cryptogamie
Algologie
2025 • 46 • 3

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art. 46 (3) — Published on 5 September 2025
www.cryptogamie.com/algologie

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Cryptogamie, Algologie est distribué en version électronique par / Cryptogamie, Algologie *is distributed electronically by*:
- BioOne® (http://www.bioone.org/loi/crya)

Cryptogamie, Algologie est une revue en flux continu publiée par les Publications scientifiques du Muséum, Paris
Cryptogamie, Algologie *is a fast track journal published by the Museum Science Press, Paris*

Les Publications scientifiques du Muséum publient aussi / *The Museum Science Press also publish*: ***Adansonia, Geodiversitas, Zoosystema, Anthropozoologica, European Journal of Taxonomy, Naturae, Comptes Rendus Palévol, Cryptogamie*** **sous-sections *Bryologie, Mycologie*.**

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Tél.: 33 (0)1 40 79 48 05 / Fax: 33 (0)1 40 79 38 40
diff.pub@mnhn.fr / http://sciencepress.mnhn.fr
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ISSN (électronique / *electronic*): 1776-0984

Desmidiales (Desmidiaceae, Zygnematophyceae) from lowland rivers and floodplain lakes of Ecuadorian Amazonia

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Submitted on 16 March 2023 | Accepted on 12 August 2024 | Published on 5 September 2025

Sánchez L., Sánchez F. R., Ríos-Touma B. & Montoya J. V. 2025. — Desmidiales (Desmidiaceae, Zygnematophyceae) from lowland rivers and floodplain lakes of Ecuadorian Amazonia. *Cryptogamie*, *Algologie* 46 (3): 31-60. https://doi.org/10.5252/cryptogamie-algologie2025v46a3. http://cryptogamie.com/algologie/46/3

ABSTRACT

We present the results of a taxonomic survey of desmidiales (Desmidiaceae Ralfs, Zygnematophyceae Round ex Guiry) in floodplain lakes and tributaries of the Napo-Aguarico River in the Ecuadorian Amazon. Surface water samples were collected for taxonomic analysis at each site during two different hydrological periods in 2021 and 2022. Our sites share a typical blackwater typology, with high water transparency, low conductivity, acidic, and soft waters. In this study we documented 42 specific or infraspecific taxa in 10 genera within the Desmidiaceae family: *Bambusina* Kützing ex Kützing (1), *Cosmarium* Corda ex Ralfs (9), *Desmidium* C.Agardh ex Ralfs (3), *Euastrum* Ehrenberg ex Ralfs (3), *Hyalotheca* Ehrenberg ex Ralfs (2), *Micrasterias* C.Agardh ex Ralfs (12), *Pleurotaenium* Nägeli (2), *Staurastrum* Meyen ex Ralfs (6), *Staurodesmus* Teiling (2), and *Xanthidium* Ehrenberg ex Ralfs (2). From those taxa, 15 are new records to the lowlands of western Amazonia, and three of them (*Cosmarium quadriverrucosum* var. *supraornatum* Skuja, *Micrasterias fimbriata* var. *spinosa* Bisset, and *Micrasterias furcata* var. *dichotoma* (Wolle) Růžička) to the Amazon Basin. The number of species recorded at various sites differed greatly. We found 28 taxa for the Lagartococha River and 27 for Delfincocha Lake. For the remaining sites, we observed only two to nine species, which may be related to the presence or absence of aquatic macrophytes. All taxa were recorded during 2022, but only 20 out of 42 were observed in 2021. This variation is likely due to the hydrological regime, as it occurs in other Neotropical floodplains. Our findings underscore the importance of conducting additional phycological studies in these largely unexplored ecosystems, which are in peril owing to oil extraction activities in the western region of the Amazon Basin.

KEY WORDS
Biodiversity,
Amazon River,
tropical wetland,
floodplain,
phytoplankton,
freshwater algae,
Napo River,
Cuyabeno Wildlife
Reserve,
new records.

RÉSUMÉ
Desmidiales (Desmidiaceae, Zygnematophyceae) des rivières de plaine et des lacs inondables de l'Amazonie équatorienne
Nous présentons les résultats d'une étude taxonomique des desmidiales (Desmidiaceae Ralfs, Zygnematophyceae Round ex Guiry) dans les lacs de plaine inondable et les affluents du fleuve Napo-Aguarico en Amazonie équatorienne. Des échantillons d'eau de surface ont été collectés pour l'analyse taxonomique sur chaque site au cours de deux périodes hydrologiques différentes en 2021 et 2022. Nos sites partagent une typologie typique d'eaux noires, avec une transparence d'eau élevée, une faible conductivité, des eaux acides et douces. Dans cette étude, nous avons documenté 42 taxons spécifiques ou infraspécifiques répartis en 10 genres au sein de la famille des Desmidiaceae : *Bambusina* Kützing ex Kützing (1), *Cosmarium* Corda ex Ralfs (9), *Desmidium* C.Agardh ex Ralfs (3), *Euastrum* Ehrenberg ex Ralfs (3), *Hyalotheca* Ehrenberg ex Ralfs (2), *Micrasterias* C.Agardh ex Ralfs (12), *Pleurotaenium* Nägeli (2), *Staurastrum* Meyen ex Ralfs (6), *Staurodesmus* Teiling (2) et *Xanthidium* Ehrenberg ex Ralfs (2). Parmi ces taxons, 15 sont de nouveaux signalements dans les basses terres de l'ouest de l'Amazonie, et trois d'entre eux (*Cosmarium quadriverrucosum* var. *supraornatum* Skuja, *Micrasterias fimbriata* var. *spinosa* Bisset et *Micrasterias furcata* var. *dichotoma* (Wolle) Růžička) dans le bassin amazonien. Le nombre d'espèces enregistrées sur les différents sites variait considérablement. Nous avons trouvé 28 taxons pour la rivière Lagartococha et 27 pour le lac Delfincocha. Pour les autres sites, nous n'avons observé que deux à neuf espèces, ce qui peut être lié à la présence ou à l'absence de macrophytes aquatiques. Tous les taxons ont été enregistrés en 2022, mais seulement 20 sur 42 ont été observés en 2021. Cette variation est probablement due au régime hydrologique, comme c'est le cas dans d'autres plaines inondables néotropicales. Nos résultats soulignent l'importance de mener des études phycologiques supplémentaires dans ces écosystèmes largement inexplorés, qui sont en péril en raison des activités d'extraction pétrolière dans la région occidentale du bassin amazonien.

MOTS CLÉS
Biodiversité,
fleuve Amazone,
zone humide tropicale,
plaine inondable,
phytoplancton,
algues d'eau douce,
fleuve Napo,
réserve faunique de Cuyabeno,
signalements nouveaux.

INTRODUCTION

Desmids belong to an entirely freshwater group of photosynthetic organisms from the class Zygnematophyceae Round ex Guiry that are usually single-celled (though they can form colonies or be pseudofilamentous), worldwide distributed, usually adapted to oligotrophic and acidic conditions, and remarkably diverse (Coesel 1996; Hall & McCourt 2015). Notably, these algae rank among the most well-documented algal groups globally due to their exceptional variety in shapes and sizes, along with their distinct cell symmetry (Brook 1981; Reynolds 2006).

The documentation of desmids in Amazonian rivers and their floodplains is no exception, and their high diversity has not gone unnoticed. Initial studies on Amazonian desmid flora primarily focused on surveying the remarkable diversity of this group. Several researchers, including Grönblad (1945), Scott *et al.* (1965), Förster (1969, 1974), Thomasson (1971, 1977), Uherkovich (1976), and Uherkovich & Franken (1980), described new species and infraspecific taxa while providing preliminary ecological information on planktonic and periphytic assemblages from lotic and lentic habitats and water types. In recent decades, a series of studies, primarily conducted in the Brazilian Amazon, have significantly advanced our understanding of how environmental factors influence desmid biodiversity patterns, spatial distribution, and seasonality. Araújo *et al.* (2022) compiled a list of the most significant research on Amazonian desmids over the past 40 years. A few of those studies focused on how the various desmid assemblages present in different habitats are affected by the type of water, as defined by Sioli (1965). That classification system divides Amazonian water types into three distinct categories: whitewater, blackwater, and clearwater. Whitewater rivers, originating in the Andes Mountains, are usually rich in nutrients, exhibit moderate to high conductivity, substantial concentrations of suspended solids, high turbidity (low transparency), and neutral to slightly alkaline waters. In contrast, blackwater rivers and tributaries, originating not in the Andes but in the forest lowlands, are nutrient-poor and have lower suspended solids concentrations, resulting in higher transparency. Tea-colored waters, low conductivities, low hardness, and acidic pH levels characterize these rivers. The dark coloration of these waters is attributed to dissolved organic compounds, primarily fulvic and tannic acids, originating from soils and vegetation. Clearwater rivers share many similarities with blackwaters but tend to have transparent to green-colored waters. However, they have pH levels and dissolved organic content that overlap with both blackwaters and whitewaters. This categorization system (Sioli 1965) has proven essential in comprehending the ecological dynamics of freshwater organisms within the Amazon Basin's aquatic ecosystems. As observed worldwide, desmids thrive in soft, oligotrophic waters with acidic to slightly alkaline pH levels (Brook 1981; Coesel & Meesters 2007), conditions held by blackwaters and clearwaters of the Amazon River Basin.

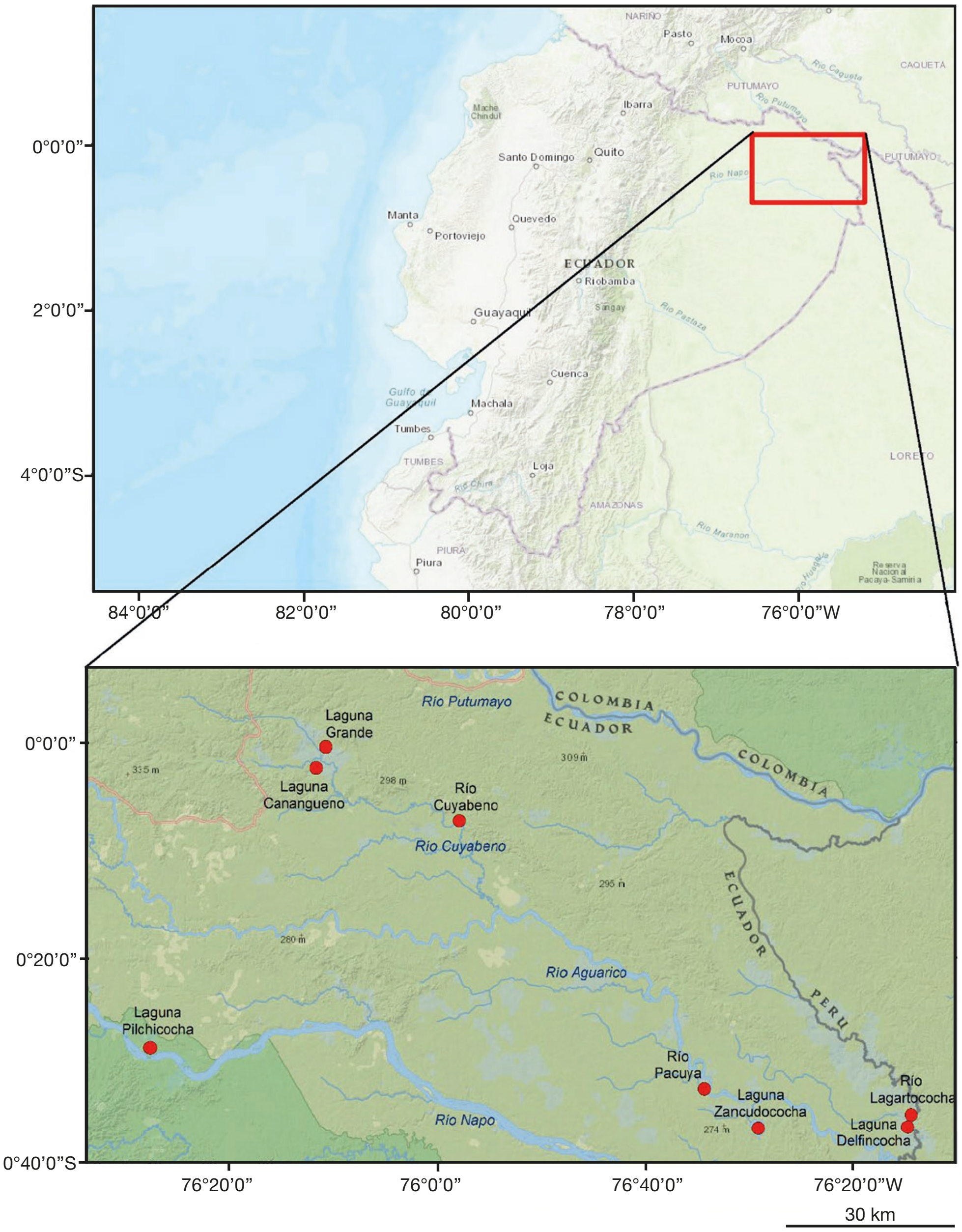

FIG. 1. — Field sites in the north-eastern Ecuadorian Amazonia where desmids (Desmidiaceae, Zygnematophyceae) were recorded in this study. Sampling sites included tributaries and floodplain lakes having tea-coloured waters, high transparency, soft waters, and low pH, and conductivity.

Most of the studies on Amazonian desmids have been conducted in blackwater habitats, where biodiversity has been found to be relatively high (Thomasson 1971). Concerning the influence of hydrological regime on the ecological dynamics of desmids' assemblages in floodplain lakes and rivers of the Amazon Basin, a few studies are showing that there is a seasonal pattern in biodiversity and abundance of these organisms (Huszar & Reynolds 1997; Melo *et al.* 2005; Melo & Souza de 2009). In those studies, there is a clear pattern showing an increase in desmid's richness during rising waters, i.e., when the floodplain is getting filled with river water during the flooding season. In those environments, the coverage of submerged and emergent floating plants rises during this time (Junk & Howard-Williams 1984), serving as a crucial substrate for periphytic desmids (Brook 1981). Aquatic macrophytes may be scarce or nonexistent in Amazonian blackwaters, which would limit their impact on the ecological dynamics of desmids. Nevertheless, submerged terrestrial vegetation may play a significant role as a substitute substrate for periphytic organisms during flooding (Melo *et al.* 2005). Additionally, the diel pattern of water column mixing, which promotes turbulence and the resuspension of organisms and sediments from the lakes' bottom, is a significant contributing factor to the persistent presence of desmids in tropical shallow lakes' plankton (Barbosa & Padisák 2002), as those of the Amazon floodplains.

TABLE 1. — Sampling sites for desmids during the high water (Aug 2021) and rising water (Apr 2022) hydrological phases. **1**, the tributary or river to which lakes are connected (parent river) is indicated within brackets; **2**, latitude (Lat.) and Longitude (Long.) are expressed in decimal degrees; **3**, sites sampled only during the rising water hydrological phase. Abbreviations: **CL**, Canangüeno Lake; **CR**, Cuyabeno River; **DL**, Delfincocha Lake; **GL**, Grande Lake; **LR**, Lagartococha River; **PL**, Pilchicocha Lake; **PR**, Pacuya River; and **ZL**, Zancudococha Lake.

Site Name[1]	**Site code**	**Lat.** **Long.**[2] **Alt. (m)**	**Site description**
Pilchicocha Lake (Napo River)	PL	–0.47311 –76.45954 230	Pilchicocha Lake lies on the left bank of the Napo River, downstream Puerto Providencia. The lake is connected to the river via a short channel. Lake micro basin is in the alluvial floodplain of the Napo River, in protected private lands. Although of being a lake associated with a whitewater river, its waters are dominated by the influx of several small blackwater creeks draining the forest.
Grande Lake (Cuyabeno River)	GL	–0.00423 –76.18261 221	Grande Lake belongs to the Cuyabeno wetlands system, and it is connected to other lakes through channels. It is a blackwater lake. There are several lodges for tourism along the margin of the lake and the presence of motorboats is common. This lake usually dries up during the dry season.
Canangüeno Lake[3] (Cuyabeno River)	CL	–0.04294 –76.19932 220	Canangüeno Lake belongs to the Cuyabeno wetlands system. This blackwater lake is connected to Grande Lake through channels. The access to this lake is granted only for authorized research activities and for indigenous people inhabiting the area. This lake often dries up during the dry season.
Delfincocha Lake (Lagartococha River)	DL	–0.59448 –75.24351 196	Delfincocha Lake is a blackwater lake in the Lagartococha wetlands, on the right bank of the Lagartococha River. It is a permanently connected lake.
Zancudococha Lake[3] (Aguarico River)	ZL	–0.58954 –75.48291 185	Zancudococha Lake is on the right bank of the Aguarico River, connected to it through a narrow channel. It is the largest lake in the Ecuadorian Amazonia in terms of area. Although of being a lake associated with a whitewater river, its waters are dominated by the influx of several small blackwater creeks draining the forest.
Cuyabeno River	CR	–0.00618 –76.17212 211	Cuyabeno River is a left margin tributary of the Aguarico River. It is a narrow and meandering blackwater river that forms a complex wetland system in its middle stretches. Its headwaters are in the Andean mountains and before entering its protected area, it drains lands subjected to land use changes in the last decades.
Lagartococha River	LR	–0.59750 –75.23869 196	Lagartococha River is a left margin tributary of the Aguarico River. It is a blackwater river, draining a conserved and remote area of the Ecuadorian Amazonia. It is in a natural protected area and constitutes the borderline between Ecuador and Peru.
Pacuya River[3]	PR	-0.53694 -75.57043 197	Pacuya River is a right margin, blackwater tributary of the Aguarico River. Its basin is very well conserved, usually used by Cofan indigenous people as one of their main places to gather food, especially fish.

For lowland Amazonian aquatic ecosystems in Ecuador, information on ecological and limnological patterns is very limited. Reports on the taxonomy and ecology of phytoplankton and periphyton of a few floodplain lakes and wetlands in the Napo River basin exist but date back to the 1980's and 1990's (Steinitz-Kannan *et al.* 1983; Miller *et al.* 1984; Colinvaux *et al.* 1985; De Oliveira & Steinitz-Kannan 1992). As far as research on desmids in lowland aquatic environments of the Ecuadorian Amazonia is concerned, no studies have reported on desmids at the species level. However, records exist for a few common genera of the Desmidiaceae Ralfs, including *Euastrum* Ehrenberg ex Ralfs, *Micrasterias* C.Agardh ex Ralfs, *Cosmarium* Ehrenberg ex Ralfs, *Staurodesmus* Teiling, and *Staurastrum* Meyen ex Ralfs (Colinvaux *et al.* 1985; Guamán & González 2016). With the aim of improving the inventory of freshwater microalgae of Ecuadorian Amazon aquatic ecosystems, we present a list of desmids (Desmidiaceae) and their occurrences, including new records and comments on the environmental conditions of their habitats and distribution for the Amazon River Basin, the Western Amazonian region, and Ecuadorian lowland rivers and lakes within the Amazon River Basin.

MATERIAL AND METHODS

STUDY AREA

This research is part of a broader limnological study within the eastern Napo-Aguarico Basin in Ecuador. This region, along with the Pastaza and the Morona-Santiago River, are the three larger Amazonian River basins within Ecuador (Fig. 1). Napo-Aguarico River Basin has been disturbed due to the presence of long-time established oil companies (Espinosa Andrade 2017). However, most of our sites are inside the limits of an Ecuadorian protected area, the Cuyabeno Wildlife Reserve. We sampled blackwater habitats within the whitewater basins of the Napo and Aguarico rivers (Table 1).

Sampling trips to eight sites in the Napo-Aguarico River Basin in Ecuador were conducted in August 2021 and in April 2022. Hydrological conditions during samplings in 2021 and 2022 corresponded to periods when water levels were high or rising, respectively (Galacatos *et al.* 2004). We also measured some basic limnological variables (Table 2) to comment on the prevailing environmental conditions at each site during those two periods.

ENVIRONMENTAL VARIABLES

At each site, we measured depth (Z, cm), water transparency (Z_{SD}, cm), water temperature (T, °C), dissolved oxygen concentration ([DO], mg·L-1), dissolved oxygen saturation percentage (DO%), pH, and specific conductivity (Spec. Cond., µS·cm-1) (Table 2). Z and Z_{SD} were measured using a Secchi disk and a marked line; T, [DO], DO%, pH, and Spec. Cond. were obtained using an *InSitu* Aquatroll 500 multiparameter sonde (Fort Collins, United States) at a depth of 0.5 m. Water hardness was measured at the laboratory using the EDTA titrimetric method no. 2340-C (American Public Health Association *et al.* 2017).

COLLECTION AND PRESERVATION OF SAMPLES

Thirty liter surface water samples for taxonomic analysis of plankton were taken at each site using plastic containers at 0.5 m depth and filtered through a 20 µm mesh plankton net. Each composite sample consisted of pooling 10 L taken at each river margin and at the center of the main channel to complete 30 L in river sites. In floodplain lakes, composite samples included three-10 L portions taken at two littoral sites and one at the center of lakes. Once filtered and concentrated in the plankton sampler's dolphin bucket, samples were poured into a 60-mL plastic bottle and preserved in the field with formalin to a concentration of 4%. In order to take pictures and examine cells in more detail, some specimens were sorted out by morphotypes and saved in microvials with Transeau solution. Finally, all specimens were put back in their sample bottles, and the preservative was changed to Transeau solution as a final preservative (Bicudo & Sormus 1982). Then, samples were concentrated to 3 mL and saved into glass vials before their deposit in the collection.

Samples were deposited at the Universidad de Cuenca's Laboratorio de Ecología Acuática Museum in Cuenca, Ecuador with codes UC-MLA292 and UC-MLA293 (Pilchicocha Lake (PL), 2021 and 2022); UC-MLA294 and UC-MLA295 (Grande Lake (GL), 2021 and 2022); UC-MLA296 (Canangüeno Lake (CL), 2022); UC-MLA297 (Zancudococha Lake (ZL), 2022); UC-MLA298 and UC-MLA299 (Delfincocha Lake (DL), 2021 and 2022); UC-MLA300 and UC-MLA301 (Lagartococha River (LR), 2021 and 2022); UC-MLA302 and UC-MLA303 (Cuyabeno River (CR), 2021 and 2022); and UC-MLA304 (Pacuya River (PR), 2022).

TAXONOMIC IDENTIFICATION

Specimens were observed under an Olympus BX51 microscope and an Olympus CKX41 inverted microscope. Digital photographs of each specimen were taken using a digital camera. To account for individual variation and to observe various views of algal specimens, cells were handled with a very fine bristle attached to a dissection needle. In most cases at least five specimens per taxon were inspected and photographed. Unfortunately, a reliable examination of chloroplasts was not possible since samples were initially preserved with formalin. ImageJ software was used to measure and annotate images (Schneider *et al.* 2012). Specimens were identified using the following specialized literature: Krieger (1937, 1939); Grönblad (1945); Krieger & Gerloff (1962, 1965); Scott *et al.* (1965); Förster (1969, 1974), Prescott *et al.* (1977); Tell (1980); Uherkovich & Franken (1980); Bicudo & Sormus (1982); Bourrelly & Couté (1982); Thérézien (1985, 1986); Couté & Thérézien (1986); Blanco & Sánchez (1986); Delgado *et al.* (2003); Lopes & Bicudo (2003); Oliveira de *et al.* (2009, 2010, 2016a, b); Coesel & Meesters (2013); Bicudo *et al.* (2014, 2015, 2018); Aquino *et al.* (2016); Bicudo & Samanez (2016); Santos *et al.* (2016); Ramos *et al.* (2021), among others.

The list of identified desmids from sampling sites of the Ecuadorian Amazon is provided (Table 3), along with information on the validity of taxa from Guiry & Guiry (2024). Authors were abbreviated according to IPNI (2023). Descriptions were provided for all taxa, while taxonomic remarks were added for the new records found for western Amazonia and for selected taxa that might be easily misidentified with similar varieties or species or presenting specific morphological variants in our populations. Life forms, whether benthic or planktonic, were assigned to each taxon based on literature records (Brook 1959; Sophia & Huszar 1996; Coesel 2001; Melo *et al.* 2005; Šťastný 2010). Unless otherwise stated, the distribution records for all taxa outside of Amazonia were mostly compiled from Guiry & Guiry (2024). The records for the Amazon River Basin, Western Amazonia (south-eastern Colombia, north-eastern Peru), and Ecuadorian Amazonia were obtained from published sources.

RESULTS

A basic physicochemical characterization of our sites showed that they share high transparency (Secchi disk depth above 100 cm), low pH (values between 4.58 and 6.09); low conductivity (range 6.54-36.1 µS·cm-1); and very variable dissolved oxygen concentration, with values showing suboxic conditions (below 1 mg·L-1 to near zero in some sites such as Lagartococha River, and Delfincocha, and Pilchicocha Lakes) to values corresponding to supersaturation conditions (9.18 mg·L-1, 124.9%; Zancudococha Lake). Hardness values showed very soft to soft waters, with very low values for Lagartococha River, and Grande and Delfincocha lakes (< 15 mg $CaCO_3$·L-1) (Table 2). Concerning hydrological variability between the two sampled seasons (high waters in 2021 and rising waters in 2022), there were not any important differences in water levels for the sites sampled in both years, though they were more variable with up and downs during the sampling period in 2021. The same can be said for the measured physicochemical parameters. For physicochemical variables, sites showed more acidic waters, with less oxygen, and less transparency at rising waters (2022) than at high waters (2021).

Within the family Desmidiaceae, order Desmidiales, we identified 42 taxa at specific or intraspecific level from 10 genera: *Bambusina* Kützing ex Kützing (1), *Cosmarium* Corda ex Ralfs (9), *Desmidium* C.Agardh ex Ralfs (3), *Euastrum* Ehrenberg ex Ralfs (3), *Hyalotheca* Ehrenberg ex Ralfs (2), *Micrasterias* C.Agardh ex Ralfs (12), *Pleurotaenium* Nägeli (2), *Staurastrum* Meyen ex Ralfs (6), *Staurodesmus* Teiling (2), and

TABLE 2. — Sampling dates, and environmental variables of floodplain lakes and lowland river sites with recorded desmids in the Ecuadorian Amazonia. Abbreviations: **Cond**, specific conductivity (in µS·cm^{-1}); **DO**, dissolved oxygen (in mg·L^{-1}, and in %); **Hard**, hardness (in mg CaCO$_3$·L^{-1}); **Temp**, temperature (in °C); **Z**, depth (in cm); **Z$_{SD}$**, Secchi disk depth (in cm).

Site, site code	Date	Z	Z$_{SD}$	Temp	DO	DO%	pH	Cond	Hard
Pilchicocha Lake, PL	18.VIII.2021	390	110	25.4	0.66	8.8	6.09	32.1	53.8
—	3.IV.2022	427	105	25.1	0.17	2.7	5.73	36.1	28.6
Grande Lake, GL	6.VIII.2021	390	145	26.8	2.60	27.8	5.78	8.0	3.5
—	7.IV.2022	435	114	25.9	0.38	4.9	4.58	6.6	14.0
Canangüeno Lake, CL	7.IV.2022	240	128	28.3	3.65	48.5	4.74	6.5	38.3
Zancudococha Lake, ZL	12.IV.2022	290	131	30.2	9.18	124.9	5.08	6.8	29.1
Delfincocha Lake, DL	12.VIII.2021	350	165	26.3	0.65	8.2	5.71	10.8	7.9
—	14.IV.2022	390	100	26.6	0.29	3.6	5.33	14.5	15.1
Lagartococha River, LR	13.VIII.2021	640	155	26.0	0.31	3.9	5.51	10.3	12.1
—	14.IV.2022	644	110	27.1	0.07	0.9	5.06	10.1	9.7
Cuyabeno River, CR	8.VIII.2021	101	114	24.7	4.20	52.4	5.96	11.6	25.2
—	8.IV.2022	117	117	25.3	4.10	51.0	5.00	10.1	19.9
Pacuya River, PR	15.IV.2022	147	147	25.5	2.59	32.3	5.05	19.3	57.7

Xanthidium Ehrenberg ex Ralfs (2) (Table 3). Most taxa are considered benthic (Table 3), usually associated with aquatic macrophytes, and although we did not collect any samples from macrophytes, their presence in our water column samples is likely incidental (part of the tychoplankton). Number of taxa recorded at each sampling site varied greatly (Table 3). Lagartococha River and Delfincocha Lake, both located on the border between Ecuador and Peru, which belong to a typical blackwater category and with very low dissolved oxygen values, had the highest number of taxa among all sites (28 and 27, respectively). In Grande Lake and Zancudococha Lake, nine and seven taxa were recorded, respectively. The number of desmids recorded for the rest of sites was very low, holding just two or three taxa. The number of new records for desmids taxa for Ecuador was 42. For the Western Amazon (lowlands) region and the Amazon Basin, there were 15 and three new records, respectively (marked in the Systematics section and Table 3 with one or two asterisks).

SYSTEMATICS

Family DESMIDIACEAE Ralfs
Genus *Bambusina* Kützing ex Kützing

Bambusina borreri (Ralfs) Cleve
(Fig. 2A)

Öfversigt af Kongl. Vetenskaps-Akademiens Förhandlingar, Stockholm 20: 496 (Cleve 1864). — *Desmidium borreri* Ralfs, *The British Desmidieae*: 375 (Ralfs 1848).

Bambusina brebissonii Kützing, *Species algarum*: 188 (Kützing 1849).

DISTRIBUTION. — Cosmopolitan. Amazon Basin: Grönblad (1945); Thomasson (1971); Melo *et al.* (2005); Souza de *et al.* (2007); Araújo *et al.* (2020). As *B. brebissonii*: Förster (1969); Uherkovich & Rai (1979); Uherkovich (1981); Souza de & Melo (2010); Cadima (2013); Feitosa *et al.* (2015). Western Amazonia (lowlands): Krieger & Scott (1957); Díaz-Olarte & Duque (2009); and Araujo (2003) as *B. brebissonii*.

DESCRIPTION

Cells 26.8-27.2 µm long, 15.9-17.0 µm wide, isthmus 16.0 µm, apex 12.1-12.8 µm, cells 1.6 times longer than wide. Hyaline cell wall. Semicells are barrel shaped with parallel lateral margins and truncated apex; shallow median sinus, open median constriction, and minimal basal inflation on either side of the isthmus.

Genus *Cosmarium* Corda ex Ralfs

Cosmarium contractum var. ***contractum*** Kirchn.
(Fig. 2B)

Kryptogamen-Flora von Schlesien Part 1 (2): 147 (Kirchner 1878).

DISTRIBUTION. — Cosmopolitan. Amazon Basin: Grönblad (1945); Förster (1969); Thomasson (1971, 1977); Uherkovich (1976); Uherkovich & Rai (1979); Sophia & Huszar (1996); Melo *et al.* (2005); Souza de *et* al. (2007); Melo & Souza de (2009); Cadima (2013); Cunha de *et al.* (2013); Feitosa *et al.* (2015). Western Amazonia (lowlands): Montoya (1974); Díaz-Olarte & Duque (2009).

DESCRIPTION

Cells 30.0-32.7 µm long, 23.0-23.5 µm wide, isthmus 8.0 µm, cells 1.3-1.4 times longer than wide. Cells with deep median constriction, cell wall finely punctate. Ellipsoid semicells, with slightly depressed apices. Each semicell with an axial chloroplast and one central pyrenoid.

Cosmarium contractum var. ***minutum*** (Delp.) Coesel*
(Fig. 2C)

Cryptogamie, Algologie 10 (3): 183 (Coesel 1989). — *Cosmarium minutum* Delponte, *Memorie della Reale Accademia delle Scienze di Torino*, serie 2, 30: 7 (Delponte 1877). — *Ursinella minuta* (Delponte) Kuntze, *Revisio generum plantarum*, Vol. 2: 925 (Kuntze 1891).

Cosmarium ellipsoideum var. *minus* Raciborski, *Pamietnik Akademii Umiejetnosci W Krakowie Wydzial Matematyczno-Przyrodniczy* 10: 84 (Raciborski 1885).

Distribution. — Cosmopolitan. Amazon Basin: Grönblad (1945); Förster (1974); Uherkovich & Franken (1980); Cadima (2013). Western Amazonia (lowlands): no records.

Description

Cells 23.0-25.4 µm long, 14.0-17.0 µm wide, isthmus 6.0 µm, cells 1.4-1.6 times longer than wide. Cells hyaline, with deep median constriction, cell wall finely punctate, median sinus open. Semicells ellipsoid, with lateral margins rounded, vertically convex, apex rounded. One axial chloroplast per semicell.

Remarks

This is a small taxon within the genus *Cosmarium*. As mentioned by Moresco *et al.* (2015) and Fadul-Souza *et al.* (2022), this variety differs from the type in terms of its smaller size. The size range of our specimens falls within the recorded ranges for the taxon in Grönblad (1945), Krieger & Gerloff (1962), Förster (1974), Moresco *et al.* (2015), and Fadul-Souza *et al.* (2022) from various regions in Brazil. The semicells of a morphologically similar taxon, *Cosmarium moniliforme* Ralfs, are semicircular. This allows these two taxa to be separated.

Cosmarium denticulatum var. ***perspinosum*** Grönblad
(Fig. 2D, E)

Acta Societatis Scienctiarum Fennicae, *Nova Series B,* 2 (6): 17 (Grönblad 1945).

Distribution. — North and South America. Amazon Basin: Thomasson (1971); Thérézien (1986); Cadima (2013). Western Amazonia (lowlands): Krieger & Scott (1957).

Description

Cells 196.2-212.0 µm long, 126.0-127.0 µm wide, isthmus 40-42 µm; cells 1.5-1.7 times longer than wide. Cell wall denticulate throughout each semicell, with denticles almost always pointing towards apices; central part of semicells with spines and granules (Fig. 2E). Semicells triangular, with rounded basal angles, straight to slightly convex lateral margins, converging towards the apex of each semicell, and slightly convex to subtruncate apical margins.

Cosmarium denticulatum var. ***triangulare*** Grönblad*
(Fig. 2F, G)

Acta Societatis Scienctiarum Fennicae, *Nova Series B,* 2 (6): 17 (Grönblad 1945).

Distribution. — South America. Amazon Basin: Grönblad (1945); Förster (1969); Thomasson (1971); Cadima (2013). Western Amazonia (lowlands): no records.

Description

Cells 165.0-176.5 µm long, 108.0-114.5 µm wide, isthmus 35-42 µm, cells 1.5-1.6 times longer than wide. Cells with deep median constriction, median sinus narrow, closed, and dilated at the apex; cell wall punctate, denticulate at margins and above the isthmus, with central part smooth (clearly shown in Fig. 2F). Pyramidal semicells with rounded basal angles, occasionally with one prominent denticle at each basal angle, lateral margins straight to slightly convex, converging towards apices; apical angles slightly rounded; apical margin subtruncate to broadly truncate, narrow.

Remarks

This taxon is easily recognizable by having pyramidal semicells, with their apical margins subtruncate to truncate, and by a smooth central part area in the semicells, while the surroundings are punctate. Our specimens' dimensions coincided with those depicted in Grönblad (1945) but are larger than the specimens described by Förster (1969).

Cosmarium pseudoconnatum Nordst.
(Fig. 2H)

Videnskabelige meddelelser fra Dansk naturhistorisk forening i København 21 (14-15): 214 (Nordstedt 1870). — *Calocylindrus pseudoconnatus* (Nordstedt) Wolle, *Bulletin of the Torrey Botanical Club* 8 (4): 39 (Wolle 1881). — *Pleurotaeniopsis pseudoconnata* (Nordstedt) Lagerheim, *Botaniska Notiser* 1887: 197 (Lagerheim (1887).

Distribution. — Cosmopolitan. Amazon Basin: Scott *et al.* (1965); Förster (1969, 1974); Thomasson (1971); Uherkovich (1976); Uherkovich & Franken (1980); Lopes & Bicudo (2003); Melo *et al.* (2005); Souza de *et al.* (2007); Melo & Souza de (2009). Western Amazonia (lowlands): Krieger & Scott (1957); Montoya (1974); Duque & Donato (1996a), Duque & Nuñez-Avellaneda (2000); Nuñez-Avellaneda (2008).

Description

Cells 46.0-54.5 µm long, 34.5-41.4 µm wide, isthmus 31.0-37.0 µm, cells 1.3 times longer than wide. Punctuated cell wall, smooth isthmic region, apical view of cells circular, median constriction not very marked, and shallow median sinus. Subsemicircular semicells, lateral view of semicell same as front. Parietal chloroplast.

Cosmarium pseudomagnificum
var. ***brasiliense*** (Kurt Först. & Eckert) Kurt Först.*
(Fig. 2I, J)

Algological Studies/Archiv für Hydrobiologie, Supplement 28: 241 (Förster 1981). — *Cosmarium pseudomagnificum* f. *brasiliense* Kurt Förster & Eckert, *Revue Algologique*, *Nouvelle Série* 7 (1): 74 (Förster 1963).

Distribution. — Brazil, Bangladesh. Amazon Basin: Förster (1969); Thomasson (1977). As *C. pseudomagnificum* f. *brasiliense*: Förster (1963); Thomasson (1971). Western Amazonia (lowlands): no records.

TABLE 3. — Desmids (Desmidiaceae, Zygnematophyceae) records for sites in the Ecuadorian Amazon. Abbreviations: **CL**, Canangüeno Lake; **CR**, Cuyabeno River; **DL**, Delfincocha Lake; **GL**, Grande Lake; **LR**, Lagartococha River; **PL**, Pilchicocha Lake; **PR**, Pacuya River; and **ZL**, Zancudococha Lake. Taxa with one or two asterisks correspond to new records for the Western Amazonia region, and the Amazon River Basin, respectively. Two types of life forms (**LF**) were distinguished: benthic (**b**) and planktonic (**p**). Species records for the high waters 2021 (○), rising waters 2022 (●), or both (◙) periods are shown for each site.

		Floodplain lakes					**Rivers**		
Species	**LF**	**PL**	**GL**	**CL**	**ZL**	**DL**	**LR**	**CR**	**PR**
Bambusina borreri (Ralfs) Cleve	b, p		●			●	●		
Cosmarium contractum var. *contractum* Kirchn.	b, p						●		
Cosmarium contractum var. *minutum* (Delp.) Coesel*	b					●			
Cosmarium denticulatum var. *perspinosum* Grönblad	b					◙	●		
Cosmarium denticulatum var. *triangulare* Grönblad*	b					●			
Cosmarium pseudoconnatum Nordst.	b, p		●			●	●		●
Cosmarium pseudomagnificum var. *brasiliense* (Kurt Först. & Eckert) Kurt Först.*	b						●		
Cosmarium pseudopyramidatum var. *borgei* Krieg. & Gerloff*	b						●		
Cosmarium pseudopyramidatum var. *pseudopyramidatum* P.Lundell	b						●		
Cosmarium quadriverrucosum var. *supraornatum* Skuja**	b						●		
Desmidium baileyi (Ralfs) ex Nordst.	b, p					●			
Desmidium grevillei (Kütz. ex Ralfs) De Bary	b, p					◙	○		
Desmidium swartzii C.Agardh ex Ralfs	b		○			●	◙		
Euastrum abruptum Nordst.	b	◙					●		
Euastrum brasiliense var. *convergens* Willi Krieg.*	b					●	●		
Euastrum evolutum var. *perornatum* A.M.Scott & Croasdale	b, p		●			●	●		
Hyalotheca dissiliens Bréb. ex Ralfs	b, p		○			◙	○		
Hyalotheca mucosa Ralfs	b, p		○		●	◙	○		
Micrasterias borgei var. *aequalis* Willi Krieg.	b					◙	○		
Micrasterias borgei var. *borgei* Willi Krieg.	b, p					◙	◙		
Micrasterias fimbriata var. *spinosa* Biss.**	b				●				
Micrasterias furcata var. *dichotoma* (Wolle) Růžička**	p				●				
Micrasterias laticeps Nordst.	b, p				●	◙	◙		
Micrasterias mahabuleshwarensis var. *amazonensis* Kurt Först.	b, p					◙	◙		
Micrasterias radians var. *brasiliensis* (Grönblad) Willi Krieg. ex Coesel & van Geest *	b, p				●	◙			
Micrasterias radiosa var. *elegantior* (G.S. West) Croasdale	b					◙			
Micrasterias radiosa var. *radiosa* Ralfs*	b, p					◙			
Micrasterias rotata Ralfs	b, p					●			
Micrasterias torreyi var. *curvata* Willi Krieg.	b					○	●		
Micrasterias torreyi var. *nordstedtiana* (Hieron.) Schmidle	b					●			
Pleurotaenium nodosum (Bailey ex Ralfs) P. Lundell	b					○	●		
Pleurotaenium trabecula Nägeli	b					◙	◙		
Staurastrum leptocladum var. *cornutum* Wille*	p	●	●	●	●			●	●
Staurastrum octangulare Grönblad	b, p	●	●						
Staurastrum pinnatum var. *reductum* Willi Krieg.*	b						●		
Staurastrum setigerum var. *subvillosum* Grönblad*	b					●	○		
Staurastrum tectum var. *ayayense* Grönblad *	b		◙	●				◙	
Staurastrum teliferum var. *pecten* (Perty) Grönblad	b						●		
Staurodesmus convergens (Ehrenb. ex Ralfs) S. Lill.	b, p						◙		
Staurodesmus triangularis (Langerh.) Teiling	p				●				
Xanthidium mamillosum var. *mediolaeve* (Grönblad) Couté & Tell*	p					◙	○		
Xanthidium trilobum Nordst.	b, p					●	●		
Number of taxa per site		3	9	2	7	27	28	2	2

DESCRIPTION

Cells 71.7-84.9 µm long, 55.4-66.8 µm wide, isthmus 24.7-30.6 µm, apex 20.2-20.4 µm, cells 1.23-1.31 times longer than wide. Cell wall with granules, punctuated. Cells are large with deep median constriction; lineal narrow median sinus, slightly widened at apex. Semicells are pyramidal-truncated, with convex lateral margins, with basal sub-rectangular corners and rounded apical corners. Apex broadly truncated, straight. Semicell lateral margins with granules (between 22 and 34); no granules were observed along the apical straight margin of each semicell. Two chloroplasts per semicell.

REMARKS

Our specimens coincided with those described originally as *C. pseudomagnificum* f. *brasiliense* by Förster (1963) and those reported in Förster (1969) as *C. pseudomagnificum* var. *brasiliense* for the Amazon, and with those in Biolo (2016) for the São Paulo State in Brazil by showing cells with similar shapes and size, although our specimens' size range is slightly larger than those of Biolo (2016) (76-81 µm L, 57-59 µm W). This species can be confused with *Cosmarium binum* Nordstedt but differs from it by having a truncated apical margin with no granules, while in *C. binum*, apical margins are convex with granules (Biolo 2016). Also, *C. binum* cells are smaller

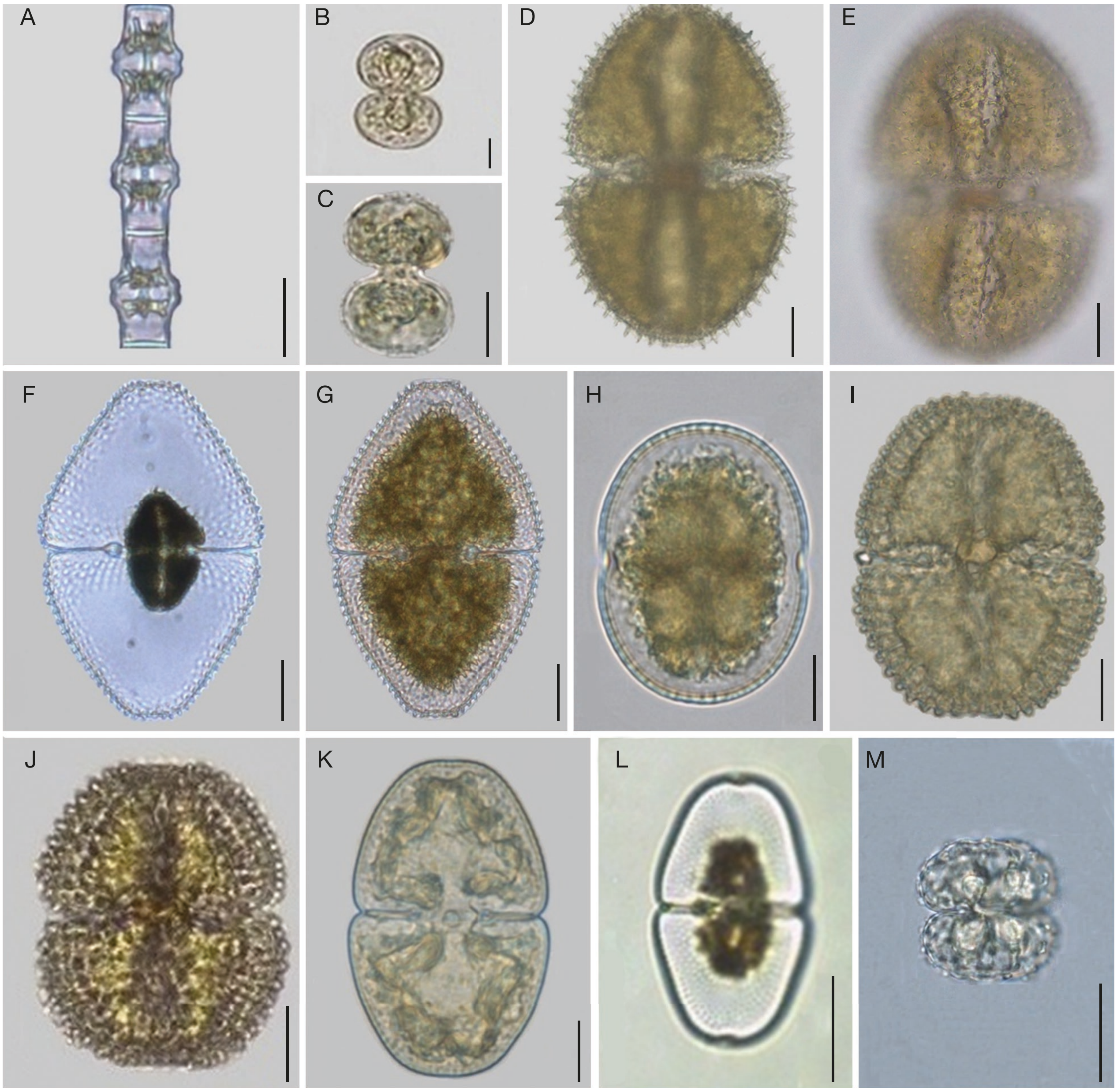

Fig. 2. — *Bambusina* Kütz. ex Kütz and *Cosmarium* Corda ex Ralfs: **A**, *Bambusina borreri* (Ralfs) Cleve; **B**, *Cosmarium contractum* var. *contractum* Kirchn.; **C**, *Cosmarium contractum* var. *minutum* (Delp.) Coesel; **D**, **E**, *Cosmarium denticulatum* var. *perspinosum* Grönblad; **F**, **G**, *Cosmarium denticulatum* var. *triangulare* Grönblad; **H**, *Cosmarium pseudoconnatum* Nordst.; **I**, **J**, *Cosmarium pseudomagnificum* var. *brasiliense* (Kurt Först. & Eckert) Kurt Först.; **K**, *Cosmarium pseudopyramidatum* var. *borgei* Krieg. & Gerloff; **L**, *Cosmarium pseudopyramidatum* var. *pseudopyramidatum* P.Lundell; **M**, *Cosmarium quadriverrucosum* var. *supraornatum* Skuja. Scale bars: A, I-K, 20 µm; B, C, H, M, 10 µm; D-G, L, 30 µm.

in size and hold a smaller number of lateral granules on each semicell, as described for specimens from Bolivia (Thérézien 1986), and Namibia (Grönblad & Croasdale 1971).

Cosmarium pseudopyramidatum var. *borgei* Krieg. & Gerloff* (Fig. 2K)

Die Gattung Cosmarium 2: 127 (Krieger & Gerloff 1965).

Distribution. — Brazil, Japan, Subantarctic Islands. Amazon Basin: Förster (1969); Thomasson (1977); Aprile & Mera (2007); Cadima (2013). Western Amazonia (lowlands): no records.

Description

Cells 64.4-66.0 µm long, 42.0-42.8 µm wide, isthmus 15.0 µm; cells 1.5-1.6 times longer than wide. Cells with oval contour, deeply constricted in the median part, linear median sinus, narrow; pyramidal-subtruncate semicells, lateral margins slightly convex, apex broadly rounded, rounded basal and apical angles, hyaline, densely punctuated cell wall but not as finely as the type variety; axial chloroplast.

Remarks

Our specimens coincided with the morphological characteristics and size presented by Krieger & Gerloff (1965) in their original description of the taxon. Also, they are similar in size to the populations described by Förster (1969) for the Brazilian Amazon, and Oliveira de *et al.* (2010) for northeast Brazil.

Cosmarium pseudopyramidatum var. *pseudopyramidatum* P. Lundell
(Fig. 2L)

Nova Acta Regiae Societatis Scientiarum Upsaliensis, serie 3, 8 (2): 41 (Lundell 1871). — *Euastrum pseudopyramidatum* (P. Lundell) F. Gay, *Essai d'une monographie locale des Conjugées*: 60 (Gay 1884).

Cosmarium pyramidatum var. *minus* Reinsch, *Abhandlungen der Naturhistorischen Gesellschaft zu Nürnberg* 3 (2): 152 (Reinsch (1866).

Cosmarium pseudopyramidatum f. *minus* Raciborski, *Rozprawy Wydzialu Matematyczno-Przyrodniczego Akademii Umiejetnosci* 2 (2): 364 (Raciborski 1892).

DISTRIBUTION. — Cosmopolitan. Amazon Basin: Thomasson (1971), Souza de *et al.* (2007); Cadima (2013). Western Amazonia (lowlands): Araujo (2003); Díaz-Olarte & Duque (2009).

DESCRIPTION
Cells 79.1-80.0 µm long, 46.8-47.2 µm wide, isthmus 16.6-16.9 µm; cells 1.7 times longer than wide. Cells have an oval shape with a profoundly constricted central section, median sinus linear, narrow, dilated at the apex; semicell pyramidal-truncated, with a shallow notch on the median part of the apex; basal angles rounded, lateral margins slightly convex to almost straight, cell wall hyaline, finely punctate; axial chloroplast; one pyrenoid.

REMARKS
Our specimens are morphologically similar but larger to the original description of Lundell (1871) and those reported by West & West (1905), Tell & Couté (1993), Oliveira de *et al.* (2010), and Aquino *et al.* (2016).

Cosmarium quadriverrucosum var. *supraornatum* Skuja**
(Fig. 2M)

Nova Acta Regiae Societatis Scientiarum Upsaliensis, serie 4, 14 (5): 139 (Skuja 1949).

DISTRIBUTION. — Brazil, Myanmar, China, Australia, and New Zealand. Amazon Basin: no records. Western Amazonia (lowlands): no records.

DESCRIPTION
Cells 5.9 µm long, 25.4 µm wide, isthmus 9.0 µm; cells as long as wide. Cells with deep median constriction, closed median sinus, straight; subcircular semicells; apical margin straight to broadly rounded; central tumor with warts on the face of the semicell, a variable number of warts in rows around the semicell, without any arrangement; axial chloroplast; two pyrenoids.

REMARKS
This taxon is small and is recognized from the type variety by having a more wavy, irregular cell outline which is given by the presence of more warts. Compared with *Cosmarium furcatospermum* West & G.S.West, *C. quadriverrucosum* var. *supraornatum* has two pyrenoids instead of one. Our specimens are morphologically similar and within size range shown for this taxon in the original description by Skuja (1949) and those reported by Oliveira de *et al.* (2010) for Brazil and Dingley (2001) for Australia.

Genus *Desmidium* C.Agardh ex Ralfs

Desmidium baileyi (Ralfs) Nordst.
(Fig. 3A)

Acta Universitatis lundensis 16 (1878-1880): 4 (Nordstedt 1880). — *Aptogonum baileyi* Ralfs, *The British Desmidieae*: 208 (Ralfs 1848).

Aptogonum tetragonum Delponte, *Memorie della Reale Accademia delle Scienze di Torino*, series 2, 28: 75 (Delponte 1873). — *Desmidium aptogonum* var. *tetragonum* (Delponte) West & G. S. West, *Transactions of the Linnean Society of London*, Botany, series 2, 6: 193 (West & West 1902). — *Desmidium elenkinii* I. A. Kisselev, *Izvestiya Otdela Prikladnoy Ikhtiologii i Nauchno-Promyaslov Issledov* 5 (2): 286, 301 (Kisselev 1927).

DISTRIBUTION. — Cosmopolitan. Amazon Basin: Grönblad (1945); Scott *et al.* (1965); Förster (1969, 1974); Uherkovich (1976, 1981); Uherkovich & Rai (1979); Melo *et al.* 2005); Souza de *et al.* (2007); Melo & Souza de (2009); Souza de & Melo (2010); Cadima (2013). Western Amazonia (lowlands): Duque & Núñez-Avellaneda (2000); Núñez-Avellaneda (2008); Díaz-Olarte & Duque (2009).

DESCRIPTION
Cells 21.0-31.3 µm long, 21.0-22.0 µm wide; cells 1.0-1.2 times longer than wide. Mostly quadrangular cells, some nearly rectangular, median constriction slightly marked, apical margin slightly depressed; lateral margin parallel to sometimes undulating near isthmus; semicells joined by cylindrical processes.

Desmidium grevillei (Kütz. ex Ralfs) De Bary
(Fig. 3B)

Untersuchungen über die Familie der Conjugaten (Zygnemeen und Desmidieen) Ein Beitrag zur physiologischen und beschreibenden Botanik: 76 (De Bary 1858). — *Didymoprium grevillei* Kützing ex Ralfs, *The British Desmidieae*: 57 (Ralfs 1848).

DISTRIBUTION. — Cosmopolitan. Amazon Basin: Feitosa *et al.* (2015). As *D. grevillii*: Scott *et al.* (1965); Förster (1969); Thomasson (1971); Melo *et al.* (2005); Melo & Souza de (2009); Cadima (2013); Cunha de *et al.* (2013). Western Amazonia (lowlands): Araujo (2003).

DESCRIPTION
Cells 22.6-26.1 µm long, 41.1-51.0 µm wide, isthmus 37.1-47.0 µm; cells 1.8-1.9 times wider than long.

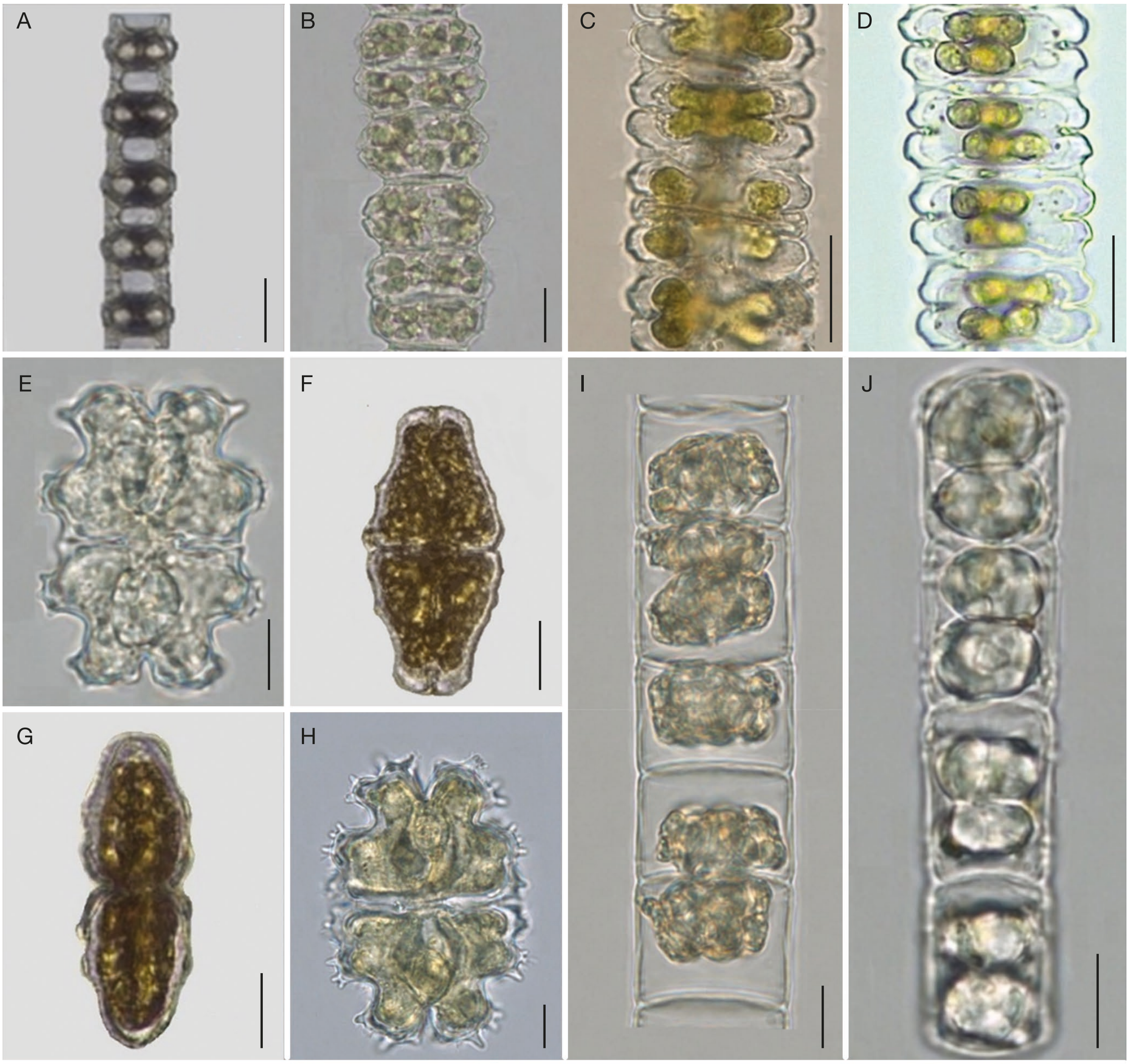

Fig. 3. — *Desmidium* C.Agardh ex Ralfs, *Euastrum* Ehrenb. ex Ralfs, and *Hyalotheca* Ehrenb. ex Ralfs. **A**, *Desmidium baileyi* (Ralfs) ex Nordst.; **B**, *Desmidium grevillei* (Kütz. ex Ralfs) De Bary; **C**, **D**, *Desmidium swartzii* C.Agardh ex Ralfs; **E**, *Euastrum abruptum* Nordst.; **F**, **G**, *Euastrum brasiliense* var. *convergens* Willi Krieg.; **H**, *Euastrum evolutum* var. *perornatum* A.M. Scott et Croasdale; **I**, *Hyalotheca dissiliens* Bréb. ex Ralfs; **J**, *Hyalotheca mucosa* Ralfs. Scale bars: A-C, F, G, 20 µm; D, E, H-J, 10 µm.

Pseudofilaments not twisted, cells slightly constricted, apices flat, so there is no cavity between adjacent cells; hyaline cell wall. Median constriction shallow, with a linear or slightly open sinus. Semicells very short, from quadrangular to pyramid truncate outline, lateral margins slightly wavy. Axial chloroplast.

Remarks

Our specimens are similar in size range and shape as those reported from Brazil (Aquino *et al.* 2018) and the British Islands (Brook & Johnson 2002). Similar taxa in shape and size include *Desmidium cylindricum* Greville ex Nordstedt, but this species has spiral pseudofilaments (Burliga *et al.* 2016) while those of *D. grevillei* were not twisted.

Desmidium swartzii C.Agardh ex Ralfs (Fig. 3C, D)

The British Desmidieae: 61 (Ralfs 1848). — *Diatoma swartzii* C.Agardh, *Dispositio algarum Sueciae, quam publico examini subjiciunt Carl Adolph Agardh & Elias Magnus Fries, Smolandus*: 34 (Agardh 1812).

Distribution. — Cosmopolitan. Amazon Basin: Grönblad (1945); Förster (1969); Thomasson (1971); Cunha de *et al.* (2013). Western Amazonia (lowlands): Ortega *et al.* (2007).

Description

Cells 16.0-20.8 µm long, 31.3-33.9 µm wide; cells 1.6-1.9 times wider than long. Pseudofilament triangular, with a single, wavy, dark, longitudinal stripe, formed by the third angle; joints somewhat quadrangular, wider than long, with two slightly angular crenulations on each lateral margin.

Genus *Euastrum* Ehrenberg ex Ralfs

Euastrum abruptum Nordst. (Fig. 3E)

Videnskabelige meddelelser fra Dansk naturhistorisk forening i Københaven 21 (14-15): 217 (Nordstedt 1870).

Euastrum subglaziovii Borge, *Öfversigt af Kongliga Vetenskaps-Akademiens Förhandlingar* 56 (7): 25 (Borge 1899).

Distribution. — Cosmopolitan. Amazon Basin: Thomasson (1977); Lopes & Bicudo (2003); Melo & Souza de (2009); Cadima (2013); Feitosa *et al.* (2015). Western Amazonia (lowlands): Araujo (2003); Díaz-Olarte & Duque (2009).

Description

Cells 44.7-46.1 µm long, 28.0-33.0 µm wide, isthmus 7.4-8.6 µm, apex 28.0 µm; cells 1.3-1.6 times longer than wide. Cells with an open median sinus in the distal portion. Semicells sub trapeziform, three-lobed, ornamented with submarginal spines and granules, each basal lobe with one median protrusion with three large tubercular granules, basal corners with one marginal spine. Apical lobe truncated, with a deep medium incision. Axial chloroplast.

Remarks

Specimens from the Ecuadorian Amazon coincided with the description given by Prescott *et al.* (1977) and with populations for the Brazilian Amazon by Lopes & Bicudo (2003), Mato Grosso State in Brazil (Camargo *et al.* 2009), and for the Upper Parana River (Moresco *et al.* 2015). However, specimens from Moresco *et al.* (2015) are slightly wider than ours. Other similar varieties, such as *Euastrum abruptum* var. *subglaziowii*, described in Krieger (1937) and Prescott *et al.* (1977), and also recorded by Moresco *et al.* (2015) for Brazil, can be separated apart from the type variety by its size proportions (smaller cells) and ornamental characters (no large granules on lateral protrusions of basal lobes).

Euastrum brasiliense var. ***convergens*** Willi Krieg.* (Fig. 3F, G)

Die Desmidiaceen Europas mit Berücksichtigung der aussereuropäischen Arten. (Dr. Rabenhorst's Kryptogamen-Flora von Deutschland, Österreich und der Schweiz: 13). Vol. 1: 484 (Krieger 1937).

Distribution. — Cosmopolitan. Amazon Basin: Thomasson (1971). Western Amazonia (lowlands): no records.

Description

Cells 85.1-92.5 µm long, 40.8-41.0 µm wide, isthmus 12.4-13.2 µm; cells 2.1-2.3 times longer than wide. Cells with a deep median constriction, punctuated cell wall, closed sinus; trapezoidal semicells; basal lobes slightly rounded, lateral margins with one slight protuberance in the midway between the base and the apex of the cell; truncated to rounded apical lobe with a median notch relatively narrow, closed in each semicell apex.

Remarks

Our specimens corresponded well in morphology with those described in Thomasson (1971) for the Brazilian Amazon. As Oliveira de *et al.* (2011a) mentioned, the specimens used by Krieger (1937) to describe the variety are larger than their specimens, which coincides with what was found in the present study.

Euastrum evolutum var. ***perornatum***
A.M.Scott & Croasdale
(Fig. 3H)

Acta Botanica Fennica 69: 32 (Scott *et al.* 1965).

Distribution. — Brazil. Amazon Basin: Scott *et al.* (1965); Förster (1969); Thomasson (1971, 1977); Uherkovich (1976); Martins (1986b); Melo *et al.* (2005, 2009); Cadima (2013). Western Amazonia (lowlands): Araujo (2003).

Description

Cells 65.3-67.9 µm long, 41.6-43.7 µm wide, isthmus 10.2-12.0 µm, apex 30.9-32.0 µm; cells 1.5-1.6 times longer than wide. Cells with a deep median constriction, almost completely enclosed, slightly open at the ends. Trapezoidal semicell, robust, three-lobed, interlobar deep incisions, U-shaped open; lateral and polar lobes with deep recesses in the apex; polar lobe with a deep sinus, V-shaped; apical angles with one to three spines, polar lobes narrower than basal lobes; cell wall hyaline, intramarginal granules, semicellular face with median protrusion formed by four to five granules surrounding one central granule.

Genus *Hyalotheca* Ehrenberg ex Ralfs

Hyalotheca dissiliens Bréb. ex Ralfs
(Fig. 3I)

The British Desmidieae: 51 (Ralfs 1848).

Conferva dissiliens Dillwyn, *British Confervae*: pl. 63 (Dillwyn 1806). — *Hyalotheca dissiliens* var. *tridentula* Nordstedt, *Lunds Universitets Årsskrift* 9 (Afh. II, 10): 48 (Nordstedt 1873). — *Hyalotheca dissiliens* var. *quadridentula* Nordstedt, *Hedwigia* 15:

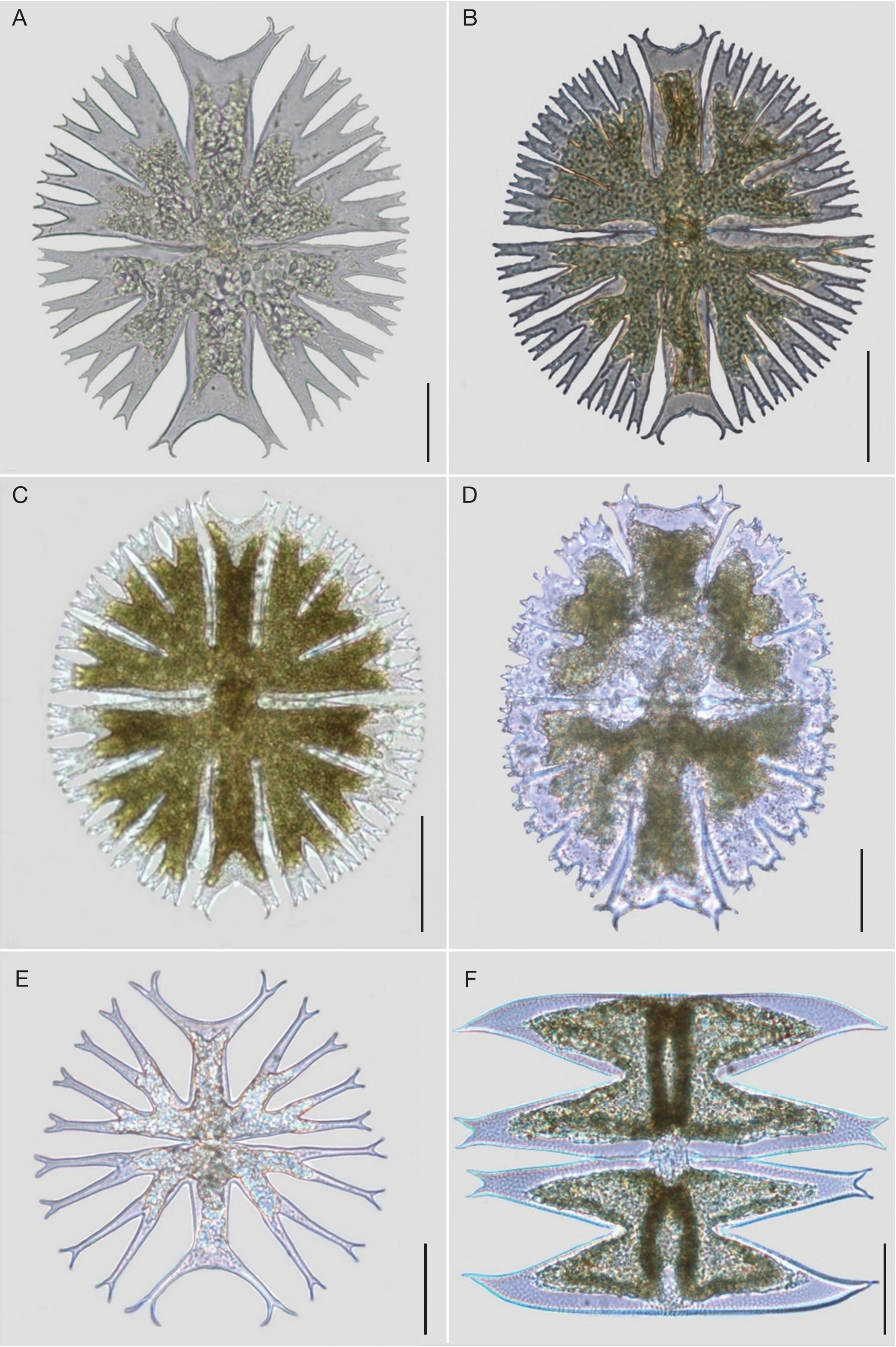

Fig. 4. — *Micrasterias* C. Agardh ex Ralfs. **A**, *Micrasterias borgei* var. *aequalis* Willi Krieg.; **B**, **C**, *Micrasterias borgei* var. *borgei* Willi Krieg.; **D**, *Micrasterias fimbriata* var. *spinosa* Biss.; **E**, *Micrasterias furcata* var. *dichotoma* (Wolle) Růžička; **F**, *Micrasterias laticeps* Nordst. Scale bars: 50 µm.

12 (Nordstedt (1876). — *Hyalotheca dissiliens* var. *bidentula* (Nordstedt) H.C.Boldt, *Bihang til Kongliga Svenska Vetenskaps-Akademiens Handlingar* 13 (Afd. III, 5): 43 (Boldt 1888).

Distribution. — Cosmopolitan. Amazon Basin: Grönblad (1945); Scott *et al.* (1965); Förster (1969); Uherkovich & Schmidt (1974); Uherkovich (1976, 1981); Thomasson (1977); Uherkovich &

Rai (1979); Gutiérrez & Cadima (2004); Melo *et al.* (2005); Souza de *et al.* (2007); Melo & Souza de (2009); Souza de & Melo (2010); Cadima (2013); Cunha de *et al.* (2013); Araújo *et al.* (2020). Western Amazonia (lowlands): Duque & Núñez-Avellaneda (2000); Núñez-Avellaneda (2008); Díaz-Olarte & Duque (2009); Ismiño *et al.* (2014, 2018).

Description

Cells 16.6-17.3 µm long, 24.9-27.8 µm wide, isthmus 21.6 µm, cells 1.5 times longer than wide. Cells with shallow median constriction, median sinus open; cell wall hyaline and smooth; apical view circular. Semicells rectangular, with rounded angles and lateral margins straight.

Hyalotheca mucosa Ralfs
(Fig. 3J)

The British Desmidieae: 53 (Ralfs 1848).

Hyalotheca ralfsii Kützing, *Species algarum*: 187 (Kützing 1849).

Distribution. — Cosmopolitan. Amazon Basin: Grönblad (1945); Förster (1969, 1974); Thomasson (1971); Martins (1980); Cadima (2013); Cunha de *et al.* (2013). Western Amazonia (lowlands): Duque & Núñez-Avellaneda (2000); Núñez-Avellaneda (2008).

Description

Cells 15.4-27.4 µm long, 14.0-14.9 µm wide; cells 1.3-1.8 times longer than wide. Cells cylindrical, quadrangular to rectangular in outline, without median constriction. Cell wall hyaline; ornamented below the apex with a double range of granules. Lateral margins smooth, parallel to each other, apical margin slightly rounded.

Genus *Micrasterias* C.Agardh ex Ralfs

Micrasterias borgei var. ***aequalis*** Willi Krieg.
(Fig. 4A)

Die Desmidiaceen Europas mit Berücksichtigung der aussereuropäischen Arten. (Dr. Rabenhorst's Kryptogamen-Flora von Deutschland, Österreich und der Schweiz: 13). Vol. 2: 86 (Krieger 1939).

Distribution. — South America. Amazon Basin: Martins (1986b). Western Amazonia (lowlands): Araujo (2003).

Description

Cells 172.7-217.0 µm long, 159.1-193.0 µm wide, isthmus 25.0-31.7 µm; apex 52.0-53.0; cells 1.1 times longer than wide. Cells subcircular in outline, deep median constriction; five-lobed semicells with acute, angular incisions. Hyaline cell wall. Semicells with spines located along the margins of the median sinus and on the margins of lateral and basal lobes and lobules. Polar lobe protruding from the lateral lobes, polar lobes opening gradually towards apex, protruding angles, two-denticulated, curved, divergent; lateral lobes of approximately equal size, each divided into two lobes by a deep incision, each subdivided by three incisions in four parts, with two denticles.

Remarks

This variety is distinguished from the type variety by the similar development of their lateral and basal lobes, in which both show divisions up to third order lobules. Instead, *M. borgei* var. *borgei* show differences between the lateral and basal lobes, with the former developing up to fourth order lobules (Bicudo & Sormus 1982). Compared with *Micrasterias sanctipaulensis* C.E.M.Bicudo & L.Sormus, *M. borgei* var. *aequalis* is larger in size and has spines on the cell wall while the first has a glabrous cell wall (Bicudo & Sormus 1982).

Micrasterias borgei var. ***borgei*** Willi Krieg.
(Fig. 4B, C)

Die Desmidiaceen Europas mit Berücksichtigung der aussereuropäischen Arten. (Dr. Rabenhorst's Kryptogamen-Flora von Deutschland, Österreich und der Schweiz: 13). Vol. 2: 86 (Krieger 1939).

Distribution. — South America and China. Amazon Basin: Grönblad (1945); Scott *et al.* (1965); Förster (1969, 1974); Thomasson (1971); Uherkovich & Rai (1979); Melo *et al.* (2005); Souza de *et al.* (2007); Melo & Souza de (2009); Melo *et al.* (2009); Cadima (2013); Cunha de *et al.* (2013); Feitosa *et al.* (2015). Western Amazonia (lowlands): Krieger & Scott (1957); Araujo (2003); Ortega *et al.* (2007).

Description

Cells 264.1-278.0 µm long, 235.0-243.5 µm wide, isthmus 32.0-38.2 µm, apex 53.5-58.5 µm; cells 1.1 times longer than wide. Cells with deep median constriction, central sinus closed, slightly open at ends; cell wall finely punctuated, with a number of spines in the middle of the basal part of the semicells, just above the isthmus, with a row of intramarginal spines along the median sinus, others on each side to the left along the deepest incisions. Semicells five-lobed, robust; polar lobe with a deep sinus, a little more than half its length; incisions between lateral lobes open and deep, U- or V-shaped; lateral lobes with consecutive bifurcations to apex, slightly curved denticles, apex divided into two divergent two-denticulated lobules, central denticles slightly oriented towards the sinus; polar lobe larger and more robust than lateral lobes.

Micrasterias fimbriata var. ***spinosa*** Biss.**
(Fig. 4D)

Annals of Scottish Natural History 1893 (7): 173 (Roy 1893). — *Micrasterias apiculata* f. *spinosa* (Bisset) West & G. S. West, *A monograph of the British Desmidiaceae*. II: 100 (West & West 1905).

Distribution. — Cosmopolitan. Amazon Basin: no records. Western Amazon: no records.

Description

Cells 256.0-259.5 µm long, 194.1-196.1 µm wide; isthmus 33.1-36.4 µm; apex: 70.0-79.5 µm; cells 1.3 times longer than wide. Cell wall with small denticles, especially along the main incisions, but their arrangement is not always regular.

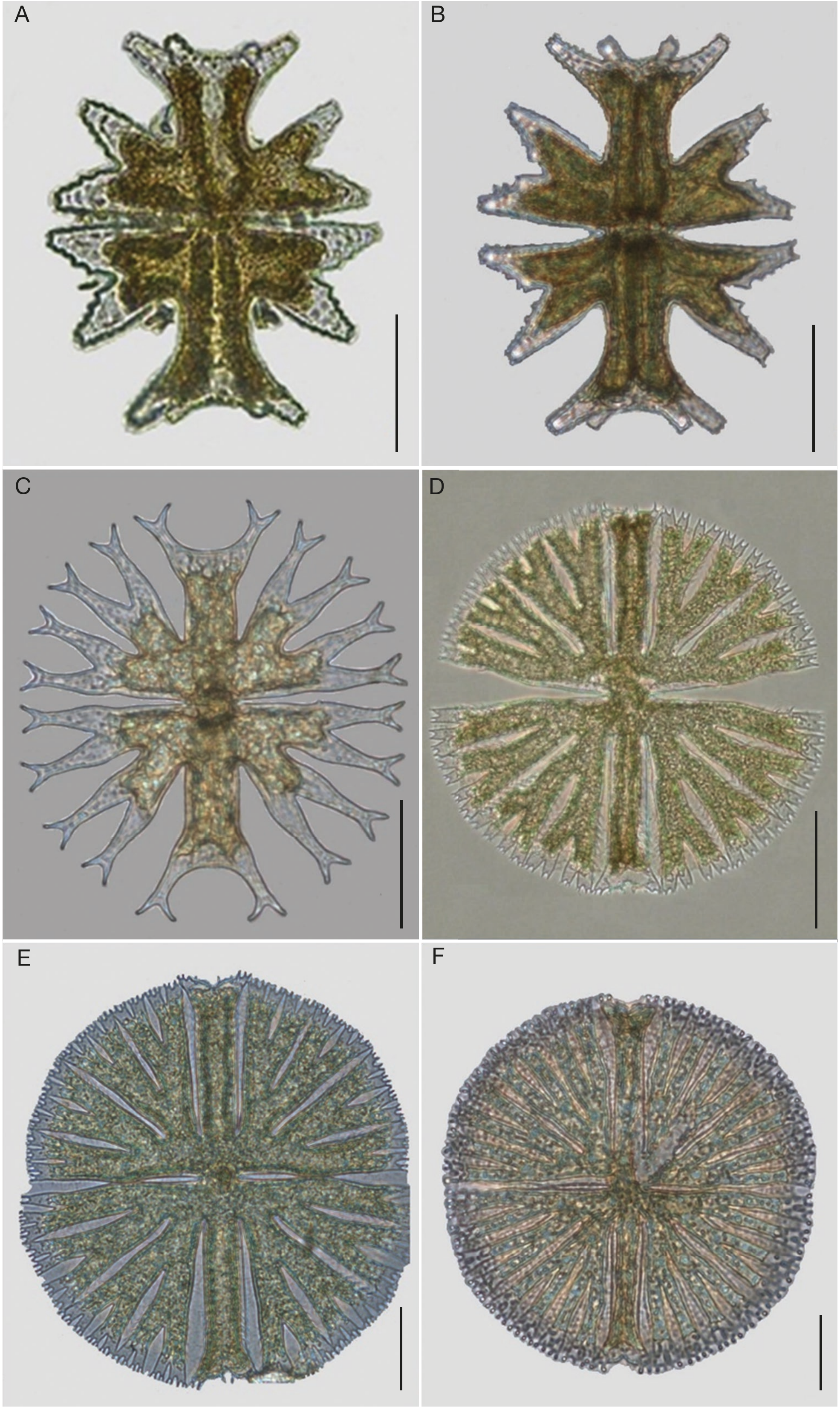

Fig. 5. — *Micrasterias* C.Agardh ex Ralfs: **A**, **B**, *Micrasterias mahabuleshwarensis* var. *amazonensis* Kurt Först.; **C**, *Micrasterias radians* var. *brasiliensis* (Grönblad) Willi Krieg. ex Coesel & Geest; **D**, **E**, *Micrasterias radiosa* var. *elegantior* (G.S. West) Croasdale; **F**, *Micrasterias radiosa* var. *radiosa* Ralfs. Scale bars: 50 µm.

The polar lobe has two two-denticulated marginal apices, which are curved and longer and thinner than the denticles on the lateral lobes; there are two subapical spines on each apical lobule. The terminations of the lateral lobes are truncated, rounded, with the presence of two robust and short denticles, accompanied by at least two shorter and less robust ones. At the concave apical margin of the polar lobes, the cell wall presents a clearly visible fringe of granules.

REMARKS

Recent works by Neustupa *et al.* (2011, 2014) resolved the species delimitation between *Micrasterias fimbriata* Ralfs, *M. rotata* Ralfs, *M. brachyptera* Lundell, and *M. apiculata* Meneghini ex Ralfs using geometric morphometrics, and genetic analyses. Neustupa *et al.* (2011) found two phylogenetic lineages for *M. fimbriata*, one geographically centred in eastern Europe and the British Isles (B-lineage), and one found in North America and western Europe (A-lineage). Our specimens coincided with the B-lineage of *M. fimbriata*. Posteriorly, Neustupa *et al.* (2014) described *M. compereana* to accomodate specimens formerly included within traditional *M. fimbriata* but with different phylogenetic position and morphological features. According to those authors, *M. fimbriata* sensu stricto most likely is restricted to temperate and boreal regions of Europe and Asia. As mentioned in Neustupa *et al.* (2011, 2014) the shape of the terminal lobes is key to identify *M. fimbriata*, and our specimens clearly present truncated lobes with spines, while surface spine layers on cells can be found in *M. fimbriata* var. *spinosa* as well as in *M. compereana*, so, that last character is not exclusive for *M. fimbriata* var. *spinosa*. Our specimens of *M. fimbriata* var. *spinosa* are morphologically similar to the drawings of the original description in Roy (1893) but ours are larger in longitude and shorter in breadth, having an elliptic contour instead of being circular.

Micrasterias furcata var. ***dichotoma*** (Wolle) Růžička**

(Fig. 4E)

Die Desmidiaceen Mitteleuropas 1 (2): 383 (Růžička 1981). — *Micrasterias dichotoma* Wolle, *Bulletin of the Torrey Botanical Club* 11: 14 (Wolle 1884a). — *Micrasterias radiata* var. *dichotoma* (Wolle) J. A. Cushman, *Rhodora* 10 (114): 108 (Cushman 1908).

DISTRIBUTION. — Europe, North and South America. Amazon Basin: no records. Western Amazonia (lowlands): no records.

DESCRIPTION

Cells 181.5-194.2 µm long, 184.0-192.5 µm wide, isthmus 19.7-22.1 µm, apex 70-83.2 µm; cells are as long as wide. Cells with a deep median constriction, median sinus open with acute angles; finely punctuated cell wall. Semicircular semicells, five-lobed, apical lobe slender, and narrowing towards the apex; apical margin slightly concave in the middle region, ends forming two processes elongated, divergent, two-denticulated; lateral and basal lobes forming approximately V-shape incisions; lateral lobes slender, similar to each other, divided into two-denticulated lobules.

REMARKS

Compared with the type variety, this taxon is larger in size, more circular in shape, polar and lateral lobes are slender, incisions among lobes are deeper, polar lobe with concavity more open, but not as open as in *M. radiata* var. *dichotoma* presented in Krieger (1939). Our measurements coincided with those shown by Krieger (1939) yet bigger than those shown in Santos *et al.* (2016).

Micrasterias laticeps Nordst.

(Fig. 4F)

Videnskabelige Meddelelser Dansk Naturhistorisk Forening 1870: 220 (Nordstedt 1870).

Tetrachastrum americanum W. Archer, *A history of infusoria, including the Desmidiaceae and Diatomaceae, British and foreign*: 725 (Pritchard 1861). — *Micrasterias disputata* H. C. Wood, *Smithsonian Contributions to Knowledge* 19 (241): 142 (Wood 1873).

DISTRIBUTION. — Cosmopolitan. Amazon Basin: Grönblad (1945); Thomasson (1971); Lopes & Bicudo (2003); Melo *et al.* (2005); Cadima (2013); Cunha de *et al.* (2013). Western Amazonia (lowlands): Krieger & Scott (1957); Montoya (1974); Duque & Donato (1993); Duque & Núñez-Avellaneda (1997); Araujo (2003); Duque & Núñez-Avellaneda (2000); Ortega *et al.* (2007); Núñez-Avellaneda (2008); Díaz-Olarte & Duque (2009).

DESCRIPTION

Cells 124.0-150.6 µm long, 162.0-197.1 µm wide, isthmus 40.1-44.5 µm; cells 1.3 times wider than long. Cells with a deep median constriction, central sinus closed near the isthmus and then opened; punctuated and hyaline cell wall. Semiorbicular semicell, three-lobed; interlobular incisions opened and deep, V-shaped; apices of the lateral and polar lobes facing to the opening of the sinus, polar lobes bigger than the lateral lobes, angles of the polar lobe acuminated and lateral lobes two-denticulated.

REMARKS

Although Bicudo & Sormus (1972) and Santos *et al.* (2016) mentioned that this taxon is highly polymorphic, especially in the curvature of the polar lobe and the opening of the interlobular incisions, specimens in our populations showed a conservative form.

Micrasterias mahabuleshwarensis
var. ***amazonensis*** Kurt Först.

(Fig. 5A, B)

Amazoniana 2 (1/2): 40 (Förster 1969).

DISTRIBUTION. — Brazil (Lopes & Bicudo 2003), Venezuela (Delgado *et al.* 2003). Amazon Basin: Förster (1969); Uherkovich (1981); Martins (1986b); Lopes & Bicudo (2003), Melo *et al.* (2009). Western Amazonia (lowlands): Díaz-Olarte & Duque (2009).

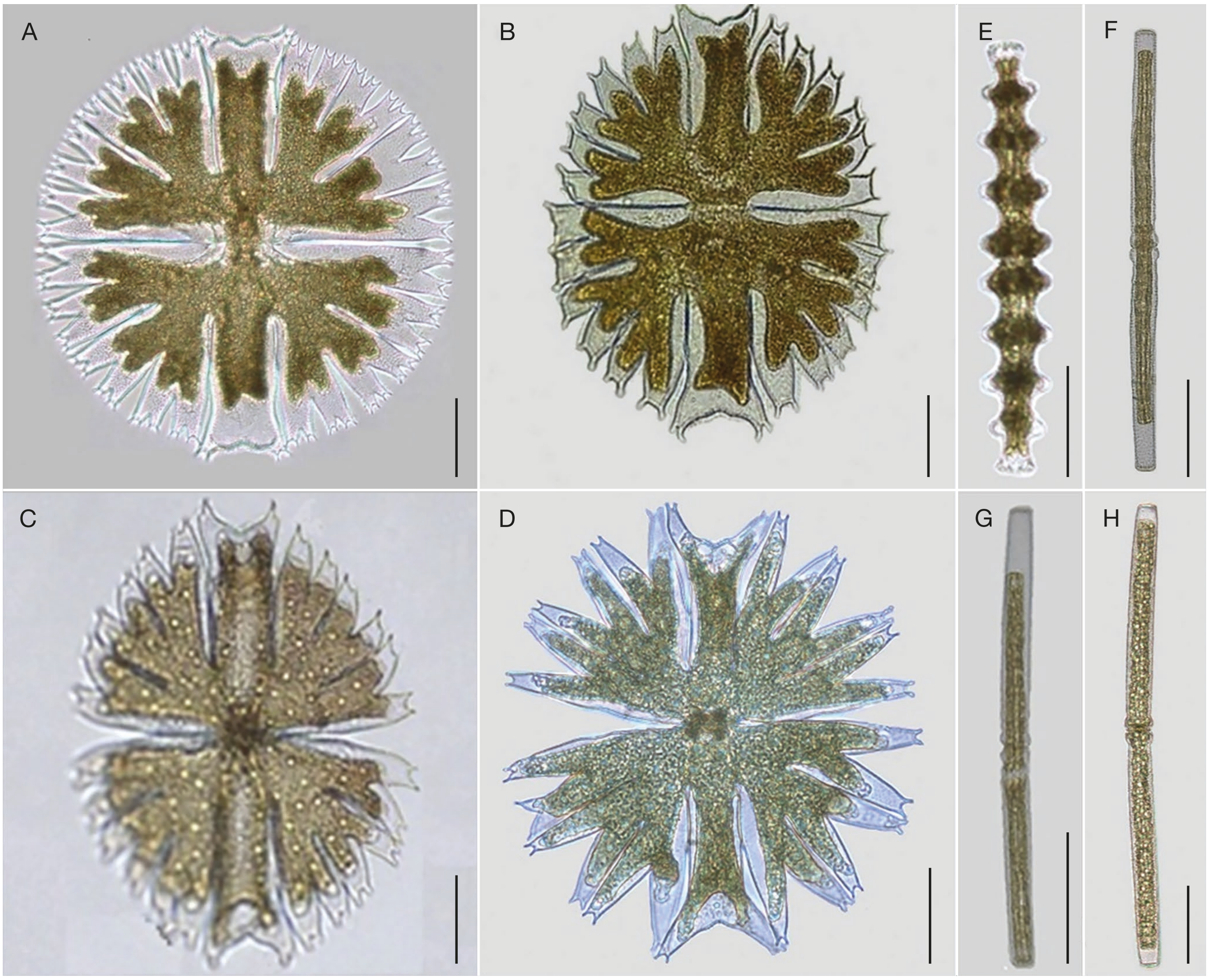

Fig. 6. — *Micrasterias* C.Agardh ex Ralfs, and *Pleurotaenium* Nägeli: **A**, *Micrasterias rotata* Ralfs; **B**, **C**, *Micrasterias torreyi* var. *curvata* Willi Krieg.; **D**, *Micrasterias torreyi* var. *nordstedtiana* (Hieron.) Schmidle; **E**, *Pleurotaenium nodosum* (Bailey ex Ralfs) P. Lundell; **F**-**H**, *Pleurotaenium trabecula* Nägeli. Scale bars: A, 60 µm; B-E, G, 50 µm; F, H, 100 µm.

Description

Cells 137.0-153.7 µm long, 116.9-161.7 µm wide, isthmus 25.8-30.0 µm, apex 67.2 µm. Cell wall with serrated margins; presence of intramarginal spines throughout the cell. Semielliptical semicells, five-lobed, deep incisions; polar lobe sharply projecting beyond the lateral lobes.

Micrasterias radians var. ***brasiliensis*** (Grönblad) Willi Krieg. ex Coesel & van Geest* (Fig. 5C)

Plant Ecology and Evolution 147 (3): 400 (Coesel & van Geest 2014). — *Micrasterias radiata* var. *brasiliensis* Grönblad, *Acta Societatis Scienctiarum Fennicae*, *Nova Series B,* 2 (6): 15 (Grönblad 1945).

Distribution. — Pantropical. Amazon Basin: Thomasson (1971). As *M. radiata* var. *brasiliensis*: Grönblad (1945); Förster (1969); Uherkovich & Schmidt (1974); Uherkovich (1976, 1981); Uherkovich & Rai (1979); Gutiérrez & Cadima (2004); Melo *et al.* (2009). As *M. furcata*: Cadima (2013). Western Amazonia (lowlands): no records.

Description

Cells 146.0-160.4 µm long, 131.0-151.1 µm wide, isthmus 18.2-20.1 µm, apex 54.7-56.6 µm; cells are 1.1 times longer than wide. Cells with deep median constriction, median sinus open with acute angles, cell wall finely punctate. Semicircular semicells, five-lobed, apical lobe about subrectangular, apical margin concave, tips forming two elongated, divergent processes, with two curved teeth; lateral and basal lobes about V-shaped, similar to each other, divided into two-tooth lobules. One remarkable characteristic of all second order lobules, is that they are widened at their base, slightly tapering towards their apices, where they are divided into two curved teeth.

REMARKS

This taxon has been subjected to a long taxonomic confusion wandering continuously between *M. radiata* Hassall ex West & G.S.West*, M. radians* W.B. Turner, *M. furcata* C.Agardh ex Ralfs, and their varieties. Coesel & van Geest (2014) finally provided a valid positioning of the taxon into *M. radians* var. *brasiliensis*, providing an insightful discussion on the gradual differences among varieties of the *Micrasterias radians* complex. In our specimens, the apical lobes protrude slightly, while in Coesel & van Geest (2014) those lobes are markedly outstanding; also, teeth on apical lobules are longer than those observed in our specimens, although all other morphological characteristics and size range shown by these authors were very similar to our specimens. From the specimens in our samples, we can add that all second order lobules show a continuous tapering from their base towards the point where they diverge into teeth, which is also observed in Coesel & van Geest (2014) for the same taxon, in Blanco & Sánchez (1986) for *M. radiata* var. *brasiliensis*, and in Bourrelly & Couté (1982) for *M. radiata* var. *radiata*.

Micrasterias radiosa var. ***elegantior*** (G.S.West) Croasdale (Fig. 5D, E)

A synopsis of North American desmids Part II. Desmidiaceae: Placodermae, Section 2: 181 (Prescott *et al.* 1977). — *Micrasterias sol* var. *elegantior* G. S. West, *Mémoires de la Société des Sciences Naturelles de Neuchâtel* 5 (2): 1035 (West 1914). — *Micrasterias radiosa* f. *elegantior* (G. S. West) G. M. Smith, *Bulletin of the Wisconsin Geological and Natural History Survey* 57 (2): 164 (Smith 1924).

Micrasterias radiosa var. *ornata* Nordstedt, *Videnskabelige meddelelser fra Dansk naturhistorisk forening i København* 21 (14-15): 223 (Nordstedt 1870). — *Micrasterias radiosa* f. *ornata* (Nordstedt) Kurt Förster, *Algological Studies/Archiv für Hydrobiologie*, Supplement 28: 246 (Förster 1981).

DISTRIBUTION. — Cosmopolitan. Amazon Basin: Thérézien (1986); Cadima (2013). As *M. radiosa* var. *ornata* f. *elegantior*: Förster (1969). As *M. radiosa* var. *ornata* f. *ornata*: Martins (1986b). Western Amazonia (lowlands): Duque & Núñez-Avellaneda (2000) and Núñez-Avellaneda (2008) as *M. radiosa* var. *ornata* f. *ornata.*

DESCRIPTION

Cells 251.8-262.0 µm long, 238.1-265.1 µm wide; isthmus 23.6-28.0 µm; apex: 41.0-43.0 µm; cells 1.15 times longer than wide. Cells with a deep median constriction, semiopen median sinus; ornamented cell wall with intramarginal denticles arranged along half of the basal margins of each semicell. Semicircular semicells, five-lobed, apical lobe subrectangular, elongated, apical margin chamfered in median region, extremities two-denticulated, lateral and basal lobes elongated, V-shaped, similar to each other, divided into lobes two-denticulated.

Micrasterias radiosa var. ***radiosa*** Ralfs* (Fig. 5F)

The British Desmidieae: 72 (Ralfs 1848).

Micrasterias sol Ehrenberg ex Kützing, *Species algarum*: 171 (Kützing 1849).

DISTRIBUTION. — Cosmopolitan. Amazon Basin: Förster (1969); Lopes & Bicudo (2003); Gutiérrez & Cadima (2004); Cadima (2013); Cunha de *et al.* (2013). Western Amazonia (lowlands): no records.

DESCRIPTION

Cells 159.0-162.2 µm long, 157.3-158.0 µm wide, isthmus 15.2-18.3 µm, apex 42.3 µm; cells as long as they are wide. Cells with a deep median constriction, central sinus almost entirely closed, opening only at the ends. Semicircular semicell, five-lobed; polar lobe with linear incision until near of the isthmus; slightly open and deep between the polar lobes; lateral lobes with consecutive bifurcations; polar lobe with V-shaped sinus, apex divided into two divergent lobules two-denticulated, polar lobe with the same size as the lateral lobes. Very deep lobular incisions between polar lobes and lateral lobes, and between lateral lobes and basal lobes.

REMARKS

Specimens analyzed here are morphologically consistent with the descriptions, drawings, and pictures shown by Förster (1969) and Lopes & Bicudo (2003) for the Amazon, Bicudo & Sormus (1982) for São Paulo, and Santos *et al.* (2016) for Bahia in Brazil.

Micrasterias rotata Ralfs (Fig. 6A)

The British Desmidieae: 71 (Ralfs 1848).

Eutomia rotata (Greville) Harvey, *A manual of the British algae*: 187 (Harvey 1841). — *Micrasterias rotata* f. *granulata* West, *Journal of the Linnean Society of London*, *Botany* 29: 134 (West 1892). — *Micrasterias rotata f. evoluta* W. B. Turner, *Kungliga Svenska Vetenskaps-Akademiens Handlingar* 25 (5): 167 (Turner 1893). — *Micrasterias rotata* var. *evoluta* (W. B. Turner) Willi Krieger, *Die Desmidiaceen Europas mit Berücksichtigung der aussereuropäischen Arten. (Dr. Rabenhorst's Kryptogamen-Flora von Deutschland, Österreich und der Schweiz*: 13). Vol. 2: 102 (Krieger 1939).

DISTRIBUTION. — Cosmopolitan. Amazon Basin: Grönblad (1945); Thomasson (1971); Uherkovich (1976, 1981); Martins (1986b), Lopes & Bicudo (2003); Melo *et al.* (2005, 2009); Cunha de *et al.* (2013); Feitosa *et al.* (2015). Western Amazonia (lowlands): Duque & Donato (1993); Duque & Núñez-Avellaneda (2000); Núñez-Avellaneda (2008).

DESCRIPTION

Cells 323.8-329.5 µm long, 313.6-321.7 µm wide; isthmus 44.2-44.5 µm; apex: 65.0-71.8 µm; cells are as long as they are wide. Large cells with circular outline, deep median constriction; hyaline cell wall, finely punctuated. Semicells five-lobed, apical lobe projecting slightly beyond the lateral lobes, apical lobe angles laterally projecting, two-denticulated; lateral, and basal lobes in a "V" shape, similar between them.

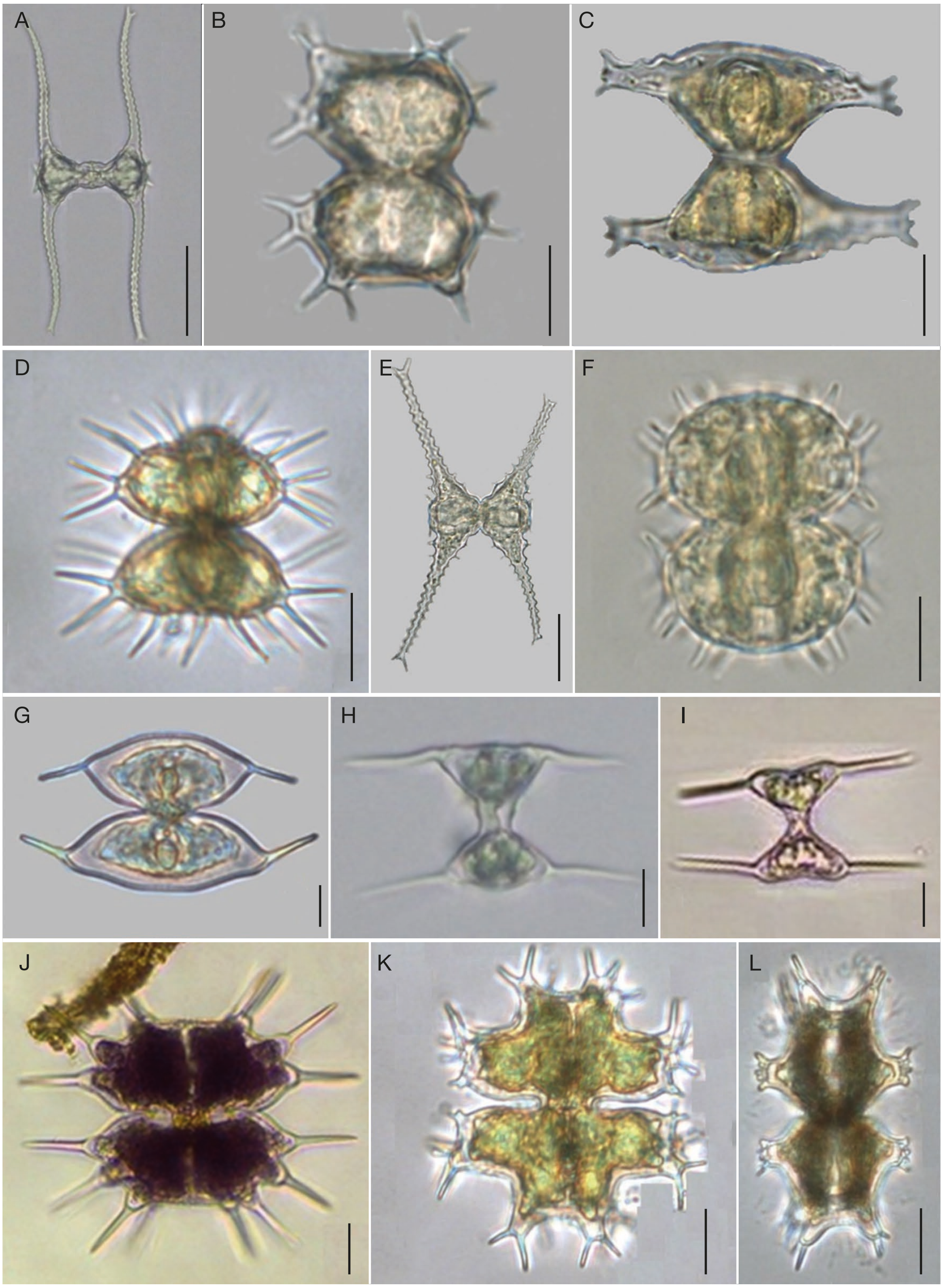

Fig. 7. — *Staurastrum* Meyen ex Ralfs, *Staurodesmus* Teiling, and *Xanthidium* Ehrenb. ex Ralfs: **A**, *Staurastrum leptocladum* var. *cornutum* Wille; **B**, *Staurastrum octangulare* Grönblad; **C**, *Staurastrum pinnatum* var. *reductum* Willi Krieg; **D**, *Staurastrum setigerum* var. *subvillosum* Grönblad; **E**, *Staurastrum tectum* var. *ayayense* Grönblad; **F**, *Staurastrum teliferum* var. *pecten* (Wolle) Grönblad; **G**, *Staurodesmus convergens* (Ehrenb. ex Ralfs) S. Lill.; **H**, **I**, *Staurodesmus triangularis* (Langerh.) Teiling; **J**, *Xanthidium mamillosum* var. *mediolaeve* (Grönblad) Couté & Tell; **K**, **L**, *Xanthidium trilobum* Nordst. Scale bars: A, D, E, G, J-L, 20 µm; B, C, F, H-I, 10 µm.

Micrasterias torreyi var. ***curvata*** Willi Krieg.
(Fig. 6B, C)

Die Desmidiaceen Europas mit Berücksichtigung der aussereuropäischen Arten. (Dr. Rabenhorst's Kryptogamen-Flora von Deutschland, Österreich und der Schweiz: 13). Vol. 2: 98 (Krieger 1939). — *Micrasterias doveri* var. *curvata* (Willi Krieger) Thomasson, *Nova Hedwigia* 42 (2-4): 342 (Thomasson 1986).

Distribution. — Cosmopolitan. Amazon Basin: Grönblad (1945); Förster (1969); Uherkovich & Rai (1979), Melo & Souza de (2009); Melo *et al.* (2009), Cadima (2013). Western Amazonia (lowlands): Araujo (2003).

Description

Cells 272.0-281.4 µm long, 204.6-209.5 µm wide; isthmus 31.8-39.0 µm; cells 1.3-1.4 times longer than wide. Semicells with semicircular outline, five- lobed, deep interlobar incisions, basal and lateral lobes divided into lobules, two- denticulated. Lateral lobes bent upwards, terminal spines unequal, the upper longer. Also, the two spines of the polar lobes distinct, the inner ones longer and curved inwards.

Micrasterias torreyi var. ***nordstedtiana*** (Hieron.) Schmidle
(Fig. 6D)

Botanische Jahrbücher für Systematik Pflanzengeschichte und Pflanzengeographie 26: 48 (Schmidle 1898).

Micrasterias hieronymusii Schmidle, *Botanische Jahrbücher für Systematik Pflanzengeschichte und Pflanzengeographie* 26: 49 (Schmidle 1898).

Distribution. — South America. Amazon Basin: Grönblad (1945); Scott *et al.* (1965); Thomasson (1971); Martins (1986b); Lopes & Bicudo (2003), Cadima (2013). Western Amazonia (lowlands): Araujo (2003).

Description

Cells 235.9-254.7 µm long, 222.0-233.0 µm wide; isthmus 30.2 µm, apex: 64.0 µm; cells 1.1 times longer than wide. Semicircular semicells, five-lobed, deep interlobar incisions, semiopen, finely punctuated cell wall. All lateral lobules of last order (there are five or six on each side) two-pointed; the lateral lobes are inflated in the inner margins, partially covering each other; polar lobes also two-pointed.

Genus *Pleurotaenium* Nägeli

Pleurotaenium nodosum (Bailey ex Ralfs) P.Lundell
(Fig. 6E)

Nova Acta Regiae Societatis Scientiarum Upsaliensis, serie 3, 8 (2): 90 (Lundell 1871). — *Docidium nodosum* Bailey ex Ralfs, *The British Desmidieae*: 218 (Ralfs 1848).

Distribution. — Cosmopolitan. Amazon Basin: Grönblad (1945); Gutiérrez & Cadima (2004); Cadima (2013). Western Amazonia (lowlands): Montoya (1974).

Description

Cells 400.0-427.3 µm long, 66.0-68.5 µm wide; isthmus 31.0-34.0 µm; apex: 32.0-33.1 µm; cells are 6-7 times longer than wide. Cells solitary, dark brown cell wall, with a deep constriction dividing the cell into two semicells, each with four inflates or bulges gradually tapering from base to tip; apices dilated, convex truncated, with a crown of eight conical teeth.

Pleurotaenium trabecula Nägeli
(Fig. 6F-H)

Neue Denkschriften der Allgemeinen Schweizerischen Gesellschaft für die Gesammten Naturwissenschaften 10 (7): 104 (Nägeli 1849).

Docidium trabecula (Ehrenberg) Reinsch, *Abhandlungen der Naturhistorischen Gesellschaft zu Nürnberg* 3 (2): 182 (Reinsch 1866). — *Pleurotaenium trabecula* f. *granulatum* G. S. West, *Journal of Botany* 37: 113 (West 1899).

Distribution. — Cosmopolitan. Amazon Basin: Grönblad (1945); Förster (1969); Thomasson (1971); Uherkovich & Franken (1980); Sophia & Huszar (1996), Gutiérrez & Cadima (2004); Cadima (2013); Cunha de *et al.* (2013). Western Amazonia (lowlands): Montoya (1974); Araujo (2003).

Description

Cells 427.0-596.0 µm long, 28.0-31.0 µm wide; isthmus 20.7-24.3 µm; apex: 16.0-23.2 µm; cells 15-19 times longer than wide. Cells solitary; cell wall hyaline, punctate. Semicells cylindric, slightly and gradually attenuated towards the apices, with a single well-defined basal inflation and rarely with a single undulation above it; lateral margins straight or slightly convex, apices truncately rounded, smooth.

Genus *Staurastrum* Meyen ex Ralfs

Staurastrum leptocladum var. ***cornutum*** Wille*
(Fig. 7A)

Bihang till Kongliga Svenska Vetenskaps-Akademiens Handlingar 8 (18): 19 (Wille 1884).

Distribution. — Cosmopolitan. Amazon Basin: Förster (1969); Thomasson (1971); Uherkovich & Schmidt (1974); Uherkovich (1976, 1981); Sophia & Huszar (1996); Melo *et al.* (2005); Cadima (2013). Western Amazonia (lowlands): no records.

Description

Cells 34.0-36.0 µm long, 85.1-104.9 µm wide with processes; isthmus: 7.5-9.5 µm. Cells are characterized by their apices with two horns arranged in a divergent way. Cells with shallow median constriction, reduced median sinus; smooth cell wall. The ornamentation on the base of the semicells is variable; subtriangular semicells, lateral angles prolonged in long processes, margins irregularly wavy, and always more or less curved upwards.

Remarks

The size and morphology of our specimens coincided with those reported by Förster (1969) for the Brazilian Amazon and Tell (1980) for Northern Argentina. This taxon was the one with the higher occurrence among all our sampling sites (it appeared in six out of eight sites) and presented a variable range in cells size, which is fairly common for this taxon (Tell 1980).

Staurastrum octangulare Grönblad
(Fig. 7B)

Acta Societatis Scienctiarum Fennicae, *Nova Series B*, 2 (6): 28 (Grönblad 1945).

Distribution. — America, South-west Asia. Amazon Basin: Grönblad (1945); Scott *et al.* (1965); Förster (1969); Sophia & Huszar (1996). Western Amazonia (lowlands): Krieger & Scott (1957).

Description

Cells 25.4-30.4 µm long, 19.7-24.7 µm wide; isthmus 9.8-13.8 µm; cells 1.5-1.9 times longer than wide. Cells small, sinus very open, inwardly acute, slightly constricted; semicells in front view subquadrate to suboval; apical and lateral angles of each semicell produced into short bifid processes with spines.

Remarks

This taxon is somewhat similar to *Staurastrum hystrix* Ralfs in size and outline, however it can be set apart by the presence of short bifid processes with spines, produced on each semicell's lateral and apical angles. Our specimens coincided morphologically with those of the original description in Grönblad (1945) and are within the size range given by Scott *et al.* (1965) and Sophia & Huszar (1996) for the species in the Brazilian Amazon.

Staurastrum pinnatum var. *reductum* Willi Krieg.*
(Fig. 7C)

Archiv für Hydrobiologie, Supplement 11: 204 (Krieger 1932).

Distribution. — Cosmopolitan. Amazon Basin: Förster (1969); Cadima (2013); Souza de *et al.* (2019). Western Amazonia (lowlands): no records.

Description

Cells 28.0-29.2 µm long, 36.5-37.7 µm wide; isthmus: 6.5-9.1 µm; cells 1.3 times wider than long. Hyaline cell wall, glabrous at the base of each semicell. Semicells oval, processes short and a pair of spines at the base of each process.

Remarks

This variety differs from the type variety by having shorter processes and by the presence of two spines at the base of each process. Our specimens correspond in morphology with those reported by Förster (1969) for the Brazilian Amazon, Oliveira de *et al.* (2016b) for the northeastern region of Brazil, and Tell (1980) for Argentina, but our specimens were slightly larger than those in Förster (1969) and Oliveira de *et al.* (2016b), and slightly shorter than size shown in Tell (1980).

Staurastrum setigerum var. *subvillosum* Grönblad*
(Fig. 7D)

Acta Societatis Scienctiarum Fennicae, Nova Series B, 2 (6): 30 (Grönblad 1945).

Distribution. — Cosmopolitan. Amazon Basin: Förster (1969, 1974); Thomasson (1971); Uherkovich & Schmidt (1974); Uherkovich (1976, 1981), Martins (1986a), Cadima (2013). Western Amazonia (lowlands): no records.

Description

Cells 42.9-47.6 µm long (without spines), 62.9-63.4 µm long (with spines); 40.2-41.9 µm wide (without spines), 62.3-63.5 µm wide (with spines); isthmus: 12.2 µm; cells 1.1 times longer than wide. Cells with strong spines, sometimes curved, highly polymorphic, with the number of spines varying from one cell to another, and even from one semicell to another.

Remarks

The morphology of our specimens corresponds well with the original description by Grönblad (1945) and with the specimens from Martins (1986a), both from the Brazilian Amazon, in having two strong spines on the angles of semicells and the presence of slender and slightly curved spines between the strong spines.

Staurastrum tectum var. *ayayense* Grönblad*
(Fig. 7E)

Acta Societatis Scienctiarum Fennicae, Nova Series B, 2 (6): 31 (Grönblad 1945).

Distribution. — France, Brazil. Amazon Basin: Grönblad (1945); Förster (1969, 1974); Thomasson (1971, 1977); Uherkovich (1976, 1981); Uherkovich & Rai (1979); Martins (1986a); Melo & Souza de (2009). Western Amazonia (lowlands): no records.

Description

Cells 27.1-31.7 µm long, 67.6-93.0 µm wide with processes, isthmus: 7.8-9.6 µm. The basal margin of the inverted triangular semicells features a single granule with two to three teeth positioned just above the isthmus, while the upper margin is indented in the middle. Each angular process boasts a nearly horizontal, diverging spine and an emarginate granule at its base. The processes are slender, long, and diverging, with toothed margins culminating in two or three denticles.

Remarks

Specimens from this taxon are variable in shape, particularly on the curvature of processes. Like our specimens, Förster's (1974) hold two or three denticles at the tip of each process.

Staurastrum teliferum var. ***pecten*** (Perty) Grönblad (Fig. 7F)

Acta Societatis Scienctiarum Fennicae, Nova Series B, 2 (6): 31 (Grönblad 1945). — *Phycastrum pecten* Perty, *Zur Kenntniss kleinster Lebensformen: nach Bau, Funktionen, Systematik, mit Specialverzeichniss der in der Schweiz beobachteten*: 210, (Perty 1852). — *Staurastrum pecten* (Perty) Wolle, *Desmids of the United States and list of American Pediastrums*: 141 (Wolle 1884b).

Distribution. — South America. Amazon Basin: Grönblad (1945); Thomasson (1971); Förster (1974). Western Amazonia (lowlands): Krieger & Scott (1957).

Description

Cells 31.2-31.6 µm long, 23.8-24.3 µm wide; isthmus: 11.8-12.6 µm; cells 1.3 times longer than wide. Hyaline cell wall, with spines. Semicells more or less reniform; open median sinus; apical view three-angled.

Genus *Staurodesmus* Teiling

Staurodesmus convergens (Ehrenb. ex Ralfs) S.Lill (Fig. 7G)

Acta Limnologica 3: 264 (Lillieroth 1950). — *Arthrodesmus convergens* Ehrenberg ex Ralfs, *The British Desmidieae*: 118 (Ralfs 1848).

Phycastrum convergens Perty, *Mittheilungen der Naturforschenden Gesellschaft in Bern 1849* (164-165): 175 (Perty 1849). — *Arthrodesmus minor* W. B. Turner, *Kungliga Svenska Vetenskaps-Akademiens Handlingar* 25 (5): 134 (Turner 1893). — *Staurodesmus convergens* var. *ralfsii* Teiling, *Arkiv för Botanik* 6: 590 (Teiling 1967). — *Staurodesmus convergens* var. *laportei* Teiling, *Arkiv för Botanik* 6: 588 (Teiling 1967). — *Staurodesmus convergens* var. *pumilus* (Nordstedt) Teiling, *Arkiv för Botanik* 6: 589 (Teiling 1967).

Distribution. — Cosmopolitan. Amazon Basin: Grönblad (1945); Thomasson (1971); Melo *et al.* (2005); Souza de & Melo (2011); Cadima (2013); Cunha de *et al.* (2013). Western Amazonia (lowlands): Araujo (2003); Duque & Donato (1996b); Duque & Núñez-Avellaneda (2000), Núñez-Avellaneda (2008); Díaz-Olarte & Duque (2009).

Description

Cells 40.0-43.7 µm long, 45.0-49.7 µm wide (without spines), 70.6-73.2 µm wide (with spines); isthmus 10.5-13.0 µm. Smooth cell walls. Subellipsoidal semicells, irregularly contoured; deeply constricted, sinus widely open at the extremity, robust and strong spines directed convergently. Apical and lateral sides slightly convex. Semicells slightly different in size.

Remarks

This taxon is considered to be very polymorphic, presenting high variability in size, semicells shape, length of spines, and spines site of insertion (Coesel & Meesters 2013).

Staurodesmus triangularis (Lagerh.) Teiling (Fig. 7H, I)

Botanica Notiser 1948: 62 (Teiling 1948). — *Arthrodesmus triangularis* Lagerheim, *Öfversigt af Kongliga Vetenskaps-Akademiens Förhandlingar* 42 (7): 244 (Lagerheim 1886).

Staurastrum dejectum subsp. *tellamii* West & G. S.West, *Journal of the Royal Microscopical Society* 1894: 10 (West & West 1894). — *Arthrodesmus triangularis* f. *triquetra* West & G. S. West, *A monograph of the British Desmidiaceae*. IV: 99 (West & West 1912). — *Staurastrum megacanthum* var. *orientale* A. M. Scott & Prescott, *Hydrobiologia* 17 (1/2): 98 (Scott & Prescott 1961). — *Staurodesmus orientalis* (A. M. Scott & Prescott) Coesel, *Cryptogamie, Algologie* 14 (2-3): 110 (Coesel 1993).

Distribution. — Cosmopolitan. Amazon Basin: Förster (1969, 1974); Thomasson (1971); Uherkovich & Schmidt (1974); Uherkovich (1976, 1981); Uherkovich & Rai (1979); Sophia & Huszar (1996); Huszar & Reynolds (1997); Melo *et al.* (2005); Souza de *et al.* (2007); Melo & Souza de (2009); Souza de & Melo (2011); Cadima (2013). Western Amazonia (lowlands): Díaz-Olarte & Duque (2009).

Description

Cells 25.2-25.8 µm long, 18.0-20.6 µm wide; isthmus 5.7-6.0 µm; cells 1.3-1.4 longer than wide. Cells with a deep, wide open sinus. The isthmus is usually elongated; the body of the semicell over the isthmus is triangular. The apex is slightly elevated by a median depression. The apical angles are rounded, and they have long spines that can be parallel, divergent, or convergent (mainly convergent in our specimens).

Remarks

Our specimens coincided morphologically with descriptions and drawings for the Brazilian Amazon specimens of *Staurodesmus triangularis* (Förster 1969, 1974; Sophia & Huszar 1996). This taxon has also been considered as highly polymorphic (Bicudo & Azevedo 1977).

Genus *Xanthidium* Ehrenb. ex Ralfs

Xanthidium mamillosum var. mediolaeve (Grönblad) Couté & Tell* (Fig. 7J)

Beihefte zur Nova Hedwigia 68: 197 (Couté & Tell 1981). — *Xanthidium antilopaeum* f. *mediolaeve* Grönblad, *Acta Societatis Scienctiarum Fennicae, Nova Series B*, 2 (6): 22 (Grönblad 1945).

Distribution. — South America and China. Amazon Basin: as *Xanthidium antilopaeum* var. *mamillosum* f. *mediolaeve*: Grönblad (1945). As *X. mamillosum* f. *mediolaeve*: Thomasson (1971). Western Amazonia (lowlands): no records.

Description

Cells 76.4 µm long (115.0 µm with spines), 83.9 µm wide (136.2 µm with spines); isthmus 31.5 µm; apex: 27.7-31.7 µm. Cell wall finely punctuated. Semicells hexagonal-pyramidal, sinus linear inwardly, outwardly greatly enlarged. The spines on each semicell are arranged apically and laterally and are

FIG. 8. — Images of sampling locations in the Ecuadorian Amazon: **A**, aerial view of Grande Lake showing flooded trees and shores with no aquatic plants; **B**, fringing floating stands of *Pontederia azurea* Sw. on the littoral margins of Pilchicocha Lake; **C**, shores of the Pacuya River devoid of aquatic plants; **D**, aquatic macrophytes on the margins of the Lagartococha River, including stands of *Utricularia* L. Photo credits: A, David Brooks; B-D, José V. Montoya.

strongly inflated at the base. The spines, which are strong, straight, and long, become sharper towards the ends.

REMARKS

This taxon is easily identifiable by the well-defined inflated base of spines in our specimens. Although our specimens are slightly smaller than those described by Grönblad (1945) from the Amazon, and Bourrelly & Couté (1982) from French Guyana, they are slightly larger in cells longitude than those shown by Camargo *et al.* (2009) for Mato Grosso, Brazil (as *Xanthidium antilopaeum* var. *mamillosum* f. *mediolaeve* Grönblad). The size of our specimens falls within the wide range of variation exhibited by specimens reported by Oliveira de *et al.* (2011b) for northeastern Brazil. As recorded in those other works, *X. mamillosum* var. *mediolaeve* presents a high variation in size.

Xanthidium trilobum Nordst.
(Fig. 7K, L)

Videnskabelige meddelelser fra Dansk naturhistorisk forening i København 21 (14-15): 230 (Nordstedt 1870).

DISTRIBUTION. — South America and Caribbean Islands. Amazon Basin: Grönblad (1945); Förster (1969, 1974); Thomasson (1971); Uherkovich (1976, 1981); Lopes & Bicudo (2003); Gutiérrez & Cadima (2004); Melo *et al.* (2005); Souza de *et al.* (2007); Melo & Souza de (2009); Souza de & Melo (2011); Cadima (2013). Western Amazonia (lowlands): Núñez-Avellaneda & Duque (2000), Araujo (2003); Díaz-Olarte & Duque (2009).

DESCRIPTION

Cells 66.7-71.4 µm long, 63.0-71.9 µm wide; isthmus 16.5-17.3 µm; cells are as long as they are wide. Semicells subhexagonal, angled with cylindrical processes, short, two-spined, rhomboid apical view, smooth cell wall. With spines and a well individualized polar lobe. Open sinus, ornamentation varies slightly from cell to cell, as well as between semicells. The apical lobe has four slightly curved spines. Lateral lobes always present a pair of recurved spines.

DISCUSSION

Among the 42 new records for the Ecuadorian Amazonia, including the 15 new records to Western Amazonia, three taxa are new additions to the Amazon River Basin: *Cosmarium quadriverrucosum* var. *supraornatum, Micrasterias fimbriata* var. *spinosa*, and *Micrasterias furcata* var. *dichotoma.*

During our sampling in 2021, the high water season was unusual, with low precipitations and low river flows (Comité ERFEN-Ecuador 2021). Desmid taxa are usually found in acidic, low conductivity, soft waters, and oligo- to mesotrophic conditions (Brook 1981; Uherkovich 1984; Melo *et al.* 2009; Hall & McCourt 2015), such as those in our sampling sites. Although sites with higher numbers of taxa held very low concentrations of dissolved oxygen, Pilchicocha Lake, where only three taxa were recorded, also had very low DO values. It is worth noting that our sites are relatively low-impacted or without impact from anthropogenic causes, and those low DO concentrations are not due to pollution or ecosystem degradation, but reflect normal conditions in these environments, especially during periods of hydrological transition or high waters (Val *et al.* 2022). In fact, a high biochemical oxygen demand occurs in the sediments and water column cyclically, as water enters the floodplain as the annual inundation pulse advances during rising waters, a phenomenon that also happens during water receding on descending waters (Townsend 2006, Brito *et al.* 2014). Although there have been reports of desmids in low-oxygen environments, it is known that desmids are sensitive to hypoxic conditions under high biochemical oxygen demand (McCarthy *et al.* 2018), which is especially true for benthic species (Volik *et al.* 2016). These anoxic and hypoxic conditions are not unusual for floodplain lakes in the Amazon (MacIntyre & Melack 1984, 1988; Huszar & Reynolds 1997); and the Orinoco (Vásquez 1992) large river floodplain ecosystems, especially during high waters and transitional periods. Also, those conditions, although not optimal, are very dynamic considering that those shallow floodplain lakes mix frequently (usually once a day at low waters) or less frequently at high waters (MacIntyre & Melack 1988). Dynamical changes on the diel temporal scale in the water column stratification - destratification have been demonstrated as an important factor for the maintenance of a high diversity of desmids in tropical lakes (Barbosa & Padisák 2002), which would otherwise sink to the bottom of these lakes.

It was unexpected to find low taxonomic richness in places like the Cuyabeno River, Canangüeno and Grande Lakes in the Cuyabeno Wildlife Reserve because those locations featured oligotrophy, soft waters, and acidic environments, all ideal for desmid to flourish. Comparatively, Melo *et al.* (2005) and Souza de *et al.* (2007) studying desmids from the water column of blackwater, oligotrophic floodplain lakes in the Brazilian Amazon found 97 and 53 Desmidiaceae taxa, respectively. Other biotic interactions with plankton or fish could explain the striking differences between these three sites and the richest Lagartococha and Delfincocha, that in the end, share most environmental conditions. An important factor described by Melo & Souza de (2009) for Amazonian lakes to explain differences in desmids richness is the presence of aquatic macrophytes in the littoral areas and that the depths were shallower, allowing the constant resuspension of cells from the bottom sediments to the water column. The potential horizontal dispersion of plankton and periphyton from the aquatic macrophyte stands in the littoral areas would be only possible in Lagartococha River, and Delfincocha and Pilchicocha lakes; all other sites did not have fringing vegetation on their margins (see Fig. 8). As explained by Bland & Brook (1974) the size and morphometry of lakes, as well as their circulation patterns in lakes with vegetated margins are responsible for differences in desmids richness. The aforementioned factors, in conjunction with the fact that only the upper water column was sampled, could help to explain the unexpected low richness values observed at certain sites.

Most desmid species are benthic (Brook 1981; Coesel & Meesters 2007), although many taxa can be found in the water column as the ones found in this study. Among the planktonic taxa found in this study are *Staurastrum leptocladum* var. *cornutum*, *Staurodesmus triangularis*, and *Xanthidium mamillosum* var. *mediolaeve* (Brook 1959; Sophia & Huszar 1996; Bicudo *et al.* 2007). Nearly the rest of the species we recorded are not planktonic but benthic, that have been likely detached from aquatic or riparian vegetation and became free-floating due to turbulence, and as such they are classified as tychoplankton (Reynolds 2006; Hall & McCourt 2015). Some of these algae can persist in the water column due to the presence of long processes, reduction of ornamentation (producing lighter cells), increase of the mucilaginous envelope, development of pseudofilaments, and the magnification of the surface to volume ratios (reducing sinking rates) (Brook 1981), giving them better adaptation to open waters.

Some of tychoplanktonic desmids, which are usually found as part of the periphyton or metaphyton, but are also found in open waters and can maintain free floating populations, have been classified as facultative plankters (Brook 1959). *Micrasterias sol* (synonymized to *M. radiosa* var. *radiosa*), *Micrasterias radiata* var. *dichotoma* (synonymized to *Micrasterias furcata* var. *dichotoma*), *Micrasterias laticeps*, *Staurodesmus convergens*, *Xanthidium trilobum*, *Desmidium grevillei*, *Hyalotheca dissiliens,* and *H. mucosa,* species found in our study, have been included in that group (Brook 1959; Sophia & Huszar 1996; Melo *et al.* 2005).

In terms of differences between the two hydrological periods sampled, all 42 species were found during the rising waters (2022), and only 20 species (48%) were detected in the high water period (2021). No species were found exclusively during 2021, while 22 (52%) were found only during 2022. This difference between the two sampling periods could be attributable to the hydrological seasonality, which is well-known to explain variability in plankton succession in Neotropical floodplain systems (Huszar & Reynolds 1997; Melo & Souza de 2009; Zalocar de Domitrovic *et al.* 2014). The greatest richness of desmids in floodplain systems in the Brazilian Amazon has been identified during periods of rising water (Huszar & Reynolds 1997; Melo *et al.* 2005; Melo & Souza de 2009). In these transition periods, when the water level is rising, a greater number of rare species associated with the benthos tend to appear. It is likely that their appearance in the plankton as tychoplankton is a consequence of the detachment of periphytic communities associated with the edges of rivers and lagoons (Melo *et al.* 2005; Melo & Souza de 2009). In periods of high water levels, the dilution effect of organisms and the dynamics of planktonic community development and succession are the factors that explain the observed decrease in both population density and species richness of microalgae (Huszar & Reynolds 1997). Interannual variability in desmids species richness is important, and patterns found for one year are not necessarily similar to the next, as it was observed in a blackwater floodplain lake in the Negro River (a major tributary of the Amazon) by Melo & Souza de (2009) during three consecutive years. In fact, the flooding dynamics of these ecosystems is the most important factor explaining the fluctuations in their ecological processes and organisms' populations (Junk *et al.* 1989; Montoya *et al.* 2011), and only with samplings encompassing annual cycles we would improve our understanding of these ecosystems of lowland Western Amazonia.

In comparison to the richness of desmids observed in other regions of the Amazon basin, the present study reports a relatively low richness. However, this study reported a substantial number of newfound records for freshwater algae in Ecuadorian and Western Amazonia, underscoring the need for further research to comprehend the biodiversity of this region of the Amazon Basin. Certain locations, including Cuyabeno and Lagartococha, potentially possess some of the greatest species richness worldwide (Alverson *et al.* 2008). These ecosystems are also at risk due to human activities, such as oil exploration and production, that cause pollution and contamination of the rivers, lakes, and wetlands (Rivera-Parra *et al.* 2020). Therefore, protecting these habitats from potential threats is important, especially during high water periods when oil spills may reach remote areas like Lagartococha and Delfincocha.

In conclusion, it seems plausible that the presence or absence of aquatic vegetation was an important factor in explaining the differences in the identities of desmids assemblages observed in the upper stratum of the water column among the sites sampled. Nevertheless, other physical processes in lakes, such as turbulence due to partial mixing of upper water masses or a total mix of the entire water column in these shallow lakes, may also contribute to the maintenance of desmids populations in the water column. Further sampling efforts in the region, including periphytic and metaphytic communities, and during other hydrological seasons, are required to provide a more comprehensive inventory of desmids.

Author contributions

Conceptualization: L. S. and J. V. M.; Field methodology: J. V. M. and F. R. S.; Separation and digital photography of specimens: L. S. and F. R. S.; Identification and curation of specimens: L. S. and J. V. M.; Writing - original draft preparation: J. V. M. and L. S; Writing - review and editing: L. S., B. R. T. and J. V. M.; project administration and funding acquisition: J. V. M. and B. R. T. All authors have read and agreed to the published version of the manuscript.

Acknowledgements

The authors want to thank the editor and three anonymous reviewers for their insightful comments that helped to improve this manuscript. The authors are grateful to the Belgian Development Cooperation (DGD) for the financial support provided and the World Wildlife Fund Inc. (WWF) for the financial, technical, and logistics support provided. This article and its findings are those of the authors and do not necessarily reflect the views of the Belgian Development Cooperation. We also received the support from Universidad de las Américas, Ecuador, project no. FGE.JMC.21.01. Nathan Lujan, Gabriela Jijón, Jessica Pacheco, Francis Boily, Jacob Tangoy, and many other collaborators provided important help and support in the field. We also thank Emilio Realpe, Laboratorio de Zoología y Ecología Acuática-LAZOEA (Universidad de Los Andes, Bogotá, Colombia) for providing access to his laboratory and optical instrumentation. Diego Vimos and Henrietta Hampel (Universidad de Cuenca, Ecuador) kindly helped us with the deposit of samples in the museum of Universidad de Cuenca. The Ecuadorian Ministry of Environment, Water, and Ecological Transition (MAATE) provided support to conduct research in the Cuyabeno Wildlife Reserve. This project was possible due to the involvement and interest of Kichwa and Siona indigenous communities that collaborated and authorized this research in their lands. Michael Burghardt helped by checking botanical nomenclature. Sampling for this study was performed under the collecting permit No. MAAE-DBI-CM-2021-0161, issued by the MAATE.

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Submitted on 16 March 2023;
accepted on 12 August 2024;
published on 5 September 2025.