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ECOSYSTEMS

Diversity and distribution of the genus *Tetmemorus* (Desmidiaceae, Zygnematophyceae) in Brazil

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Abstract: In the present study, a taxonomic review was conducted on representatives of the genus *Tetmemorus* (Desmidiaceae, Zygnematophyceae) documented within Brazilian territory. This review involved compiling data from the literature and analyzing samples collected throughout the Bahia State, updating our knowledge about this genus in Brazil. For each identified taxon, we provided information such as description, distribution across biomes and states, watersheds, ecological aspects (including habitat and community types), a list of examined (and excluded) materials, and taxonomic comments. Additionally, a taxonomic key for all species reported in Brazil was provided. Through this comprehensive review, we identified a total of eight *Tetmemorus* taxa occurring in Brazilian territory, comprising five species (*T. brebissonii*, *T. furcatus*, *T. granulatus*, *T. laevis*, *T. planctonicus*) and three non-typical varieties (*T. brebissonii* var. *minor*, *T. laevis* var. *borgei*, *T. laevis* var. *minutus*).

Key words: algae, desmids, periphyton, phytoplankton, taxonomy.

INTRODUCTION

Desmids, belonging to the Zygnematophyceae class, form a diverse group of Streptophyta algae, comprising approximately 60 genera found exclusively in continental aquatic environments. This class has two subclasses: Spirogloeophycidae, with one representative *Spirogloea muscicola* (De Bary) Melkonian, a sister group of all desmids, and Zygnematophycidae, containing the other genera (Cheng et al. 2019), with four orders (Desmidiales, Serritaeniales, Spirogyrales, and Zygnematales) (Hess et al. 2022). A striking and exclusive feature of the Zygnematophyceae is conjugation-type sexual reproduction, in which two adult cells unite and release their protoplasmic contents, which act as flagellated amoeboid gametes that fuse to form a diploid zygospore. Asexual reproduction occurs by bipartition (Brook 1981, Hall & McCourt 2017).

In Brazil, 45 genera of desmids have been recorded (Bicudo & Menezes 2017), including *Tetmemorus* Ralfs *ex* Ralfs. This genus is characterized by solitary, cylindrical, fusiform cells, shallow median constriction, and deep apical incision; a smooth cell wall with scattered pores or ornamented with elongated scrobicles arranged in transverse or longitudinal series; and axial chloroplasts, with one or more pyrenoids.

Molecular data have shown that species such as *Tetmemorus brebissonii* and *T. laevis* form a well-supported clade embedded in a clade with *Euastrum* taxa (Hall et al. 2008), or in a clade with *Euastrum*, *Cosmarium,* and *Actinotaenium cucurbita* (Brebisson) Teiling taxa (Gontcharov & Melkonian 2011). However, to date, the small number of sequences from *Tetmemorus* and

Euastrum does not allow for a better assessment of the phylogenetic relationships within the *Euastrum* assemblage (Gontcharov & Melkonian 2011). According to these authors, some taxa of this assemblage (mainly those of the *Euastrum*2 clade) share characteristics with species of the genus *Tetmemorus*, such as elongated cells, smooth walls, and apical incision in the semicells. According to Guiry & Guiry (2021), there are 17 known species of the genus, eight of which are taxonomically valid, in addition to 40 infraspecific taxa.

The present study aimed to carry out a taxonomic review of representatives of the genus *Tetmemorus* Ralfs *ex* Ralfs (Desmidiaceae) occurring in Brazil.

MATERIALS AND METHODS

Samples of continental microalgae collected in different aquatic environments in Bahia State, most of them from rivers and lakes on the north coast and Chapada Diamantina, were analyzed at the Phycology Laboratory, State University of Feira de Santana. These samples are stored in the Herbarium of the State University of Feira de Santana (HUEFS).

All materials were analyzed using an Olympus BX43 binocular microscope. At the Instituto Gonçalo-Moniz (Fiocruz-Bahia) a part of the material was submitted to complementary analyses by scanning electron microscopy (SEM), according to the protocols of Ramos et al. (2017) and Moura et al. (2021), to detail the cell wall characteristics of *Tetmemorus* species.

The morphological features of *Tetmemorus* representatives were analyzed, pointing out those of greater taxonomic importance. In addition to analyzing the material registered in HUEFS, all taxa reported in Brazil were reviewed based on the characteristics described and illustrated in the literature, as well as compared with their original protologues.

Information was provided for each taxon, such as descriptions, illustrations, updated geographic distribution in Brazil, list of analyzed material, ecological aspects such as type of habitat and life form, biome, watersheds, and taxonomic comments. In addition, for some taxa, there is a List of Material Excluded, which comprises records with insufficient information for reanalysis, as generally there are only citations or the illustrations are lacking.

Illustrations have been provided in drawings and photographs using a light microscope and SEM to demonstrate the variability of the material analyzed in all taxonomic views. The drawings were made using the Inkscape software, while the optical microscopy photographs were taken with a MicroPublisher camera (QImaging MP5.0-RTV-CLR-10-C). SEM images were taken at the Instituto Gonçalo Moniz (Fiocruz-Bahia) with a camera adapted to the JEOL 6390 LV Microscope.

RESULTS AND DISCUSSION

Tetmemorus Ralfs ex Ralfs, 1848

Cells free-living, solitary, straight, ranging from cylindrical to fusiform, longer than wide, with shallow median constriction and open sinus; apices rounded to slightly truncated, with narrow, deep vertical midline incision, usually closed, and rarely open. The cell wall may be smooth, punctate, or ornamented with scrobicles. Chloroplast single, axial, stellate, with 1–9 pyrenoids arranged in a median series.

In Brazil, the genus *Tetmemorus* is represented by eight taxa, distributed in five species and three non-typical varieties, which can be identified using the key below.

Taxonomic key for the five species of *Tetmemorus* occurring in Brazil

1 Cell in frontal view cylindrical, with cell wall ornamented by scrobicles.....*T. brebissonii*

- Cell in frontal view fusiform, with smooth wall 2

2 Cell outline in front and lateral views similar .....*T. planctonicus*

- Cell outline in front and side views distinctive.....3

3 Apical incisions V-shaped, open..... *T. furcatus*

- Apical incisions linear, closed 4

4 Cell in front view strongly tapered towards apices, generally longer than 150 µm.....*T. granulatus*

- Cell in frontal view slightly tapered towards apices, generally shorter than 150 µm.....*T. laevis*

Tetmemorus brebissonii Ralfs *ex* Ralfs var. ***brebissonii*** (Figs. 1a-b, 2a-d, f)

Brit. Desm. 145, pl. 24, fig. 1a-f. 1848.

Brazilian records accounted in *T. brebissonii*

Tetmemorus brebissonii forma in Borge (1903: 116, Pl. 5, Fig. 9) *Tetmemorus laevis* var. *tropicus* Willi Krieger in Bicudo & Ventrice (1968: 9, Figs. 39-40) *Tetmemorus laevis* (Kützing) Ralfs in Aprile & Mera (2007:11, Fig.25)

Cells cylindrical, 4.7-5 times longer than wide, 100-200 µm long, 20-40 µm wide, isthmus 18-40 µm wide, shallow median constriction, open median sinus; lateral margins parallel, apical margin broadly rounded, median apical incision deep, closed; cell wall ornamented with longitudinal series of scrobicles; circular apical view; around 5 pyrenoids per semicell.

Geographic distribution in Brazil: Rio Grande do Sul (Borge 1903), Minas Gerais (Bicudo & Ventrice 1968), Bahia (Martins & Bicudo 1987, Bicudo & Martins 1989, Oliveira et al. 2014), Rio de Janeiro (Bicudo & Picelli-Vicentim 1988), São Paulo (Bicudo et al. 2014), Paraná (Bittencourt-Oliveira 1993, Menezes et al. 2011), Amazonas (Aprile & Mera 2007).

Biomes: Atlantic Forest, Amazon, Cerrado, Caatinga.

Watersheds: South Atlantic, Eastern Atlantic, Southeast Atlantic, Paraná.

Habitat: oligo-mesotrophic environments; lakes, ponds, swamps, rivers, streams, waterfalls, *Sphagnum* fields in mountainous areas.

Communities: plankton, metaphyton, periphyton.

Material examined: BAHIA: Mata de São João, 11/I/2009, I.B. Oliveira & C.W.N. Moura s.n. (HUEFS 155599, HUEFS 155603, HUEFS 155610, HUEFS 155611); 14/III/2009, I.B. Oliveira & C.W.N. Moura s.n. (HUEFS 155706); Esplanada, 14/III/2009, I.B. Oliveira & C.W.N. Moura s.n. (HUEFS 155692); Palmeiras, 26/II/2017, G.J.P. Ramos s.n. (HUEFS 244148); Piatã, 14/VII/2017, G.J.P. Ramos s.n. et al. (HUEFS 244150); Itaparica, 23/VII/2015, M.A. Santos & C.A. Ribeiro (HUEFS 219231); Vera Cruz, 22/IX/2015, M.A. Santos & C.A. Ribeiro (HUEFS 219244); Salvador, 16/VIII/2014, M.A. Santos et al. s.n. (HUEFS 219780); Camaçari, 22/XI/2014, M.A. Santos et al. s.n. (HUEFS 219822).

Note: *Tetmemorus brebissonii* has a wide distribution, being recorded on most continents, making it one of the best-known species of the genus. The presence of a cell wall decorated with scrobicles organized in a longitudinal series, in addition to its cylindrical cell outline with margins parallel and widely rounded apices, allows *T. brebissonii* to be separated from the other species of the genus.

Based on populations of *T. brebissonii* var. *intermedius* Flensburg in Europe, Van Westen (2015) considered that cell morphometry values (4.5 to 6 times longer than wide, 100–123 µm long, 19.5–23 µm wide, 16.5–20.5 µm isthmus) and

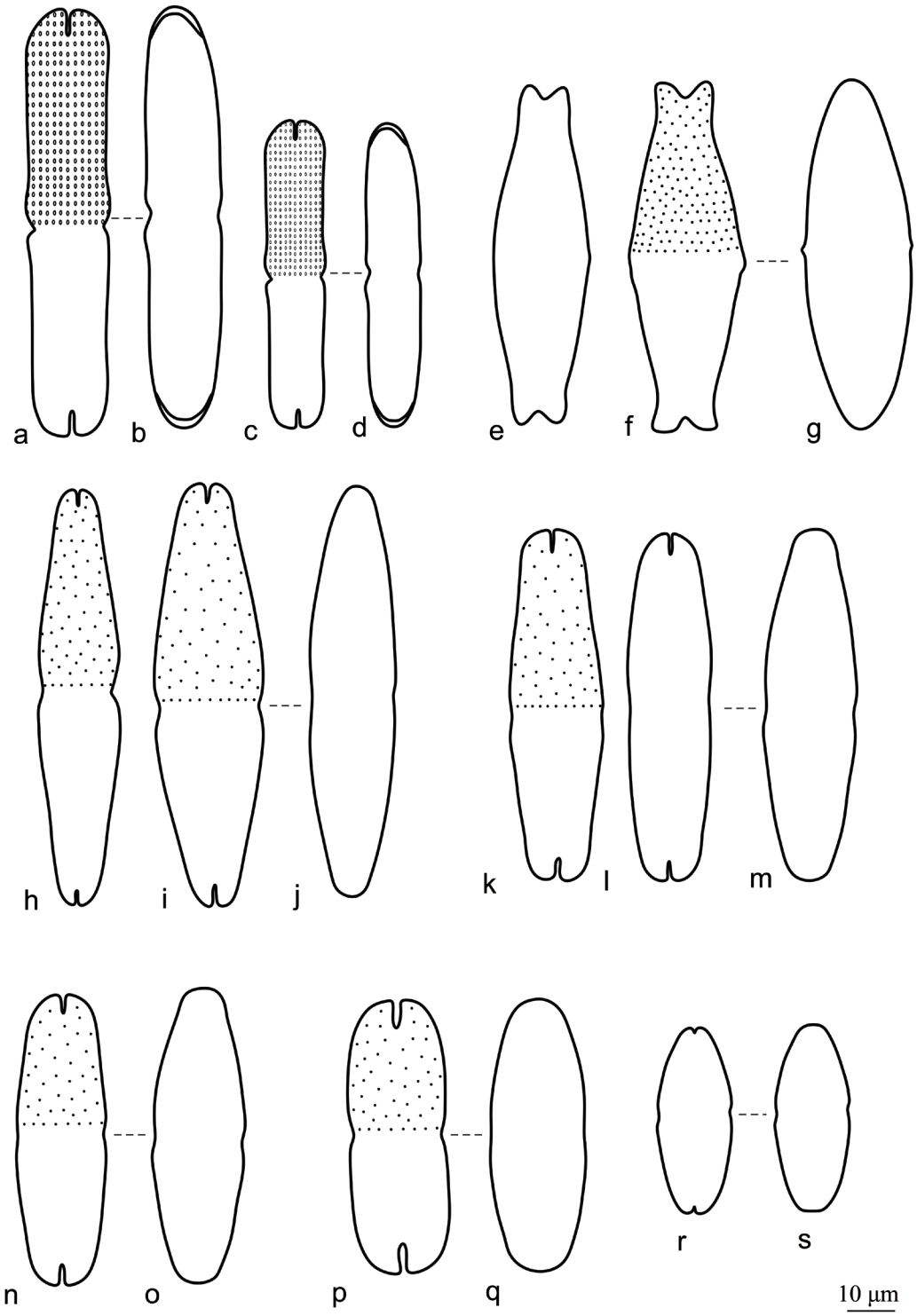

Figure 1. *Tetmemorus* of Brazil (line drawings). **a-b)** *T. brebissonii* var. *brebissonii* (a) front view, (b) side view. **c-d)** *T. brebissonii* var. *minor* (c) front view, (d) side view. **e-g)** *T. furcatus* (e-f) front view, (g) side view. **h-j)** *T. granulatus* (h-i) front view, (j) side view. **k-m)** *T. laevis* var. *laevis* (k-l) front view, (m) side view. **n-o)** *T. laevis* var. *minutus* (n) front view, (o) side view. **p-q)** *T. laevis* var. *borgei* (p) front view, (q) side view. **r-s)** *T. planctonicus* (r) front view, (s) side view.

ecological preferences [pH = 3.8–4.3 (–4.7); EC = 20–80 µS cm^{-1}] were distinct from those reported for *T. brebissonii* and elevated this variety to the category of species, as *Tetmemorus flensburgii* Van Westen. To date, it has only been registered in Europe and North America.

Considering only the cell dimensions, it is possible that some of the Brazilian records, identified as *T. brebissonii* (Martins & Bicudo 1987, Menezes et al. 2011, Oliveira et al. 2014) and *T. brebissonii* var. *minus* (Förster 1964, Bicudo 1969), are representatives of *Tetmemorus flensburgii*. However, according to Růžička (1981), *T. brebissonii* var. *brebissonii* shows a wide variation in cell metric limits [(100–) 150–220 (–270–320) compr. × (19–) 25–40 (–48) µm wide], which naturally depends on the environmental conditions to which the species is subjected. Therefore, for the time being, we consider that the aforementioned records from Brazil, with metric limits close to *T. flensburgii*, remain as representatives of *T. brebissonii* var. *brebissonii* until integrative studies are carried out and ecological preferences are clarified.

Another species worth noting is *Tetmemorus penioides* A.W.Bennett, described for Europe (Lancashire, Furness Fells, England). Although this taxon is considered taxonomically valid in the Algaebase (Guiry & Guiry 2021), it had already been referred to by Krieger (1937) as a synonym of *Tetmemorus brebissonii*. We fully agree with this synonymy because all morphometric features of *T. penioides* are within the circumscription of *Tetmemorus brebissonii*.

Regarding materials from Brazil, Bicudo & Ventrice (1968) reported the occurrence of *T. laevis* var. *tropicus* Willi Krieger, a taxon described in 1937 by Krieger for Indonesia. According to the first authors, the Brazilian specimens studied had elongated cells (5-5.5 times longer than wide) and sharply tapered poles. However, despite the wall not being represented by the longitudinal series of pores, the illustrated specimens (Bicudo & Ventrice 1968: figs. 39-40), as well as the metric limits of the cells, were identical to *T. brebissonii*, also reported for the same place. Thus, we consider it more appropriate that this record of *T. laevis* var. *tropicus* to Brejo da Lapa be treated as a synonym of *T. brebissonii*.

Material excluded:

Tetmemorus brebissonii Ralfs ex Ralfs var. *brebissonii:*

Borge 1918 (citation only)

Borge 1925 (citation only, the illustration refers to *Closterium brebissonii*)

Krieger 1950 (no illustration)

Scott et al. 1965 (citation only)

Nordstedt 1878 (no illustration)

Tetmemorus brebissonii Ralfs ex Ralfs var. *attenuatus*:

Børgesen 1891 (no illustration)

Borge 1903 (citation only)

Borge 1918 (citation only)

Tetmemorus brebissonii Ralfs ex Ralfs var. ***minor*** De Bary (Fig. 1c-d, 2e)

Untersuch. Fam. Conjugat., p. 73, pl. 5, fig. 19. 1858.

This variety differs from the nominate variety in having smaller cell dimensions, with

cells approximately 4 times longer than wide, 60-75 (-111) µm long, 15-19 (-24) µm wide, isthmus 12-15 (-18) µm wide.

Geographic distribution in Brazil: Bahia (Förster 1964, Oliveira et al. 2014).

Biome: Atlantic Forest.

Watershed: Eastern Atlantic.

Habitat: ponds and rivers.

Communities: plankton, metaphyton, periphyton.

Material examined: BAHIA: Mata de São João, 11/I/2009, I.B. Oliveira & C.W.N. Moura s.n. (HUEFS 155599, HUEFS 155703), 14/III/2009, I.B. Oliveira

& C.W.N. Moura s.n. (HUEFS 155599); Conde, 01/III/2009, I.B. Oliveira & J. Farias s.n. (HUEFS 155658); Entre Rios, 26/VII/2009, I.B. Oliveira et al. s.n. (HUEFS 155754).

Note: According to Bicudo et al. (2014), the specimens identified as *T. brebissoni* var. *minor* by Bicudo (1969) for the State of São Paulo, refer to *T. laevis*, due to the presence of a finely punctuated wall. Among the most common morphological variations reported for var. *minor*, are the base of the semicells, which may present a small protrusion in the isthmus region, in addition to the margins of the semicells, which are straight to slightly concave.

Tetmemorus furcatus G.J.P.Ramos & C.W.N.Moura (Figs. 1e-g, 3a-e)

Phytotaxa, p. 194, figs. 63–65. 2019.

Cells fusiform, 2.7-3.2 times longer than wide, 85–105(-130) µm long, 26–38 µm wide, isthmus 23–30 (-37) µm wide, shallow median constriction; smooth lateral margins, slightly concave converging towards the apices, median apical incision V-shaped, deep, open; cell wall hyaline, thick, finely punctuated; circular in apical view.

Geographic distribution in Brazil: Bahia (Ramos et al. 2019).

Type locality: Águas Claras, Vale do Capão, Palmeiras, Bahia, Brazil.

Biome: Caatinga.

Watershed: Eastern Atlantic.

Habitat: stream in a mountainous region.

Communities: periphyton, metaphyton.

Material examined: BAHIA: Palmeiras, 26/II/2017, G.J.P. Ramos s.n. (HUEFS 244148!).

Note: This species is apparently endemic to Brazil and so far, known only from its type locality. It has been reported to occur in metaphyton and periphyton of filamentous algae, on the bank of a stream formed by small waterfalls in the region of Águas Claras in Vale do Capão, Chapada Diamantina, Bahia, northeastern Brazil.

Tetmemorus furcatus is easily recognized by its fusiform cell outline with a noteworthy open apical incision, V-shaped. However, it should be compared with *Tetmemorus fissus* West & G.S.West, another species of the genus that presents an open apical incision. This latter species, described for Huíla, Angola, differs in that it has an elliptical cell outline, semicells with convex lateral margins, an open sinus in the median region of the cell, in addition to the much smaller dimensions (42 µm long, 18 µm wide).

It is possible that this pattern with an open apical incision is typical of the tropical region, since the only two species of the genus with this characteristic were recorded only in Brazil and Angola.

Tetmemorus granulatus Brébisson ex Ralfs (Figs. 1h-j, 2g-o)

Brit. Desm. 147, pl. 24, fig. 2a-c. 1848.

Heterotypic synonyms

Tetmemorus granulatus Brébisson *ex* Ralfs var. *attenuatus* West
Tetmemorus granulatus Brébisson *ex* Ralfs var. *constrictus* Kurt Förster
Tetmemorus laevis Ralfs *ex* Ralfs var. *tropicus* Willi Krieger

Brazilian records accounted in *T. granulatus*

Tetmemorus granulatus Brébisson *ex* Ralfs var. *constrictus* Kurt Förster forma in Uherkovich & Franken (1980:53, pl.3, fig. 11)

Tetmemorus laevis Ralfs *ex* Ralfs var. *tropicus* Willi Krieger in Martins & Bicudo (1987:6, fig. 15), Bicudo et al. (2014:185, fig. 370)

Cells markedly fusiform, 4-5 times longer than wide, 110–200 µm long, (16-) 22–48 µm wide, isthmus (8–) 16–27 (–44) µm wide, shallow median constriction, shallow, subacuteangular sinus; semicell cylindrical-fusiform, smooth lateral margins, slightly concave in the median region, narrow and rounded apices, median apical

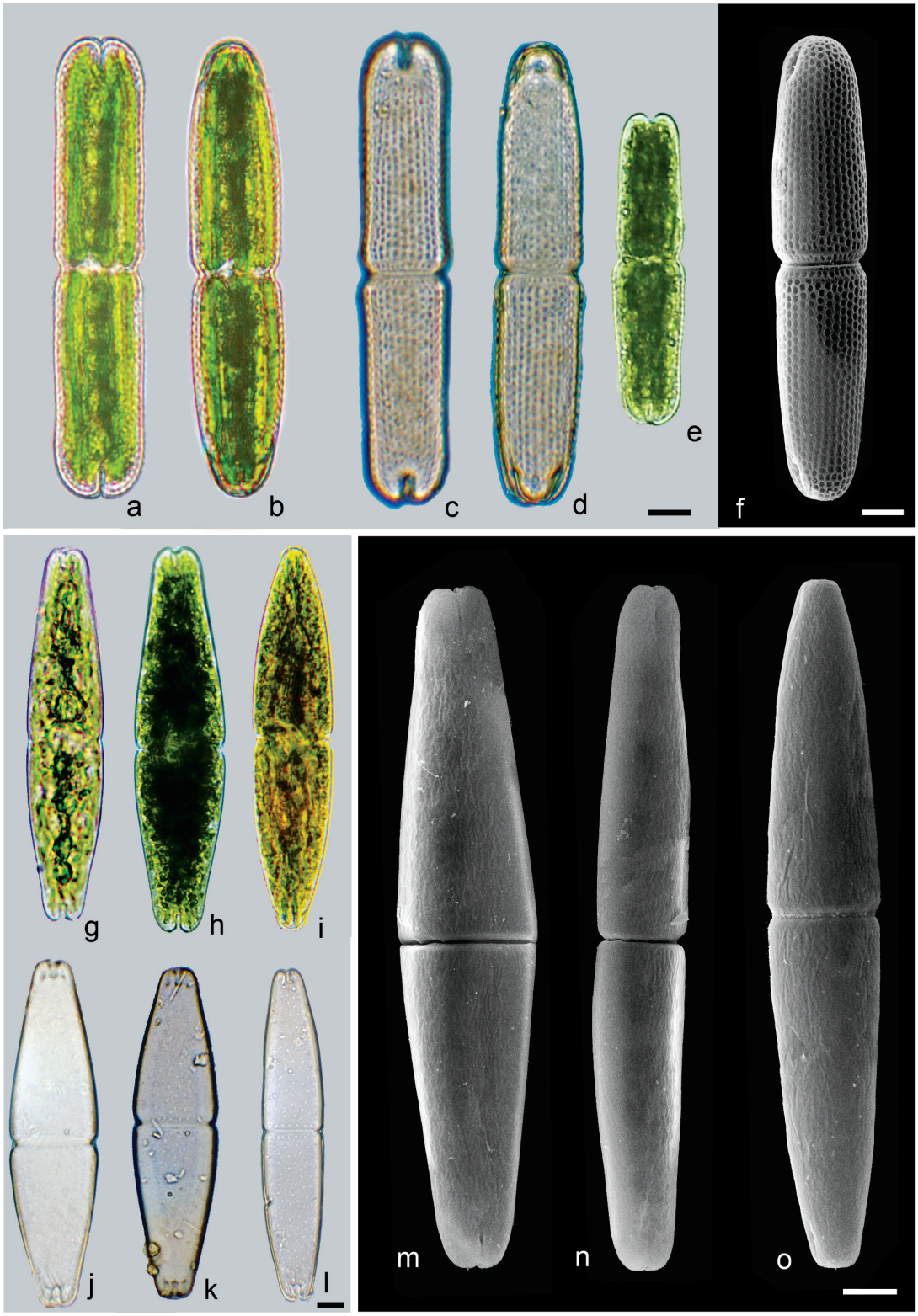

Figure 2. *Tetmemorus* of Brazil in light microscopy (a-e, g-l) and scanning electron microscopy (f, m-o). **a-d, f)** *T. brebissonii* var. *brebissonii* (a, c) front view, (b, d, f) lateral view, **e)** *T. brebissonii* var. *minor* (front view). **g-o)** *T. granulatus* (g-h, j-k, m, n) front view, (i, o) lateral view. Bars - 10µm.

incision deep, linear; hyaline cell wall, irregularly punctuated with a horizontal row of fine pores close to the isthmus; zygospores globose to elliptical, smooth walled.

Geographic distribution in Brazil: Bahia (Martins & Bicudo 1987, Oliveira et al. 2014), Rio de Janeiro (Bicudo & Bicudo 1969, Bicudo & Picelli-Vicentim 1988), São Paulo (Bicudo & Bicudo 1965, Bicudo 1969, Bicudo et al. 1998, 2014), Amazonas (Uherkovich & Franken 1980), Pará (Scott et al. 1965, Förster 1969), Paraná (Menezes et al. 2011), Tocantins (Förster 1964).

Biomes: Atlantic Forest, Amazon, Cerrado.

Watersheds: South Atlantic, Eastern Atlantic, Southeast Atlantic, Paraná, Amazon, Tocantins-Araguaia.

Habitat: oligo-mesotrophic environments such as ponds, floodplain, streams, rivers, reservoirs, springs, small waterfalls, *Sphagnum* L. fields in mountainous regions.

Communities: plankton, metaphyton, periphyton.

Material examined: BAHIA: Esplanada, 14/II/2009, I.B. Oliveira & C.W.N. Moura s.n (HUEFS 155614), 28/II/2009, I.B. Oliveira & C.W.N. Moura s.n (HUEFS 155641), 14/III/2009, I.B. Oliveira & C.W.N. Moura s.n (HUEFS 155698); Mata de São João, 14/III/2009, I.B. Oliveira et al. s.n. (HUEFS 155703), 1/IX/2014, M.A.Santos et al. s.n. (HUEFS 219787); Entre Rios, 26/VII/2009, I.B. Oliveira et al. s.n.(HUEFS 155748); Palmeiras, 26/II/2017, G.J.P. Ramos s.n. (HUEFS 244148); Piatã, 14/VII/2017, G.J.P. Ramos et al. s.n. (HUEFS 244149); Itaparica, 23/VII/2015, M.A. Santos & C.A. Ribeiro (HUEFS 219231); Pojuca, 15/XI/2014, M.A. Santos & G.J.P. Ramos (HUEFS 219820).

Note: *Tetmemorus granulatus* is one of the best-known species of the genus, with several records on different continents. This species is notable for its markedly fusiform cells with rounded, narrow apices. Despite this, certain morphotypes are commonly confused with *T. laevis*, especially those that are wider and with not so sharp apices. As these two species are commonly found in the same environments, and present a certain polymorphism, the differentiation of these taxa in some cases can be a little complicated, requiring a more detailed population analysis. However, *Tetmemorus granulatus* has cells that are strongly tapered towards the apices, generally longer than 150 µm, whereas those of *T. laevis* are slightly tapered towards the apices, which are largely rounded, and the cells are generally smaller than 150 µm.

Tetmemorus laevis var. *tropicus* is an example of how representatives of these two species can be confused. This variety was proposed by Krieger (1937), based on material from Sumatra and Java (Indonesia), to accommodate remarkably thinner specimens of *T. laevis*. We analyzed several samples from Bahia and this slender morphotype was quite common to be found, especially in samples from the northern coast of the state. However, such specimens are much closer morphologically to *T. granulatus* than to *T. laevis*, mainly due to their markedly fusiform contour with sharper apices.

From population studies, we have noticed a great morphological variation, mainly in the base and middle region of the semicells, which varied from little to very inflated. This variation was noticeable many times in the same cell (one semicell more inflated than the other), but in all studied specimens the fusiform pattern was maintained. A variable constriction near the apex was also observed in some specimens of *T. granulatus*, similar to that reported in *T. granulatus* var. *constrictus* Kurt Forster. However, we do not consider this feature a sufficient taxonomic character to support this variety, as it is quite variable at the population level. Thus, considering this broad phenotypic plasticity, *T. laevis* var. *tropicus* and *T. granulatus* var. *constrictus* were accounted here as heterotypic synonyms of *T. granulatus*.

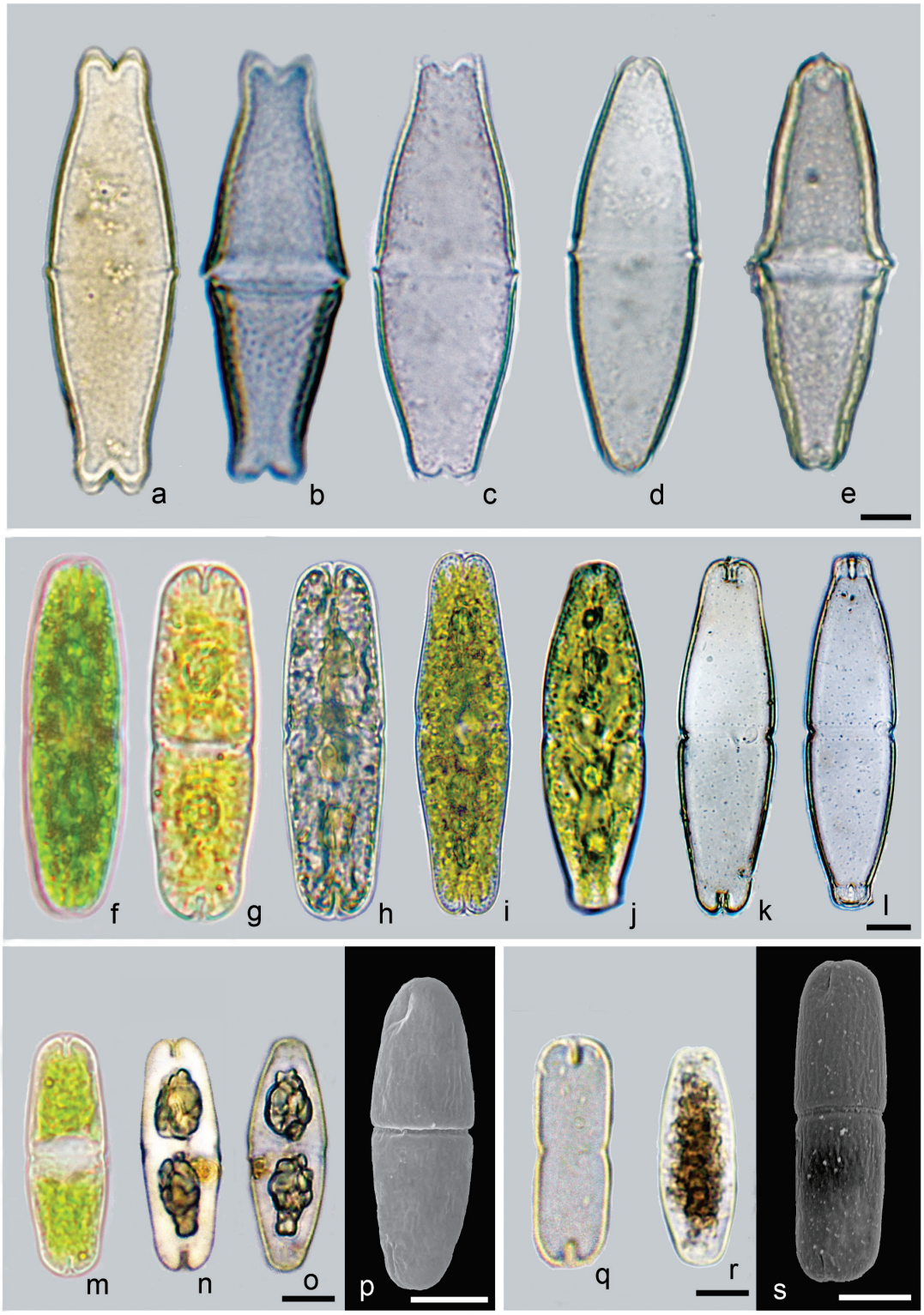

Figure 3. ***Tetmemorus*** **from of Brasil in light microscopy (a-o, q-r) and scanning electron microscopy (p, s). a-e)** ***T. furcatus*** **(a-c) front view, (d-e) lateral view. f-l)** ***T. laevis var. laevis*** **(f-i, k) front view, (j, l) lateral view. m-p)** ***T. laevis*** **var.** ***minutus*** **(m-n) front view, (n. p) lateral view. q-s)** ***T. laevis*** **var.** ***borgei*** **(q, s) front view, (r) lateral view. Bars - 10µm.**

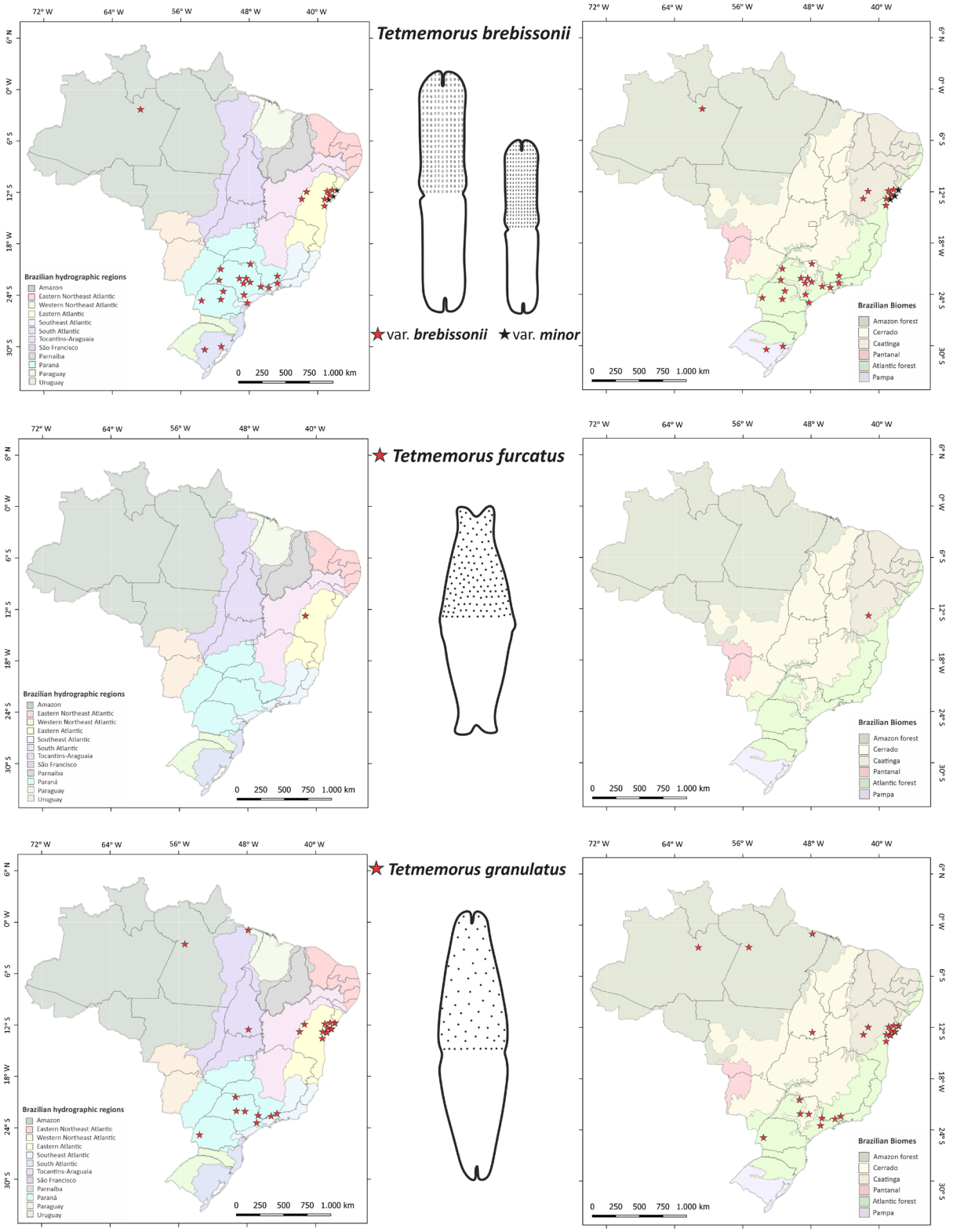

Figure 4. Geographic distribution of *Tetmemorus brebissonii, T. furcatus* and *T. granulatus* in the Brazilian watersheds and biomes.

Material excluded:

Grönblad 1945 (no illustration)
Nordstedt 1869 (no illustration)
Warming 1892 (no illustration)
Dickie 1880 (no illustration)

Tetmemorus laevis Ralfs ex Ralfs var. ***laevis*** (Figs. 1k-m, 3f-l)

Brit. Desm. 146, pl. 24, fig. 3. 1848.

Brazilian records accounted in *T. laevis* var. *laevis*

Tetmemorus laevis (Kützing) Ralfs var. *continuus* Nordstedt in Borge (1918: pl. 5, fig. 11)

Tetmemorus laevis (Kützing) Ralfs f. *brunneus* Kurt Förster & Eckert in Förster (1964: 347, Pl. 2, fig. 16; Pl. 39, fig. 21)

Tetmemorus laevis (Kützing) Ralfs forma in Förster (1964: 347, Pl. 2, fig. 17)

Tetmemorus brebissonii (Meneghini) Ralfs var. *minor* De Bary in Bicudo (1969: 440, Pl. 121, fig. 87)

Cells slightly fusiform, 2.8-3.5 times longer than wide, 78–137(-173) µm long, 22–48 µm wide, isthmus (8–) 16–28 (–31) µm wide, shallow median constriction, subrectangular median sinus, shallow; smooth lateral margins, concave in the median region, slightly tapered, widely rounded apices, median apical incision deep, linear; hyaline cell wall, irregularly punctuated with a horizontal row of fine pores close to the isthmus; globose zygospores surrounded by an envelope with conical angles.

Geographic distribution in Brazil: Rio de Janeiro (Bicudo & Picelli-Vicentim 1988, Sophia 1991), São Paulo (Borge 1918, Bicudo 1969, Bicudo & Bicudo 1969, Bicudo et al. 2014), Pará (Scott et al. 1965, Förster 1969), Paraná (Bittencourt-Oliveira 1993), Bahia (Förster 1964, Oliveira et al. 2014), Tocantins (Förster 1964).

Biomes: Atlantic Forest, Amazon, Cerrado.

Watersheds: Eastern Atlantic, Southeast Atlantic, Paraná, Amazon, Tocantins-Araguaia.

Habitat: oligo-mesotrophic environments such as ponds, rivers, floodplains, *Sphagnum* fields in mountainous areas.

Communities: plankton, metaphyton, periphyton.

Material examined: BAHIA: Entre Rios, 26/VII/2009, Oliveira et al. s.n. (HUEFS 155776, HUEFS 155779); Conde, 02/VIII/2009, Oliveira et al. s.n. (HUEFS 155802); Palmeiras, 26/II/2017, G.J.P. Ramos s.n. (HUEFS 244148); Esplanada, 14/III/2009, I.B. Oliveira & C.W.N. Moura s.n (HUEFS 155698), 14/III/2009, I.B. Oliveira & C.W.N. Moura s.n. (HUEFS 155692).

Note: *Tetmemorus laevis* is distinguished from other species of the genus by presenting slightly fusiform cells with widely rounded apices in the frontal view. In the material from Bahia, we noticed a certain polymorphism in the cell outline, with slightly fusiform to almost oblong cells. Another variable feature is the apex, which can be either rounded (more common) or slightly truncated in the lateral view. This phenotypic plasticity was also observed by Bicudo et al. (2014) based on analyses of material collected in São Paulo. These latter authors also pointed out the variation in the intensity and density of cell wall punctuation. However, in specimens from Bahia, we noticed little variation in the cell wall pattern, in which punctuations were generally evenly spaced. According to Coesel & Meesters (2007), *T. laevis* can be found in both acidophilic and oligotrophic aquatic environments as well as in subaerial environments associated with *Sphagnum* and on the surface of moist soils.

Material excluded:

Nordstedt 1878 (no illustration)
Børgesen 1891 (no illustration)
Möbius 1889 (no illustration)
Borge 1903, 1918 (no illustration)
Grönblad 1945 (no illustration)
Krieger 1950 (no illustration)

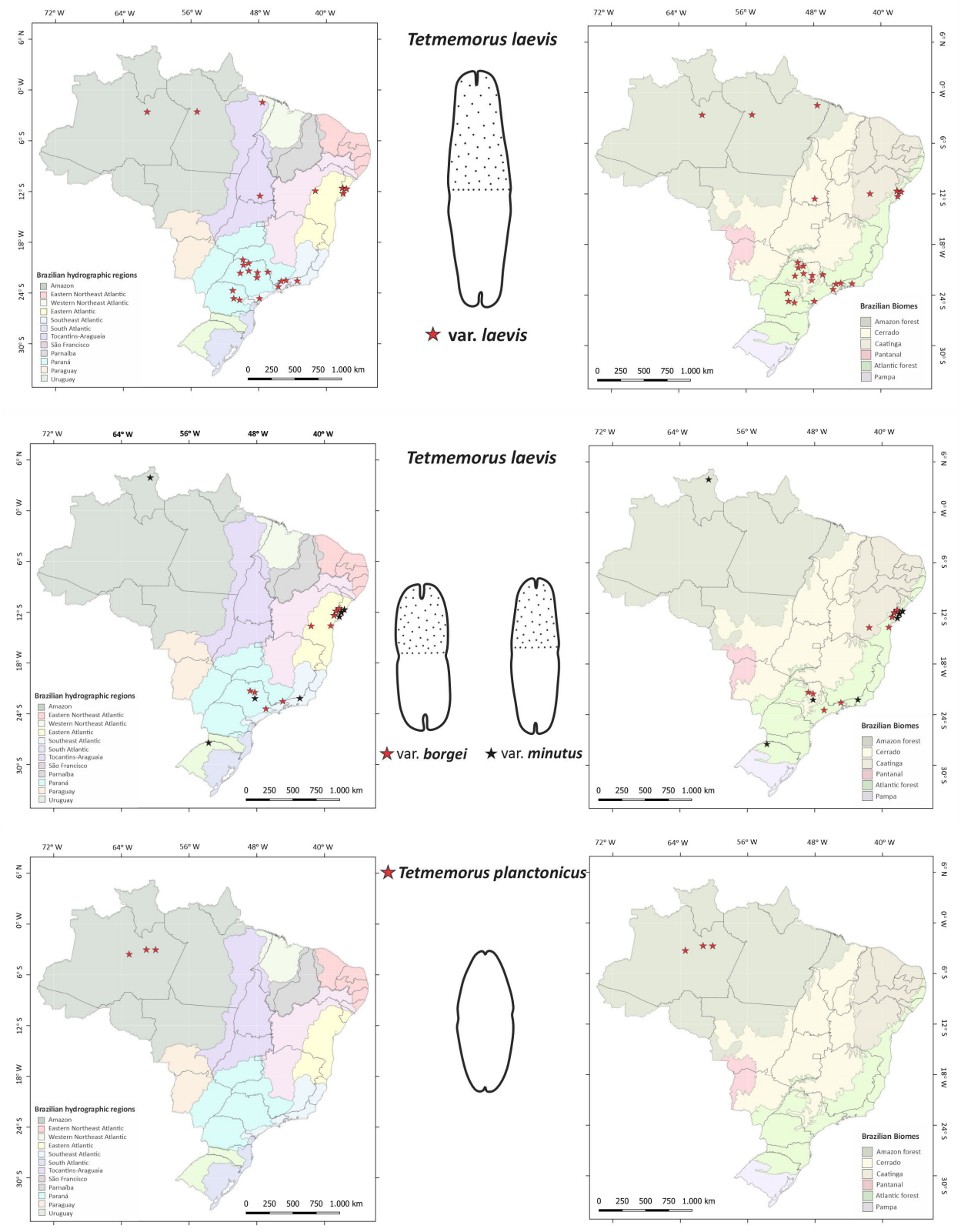

Figure 5. Geographic distribution of *Tetmemorus laevis* and *T. planctonicus* in the Brazilian watersheds and biomes.

Figure 6. Types of habitats where *Tetmemorus* taxa commonly found in Brazil. a) stream. b) *Sphagnum* field. c-d) temporary ponds. e) Population of *Tetmemorus laevis* with some algae associated.

Tetmemorus laevis Ralfs *ex* Ralfs var. ***borgei*** Kurt Förster (Figs. 1p-q, 3q-s)

Khumbu Himal. Ergebnisse 2: 35. 1965.

Brazilian record accounted in *T. laevis* var. *borgei*

Tetmemorus laevis Ralfs ex Ralfs var. *minutus* (De Bary) Willi Krieger in Oliveira et al. (2014: 29, figs. 78-79).

It differs from the nominate variety in having smaller, oblong cells, parallel margins, and broadly rounded apices. Cell about 2.7 times longer than wide, 37-69 (-92) µm long, 13-19 (-33) µm wide, isthmus 11-17 (-31) µm wide.

Geographic distribution in Brazil: São Paulo (Bicudo et al. 2014), Bahia (Martins & Bicudo 1987, Oliveira et al. 2014).

Biomes: Atlantic Forest, Cerrado.

Watersheds: Eastern Atlantic, Southeast Atlantic, Paraná.

Habitat: oligo-mesotrophic environments such as ponds, rivers, *Sphagnum* fields in mountainous regions.

Communities: plankton, metaphyton, periphyton.

Material examined: BAHIA: Mata de São João, 1/11/2009, I.B.Oliveira & C.W.N. Moura s.n. (HUEFS 155599); Entre Rios, 26/VII/2009, I.B. Oliveira et al. s.n. (HUEFS 155776, HUEFS 155779); Conde, 02/VIII/2009, I.B. Oliveira & C.W.N. Moura s.n. (HUEFS 155802), 12/VII/2009, I.B. Oliveira & C.W.N. Moura s.n. (HUEFS 155729); Rio de Contas, 01/V/2011, A.V.F. Lima s.n. (HUEFS 244147).

Note: Material identified as *Tetmemorus laevis* Ralfs ex Ralfs var. *minutus* by Oliveira et

al. (2014: 29, figs. 78-79) presents oblong cells, with parallel margins and widely rounded apices; therefore, it has been re-identified as var. *borgei*.

Tetmemorus laevis Ralfs ex Ralfs var. ***minutus*** (De Bary) Willi Krieger (Figs. 1n-o, 3m-o)

Rabenhorst's Krypt.-Fl. Deutschl., 2.Aufl., 13(1,3): 457. 1937.

Basionym: *Tetmemorus minutus* De Bary, Untersuch. Conjugaten, p.74, pl. 5, fig. 10. 1858.

Brazilian records accounted in *T. laevis* var. *minutus*

Tetmemorus laevis Ralfs ex Ralfs var. *borgei* Kurt Förster in Sophia (1991: 99, figs. 72-73)

Tetmemorus laevis Ralfs ex Ralfs var. *borgei* Kurt Förster in Oliveira et al. (2014: 29, figs. 76-77)

Tetmemorus minutus De Bary forma Borge (1918: 63, Pl. 5, fig. 12)

It differs from the nominate variety in having smaller cell dimensions, generally with slight conical semicells.

Cells 2.8-4 times longer than wide, 42-77 µm long, 15-20 µm wide, isthmus 14-17 µm wide.

Geographic distribution in Brazil: Bahia (Oliveira et al. 2014), Rio Grande do Sul (Sophia et al. 2005), São Paulo (Borge 1918), Roraima (Förster 1963), Pará (Scott et al. 1965), Rio de Janeiro (Sophia 1991).

Biomes: Atlantic Forest, Amazon, Cerrado.

Watersheds: Eastern Atlantic, Southeast Atlantic, South Atlantic.

Habitat: oligo-mesotrophic environments such as ponds, rivers, *Sphagnum* fields in mountainous areas.

Communities: plankton, metaphyton, periphyton.

Material examined: BAHIA: Mata de São João, 1/11/2009, I.B.Oliveira & C.W.N. Moura s.n. (HUEFS 155599); Entre Rios, 26/VII/2009, I.B.Oliveira et al. s.n. (HUEFS 155776, HUEFS 155779); Conde, 02/VIII/2009, I.B.Oliveira & C.W.N. Moura s.n. (HUEFS 155802).

Note: The records of *Tetmemorus laevis* var. *borgei* reported by Sophia (1991) and Oliveira et al. (2014) for the states of Rio de Janeiro and Bahia, respectively, were reidentified as *T. laevis* var. *minutus* because of the slightly fusiform outline of the cells, with more attenuated apices, differing from var. *borgei,* which has an approximately oblong outline, with parallel lateral margins and broadly rounded apices.

Tetmemorus planctonicus (Kurt Förster) Kurt Förster (Fig. 1r-s)

Arch. Hydrobiol. Suppl. 60(3) (Algol. Stud. 28): 247. 1981.

Basionym: *Tetmemorus laevis* (Kützing) Ralfs var. *planctonicus* Kurt Förster ex Kurt Förster.

Cells 2-3 times longer than wide, 28-38 µm long, 12.5-15µm wide, isthmus 12-14 µm, shallow median constriction, median apical incision shallow; semicells gradually tapering towards apices, which may be truncated or rounded; cell wall smooth, hyaline; one pyrenoid per semicell.

Geographical distribution in Brazil: Amazonas (Förster 1974).

Locations of the syntypes: Igarapé Laguinho, Municipalities of Anori, Maués and Canumã, Lago do Elias and Rio Canumä, Amazonas State, Brazil.

Biome: Amazon.

Watershed: Amazon.

Habitat: lakes, rivers, streams; pH = 5.1, temp. 28.7°C.

Community: plankton.

Note: This taxon was originally proposed by Förster (1974) as *Tetmemorus laevis* var. *planctonicus,* from planktonic material collected on the surface of aquatic environments at three localities (Igarapé Laguinho, Lago do Elias, and Rio Canumä) (Anori, Maués, and Canumã) in the State of Amazonas. However, at that time, Förster did not designate the type, which made the

taxon invalid. Many years later, Förster (1981a) finally validated the then variety by designating the iconotype "Pl.2, fig.14 in Förster (1974:154)". In the same year, Förster (1981b) re-evaluated the variety, raising it to the level of species *Tetmemorus planctonicus*.

It is notably one of the smallest species of the genus, showing the same cellular outline in both side and frontal views. As observed by Förster (1974), the studied populations showed morphological variations both at the apex of the cells (from rounded to truncated) and at the edges of the semicells (more or less convex). The cell wall is distinctive for being smooth and devoid of ornamentation or prominent pores, which also differs from other species. In addition, according to the authors, this species can be compared to *T. laevis* var. *minutus*, differing mainly by its smaller dimensions, rotational shape (front and side views), hyaline cell wall, and cell outline. Förster also highlighted the different ecological preferences of these two taxa: *T. laevis* var. *minutus* occurs more frequently in humid terrestrial environments, such as soils, rock surfaces, and *Sphagnum* fields, whereas *T. planctonicus* has only been recorded in plankton from aquatic environments.

From the present study, knowledge about the genus *Tetmemorus* from Brazil has been expanded. However, gaps remain in the distribution of this genus along that country, especially in the Central-West, North, and Northeast (Figures 4-5). Most records are for São Paulo and Bahia, which reflects the large numbers of samplings and of desmidiologists working in those states. Regarding the type of habitat, we noticed that representatives of this genus in Brazil are more commonly found in *Sphagnum* fields, shallow streams, and temporary ponds (Fig. 6), especially under acidic conditions, as pointed out by Coesel & Meesters (2007) for Europe. Furthermore, other desmids that generally occur with *Tetmemorus* include representatives of the genera *Actinotaenium*, *Cylindrocystis, Netrium*, and *Penium*.

As some species are possibly endemic to Brazil (*T. furcatus* and *T. planctonicus*), we recommend expanding the investigation of the diversity of this genus, mainly in mountainous regions. Finally, the use of taxonomic tools, such as SEM, physiology, molecular data, and geometric morphometry, is desirable to complement morphological analysis from light microscopy, as well as modelling to comprehend the relationship between the taxa of *Tetmemorus* and its distribution patterns.

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