape, 1 central pyrenoid. Coenobium 61.1–70.2 μm , outer cells 11.1–12 $\times$ 10–11.2 μm , inner cells 10–12.5 $\times$ 15.5–16.7, intercellular spaces 2.2–5.5 μm .

Material examined - new records: Britânia, Tigres Lake, 15°14'09"S, 51°09'27"W, 4.VI.2004, I.S. Nogueira 880 (UFG). 15°15'46"S, 51°08'41"W, 13.VII.2004, I.S. Nogueira 902 (UFG). 15°15'12"S, 51°08'33"W, 13.VII.2004, I.S. Nogueira 903 (UFG). 15°13'43"S, 51°09'14"W, 14.VII.2004, I.S. Nogueira 906 (UFG). 15°11'47"S, 51°09'57"W, 14.VII.2004, I.S. Nogueira 908 (UFG). 15°18'58"S, 51°09'56"W, 19.VIII.2004, I.S. Nogueira (UFG 29895). 15°17'57"S, 51°10'07"W, 19.VIII.2004, I.S. Nogueira 946 (UFG). 15°16'47"S, 51°09'44"W, 19.VIII.2004, I.S. Nogueira 947 (UFG). 15°15'12"S, 51°08'33"W, 19.VIII.2004, I.S. Nogueira 950 (UFG). 15°14'17"S, 51°08'59"W, 19.VIII.2004, I.S. Nogueira 951 (UFG). 15°14'09"S, 51°09'27"W, 19.VIII.2004, I.S. Nogueira 952 (UFG). 15°13'18"S, 51°10'06"W, 20.VIII.2004, I.S. Nogueira 954 (UFG). 15°17'57"S, 51°10'07"W, 9.IX.2004, I.S. Nogueira 986 (UFG). 15°16'47"S, 51°09'44"W, 9.IX.2004, I.S. Nogueira 987

(UFG). 15°16'17"S, 51°09'10"W, 9.IX.2004, I.S. Nogueira 988 (UFG). 15°15'12"S, 51°08'33"W, 9.IX.2004, I.S. Nogueira 990 (UFG). 15°14'17"S, 51°08'59"W, 9.IX.2004, I.S. Nogueira 991 (UFG). 15°16'47"S, 51°09'44"W, 16.X.2004, I.S. Nogueira 1025 (UFG). 15°15'12"S, 51°08'33"W, 16.X.2004, I.S. Nogueira 1028 (UFG). 15°14'17"S, 51°08'59"W, 16.X.2004, I.S. Nogueira 1029 (UFG). 15°14'09"S, 51°09'27"W, 16.X.2004, I.S. Nogueira 1030 (UFG). 15°13'43"S, 51°09'14"W, 17.X.2004, I.S. Nogueira 1031 (UFG). 15°11'47"S, 51°09'57"W, 17.X.2004, I.S. Nogueira 1033 (UFG). 15°18'58"S, 51°09'56"W, 5.XI.2004, I.S. Nogueira 1115 (UFG). 15°17'57"S, 51°10'07"W, 5.XI.2004, I.S. Nogueira 1116 (UFG). 15°16'47"S, 51°09'44"W, 5.XI.2004, I.S. Nogueira 1117 (UFG). 15°16'17"S, 51°09'10"W, 5.XI.2004, I.S. Nogueira 1118 (UFG). 15°15'46"S, 51°08'41"W, 5.XI.2004, I.S. Nogueira 1119 (UFG). 15°15'12"S, 51°08'33"W, 5.XI.2004, I.S. Nogueira 1120 (UFG). 15°14'17"S, 51°08'59"W, 5.XI.2004, I.S. Nogueira 1121 (UFG). 15°13'43"S, 51°09'14"W, 6.XI.2004, I.S. Nogueira 1123 (UFG). 15°13'18"S, 51°10'06"W, 6.XI.2004, I.S. Nogueira 1124 (UFG). 15°11'47"S, 51°09'57"W,

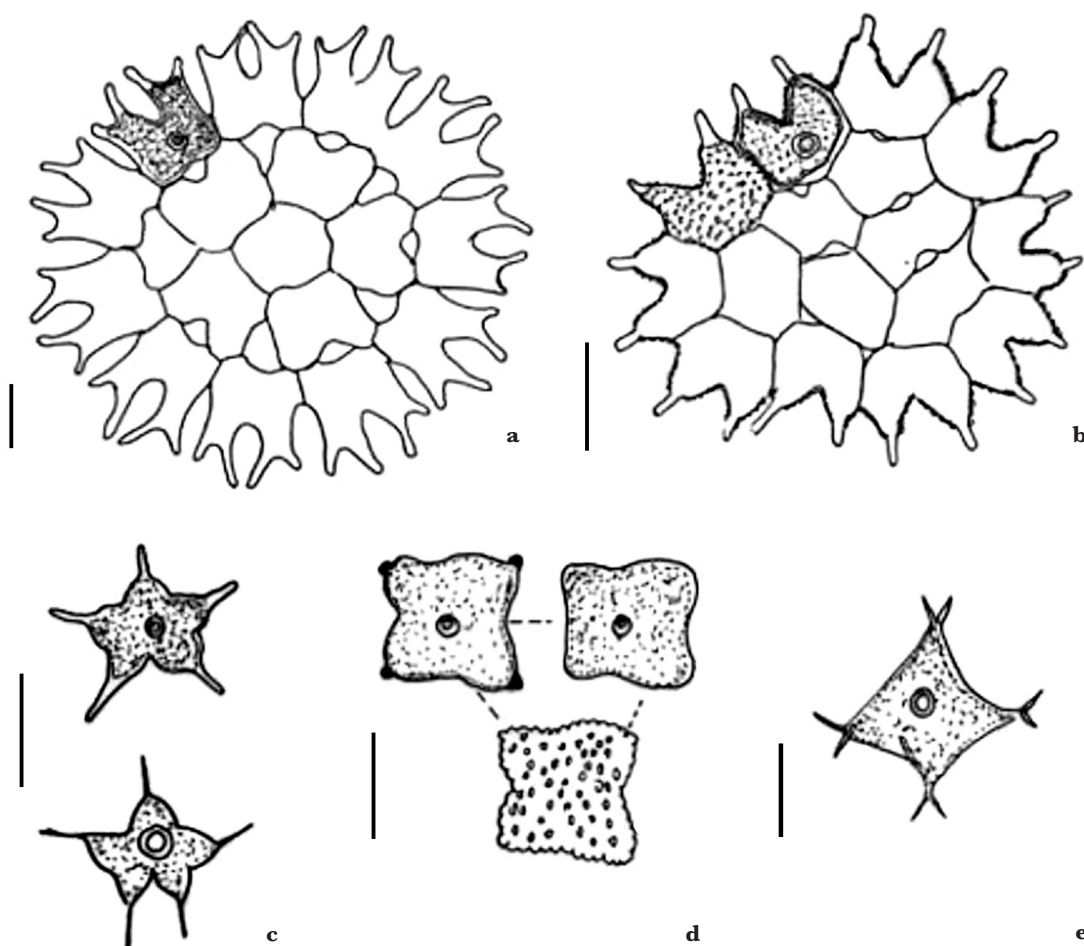


Figure 5 – a-e. Schematic figures, via OM (optical microscopy) – a. *Parapediastrium biradiatum* var. *longicornutum*; b. *Pseudopediastrium cornutum*; c. *Tetradron caudatum*; d. *T. minimum*; e. *T. regulare* var. *bifurcatum*. The scale bar is approximately 10 μm (a. I.S. Nogueira 617; b. I.S. Nogueira 1121; c. I.S. Nogueira 655; d. I.S. Nogueira 622; e. I.S. Nogueira 630).

6.XI.2004, *I.S. Nogueira 1125* (UFG). Tigrinho Lake, 15°14'38"S, 51°10'38"W, 5.VI.2004, *I.S. Nogueira 897* (UFG). 15°12'51"S, 51°10'22"W, 14.VII.2004, *I.S. Nogueira 940* (UFG). 15°12'51"S, 51°10'22"W, 14.VII.2004, *I.S. Nogueira 941* (UFG). 15°14'38"S, 51°10'38"W, 14.VII.2004, *I.S. Nogueira 943* (UFG). Nova Crixás, Fuzil Lagoon, 14°00'06"S, 50°51'57"W, 1.II.2000, *I.S. Nogueira 645* (UFG). Landi Lagoon, 13°56'34"S, 50°50'42"W, 1.II.2000, *I.S. Nogueira 646* (UFG). 13°56'34"S, 50°50'42"W, 1.III.2001, *I.S. Nogueira 723* (UFG). São Joaquim Lagoon, 13°51'36"S, 50°50'24"W, 1.VIII.2000, *I.S. Nogueira 681* (UFG). São José dos Bandeirantes Lagoon, 13°42'79"S, 50°48'63"W, 1.II.2000, *I.S. Nogueira 649* (UFG). 13°42'79"S, 50°48'63"W, 1.VIII.2001, *I.S. Nogueira 751* (UFG). São Miguel do Araguaia, Bandeirantes Lagoon, 13°26'020"S, 50°38'936"W, 1.VIII.2000, *I.S. Nogueira 687* (UFG). Barra Lagoon, 13°21'510"S, 50°37'142"W, 1.VIII.2001, *I.S. Nogueira 733* (UFG). 13°21'510"S, 50°37'142"W, 1.VIII.2001, *I.S. Nogueira 757* (UFG). Brito Lagoon, 13°10'076"S, 50°34'990"W, 1.VIII.2001, *I.S. Nogueira 736* (UFG). 13°10'076"S, 50°34'990"W, 1.VIII.2001, *I.S. Nogueira 760* (UFG). Cocal Lagoon, 13°26'020"S, 50°38'936"W, 1.II.2000, *I.S. Nogueira 640* (UFG). 13°26'020"S, 50°38'936"W, 1.VIII.2000, *I.S. Nogueira 686* (UFG). Japonês Lagoon, 13°21'510"S, 50°37'142"W, 1.III.2001, *I.S. Nogueira 691* (UFG). 13°26'020"S, 50°38'936"W, 1.VIII.2001, *I.S. Nogueira 754* (UFG). Luís Alves Lagoon, 13°13'488"S, 50°34'296"W, 1.VIII.2001, *I.S. Nogueira 758* (UFG). 13°13'488"S, 50°34'296"W, 1.VIII.2001, *I.S. Nogueira 759* (UFG). Montaria Lagoon, 13°23'478"S, 50°42'555"W, 1.VIII.2001, *I.S. Nogueira 755* (UFG). Piedade Lagoon, 13°23'478"S, 50°42'555"W, 1.VIII.2000, *I.S. Nogueira 688* (UFG).

Additional material examined - previously recorded:

BRAZIL. GOIÁS: Goiânia, Bosque dos Buritis Lake, 16°40'83"S, 49°15'68"W, 25.VIII.2000, *I.S. Nogueira 615* (UFG). 16°40'83"S, 49°15'68"W, 15.IX.2000, *I.S. Nogueira 624* (UFG). 16°40'83"S, 49°15'68"W, 23.VIII.2001, *I.S. Nogueira 707* (UFG). 16°40'83"S, 49°15'68"W, 4.X.2001, *I.S. Nogueira 711* (UFG). Jardim Botânico Lake, 16°43'48"S, 49°15'16"W, 25.VIII.2000, *I.S. Nogueira 618* (UFG). 16°43'48"S, 49°15'16"W, 8.II.2001, *I.S. Nogueira 655* (UFG). 16°43'48"S, 49°15'16"W, 8.III.2001, *I.S. Nogueira 661* (UFG). 16°43'48"S, 49°15'16"W, 23.VIII.2001, *I.S. Nogueira 704* (UFG). 16°43'48"S, 49°15'16"W, 4.X.2001, *I.S. Nogueira 708* (UFG). 16°43'48"S, 49°15'16"W, 9.XI.2001, *I.S. Nogueira 762* (UFG). Parque Vaca Brava Lake, 16°42'54"S, 49°16'25"W, 8.III.2001, *I.S. Nogueira 662* (UFG). 16°42'54"S, 49°16'25"W, 23.VIII.2001, *I.S. Nogueira 705* (UFG). Rosas Lake, 16°43'48"S, 49°15'16"W, 15.IX.2000, *I.S. Nogueira 621* (UFG). 16°40'78"S, 49°16'46"W, 15.IX.2000, *I.S. Nogueira 622* (UFG). 16°40'78"S, 49°16'46"W, 8.II.2001, *I.S. Nogueira 657* (UFG). 16°40'78"S, 49°16'46"W, 8.III.2001, *I.S. Nogueira 663* (UFG). 16°40'78"S, 49°16'46"W, 8.VI.2001, *I.S. Nogueira 698* (UFG). 16°40'78"S, 49°16'46"W, 23.VIII.2001, *I.S. Nogueira 706* (UFG). 16°40'78"S, 49°16'46"W, 9.XI.2001, *I.S. Nogueira 764* (UFG). Nogueira *et al.* 2008. Nova Roma, Forquilha River, 13°57'42"S, 46°58'57"W, IX.2004, *I.S. Nogueira 1065* (UFG). Silva 2007.

This species is recorded in plankton, metaphyton, and periphyton in oligotrophic, mesotrophic, or eutrophic environments. Cosmopolitan, with records from Australia, the Americas, Asia, Africa, the Arctic, the Antarctic, and Europe.

7. *Pediastrum duplex* var. *duplex* f. *cohaerens* Bohlin 1897. Fig. 6a-i

Coenobium oblong or circular, planar to concave, 16–32 cells, 2–3 concentric cell layers, intercellular spaces present. External cells polygonal, joined together by 1/4 of their upper portion and 1/3 of their lower portion, with 1 pair of short lobes, 1/2 the cell length, divergent and equal, conical, joined to the neighboring cell lobe in an overlapping manner, older coenobia may slough off, discrete apical annular thickening, short process, 1/4 of the cell length, conical, broad V-shaped incision, inner cells H-shaped, with concave sides, joined together at their corners, cell wall slightly reticulate. Chloroplast parietal, accompanying the cell shape, 1 central pyrenoid. SEM: cell with reticulate surface, formed by densely thickened striations, distributed in parallel, with regions of interconnection, with clear granular thickenings, tip of the processes with a dense annular thickening. Coenobium 48.5–117 µm, outer cells 4–23 × 5.5–18 µm, inner cells 6–20 × 5.5–15 µm.

Material examined - new records: Aruanã, Azul Lagoon, 14°46'647"S, 51°01'816"W, 1.II.2000, *I.S. Nogueira 631* (UFG). 14°46'647"S, 51°01'816"W, III.2001, *I.S. Nogueira 714* (UFG). Campos Lagoon, 14°47'927"S, 51°01'903"W, 1.VIII.2000, *I.S. Nogueira 671* (UFG). Cangas lagoon, 14°38'67"S, 50°59'87"W, 1.VIII.2001, *I.S. Nogueira 742* (UFG). Luís Alves Lagoon, 14°50'474"S, 51°05'759"W, 1.VIII.2001, *I.S. Nogueira 737* (UFG). Britânia, Tigres Lake, 15°16'47"S, 51°09'44"W, 13.VII.2004, *I.S. Nogueira 900* (UFG). 15°14'17"S, 51°08'59"W, 16.X.2004, *I.S. Nogueira 1029* (UFG). 15°14'17"S, 51°08'59"W, 17.VII.2008, *I.S. Nogueira 1232* (UFG). 15°17'57"S, 51°10'7"W, 19.VIII.2008, *I.S. Nogueira 1240* (UFG). 15°16'47"S, 51°09'44"W, 19.VIII.2008, *I.S. Nogueira 1241* (UFG). 15°15'12"S, 51°08'33"W, 19.VIII.2008, *I.S. Nogueira 1244* (UFG). 15°14'09"S, 51°09'27"W, 19.VIII.2008, *I.S. Nogueira 1246* (UFG). 15°18'58"S, 51°09'56"W, 19.X.2008, *I.S. Nogueira 1265* (UFG). 15°18'58"S, 51°09'56"W, 15.XI.2008, *I.S. Nogueira 1278* (UFG). 15°16'47"S, 51°09'44"W, 15.XI.2008, *I.S. Nogueira 1280* (UFG). 15°16'17"S, 51°09'10"W, 15.XI.2008, *I.S. Nogueira 1281* (UFG). 15°13'43"S, 51°09'14"W, 16.XI.2008, *I.S. Nogueira 1286* (UFG). 15°15'12"S, 51°08'33"W, 11.XII.2008, *I.S. Nogueira 1296* (UFG). Tigrinho Lake, 15°12'51"S, 51°10'22"W, 5.VI.2004, *I.S. Nogueira 883* (UFG). 15°14'38"S, 51°10'38"W, 5.VI.2004, *I.S. Nogueira 897* (UFG). 15°14'38"S, 51°10'38"W, 10.IX.2004, *I.S. Nogueira 1018* (UFG). Formosa, Swamp, 15°09'32"S, 47°28'05"W IX.2003, *I.S. Nogueira 829* (UFG). Flores de Goiás, irrigation dam, 14°32'12"S, 47°01'51"W, III.2003, *I.S. Nogueira 847* (UFG). Paranã River, 14°27'21"S, 47°06'05"W, IX.2003, *I.S. Nogueira 1081* (UFG). Goiânia, Samambaia Dam, 16°35'71"S, 49°16'84"W, IX.2006, *I.S. Nogueira* (UFG). Iaciara, Paranã River, 14°02'49"S, 46°50'25"W IX.2003, *I.S. Nogueira 1058* (UFG). Nova Crixás, Cocal Lagoon, 13°51'361"S, 50°48'63"W, 1.II.2000, *I.S. Nogueira 648* (UFG). 13°51'361"S, 50°48'63"W, 1.VIII.2000, *I.S. Nogueira 682* (UFG). 13°51'361"S, 50°48'63"W, 1.III.2001, *I.S. Nogueira 725* (UFG). 13°51'361"S, 50°48'63"W, 1.VIII.2001, *I.S. Nogueira 750* (UFG). Bandeirantes Lagoon, 13°42'79"S, 50°48'63"W, 1.VIII.2000, *I.S. Nogueira 683* (UFG). São Miguel do Araguaia, Montaria Lagoon, 13°23'478"S,

50°42'555"W, 1.VIII.2001, I.S. Nogueira 756 (UFG). São José dos Bandeirantes Lagoon, 13°35'56 2"S, 50°45'749"W, 1.III.2001, I.S. Nogueira 728 (UFG). Piedade Lagoon, 13°35'56 2"S, 50°45'749"W, 1.II.2000, I.S. Nogueira 642 (UFG). 13°35'56 2"S, 50°45'749"W, 1.VIII.2000, I.S. Nogueira 684 (UFG). 13°35'562"S, 50°45'749"W, 1.VIII.2001, I.S. Nogueira 752 (UFG).

Additional material examined - previously recorded: BRAZIL. GOIÁS: Formosa, Swamp, 15°09'32"S, 47°28'04"W, III.2004, I.S. Nogueira 829 (UFG). Flores de Goiás, irrigation dam, 14°32'12"S, 47°01'50"W, III.2004, I.S. Nogueira 847 (UFG). Paranã River, 14°27'20"S, 47°06'05"W, IX.2004, I.S. Nogueira 1081 (UFG). Iaciara, Paranã River, 14°02'49"S, 46°50'24"W, IX.2004, I.S. Nogueira 1058 (UFG). Silva 2007.

This species is recorded in plankton, metaphyton, and periphyton of oligotrophic and mesotrophic environments. Neotropical taxon, there are records from the Americas (Brazil, Mexico, and Uruguay).

Pediastrum duplex var. *duplex* f. *cohaerens* has been the subject of extensive taxonomic issues over time. Initially described by Bohlin (1897) in Mato Grosso State and Paraguay, this taxon is characterized by having divergent lobes joined at their extremities, with overlapping processes. These lobes tend to detach, however, in the adult or senescent phase. Ergashev (1979) elevated it to

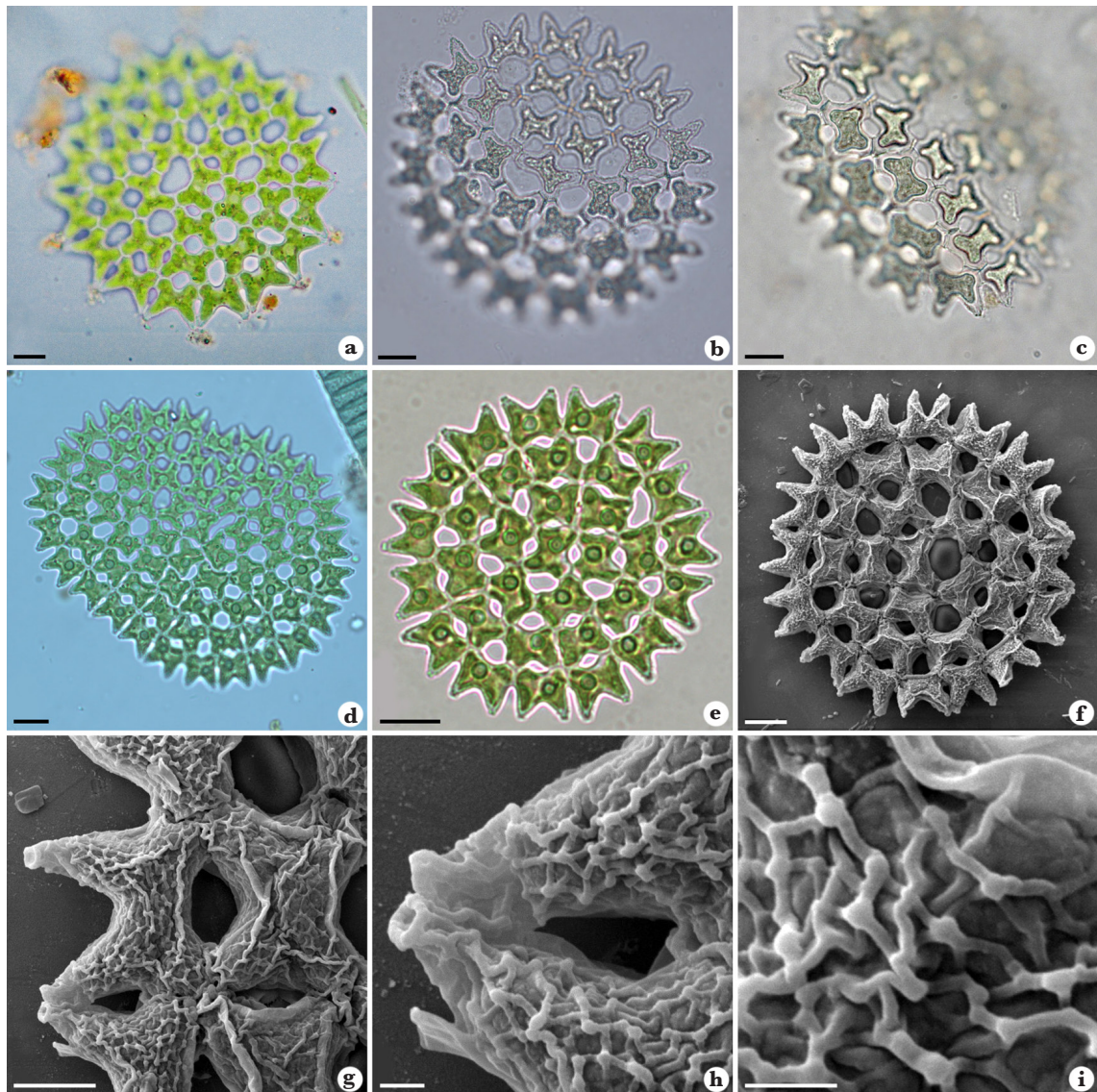


Figure 6 – a-i. Figure of *in situ* and cultivated material of *Pediastrum duplex* var. *duplex* f. *cohaerens* via OM (optical microscopy) and SEM (scanning electron microscopy) – a-c. *in situ*; d-i. cultivated – a-e. OM; f-j. SEM. (a-b. IS Nogueira 883; c. 1246; d-i. Fixed replica, IS Nogueira). Scale bars: a-e. 10 µm; f = 10 µm; g = 5 µm; h-i = 1 µm.

a variety, but the proposed new combination was considered an invalid name according to the *Index Nominum Algarum*.

Different taxonomic positions have been proposed for *P. duplex* var. *duplex* f. *cohaerens*. Komárek & Jankovská (2001) considered it a synonym of *P. argentinensis*. Lenarczyk & Saluga (2018) suggested that *P. duplex* var. *duplex* f. *cohaerens* was more closely related to *Pediastrum duplex* var. *rugulosum* than to *P. argentinense*. The strain acoi392 was analyzed in studies by McManus & Lewis (2011) and Lenarczyk & Saluga (2018) and was subsequently assigned to *P. duplex* var. *duplex* f. *cohaerens*. However, these authors later found that the morphology of strain acoi392 was similar to var. *rugulosum*. Other works mentioning f. *cohaerens* refer to the same strain but do not provide an figure of the morphotype, making it challenging to characterize its cytomorphology. Works citing strain acoi391 still place it in the genus *Pediastrum*.

The analysis of marginal cells has been considered important by Lenarczyk (2019) for identifying coenobium morphospecies of some Hydrodictyaceae. In the present study, it was evident that *P. duplex* var. *duplex* f. *cohaerens* significantly differed from *P. argentinense* when considering the morphology of the marginal cells.

During their cultivation in the present study, the morphotypes of *P. duplex* var. *duplex* f. *cohaerens* consistently exhibited marginal cells with characteristics similar to those described by Bohlin (1897), including a deep V-shaped incision and processes that often overlap lateral cells. One hundred and seventy-one specimens from native populations from Tigres Lake were analyzed and were found to maintain consistent marginal cell characteristics over 15 years of sampling. None of the samples, whether cultivated or from natural populations, exhibited coenobium similar to those of *P. argentinense*.

The present study analyzed the original work as well as recent studies, emphasizing the importance of more detailed analyses of tropical specimens of *P. duplex* var. *duplex* f. *cohaerens* (including DNA information) for determining the correct position of this taxonomic form. It was therefore deemed appropriate to maintain this taxon according to the original work until a scientific consensus could be reached, following the guidelines of the International Code of Algae, Plants, and Fungi.

8. *Pseudopediastrum cornutum* (Raciborski) Lenarczyk 2020. Fig. 5b

Coenobium circular, planar to concave, 8–16 cells, 2–3 concentric layers, intercellular spaces present. Marginal cells polygonal, joined together

along 1/5 of the lower portion, the base of the cell planar to concave, 1 pair of lobes, conical-truncate, dilated base, 2/3 of the cell length, apices truncate, H-shaped, with concave sides, joined together at their corners, external incision V-shaped, walls granulated. Chloroplast accompanies the cell shape, 1 pyrenoid. Coenobium 50–98.2 µm, outer cells 8–18.3 × 6.7–17.8 µm, inner cells 7.5–15 × 6–15 µm, intercellular spaces 2.3–7.9 µm.

Material examined - new records: Britânia, Tigres Lake, 15°14'17"S, 51°08'59"W, 5.XI.2004, I.S. Nogueira 1121 (UFG). 15°15'12"S, 51°08'33"W, 13.VII.2004, I.S. Nogueira 903 (UFG).

This species is recorded in plankton in oligotrophic, mesotrophic, and eutrophic environments. Cosmopolitan, with records from the Americas, Europe, and Oceania.

Lenarczyk (2019) examined the morphological variability of the infraspecific taxa of *Pseudopediastrum boryanum* and reported significant morphological variations in the lobes and processes among the different varieties, suggesting a strong evolutionary constraint.

Lenarczyk *et al.* (2020) conducted phylogenetic analyses to assess morphological differences and their implications for infraspecific taxa. The study highlighted that the variability of the marginal cells could lead to misinterpretations of the infraspecific taxa. Based on statistical and molecular data, the authors proposed a new combination for *Pseudopediastrum boryanum* (Turpin) E. Hegewald in Buchheim var. *cornutum* (Raciborski) Tsarenko, elevating it to the species level.

9. *Sorastrum americanum* (Bohlin) Schmidle 1899. Fig. 4b

Coenobium spherical, 8–16 cells, radial layout, converging to a conspicuous central body. Cells pyramidal, distal portion 4 angled, with concave to straight margins, 4 narrow processes, long, 1/4 of the cell length, 1 for each angle, proximal portion narrowed into a long peduncle with a polygonal base, 1/4 of the cell length, forming a central polygonal body that joins the cells together. Chloroplasts accompany the cell shape, 1 pyrenoid. Coenobium 50–68.8 µm, cell 30.1–35.4 × 12–15.4 µm, 8–9.6 µm.

Material examined - new records: Britânia, Tigres Lake, 15°16'47"S, 51°09'44"W, 9.IX.2004, I.S. Nogueira 987 (UFG). 15°16'17"S, 51°09'10"W, 9.IX.2004, I.S. Nogueira 988 (UFG). 15°15'12"S, 51°08'33"W, 9.IX.2004, I.S. Nogueira 990 (UFG). 15°15'12"S, 51°08'33"W, 5.VI.2004, I.S. Nogueira 1120 (UFG). 15°18'58"S, 51°09'56"W, 19.VIII.2008, I.S. Nogueira 1239 (UFG). 15°16'47"S, 51°09'44"W, 21.I.2009, I.S. Nogueira 1306 (UFG). 15°16'17"S, 51°09'10"W, 21.I.2009, I.S. Nogueira 1307 (UFG). 15°13'43"S, 51°09'14"W, 22.I.2009, I.S. Nogueira 1312 (UFG).

This species is recorded in plankton and metaphyton of oligotrophic and mesotrophic

environments. Cosmopolitan, with records from Africa, the Americas, Asia, and Europe.

10. *Stauridium tetras* (Ehrenberg) E Hegewald Fig. 4c-d

Coenobium circular or cruciate, planar, 4–8–16 cells, 2–3 concentric layers, no (or rarely) intercellular spaces. Marginal cells trapezoidal, joined together along 3/4 of the lateral margin, cell base straight, 1 pair of lobes of equal sizes, elongated, 2/3 of the cell length, each bifurcated into 2 unequal secondary lobes, the longer (inner) lobe 1/10 of the cell length, the shorter (external) lobe 1/20 of the cell length, short-cylindrical processes, 1/40 of the cell length, inner cells trapezoidal, with a deep, narrow, V-shaped incision, secondary incision narrow V-shaped, cell wall smooth. Chloroplast accompanies the cell shape, 1 central pyrenoid. Coenobium 28.3–34.5 μm , outer cells 10.1–10.9 $\times$ 9.5–11 μm , inner cells 9–11 $\times$ 9.2–11 μm .

Material examined - new records: Britânia, Tigres Lake, 15°17'57"S, 51°10'07"W, 4.VI.2004, *I.S. Nogueira* 876 (UFG). 15°16'17"S, 51°09'10"W, 4.VI.2004, *I.S. Nogueira* 877 (UFG). 15°15'12"S, 51°08'33"W, 4.VI.2004, *I.S. Nogueira* 878 (UFG). 15°14'17"S, 51°08'59"W, 4.VI.2004, *I.S. Nogueira* 879 (UFG). 15°13'18"S, 51°10'06"W, 4.VI.2004, *I.S. Nogueira* 881 (UFG). 15°16'17"S, 51°09'10"W, 13.VII.2004, *I.S. Nogueira* 901 (UFG). 15°14'17"S, 51°08'59"W, 13.VII.2004, *I.S. Nogueira* 904 (UFG). 15°14'09"S, 51°09'27"W, 13.VII.2004, *I.S. Nogueira* 905 (UFG). 15°11'47"S, 51°09'57"W, 19.VIII.2004, *I.S. Nogueira* 908 (UFG). 15°16'47"S, 51°09'44"W, 19.VIII.2004, *I.S. Nogueira* 947 (UFG). 15°16'17"S, 51°09'10"W, 19.VIII.2004, *I.S. Nogueira* 948 (UFG). 15°15'46"S, 51°08'41"W, 19.VIII.2004, *I.S. Nogueira* 949 (UFG). 15°15'12"S, 51°08'33"W, 19.VIII.2004, *I.S. Nogueira* 950 (UFG). 15°13'18"S, 51°10'06"W, 20.VIII.2004, *I.S. Nogueira* 954 (UFG). 15°16'47"S, 51°09'44"W, 9.IX.2004, *I.S. Nogueira* 987 (UFG). 15°16'17"S, 51°09'10"W, 9.IX.2004, *I.S. Nogueira* 988 (UFG). 15°15'46"S, 51°08'41"W, 9.IX.2004, *I.S. Nogueira* 989 (UFG). 15°15'12"S, 51°08'33"W, 9.IX.2004, *I.S. Nogueira* 990 (UFG). 15°16'47"S, 51°09'44"W, 16.X.2004, *I.S. Nogueira* 1025 (UFG). 15°16'17"S, 51°09'10"W, 16.X.2004, *I.S. Nogueira* 1026 (UFG). 15°15'46"S, 51°08'41"W, 16.X.2004, *I.S. Nogueira* 1027 (UFG). 15°15'12"S, 51°08'33"W, 16.X.2004, *I.S. Nogueira* 1028 (UFG). 15°14'17"S, 51°08'59"W, 16.X.2004, *I.S. Nogueira* 1029 (UFG). 15°14'9"S, 51°09'27"W, 16.X.2004, *I.S. Nogueira* 1030 (UFG). 15°13'43"S, 51°09'14"W, 17.X.2004, *I.S. Nogueira* 1031 (UFG). 15°17'57"S, 51°10'07"W, 5.XI.2004, *I.S. Nogueira* 1116 (UFG). 15°16'47"S, 51°09'44"W, 5.XI.2004, *I.S. Nogueira* 1117 (UFG). 15°16'17"S, 51°09'10"W, 5.XI.2004, *I.S. Nogueira* 1118 (UFG). 15°15'46"S, 51°08'41"W, 5.XI.2004, *I.S. Nogueira* 1119 (UFG). 15°15'12"S, 51°08'33"W, 5.XI.2004, *I.S. Nogueira* 1120 (UFG). 15°14'17"S, 51°08'59"W, 5.XI.2004, *I.S. Nogueira* 1121 (UFG). 15°14'9"S, 51°09'27"W, 5.XI.2004, *I.S. Nogueira* 1122 (UFG). 15°13'43"S, 51°09'14"W, 6.XI.2004, *I.S. Nogueira* 1123 (UFG). 15°13'43"S, 51°09'14"W, 20.X.2008, *I.S. Nogueira* 1273 (UFG). 15°16'47"S, 51°09'44"W, 15.XI.2008, *I.S. Nogueira* 1280 (UFG). 15°14'09"S, 51°09'27"W, 15.XI.2008, *I.S. Nogueira* 1285 (UFG). Tigrinho Lake, 15°14'38"S, 51°10'38"W, 5.VI.2004, *I.S. Nogueira* 895 (UFG). 15°14'38"S, 51°10'38"W, 20.VIII.2004, *I.S. Nogueira* 980

(UFG). 15°14'38"S, 51°10'38"W, 6.XI.2004, *I.S. Nogueira* 1113 (UFG). São Miguel do Araguaia, Montaria Lagoon, 13°21'510"S, 50°37'142"W, 1.VIII.2001, *I.S. Nogueira* 689 (UFG). 13°23'478"S, 50°42'555"W, 1.VIII.2001, *I.S. Nogueira* 756 (UFG). 13°21'510"S, 50°37'142"W, 1.VIII.2000, (UFG 26889). Formosa, Jataí River, 15°06'58"S, 47°27'43"W, IX.2003, *I.S. Nogueira* 1099 (UFG). 13°23'478"S, 50°42'555"W, 1.VIII.2001 (UFG 26951).

Additional material examined - previously recorded:

BRAZIL. GOIÁS: Formosa, Jataí River, 15°06'58"S, 47°27'43"W, IX.2004, *I.S. Nogueira* 1099 (UFG). Silva 2007

This species is recorded in plankton and periphyton from oligotrophic to eutrophic environments. Cosmopolitan, with records from Africa, the Americas, Asia, Australia, Europe, the Arctic, and the Antarctic.

11. *Tetraedron caudatum* (Corda) Hansgirg 1888.

Fig. 5c

Solitary cell, 5-angular, planar, rounded corners with processes extending towards different planes. Chloroplast accompanies the cell shape, 1 pyrenoid. Cell 5–12 μm , processes 0.5–3.8 μm long. **Additional material examined - previously recorded:** BRASIL. GOIÁS: Goiânia, Jardim Botânico Lake, 16°43'48"S, 49°15'16"W, 8.II.2001, *I.S. Nogueira* 655 (UFG). Parque Vaca Brava Lake, 16°42'54"S, 49°16'25"W, 23.VIII.2001, *I.S. Nogueira* 705 (UFG). Rosas Lake, 16°40'78"S, 49°16'46"W, 8.III.2001, *I.S. Nogueira* 663 (UFG). 16°40'78"S, 49°16'46"W, 23.VIII.2001, *I.S. Nogueira* 706 (UFG). 16°40'78"S, 49°16'46"W, 25.VIII.2000, *I.S. Nogueira* 616 (UFG). *Nogueira et al.* 2008.

Found in plankton. Cosmopolitan, with records from Africa, the Americas, Australia, Asia, and Europe.

12. *Tetraedron minimum* (A Braun) Hansgirg 1889.

Fig. 5d

Solitary cell, 4-angular, one of the corners may occur in a different plane, corners rounded, with or without 1 papilla, concave or straight margins, cell wall smooth. 1 pyrenoid. Cells 5.2–11.2 μm long.

Material examined - new records: Goiás, Britânia, Tigres Lake, 15°17'57"S, 51°10'07"W, 19.VIII.2004, *I.S. Nogueira* 946 (UFG). Tigrinho Lake, 15°14'38"S, 51°10'38"W, 5.XI.2004, *I.S. Nogueira* 895 (UFG). 15°14'38"S, 51°10'38"W, 20.VIII.2004, *I.S. Nogueira* 981 (UFG). São João da Aliança, Macacão River, 14°08'35"S, 47°13'56"W, IX.2003, *I.S. Nogueira* 1109 (UFG).

Additional material examined - previously recorded:

BRAZIL. GOIÁS: Goiânia, Bosque dos Buritis Lake, 16°40'83"S, 49°15'68"W, 23.VIII.2001, *I.S. Nogueira* 707 (UFG). Jardim Botânico Lake, 16°43'48"S, 49°15'16"W, 8.II.2001, *I.S. Nogueira* 655 (UFG). Rosas lake, 16°40'78"S, 49°16'46"W, 25.VIII.2000, *I.S. Nogueira* 617 (UFG). 16°40'78"S, 49°16'46"W, 23.VIII.2001, *I.S. Nogueira* 706 (UFG). *Nogueira et al.* 2008.

This species is recorded in plankton from eutrophic environments. Cosmopolitan, with records from Africa, the Americas, Asia, and Europe.

13. *Tetraëdron regulare* var. *bifurcatum* Wille 1898. Fig. 5e

Solitary cell, tetrahedral, sides straight to slightly convex, corners with two spines, and cell wall smooth. Cell 5.2–11.2 μm long.

Material examined - new records: Aruanã, Dumbazinho Lagoon, 14°50'47"S, 51°05'75"W, 1.III.2001, I.S. Nogueira 630 (UFG). Flores de Goiás, irrigation dam, 14°32'12"S, 47°01'51"W, III.2003, I.S. Nogueira 847 (UFG). Goiânia, Rosas Lake, 16°40'78"S, 49°16'46"W, 25.VIII.2000, I.S. Nogueira 616 (UFG). 16°40'81"S, 49°16'44"W, 25.VIII.2000, I.S. Nogueira 617 (UFG). São Miguel do Araguaia, Ribeirão Dantas Lagoon, 13°30'017"S, 50°44'208"W, 1.II.2000, I.S. Nogueira 641 (UFG).

This species is recorded in plankton and periphyton from oligotrophic to eutrophic environments, more common in eutrophic. Cosmopolitan, with records from Africa, the Americas, Asia, Australia, Europe, the Arctic, and the Antarctic.

14. *Tetraedron triangulare* Korshikov 1953. Fig. 4e

Solitary cell, pyramidal, sides generally straight, corners rounded, cell wall straight to slightly concave. Chloroplast accompanies cell shape, 1 central pyrenoid.

Material examined - new records: Britânia, Tigres Lake, 15°16'17"S, 51°09'10"W, 19.VIII.2004, I.S. Nogueira 948 (UFG). 15°17'57"S, 51°10'7"W, 5.VI.2004, I.S. Nogueira 1115 (UFG).

Additional material examined - previously recorded: BRAZIL. GOIÁS: Goiânia, Jardim Botânico Lake, 16°43'48"S, 49°15'16"W, 15.IX.2000, I.S. Nogueira 621 (UFG). 16°43'48"S, 49°15'16"W, 8.II.2001, I.S. Nogueira 655 (UFG). 16°43'48"S, 49°15'16"W, 8.II.2001, I.S. Nogueira 656 (UFG). Rosas Lake, 16°40'78"S, 49°16'46"W, 8.III.2001, I.S. Nogueira 663 (UFG). 16°40'78"S, 49°16'46"W, 8.VI.2001, I.S. Nogueira 698 (UFG). Nogueira *et al.* 2008.

This species is recorded in plankton in oligotrophic, mesotrophic, and eutrophic environments. Cosmopolitan, with records from Africa, the Americas, Asia, and Europe.

Tetraedron triangulare is rarely observed in Brazil. There are records in oligo- to mesotrophic environments in Cuba (Comas 1996). In the present study, it was also recorded in a eutrophic environment. The populations analyzed were little representative, but the cytological characteristics were sufficient for correct identification.

Frequency and geographical distribution

The Hydrodictyaceae family exhibits only rare occurrences in Goiás state, despite the analysis of a substantial number of samples. Even in areas that have been extensively sampled, such as Britânia and Goiânia, records for the family remain scarce (Tab. 1). Among the recorded taxa, *Pediastrum duplex* var. *duplex* (17.9%) and *Stauridium tetras* (12.5%) were common and the most prevalent in the state.

When examining the different municipalities, Goiânia showed the highest representation of the family, with 11 infrageneric taxa recorded in this study, mainly in artificial urban lakes. The most frequent taxon in this municipality was *Monactinus simplex*. Municipalities such as São João da Aliança, Nova Roma, and Iaciara, on the other hand, had the lowest numbers of Hydrodictyaceae.

The geographical distribution of Hydrodictyaceae taxa within Goiás state (Fig. 7) indicates that there are still regions without any representatives, specifically the southern and central areas of the state. Artificial urban lakes in Goiânia and Lake Tigres in Britânia had the highest number of representative taxa, largely due to intensive sampling efforts over the years. Samples were collected from lentic and lotic environments in the southern region of Goiás, but no Hydrodictyaceae species were recorded.

Overall, our findings suggest that Hydrodictyaceae are relatively rare in Goiás State, although with some localized hotspots of occurrence in artificial urban lakes and specific natural lakes. The absence of representatives in certain regions and environments of the state indicates spatial variation in the distribution of this family.

Discussion

The distribution of Hydrodictyaceae in Goiás state, despite its low frequencies of occurrence, is widespread, particularly in lentic environments, with only 18.4% of occurrences in lotic environments. The state's climatic conditions, characterized by distinct dry and rainy seasons, contribute to fluctuations in water volumes in lentic aquatic environments, which in turn affect water quality (D'Alessandro & Nogueira 2018) and may influence the distribution of this family. In this study, representatives of Hydrodictyaceae were found in environments with varying trophic levels, predominantly in eutrophic environments. They were less frequent in oligotrophic to mesotrophic environments or in lotic environments with upland characteristics.

Goiás is an agribusiness-oriented state, and many rural areas have undergone strong significant transitions from lotic to lentic environments. During the rainy season, temporary lentic environments form in plateau areas as natural aquatic environments increase in depth and area, interacting with the surrounding landscape in water/land transition zones (Latrubesse *et al.* 2019). However, many of the environments sampled in the early 21st century in Goiás no longer exist, as they have been drained and converted to agricultural use. The importance of old samples

from different locations in Goiás, deposited in the UFG Herbarium, cannot be overstated, as they have helped document the occurrence and geographical distribution of taxa, particularly in extinct or modified environments.

The geographical distribution of Hydrodictyaceae taxa indicates that the central region of the state is predominantly composed of mountainous lotic environments. In contrast, lentic environments, where representatives of this family are most commonly found, are predominantly artificial, especially within the urban perimeter of Goiânia. In the southern region of the state, lentic environments are primarily creek beds, most of which have acidic waters (Dunck *et al.* 2013). Acidic conditions are not favorable for the development of the Chlorophyceae, including Hydrodictyaceae (Brodie & Lewis 2007).

The trophic levels of certain environments in Goiás state were analyzed by Nogueira *et al.* (2008), Nabout *et al.* (2006), D'Alessandro & Nogueira (2018), and Silva (2007). Concurrently, the physicochemical parameters of their waters were in some of the samples collected by these authors (Santos *et al.* in prep.). The higher occurrence of Hydrodictyaceae in Goiás appears to be associated with eutrophic environments. Representatives of this family have been documented in eutrophic environments in other parts of Brazil (Sant'Anna *et al.* 1989; Nogueira *et al.* 2008; Rodrigues *et al.* 2010; Rosini *et al.* 2012; Lozaiza-Restano & Bicudo 2014, among others).

Some Hydrodictyaceae taxa are tolerant of eutrophic conditions and their cosmopolitan nature facilitates their widespread geographical distributions in lentic environments in Goiás.

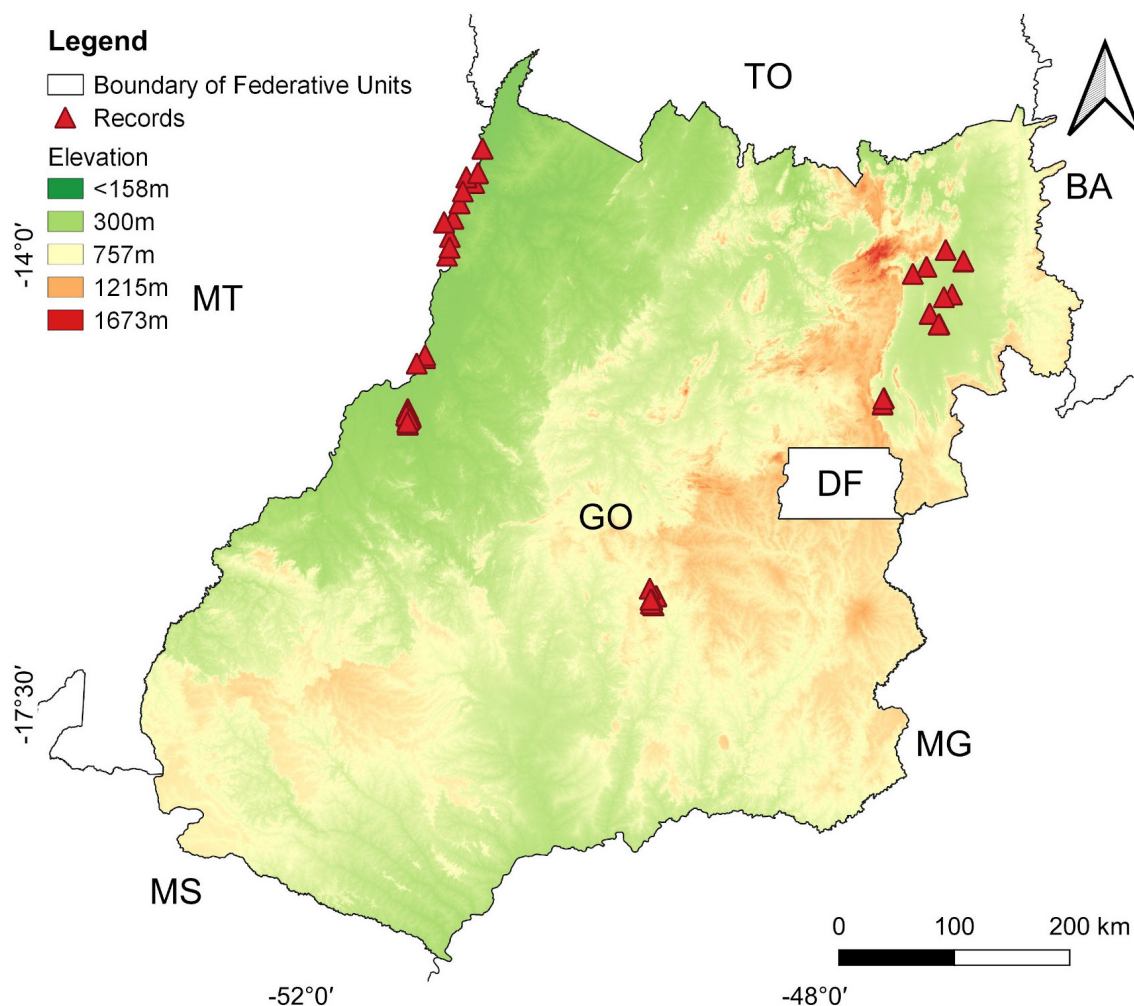


Figure 7 – Elevation map showing the geographical localization of the sampling sites (marked by red triangles) where representatives of Hydrodictyaceae were collected in state of Goiás, Brazil, based on records from the UFG Herbarium.

Examples observed in this study include *M. simplex*, *P. duplex* var. *duplex*, *P. biradiatum* var. *biradiatum*, and *S. tetras*, aligning with the findings of Komárek and Fott (1983), Komarek & Jankovská (2001), and Comas (1996).

Conversely, certain Hydrodictyaceae taxa have been recorded in clean-water environments in Brazil, such as *P. argentinense* and *P. duplex* var. *duplex* f. *cohaerens*. *Parapediastrium argentinense*, for example, has been documented in clean-water environments in Bahia State (Ramos *et al.* 2016). Hydrodictyaceae have likewise been documented in various types of lentic environments in different regions of Brazil (Sant'Anna *et al.* 1989; Hentschke & Torgan 2010; Ramos *et al.* 2016; Nogueira *et al.* 2008).

Many Hydrodictyaceae taxa have cosmopolitan distributions (e.g., Komárek & Fott 1983; Sant'Anna 1984; De-Lamônica-Freire & Sant'Anna 1993). This study recorded the highest number of Hydrodictyaceae taxa for any Brazilian state, largely due to the extensive sampling efforts in specific environments, such as from Tigres Lake in Britânia and urban lakes in Goiânia.

Two taxa special attention in this study: *Parapediastrium argentinense*, a neotropical taxon (Parra 1979; Tell 1979; Komarek & Jankovská 2001; Garduño-Solórzano *et al.* 2016) typically occurring in oligo to mesotrophic environments in Goiás but also with wide distribution in lentic environments throughout seven municipalities with similar characteristics. It is a rare species closely related to *P. duplex* var. *duplex* f. *cohaerens*. Both taxa are restricted to environments with comparable trophic levels. However, taxonomic issues regarding *P. duplex* var. *duplex* f. *cohaerens* have been noted in the literature, with frequent confusion with *P. argentinense* (Komarek & Jankovská 2001; Lenarczyk & Saluga 2018). Differences in the morphologies of the marginal cells of these two taxa, particularly regarding the lobes and the medium incisions in their V-shaped marginal cells, suggest the need for further detailed analyses and comparisons of both natural and cultivated populations. Molecular analysis of morphotypes aligned with iconotypes of these taxa could provide additional insights. The importance of marginal cell morphometry in Hydrodictyaceae has been highlighted by Lenarczyk (2019), particularly in studies of coenobium taxa.

Cultivation of *P. duplex* var. *duplex* f. *cohaerens* specimens from Goiás revealed that most cultivated individuals exhibited coenobium similar to those described by Bohlin (1897), including the morphology of marginal cells and the respective median incision. The same characteristics were also observed in natural populations. However, no coenobium or marginal cells resembling those

proposed by Tell (1979) for *P. argentinense* were observed.

Further studies will be needed to refine the taxonomy of *P. argentinense* and *P. duplex* var. *duplex* f. *cohaerens*, particularly through molecular analysis of these less-studied taxa. Lenarczyk & Saluga (2018) analyzed a single strain (ACOI391) from Portugal, which they considered as having poor phylogenetic support and were unable to identify as *P. duplex* var. *duplex* f. *cohaerens*. Confusion between *P. argentinense* and *P. duplex* var. *duplex* f. *cohaerens* is so common that Lenarczyk *et al.* (2015) mistakenly identified a specimen of *P. duplex* var. *duplex* f. *cohaerens* collected in Uruguay as *P. argentinense*. *P. duplex* var. *duplex* f. *cohaerens* has been continuously recorded in Tigres Lake (Britânia, GO) from 2004 to 2018.

Parapediastrium biradiatum var. *biradiatum* were found in oligo-mesotrophic environments, exhibiting both concentric and spiral morphologies. While those configurations have not been commonly reported in the literature, 10% of the field samples displayed spiral coenobia. Such coenobia were recorded in Tigres Lake as well as in isolated specimens maintained in cultivation. The spiral coenobium observed in unialgal culture originated from an initially concentric coenobium (Fig. 4f). The possibility that spiral morphology arise from concentric morphology highlights the need to investigate the factors driving these morphological variations and their ecological significance.

Parapediastrium biradiatum var. *longicornutum* was recorded in eutrophic environments, particularly urban lakes in Goiânia. This suggests that different varieties of *P. biradiatum* exhibit preferences for distinct trophic conditions.

The observed trophic preferences of these varieties highlight their ecological distinctiveness and the ability of the same species to occupy different environmental niches. These differences in trophic preferences can be attributed to physiological and ecological adaptations, enabling efficient resource utilization in specific environments. However, this raises an important taxonomic question: to what extent do these differences justify taxonomic separation, particularly when they result in morphological within *Parapediastrium biradiatum*? Further studies will be needed to assess the taxonomic relevance of these morphological variations.

Phycological studies integrating analysis of representative natural populations and unialgal cultivation were essential for delimiting taxa in different regions of Goiás. Additionally, knowledge of the trophic states of the studied environments facilitated observations of species distributions and occurrences, aiding future sampling efforts. Despite extensive sampling, the southern region

of the state, characterized by creek beds and some reservoirs, remains underrepresented in Hydrodictyaceae records, underscoring the need for further investigations, particularly molecular studies of neotropical taxa.

Acknowledgements

The authors express their gratitude to the Fundação de Amparo à Pesquisa do Estado de Goiás (Proc. FAPEG 201410267001737), for providing funding support for the Project “Taxonomical diversity of cyanobacteria and algae of the state of Goiás” and the project “Floristic survey of Parque Nacional da Chapada dos Veadeiros” (Proc. FAPEG 307371/2013). Additionally, they would like to acknowledge the CNPQ/UFG Scientific Initiation Scholarship program, for granting the first author a scholarship throughout 2020 and 2021.

Data Availability Statement

In accordance with Open Science communication practices, the authors inform that there is no data sharing of this manuscript.

References

- Anderson RA & Kawachi M (2005) Traditional microalgae isolation techniques. In: Anderson RA (ed.) *Algal culturing techniques*. Elsevier Academic Press, New York. Pp. 83-100.
- Bayma AP & Sano EE (2015) Séries temporais de índices de vegetação (NDVI e EVI) do *sensor modis* para detecção de desmatamentos no bioma cerrado. *Boletim de Ciências Geodésicas* 21: 797-813.
- Bicudo CEDM & Menezes M (2017) Gêneros de algas continentais do Brasil chave para identificação e descrições. Rima, São Paulo. 552p.
- Boaventura GR, Rodrigues LAP & Maiar Jr. FJP (2007) Características físicas - avaliação da qualidade da água no vale do Paran  - GO. In: Silva MJM (ed.) *Invent rio da biota aqu tica com vistas   conserva  o e utiliza  o sustent vel do bioma cerrado (serra e vale do rio Paran )*. Cap.2. Minist rio do Meio Ambiente, PROBIO, Bras lia. Pp. 8-35.
- Bohlin K (1897) Die Algen der ersten Regnell'schen Expedition. 1: Protococcoideen. Bihang till Svenska Vetenskapsakademie Handlingar 23: 3-47.
- Borge O (1925) Die Von Dr. F.C. Hoehseew hrend der Expedition Roosevelt-Rondon gesammelten S sswasseralgen. *Arkiv f r Botanik* 17: 1-56.
- Buchheim M, Buchheim J, Carlson T, Braband A, Hepperle D, Krienitz L & Hegewald E (2005) Phylogeny of the hydrodictyaceae (Chlorophyceae): inferences from rDNA data. *Journal of Phycology* 41: 1039-1054.
- Cardoso MRD, Marcuzzo FFN & Barros JR (2014) Climatic classification of K ppen-Geiger for the state of Goias and Federal District. *Acta Geogr fica* 8: 40-55.
- Comas AG (1996) Las chlorococcales dulci cu colas de Cuba. *Bibliotheca Phycologica*, Band 99. J. Cramer, Berlin, Stuttgart. 192p.
- D'Alessandro EB & Nogueira IS (2017) Algas planct nicas flageladas e coc ides verdes de um lago no Parque Beija-flor lake, Goi nia, GO, Brasil. *Hoehnea* 44: 415-430.
- D'Alessandro E & Nogueira I (2018) Avalia  o do  ndice de estado tr fico no lago dos Tigres, Brit mia, Go  s. *Revista Gest o e Sustentabilidade Ambiental* 7: 98-128.
- De-Lam nica-Freire EM & Sant'Anna CL (1993) Chlorococcales (Chlorophyceae) da Esta  o Ecol gica da Ilha de Taia  , estado de Mato Grosso, Brasil. *Hoehnea* 21: 107-118.
- De-Lam nica-Freire EM (1989) Cat logo das algas referidas para o estado de Mato Grosso, Brasil, 1. *Revista Brasileira de Biologia* 49: 671-677.
- Dunck B, Nogueira IS & Felisberto SA (2013) Composi  o e diversidade de algas per fiticas em veredas sob diferentes impactos antr picos (Go  s, Brasil). *Iheringia, S rie Bot nica* 68: 237-248.
- Dunck B, Junqueira MG, Bichoff A, Silva MV, Pineda A, Paula ACM, Zanco BF, Moresco GA, Iatskiu P, Bortolini JC, Souza YR, Train S, Rodrigues LC, Jati S & Rodrigues L (2018) Periphytic and planktonic algae records from the upper Paran  river floodplain, Brazil: an update. *Hoehnea* 45: 560-590. DOI: 10.1590/2236-8906-03/2018
- Felisberto SA, Rodrigues L & Leandrini JA (2001) Chlorococcales registradas na comunidade per fitica, no reservat rio de Corumb , estado de Go  s, Brasil, antes e ap s o represamento das  guas. *Acta Scientiarum. Biological Sciences* 23: 275-282.
- Freitas LC & Loverde-Oliveira SM (2013) Checklist of algae from Phylum Chlorophyta recorded for the state of Mato Grosso, Brazil. *Check List* 9: 1471-1483.
- Gardu  o-Sol rzano G, Guill n-Ruiz DL, Campos JE, Comas-Gonz lez AA, Mart nez-Garc a M & Quintanar-Zu  iga RE (2016) *Pediastrum sensu lato* (Chlorophyceae) of Central Mexico. *Cryptogamie, Algologie* 37: 273-295.
- Guille A (1970) Benthic bionomy of continental shelf of the french Catalane coast. II. Benthic communities of the macrofauna. *Vie et Milieu* 21: 149-280.
- Guiry MD & Guiry GM (2021) *AlgaeBase*. National University of Ireland, Galway. Available at <<http://www.algaebase.org>>. Access on 16 April 2021.
- Instituto Brasileiro de Geografia e Estat stica - IBGE (2010) Censo demogr fico brasileiro 2010. IBGE, Bras lia. Available at <<https://censo2010.ibge.gov.br/>>. Access on 19 august 2020.
- Jacinavicius FR, Gama J nior WA, Azevedo MDP & Samt'Anna C (2013) Manual para cultivo de cianobact rias. Secretaria do Meio Ambiente, S o Paulo. 28p.
- Kom rek J & Fott B (1983) Das Phytoplankton des S  wassers. Systematik und Biologie Band 16, Teil 7, 1 H lfte. E. schweizerbart'sche verlagsbuchhandlung, Stuttgart. 1044p.
- Kom rek J & Jankovsk  V (2001) Review of the green algal genus *Pediastrum*; Implication for pollenanalytical Research. J. Cramer, Berlin, Stuttgart. 125p.
- Krienitz L & Bock C (2012) Present state of the systematics of planktonic coccoid green algae of inland waters. *Hydrobiologia* 698: 295-326.
- Latrubesse EM, Arima E, Ferreira ME, Nogueira SH, Wittmann F, Dias MS & Bayer M (2019) Fostering water resource governance and conservation in the Brazilian *Cerrado* biome. *Conservation Science and Practice* 1: e77.

- Lenarczyk J (2019) Evolution of morphological variability and modularity in single cells of algal colonies: a case study *Pseudopediastrum* (Hydrodictyaceae, Sphaeropleales, Chlorophyceae). *Phycologia* 58: 180-191.
- Lenarczyk J & Saługa M (2018) Evolutionary relationships between the varieties of green algae *Pediastrum boryanum* and *P. duplex* sl (Chlorophyceae, Hydrodictyaceae). *Fottea* 18: 170-188.
- Lenarczyk J, Saługa M & Piątek J (2020) Integrative approach helps clarify confusing taxonomy of the *Pseudopediastrum boryanum* species complex (Chlorophyceae), including recognition of five distinct species. *Journal of Phycology* 56: 1557-1574.
- Loaiza-Restano AM & Bicudo CEM (2014) Criptógamos do Parque Estadual das Fontes do Ipiranga, São Paulo, SP, Brasil. *Algas* 40: Chlorophyceae (Hydrodictyaceae). *Hoehnea* 41: 353-364.
- Monteiro MDR, Melo NFAC, Silva Alves MAM & Paiva RS (2009) Composição e distribuição do microfitoplâncton do River Guamá no trecho entre Belém e São Miguel do Guamá, Pará, Brasil. *Boletim do Museu Paraense Emílio Goeldi-Ciências Naturais* 4: 341-351.
- McManus HA & Lewis LA (2005) Molecular phylogenetics, morphological variation and colony-form evolution in the family Hydrodictyaceae (Sphaeropleales, Chlorophyta). *Phycologia* 44: 582-595.
- McManus HA & Lewis LA (2011) Molecular phylogenetic relationships in the freshwater family hydrodictyaceae (Sphaeropleales, Chlorophyceae), with an emphasis on *Pediastrum duplex*. *Journal of Phycology* 47: 152-163.
- McManus HA, Lewis LA & Schultz ET (2011) Distinguishing multiple lineages of *Pediastrum duplex* with morphometrics and a proposal for *lacunastrum* gen. nov¹. *Journal of phycology* 47: 123-130.
- Nogueira IS (1999) Estrutura e dinâmica da comunidade fitoplanctônica da represa Samambaia, Goiás, Brasil. Tese de Doutorado. Universidade de São Paulo, São Paulo. 341p.
- Nogueira IS & Leandro-Rodrigues NC (1999) Algas planctônicas de um lago artificial do Lake of the Jardim Botânico Chico Mendes, Goiânia, Goiás: florística e algumas considerações ecológicas. *Revista brasileira de Biologia* 59: 377-395.
- Nogueira IS, Nabout JC, Oliveira JE & Silva KD (2008) Diversidade (alfa, beta e gama) da comunidade fitoplanctônica de quatro lagos artificiais urbanos do município de Goiânia, GO. *Hoehnea* 35: 219-233.
- Oliveira MD & Calheiros DF (2000) Flood pulse influence on phytoplankton communities of the south Pantanal floodplain, Brazil. *Hydrobiologia* 427: 101-112.
- Parra OOB (1979) Revision der Gattung *Pediastrum* Meyen (Chlorophyta). *Bibliotheca Phycologica* Band 48. J. Cramer, Hirschberg. 186p.
- Perbiche-Neves G, Ferrareze M, Ghidini AR, Brito L & Shirata MT (2007) Assembléias microfitoplanctônicas num lago urbano da cidade de Curitiba (estado do Paraná, Brasil). *Estudos de Biologia* 29: 43-51. DOI: 10.7213/reb.v29i66.22208
- Rodrigues LL, Sant'Anna CL & Tucci A (2010) Chlorophyceae das Represas Billings (Braço Taquacetuba) e Guarapiranga, SP, Brasil. *Brazilian Journal of Botany* 33: 247-264.
- Ramos GJ, Bicudo CEM, Góes-Neto A & Moura CW (2016) Hydrodictyaceae (Chlorophyceae, Chlorophyta) do Pantanal dos Marimbus, Chapada Diamantina, Bahia, Brasil. *Iheringia, Série Botânica* 71: 13-21.
- Sant'Anna CL (1984) Chlorococcales (Chlorophyceae) do estado de São Paulo, Brasil. *Lubrecht e Cramer, Berlin*. 348p.
- Sant'Anna CL, Azevedo MTP & Sormus L (1989) Fitoplankton do lago da Garcas, Parque Estadual das Fontes do Ipiranga São Paulo, SP, Brasil: estudo taxonomico e aspectos taxonômicos. *Hoehnea* 16: 89-131.
- Silva CA, Train S & Rodrigues LC (2001) Estrutura e dinâmica da comunidade fitoplanctônica a jusante e montante do reservatório de Corumbá, Caldas Novas, estado de Goiás, Brasil. *Acta Scientiarum. Biological Sciences* 23: 283-290.
- Silva MJL, Pilatti MC, Bortolini JC, Baumgartner G & Bueno NC (2023) Chlorophyceae e Trebouxiophyceae (Chlorophyta) em rios da área de influência da Usina Hidrelétrica do Baixo Iguaçu, estado do Paraná, Brasil. *Hoehnea* 50: 1-21.
- Tell G (1979) Chlorophyceae d'eau douce rares et nouvelles de la Republique Argentina. *Revue Algologique, Nouvelle Serie* 14: 39-48.
- Tundisi JG & Tundisi TM (2008) *Limnologia*. Oficina de textos, São Paulo. 632p.