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Article

Gomphonema Ehrenberg (Bacillariophyceae, Gomphonemataceae) of the São Francisco Falso River, Paraná, Brazil

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Abstract: *Gomphonema* Ehrenberg is a genus well represented in periphytic algal flora of epicontinental environments. The substrate colonization is facilitated by the secretion of mucilage by the pore field, allowing cell adhesion. Samples were scraped off and analyzed from vegetative portions of the macrophyte *Eichhornia azurea* Kunth, collected in São Francisco Falso River, located in Santa Helena City, Paraná State. The sampling occurred in four different sites, in four different periods, totaling 16 samples. The quantitative material analysis resulted in 28 identified taxa, in which *Gomphonema brasiliense* ssp. *pacificum*, *Gomphonema neoapiculatum* Lange-Bertalot, Reichardt & Metzeltin *Gomphonema pantropicum* Reichardt and *Gomphonema perapicatum* Metzeltin & Lange-Bertalot represented pioneer citations for Paraná diatomflorula. The ultrastructure observations of some species were crucial to distinguish a few taxa, as *Gomphonema brasiliense* and *Gomphonema brasiliensoide* D. Metzeltin, Lange-Bertalot & F. García-Rodríguez. We suggest future studies in this environment, once it has propitious characteristics to the development of epilithic diatoms. Moreover, phylogenetic studies are also recommended for a better distinction of taxa with a wide morphologic variation.
Keywords: *Lotic environment, diatoms, taxonomy, ultrastructure.*

Gomphonema Ehrenberg (Bacillariophyceae, Gomphonemataceae) do rio São Francisco Falso, Paraná, Brasil

Resumo: *Gomphonema* Ehrenberg é um gênero bem representado na flora algal perifítica de ambientes epicontinentais. A colonização de substratos é facilitada pela secreção de mucilagem pelo campo de poros permitindo a adesão das células. As amostras analisadas foram removidas das porções vegetativas da macrófita *Eichhornia azurea* Kunth, coletadas no rio São Francisco Falso, localizado no município de Santa Helena, Paraná. As coletas ocorreram em quatro estações de amostragem, em quatro períodos diferentes, totalizando 16 amostras. A análise qualitativa do material resultou na identificação de 28 táxons, sendo que *Gomphonema brasiliense* ssp. *pacificum*, *Gomphonema neoapiculatum* Lange-Bertalot, Reichardt & Metzeltin *Gomphonema pantropicum* Reichardt e *Gomphonema perapicatum* Metzeltin & Lange-Bertalot constituíram citações pioneiras para a diatomoflórula do Paraná. As observações da ultra-estrutura de algumas espécies foram decisivas para distinção entre alguns táxons, como por exemplo, *Gomphonema brasiliense* Grunow e *Gomphonema brasiliensoide* D. Metzeltin, Lange-Bertalot & F. García-Rodríguez. Sugerem-se futuros estudos desse ambiente, uma vez que o mesmo possui características propícias ao desenvolvimento de diatomáceas epilíticas, além de estudos filogenéticos para melhor distinção dos táxons com ampla variação morfológica.
Palavras-chave: *Ambiente lótico, diatomáceas, taxonomia, ultraestrutura.*

Introduction

In 1832, Ehrenberg proposed the genus *Gomphonema*, which comprises biraphide heteropolar species, with valves linear to linear-lanceolate and apical ends wider than basal ends (Round et al. 1990). The raphe is central, straight or slightly sinuous, with straight or slightly curved and expanded proximal endings, and slightly curved distal endings (Ludwig & Tremarin 2006). The striae can be uniseriate or partly to entirely biseriate, and one or rarely two isolated pore occur at the central region of the valve (Round et al. 1990; Levkov et al. 2016).

Gomphonema individuals are common in haptobenthic communities of epicontinental waters, and can present epipelic, epilithic or epiphytic habit. The epiphytic habit is facilitated due to the mucilaginous stalks or pads secreted by the pore fields located in the valve basal ends (Round et al. 1990, Wojtal 2003, Cox 2015).

The genus presents various cosmopolite species, generally well represented in richness and abundance in aquatic environments. However, the wide valve morphological variation hampers the group taxonomy (Krammer & Lange-Bertalot 1986, 1991). Several papers were published aiming to clarify the genus specific taxonomic issue, highlighting Reichardt & Lange-Bertalot (1991), Kociolek & Stoermer (1991), Kociolek & Kingston (1999), Reichardt (1997, 1999, 2001, 2007, 2008, 2015 a, b) and Levkov et al. (2016). Most of other existent contributions resulted from foreign floristic papers, or from South-American tropical samples examined by foreign researchers (Metzeltin & Lange-Bertalot 1998, 2007, Metzeltin et al. 2005).

Approximately 500 species had been registered for science so far (Fourtanier & Kociolek 2011), from which 25 were catalogued for Brazil by Eskinazi-Leça et al. (2013). Other diatom catalogues as Da Silva et al. (2011), accounted 21 species for Center-West Brazilian region, and Tremarin et al. (2009b) registered 40 species for Paraná State.

In Paraná State, the study about *Gomphonema* species carried out by Tremarin et al. (2009a) in samples collected in Maurício River – Curitiba metropolitan region – stands out, resulting in 19 identified taxa. In São Francisco Falso River, Silva et al. (2007) registered 26 *Gomphonema* species, presenting the occurrence in samples but not providing a taxonomic characterization of the populations or morphometric and meristic data.

We conducted a taxonomic study of *Gomphonema* species found adhered on the macrophyte *Eichhornia azurea* Kunth, using samples collected in São Francisco Falso River, in Santa Helena City, Paraná, Brazil.

Material and Methods

São Francisco Falso River (38.8 km^2) is the main former of the flooded area in Santa Helena City, west of Paraná. According to the park management plan, the geographic region is characterized by a transition between tropical climate, with two well defined rainy seasons, and temperate climate, in which the rain is distributed equally over the year, with average temperatures between 15 ºC and 25 ºC. The plan also characterizes the climate as humid subtropical, or mesothermal with pronounced summers (Cfa), with possibilities of a small dry during winter that would characterize the climate as Cw (Plano de Manejo, 1999).

The samples were collected in January, February, May and June 2004, in four sampling sites along São Francisco Falso River (Figure 1), with 4 collections and 16 samples. Petioles in adult stage (on average 50 cm long) were collected from the macrophyte *Eirchhornia azurea* Kunth., stored in 300 mL polyethylene flasks, and forwarded to the laboratory for epiphyte extraction.

The samples with epiphytic diatom were scraped off the petioles with a toothbrush and preserved in Transeau solution, in 1:1 proportion (Ludwig & Tremarin 2006). The biological material was housed at the herbarium of the Universidade Estadual do Oeste do Paraná (UNOP-Algae), Cascavel *campus*, and registered as shown on Table 1.

In the taxonomic analysis, subsamples were cleaned with KMnO4 and HCl (Simonsen 1974) modified by Moreira-Filho & Valente-Moreira (1981), and permanent slides were mounted using Naphrax®. Whenever was possible, at least 10 individuals were analyzed for taxon identification.

Samples were cleaned, placed in aluminium stubs and subjected to metallization with gold, in Balzers Union SCD 030. The slides were observed in Olympus BX60 light microscope (LM) equipped with an Olympus DP71 digital camera. The scanning electron microscopy (SEM) images were performed in a JEOL JSM 6360LV microscope (Eletronic Microscopy Center - Federal University of Paraná).

The terminology followed Barber & Haworth (1981) and taxonomic classification followed Cox (2015). For identification of the species we used specialized literature, as Hustedt (1930), Patrick & Reimer (1975), Krammer & Lange-Bertalot (1986, 1991), Metzeltin & Lange-Bertalot (1998, 2007), Metzeltin et al. (2005), Rumrich et al. (2000), as of other articles available in periodics.

Results and Discussion

The material analysis resulted in the determination of twenty-eight (28) *Gomphonema* taxa in specific level.

1. Taxa description:

Gomphonema affine Kützing var. *affine*. Bacill., p. 86, pl. 30, Figure. 54, 1844.
Figures. 2–4; 77–80.

Valves rhombic-lanceolate to lanceolate, apical and basal ends attenuate-rounded. Raphe-sternum narrow and linear. Central area unilaterally expanded, limited by a shortened stria. Raphe lateral, sinuous, with proximal ends dilated to pores. Striae parallel at median region to radiate toward the valve ends. Areolae conspicuous in OM. Stigma at the end of a median stria, slightly more shortened than the adjacent. Length: 43.3–80.3 µm; width: 10.2–13.2 µm; length/width ratio: 4.3–6.3; 8–10 striae in 10 µm; 18–22 areolae in 10 µm.

In SEM, stigma externally elliptic and striae uniseriate with areola in "C" shape (Figure 79). Raphe with proximal ends dilated into pores (Figure 79), curved to the opposite side of the stigma (Figure 77), and distal ends deflected and extending toward the valve mantle (Figue 78). Pore field formed by rounded poroids disposed in both sides of the terminal raphe fissure (Figure 80).

Comment: due to the wide metric amplitude already registered in many manuscripts for *Gomphonema affine* var. *affine*, we opted to follow the taxonomic review written by Reichardt (1999), since his work presents more limited meristic data (length: 36–88 µm; width: 9–13.6

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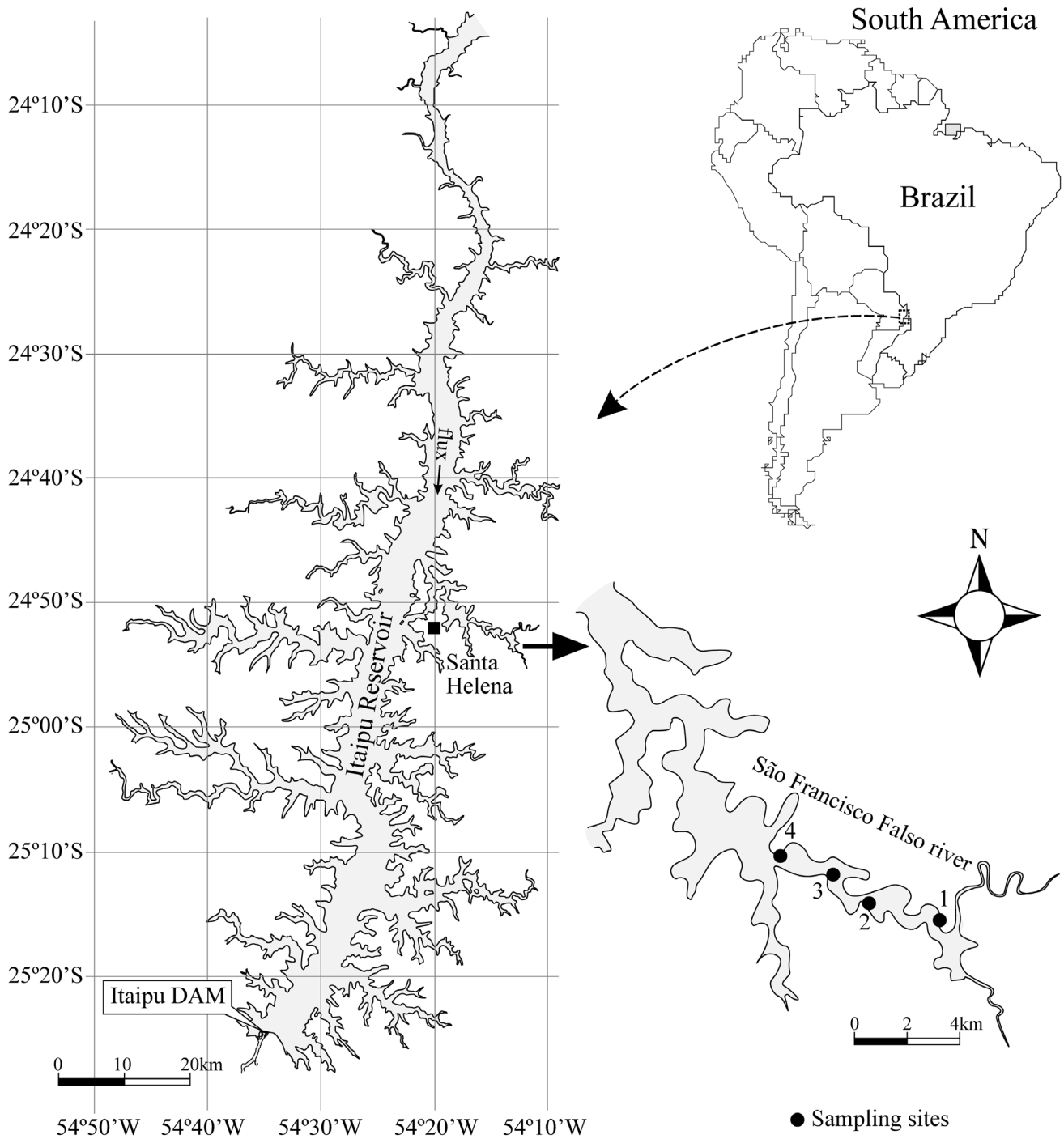


Figure 1. Sampling sites over São Francisco Falso River, in Santa Helena, Paraná State, Brazil.

µm 8–11 striae in 10 µm; 18–23 areolae in 10 µm), and illustrates a wide morphological variaton, including the lectotype.

Consulted literature: Reichardt (1999).

Geographic distribution for Paraná State: Almirante Tamandaré, Maringá, Matinhos, Pontal do Paraná, Porto Rico, Tijucas do Sul, Santa Helena (Tremarin et al. 2009b), Maringá (Moresco & Rodrigues 2016).

Occurrence in samples: UNOP-Algae 2235, 2236, 2237, 2245, 2246, 2259, 2260, 2261, 2263, 2264 and 2265.

Gomphonema affinopsis Metzeltin, Lange- Bertalot and García-Rodríguez. Iconogr. Diatomol. 15. p.77, pl.147, Figure. 9-14, 2005. Figures. 5–7; 81–84.

Valves clavate-lanceolate, apical ends widely attenuate-rounded and basal ends attenuate-rounded. Raphe-sternum linear, straight. Central area unilaterally expanded, limited by a shortened stria. Raphe lateral, sinuous, with proximal ends dilated in pore shape, slightly curved to the stigma. Striae parallel at median region to radiate toward the valve

Table 1. Reference of the São Francisco Falso river examined material housed at the herbarium of Universidade Estadual do Oeste do Paraná (UNOP-Algae), Cascavel *campus*, and its respective register number.

UNOP-Algae	Collect Date	Sampling site	Coordinates	Collector
2234	19/01/2004	S1	24º52'41''S e 54º13'35''W	N.C. Bueno
2235	19/01/2004	S2	24º52'28'' S e 54º15'17''W	N.C. Bueno
2236	19/01/2004	S3	24º51'52''S e 54º16'02''W	N.C. Bueno
2237	19/01/2004	S4	24º51'30''S e 54º17'11''W	N.C. Bueno
2244	03/02/2004	S1	24º52'41''S e 54º13'35''W	N.C. Bueno
2245	03/02/2004	S2	24º52'28''S e 54º15'17''W	N.C. Bueno
2246	03/02/2004	S3	24º51'52''S e 54º16'02''W	N.C. Bueno
2247	03/02/2004	S4	24º51'30''S e 54º17'11''W	N.C. Bueno
2258	10/05/2004	S1	24º52'41''S e 54º13'35''W	N.C. Bueno
2259	10/05/2004	S2	24º52'28''S e 54º15'17''W	N.C. Bueno
2260	10/05/2004	S3	24º51'52''S e 54º16'02''W	N.C. Bueno
2261	10/05/2004	S4	24º51'30''S e 54º17'11''W	N.C. Bueno
2263	17/06/2004	S1	24º52'41''S e 54º13'35''W	N.C. Bueno
2264	17/06/2004	S2	24º52'28''S e 54º15'17''W	N.C. Bueno
2265	17/06/2004	S3	24º51'52''S e 54º16'02''W	N.C. Bueno
2266	17/06/2004	S4	24º51'30''S e 54º17'11''W	N.C. Bueno

ends. Areolae generally conspicuous in LM. Stigma at the end of a median stria, slightly shorter than the adjacent. Length: 31–50.6 µm; width: 11–13.5 µm; length/width ratio: 2.5–4; 10–12 striae in 10 µm; 16–22 areolae in 10 µm.

In SEM, the valve internal view presents stigma transapically elongated (Figure 83), raphe with proximal ends curved toward the stigma (Figure 83), distal ends curved to the opposite side of stigma (Figures 81 and 82), ending in prominent helictoglossa (Figure 84). Striae uniseriate.

Comment: the species has valve structure similar to *Gomphonema mexicanum* Grunow, however some characteristics as areolae density and end morphology allow the distinction between these species, once *G. affinopsis* has 15–18 areolae in 10 µm and apice attenuate-rounded, while *G. mexicanum* has 21–25 areolae in 10 µm and apice subrostrate to rounded (Metzeltin & Lange-Bertalot 1998, Metzeltin et al. 2005). In the individuals sampled, by their characteristic attenuate-rounded apical end and by their wide variation in number of areolae 16–22 in 10 µm, the opted taxonomic identification is *G. affinopsis*. More specific studies are suggested with taxonomic clarification of the group.

Consulted literature: Metzeltin et al. (2005) and Metzeltin & Lange-Bertalot (1998).

Geographic distribution for Paraná State: Foz do Iguaçu (Bartozek et al. 2013).

Occurrence in samples: UNOP-Algae 2235, 2236, 2237, 2246, 2247, 2259, 2260, 2263, 2264 and 2265.

Gomphonema angustatum (Kützing) Rabenhorst. Fl. Europaea Alg., sect. 1, p. 283, 1864.
Figures. 8–11.

Valves lanceolate, apical ends subrostrate to attenuate and basal ends attenuate. Raphe-sternum linear, straight. Central area unilaterally expanded, limited by a shortened stria. Raphe straight to slightly sinuous, with proximal ends slightly curved toward the stigma. Striae radiate, more spaced at central region. Areolae inconspicuous. Stigma at the end of a median stria, slightly shorter than the adjacent. Length: 26.1–40.3 µm; width: 5.5–6 µm; length/width ratio: 4.9–6.7; 10–12 striae in 10 µm.

Comment: *Gomphonema angustatum* and *G. subangustatum* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito are similar, distinguishing by the higher metric amplitude of *G. augustatum* (length: 16–48 µm and width: 4–5.4 µm), and lower density of striae (10–14 striae in 10 µm) in relation to *G. subangustatum* (length: 10–36 µm and width: 5.3–6.7 µm, 13–18 striae in 10 µm) (Lange-Bertalot et al. 2003). Reichardt (1999) presents the species lectotype, showing a wide morphological variation at of the ends, and in the striae distribution. Levkov et al. (2016) states that morphological variations of valve and ends are considered common in the species, which were determinant characteristics for taxonomic determination of the São Francisco Falso River population.

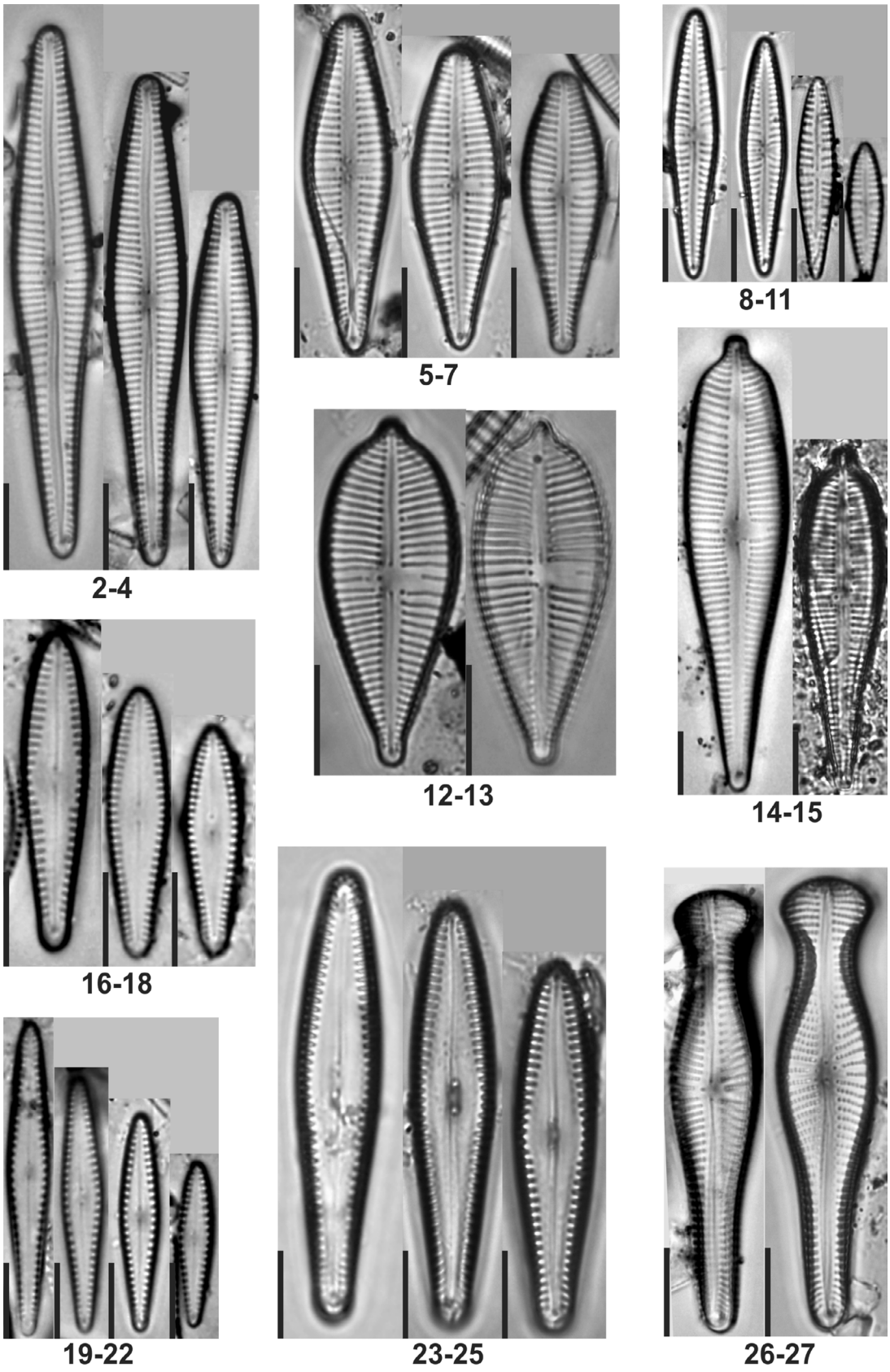
Consulted literature: Reichardt (1999) and Levkov et al. (2016).

Geographic distribution for Paraná State: Curitiba, Tijucas do Sul, Ponta Grossa, Fazenda Rio Grande (Tremarin et al. 2009b), São José dos Pinhais (Faria et al. 2010).

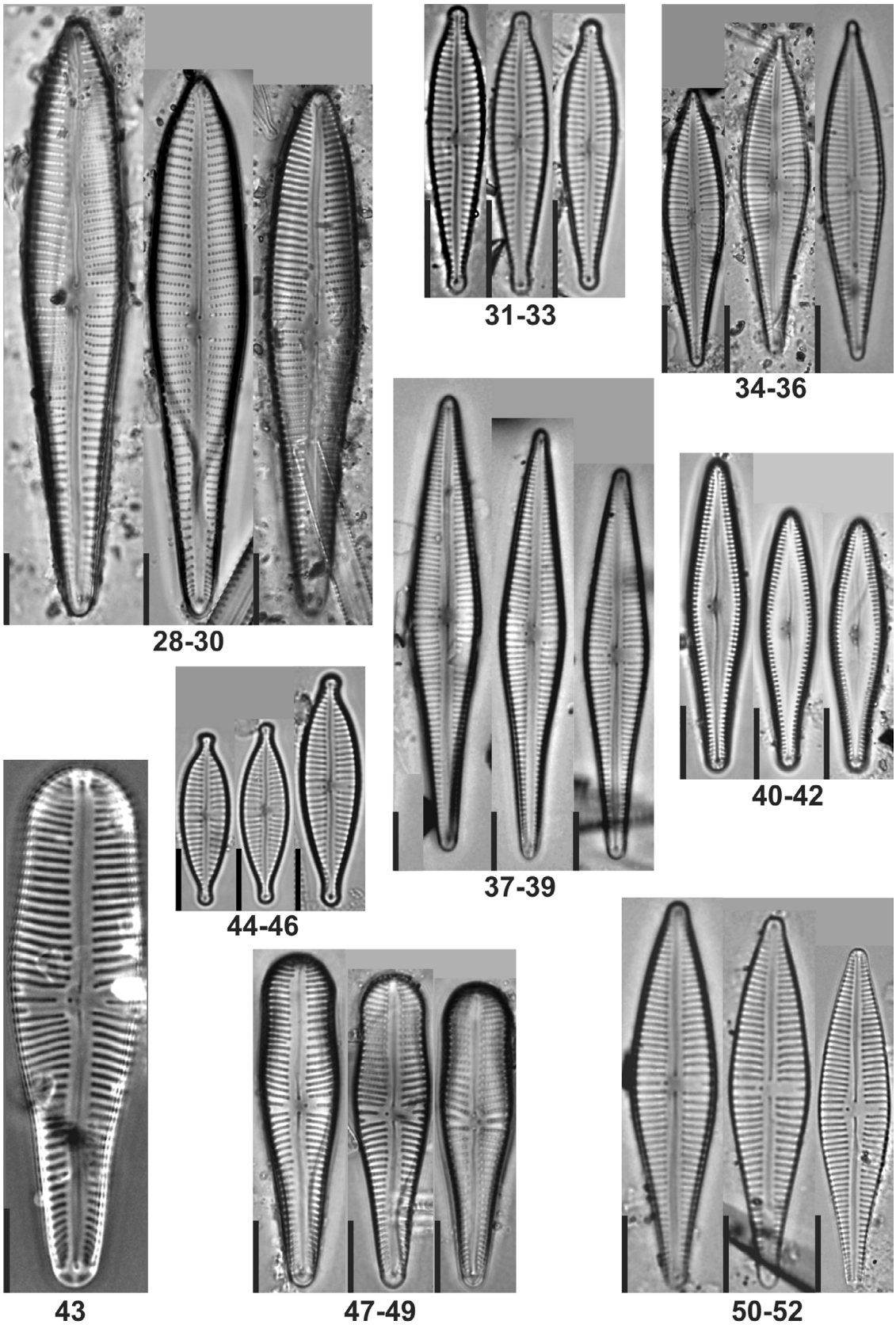
Occurrence in samples: UNOP-Algae 2234, 2235, 2236, 2237, 2245, 2246, 2258, 2259, 2260 and 2264.

Gomphonema augur Ehrenberg, Ber. Akad. Wiss. Berlin. p. 211, 1840.
Figures. 12–13.

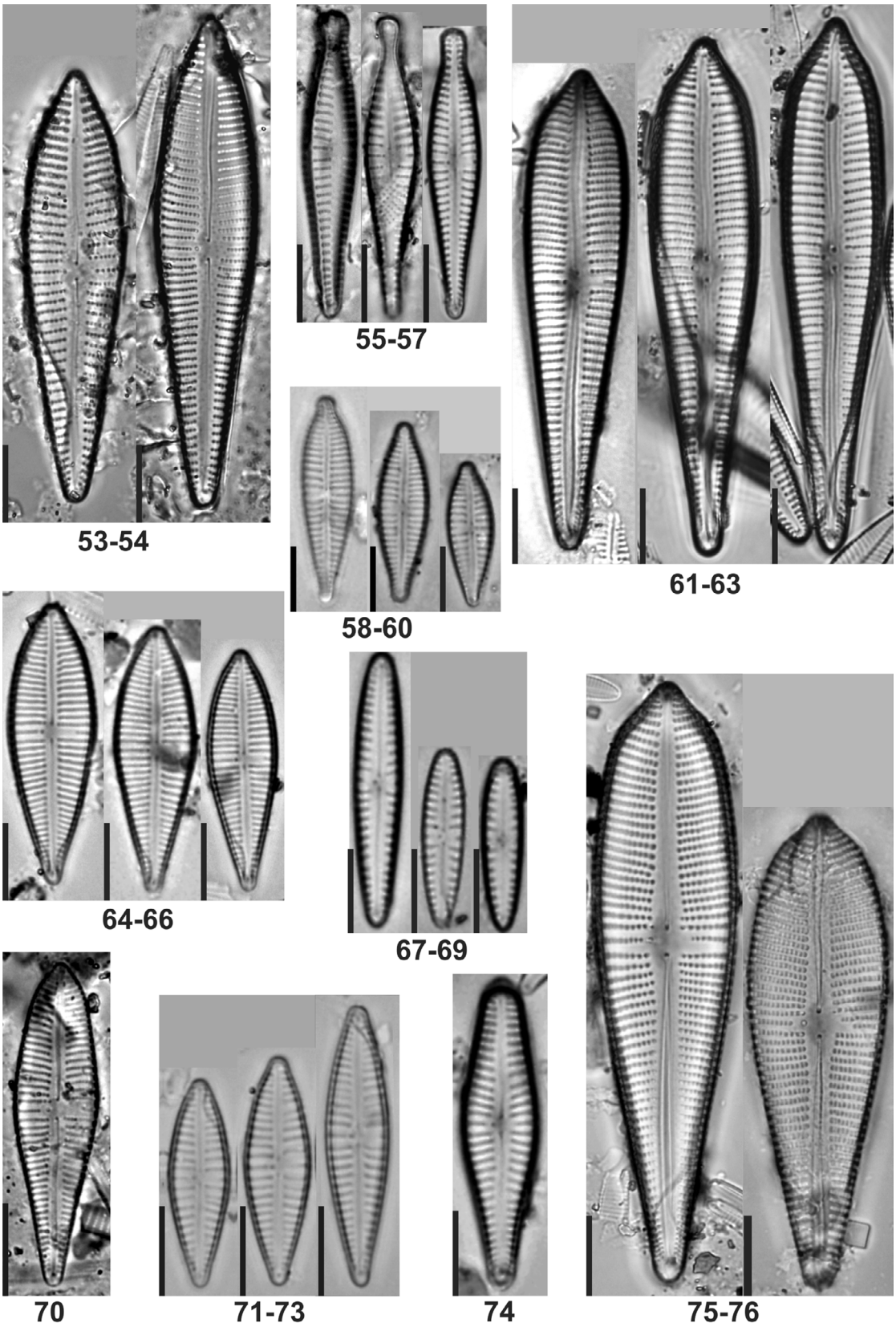
Valves clavate-lanceolate, apical ends subrostrate and basal ends subcapitate-rounded. Raphe-sternum linear. Central area expanded unilaterally, limited by a shortening stria. Raphe slightly sinuous, with proximal ends dilated into pores, slightly curved toward the stigma and distal ends indistinct. Striae parallel and more spaced at median region, and radiate toward the ends. Areolae inconspicuous. Stigma at a median stria. Length: 30.7–31.4 µm; width: 12.3–13.1 µm; length/width ratio: 2.3–2.5; 9–10 striae in 10 µm.



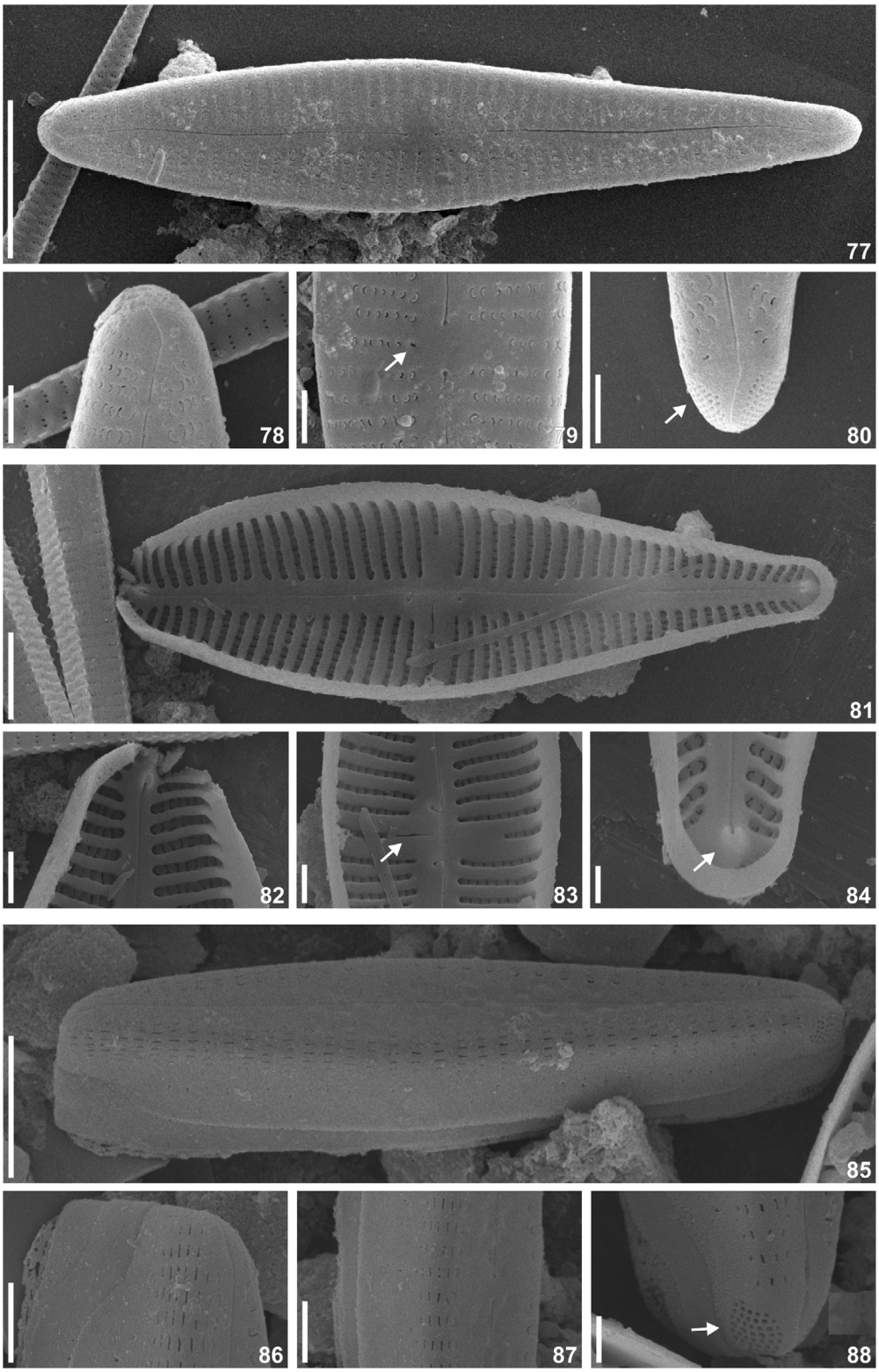
Figures 2–27. Figures. 2–4. *Gomphonema affine* var. *affine*. Figures. 5–7. *Gomphonema affinopsis*. Figures. 8–11. *Gomphonema angustatum*. Figures. 12–13. *Gomphonema augur*. Figures. 14–15. *Gomphonema augur* var. *turris*. Figures. 16–18. *Gomphonema brasiliense*. Figures. 19–22. *Gomphonema brasiliense* ssp. *pacificum*. Figures. 23–25. *Gomphonema brasiliensoide*. Figures. 26–27. *Gomphonema capitatum*. Scales: 10 µm.



Figures 28–52. Figures. 28–30. *Gomphonema contraturris*. Figures. 31–33. *Gomphonema exilissimum*. Figures. 34–36. *Gomphonema graciloides*. Figures. 37–39. *Gomphonema guaraniarum*. Figures. 40–42. *Gomphonema hawaiiense*. Figure. 43. *Gomphonema italicum*. Figures. 44–46. *Gomphonema lagenula*. Figures. 47–49. *Gomphonema laticollum*. Figures. 50–52. *Gomphonema naviculoides*. Scales: 10 µm.



Figures 53–76. Figures. 53–54. *Gomphonema neoapiculatum*. Figures. 55–57. *Gomphonema pantropicum*. Figures. 58–60. *Gomphonema parvulum*. Figures. 61–63. *Gomphonema perapicatum*. Figures. 64–66. *Gomphonema pseudoaugur*. Figures. 67–69. *Gomphonema pumilum*. Figure. 70. *Gomphonema salae*. Figures. 71–73. *Gomphonema saprophilum*. Figure. 74. *Gomphonema subclavatum*. Figures. 75–76. *Gomphonema turris* var. *coarctata*. Scales: 10 µm.



Figures 77–88. Figures. 77–80. *Gomphonema affine* var. *affine*, external view. Figure. 77. General valve view. Figure. 78. Detail of apical ends. Figure. 79. Detail of median region, proximal raphe ends and stigma opening (arrow). Figure. 80. Detail of basal ends showing the pore field (arrow). Figures. 81–84. *Gomphonema affinopsis*, internal view. Figure. 81. General valve view. Figure. 82. Detail of apical ends. Figure. 83. Detail of median region showing the stigma opening (arrow) and proximal raphe ends. Figure. 84. Detail of basal ends, showing the helictoglossa (arrow). Figures. 85–88. *Gomphonema brasiliense*, external view. Figure. 85. General valve view. Note the irregular depressions of the raphe–sternum and the longitudinally elongated striae. Figure. 86. Detail of apical ends. Figure. 87. Detail of median region. Figure. 88. Detail of basal ends showing the pore field (arrow). Scales: Figure. 77. 10 µm. Figures. 78–80; 82–83; 86–87. 2 µm. Figures. 81; 85. 5 µm. Figures. 84; 88. 1 µm.

 http://dx.doi.org/10.1590/1676-0611-BN-2017-0495

Comment: Janh (1986) stated that the shape "*turris*" is a morphological variation of *Gomphonema augur* and not a distinct species, explaining that the valve size is not a decisive criteria for species differentiation. Although *G. augur* presents a wide range of valve measures, Levkov et al. (2016) defined a more limited metric amplitude than other authors as Krammer & Lange-Bertalot (1997) (Length: 25–42 µm; width: 11.5–13 µm; Length: 17–130 µm; width: 8–20 µm respectively), but similar to individuals from São Francisco Falso River.

Consulted literature: Frenguelli (1933) and Krammer & Lange-Bertalot (1997).

Geographic distribution for Paraná State: Antonina, Curitiba, Ponta Grossa, Porto Rico, Capitão Leônidas Marques, Ipiranga, Telêmaco Borba, Sapopema, Londrina, Tijucas do Sul (Tremarin et al. 2009b), São José dos Pinhais (Faria et al. 2010).

Occurrence in samples: UNOP-Algae 2263.

Gomphonema augur var. *turris* (Ehrenberg) Lange-Bertalot in Krammer & Lange-Bertalot. Bibl. Diatomol., 9: 44-45; pl. 37, Figure. 1-7, pl. 38, Figure. 1-4, 8-12, 1985.
Figures. 14–15.

Valves clavate, apical ends rostrate, basal ends attenuate-rounded. Raphe-sternum linear. Central area slightly elliptic, expanded unilaterally, limited by shortening median striae. Raphe slightly sinuous, proximal ends dilated to pores, curved to the side of stigma and distal ends indistinct. Striae parallel at median region, more space between each other to radiate toward the ends. Areolae conspicuous. Stigma at the end of a median stria. Length: 54.3–71.5 µm; width: 13.9–16.4 µm; length/width ratio: 3.9–4.2; 9–10 striae in 10 µm; 18–20 areolae in 10 µm.

Comment: Krammer & Lange-Bertalot (1986) described *Gomphonema augur* var. *turris* with wide morphological variation (Length: 35–130 µm; width: 12–20 µm), creating considerable taxonomic uncertainty. Marquardt & Bicudo (2014) argued the same morphological variation, opting the individuals similar to the ones found in São Francisco Falso River as *G. augur* var. *turris* because of size disparity to *G. augur*. Therefore, population taxonomy was based on valve length and apical ends rostrate, which differentiate the species from other similars as *Gomphonema turris* var. *coarctata* and *Gomphonema perapicatum*.

Consulted literature: Krammer & Lange-Bertalot (1986).

Geographic distribution for Paraná State: Maringá (Moresco & Rodrigues 2016).

Occurrence in samples: UNOP-Algae 2236, 2260 and 2264.

Gomphonema brasiliense Grunow In Schneider (ed.), Naturw. Beitr. Kenntn. Kaukasusländer, p. 110, 1878.
Figures. 16–18; 85–88.

Valves clavate-lanceolate, apical ends rounded and basal ends attenuate-rounded. Rhape-sternum wide and lanceolate. Central area indistinct. Raphe slightly sinuous, with proximal ends slightly curved, dilated into pores, and distal ends indistinct. Striae transapical short, parallel at median region and slightly radiate toward the ends. Areolae inconspicuous. Stigma absent. Length: 21–32.9 µm; width: 5.9–7 µm; length/width ratio: 4–4.6; 13–15 striae in 10 µm.

In SEM, the raphe-sternum is ornamented by slight irregular depressions (Figure 85). Striae are uniseriate (Figure 85–88). The areolae are elongated longitudinally, except near the axial area, where they are "C" shaped . Pore field formed by rounded poroids are disposed in both sides of the terminal raphe fissure (Figure 88).

Comment: *Gomphonema demerarae* Grunow (Frenguelli) has valves with wider metrical amplitude (67–130 µm long and 15–21 µm wide) and lower striae density (8–9 in 10 µm) compared with *Gomphonema brasiliense* (Metzeltin & Lange-Bertalot 1998). However, Metzeltin et al. (2005) state that the latter differs from *Gomphonema brasiliensoide* by presenting uniseriate striae.

Tremarin et al. (2009a) presents *Gomphonema* sp. 4, very well illustrated in LM and SEM, which certainly refers to *G. brasiliense* described in this study.

Consulted literature: Krammer & Lange-Bertalot (1985), Metzeltin et al. (2005) and Tremarin et al. 2009a.

Geographic distribution for Paraná State: Fazenda Rio Grande (*Gomphonema* sp. 4, Tremarin et al. 2009a), Capitão Leônidas Marques, Barra do Chopim, Castro, Cruzeiro do Iguaçu, Curitiba, Jaguariaíva, Lindoeste, Maringá, Matinhos, Nova Prata do Iguaçu, Pontal do Paraná, Ponta Grossa, Salto do Lontra, Sengés, Três Barras do Paraná, Tijucas do Sul, Santa Helena, Santa Tereza do Oeste (Tremarin et al. 2009b), Maringá (Moresco & Rodrigues 2016).

Occurrence in samples: UNOP-Algae 2236, 2237, 2245, 2246, 2260 and 2265.

Gomphonema brasiliense ssp. *pacificum* G. Moser, Lange-Bertalot & D. Metzeltin, Bibl. Diatomol., 38:185-186; pl. 50, Figure. 1-6, 1998.
Figures. 19–22; 89–92.

Valves narrowly lanceolate, apical and basal ends attenuate-rounded. Raphe-sternum wide and lanceolate. Central area indistinct. Raphe straight, with proximal ends slightly dilated to pores, and distal ends indistinct. Transapical striae short, parallel to radiate toward the ends. Areolae inconspicuous. Stigma absent. Length: 19.9–26.6 µm; width: 4–4.9 µm; length/width ratio: 4.8–5.4; 12–14 striae in 10 µm.

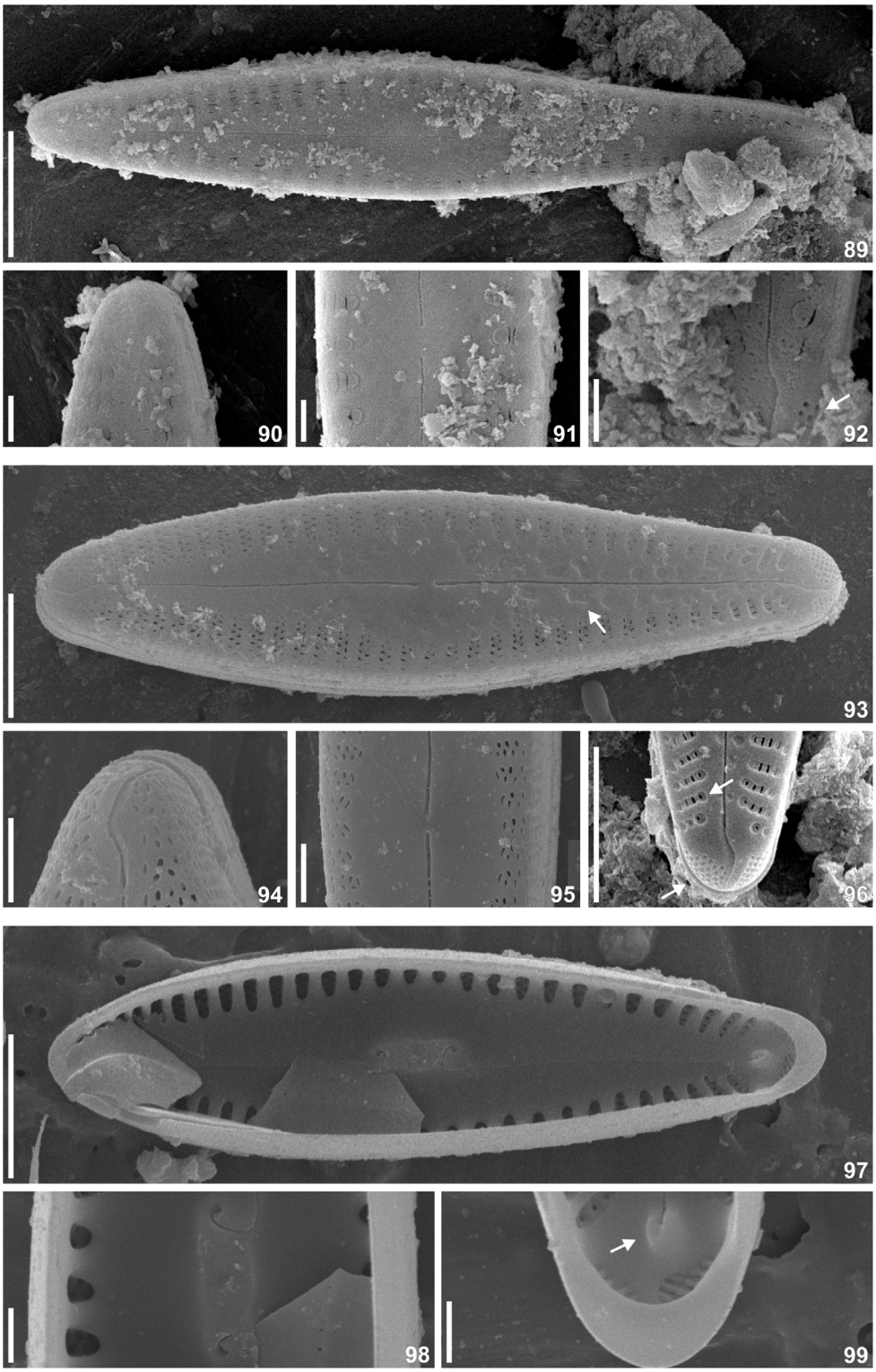
In SEM, distal raphe ends are slightly curved, extending onto the mantle (Figures 90 and 92). Striae are uniseriate (Figure 89). The areolae are elongated longitudinally, straight or in "C" shape (Figures 90–92). Pore field formed by rounded poroids (Figure 92).

Comment: *Gomphonema brasiliense* ssp. *pacificum* differentiates from *G. brasiliense* by its valves outline narrowly lanceolate, apical ends more attenuate and smaller dimensions (length 16–36 µm, width 3.5–4.5 µm) (Moser et al. 1998); in which the width of *G. brasiliense* is wider (length: 22–44 µm, width: 5.5–6.7 µm) (Metzeltin et al. 2005). SEM literature registers differentiating the species were not found. However, in the illustrations registered in this study, it is possible to observe that the areolae of *G. brasiliense* ssp. *pacificum* are more delicate and slightly curved (Figures 90–92), different from *G. brasiliense*, with more linear areolae (Figures 86–88). The individuals from São Francisco Falso River that are similar to those described by Moser et al. (1998) and Metzeltin et al. (2005), were classified as *G. brasiliense* ssp. *pacificum*.

Consulted literature: Moser et al. (1998).

Geographic distribution for Paraná State: first citation for Paraná.

Occurrence in samples: UNOP-Algae 2235, 2236, 2237, 2245, 2246, 2260 and 2265.



Figures 89–99. Figures. 89–92. *Gomphonema brasiliense* ssp. *pacificum*, external view. Figure. 89. General valve view showing the uniseriate striae. Figure. 90. Detail of apical ends, with distal raphe end curving onto the valve mantle. Figure. 91. Detail of median region. Figure. 92. Detail of basal ends showing the pore field (arrow) and the distal raphe end curving onto the valve mantle. Figures 93–99. *Gomphonema brasiliensoide*. Figure. 93. External valve view. Note the irregular depressions of the raphe–sternum (arrow). Figure. 94. Detail of external apical ends, showing the distal raphe end curving onto the valve mantle and the uniseriate striae. Figure. 95. Detail of median region. Figure. 96. Detail of basal ends, showing the uniseriate striae (top arrow) and the pore field (bottom arrow). Figure. 97. Internal valve view. Figure. 98. Detail of median region with proximal raphe ends curved in sickle shape. Figure. 99. Detail of basal ends, with distal raphe ends ending in prominent helictoglossa (arrow). Scales: Figures. 90–92; 98–99. 1 µm. Figures. 94–95. 2 µm. Figures. 89; 93; 96–97. 5 µm.

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Gomphonema brasiliensoide D. Metzeltin, Lange-Bertalot & F. García-Rodríguez, Iconogr. Diatomol. 15: 80; pl. 149, Figures 1-10, 2005.
Figures. 23–25; 93–99.

Valves clavate-lanceolate, apical and basal ends attenuate-rounded. Raphe-sternum wide and lanceolate. Central area indistinct. Raphe slightly sinuous, with proximal ends slightly curved and dilated into pores, and distal ends indistinct. Transapical striae short, parallel to radiate toward the ends. Areolae inconspicuous. Stigma absent. Length: 33–51.5 µm; width: 7.5–9.6 µm; length/width ratio: 4–6; 10–12 striae in 10 µm.

In SEM, the external view shows the raphe-sternum ornamented with weak irregular depressions (Figure 93). Striae are bisseriate along the valve and uniseriate at basal ends (Figures 93–96). The areolae are rounded to elongated longitudinally in both sides of the terminal raphe fissure (Figures 94–96). In internal view, the raphe presents proximal ends curved in sickle shape (Figure 98) and distal ends ending in prominent helictoglossa (Figure 99).

Comment: *Gomphonema brasiliensoide* has striae bisseriate observed in SEM, the main feature that differs it from *G. brasiliense*, which presents striae uniseriate (Metzeltin et al. 2005). The same literature describes *G. brasiliense* with valves less lanceolate, apical ends wider and more rounded, lower metrical amplitude (width: 5.5–6.7 µm) and higher striae density (14–15 in 10 µm) than in *G. brasiliensoide* (width 6.6–9 µm and 10–12 striae in 10 µm).

Consulted literatures: Krammer & Lange-Bertalot (1985) e Metzeltin et al. (2005).

Geographic distribution for Paraná State: Foz do Iguaçu (Bartozek et al. 2013, Nardelli et al. 2016).

Occurrence in samples: UNOP-Algae 2234, 2236, 2237, 2259, 2260, 2264 and 2265.

Gomphonema capitatum Ehrenberg, Die Infusionsthierchen als vollkommene Organismen: Ein Blick in das tiefere organische Leben der Natur. p. 217; pl. 18, Figure. 2, 1838.
Figures. 26–27.

Valves clavate with median region swollen, apical ends truncate-rounded, and basal ends rounded. Raphe-sternum linear. Central area elliptic, limited by irregular shortening median striae. Raphe slightly sinuous, with proximal ends dilated into pores and curved toward the stigma and distal ends hook shaped, curved oppositely to the stigma. Striae radiate. Areolae inconspicuous. Stigma at central region. Length: 49.5–51 µm; width: 9.7–11.7 µm; length/width ratio: 4.3–5.1; 10–11 striae in 10 µm; 13–19 areolae in 10 µm.

Comment: the analyzed specimens resemble the ones described by Reichardt (2001) as *Gomphonema capitatum* because the apical region is less constricted than *Gomphonema anglicum*, and rounded. *G. anglicum* presents a more accentuated constriction in the apical region and apice truncate-capitate, which are distinct characteristics of the studied population in this present work.

Consulted literature: Reichardt (2001).

Geographic distribution for Paraná State: Almirante Tamandaré, Curitiba, Ponta Grossa, Santa Helena, Fazenda Rio Grande (Tremarin et al. 2009b).

Occurrence in samples: UNOP-Algae 2264.

Gomphonema contraturris Lange-Bertalot & Reichardt in Lange-Bertalot, Bibl. Diatomol. 27:57, pl. 78, Figure. 2-9, pl. 79, Figure. 1-5, 1993.
Figures. 28–30.

Valves clavate-lanceolate, apical ends cuneate-apiculate and basal ends attenuate-rounded. Raphe-sternum linear. Central area unilaterally expanded, limited by the shortening of a median stria. Raphe sinuous and slightly lateral, proximal ends dilated into pores, curved toward the stigma, distal ends in hook shape, curved toward the opposite side of stigma. Striae parallel to radiate, more spaced between each other at central region. Areolae conspicuous. Stigma at the end of a median elongated stria. Length: 73.3–87.9 µm; width: 11.5–14.9 µm; length/width ratio: 5.6–6.4; 8–10 striae in 10 µm; 16–20 areolae in 10 µm.

Comment: *Gomphonema contraturris*, proposed by Lange-Bertalot & Reichardt in Lange-Bertalot (1993) presents morphology similar to São Francisco Falso River individuals, except for the widely subrostrate to subrostrate apical end. However, the authors synonymize *G. contraturris* with *G. acuminatum* var. *turris* (Ehrenberg) Cleve sensu Fricke, which has apice acuminate. Despite the disagreement, the characteristics of *Gomphonema contraturris* population were taken into account to taxonomically identify the specimens here described.

Consulted literature: Lange-Bertalot (1993) and Metzeltin et al. (2005).

Geographic distribution for Paraná State: Fazenda Rio Grande (Tremarin et al. 2009b), Curitiba (Bertolli et al. 2010).

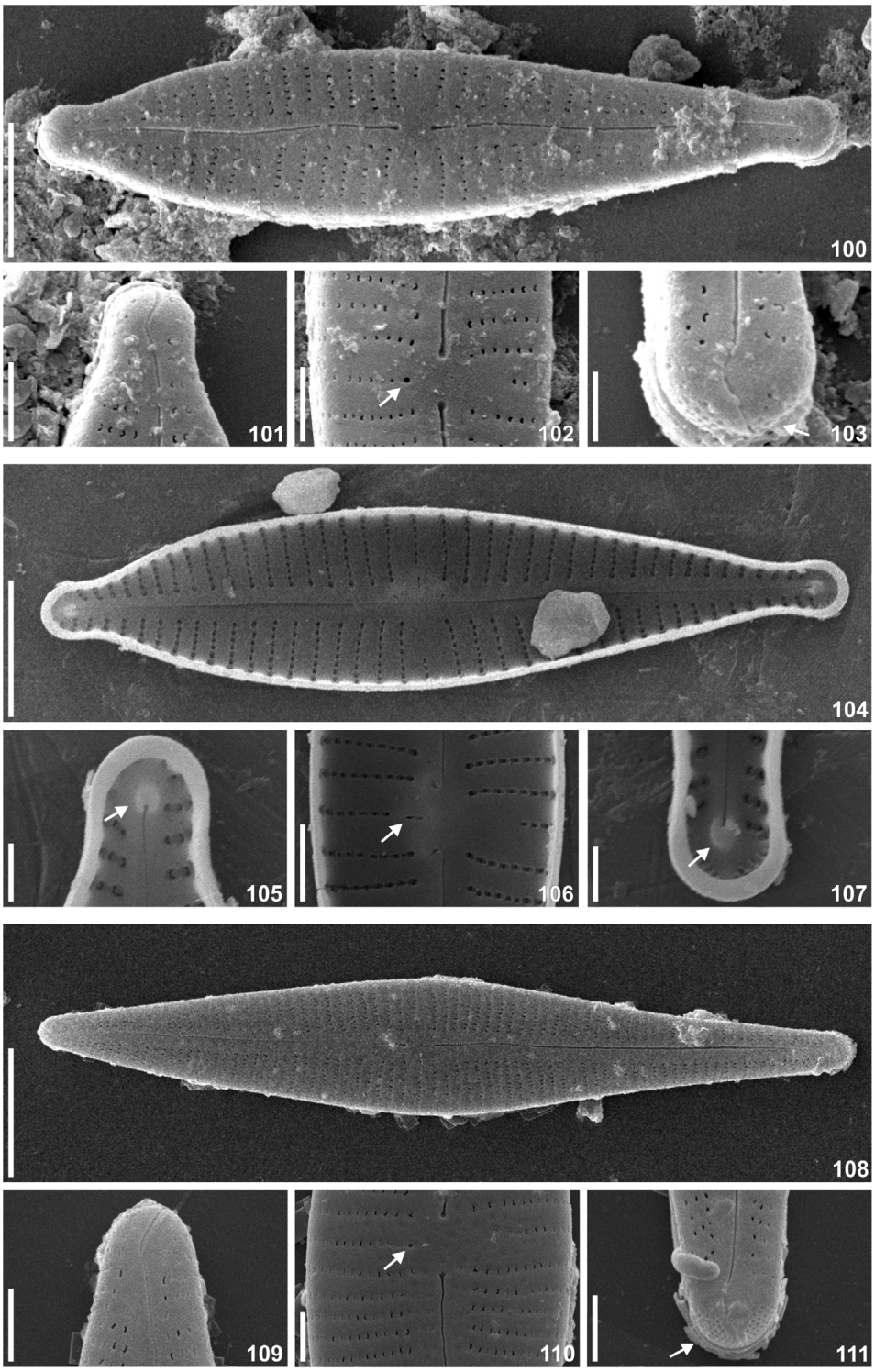
Occurrence in samples: UNOP-Algae 2259, 2260, 2263, 2264 and 2265.

Gomphonema exilissimum (Grunow) Lange-Bertalot et Reichardt in Lange-Bertalot & Metzeltin, Iconogr. Diatomol., 2:390, 1996.
Figures. 31–33; 100–107.

Valves elliptic-lanceolate, apical and basal ends subcapitate to rostrate. Raphe-sternum linear and narrow, extending toward the median region. Central area formed by shortening stria at one side and stria slightly shortened at the opposite side, with one stigma. Raphe slightly sinuous. Striae radiate to parallel, more spaced at central area. Areolae inconspicuous. Stigma at central region. Length: 31–38 µm; width: 6–7.3 µm; length/width ratio: 4–5.4; 11–12 striae in 10 µm.

In SEM, external view shows the proximal ends of the raphe straight to slightly curved and distal ends and stigma aperture rounded (Figures 101–103). Striae uniseriate (Figure 100). External areolae aperture mostly reniform (Figures 100–103). Internal valves view shows proximal raphe ends curved in sickle shape (Figure 106) and distal ends ending in prominent helictoglossa (Figures 105 and 107).

Comment: Jüttner et al. (2013) characterize the variety *exilissimum* carefully, differentiating it from *Gomphonema parvulum* according to the length x width ratio. In this case, the individuals that showed sizes between 4 and 6 µm were grouped as *G. exilissimum*, while the valves that presented ratio higher or lower were identified as *G. parvulum*. *Gomphonema lagenula*, also similar, can be differentiated by its assymetric valve shape, ends subcapitate to capitate and more pronounced, and by areolae shape, observed in SEM, generally more delicate and in "C" shape (Levkov et al. 2016). However, this separation does not solve all questions, since some individuals did not present this differentiation.



Figures 100–111. Figures. 100–107. *Gomphonema exilissimum*. Figure. 100. External valve view, with uniseriate and reniform striae. Figure. 101. Detail of external apical ends, with distal raphe end curving onto the valve mantle. Figure. 102. Detail of median region, showing the stigma opening (arrow) and the proximal raphe ends. Figure. 103. Detail of basal ends showing the pore field (arrow). Figure. 104. Internal valve view. Figure. 105. Detail of internal apical ends, showing the helictoglossa (arrow). Figure. 106. Detail of internal median region, showing the stigma opening (arrow). Figure. 107. Detail of internal basal ends, with distal raphe ends ending in prominent helictoglossa (arrow). Figures. 108–111. *Gomphonema guaraniarum*, external view. Figure. 108. General valve view, with uniseriate striae. Figure. 109. Detail of apical ends, with distal raphe ends curving onto the mantle. Figure. 110. Detail of median region, showing the stigma opening (arrow) and the proximal raphe endings. Figure. 111. Detail of basal ends, showing the pore field (arrow). Scales: Figures. 88; 103; 105; 107. 1 µm. Figures. 101–102; 106; 109–111. 2 µm. Figures. 100; 104. 5 µm. Figure. 108. 10 µm.

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Consulted literature: Krammer & Lange-Bertalot (1997) and Levkov et al. (2016).

Geographic distribution for Paraná State: General Carneiro, Santa Helena, cited as *Gomphonema exilissimum* (Grunow) Lange-Bertalot & Reichardt var. *exilissimum* (Tremarin et al. 2009b), Curitiba (Bertolli et al. 2010).

Occurrence in samples: UNOP-Algae 2234, 2235, 2236, 2245, 2246, 2260, 2263, 2265 and 2266.

Gomphonema graciloides Hustedt, Int Rev Ges Hydrobio., 50:391-41, 1965.
Figures. 34–36.

Valves lanceolate, apical ends apiculate and basal ends attenuate-rounded. Raphe-sternum narrow. Central area asymmetrical, limited by the shortening of a median stria. Raphe slightly lateral, sinuous, with proximal ends dilated into pore and curved toward the stigma, distal ends indistinct. Striae parallel, more spaced in median region and radiate toward the ends. Areolae conspicuous, sometimes not. Stigma at central region. Length: 35.5–49.6 µm; width: 8.2–10.5 µm; length/width ratio: 3.5–5.9; 10–12 striae in 10 µm; 20–21 areolae in 10 µm.

Comment: Hustedt (1965) proposed the species basing on Brazilian material (São Paulo – Itatiaia), musciculous, at 1000 m elevation. The sizes described by the author are: length 44 µm, width 10 µm, 12–15 striae and 28 areolae in 10 µm; reasonably close measurements to the ones found in São Francisco Falso River material. The individuals found in our study presented lower density of areolae than those registered by Reichardt (2015a). However, the author indicates that the striae of *G. graciloides* has variable areolae number. Besides, the population from São Francisco Falso river has individuals with ends more apiculate in comparison to the ones illustrated by Reichardt (2015a), although the valve morphology and sizes are similar alike (length: 22–56 µm, width: 7.5–9.4 µm, 12–16 striae in 10 µm).

Consulted literature: Hustedt (1965) and Reichardt (2015a).

Geographic distribution for Paraná State: Piraquara (Marra et al. 2016).

Occurrence in samples: UNOP-Algae 2235, 2236, 2245, 2246, 2252, 2260, 2263 and 2264.

Gomphonema guaraniarum Metzeltin & Lange-Bertalot in Lange-Bertalot, Iconogr. Diatomol., 18:147, pl. 212, Figure. 9-14, 2007.
Figures. 37–39; 108–111.

Valves rhombic-lanceolate, apical and basal ends attenuate-rounded. Raphe-sternum narrow and linear. Central area unilaterally expanded, limited by shortening median striae. Raphe slightly sinuous with proximal ends punctuate and slightly curved toward the stigma. Transapical striae, slightly radiate becoming parallel at central region. Areolae inconspicuous. Stigma at the end of central stria. Length: 58–77 µm; width: 10–12 µm; length/width ratio: 5.5–7; 10–12 striae in 10 µm.

In SEM, stigma are delicated and rounded, striae are uniseriate with areolae rounded to elongated longitudinally (Figures 108–111). Raphe ends are dilated into pores (Figure 110), and distal ends curved extending on valve mantle (Figures 109 and 111). Pore field are formed by rounded poroids disposed in both sides of terminal raphe fissure (Figure 111).

Comment: *Gomphonema gracile* Ehrenberg, similar species, has narrower lanceolate valves (5.5–9 µm) and apice less attenuate than *G. guaraniarum* (Metzeltin & Lange-Bertalot 2007).

Consulted literature: Metzeltin & Lange-Bertalot (2007) and Reichardt (2015a).

Geographic distribution for Paraná State: Piraquara (Marra et al. 2016).

Occurrence in samples: UNOP-Algae 2236, 2246, 2264 and 2265.

Gomphonema hawaiiense Reichardt, Nova Hedwigia 81(1-2): 115-144, pl. 2, Figures 1-13, 2005.
Figures. 40–42; 112–115.

Valves lanceolate to rhombic-lanceolate, apical and basal ends attenuate-rounded. Axial area wide and lanceolate. Central area indistinct. Raphe slightly sinuous, with proximal ends dilated into pore, curved toward the stigma and distal ends indistinct. Transapical shortened striae, parallel at median region and radiate at the ends. Areolae inconspicuous. Stigma at central region. Length: 27–55 µm; width: 7.5–10.5 µm; length/width ratio: 3–5; 14–16 striae in 10 µm.

In SEM, the distal raphe ends are curved to the opposite side of the stigma, while the proximal ends are dilated to pores, curved toward the stigma (Figures 112–115). The raphe is filiform and strongly sinuous (Figure 112). The striae are uniseriate over the valve and the areolae elongated longitudinally (Figures 113–115). The stigma is delicate and rounded (Figure 114). The pore field is formed by rounded poroids, disposed in both sides of the terminal raphe fissure (Figure 115).

Comment: *G. hawaiiense* is similar to *G. brasiliense*. Reichardt (2005) states that *G. brasiliense* presents valve shape claviform and stigma is absent. Morphological similarities between *G. hawaiiense* e *G. entolejum* Østrup are evident. However, *G. entolejum* has the valves rhombic-lanceolate larger in length (37.6–78.3 µm) than *G. hawaiiense* (24–48 µm), apices rounded, striae rougher and raphe less sinuous (Reichardt 2005).

Consulted literature: Reichardt (2005).

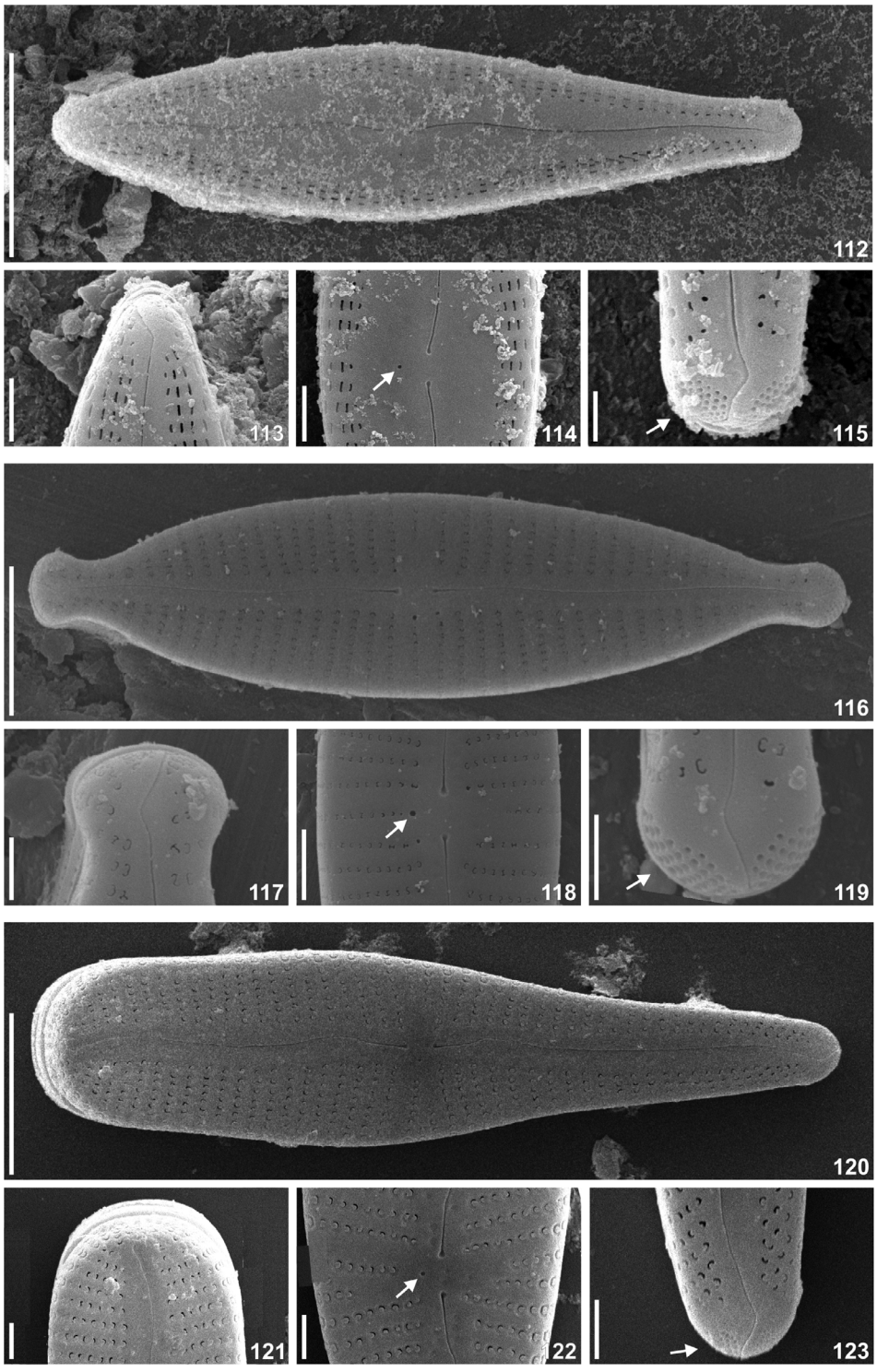
Geographic distribution for Paraná State: Fazenda Rio Grande (Tremarin et al. 2009b), Foz do Iguaçu (Bartozek et al. 2013), Piraquara (Marra et al. 2016).

Occurrence in samples: UNOP-Algae 2236, 2260 and 2265.

Gomphonema italicum Kützing, Bacill. P. 85, pl. 30, Figure. 75. 1844.
Basionym: *Gomphonema constrictum* var. *capitatum* sensu Grunow in Van Heurck, Syn. Diatom. Belgique, pl. 23, Figure. 7, 1880-85
Figure. 43.

Valves clavate, apical ends widely rounded, and basal ends acuminate-rounded. Raphe-sternum linear and narrow, extending slightly at central area. Central area limited by 2–3 striae irregularly shortened. Raphe slightly sinuous, proximal raphe ends slightly rounded and curved to the side of stigma, distal ends indistinct and curved to the opposite side of stigma. Striae radiate, irregularly shortened at median region. Areolae inconspicuous. Stigma at the end of central stria. Length: 59–60.6 µm; width: 14.2–15.3 µm; length/width ratio: 3.9–4.1; 8–10 striae in 10 µm.

Comment: the species differs from *G. laticollum* E. Reichardt by the more elongated valves. The analyzed specimens present striation more



Figures 112–123. Figures. 112–115. *Gomphonema hawaiiense*, external view. Figure. 112. Gerenal valve view, showing the raphe and striae shape. Figure. 113. Detail of apical ends. Figure. 114. Detail of median region, showing the stigma opening (arrow) and proximal raphe ends. Figure. 115. Detail of basal ends, showing the pore field (arrow). Figures 116–119. *Gomphonema lagenula*, external view. Figure. 116. General valve view, showing the raphe and striae shape. Figure. 117. Detail of apical ends, with distal raphe end curving onto the valve mantle. Figure. 118. Detail of median region, showing the stigma opening (arrow) and the proximal raphe endings. Figure. 119. Detail of basal ends, showing the pore field (arrow). Figures. 120–123. *Gomphonema laticollum*. Figure. 120. External valve view, showing the areolae shape. Figure. 121. Detail of apical ends. Figure. 122. Detail of median region, showing the stigma opening (arrow) and proximal raphe ends. Figure. 123. Detail of basal ends, showing the pore field (arrow). Scales: Figures. 115; 117; 119. 1 µm. Figures. 113–114; 118; 121–123. 2 µm. Figure. 116. 5 µm. Figures. 112; 120. 10 µm.

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delicate and valve body poles undifferentiated, similar to the specimens described as *G. italicum* Kützing (Reichardt 2001), characteristics considered criteria for the taxonomic determination.

Consulted literature: Reichardt (2001).

Geographic distribution for Paraná State: Curitiba, Ponta Grossa (Tremarin et al. 2009).

Occurrence in samples: UNOP-Algae 2264.

Gomphonema lagenula Kützing, Die Kieselschaligen Bacillarien oder Diatomeen. p. 85, pl.30, Figure. 60. 1844.
Figures. 44–46; 116–119.

Valves lanceolate to elliptic-lanceolate, apical ends subcapitate to subrostrate and basal ends subcapitate. Raphe-sternum linear and narrow. Central area limited by the shortening of a median stria. Raphe straight, proximal ends curved to the stigma. Striae parallel to slightly radiate, median striae farther from the adjacent. Areolae inconspicuous. Stigma at the end of a median stria. Length: 23–32.8 µm; width: 7–9.3 µm; length/width ratio: 3–5; 11–13 striae in 10 µm.

In SEM, the raphe presents proximal ends dilated into pores (Figure 118) and distal ends curved to the opposite side of the stigma (Figures 117 and 119). Striae uniseriate (Figures 116–119). Pore field formed by rounded poroids that are disposed in both sides of the terminal raphe fissure (Figure 119).

Comment: the species presents similar morphology to *Gomphonema parvulum* (Kützing) Kützing. However, it differs by the rostrate apical end presented by *G. parvulum* and subcapitate to capitate showed by *G. lagenula* (Abarca et al. 2014). This species has large morphological variation in the analyzed community as well as in the literature, therefore making the taxonomic identification confuse and complex. Studies about the molecular biology of the valve morphology can assist future identification of species.

Consulted literature: Abarca et al. (2014) and Levkov et al. (2016).

Geographic distribution for Paraná State: Curitiba, Fazenda Rio Grande, General Carneiro, Rio Negro, Santa Helena (Tremarin et al. 2009b), São José dos Pinhais (Faria et al. 2010), Pinhais (Silva et al. 2010), General Carneiro (Santos et al. 2011), Maringá (Moresco & Rodrigues 2013), Maringá (Moresco & Rodrigues 2016).

Occurrence in samples: UNOP-Algae 2234, 2235, 2236, 2237, 2244, 2245, 2247, 2258, 2259, 2260, 2261, 2263, 2264, 2265 and 2266.

Gomphonema laticollum Reichardt, In Lange-Bertalot Festschrift. Studies on Diatoms, p. 199, pl. 5, Figure. 1-14. 2001.
Figures. 47–49; 120–126.

Valves clavate, apical ends widely rounded and basal ends acuminate-rounded. Raphe-sternum linear and narrow, slightly elongating at the valve middle. Central area limited by 2–3 striae irregularly shortened. Raphe slightly sinuous, proximal raphe ends slightly rounded and curved to the stigma side, distal ends indistinct and curved to the opposite side of the stigma. Striae radiate toward the ends, irregularly shortened at the valve median region. Areolae generally conspicuous. Stigma at the median stria end.

Length: 42.2–62.7 µm; width: 10.8–13 µm; length/width ratio: 4.3–5.2; 9–10 striae in 10 µm; 20–21 areolae in 10 µm.

In SEM, external view shows proximal ends of the raphe straight to slightly curved and distal ends and stigma delicated and rounded (Figures 121–123). Striae uniseriate with areola in "C" shape (Figure 120). Internal valve view shows proximal raphe ends hooked and stigma elongated (Figures 124–126).

Comment: São Francisco Falso River individuals are similar to holotype described by Reichardt (2001), although slightly bigger (length: 26–57 µm; width: 9.6–13.3 µm). Population is also alike to *Gomphonema laticollum* morphotype I from Levkov et al. (2016) (length: 23–62 µm; width: 9–12.5 µm), possessing valve margins slightly constricted in apical ends.

Consulted literature: Reichardt (2001) and Levkov et al. (2016).

Geographic distribution for Paraná State: Fazenda Rio Grande, Santa Helena (Tremarin et al. 2009b), Curitiba (Bertolli et al. 2010), Pinhais (Silva et al. 2010), Foz do Iguaçu (Bartozek et al. 2013).

Occurrence in samples: UNOP-Algae 2260 and 2265.

Gomphonema naviculoides W. Smith, Synopsis of British Diatomaceae, p. 98, pl. 32-60, 1856.
Figures. 50–52; 127–130.

Valves rhombic-lanceolate, apical and basal ends attenuate-rounded. Raphe-sternum linear and narrow. Central area asymmetric, expanded unilaterally and limited by shortened median striae. Raphe straight to slightly lateral with proximal ends punctuate and slightly curved toward the stigma. Transapical striae slightly radiate becoming parallel at central region. Areolae inconspicuous. Stigma at the median stria end. Length: 41.2–49.7 µm; width: 10–11.4 µm; length/width ratio: 3.9–4.8; 10–11 striae in 10 µm.

In SEM, the species presents stigma externally elliptic (Figure 129). Raphe slightly lateral and sinuous (Figure 127), with proximal ends dilated into pores (Figure 129) and distal ends extending on valve mantle, both curved to the same side of the stigma (Figures 128 and 130). Striae uniseriate, areolae "C" shaped (Figures 127–130). Pore field formed by rounded poroids, disposed in both sides of the terminal raphe fissure (Figure 130).

Comment: *Gomphonema naviculoides* resembles *Gomphonema guaraniarum* by their valve morphology. However, they differ in valve measures, since *G. guaraniarum* is 50–90 µm long and 10.3–12 µm wide (Metzeltin & Lange-Bertalot 2007), which are the criteria that differentiate the population from São Francisco Falso River.

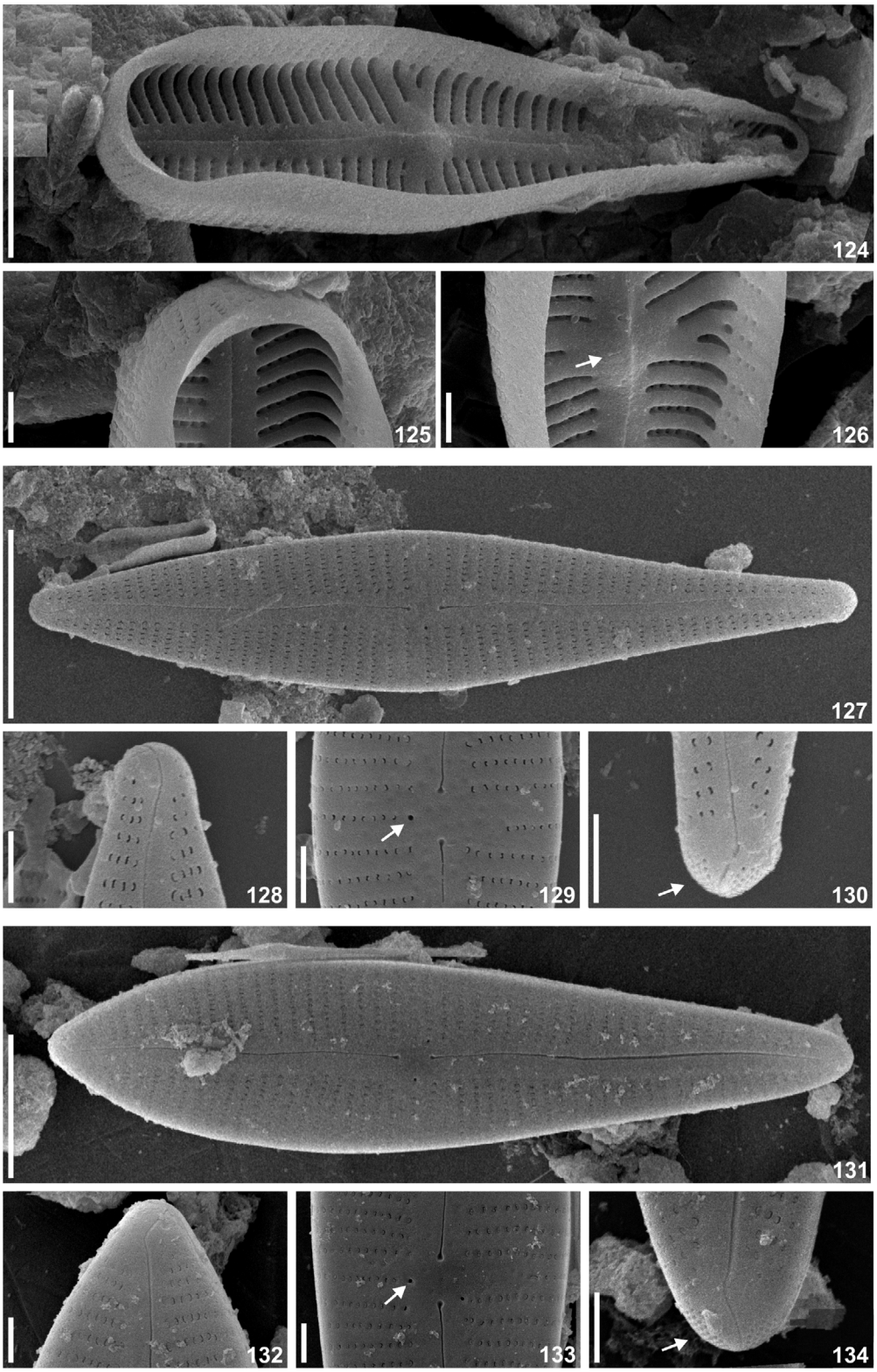
Consulted literature: Reichardt (2015a).

Geographic distribution for Paraná State: Piraquara (Marra et al. 2016).

Occurrence in samples: UNOP-Algae 2236, 2264 and 2265.

Gomphonema neoapiculatum Lange-Bertalot, Reichardt et Metzeltin In: Metzeltin & Lange-Bertalot, Iconogr. Diatomol. 5:120-121; pl. 157, Figure. 6-9, 1998.
Figures. 53–54; 131–134.

Valves clavate, apical ends cuneate-subrostrate and basal ends attenuate-rounded. Raphe-sternum linear. Central area asymmetric and limited by the shortening of the median striae. Raphe slightly sinuous, with proximal ends dilated into pores and curved toward to the stigma, distal ends curved in hook shape. Striae parallel at median region, more spaced between each other to radiate toward the ends. Areolae conspicuous. Stigma at the median stria end. Length: 63.2–65.5 µm; width: 12.8–15 µm; length/width ratio: 4.3–4.9; 8–9 striae in 10 µm; 16–17 areolae in 10 µm.



Figures 124–134. Figures. 124–126. *Gomphonema laticollum*. Figure. 124. Internal valve view. Figure. 125. Detail of apical ends. Figure. 126. Detail of median region, showing the stigma opening (arrow). Figures. 127–130. *Gomphonema naviculoides*, external view. Figure. 127. General valve view, showing raphe and areolae shape. Figure. 128. Detail of apical ends, with distal raphe end curving onto the valve mantle. Figure 129. Detail of median region, showing the stigma opening (arrow) and proximal raphe ends. Figure. 130. Detail of basal ends, showing the pore field (arrow). Figures. 131–134. *Gomphonema neoapiculatum*, external view. Figure. 131. General valve view, showing striae and areolae shape. Figure. 132. Detail of apical ends, with distal raphe end curving onto the valve mantle. Figure. 133. Detail of median region, showing the stigma opening (arrow) and proximal raphe ends. Figure. 134. Detail of basal ends, showing the pore field (arrow). Scales: Figures. 125–126; 128–130; 132–134. 2 µm. Figures. 124; 127; 131. 10 µm.

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In SEM, the species presents stigma externally elliptic (Figure 133). Striae uniseriate, areolae "C" shaped (Figures 131–134). Pore field formed by rounded poroids that are disposed in both sides of the terminal raphe fissure (Figure 134).

Comment: according to Metzeltin & Lange-Bertalot (1998), even though *G. neoapiculatum* is similar to *Gomphonema apicatum* Ehrenberg, the last one presents valves more lanceolate and less clavate, with apical ends narrowly cuneate-rounded to slightly apiculate. The same book describes *G. neoapiculatum* with valves clavate and apical ends apiculate to subrostrate, similar to the population found in São Francisco Falso River population. Other similar taxon, *Gomphonema perapicatum* Metzeltin & Lange-Bertalot, can be distinguished by its wider valves (12–13.5 µm) and lower striae and areolae density (7–8 and 15–18 in 10 µm, respectively) (Metzeltin & Lange-Bertalot 2007). However, considering the measures overlapping, we choose the shape of the valve, clearly more clavate, and subrostrate ends in *G. perapicatum* as criteria to separate both taxa.

Consulted literature: Metzeltin & Lange-Bertalot (1998).

Geographic distribution for Paraná State: first citation for Paraná.

Occurrence in samples: 2259, 2260, 2264 and 2265.

Gomphonema pantropicum Reichardt, Fottea 15(1):27-38, pl. 1, Figure. 120, 2015.
Figures. 55–57.

Valves clavate-lanceolate, presenting intumescence at central region, apical ends capitate and narrowly rounded, and basal ends attenuate-rounded. Raphe-sternum linear, narrow, slightly enlarging toward the median region. Central area irregularly expanded, limited by the shortening of a median stria. Raphe slightly sinuous, with proximal ends dilated into pores, slightly curved to the stigma side, distal ends indistinct. Striae radiate, more spaced at central region. Areolae inconspicuous. Stigma at median stria end. Length: 37.3–38.8 µm; width: 6.5–6.9 µm; length/width ratio: 5.4–5.6; 9–10 striae in 10 µm.

Comment: *G. pantropicum* Reichardt was considered until just recently as *G. subtile* Ehrenberg. Marquardt & Bicudo (2014) described this last taxon with apical end rostrate to capitate, characterized by the strong constriction of the valve close to the ends. According to the review written by Reichardt (2015b), this characteristic belongs to *G. pantropicum*, once *G. subtile* has apical end extended and widely capitate.

The identification of *G. pantropicum* was identified as *G. subtile* by Marra et al. (2016), also reflect the recent alteration of this taxon. Roy & Keshri (2015) describe a similar taxon, identifying it as *Gomphonema* cf. *pantropicum*. The individuals analyzed in this work match with the description given by Reichardt (2015b), therefore being identified as *G. pantropicum*.

Consulted literature: Reichardt (2015b).

Geographic distribution for Paraná State: first citation for Paraná.

Occurrence in samples: UNOP-Algae 2264, 2265 and 2266.

Gomphonema parvulum (Kützing) Kützing, Sp. Alg., p. 65. 1849.
Figures. 58–60; 135–138.

Valves lanceolate to elliptic-lanceolate, apical ends subrostrate and basal ends attenuate-rounded. Raphe-sternum linear, narrow. Central area irregular and narrow, limited by a irregular shortening of a median stria. Raphe straight to slightly sinuous, proximal ends curved to the stigma side. Striae parallel to slightly radiate at the ends. Areolae inconspicuous. Stigma at the median stria end. Length: 18–31 µm; width: 6–7.5 µm; length/width ratio: 2.9–4.3; 10–12 striae in 10 µm.

In SEM, the species presents stigma externally elliptic (Figure 137). Striae uniseriate, areolae "C" shaped (Figures 135–138). Pore field formed by rounded poroids disposed in both sides of the terminal raphe fissure (Figure 138).

Comment: *Gomphonema parvulum* (Kützing) Kützing is registered in the literature with a wide morphological variation, creating confusion in the species circumscription. Further molecular studies are necessary to better circumscribe the species and its morphological variations. According to Levkov et al. (2016) apical and basal ends are both shortly rostrate.

Consulted literature: Levkov et al. (2016).

Geographic distribution for Paraná State: Andirá, Apucarana, Bituruna, Bocaiúva do Sul, Campina Grande do Sul, Campo Largo, Campo Mourão, Cambará, Capitão Leônidas Marques, Carambeí, Corbélia, Castro, Cascavel, Cruzeiro do Iguaçu, Curitiba, Diamante do Norte, Fazenda Rio Grande, Guarapuava, Ipiranga, Itaguajé, Itambaracá, Londrina, Mangueirinha, Maringá, Nova Prata do Iguaçu, Pinhais, Pinhão, Piraquara, Ponta Grossa, Porecatu, Porto Rico, Prudentópolis, Quedas do Iguaçu, Reserva do Iguaçu, Ribeirão Claro, Rio Bonito do Iguaçu, Santa Helena, Santa Maria do Oeste, São Jorge d'Oeste, São José dos Pinhais, Sapopema, Saudade do Iguaçu, Tamarana, Telêmaco Borba, Tijucas do Sul, União da Vitória (Tremarin et al. 2009a), Araucária (Bertolli et al. 2010), Guarapuava (Marquardt et al. 2010), São José dos Pinhais (Faria et al. 2010), Piraquara (Silva et al. 2010), Cambará, Porecatu, Ribeirão Claro (Fontana & Bicudo 2012), Piraquara (Marra et al. 2016).

Occurrence in samples: UNOP-Algae 2234, 2235, 2236, 2237, 2244, 2245, 2246, 2247, 2258, 2259, 2260, 2261, 2263, 2264, 2265 and 2266.

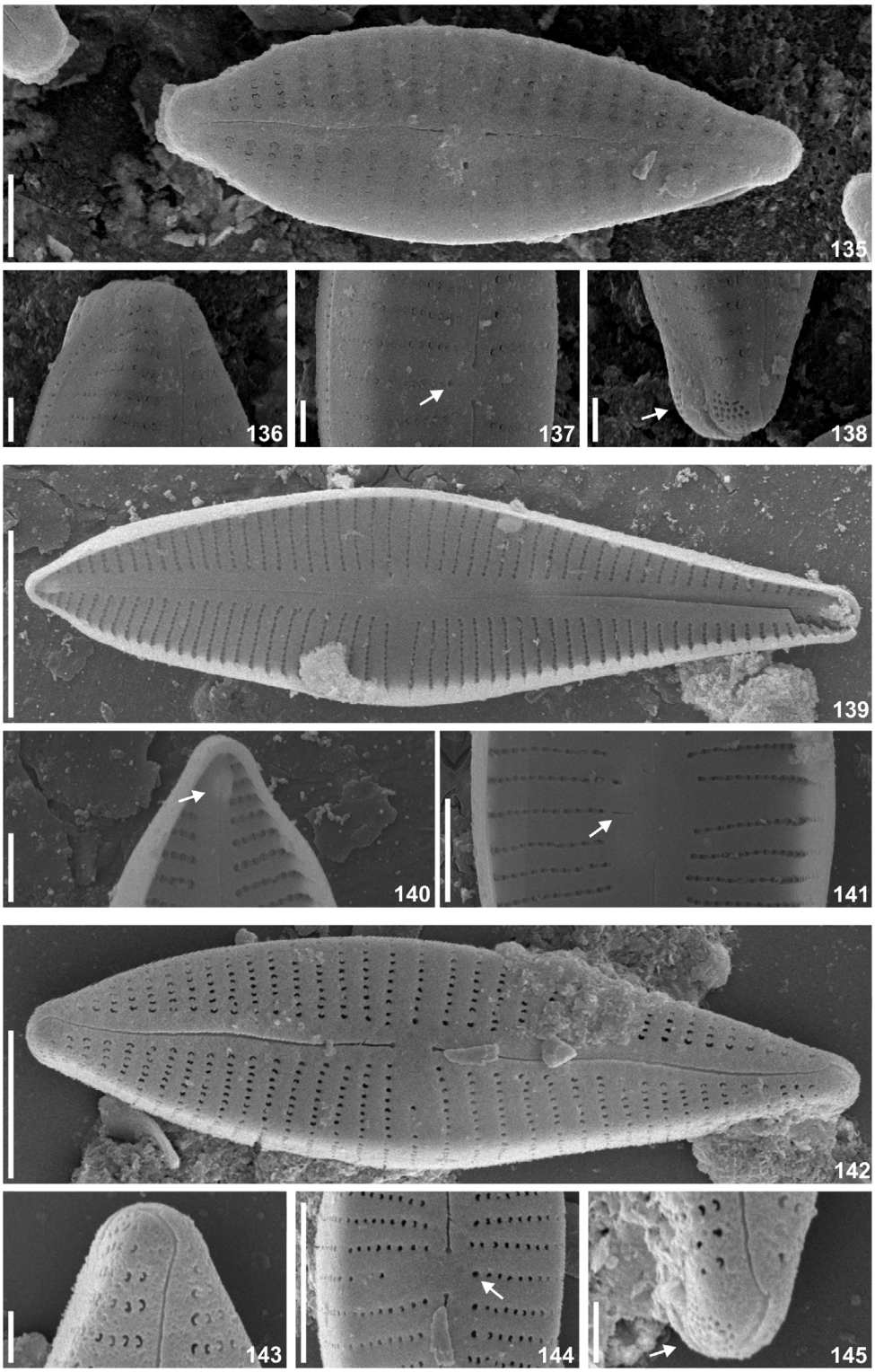
Gomphonema perapicatum Metzeltin & Lange-Bertalot, Iconogr. Diatomol. 18:150-151, pl. 210, Figures 6-10. 2007.
Figures. 61–63; 139–141.

Valves clavate, apical ends narrowly cuneate and apiculate, basal ends attenuate-rounded. Central area asymmetric and limited by the shortening of a median striae. Raphe slightly sinuous, with proximal ends dilated into pores and curved toward stigma, distal ends curved in hook shape. Striae parallel at median region, more spaced between each other to radiate toward the ends. Areolae conspicuous. Stigma at central stria end. Length: 51.8–78.3 µm; width: 11.6–14.6 µm; length/width ratio: 4.2–5.4; 8–9 striae in 10 µm; 16–24 areolae in 10 µm.

In SEM, internal valve view shows proximal raphe ends curved in sickle shape and distal ends curved to opposite side of the stigma (Figures 139–141), ending in prominent helictoglossa (Figure 140) and stigma elongated (Figure 141).

Comment: *Gomphonema perapicatum* resembles *Gomphonema apicatum* Ehrenberg. However, the first presents apical ends acuminate-apiculate and the wider portion of the valve is next to the apice, which makes the valves more claviform than lanceolate (Metzeltin & Lange-Bertalot 2007). Furthermore, the dimensions of *G. apicatum* are smaller (45–50 µm length) (Patrick & Reimer 1975).

Consulted literature: Metzeltin & Lange-Bertalot (2007).



Figures 135–145. Figures. 135–138. *Gomphonema parvulum*, external view. Figure. 135. General valve view, showing uniseriate striae and areolae shape. Figure. 136. Detail of apical ends. Figure. 137. Detail of median region, showing the stigma opening (arrow). Figure. 138. Detail of basal ends, showing the pore field (arrow). Figures. 139–141. *Gomphonema perapicatum*, internal view. Figure. 139. General valve view. Figure. 140. Detail of apical ends, showing the helictoglossa (arrow). Figure. 141. Detail of median region, showing the stigma opening (arrow) and the shape of proximal raphe ends. Figures. 142–145. *Gomphonema pseudoaugur*, external view. Figure. 142. General valve view, showing uniseriate striae and raphe shape. Figure. 143. Detail of apical ends, with distal raphe end curving onto the valve mantle. Figure. 144. Detail of median region, showing the stigma opening (arrow) and proximal raphe ends. Figure. 145. Detail of basal ends, showing the pore field (arrow). Scales: Figures. 136–138; 143; 145. 1 µm. Figures. 135; 140–141. 2 µm. Figures. 142; 144. 5 µm. Figure. 139. 10 µm.

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Geographic distribution for Paraná State: first citation for Paraná.

Occurrence in samples: UNOP-Algae 2236, 2246, 2259, 2260, 2264 and 2265.

Gomphonema pseudoaugur Lange-Bertalot, Arch. Hydrobiol. Supp. 56:213-214, 1979.
Figures. 64–66; 142–145.

Valves lanceolate, apical ends rostrate to subrostrate and basal ends attenuate. Raphe-sternum linear and narrow. Central area unilateral limited by shortening of a median stria. Raphe slightly sinuous, proximal ends dilated into pores and curved toward the stigma. Striae parallel to radiate, more spaced at median region. Areolae inconspicuous. Stigma at central area. Length: 23.6–36.1 µm; width: 9–11.1 µm; length/width ratio: 3–3.5; 11–12 striae in 10 µm.

In SEM, external view shows proximal ends of the raphe straight to slightly curved and distal ends and stigma aperture rounded (Figures 142–145). Striae uniseriate (Figure 142). External areolae aperture mostly reniform (Figures 142–145). Pore field formed by rounded poroids disposed in both sides of the terminal raphe fissure. (Figure 145).

Comment: even though *G. pseudoaugur* is similar to *Gomphonema augur* Ehreberg, the last presents apical ends capitate and valve widely clavate-lanceolate (Krammer & Lange-Bertalot 1986).

Consulted literature: Krammer & Lange-Bertalot (1986).

Geographic distribution for Paraná State: Capitão Leônidas Marques, Cascavel, Fazenda Rio Grande, General Carneiro, Lindoeste, Maringá, Matinhos, Pontal do Paraná, Prundentópolis, Rio Negro, Santa Helena, Santa Tereza do Oeste (Tremarin et al. 2009b), Piraquara (Marra et al. 2016).

Occurrence in samples: UNOP-Algae 2236, 2237, 2244, 2245, 2246, 2260, 2261, 2263, 2264 and 2265.

Gomphonema pumilum (Grunow) Reichardt & Lange-Bertalot, Nova Hedwigia 53(3-4):519-544. p.528, pl. 6, Figure.4-11. 1991.
Figures. 67–69.

Valves clavate, apical ends rounded and basal ends attenuate. Raphe-sternum linear to lanceolate. Central area rounded. Raphe straight, proximal ends dilated into pores, curved to the stigma side. Striae parallel to radiate. Areolae inconspicuous in OM. Stigma at the median stria end. Length: 16.4–31.8 µm; width: 4.6–6.9 µm; length/width ratio: 3.2–5.1; 10–11 striae in 10 µm.

Comment: the species resembles *G. pumilum* varieties registered by Reichardt (1997). *Gomphonema pumilum* var. *rigidum* Reichardt et Lange-Bertalot has linear-lanceolate valve, while in *G. pumilum*, the valve is lanceolate.

Consulted literature: Metzeltin et al. (2005) and Reichardt (1997).

Geographic distribution for Paraná State: Barra do Chopim, Capitão Leônidas Marques, Castro, General Carneiro, Jaguariaíva, Lindoeste, Maringá, Matinhos, Nova Prata do Iguaçu, Pontal do Paraná, Prudentópolis, Rio Negro, Salto do Lontra, Santa Helena, Santa Tereza do Oeste, Sengés, Três Barras do Paraná cited as *Gomphonema pumilum* (Grunow) Reichardt & Lange-Bertalot var. *pumilum* (Tremarin et al. 2009b), Maringá (Moresco & Rodrigues 2016).

Occurrence in samples: UNOP-Algae 2235, 2236, 2237, 2245, 2246, 2259, 2260, 2263, 2264 and 2265.

Gomphonema salae Lange-Bertalot & Reichardt, Iconogr. Diatomol. 5:124-126; 548-549, pl. 157, Figures 3-5, 1998.
Figure. 70.

Valves clavate-lanceolate, with slight intumescence at median region, apical ends cuneate-subrostrate and basal ends attenuate-rounded. Raphe-sternum linear and narrow. Irregular central area, limited by shortening of a median stria. Raphe slightly sinuous, with proximal ends dilated into pores, curved to the stigma side, distal ends indistinct. Striae parallel at median region to slightly radiate at the ends. Areolae inconspicuous. Stigma at median stria end. Length: 34.8 µm; width: 8.8 µm; length/width ratio: 3.9; 14 striae in 10 µm.

Comment: only one specimen was found, with measurements and striae number corresponding to the species originally described by Metzeltin & Lange-Bertalot (1998) (length 40–55 µm, width 10–11 µm and 12–14 striae in 10 µm). Tremarin et al. (2009b) registered *G. salae* with similar structure to the individual from São Francisco Falso River.

Consulted literature: Metzeltin & Lange-Bertalot (1998).

Geographic distribution for Paraná State: Fazenda Rio Grande (Tremarin et al. 2009b).

Occurrence in samples: UNOP-Algae 2236.

Gomphonema saprophilum (Lange-Bertalot & Reichardt) Abarca, Jahn, Zimmermann & Enke in Levkov, Mitic-Kopanja & Reichardt, Plos One, v. 9, p. 1-18, 2014.
Figures. 71–73

Valves lanceolate, apical and basal ends widely subrostrate. Raphe-sternum linear and narrow. Central area unilaterally expanded, limited by shortened median striae. Raphe straight with proximal ends in pore shape and curved toward the stigma. Striae parallel to radiate. Areolae inconspicuous. Stigma at median stria end. Length: 15.7–16.9 µm; width: 5.9–6.7 µm; length/width ratio: 2.5–2.6; 12–14 striae in 10 µm.

Comment: *Gomphonema saprophilum* differs from *Gomphonema parvulum* (Kützing) Kützing mostly by the rhomboidal valve shape, and by its wider headpole (Abarca et al. 2014, Levkov et al. 2016). According to Abarca et al. (2014) *G. saprophilum* usually presents wider valves (6–8 µm) compared to *G. parvulum*. However, since the analyzed populations have similar measures, the taxonomic determination was mainly based on the valve morphology. In our study, *G. parvulum* showed a slightly lower striae density (10–12 in 10 µm).

Consulted literature: Levkov et al. (2016).

Geographic distribution for Paraná State: Rio Negro (Tremarin et al. 2009b), Piraquara (Marra et al. 2016).

Occurrence in samples: UNOP-Algae 2235, 2236, 2237, 2245, 2259, 2264 and 2265.

Gomphonema subclavatum Grunow in Van Heurck, Diat. Franz Josefs-Land 98, p. 46, pl. 1 (A), Figure. 13, 1884.
Figure. 74.

Valves rhombic-lanceolate, apical ends rounded and basal ends attenuate-rounded. Raphe-sternum linear, extending toward the median region. Central area elliptic, limited by shortening of the median striae. Raphe slightly sinuous, proximal ends dilated into pore shape, curved toward the stigma and distal ends slightly curved to the same side. Striae

radiate, tending to parallel close to the ends. Areolae inconspicuous. Stigma at the median stria end. Length: 35.5 µm; width: 9 µm; length/width ratio: 3.9; 10 striae in 10 µm.

Comment: *Gomphonema subclavatum* has wide morphological variation, but the only specimen found possesses similarity with other registered individuals in Krammer & Lange-Bertalot (1991) and Levkov et al. (2016).

Consulted literature: Krammer & Lange-Bertalot (1991) and Levkov et al. (2016).

Geographic distribution for Paraná State: Almirante Tamandaré, Curitiba, Ponta Grossa, Santa Helena (Tremarin et al. 2009b).

Occurrence in samples: UNOP-Algae 2264.

Gomphonema turris var. *coarctata* (Frenguelli) Frenguelli, Rev. Mus. La Plata, Sec. Bot. 3:275, 1941.
Figures. 75–76.

Valves clavate, apical ends cuneate-subrostrate and basal ends attenuate-rounded. Raphe-sternum linear. Central area unilaterally expanded, limited by irregular shortening of the median striae. Raphe slightly sinuous, with proximal ends dilated into pores and curved to the stigma side. Striae parallel at median region, more spaced between each other, to radiate toward the ends. Areolae conspicuous. Stigma at the median stria end. Length: 58.4–75.6 µm; width: 15.6–18.6 µm; length/width ratio: 3.1–4.1; 7–10 striae in 10 µm; 10–13 areolae in 10 µm.

Comment: the species differs from its typical variety by the valve outline characteristically claviform, wider valves, shorter apices and elliptic central area. Tremarin et al. (2009) presented similar specimens to the ones in the population, describring them as *Gomphonema turris* var. *coarctata* morphotype 1 and 2, the first with valves more apiculate, apice less highlighted and central area elliptic, and the second with valves clavate, apice highlighted and central area linear. The population from São Francisco Falso River showed both morphological variations. It is recommended further and more specified studies in order to distinguish the morphotypes.

Consulted literature: Frenguelli (1933, 1941) and Metzeltin et al. (2005).

Geographic distribution for Paraná State: Fazenda Rio Grande (Tremarin et al. 2009b).

Occurrence in samples: UNOP-Algae 2237, 2263 and 2265.

Final considerations

Overall, we observed large morphological variations in the *Gomphonema* populations. *Gomphonema parvulum*, *Gomphonema exilissimum* and *Gomphonema lagenula* were often difficult to distinguish from other similar species. The description and comparison of specimens with specialized literature (Table 2) were decisive for taxa description. As a criterion for *Gomphonema exilissimum* definition we used length/width ratio and for *Gomphonema parvulum* the rostrate apical and basal ends. To differentiate species from *Gomphonema lagenula*, which is also similar, we defined as criteria the assymetric valve contour, ends subcaptate to capitate more pronounced, and areolae shapes, observed in SEM.

In some specific cases, the ultrastructure analysis was necessary to define the individual taxon, as *Gomphonema brasiliense* and *Gomphonema brasiliensoide* that were separated mostly by their uniseriate and biseriate striae, respectively, and *Gomphonema brasiliense* ssp. *pacificum,* which possesses more delicate and elongated areolae than the type species.

Among the diatom floristic survey studies in Paraná, only Silva et al. (2007) discussed exclusively about the genus *Gomphonema*. Tremarin et al. (2009a) performed the taxonomic survey of *Gomphonema* and *Gomphosphenia*. Concerning of the West side of the State, these studies represented the largest genus diversity of the last couple years (26 and 19 taxa, respectively). Recent papers in Paraná comprising the epiphytic diatom taxonomy as Bertolli et al. (2010), Silva et al. (2010), Santos et al. (2011), Moresco & Rodrigues (2013), and Moresco & Rodrigues (2016) did not exceed 11 *Gomphonema* registered species, highlighting that the 28 taxa registered in this paper respond to the analyzed environment specificity.

In qualitative analysis of two collections from São Francisco Falso River (January and June), also comprised in this current study, Silva et al. (2007) listed the *Gomphonema* taxa and their respective temporal and spatial distributions, but without taxonomic comments and illustrating only a few of them. Moreover, four species (*Gomphonema subtile, Gomphonema mexicanum, Gomphonema affine* and *Gomphonema gracile)* were differently identified in this paper (as *Gomphonema pantropicum, Gomphonema affinopsis, Gomphonema graciloides e Gomphonema guaraniarum*, respectively), mostly because of the criteria used, as the apical ending shapes and valve length.

This study broadens the knowledge about ultrastructure of several *Gomphonema* species, due to the lack of more specific taxonomic descriptions and illustrations involving SEM.

Future similar studies in this environment need to be conducted in order to continue to explore the diatom Brazilian flora, since it has propitious characteristics to the development of epilithic diatoms.

We also emphasize that studies using molecular tools are fundamental to better circumscribe *Gomphonema* species, due to the wide morphological variation of valve shape.

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Author Contributions

Gabriela Medeiros: Contribution to data collections;

Gabriela Medeiros, Thelma Ludwig, Norma Bueno: Contribution to data analysis and interpretation;

Gabriela Medeiros, Mailor Amaral, Paula Ferreira: Contribution to manuscript preparation;

Gabriela Medeiros, Mailor Amaral, Thelma Ludwig, Norma Bueno: Contribution to critical revision, adding intelectual content.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

Table 2. Valve morphology and morphometric and meristic limits of *Gomphonema* species found in São Francisco Falso River compared with data from the literature used for taxonomic classification. Similar taxa are grouped for better comparison.

	Reference	Length (µm)	Width (µm)	Length/width ratio	Striae (in 10 µm)	Areolae (in 10 µm)	Valve outline	Apical end	Basal end	Stigma
G. brasiliense	This study	21–32.9	5.9–7	4–4.6	13–15	Inconspicuous	Clavate-lanceolate	Rounded	Attenuate-rounded	Absent
	Metzeltin et al. (2005)	22–44	5.5–6.7	*	14–15	Inconspicuous	Clavate-lanceolate	Attenuate-rounded	Attenuate-rounded	Absent
G. brasiliensoide	This study	33–51.5	7.5–9.6	4–6	10–12	Inconspicuous	Clavate-lanceolate	Attenuate-rounded	Attenuate-rounded	Absent
	Metzeltin et al. (2005)	24–60	6.6–9	*	10–12	Inconspicuous	Clavate-lanceolate	Attenuate-rounded	Attenuate-rounded	Absent
G. brasiliense ssp. *pacificum*	This study	19.9–26.6	4–4.9	4.8–5.4	12–14	Inconspicuous	Narrowly lanceolate	Attenuate-rounded	Attenuate-rounded	Present
	Moser et al. (1998)	16–36	3.5–4.5	*	*	Inconspicuous	Lanceolate	Rounded	Attenuate to rounded	Present
G. hawaiiense	This study	27–55	7.5–10.5	3–5	14–16	Inconspicuous	Lanceolate to rhombic-lanceolate	Attenuate-rounded	Attenuate-rounded	Present
	Reichardt (2005)	28–48	6.4–7.5	*	14–16	Inconspicuous	Clavate to narrowly rhombic-lanceolate	Attenuate	Strongly attenuate	Present
G. exilissimum	This study	31–38	6–7.3	4–5.4	11–12	Inconspicuous	Elliptic-lanceolate	Subcapitate to rostrate	Subcapitate to rostrate	Present
	Jüttner et al. (2013)	20.9–39.2	4.3–5.9	3.9–6.8	14–16 in the middle 16–18 near the apices	Inconspicuous	Clavate and narrowly elliptic-lanceolate	Subcapitate to rostrate	Subcapitate to rostrate	Present
G. lagenula	This study	23–32.8	7–9.3	3–5	11–13	Inconspicuous	Lanceolate to elliptic-lanceolate	Subcapitate to subrostrate	Subcapitate	Present
	Levkov et al. (2016)	15–27	4.5–7.5	*	12–14	35–40	Elliptic-lanceolate	Subcapitate to subrostrate	Subcapitate	Present
G. parvulum	This study	18–31	6–7.5	2.9–4.3	10–12	Inconspicuous	Lanceolate to elliptic-lanceolate	Subrostrate	Attenuate-rounded	Present
	Levkov et al. (2016)	17–30	5.5–7.5	*	10–14	35–40	Clavate to elliptic-lanceolate	Shortly rostrate	Shortly rostrate	Present
G. saprophilum	This study	15.7–16.9	5.9–6.7	2.5–2.6	12–14	Inconspicuous	Lanceolate	Broadly subrostrate	Broadly subrostrate	Present
	Abarca et al. (2014)	22–27	6–8	*	*	Inconspicuous	Clavate-lanceolate	Shortly rostrate	Obtuse or capitate	Present
	Levkov et al. (2016)	24–47	7.5–8.5	*	9–12	Inconspicuous	Lanceolate to broadly clavate	Narrowly rounded	Narrowly rounded	Present
G. capitatum	This study	49.5-51	9.7–11.7	4.3–5.1	10–11	13–19	Clavate	Truncate-rounded	Rounded	Present
	Reichardt (2001)	18–55	8.3–12.6	*	9–13	21–27	Clavate	Broadly rounded	Narrowly rounded	Present
	Levkov et al. (2016)	44–52	10.5–12	*	9–12	22–26	Clavate	Broadly capitate	Narrowly rounded	Present
G. italicum	This study	59–60.6	14.2–15.3	3.9–4.1	8–10	*	Clavate	Broadly rounded	Acuminate-rounded	Present
	Reichardt (2001)	19–53.5	9.3–14	*	10–16	23–29	Clavate	Broadly rounded	Narrowly rounded	Present
G. laticollum	This study	50.8–67.5	10.8–12.1	4.3–5.2	8–9	12–16	Clavate	Broadly rounded	Acuminate-rounded	Present
	Reichardt (2001)	26–57	9.6–13.3	*	9–12	*	Clavate	Broadly rounded	Narrowly rounded	Present
	Levkov et al. (2016)	23–62	9–12.5	*	10–13	21–32	Clavate	Broadly rounded to truncate	Narrowly rounded	Present

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