Coscinodiscophyceae and Fragilariophyceae (Diatomeae) in the Iguaçu River, Paraná, Brazil

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ABSTRACT
A taxonomic survey was carried out on Coscinodiscophyceae and Fragilariophyceae found in the Iguaçu River catchment area within Iguaçu National Park, in the state of Paraná, Brazil. Between September 2007 and August 2008, we collected 24 samples from two stations on the Iguaçu River, upstream and downstream of the falls. We identified 37 taxa, including 22 specific and infraspecific taxa of Coscinodiscophyceae, together with 15 specific and infraspecific taxa of Fragilariophyceae. Melosira ruttneri Hustedt and Fragilaria alpestris Krasske ex Hustedt represent new records for Brazil.

Key words: diatoms, lotic systems, southern Brazil, taxonomy

Introduction
Diatoms are algae with siliceous cell walls that are fairly well-represented in aquatic systems, in terms of richness as well as abundance (Hoek et al. 1995). The identification of these organisms is complex (Stoermer & Smol 1999) because of variations in the form and frustule ornamentation. In water quality studies, diatoms are excellent bioindicators (Round 1991; Descy & Ector 1999), mainly because of their short life cycle and their selective sensitivity to certain limnological conditions, making them respond promptly to environmental changes (Lobo et al. 2002; Stevenson & Smol 2003).

Taxonomic studies are of extreme importance for expanding knowledge on the biodiversity of diatoms (Lobo et al. 2002). They enable the proposal of indices that might express the ecological significance of the complex relationships among species in the environments studied (Senna & Magrin 1999; Dinnerstein et al. 1995). Floristic surveys of diatoms in the watershed of the Iguaçu River started with Moreira-Filho et al. (1973), Contin (1990) and Lozovei & Shirata (1990), in a stretch of the river near the municipality of Curitiba. Subsequently, other studies of diatoms were conducted along the watershed. Ludwig & Flóres (1995; 1997) conducted studies in rivers within the catchment area of the Segredo hydroelectric power plant, and Brassac et al. (1999) studied the area around the Salto Caxias hydroelectric power plant, both identifying centric diatoms. Similar studies were conducted by Tremarin et al. (2009a), in the Mauricio River, and by Santos et al. (2011), in the Salto Amazonas River and in an artificial lake in the municipality of General Carneiro. Other studies of diatoms in the Iguaçu River were performed by Brassac & Ludwig (2003; 2005; 2006), Ludwig et al. (2008) and by Bartozek et al. (2013). At Iguaçu Falls, Metzeltin & Lange-Bertalot (1998; 2007) identified 45 taxa, of which only six were centric and none were araphid.

The aim of this study was to inventory the species and taxonomic varieties of the classes Coscinodiscophyceae and Fragilariophyceae in the Iguaçu River, within the catchment area of Iguaçu National Park, thereby expanding the knowledge on the flora of the diatoms of the state of Paraná and providing support for future studies on this community of rheophilic species in freshwater environments.

Material and methods
Iguaçu National Park, which comprises approximately 169765.00 ha, is the largest protected area within the Atlantic Forest biome of Brazil. The area has a humid temperate climate (Ibama 1999); the average annual rainfall in the Iguaçu River watershed is approximately 1500 mm/year; and the rainfall distribution is fairly irregular in time and...
space, without a well-defined wet period (Lactec 2005). The mean annual temperature is 26 °C, monthly averages ranging from 3 °C to 40 °C (Salamuni et al. 2002).

The Iguaçu River watershed, located at the southern portion of the state of Paraná, is the largest drainage basin in the state and extends into the state of Santa Catarina as well as into some areas of Argentina (Maack 2002). The river is 1275 km in length, and its drainage area covers 70800 km² and flowing in an east-west direction from the source at the Serra do Mar mountain range to the mouth in the Paraná River (Paraná 2010).

Two sampling stations were selected, in the backwater, on the right bank of the Iguaçu River, in the municipality of Foz do Iguaçu (Fig. 1):
- Station 1 (25°35'72"S, 54°23'63"W), located upstream of Iguaçu Falls, with a width of 869.89-1200.00 m, a flow rate of 0.424 m.s⁻¹ and a depth ranging from 0.90 m to 4.62 m, depending on the season (Paraná 2010).
- Station 2 (25°38'55"S, 54°27'27.5"W), located downstream of Iguaçu Falls, with a width of 69.89 m, a flow rate of 6.8 m s⁻¹ and a depth ranging from 4.62 m to 27.00 m, depending on the season (Paraná 2010).

A total of 24 samples were monthly collected between September 2007 and August 2008 from subsurface water at both stations (Tab. 1). The samples were fixed with Transeau’s solution (Bicudo & Menezes 2006) and oxidized by the technique proposed by Simonsen (1974) modified by Moreira-Filho & Valente-Moreira (1981). Microscope slides were prepared using Naphrax® as mountant (refractive index = 1.73; Brunel Microscopes Ltd., Chippenham, UK). The analysis of the permanent slides was performed with an Olympus BX60 optical microscope coupled to an Olympus DP71 microscope digital camera (Olympus, Tokyo, Japan). The systematic classification and the terminology followed Round et al. (1990) and Houk & Klee (2004).

For all of the taxa identified, we quantified morphometric and meristic characters — apical axis (AA); transapical axis (TA); pervalvar axis (PA); mantle height (MH); diameter (D); striae (S); areolae (A) and fultoportulae (F) — providing descriptions and including comments when relevant.

Frequencies of the taxa were based on the observation of samples in permanent slides and calculated with the following equation:

\[ F = \left( \frac{p}{P} \times 100 \right) \]

where \( F \) is the frequency, \( p \) is the number of samples containing the species and \( P \) is the total number of samples analyzed. The diatom taxa identified in the 24 samples were classified into the following categories (Dajoz 2005): constant (\( F \geq 70\% \) in the samples), frequent (\( 30\% \geq F \leq 69\% \)), sporadic (\( 10\% \geq F \leq 29\% \)) and occasional (\( F \leq 9\% \)).

The material was deposited in the Herbarium of the Universidade Estadual do Oeste do Paraná (UNOP, Western Paraná State University), Cascavel campus.
Results and discussion

In the taxonomic evaluation, 37 taxa were identified. Of those, 22 belonged to the class Coscinodiscophyceae, within seven families and nine genera, with one taxon identified down to the genus level, 17 identified down to the species level, four identified down to the level of variety and two identified as non-typical taxonomic forms. In the class Fragilariophyceae, we identified 15 taxa, within one family and four genera, with one taxon identified down to the genus level, 13 taxa identified down to the species level and two taxa identified as non-typical taxonomic forms.

Coscinodiscophyceae Round & Crawford in Round et al. 1990
Thalassiosirales Glezer & Makarova 1986
Stephanodiscaceae Glezer & Makarova 1986

Valves circular, valve surface slightly undulate, hyaline or slightly granulate central area with one or two fultoportulae, robust marginal striae occupying one third of the valve radius. D: 14-16 μm; S: 7-9 in 10 μm. Sporadic taxon, occurring in 12.4% of the samples.

The material studied was coincident with the characters described and illustrated by Krammer & Lange-Bertalot (1991) and Contin (1990). Occurrence in samples: UNOP 2704, 2711, 2712.


Valves circular, valve surface slightly convex and with a marginal ring of fultoportulae, intercalated with 1-3 rimoprtulae. The marginal areolae are smaller and radially arranged, whereas the central areolae are larger and irregularly arranged. D: 12.8-25.8 μm; A: 16-20 in 10 μm; F: 2-3 in 10 μm. Constant taxon, occurring in 83.3% of the samples.

The morphometry of the specimens studied was coincident with the description of Thalassiosira rudis by Ludwig et al. (2008) for freshwater environments (Iguaçu River and its tributaries). Tuji et al. (2012) transferred the species to the genus Spicaticribra Johansen, Kociolek & Lowe. Those authors differentiated Spicaticribra rudis from Spicaticribra kingstonii Johansen, Kociolek & Lowe by the pattern of the areolae in the central region of the valve and by the position

Table 1. Collection dates, UNOP Herbarium accession number of the herbarium samples from stations 1 and 2, upstream and downstream of Iguaçu Falls, respectively and samples collectors. Iguaçu National Park, state of Paraná, Brazil.

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<th>Collector(s)</th>
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UNOP – Universidade Estadual do Oeste do Paraná (Western Paraná State University).
of the rimoportula (Tuji et al. 2012). *Spicaticribra* differs from the genus *Thalassiosira* Cleve by the presence of a network of channels with an anastomosed (bifurcated) pattern and without central fultoportulae (Karthick & Kociolek 2011).

Occurrence in samples: UNOP 2702, 2703, 2704, 2705, 2707, 2708, 2711, 2712, 2713, 2714, 2715, 2717, 2726, 2727, 2728, 2729, 2730, 2731, 2799, 2800.

**Melosira ruttneri** Hustedt. Archiv für Hydrobiologie 15: 140-141, pl. 9, fig. 11-16. 1937. Fig. 8-10

Valves cylindrical, forming rectilinear chains connected by the valve faces. Valve surface slightly convex displaying concave extremity covered with coarse granules larger in the extremities. Mantle with striae slightly curved to the right, circular to ovate areolae on the entire surface of the mantle. MH: 11-15.4 μm; D: 13.2-28.4 μm; S: 20-22 in 10 μm; A: 14-16 in 10 μm. Frequent taxon, occurring in 33.3% of the samples.

Little is known about the geographic distribution of *Melosira ruttneri*, because there are very few records of it in the literature. The population analyzed is consistent with the descriptions of Hustedt (1937) and the illustrations made by Simonsen (1987). For a better description of this species, future studies should involve a larger number of specimens, examined under electron microscopy.

Occurrence in samples: UNOP 2702, 2703, 2704, 2705, 2707, 2711, 2712, 2713, 2714, 2715, 2717, 2726, 2727, 2728, 2729, 2730, 2731, 2799, 2800.

Occurrence: first record for Brazil.

**Melosira sp.**

Fig. 6a-b

Valve cylindrical in girdle view, forming non-rectilinear chains connected by the valve faces. Mantle straight to slightly concave with extremities facing outward in the region of the junction with the complementary valve. Frustule with one concave valve face and one convex valve face in order to dock with the adjacent valve, which has the opposing curvature. Valve surface with inconspicuous ornamentations under optical microscopy. MH: 27-32.5 μm; D: 25.3-33.2 μm. Occasional taxon, occurring in only 4.2% of the samples.

This taxon was found in only one collection during the study period, and no similar specimens were found in the literature consulted. We opted to identify the taxon only down to the genus level and suggest studies involving a larger number of specimens, examined under electron microscopy to confirm a new species of *Melosira* Agardh.

Occurrence in samples: UNOP 2800.

**Melosira undulata var. normanii** Arnott. In: Van Heurck, Synopsis. 90, f. 7. 1882.

Fig. 7

Circular valve surface displaying a polygonal internal wall, ornamented with areolae in radial lines in the extremities, sometimes with ramifications, and approaching the center in radial spiral. MH: not visualized. D: 55-67 μm; S: 11 in 10 μm; A: 14-15 in 10 μm. Sporadic taxon, with 12.4% of occurrence.

The morphological characters and the cellular dimensions of *Melosira undulata var. normanii* are in agreement with the descriptions of Brassac et al. (1999) for the state of Paraná and of Garcia (2009) for the state of Rio Grande do Sul. However, the cellular dimensions differ from those of the species found by Rosa et al. (1994; D: 45.4 μm) for lakes in Rio Grande do Sul.

*Melosira undulata var. normanii* differs from the typical variety by displaying radial striae with a spiral arrangement in the central region (Brassac et al. 1999). Krammer & Lange-Bertalot (1991) stated that *M. undulata var. normanii* displays valves in a polygon, rather than the circular form observed in *M. undulata* (Ehrenberg) Kützing var. *undulata*.

Occurrence in samples: UNOP 2711, 2730, 2800.

**Melosira varians** Agardh. Flora oder Botanische Zeitung. p. 628. 1827.

Fig. 11-12

Valves cylindrical, forming rectilinear chains, inconspicuous marginal spines connecting the valve faces. Valve surface and mantle ornamented with delicate, inconspicuous areolae. MH: (6.5) 9.4-20.2 μm; D: 15-39.5 μm. Frequent taxon, occurring in 54% of the samples.

Occurrence in samples: UNOP 2703, 2705, 2708, 2710, 2711, 2712, 2714, 2726, 2728, 2729, 2730, 2799, 2800.

**Aulacoseiraceae Crawford 1990**


Fig. 33

Valves cylindrical, in straight chains, lines of round to square areolae, curving to the right. MH: 8.1-14.8 μm; D: 5.5-9.1 (14.2) μm; S: 14-18 in 10 μm; A: 12-16 in 10 μm. Frequent taxon, occurring in 16.6% of the samples.

Occurrence in samples: UNOP 2705, 2712, 2714, 2716, 2727, 2728, 2730, 2799, 2800.


Fig. 34

Valves cylindrical, in curved or helicoidal chains, mantle with striae oblique in relation to the pervalvar axis, curved to the right; separation spines of equal size. MH: 7.7-15.1 μm; D: 4.8-7.3 μm; S: 14-16 in 10 μm; A: 14-18 in 10 μm. Frequent taxon, occurring in 37.5% of the samples.

Occurrence in samples: UNOP 2703, 2704, 2708, 2712, 2714, 2717, 2729, 2799, 2800.


Fig. 20-22
Fig. 23-24
Valves cylindrical, in straight chains with one or two long spines. Mantle with visible areolae in slightly curved to almost straight lines. MH: 12.4-17.4 μm; D: 3.3-4.5 μm; S: 12-15 in 10 μm; A: 12-14 in 10 μm. Sporadic taxon, occurring in 29.1% of the samples. Occurrence in samples: UNOP 2706, 2708, 2714, 2726, 2727, 2728, 2729, 2730, 2731, 2799, 2800.

Aulacoseira granulata var. australiensis (Grunow) Moro. Arquivos de Biologia e Tecnologia 34 (2): 353-359. 1991. Fig. 31-32
Valves cylindrical, in straight chains. Mantle with large square areolae in slightly curved or straight lines. Rimoporate visible always on the opposite side of the small spines of the cell. MH: 16.8-25.3 μm; D: 15.2-20 μm; S: 6-10 in 10 μm; A: 5-7 in 10 μm. Occasional taxon, occurring in 20.8% of the samples.

Fig. 25
Valves cylindrical, in short chains. Mantle with large areolae in slightly curved or straight lines. MH: 16.1-23 μm; D: 7.8-12.8 μm; S: 6-10 in 10 μm; A: 6-10 in 10 μm. Sporadic taxon, occurring in 12.4% of the samples. Occurrence in samples: UNOP 2714, 2716, 2729, 2730, 2800.

Fig. 26
Valves cylindrical, in straight chains. Mantle with thin areolae, almost indistinguishable under light microscopy, with 2-4 straight or slightly curved spines. MH: 15.6-16.7 μm; D: 7.5-7.9 μm; S: inconspicuous. Occasional taxon, occurring in only 4.2% of the samples. Occurrence in samples: UNOP 2708.

Cells cylindrical, in straight chains, with spines in the shape of a crown. Mantle with elliptic areolae, arranged in spiral lines curved to the left. MH: 12.6 μm; D: 14 μm; S: 22 in 10 μm; A: 20-22 in 10 μm. Occasional taxon, occurring in only 4.2% of the samples. Occurrence in samples: UNOP 2726.

Aulacoseira pusilla (Meister) Tuji & Houk. Bulletin of the National Science Museum 30(2): 38. 2004. Fig. 27-29b
Valves cylindrical, with short spines originating from the end of two rows of areolae. Mantle with lines of delicate areolae, not always visible, curved to the right. MH: 3.3-5.7 μm; D: 5.9-8.8 μm; S: 16-20 in 10 μm; A: 16-22 in 10 μm. Sporadic taxon, occurring in 25% of the samples. Occurrence in samples: UNOP 2703, 2708, 2712, 2726, 2727, 2730, 2800.

Orthoseira italica (Ehrenberg) Round, Crawford & Mann. The Diatoms, p. 174. 1990. Fig. 13-15
In girdle view, cells forming spiral or rectangular bands, exhibiting straight to slightly oblique rows of small areolae. PA: 16-38.5 μm; D: 12.4-19 μm; MH: 7.1-18; S: 16-20 in 10 μm; A: 16-20 in 10 μm. Sporadic taxon, occurring in 12.5% of the samples.

The specimen found is similar to those of the dendrotes-group analyzed by Houk (1993, fig. 1-6); to the material identified as Orthoseira roeseana, collected by Brassac et al. (1999, fig. 29) and Metzeltin et al. (2005, pl. 2:1-3); and to the specimens illustrated by Krammer & Lange-Bertalot (1991: pl. 11: 4-5) denominated Orthoseira roeseana morphotype spiralis.

As reported by Houk (1993), and using the studies of Krammer (1991) and Brassac et al. (1999) as examples, we found that the taxon studied here has been erroneously identified by several taxonomists as Orthoseira roeseana var. roeseana and Orthoseira roeseana morphotype spiralis, because of its complicated interpretation. The taxa have therefore been gathered in two morphological groups, considering the pattern of striae on the mantle and the presence or absence of undulating spirals in the cingulum. Occurrence in samples: UNOP 2708, 2729, 2800.

Orthoseira epidendron (Ehrenberg) Round, Crawford & Mann. The Diatoms, 96. 1990. Fig. 18-19
In girdle view, cells forming well-connected rectangular bands, with circular areolae. Valves with triangular margins, pointed, conspicuous spines and alternating fields with or without spines. MH: 14 μm; D: 29.6 μm; S: 11 in 10 μm; A: 10 in 10 μm. Occasional taxon, occurring in only 4.2% of the samples.
The specimen found is similar to the material examined by Metzeltin & Lange-Bertalot (2007, pl. 10, fig. 5) and identified as *Orthoseira cf. dendrophila*. However, *Orthoseira epidendron* differs from *Orthoseira dendrophila* (Ehrenberg) Round, Crawford & Mann by displaying dichotomous striae near the cingulum, the spines forming a continuous ring at the valve margin, with ribs that extend into the mantle. Conversely, *Orthoseira dendroteres* is characterized by uniseriate striae on the mantle and spines separated by areas with small pores near the valve margin (Houk 2003).

Occurrence in samples: UNOP 2799.


Fig. 16-17b

In girdle view, cells forming rectangular bands, with rows of areolate, straight to slightly oblique striae. Valves circular with a flat surface, undulate at the margin, with conspicuous marginal spines. Central area with carinopertulate, areolate striae forming irregular and radial rows. PA: 15.5-26.4 μm; MH: 7.2-11.1 μm; D: 9.3-12.8 μm; in girdle view, S: 12-16 in 10 μm; A: 16 in 10 μm; in valve view, S: 20 in 10 μm; A: 19 in 10 μm. Sporadic taxon, occurring in 12.5% of the samples.

Occurrence in samples: UNOP 2712, 2799, 2780.

Triceratiaceae Round & Crawford 1990

Triceratiaceae Lemmermann 1899


Fig. 35

Valve face approximately circular; circular areolae in radial lines; prominent ocelli present at an opposite position at the valve margin. Two to three rimoportulae at a right angle, with a more central location, transversal to the ocelli. D: short axis 70-93.7 μm, long axis 75.5-108.8 μm; S: 11-12 in 10 μm; A: 10-11 in 10 μm. Frequent taxon, occurring in 54.1% of the samples.

The species *Pleurosira laevis* differs from *Pleurosira socotrensis* (Kitton) Compère by displaying areolae arranged in radial rows from the margin to the central region of the valve face (Ludwig et al. 2004). It also differs from *Pleurosira indica* Karthick & Kociolek by displaying areolae arranged in short radial lines at the margin and irregularly arranged areolae in the central part of the valve (Karthick & Kociolek 2011). *Pleurosira laevis* prefers lotic environments (Kociolek et al. 1983) and has a wide distribution for the state of Paraná (Tremarin et al. 2009b).

Occurrence in samples: UNOP 2703, 2704, 2705, 2706, 2708, 2711, 2712, 2714, 2715, 2716, 2728, 2730, 2799.

Biddulphiales Krieger 1954

Biddulphiales Kützing 1844


Fig. 36

Valve multipolar, with margins in the shape of two superimposed triangles. Pseudocelli located at the three poles of the triangle, containing small pores, position inferior to the opposite triangle. One conspicuous rimoportula in the valve face. Ornamentations with loculate areolae. In girdle view, cells rectangular with a high perivalvar axis (not illustrated). Measures of the long axis: 81.4-99.7 μm, and short axis: 80.5-97 μm; A: 4-7 in 10 μm. Frequent taxon, occurring in 54.1% of the samples.

Occurrence in samples: UNOP 2705, 2706, 2707, 2708, 2711, 2712, 2713, 2714, 2715, 2716, 2726, 2729, 2730.


Fig. 37

Valves tri-undulate, narrowing slightly toward the capitate apices. Pseudocelli located at the apical poles, containing small pores. One conspicuous rimoportula lateral to the transapical center. Ornamentations with loculate areolae, irregularly spaced, filling the entire valve face and mantle. In girdle view, tabular (not illustrated). AA: 157.4-185.0 μm; TA: 48.4-65.0 μm; A: 6-8 in 10 μm. Frequent taxon, occurring in 54.1% of the samples.

The genera *Terpsinoë* Ehrenberg and *Hydrosera* Wallich were both found in the same collection months. As described by Round et al. (1990), the structure and ecology of the genus *Terpsinoë* are frequently related to those of *Hydrosera*.

Occurrence in samples: UNOP 2705, 2706, 2707, 2708, 2709, 2710, 2711, 2712, 2714, 2716, 2726, 2728, 2731.

Fragilariaceae Round in Round et al. 1990.

Fragilariaceae Greville 1833


Fig. 51

Valve linear, narrow, with quite round capitate to subcapitate extremities; axial area linear to linear-lanceolate; central area occasionally extending to the margins, with slight bilateral swelling; nearly parallel striae intercalated with those of the opposite margin. AA: 38 μm; TA: 4 μm; S: 13 in 10 μm. Occasional taxon, occurring in only one of the samples.

The specimen found is similar to the type specimen of *Fragilaria alpestris* (AA: 20-50; TA: 2.5-3; S: 13-16 in 10 μm) shown by Lange-Bertalot et al. (1996). It is also in agreement with the specimens described by Kramer & Lange-Bertalot (1991, fig. 111: 25-28, AA: 20-50 μm; TA: 2.5-3 μm; S: 12-14 (16) in 10 μm).

Occurrence in samples: UNOP 2710.

Occurrence: first record for Brazil.


Fig. 53
Coscinodiscophyceae and Fragilariophyceae (Diatomeae) in the Iguaçu River, Paraná, Brazil


Valves linear-lanceolate; extremities subcapitate; axial area narrow linear; central area rectangular; striae parallel, intercalated with the striae of the opposite margin. AA: 37.9-52 μm; TA: 5.2-7.3 μm; S: 9-13 in 10 μm. Sporadic taxon, occurring in 29.1% of the samples.

For this study, we considered the morphological characters of the valve outline and the central area, as described by Patrick & Reimer (1966), who distinguished *Fragilaria capucina* by its linear shape and thin striae. The study population was identified as *F. capucina* because the material did not show round attenuated apices typical of *F. fragilarioides* or unilateral swelling such as that observed for *F. vaucheriae* (Patrick & Reimer 1966).

Larger measures in width (4.1-7.8 μm) were also found by Fontana & Bicudo (2009). The *Fragilaria capucina* complex is highly polymorphic (Landucci & Ludwig 2005).

Ludwig & Flôres (1997) commented on the difficulty in distinguishing among the varieties of *F. capucina* and have selected some criteria for distinguishing them.

Occurrence in samples: UNOP 2705, 2712, 2714, 2716, 2726, 2727, 2730.


Valves linear-lanceolate; extremities subcapitate; axial area narrow; central area quadrangular, parallel striae intercalated with the striae of the opposite margin. AA: 28.6-36.4 μm; TA: 4.1-6.3 μm; S: 11-13 in 10 μm. Sporadic taxon, occurring in 29.1% of the samples.

In the analysis of the material, we considered the parameter described by Ludwig & Flôres (1997): the presence of a quadrangular bilateral central area. The material studied was coincident with that cited in Patrick & Reimer (1966, pl. 6, fig. 3), except for the transapical axis, which was larger than the 3-4 μm.

Occurrence in samples: UNOP 2702, 2703, 2704, 2705, 2712, 2727, 2730.


Valve linear-lanceolate, with slight bilateral swelling, evolving to constriction, in the median region. Valve extremities subcapitate; axial area narrow, becoming slightly wider toward the central area, crossed by very light, parallel striae, proximal to each other in the center, and intercalated with those of the opposite margin toward the extremities. AA: 118.4 μm; TA: 5.5 μm; S: 11 in 10 μm. Occasional taxon, occurring in only 4.16% of the samples.

This taxon differs from the other named varieties in that it exhibits greater swelling in the median region and thicker striae. The study specimen was coincident with the description provided by Contin (1990) for material also collected from the Iguaçu River (AA: 117.6 μm; TA: 4.75 μm; S: 12 in 10 μm), and with that provided by Patrick & Reimer (1966) for the taxon (AA: 90-120 μm; TA: 3.4 μm; S: 11-14 in 10 μm), except for the difference in the size of the transapical axis, which was larger in our specimen.

Occurrence in samples: UNOP 2716.


Valves linear to slightly lanceolate; extremities subcapitate; bilateral swelling in the central area, flanked by two constrictions, one at either margin of the valve; striae parallel or nearly parallel intercalated with the striae of the opposite margin, median region with indistinct or interrupted striae. AA: 34.3-83.8 μm; TA: 3.6-5.6 μm; S: 11-13 in 10 μm. Constant taxon, occurring in 79.1% of the samples.

The population-based study allowed clear visualization of the bilateral swelling. Patrick & Reimer (1966) distinguished *Synedra rumpens* var. *fragilarioides* (basionym) by its bilateral swelling in the central area. In this aspect, the material studied was coincident with that studied by those authors, except for displaying frustules with a shorter apical axis (AA: 40-75 μm), similar to the observations made by Flôres et al. (1999), who also noted a wide variation (AA: 20.8-80.3 μm).

Occurrence in samples: UNOP 2702, 2703, 2704, 2705, 2706, 2708, 2710, 2712, 2713, 2714, 2715, 2716, 2717, 2727, 2728, 2730, 2731, 2799, 2800.


Valves linear to linear-lanceolate; extremities attenuate to rostrate; axial area very narrow; central area rectangular, with slight constriction; striae parallel. AA: 26.5-31.4 μm; TA: 3.3-4.3 μm; S: 12 in 10 μm. Sporadic taxon, occurring in 20.8% of the samples.

Identifications were based on the constriction in the central area, which coincided with the illustrations of Patrick & Reimer (1966), Krammer & Lange-Bertalot (1991) and Ludwig & Flôres (1997).

Occurrence in samples: UNOP 2705, 2706, 2707, 2708, 2712.


Valves linear-lanceolate; extremities rostrate, attenuate to subcapitate; axial area linear to linear-lanceolate; central area occasionally extending to the margins, with a slight constriction preceding bilateral swelling in the median portion of the region; striae nearly parallel, intercalated with those of the opposite margin. AA: 25.6-26.5 μm; TA: 3.3-3.5 μm; S: 12-13 in 10 μm. Occasional taxon, occurring in only 8.3% of the samples.

Patrick & Reimer (1966) commented that this taxon is similar to *Fragilaria rumpens* (Kützing) Carlson except for...
the fact that its length/width ratio is typically smaller than that found in *F. rumpens* and that it is more lanceolate. Identifications were based on the swelling in the central area, which was more prominent than in similar species. The study material was coincident with that described by Patrick & Reimer (1966) and Contin (1990), which was identified as *Synedra socia*, except in that the number of striae was higher than that reported by those authors (17 and 15-17 in 10 μm, respectively).

Ludwig & Flôres (1997) identified similar material as *Fragilaria capucina* var. *fragilarioides*. The species commonly displays valves of larger dimensions, without such a prominent constriction causing bilateral swelling in the median region, as is typical of *Fragilaria socia*.

Occurrence in samples: UNOP 2730, 2800.

**Fragilaria sp.**

Fig. 56

Valve linear; margins straight; extremity subcapitate; axial area linear; central area absent; straight striae, intercalated with those of the opposite margin. AA: 35 μm; TA: 5.9 μm; S: 12 in 10 μm. Occasional taxon, occurring in only one of the samples.

The specimen found is similar to the type specimen of *Fragilaria fonticola* Hustedt illustrated by Simonsen (1987, pl. 320: 21-26, AA: 20-35 μm; TA: 4-5 μm; S: 13-15 in 10 μm), but differs from it by the lanceolate valve outline and by the lanceolate and larger axial area. As shown by Krammer & Lange-Bertalot (1991), *F. fonticola* also possesses linear to lanceolate valve margins, similar to those shown in the illustrations of Patrick & Reimer [1966, pl. 5: 16 - as *Synedra fasciculata var. truncata* (Greville) Patrick], as well as in those of Metzeltin et al. (2005, pl. 14: 17-23), who also reported a higher number of striae. Patrick & Reimer (1966, pl: 5, fig. 6) documented a specimen very similar to the one found in this study as *Synedra minuscula* Grun. The authors described the specimen as having a linear valve, abruptly attenuate, with rounded extremities, and characterize the taxon by the shape, the absence of a central area and the size of the valve (AA: 15-39 μm; TA: 2-3.5 μm; S: 15-18 in 10 μm). In addition, the specimen described by Rumrich et al. (2000, pl. 7, fig. 7) as *Fragilaria* sp. is very similar to the specimen studied here, although the authors provided no morphological descriptions and it was therefore impossible to confirm other data.

We opted to identify the specimen only down to the genus level, because we found no another specimens with the same morphometric characters in the literature consulted. The specimen found in the present study was unique; whether it represents a variation in the population is uncertain. Occurrence in samples: UNOP 2799.

**Fragilaria vaucheriae** (Kützing) Petersen, Botaniska Notiser 122(1-3): 167, fig. 1c-g. 1938.

Fig. 55

Valves linear to linear-lanceolate; attenuate toward the apices; extremities rostrate-round; axial area linear to slightly lanceolate; unilateral swelling in the central area. Striae parallel or slightly swollen sometimes slightly shortened on the side opposite the swollen area. AA: 15.5-31.8 μm; TA: 4.7-7 μm; S: 8-12 in 10 μm. Sporadic taxon, occurring in 29.1% of the samples.

In several studies (Flôres et al. 1999; Brassac & Ludwig 2003; Ferrari & Ludwig 2007), the taxon *Fragilaria vaucheriae* has shown great morphological variation, displaying individuals in transition from one form to another. Patrick & Reimer (1966) described *F. vaucheriae* as having an asymmetrical central area, typically with unilateral swelling. Conversely, Bicudo et al. (1993) observed individuals with unilateral and bilateral swelling. Individuals with bilateral swelling probably correspond to another taxon. The material described by Patrick & Reimer (1966) differs from that studied here in terms of its higher striae density (12-16 in 10 μm) and much smaller transapical axis (2-4 μm). The density of striae of the specimens examined in our study was coincident with those described by Krammer & Lange-Bertalot (1991, S: 9-14 in 10 μm), although our specimens displayed greater variation in the width of the transapical axis than the 4-5 μm reported by those authors. Occurrence in samples: UNOP 2705, 2708, 2712, 2727, 2728, 2730, 2800.


Fig. 66

Valve linear to widely lanceolate, with median constriction; extremities subcapitate; axial and central areas inconspicuous or absent; transapical striae parallel along the entire length of the valve. AA: 49.1 μm; TA: 6.8 μm in the constricted central area and 7.7 μm at the widest point; S: 17 in 10 μm. Occasional taxon, occurring in only 4.2% of the samples.

The specimen was coincident with the specimens of *Fragilaria javanica* shown by Metzeltin & Lange-Bertalot (1998, fig. 1-6). The specimens of *F. javanica*, illustrated by Krammer & Lange-Bertalot (1991) and Metzeltin & Lange-Bertalot (1998), in their majority, display valves without constriction or with a slight median constriction, as do those described by Brassac & Ludwig (2003), Landucci & Ludwig (2005) and Ferrari & Ludwig (2007), with considerable variation in striae density.

*Fragilariforma javanica* possesses valve dimensions, apex shapes and a valve outline very similar to those of *Fragilariforma virescens* (Ralfs) Williams & Round (Brassac & Ludwig 2003) and *Fragilariforma strangulata* (Zanon) Williams & Round (Hustedt 1949; Simonsen 1987; Williams & Round 1987; Krammer & Lange-Bertalot 1991). To solve the uncertainty regarding to the conspecificity of these three species, studies of type material are required (Landucci & Ludwig 2005; Wetzel et al. 2013).

Occurrence in samples: UNOP 2730.
Staurosirella crassa (Metzeltin & Lange-Bertalot) Ribeiro & Torgan. In Ribeiro et al., Revista Brasileira de Paleontologia 13(1): 24. 2010. Fig. 59-65

Valves elliptic-lanceolate; extremities rounded to subrostrate; axial area widely or narrowly linear; central area absent; transapical striae composed of alternating coarse slits. PA: 9-12 μm; AA: 27.1-37.5 μm; TA: 6.1-9.7 μm; S: 5-7 in 10 μm. Frequent taxon, occurring in 54.1% of the samples.

The population was coincident with the specimens of Fragilaria crassa described by Metzeltin & Lange-Bertalot (1998, pl. 20-23), which also display wide morphological variation (AA: 22-50 μm; TA: 9-10 μm; S: 4-5 in 10 μm), as also reported by Bertolli et al. (2010, AA: 16.6-37.9 μm; TA: 4.7-5.5 μm; S: 7 in 10 μm).

Occurrence in samples: UNOP 2705, 2707, 2711, 2712, 2714, 2726, 2727, 2728, 2729, 2730, 2731, 2799, 2800.

Staurosirella dubia (Grunow) Morales & Manoylov. In Morales, Manoylov & Bahl, Proceedings of the Academy of Natural Sciences of Philadelphia 160: 43. 2010. Fig. 57

Valve lanceolate; extremities rounded; axial area lanceolate; striae slightly radial, intercalated with those of the opposite margin. AA: 23 μm; TA: 5.6 μm; S: 6 in 10 μm. Occasional taxon, occurring in only 4.2% of the samples.

The study specimen was coincident with the morphometry of Staurosirella dubia shown by Morales & Manoylov (2006, AA: 6-38 μm; TA: 3.5-6.5 μm; S: 6-10 in 10 μm) and the descriptions of Hustedt (1931), who refers to a species with lanceolate valves, with rounded apices, a wide and central axial area, and shorter striae (fig. 13-25). Patrick & Reimer (1966) show individuals with a narrower range (AA: 10-15 μm) not found in this study.

Smaller specimens of Staurosirella subcapitata (Frenguelli) Morales tend to lose their typical well-lanceolate outline, and become very similar to S. dubia, as seen by Morales & Manoylov (2006), and the two species can be confused without a detailed analysis. Occurrence in samples: UNOP 2730.

Staurosirella pinnata (Ehrenberg) Williams & Round. Diatom Research 2: 274. 1987. Fig. 58

Valves oval to elliptic; extremities rounded; axial area lanceolate and narrow; striae robust, radial in the apices and almost parallel in the median portion of the valve, alternated with those of the opposite margin; absence of central area. AA: 8.8 μm; TA: 4 μm; S: 10 in 10 μm. Occasional taxon, occurring in only 4.2% of the samples.

The specimen found was identified as Staurosirella pinnata because it displayed a valve structure that was more oval, similar to the specimens examined by Ehrenberg (1843). The axial area is pronounced, with coarser striae (Morales 2001). Our specimen was coincident with the descriptions of Fragilaria pinnata var. pinnata of Patrick & Reimer (1966), Krammer & Lange-Bertalot (1991) and Flores et al. (1999).

Morales & Manoylov (2006) stated that the valves of Staurosirella pinnata are smaller and more oval in shape than are those of Staurosirella martyi (Héribaud) E.A. Morales & Manoylov, which are large, elliptic and rarely oval, with rounded extremities. Paul et al. (2008) concluded that it is very difficult to distinguish Staurosira venter (Ehrenberg) Cleve & Müller from S. pinnata and that reliable characters are the width of the valve (mean: S. venter: 4.7 μm, S. pinnata: 3.7 μm) and the length of the areolae of the margin (mean: S. venter: 0.2 μm, S. pinnata: 0.5 μm), which can be visualized with a high-quality optical microscope.

According to Morales et al. (2010), Staurosirella pinnata remains unclear, appearing in various forms and sizes in the literature. Because the type specimen of this taxon has not been studied in detail, it is hard to determine which variations correspond to S. pinnata. The identification of S. pinnata most accepted by researchers is still based on the concepts of Hustedt (1931) and Morales (2001). Occurrence in samples: UNOP 2712.

Synedra goulardii Brébisson ex Cleve & Grunow, Kongl. Sven. Vet.-Akad. Handl. 17(2): 117, pl. 6, fig. 119. 1880. Fig. 38-49

Valves linear-lanceolate to lanceolate; slight to pronounced median constriction; extremities rostrate, rostrate-capitate or subcapitate; axial area linear; central area quadrangular to rounded, delimited by smaller striae, parallel to the opposite margin. AA: 52.8-215 μm; TA: 7.5-14 μm; S: 8-10 in 10 μm. Constant taxon, occurring in 100% of the samples.

The population studied exhibited marked polymorphism regarding the valve outline, the extremities and the form of the central area. Patrick & Reimer (1966) described two varieties of Synedra other than S. goulardii: Synedra ulna var. contracta Østrup (p.7, fig. 3) - accepted as Ulnaria contracta (Ostrup) Morales & Vis—and Synedra ulna var. oxyrhythmus f. medicontracta (Forti) Hustedt (p.7, fig. 4) which are consistent with the polymorphic population here shown. A more detailed study of the population under electron microscopy would be necessary in order to identify characters that are diagnostic in differentiating among the specimens.

Occurrence in samples: UNOP 2702, 2703, 2704, 2705, 2706, 2707, 2708, 2709, 2710, 2711, 2712, 2713, 2714, 2715, 2716, 2717, 2726, 2727, 2728, 2729, 2730, 2731, 2799, 2800.

Ulnaria ulna (Nitzsch) Compère. In Jahn et al. Studies on diatoms, p. 100. 2001. Fig. 70-73

Valves linear without median constriction, narrowing toward the rostrate to subcapitate extremities; axial area linear and narrow; central area rectangular (in populations of individuals with smaller dimensions, the central area is
Coscinodiscophyceae and Fragilariophyceae (Diatomeae) in the Iguazu River, Paraná, Brazil


Scales: 10 μm.
smaller, circular or elliptic). In the central area, difficult to visualize striae often occur, running parallel to the striae of the opposite margin. AA: 27.1-37.5 μm; TA: 6.1-9.7 μm; S: 5-7 in 10 μm. Frequent taxon, occurring in 75% of the samples.

The population studied displayed wide morphologic variation. Patrick & Reimer (1966) showed different varieties for the species according to the morphology of the extremities, the valve outline, and the presence or absence of the central area. The specimens found were grouped as *Ulnaria ulna*. Although they displayed wide morphologic variation, all specimens showed a rectangular to circular central area and no median constriction.

Occurrence in samples: UNOP 2702, 2703, 2704, 2706, 2709, 2710, 2712, 2714, 2715, 2716, 2717, 2726, 2727, 2728, 2729, 2730, 2799, 2800.

Of the 37 taxa identified, the most well-represented genus was *Fragilaria* Lyngbye with 10 taxa, followed by *Aulacoseira* Thwaites with nine. Species richness was higher at station 1 than at station 2 (36 taxa vs. 27). *Aulacoseira herzogii*, *A. granulata* var. *valida* f. *curvata*, *A. italica*, *Orthoseira epidendron*, *Fragilaria alpestris*, *F. crotonensis* var. *oregona*, *Fragilaria sp.*, *F. javanica*, *Staurosirella pinnata* and *S. dubia* were exclusive to station 1, whereas only *Melosira* sp. was exclusive to station 2.

Of the 37 taxa found, six (16.2%) were constant, seven (18.9%) were frequent, 13 (35.1%) were sporadic and 11 (29.7%) were occasional. Occasional taxa occurred in one sample, in some cases represented by a single individual (*Fragilaria alpestris*, *Fragilaria sp.*). The diatoms *Melosira ruttneri* and *Fragilaria alpestris* constituted new records for Brazil. *Aulacoseira granulata* var. *valida* f. *curvata*; *A. granulata* var. *australiensis*; *A. pusilla*; *Fragilaria capucina* var. *capucina*; and *Staurosirella lla crassa*—were new records for the Iguazu River.

The genus *Melosira* Agardh includes few freshwater species, represented by only ten taxa, six of which have been recorded for Brazil (Ludwig & Bigunas, 2006). At our study site, we identified three species of *Melosira* (M. *varians*, M. *undulata* var. *normanii* and M. *ruttneri*), as well as one population identified only down to the genus level. *Melosira varians* is one of the most common species of this genus (Round *et al.* 1990) and is commonly found in eutrophic rivers and lakes (Reynolds *et al.* 2002). *Melosira undulata* var. *normanii*, a taxon whose distribution in Brazilian waters is much more restricted than that of *M. varians* (Rosa *et al.* 1994; Garcia 2009), has been recorded for France (Germain 1981) and for other tropical areas (Krammer & Lange-Bertalot 1991), as well as in large oligotrophic lakes and dystrophic rivers in North America (Manguin 1949). The geographic distribution of *M. ruttneri* remains largely unknown, and the present study provided its first record for Brazil. *Melosira* sp. displayed some structures that differ from those found in the available literature. There is a need for further studies, involving electron microscopy and a larger number of specimens, in order to discuss its identity in greater detail.

Questions remain regarding the true identity of the taxon *Fragilaria* sp., in comparison with the descriptions in the literature (Simonsen 1987; Krammer & Lange Bertalot 1991), because of the absence of illustrations or descriptions of morphologically similar individuals. Further detailed studies are required in order to determine whether this is a new species.

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