

Knowledge shortfalls: new records of Bacillariophyceae from the Lower Iguaçu River, Paraná State, Brazil

Kamili Aparecida Batista Gomes

UNIOESTE: Universidade Estadual do Oeste do Parana

Margaret Seghetto Nardelli

margaretseghetto@gmail.com

UNIOESTE: Universidade Estadual do Oeste do Parana <https://orcid.org/0000-0002-5280-3185>

Norma Catarina Bueno

UNIOESTE: Universidade Estadual do Oeste do Parana

Research Article

Keywords: diatoms, floristic survey, lotic environment, phytoplankton, southern Brazil, taxonomy

Posted Date: September 7th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10706023/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

**Knowledge shortfalls: new records of Bacillariophyceae from the Lower Iguaçu River,
Paraná State, Brazil**

Kamili Aparecida Batista Gomes¹, Margaret Seghetto Nardelli^{1*}, Norma Catarina Bueno¹

¹Graduate Program in Conservation and Management of Natural Resources (PPRN), Western
Paraná State University (UNIOESTE), Rua Universitária 1619, Jardim Universitário, 85819-
110, Cascavel, Paraná, Brazil

*Corresponding author: margaretseghetto@hotmail.com

Kamili Aparecida Batista Gomes, e-mail: kamilibatistagomes@gmail.com,
<https://orcid.org/0009-0003-4485-3777>

Margaret Seghetto Nardelli, e-mail: margaretseghetto@hotmail.com, <https://orcid.org/0000-0002-5280-3185>

Norma Catarina Bueno, e-mail: normabueno24@gmail.com, <https://orcid.org/0000-0001-6939-9222>

This paper is part of the undergraduate thesis of the first author.

Running title: New records of Bacillariophyceae from the Lower Iguaçu River

Acknowledgements

The authors thank the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio, Chico Mendes Institute for Biodiversity Conservation) for providing the necessary research permits, and the staff of Iguaçu National Park for logistical support during sample collection. M.S. Nardelli thanks the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the Master's scholarship awarded in 2013 and the Fundação Araucária (FA) for the technical support fellowship granted in 2026. K.A.B. Gomes thanks the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the undergraduate research fellowship. N.C. Bueno thanks the Fundação Araucária (FA) and the Companhia de Saneamento do Paraná (SANEPAR) for financial support, and the Conselho Nacional de

Desenvolvimento Científico e Tecnológico (CNPq) for a research productivity grant (301866/2025-2).

Authors' contributions

K.A.B. Gomes: taxonomic contribution; manuscript review and preparation; contribution of intellectual content. M.S. Nardelli: contribution to the study concept and design; taxonomic contribution; field work and provision of geographic data; writing of the original draft; writing, review and editing; contribution of intellectual content. N.C. Bueno: acquisition of resources; supervision; contribution to the study concept and design; contribution to sample collection and provision of samples and geographic data; manuscript review; contribution of intellectual content.

Abstract

This study analyzed, identified and documented new records of planktonic species of the class Bacillariophyceae in the Lower Iguaçu River, within the area of Iguaçu National Park, Paraná State, Brazil. Samples were collected monthly between September 2010 and September 2011 at two plankton sampling stations, one upstream and one downstream of the Iguaçu Falls.

Analysis of the Bacillariophyceae assemblage of the Lower Iguaçu River (deposited in the UNOPA collection and recorded on the SpeciesLink platform) yielded 11 species recorded for the first time in Brazil: *Achnanthes inflata* var. *javanica* H.P.Gandhi, *A. coarctata* var. *sinaensis* Hustedt, *Achnanthidium deflexum* (C.W.Reimer) J.C.Kingston, *A. standeri* (Cholnoky) J.C.Taylor, E.Morales & Ector, *Amphipleura pellucida* var. *oregonica* Grunow, *Craticula perrotettii* Grunow, *Diadesmis confervacea* f. *rostrata* (Krasske) Metzeltin & Lange-Bertalot, *Encyonema kukenanum* Krammer, *E. lapponicum* (A.Cleve) Krammer, *E. lembus* (Carter & Denny) Krammer and *E. riotecense* Krammer. Four species were recorded for the first time in the state of Paraná: *Adlafia bryophila* (J.B.Petersen) Lange-Bertalot, *Chamaepinnularia submuscicola* (Krasske) Lange-Bertalot, *Pinnularia borealis* var. *islandica* Krammer and *P. domingensis* (Cleve) Hustedt. These results show that, even in previously studied watersheds, knowledge of diatom diversity and distribution is still far from complete. They reflect both the Linnean shortfall, related to incomplete knowledge of taxonomic diversity, and the Wallacean shortfall, related to limitations in the knowledge of the geographic distribution of species.

Keywords: diatoms, floristic survey, lotic environment, phytoplankton, southern Brazil, taxonomy

Introduction

The class Bacillariophyceae shows the greatest species diversity among diatom groups, a feature that makes it particularly relevant for taxonomic and ecological studies in continental

aquatic ecosystems. The class comprises organisms with a monoraphid or biraphid raphe system, which may be central or marginal, and whose cells are bipolar and generally bilaterally symmetrical (Round et al. 2007).

However, a better understanding of these algae and of their ecology depends first on identifying and taxonomically classifying the species that inhabit their environments. Despite the recognized biological and taxonomic importance of this group (e.g. Round et al. 2007; Hortal et al. 2015; Barua 2025; Bhat et al. 2025; Kociolek et al. 2026), as well as its ecological importance (e.g. Lobo et al. 2002; Nardelli et al. 2016; Amaral et al. 2024; Taurozzi et al. 2024; Yadav et al. 2026), many species within the class remain understudied, and research effort is small when compared with the 21,327 species already described (Guiry and Guiry 2026).

At the national level, the chapter *Bacillariophyta* (Ludwig and Tremarin 2017), part of the work *Gêneros de Algas de Águas Continentais do Brasil* (Bicudo and Menezes 2017), stands out. Another important contribution is the book *Diatomáceas (Bacillariophyta) do Pantanal brasileiro: contribuição florística de espécies depositadas em sedimentos recentes* (Nardelli et al. 2021), developed for the state of Mato Grosso. That work brings together a large number of representatives of the class Bacillariophyceae and reveals a high species diversity, much of it floristically similar to that recorded in rivers of the state of Paraná.

Despite the growing body of knowledge on this highly diverse group, records of diatoms in the state of Paraná remain sporadic, and the available studies focus predominantly on particular families or genera. Among them, the chapter on Bacillariophyta (Nardelli et al. 2022) stands out, which is included in the volume that compiles the algal flora of western Paraná (Bueno et al. 2022).

For the Iguaçu River, an important river system in southern Brazil, records of the class Bacillariophyceae are restricted to floristic studies begun in the 1970s and 1990s by Moreira-

Filho et al. (1973) and Ludwig and Flôres (1995), and later continued by Brassac and Ludwig (2005, 2006), Bartozek et al. (2013) and Pereira et al. (2026), the last of which made an important contribution to the knowledge of *Gomphonema* species in this environment.

Besides the articles and books cited above, other publications deal with genera that do not belong to the class Bacillariophyceae, or consist of lists of identified species without illustrations. Studies based on a more comprehensive floristic approach to the Iguaçu River therefore remain scarce.

In this context, the present study expands the knowledge of the diatom flora of the Iguaçu River. We argue that the new records reported here result from the gradual narrowing of the Linnean shortfall, related to incomplete knowledge of actual taxonomic diversity, and of the Wallacean shortfall, related to incomplete knowledge of the geographic distribution of species, rather than from an absence of previous research, which reinforces the scientific relevance of this work.

This study aimed to carry out a floristic survey of the class Bacillariophyceae and, among the taxa recorded, to analyze, identify and document new records for Brazil and for the state of Paraná, based on species from the Lower Iguaçu River, within the area of Iguaçu National Park, Paraná, Brazil.

Material and methods

The Iguaçu River basin covers an area of 54,820.4 km², mostly within Brazilian territory, with a small portion in Argentina. The Iguaçu River is formed by the confluence of the Iraí and Atuba rivers, east of Curitiba, on the border with the municipality of Pinhais, and flows westwards across the state of Paraná to its mouth on the Paraná River (Paraná 2026). The river is approximately 1,200 km long and has the Iguaçu Falls as its main geomorphological feature. Upstream of the falls, the river reaches a width of about 1,200 m, narrowing to between 65 and 100 m near the canyon (Maack 1968).

The climate of the region is classified as humid subtropical mesothermal (Cfa) according to the Köppen-Geiger system (Peel et al. 2007). The mean maximum temperature is 26 °C and the mean minimum is 15 °C (Salamuni et al. 2002). Mean annual precipitation in the Lower Iguaçu River ranges from 1,750 to 2,000 mm (Borges et al. 2021).

Samples were collected between September 2010 and September 2011, except in November 2010, at two sampling stations (S1 and S2) in the Lower Iguaçu River (Fig. 1), selected to account for the heterogeneity of the environments in terms of water depth, width and turbulence.

Station 1 (S1): Cais Bananeiras, upstream of the Iguaçu Falls, within Iguaçu National Park (PNI), at 25°39'12.8" S and 54°25'34.0" W. At this station the river ranges in width from 869.89 to 1,200 m and shows lower turbulence than Station 2 (S2), with a mean current velocity of 0.42 m s⁻¹. Depth ranges from 0.90 m during periods of lower flow to 4.62 m during months of higher discharge. The banks are covered by native vegetation (Nardelli et al. 2016).

Station 2 (S2): Cais Macuco Safari, downstream of the Iguaçu Falls, within the PNI area, at 25°38'55.4" S and 54°27'31.0" W. In this stretch the river has a mean width of 69.89 m. Depth ranges from 4.62 m under normal conditions to 27.46 m during periods of high flow, with a mean current velocity of 6.8 m s⁻¹. The banks are covered by native vegetation and the channel is bounded by the rocky walls characteristic of the canyon (Nardelli et al. 2016).

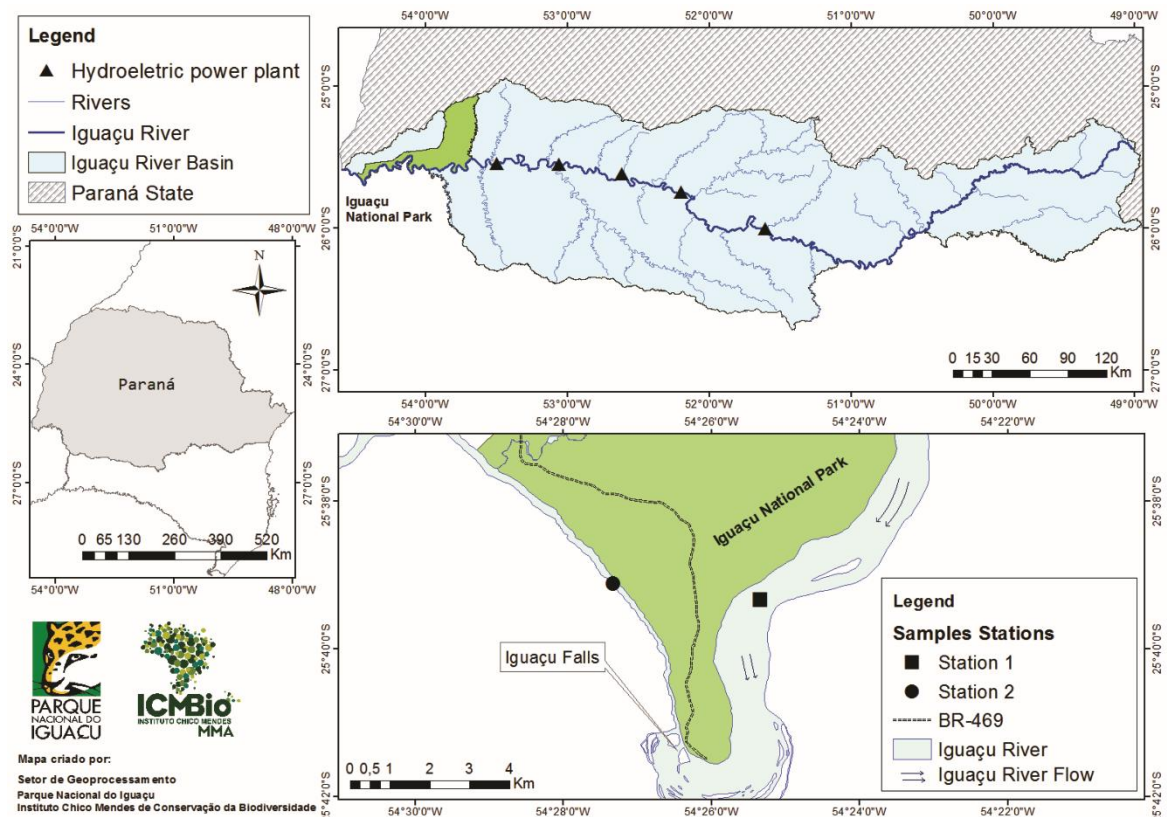


Fig. 1 Location of the sampling stations: Station 1 (S1) upstream and Station 2 (S2) downstream of the Iguazu Falls, Iguazu River, Paraná State, Brazil (map provided by Iguazu National Park)

For the present study, 24 samples (S1, $n = 12$; S2, $n = 12$) were analyzed. Samples were obtained by tows with a phytoplankton net (25 μm mesh) just below the water surface, focused on the strongest current of the river. The material collected was fixed with Transeau's solution in a 1:1 ratio, as described by Bicudo and Menezes (2017).

For sample analysis, a 10 mL aliquot was oxidized following the technique of Simonsen (1974), as adapted by Moreira-Filho and Valente-Moreira (1981). Permanent slides were mounted with Naphrax® resin ($RI = 1.73$) — refractive index. Observation, measurement and photographic documentation of the taxa were carried out under light microscopy, using an Olympus® BX60 binocular microscope equipped with an Olympus® DP71 camera and a Zeiss® Axiolab 5 microscope equipped with an Axiocam 208 colour camera, both operated at 1,000 $\times$ magnification.

Taxa were identified using specialized literature and original species descriptions, including Krammer and Lange-Bertalot (1985, 1986), Patrick and Reimer (1966, 1975), Krammer (1997, 2000), Lange-Bertalot (2001), Metzeltin et al. (2005), Siver et al. (2005) and Metzeltin and Lange-Bertalot (1998, 2007), as well as articles dealing specifically with the groups analyzed.

For all taxa identified, the following measurements were recorded whenever possible: length (L), width (W), striae density (S), striae apical (SA), dorsal central striae (SCD), ventral central striae (SCV) and areolae (A) in 10 μm , and branch length (LB). The terminology used in the morphological descriptions followed Barber and Haworth (1981) and Cox (2015) and, for isolated pores, Cox and Van de Vijver (2024).

The permanent slides and the liquid samples are housed in the Herbarium of the Western Paraná State University (UNOPA), Cascavel Campus, a member of the Brazilian Herbarium Network. The species associated with the material examined will be made available on the SpeciesLink platform. The specimens will be registered according to the information presented in Table 1.

Table 1 Samples from the Lower Iguaçu River, collection date, sample registration number in the UNOPA Herbarium for Station 1 (S1) and Station 2 (S2), and collectors

Collection date	UNOPA S1	UNOPA S2	Collectors
15/IX/2010	3160/3161	3155/3156	M.S. Nardelli and N.C. Bueno
19/X/2010	3226/3227	3215/3214	M.S. Nardelli and N.C. Bueno
22/XII/2010	3344/3345	3341/3343	M.S. Nardelli and N.C. Bueno
26/I/2011	3411/3413	3409/3410	M.S. Nardelli and N.C. Bueno
23/II/2011	3472/3473	3468/3469	M.S. Nardelli and N.C. Bueno
23/III/2011	3536/3537	3533/3535	M.S. Nardelli and N.C. Bueno

Collection date	UNOPA S1	UNOPA S2	Collectors
27/IV/2011	3607/3608	3602/3603	M.S. Nardelli and N.C. Bueno
31/V/2011	3681/3682	3672/3673	M.S. Nardelli and N.C. Bueno
29/VI/2011	3717/3718	3712/3713	M.S. Nardelli and N.C. Bueno
28/VII/2011	3759/3760	3754/3755	M.S. Nardelli and N.C. Bueno
24/VIII/2011	3777/3778	3772/3773	M.S. Nardelli and N.C. Bueno
28/IX/2011	3787/3788	3782/3783	M.S. Nardelli and N.C. Bueno

To confirm the first records for Brazil and for the state of Paraná, the oldest and the most recent checklists were consulted, and the articles cited in those checklists were checked directly in order to confirm each record. The online platforms Re flora - Flora e Funga do Brasil (<https://reflora.jbrj.gov.br/consulta/#CondicaoTaxonCP>) and AlgaeBase (<https://www.algaebase.org/>) were also consulted for Brazilian records, in addition to published articles in the field.

As a criterion, species were accepted as previously recorded for Brazil or for the state of Paraná only when published in articles or books and accompanied by an illustration of the species allowing proper comparison. Descriptions and comments are provided for species representing a first record for Brazil (*) or for the state of Paraná (**).

Results

Analysis of the Bacillariophyceae assemblage of the Lower Iguaçu River (deposited in the UNOPA collection and recorded on the SpeciesLink platform) yielded 11 species recorded for the first time in Brazil and four recorded for the first time in the state of Paraná. The first records for Brazil are *Achnanthes inflata* var. *javanica* H.P.Gandhi, *A. coarctata* var. *sinaensis* Hustedt, *Achnanthidium deflexum* (C.W.Reimer) J.C.Kingston, *A. standeri* (Cholnoky) J.C.Taylor, E.Morales & Ector, *Amphipleura pellucida* var. *oregonica* Grunow,

Craticula perrotettii Grunow, *Diadesmis confervacea* f. *rostrata* (Krasske) Metzeltin & Lange-Bertalot, *Encyonema kukenanum* Krammer, *E. lapponicum* (A.Cleve) Krammer, *E. lembus* (Carter & Denny) Krammer and *E. riotecense* Krammer. The first records for the state of Paraná are *Adlafia bryophila* (J.B.Petersen) Lange-Bertalot, *Chamaepinnularia submuscicola* (Krasske) Lange-Bertalot, *Pinnularia borealis* var. *islandica* Krammer and *P. domingensis* (Cleve) Hustedt. Morphometric descriptions, comments and light microscopy (LM) illustrations are presented below.

Phylum Bacillariophyta Karsten, 1928

Class Bacillariophyceae Haeckel, 1878

**Achnanthes inflata* var. *javanica* H.P.Gandhi 1966: 95, pl. 12: figs 38, 39

Fig. 2-5

Valves with a dilated median region; apices cuneate and rounded, narrower than the median region of the valve. Central area of the raphid valve transapically expanded to the valve margins; rapheless valve with a hyaline line along its apical length, near the lateral margin. Raphe filiform, with visibly expanded proximal ends. Striae radiate on the raphid valve and almost straight on the rapheless valve, formed by coarse areolae visible under light microscopy.

Dimensions: L: 86.0-118.0 µm; W: 24.6-29.7 µm; S: 7-8 in 10 µm; A: 7-8 in 10 µm

Comments: *Achnanthes inflata* var. *inflata* (Kützinger) Grunow, *A. inflatagrandis* Metzeltin, Lange-Bertalot & García-Rodríguez and *A. elata* (Leuduger-Fortmorel) Gandhi are morphologically similar to the species studied here. However, var. *inflata* is smaller (L: 30.0-65.0 µm; W: 10.0-20.0 µm) and has a higher density of striae and areolae (S: 10-13 in 10 µm; A: 11-12 in 10 µm) than var. *javanica* (L: 70.0-81.0 µm; W: 22.0-22.5 µm; S: 8-9.5 in 10 µm; A: 9-10 in 10 µm), as described by Gandhi (1966, figs 38, 39). *Achnanthes inflatagrandis* and *A. elata* show no differences in striae and areolae density; however, the latter is narrower (W:

14.0-15.0 μm), based on the measurements provided by Leuduger-Fortmorel (1879, as *Navicula elata*), and the former has a more gibbous median region and broadly rounded apices, rather than the cuneate apices of *A. inflata* var. *javanica*.

**Achnanthes coarctata* var. *sinaensis* Hustedt 1949: 43, pl. 1: figs 6, 7

Fig. 6-9

Valves linear, swollen in the median region and narrowing towards rounded, rostrate apices. Central area of the raphid valve transapically expanded to the margins; rapheless valve with a visible hyaline line near the lateral margin, in the swollen region. Raphe with distinct proximal ends. Striae radiate on the raphid valve, and straight to slightly radiate at the apices on the rapheless valve. Punctate areolae more distinct on the rapheless valve.

Dimensions: L: 41.5-49.8 μm ; W: 12.1-13.1 μm ; S: 11-13 in 10 μm ; A: 14-16 in 10 μm

Comments: *Achnanthes mauiensis* R.L.Lowe & A.R.Sherwood and *Achnanthes muelleri* G.W.F.Carlson are morphologically similar to the species studied here. However, the former is much smaller (L: 20.0-28.0 μm ; W: 5.0-7.5 μm) than *A. coarctata* var. *sinaensis* (L: 50.0 μm ; W: 10.0-12.0 μm ; Hustedt 1949), and the latter, as illustrated by Carlson (1913, fig. 6), differs in the short striae of the central area, which were not observed in the specimens studied here.

**Achnanthidium deflexum* (C.W.Reimer) J.C.Kingston 2000: 410

Fig. 10-13

Valves linear-lanceolate, with slightly protracted apices. Axial area linear, widening slightly towards the central area, which is asymmetrically rectangular. Raphe with teardrop-shaped terminal fissures. Striae distinct in the central region of the valve. No rapheless valves were observed. Areolae inconspicuous.

Dimensions: L: 9.0-24.2 μm ; W: 4.0-5.2 μm ; S: inconspicuous; A: inconspicuous

Comments: Potapova and Ponader (2004) compared the species studied here with *A. pyrenaicum* (Hustedt) H.Kobayashi and concluded that they are morphologically similar. However, *A. deflexum* has slightly coarser striae and, as a rule, larger valves (L: 7.4-27.1 μm ; W: 3.5-5.2 μm) than *A. pyrenaicum* (L: 8.4-18.4 μm ; W: 2.7-4.6 μm).

**Achnanthidium standeri* (Cholnoky) J.C.Taylor, E.Morales & Ector 2011: 155

Fig. 14-17

Valves linear to linear-lanceolate; apices slightly protracted, rounded. Axial area linear, widening slightly towards the rectangular central area. Raphe filiform, with clearly expanded proximal ends. A view of the rapheless valve was not obtained. In girdle view the frustules are slightly bent (genuflexed), and the concave valve shows a clearly visible, thickened central nodule. In girdle view the valves show a clear area between the valve face and the mantle.

Dimensions: L: 14.7-17.9 μm ; W: 3.8-4.0 μm ; S: inconspicuous; A: inconspicuous

Comments: *Achnanthidium standeri*, as described by Taylor et al. (2011), was found at a site dominated by taxa that require oxygen-rich, fast-flowing water. The specimens studied here were also found in a lotic environment, near the Iguaçu Falls, where water turbulence may generate oxygen-rich conditions. In his description of the species, Cholnoky (1957) reported a narrower length range (L: 24.0-38.0 μm); however, Taylor et al. (2011), on examining the type specimen, described a wider range (L: 8.0-37.0 μm), which encompasses the dimensions found in the present study.

***Adlafia bryophila* (J.B.Petersen) Lange-Bertalot 1998: 89

Fig. 18-21

Valves with straight or slightly convex margins. Apices protracted and rounded, subcapitate. Axial area narrow, slightly widened in the median region; central area with strongly radiate striae. Raphe filiform and distinct.

Dimensions: L: 15.6 µm; W: 4.3-4.6 µm; S: 20-24 in 10 µm; A: inconspicuous

Comments: The only record found under the name *Adlafia bryophila* was that of Schneck et al. (2008), who reported the species for Rio Grande do Sul. The specimen from the Antas River has dimensions (L: 18.0 µm; W: 4.0 µm; S: 23 in 10 µm) similar to those of the specimens found in the Iguaçu River. The species studied here resembles *Adlafia drouetiana* (R.M.Patrick) Metzeltin & Lange-Bertalot; however, the latter is more robust and has more convex and undulate lateral margins than *Adlafia bryophila*.

**Amphipleura pellucida* var. *oregonica* Grunow 1877: 179

Fig. 22-25

Valves fusiform, with protracted, rounded, linear apices. Median axial area formed by a narrow rib extending along the apical axis, branching at the distal ends into a large, branch-like rib that surrounds the raphe system. Transapical and apical striae inconspicuous.

Dimensions: L: 190.7-241.4 µm; W: 23.0-28.6 µm; LB: 42-47 µm; S: inconspicuous; A: inconspicuous

Comments: In addition to Grunow (1877), Cleve (1894) described several forms related to *Amphipleura pellucida* (Kützing) Kützing that fall within the group of large *Amphipleura* species in terms of length: *A. pellucida* (L: 80.0-140.0 µm), *A. pellucida* var. *lindheimeri* (Grunow) Cleve (= *A. lindheimeri* Grunow, L: 150.0-160.0 µm), *A. pellucida* var. *intermedia* Grunow (L: 190.0-200.0 µm), *A. pellucida* var. *maxima* (H.L.Smith) Cleve (L: 370.0 µm), *A. pellucida* var. *truani* V.H. (L: 260.0 µm), *A. pellucida* var. *recta* Kitton (L: 226.0 µm) and *A. pellucida* var. *schumannii* Grunow (L: 180.0 µm), together with *A. pellucida* var. *oregonica* Grunow (L: 330.0 µm). Almost all the varieties cited by Cleve (1894) appear to share similar characteristics and differ mainly in their dimensions: widths range from the smaller values of *A. pellucida* var. *pellucida* (W: 7.0-9.0 µm) to the greater width of *A. pellucida* var. *maxima* (W: 40.0 µm), with var. *oregonica* showing an intermediate value (W: 27.0 µm). Grunow

(1877) reported that the forms cited are closely related to *Amphipleura pellucida* and suggested that they are best regarded as varieties of that species. The taxon studied here was cited by Cleve (1894) both as a species (*A. oregonica* Grunow) and as a variety (*A. pellucida* var. *oregonica* Grunow), and its taxonomic position requires more detailed investigation. The species studied here differs from *Amphipleura pellucida* var. *pellucida* (Kützing) Kützing and from *A. lindheimeri* Grunow. *Amphipleura pellucida* var. *pellucida* is morphologically similar but has smaller dimensions (L: 80.0-140.0 µm; W: 7.0-9.0 µm) than *A. pellucida* var. *oregonica* (L: 330.0 µm; W: 27.0 µm). It also differs morphologically from *A. lindheimeri*: although both are large, *A. pellucida* var. *oregonica* has a linear-fusiform valve and lacks the rhombic margins of *A. lindheimeri*.

*****Chamaepinnularia submuscicola* (Krasske) Lange-Bertalot 1998: 27, pl. 3: figs 1-4**

Fig. 26

Valves linear, with a slight central swelling. Apices protracted and rounded. Axial area lanceolate, gradually widening towards the central area. Raphe filiform, slightly arched. Striae robust, more widely spaced at the centre and strongly radiate, becoming convergent towards the apices.

Dimensions: L: 15.3 µm; W: 4.6 µm; S: 18-20 in 10 µm; A: inconspicuous

Comments: *Chamaepinnularia submuscicola* is similar to *C. muscicola* (J.B.Petersen)

Kulikovskiy, Lange-Bertalot & A.Witkowski, differing mainly in its striation. It can also be compared with *C. rhombelliptica* Lange-Bertalot; however, the latter has finer striae than the robust striation of *C. submuscicola*, as well as a higher striae density (S: 21-24 in 10 µm) than *C. submuscicola* (S: 18 in 10 µm). Faustino et al. (2016) reported the species for the state of São Paulo, in agreement with the specimens studied here, and Faria et al. (2019) cited the species for the state of Paraná; however, the latter authors did not provide illustrations allowing proper comparison. All studies reporting *C. submuscicola* note that the species is

rarely found and always observed in low abundance (Krasske 1939; Wojtal 2009; Faustino et al. 2016). In the Iguçu River, where only planktonic samples were collected, a single specimen was found, which indicates that the species is rare at this site.

**Craticula perrotettii* Grunow 1868: 20, pl. 1: fig. 1

Fig. 27

Valves broadly lanceolate; apices slightly protracted and obtuse. Axial area narrow and linear, widening near the lanceolate central area. Raphe straight and filiform, with proximal ends expanded into central pores and slightly deflected. Transapical and apical striae clearly visible under light microscopy and parallel throughout their length.

Dimensions: **L:** 149.2 µm; **W:** 39.3 µm; **S:** 12-13 in 10 µm; **A:** 8-9 in 10 µm

Comments: *Craticula acidoclinata* Lange-Bertalot & Metzeltin shares morphological characteristics with the species studied here; however, it has more protracted apices and a narrower width (W: 16.0-23.0 µm) than specimens of *C. perrotettii* of similar length (W: 22.9-30.5 µm; Grunow 1868), which gives *C. acidoclinata* a more slender appearance. One of the most visible differences under light microscopy, and one that clearly distinguishes *C. perrotettii* from other species of the genus such as *C. acidoclinata* and *C. cuspidata* (Kützing) D.G.Mann, is the presence of thick longitudinal lines formed by the interstriae; these lines are not as distinct in other *Craticula* species of similar morphology. A record of *C. perrotettii* was found for the state of São Paulo (Villac et al. 2008); however, that article is a biodiversity checklist and does not present a specimen that can be compared with the present study.

**Diadesmis confervacea* f. *rostrata* (Krasske) Metzeltin & Lange-Bertalot 2007: 72, pl. 147: figs 1-5

Fig. 28

Valves elliptic-lanceolate, with protracted, obtuse-rounded apices. Axial area narrower near the apices, widening into a broad, rhombic-lanceolate central area. Raphe straight and

filiform, with proximal ends expanded into pores. Striae radiate and of varying length, shorter in the central area. Areolae distinct, varying in size and shape, and visible under light microscopy.

Dimensions: L: 27.2 μm ; W: 9.4 μm ; S: 20-21 in 10 μm ; A: inconspicuous

Comments: *Diadesmis confervacea* is similar to the taxon studied here; however, *Diadesmis confervacea* f. *rostrata* has markedly protracted apices, in contrast to the apiculate, non-protracted apices of the former. In order to compare it with the specimen found in the Iguazu River, and since no dimensions were provided in the description available in the relevant literature, five images were measured using the scale bars provided (L: 20.0-31.3 μm ; W: 6.7-9.3 μm) for *Navicula confervacea* fo. *rostrata* Krasske (= *Diadesmis confervacea* f. *rostrata*), as illustrated in Lange-Bertalot et al. (1996, p. 102: fig. 5, and p. 231: figs 5, 5', 6-7, 7'). Both the images and the dimensions match the specimens recorded here. The specimens recorded by Metzeltin and Lange-Bertalot (2007) also match morphologically those of the present study. Montoya-Moreno et al. (2012) described the species as a first record for Colombia, and that population matches morphometrically (L: 25.5-36.3 μm ; W: 7.5-10.7 μm ; S: 20-24 in 10 μm) the specimen found in the Iguazu River.

**Encyonema kukenanum* Krammer 1997: 21, 184, pl. 106: figs 7-9

Fig. 29-33

Valves dorsiventral; dorsal margin convex, ventral margin straight. Apices rounded, not protracted. Axial area narrow. Central area hyaline, without isolated pores (stigma). Raphe filiform, with distal fissures deflected towards the ventral margin and proximal fissures curved towards the dorsal margin. Dorsal striae radiate, ventral striae almost straight.

Dimensions: L: 17.4-25.2 μm ; W: 5.7-6.6 μm ; S: 11-12 in 10 μm ; A: inconspicuous

Comments: *Encyonema minutum* (Hilse) D.G.Mann is similar to the species studied here.

However, it has an inflated ventral margin and protracted, truncate apices that project towards

the ventral margin, unlike *E. kukenanum*, which has rounded, non-protracted apices and a straight ventral margin. It is also similar to *Encyonema venezolanum* Krammer, but differs in having a slightly convex ventral margin in smaller specimens and an inflated margin with protracted apices in larger specimens, characteristics not observed in *Encyonema kukenanum*.

**Encyonema lapponicum* (A.Cleve) Krammer 1997: 25

Fig. 34

Valves dorsiventral, with triundulate margins and a more pronounced median undulation. Apices obtuse. Axial area linear on the dorsal side, gradually widening towards the central area on the ventral side. Raphe distinct, with distal fissures deflected towards the ventral margin and proximal fissures curved towards the dorsal margin. Ventral striae straight and longer, radiate at the ends, irregular and shorter towards the central area. Dorsal striae radiate, more widely spaced at the centre than at the ends. Striae irregular at the dorsal ends, with the terminal striae positioned close to the raphe margin on the ventral side.

Dimensions: L: 56.9 µm; W: 10.3 µm; SA: 10 in 10 µm; SCV: 9 in 10 µm; SCD: 8 in 10 µm; A: inconspicuous

Comments: The species studied here resembles *Encyonema norvegicum* var. *capitata* Krammer, but the latter has capitate apices, a less dorsiventral valve and a higher striae density (S: 12-16 in 10 µm), whereas the species studied here has obtuse apices and a lower striae density (S: 8-10 in 10 µm). It is morphologically similar to *E. sibericum* Krammer & Lange-Bertalot, and both species show three undulations on the ventral and dorsal margins; however, *E. lapponicum* is more robust (L: 26.0-54.0 µm; W: 5.0-8.5 µm) than *E. sibericum* (L: 30.0-45.0 µm; W: 5.8-6.7 µm), and the latter has a higher striae density (S: 12-14 in 10 µm).

**Encyonema lembus* (Carter & Denny) Krammer 1997: 314

Fig. 35

Valves dorsiventral, lanceolate, with the dorsal margin more convex than the ventral margin. Apices protracted, distinctly capitate. Axial area lanceolate, curved, following the valve outline and gradually widening towards the indistinct central area. Raphe nearly straight, with distal fissures deflected towards the ventral margin and imperceptible proximal fissures. Striae radiate and robust.

Dimensions: L: 24.8 µm; W: 5.5 µm; SCV: 10 in 10 µm; SCD: 11 in 10 µm; A: inconspicuous

Comments: The species studied here resembles *Encyonema javanicum* var. *mengeae* (Cholnoky) Krammer. However, they differ in the straighter, more delicate striae and narrower axial area of *E. javanicum* var. *mengeae*, in contrast to the robust, radiate striae and lanceolate axial area of *E. lembus*. No other studies describing the species were found, apart from the record in the original publication. The specimen studied here matches morphometrically (as *Cymbella lembus*, L: 22.0 µm; W: 4.5 µm) the species published by Carter and Denny (1992).

**Encyonema riotecense* Krammer 1997: 93, 169, pl. 41: figs 1-6

Fig. 36-37

Valves dorsiventral, with a convex dorsal margin and a slightly convex to almost straight ventral margin in smaller valves. Apices broadly rounded. Axial area slightly lanceolate, widening towards the central area. Raphe eccentric, distinct, with proximal fissures inclined towards the dorsal margin and distal fissures deflected towards the ventral margin. Dorsal striae slightly radiate in the median portion, becoming more radiate towards the apices. Ventral striae convergent at the ends and radiate towards the median portion.

Dimensions: L: 35.0-44.9 µm; W: 8.1-10.0 µm; SA: 12 in 10 µm; SCV: 10 in 10 µm; SCD: 11 in 10 µm; A: inconspicuous

Comments: Silva et al. (2010) presented two taxa as *Encyonema* sp. (figs 11-12) and compared them with *E. riotecense*; however, they reported that the specimens show a median dorsal stigma-like pore (stigmoid), whereas Krammer (1997), in his description of the species, stated that the stigmoid is absent. No other records of the species were found for further comparison.

*****Pinnularia borealis* var. *islandica*** Krammer 2000: 25, 209, pl. 6: fig. 5, pl. 7: figs 1-5

Fig. 38-41

Valves linear-elliptic, with slightly convex margins and rounded apices. Axial area narrow, gradually widening towards the centre. Central area transverse, formed by shorter striae on both sides. Raphe straight, with distinct, teardrop-shaped proximal fissures curved to the side opposite the hooked distal ends. Striae robust and irregularly arranged, ranging from slightly to strongly radiate, and convergent at the apices.

Dimensions: L: 42.8-51.5 µm; W: 10.3-11.6 µm; S: 4-5 in 10 µm; A: inconspicuous

Comments: *Pinnularia borealis* var. *islandica* Krammer and *P. borealis* var. *subislandica* Krammer are morphologically similar; however, they differ in their dimensions, as recorded by Krammer (2000). *Pinnularia borealis* var. *subislandica* is markedly shorter (L: 30.0-47.0 µm; W: 9.4-11.5 µm) than var. *islandica* (L: 40.0-52.0 µm; W: 10.0-12.0 µm). Although the two varieties are similar in width, var. *subislandica* has more convex lateral margins than the straighter margins of var. *islandica*.

*****Pinnularia domingensis*** (Cleve) Hustedt 1934: pl. 386: fig. 5

Fig. 42

Valves linear, inflated in the median portion and with broadly rounded apices. Axial area approximately one quarter of the valve width. Central area rounded and asymmetric. Raphe straight, with proximal ends curved towards the same side and distal ends hooked.

Transapical striae radiate in the median region of the valve and convergent at the ends.

Dimensions: L: 315.7-335.5 µm; W: 39.4-40.5 µm; S: 6-8 in 10 µm; A: inconspicuous

Comments: *Pinnularia domingensis* and *P. gigaformis* Krammer & Metzeltin are morphologically similar but differ in their length-to-width ratio: 7.8 in the former, which gives it a much more robust appearance, against 9.2-9.7 in *P. gigaformis*, which has a more slender morphology (Metzeltin and Lange-Bertalot 1998). The species studied here can also be compared with *Pinnularia latevittata* Cleve; however, the latter lacks an inflated central region and is shorter (L: 160.0-230.0 µm) than *P. domingensis* (L: 360.0 µm). *Pinnularia domingensis* (= *Pinnularia latevittata* var. *domingensis* Cleve) has previously been reported for Rio Grande do Sul (Silva 1987) and Mato Grosso (Nardelli et al. 2021).

Discussion

The present study expands the knowledge of the diatom flora of the Iguaçu River. The results show that, even in a previously investigated river basin, the understanding of diatom diversity and distribution is still far from complete. The data reflect both the Linnean shortfall, related to incomplete knowledge of taxonomic diversity, and the Wallacean shortfall, related to limitations in the knowledge of the geographic distribution of species (Bini et al. 2006; Hortal et al. 2015). For diatoms, these gaps tend to be reduced through the continuous refinement of taxonomy, the revision of species previously identified under broad taxonomic concepts and an increased sampling effort across different habitats. New records can therefore be expected even in regions considered relatively well known from a floristic point of view.

Declarations

Funding: This study was supported by the Fundação Araucária (FA), the Companhia de Saneamento do Paraná (SANEPAR), the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, grant number 301866/2025-2).

Competing interests: The authors have no relevant financial or non-financial interests to disclose.

Data availability: All data generated or analyzed during this study are included in this published article. The permanent slides and liquid samples are deposited in the Herbarium of the Western Paraná State University (UNOPA), Cascavel Campus, and the associated records are available on the SpeciesLink platform.

Ethics approval: Samples were collected under research permits issued by the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio).

References

- Amaral MWW, Medeiros G, Daufenbach V, Sampaio CS, Reis RR, Ludwig TAV, Bueno NC (2024) Taxonomy of epilithic diatoms and teratological forms under the presence of metals in surface sediment. *Phytotaxa* 647:237-273. <https://doi.org/10.11646/phytotaxa.647.3.3>
- Barber HG, Haworth EY (1981) A guide to the morphology of the diatom frustule: with a key to the British freshwater genera. Freshwater Biological Association, Ambleside
- Bartozek ECR, Bueno NC, Ludwig TAV, Tremarin PI, Nardelli MS, Rocha ACR (2013) Diatoms (Bacillariophyceae) of Iguaçu National Park, Foz do Iguaçu, Brazil. *Acta Botanica Brasilica* 27:108-123
- Barua P (2025) Diatoms as microbial architects of the silica cycle: ecological significance, biogenic bioactives, and emerging biotechnological applications. *Microbial Bioactives* 8:1-12. <https://doi.org/10.25163/microbbioacts.8110298>
- Bhat K, Ajees MA, Kumar P, Vibha, Bhat VG, Nayak R, Mazumder N (2025) Diatoms: harnessing nature's microscopic marvels for biosensing and multifaceted applications. *Biophysical Reviews* 17:103-125. <https://doi.org/10.1007/s12551-024-01249-8>
- Bicudo CEM, Menezes M (2017) Gêneros de algas de águas continentais do Brasil: chave para identificação e descrições, 3rd edn. Rima, São Carlos

Bini LM, Diniz-Filho JAF, Rangel TFLVB, Bastos RP, Pinto MP (2006) Challenging Wallacean and Linnean shortfalls: knowledge gradients and conservation planning in a biodiversity hotspot. *Diversity and Distributions* 12:475-482. <https://doi.org/10.1111/j.1366-9516.2006.00286.x>

Borges A, Fujita RH, Binda AL (2021) As chuvas do baixo rio Iguaçu (Sudoeste do Paraná) no período de 1976 a 2016. *Geosul* 36:64-85. <https://doi.org/10.5007/2177-5230.2021.e71496>

Brassac NM, Ludwig TAV (2005) Amphipleuraceae e Diploneidaceae (Bacillariophyceae) da bacia do rio Iguaçu, PR, Brasil. *Acta Botanica Brasilica* 19:359-368. <https://doi.org/10.1590/S0102-33062005000200019>

Brassac NM, Ludwig TAV (2006) Diatomáceas da bacia do rio Iguaçu, Paraná, Brasil: *Pinnularia* e *Caloneis*. *Hoehnea* 33:127-142

Bueno NC, Bortolini JC, Nardelli MS, Biolo S (eds) (2022) Ficoflora: Bacillariophyta, Chlorophyta, Streptophyta e Euglenophyceae de ambientes aquáticos continentais do Oeste do Paraná, Sul do Brasil. Edunioeste, Cascavel

Carlson GWF (1913) Süßwasser-Algen aus der Antarktis, Süd-Georgien und den Falkland Inseln. Lithographisches Institut des Generalstabs, Stockholm

Carter JR, Denny P (1992) Freshwater algae of Sierra Leone, IV. Bacillariophyceae. Part (iii). Diatoms from the Lake Sonfon region and from Lake Popei. *Nova Hedwigia* 54:159-211. <https://doi.org/10.1127/nova.hedwigia/54/1992/159>

Cholnoky BJ (1957) Über die Diatomeenflora einiger Gewässer in den Magalies-Bergen nahe Rustenburg (Transvaal). *Botaniska Notiser* 110:325-362

Cleve PT (1894) Synopsis of the naviculoid diatoms, part I. *Kongliga Svenska Vetenskaps-Akademiens Handlingar* 26:1-194

Cox EJ (2015) Diatoms, Diatomaceae (Bacillariophyceae s.l., Bacillariophyta). In: Frey W (ed) Syllabus of plant families. A. Engler's Syllabus der Pflanzenfamilien, 13th edn, part 2/1: photoautotrophic eukaryotic algae. Borntraeger, Stuttgart

Cox EJ, Van de Vijver B (2024) What constitutes a stigma? A review of isolated pores in raphid diatoms (Bacillariophyceae) and the value of precise terminology. *Journal of Phycology* 60:1498-1513. <https://doi.org/10.1111/jpy.13522>

Faria DM, Costin JC, Tremarin PI, Ludwig TAV (2019) Temporal changes in biological traits of diatom communities in response to an oil spill in a subtropical river. *Anais da Academia Brasileira de Ciencias* 91:e20170863. <https://doi.org/10.1590/0001-3765201920170863>

Faustino SB, Fontana L, Bartozek ECR, Bicudo CEM, Bicudo DC (2016) Composition and distribution of diatom assemblages from core and surface sediments of a water supply reservoir in Southeastern Brazil. *Biota Neotropica* 16:e20150129. <https://doi.org/10.1590/1676-0611-BN-2015-0129>

Gandhi HP (1966) The fresh-water diatom flora of the Jog-Falls, Mysore State. *Nova Hedwigia* 11:89-197

Grunow A (1868) Algae. In: Fenzl E (ed) *Reise der österreichischen Fregatte Novara um die Erde in den Jahren 1857, 1858, 1859 unter den Befehlen des Commodore B. von Wüllerstorff-Urbair. Botanischer Theil. Erster Band. Sporenpflanzen.* Karl Gerold's Sohn, Vienna

Grunow A (1877) New diatoms from Honduras, with notes by F. Kitton. *Monthly Microscopical Journal* 18:165-186. <https://doi.org/10.1111/j.1365-2818.1877.tb00123.x>

Guiry MD, Guiry GM (2026) *AlgaeBase*. World-wide electronic publication, National University of Ireland, Galway. <https://www.algaebase.org>. Accessed 22 January 2026

Hortal J, de Bello F, Diniz-Filho JAF, Lewinsohn TM, Lobo JM, Ladle RJ (2015) Seven shortfalls that beset large-scale knowledge of biodiversity. *Annual Review of Ecology*,

Evolution, and Systematics 46:523-549. <https://doi.org/10.1146/annurev-ecolsys-112414-054400>

Hustedt F (1949) Diatomeen von der Sinai-Halbinsel und aus dem Libanon-Gebiet.

Hydrobiologia 2:24-55. <https://doi.org/10.1007/BF00117694>

Kingston, J.C. (2000). New combinations in the freshwater Fragilariaceae and Achnanthidiaceae. Diatom Research 15(2): 409-411.

<http://dx.doi.org/10.1080/0269249X.2000.9705504>

Kociolek JP, Ashworth MP, Alverson A (2026) A phylogenetic classification of diatoms (Bacillariophyta). Journal of Phycology 62:44-67. <https://doi.org/10.1111/jpy.70125>

Krammer K (1997) Die cymbelloiden Diatomeen. Eine Monographie der weltweit bekannten Taxa. Teil 2. *Encyonema* part., *Encyonopsis* und *Cymbellopsis*. Bibliotheca Diatomologica 37. J Cramer, Berlin

Krammer K (2000) The genus *Pinnularia*. In: Lange-Bertalot H (ed) Diatoms of Europe: diatoms of the European inland waters and comparable habitats, vol 1. ARG Gantner, Ruggell

Krammer K, Lange-Bertalot H (1985) Naviculaceae. Neue und wenig bekannte Taxa, neue Kombinationen und Synonyme sowie Bemerkungen zu einigen Gattungen. Bibliotheca Diatomologica 9. J Cramer, Berlin

Krammer K, Lange-Bertalot H (1986) Bacillariophyceae. 1. Teil: Naviculaceae. In: Ettl H, Gerloff J, Heynig H, Mollenhauer D (eds) Süßwasserflora von Mitteleuropa, Band 2/1. Gustav Fischer, Jena

Krasske G (1939) Zur Kieselalgenflora Südchiles. Archiv für Hydrobiologie 35:349-468

Lange-Bertalot H (1998) *Adlafia bryophila*. In: Moser, G., Lange-Bertalot, H. & Metzeltin, D. (ed). Insel der Endemiten. Geobotanisches Phänomen Neukaledonien. Island of endemics New Caledonia - a geobotanical phenomenon. Bibliotheca Diatomologica 38. Gebrüder Borntraeger Verlag, Berlin

- Lange-Bertalot H (2001) *Navicula* sensu stricto. 10 genera separated from *Navicula* sensu lato. *Frustulia*. Diatoms of Europe: diatoms of the European inland waters and comparable habitats, vol 2. ARG Gantner, Ruggell
- Lange-Bertalot H, Külbs K, Lauser T, Nörpel-Schempp M, Willmann M (1996) Diatom taxa introduced by Georg Krasske: documentation and revision. *Iconographia Diatomologica* 3. Koeltz Scientific Books, Königstein
- Leuduger-Fortmorel G (1879) Catalogue des diatomées de l'Île Ceylan. Librairie Francisque Guyon, Saint-Brieuc
- Lobo EA, Callegaro VLM, Bender EP (2002) Utilização de algas diatomáceas epilíticas como indicadores da qualidade da água em rios e arroios da região hidrográfica do Guaíba, RS, Brasil. EDUNISC, Santa Cruz do Sul
- Ludwig TAV, Flôres TL (1995) Diatomoflórula dos rios da região a ser inundada para a construção da Usina Hidrelétrica de Segredo, Paraná. I. Coscinodiscaceae, Bacillariophyceae (Achnanthales e Eunotiales) e Fragilariophyceae (*Meridion* e *Asterionella*). *Arquivos de Biologia e Tecnologia* 38:631-650
- Ludwig TAV, Tremarin PI (2017) Bacillariophyta. In: Bicudo CEM, Menezes M (eds) *Gêneros de algas de águas continentais do Brasil: chave para identificação e descrições*, 3rd edn. Rima, São Carlos, pp 435-456
- Maack R (1968) Geografia física do Estado do Paraná. Universidade Federal do Paraná, Curitiba
- Metzeltin D, Lange-Bertalot H (1998) Tropical diatoms of South America I: about 700 predominantly rarely known or new taxa representative of the neotropical flora. *Iconographia Diatomologica* 5. Koeltz Scientific Books, Königstein
- Metzeltin D, Lange-Bertalot H (2007) Tropical diatoms of South America II: special remarks on biogeographic disjunction. *Iconographia Diatomologica* 18. ARG Gantner, Ruggell

Metzeltin D, Lange-Bertalot H, García-Rodríguez F (2005) Diatoms of Uruguay, compared with other taxa from South America and elsewhere. *Iconographia Diatomologica* 15. Koeltz Scientific Books, Königstein

Montoya-Moreno Y, Sala SE, Vouilloud AA, Aguirre N (2012) Diatomeas (Bacillariophyta) perifíticas del complejo cenagoso de Ayapel, Colombia. I. *Caldasia* 34:454-474

Moreira-Filho H, Valente-Moreira IM (1981) Avaliação taxonômica e ecológica das diatomáceas (Bacillariophyceae) epífitas em algas pluricelulares obtidas nos litorais dos Estados do Paraná, Santa Catarina e São Paulo. *Boletim do Museu Botânico Municipal* 47:1-17

Moreira-Filho H, Valente-Moreira IM, Cecy IIM (1973) Diatomáceas na barragem de captação d'água (SANEPAR) do rio Iguaçu, Estado do Paraná. *Acta Biologica Paranaense* 2:133-145. <https://doi.org/10.5380/abpr.v2i0.827>

Nardelli MS, Bueno NC, Ludwig TAV, Guimarães ATB (2016) Structure and dynamics of the planktonic diatom community in the Iguassu River, Paraná State, Brazil. *Brazilian Journal of Biology* 76:374-386. <https://doi.org/10.1590/1519-6984.16114>

Nardelli MS, Tremarin PI, Bicudo DC, Cordovil CMS, Sampaio SC (2021) Diatomáceas (Bacillariophyta) do Pantanal brasileiro: contribuição florística de espécies depositadas em sedimentos recentes. *Edunioeste*, Cascavel

Nardelli MS, Bartozek ECR, Amaral MWW, Medeiros G, Favaretto CCR (2022) Bacillariophyta: Coscinodiscophyceae, Fragilariophyceae e Bacillariophyceae. In: Bueno NC, Bortolini JC, Nardelli MS, Biolo S (eds) *Ficoflora: Bacillariophyta, Chlorophyta, Streptophyta e Euglenophyceae de ambientes aquáticos continentais do Oeste do Paraná, Sul do Brasil*. *Edunioeste*, Cascavel

Paraná (2026) *Bacias hidrográficas do Paraná: série histórica*. Secretaria de Estado do Meio Ambiente e Recursos Hídricos (SEMA), Curitiba.

<https://pt.scribd.com/document/548368347/Revista-Bacias-Hidrograficas>. Accessed 25 May 2026

Patrick R, Reimer CW (1966) The diatoms of the United States, vol 1. The Academy of Natural Sciences of Philadelphia, Philadelphia

Patrick R, Reimer CW (1975) The diatoms of the United States, vol 2. The Academy of Natural Sciences of Philadelphia, Philadelphia

Peel MC, Finlayson BL, McMahon TA (2007) Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences* 11:1633-1644.

<https://doi.org/10.5194/hess-11-1633-2007>

Pereira EL, Nardelli MS, Bueno NC (2026) *Gomphonema* Ehrenberg (Bacillariophyceae) from the Lower Iguaçu River, Paraná State, Brazil: taxonomy and new records. *Hoehnea* 53:e122025. <https://doi.org/10.1590/2236-8906e122025>

Potapova MG, Ponader KC (2004) Two common North American diatoms, *Achnanthes rivulare* sp. nov. and *A. deflexum* (Reimer) Kingston: morphology, ecology and comparison with related species. *Diatom Research* 19:33-57.

<https://doi.org/10.1080/0269249X.2004.9705606>

Round FE, Crawford RM, Mann DG (2007) The diatoms: biology and morphology of the genera. Cambridge University Press, New York

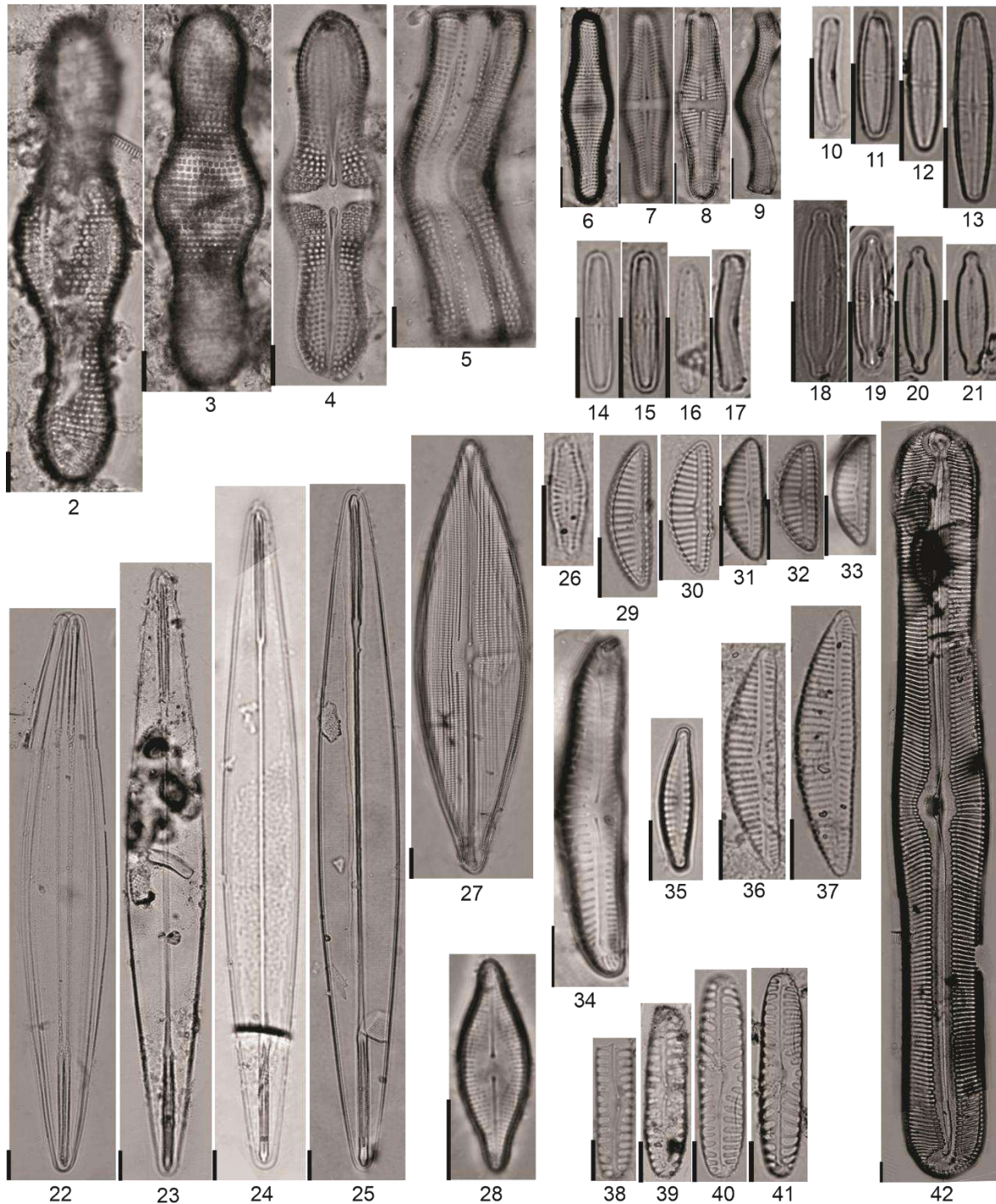
Salamuni R, Salamuni E, Rocha LA, Rocha AL (2002) Parque Nacional do Iguaçu, PR: cataratas de fama mundial. In: Schobbenhaus C, Campos DA, Queiroz ET, Winge M, Berbert-Born MLC (eds) *Sítios geológicos e paleontológicos do Brasil*. Departamento Nacional de Produção Mineral (DNPM), Brasília

Schneck F, Torgan LC, Schwarzbald A (2008) Diatomáceas epilíticas em riacho de altitude no Sul do Brasil. *Rodriguesia* 59:325-338

- Silva RL (1987) Estudo taxonômico das diatomáceas (Bacillariophyceae) coletadas no Arroio do Faxinal (Sanga da Água Boa), Torres, Rio Grande do Sul, Brasil. *Insula* 17:1-174
- Silva AM, Ludwig TAV, Tremarin PI, Vercellino IS (2010) Diatomáceas perifíticas em um sistema eutrófico brasileiro (Reservatório do Iraí, estado do Paraná). *Acta Botanica Brasilica* 24:997-1016. <https://doi.org/10.1590/S0102-33062010000400015>
- Simonsen R (1974) The diatom plankton of the Indian Ocean Expedition of R/V “Meteor”, 1964-65. “Meteor” Forschungsergebnisse, Reihe D-Biologie 19:1-66
- Siver PA, Hamilton PB, Stachura-Suchoples K, Kociolek JP (2005) Diatoms of North America: the freshwater flora of Cape Cod. *Iconographia Diatomologica* 14. ARG Gantner, Ruggell
- Taurozzi D, Cesarini G, Scalici M (2024) Diatoms as bioindicators for health assessments of ephemeral freshwater ecosystems: a comprehensive review. *Ecological Indicators* 166:112309. <https://doi.org/10.1016/j.ecolind.2024.112309>
- Taylor JC, Morales EA, Ector L (2011) *Achnantheidium standeri* (Cholnoky) comb. nov. and *Achnantheidium taiaense* (J.R.Carter et Denny) comb. nov., two new combinations of morphologically similar *Achnantheidium* species from Africa. *Algological Studies* 136/137:151-166. <https://doi.org/10.1127/1864-1318/2011/0136-0151>
- Villac MC, Cabral-Noronha VAP, Pinto TO (2008) The phytoplankton biodiversity of the coast of the state of São Paulo, Brazil. *Biota Neotropica* 8:151-173. <https://doi.org/10.1590/S1676-06032008000300015>
- Wojtal AZ (2009) The diatoms of Kobylanka stream near Kraków (Wyżyna Krakowsko-Częstochowska Upland, S Poland). *Polish Botanical Journal* 54:129-330
- Yadav A, Srivastava A, Verma J (2026) Ecotoxicological assessment of emerging pollutants and diatom vulnerability in aquatic ecosystems. *Discover Water* 6:47. <https://doi.org/10.1007/s43832-025-00339-2>

Figure captions

Fig. 1 Location of the sampling stations: Station 1 (S1) upstream and Station 2 (S2) downstream of the Iguazu Falls, Iguazu River, Paraná State, Brazil (map provided by Iguazu National Park)



Figs 2-42 New records of species from the Iguazu River. **2-5** *Achnanthes inflata* var. *javanica*; **6-9** *A. coarctata* var. *sinaensis*; **10-13** *Achnanthidium deflexum*; **14-17** *A. standeri*;

18-21 *Adlafia bryophila*; **22-25** *Amphipleura pellucida* var. *oregonica*; **26** *Chamaepinnularia submuscicola*; **27** *Craticula perrotettii*; **28** *Diadesmis confervacea* f. *rostrata*; **29-33** *Encyonema kukenanum*; **34** *E. lapponicum*; **35** *E. lembus*; **36-37** *E. riotecense*; **38-41** *Pinnularia borealis* var. *islandica*; **42** *P. domingensis*