Diatoms from distinct habitats of a highly heterogeneous reservoir, Billings Complex, southeastern Brazil[1]

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ABSTRACT - (Diatoms from distinct habitats of a highly heterogeneous reservoir, Billings Complex, southeastern Brazil). A diatom survey was carried out in the largest reservoir of the city of São Paulo. Twenty-four phytoplankton, 15 periphyton, and 12 surface sediment samples covering a gradient of trophic states were collected in 2009 and 2010. Overall, 67 taxa were sampled (60 species and varieties and seven identified at the genus level). Four species are new records to Brazil (*Stephanodiscus minutulus*, *Fragilaria aquaplus*, *F. perminuta* and *Ulnaria ferefusiformis*), and beyond those, six others are new records to the State of São Paulo. Periphyton accounted for the highest number of species (68.6%) and exclusive taxa (21). The eutrophic and natural mesotrophic regions presented the highest number of species (46 and 41 taxa, respectively), contrasting with the hypereutrophic and artificial mesotrophic regions (22 taxa each). Present findings highlight that the local biodiversity can be directly influenced by the type of habitat analyzed, and different habitats should be included for improving the knowledge of local biodiversity.
Keywords: periphyton, phytoplankton, surface sediment, taxonomic survey, trophic gradient

RESUMO - (Diatomáceas de diferentes habitats em um reservatório altamente heterogêneo, Complexo Billings, Sudeste do Brasil). O levantamento taxonômico foi realizado no maior reservatório da cidade de São Paulo. Vinte e quatro amostras de fitoplâncton, 15 de perifíton e 12 de sedimentos superficiais cobrindo um gradiente trófico foram coletadas em 2009 e 2010. No geral, 67 táxons foram registrados (60 espécies e variedades e sete em nível genérico). Quatro espécies são novas citações para o Brasil (*Stephanodiscus minutulus*, *Fragilaria aquaplus*, *F. perminuta* e *Ulnaria ferefusiformis*), além de outras seis novas citações para o Estado de São Paulo. O perifíton contribuiu com o maior número de espécies (68,6%) e táxons exclusivos (21). A região eutrófica e mesotrófica natural apresentaram o maior número de espécies (46 e 41, respectivamente), contrastando com a região supereutrófica e mesotrófica artificial (22 táxons cada). O resultado encontrado destaca que a biodiversidade local pode ser diretamente influenciada pelo tipo de habitat analisado, e que diferentes habitats devem ser incluídos para aumentar o conhecimento da biodiversidade local.
Palavras-chave: fitoplâncton, gradiente trófico, levantamento florístico, perifíton, sedimento superficial

Introduction

Diatoms compose a very diverse group of algae, including 15,000 described living species (Mann & Droop 1996, Williams & Reid 2006). Such organisms have great ecological importance in the cycles of carbon and silica, as well as being bioindicators of recent and preterit environmental changes (Chepurnov *et al*. 2004, Smol 2008). Thus, this group of algae has been receiving greater attention in southern Brazil (*e.g.*, Tremarin *et al*. 2009, 2010, Bertolli *et al*. 2010, Silva *et al*. 2010, Santos *et al*. 2011, Bartozek *et al*. 2013, Nardelli *et al*. 2014, Marra *et al*. 2016). Furthermore, several new diatom taxa have been proposed in recent years to the country (*e.g.*, Wetzel *et al*. 2010, 2012, Metzeltin & Tremarin 2011, Tremarin *et al.* 2013, 2014, Pereira *et al*. 2014, Wetzel & Ector 2014, Wengrat *et al*. 2015, 2016, Marquardt *et al*. 2016).

In the southeast, especially in the State of São Paulo, taxonomic study of diatoms presenting illustrations, measurements, and/or comments has markedly increased in the last decade. The contributions range from rivers (Souza & Senna 2009, Bere 2010, Bere & Tundisi 2010) to reservoirs (Graça *et al*. 2007, Moutinho *et al.* 2007, Fontana & Bicudo 2009, 2012, Almeida & Bicudo 2014) and other

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environments (*e.g.*, Morandi *et al*. 2006, Rocha & Bicudo 2008, Bicudo *et al*. 2009). In reservoirs, most studies address planktonic or periphytic diatoms and lately have included diatoms from sediments (Fontana & Bicudo 2009, 2012, Almeida & Bicudo 2014, Faustino *et al.* 2016). The increased number of newly described species highlights the scant knowledge of diatoms from the State of São Paulo (Almeida *et al.* 2015, 2016, Wengrat *et al*. 2015, 2016, Marquardt *et al.* 2016, Costa *et al.* 2017a, b).

Phytoplankton of the Billings Complex have been studied since the mid-60s (*e.g*., Branco 1962, Carvalho *et al*. 1997, Beyruth & Pereira 2002, Mariani *et al*. 2006, Rodrigues *et al*. 2010). Nevertheless, diatoms are generally only cited either at the genus level or at the species level when frequently observed. As for sediment and periphyton, there is no information on diatom assemblages for this reservoir, only two descriptions of new species (*Encyonopsis* and *Fragilaria*) and a study about *Eunotia* species including samples from Billings Complex (Wengrat *et al*. 2015, 2016, Costa *et al.* 2017b).

Billings Complex is the largest water reservoir in the metropolitan region of São Paulo and has multiple uses such as public water supply, energy generation, and recreation (Carvalho *et al.* 1997). This system has been highly impacted by contamination over the last six decades (Capobianco & Wathely 2002). Although predominantly eutrophic to supereutrophic, the reservoir still preserves two mesotrophic regions (Wengrat & Bicudo 2011), one of them manipulated by the application of algicides to control cyanobacteria blooms (Capobianco & Wathely 2002).

This study aims to expand the knowledge of biodiversity and ecology of tropical diatoms, particularly in southeastern Brazil. It brings a new contribution to the study of diatom flora in Brazil by including more than two different diatom assemblages in a taxonomic survey (from phytoplankton, periphyton, and from surface sediment). In addition, it is the first diatom survey in Billings Complex, a highly heterogeneous reservoir with a range of trophic states.

Materials and methods

Billings Complex (23°47'S, 46°40'W) is located in the Upper Tietê River Basin, in the State of São Paulo in southeastern Brazil, a highly populated urban area (figure 1). It is the largest and one of the oldest reservoirs in the metropolitan region of São Paulo. It has

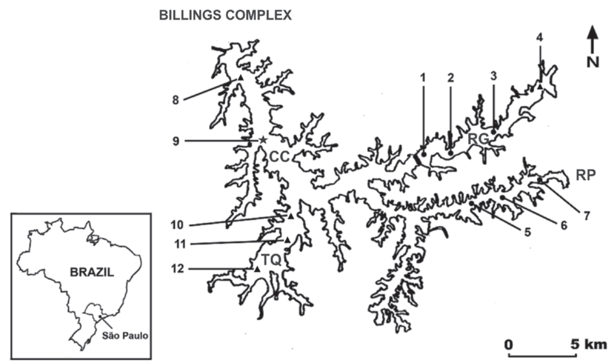


Figure 1. Sampling sites and corresponding TSI in Billings Complex. RG: Rio Grande Reservoir (1-4), RP: Rio Pequeno branch (5-6), CC: Central body (8-9), TQ: Taquacetuba branch (10-12), circles: mesotrophic sites, triangles: eutrophic sites and star: supereutrophic site (modified from Wengrat & Bicudo 2011).

surface area of 120 km², a drainage basin of 560 km², and encompasses six municipalities (Capobianco & Wathely 2002). The complex has a dendritic pattern, with a narrow and elongated central body and several compartments (branches). One of the branches (Rio Grande Reservoir) was completely isolated from Billings Complex in 1981 for public water supply. This complex is a highly heterogeneous environment, ranging from mesotrophic to supereutrophic (Wengrat & Bicudo 2011).

Twelve sampling stations were defined according to the spatial heterogeneity (figure 1) and distributed among the Rio Grande Reservoir (sites 1-4), the Rio Pequeno branch (sites 5-7), the central body (sites 8, 9), and the Taquacetuba branch (sites 10-12). Limnological features of these sampling stations were previously published in Wengrat & Bicudo (2011). Trophic states range from natural mesotrophic (sites 5-7), to artificial mesotrophic (sites 1-3), eutrophic (sites 4, 8, 10-12), and supereutrophic (site 9), following the trophic classification system of Lamparelli (2004).

Phytoplankton samples were collected with a van Dorn sampler at three depths (surface, middle and bottom) and integrated for diatom analysis. Periphyton was scraped using a toothbrush from stones and removed using distilled water jets from aquatic macrophytes. Samplings occurred during winter (August 2009) and summer (February 2010). Surface sediments (the top 2 cm) were collected with a gravity corer in winter, since they provide spatially and temporally integrated record of the recent changes that have occurred in the system (Smol 2008). A total of 51 samples were collected (24 phytoplanktonic, 15 periphytic, and 12 from surface sediments). Samples were fixed and preserved with aqueous solution of 4% formaldehyde.

Small aliquots of raw samples were digested using concentrated hydrogen peroxide (H_2O_2 35%) and hydrochloric acid (HCl 37%) (ECS 2003). Following digestion and decantation, cleaned material was diluted with deionized water and mounted on permanent slides using Naphrax mounting medium. Optical observations, measurements, and photographs were performed with a light microscope Zeiss® (Axioskop 2 plus Type) with a MRc5 high-resolution digital camera at 1000× magnification.

For all taxa, specific measurements used in the taxonomy of each group (*e.g.*, D: diameter; L: length; H: mantle height; W: width; L/W: length/width ratio; A: areolae; C: alar canals; F: fibulae; S: striae), illustrations, and habitat (F: phytoplankton; P: periphyton; SS: surface sediment) were provided. For new records and taxa poorly known in Brazil, descriptions and relevant comments were provided. The pioneer records in Brazil were based on published studies presenting taxonomic information (illustration, comments, or measurements). Taxonomy and nomenclature followed classic studies, recent publications (*e.g.*, Round *et al*. 1990, Rumrich *et al*. 2000, Håkansson 2002, Metzeltin & Lange-Bertalot 2007, Tremarin *et al*. 2010, Lange-Bertalot *et al*. 2011, Santos *et al*. 2011), and the on-line catalogue of diatom names (Fourtanier & Kociolek 2011). Permanent slides as well as raw samples were deposited at the Herbário Científico do Estado Maria Eneyda P. Kauffmann Fidalgo (SP), Secretaria do Meio Ambiente do Estado de São Paulo, Brasil.

The quantitative analysis was also performed under the light microscope at 1000× magnification and counting at least 400 valves per slide/sample. In this way, all taxa with relative abundance equal to or above 2% (as a percentage of the total diatom counts in each sample) were considered in this study.

Results and Discussion

We found 67 taxa of diatoms (60 species and varieties and seven at the genus level) distributed in 16 families and 28 genera. The new or poorly known taxa for Brazil are described below. Other taxa more commonly reported in Brazilian literature are listed in table 1 along with the morphometric characteristics, access number of the herbarium, habitat, and respective figures. Taxa preceded by one asterisk represent new records for Brazil and taxa preceded by two asterisks represent new records for the State of São Paulo.

Stephanodiscaceae

Stephanodiscus **Ehrenberg**

Stephanodiscus minutulus (Kützing) Cleve & J.D. Möller, Diatoms VI, 300. 1882.
Figures 13-14

Morphometry: D: 5.7-7.8 µm; S: 16-18 in 10 µm.

The confusion in the taxonomy of this species is due to its proximity to *S. parvus* Stoermer & Håkansson. According to Håkansson (2002), the position of the fultoportulae on the valve face is a distinctive feature, being slightly eccentric in *S. parvus* and situated in a heterotopic position in *S. minutulus*. However, several authors consider both species as synonyms since *Stephanodiscus minutulus* is considered a polymorphic taxon, depending on the chemical conditions of the water (Kobayasi *et al*. 1985, Scheffler & Morabito 2003, Cruces *et al*. 2010).

Specimens found in Billings Complex have some fultoportulae situated at different positions on the valve face. Therefore, we considered both taxa as synonyms, following previous authors and adopting the oldest name validly published.

The species is cited here for the first time in Brazil. It was found in the Taquacetuba branch (phytoplankton), Rio Grande Reservoir, and the central body (periphyton), in mesotrophic to supereutrophic conditions.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Rio Grande, 5-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP427898); Taquacetuba, 11-II-2011, *S. Wengrat & D.C. Bicudo* (SP401580); Central body, 11-II-2011, *S. Wengrat & D.C. Bicudo* (SP427910).

Fragilariaceae

Fragilaria Lyngbye

Fragilaria aquaplus Lange-Bertalot & Ulrich, Lauterbornia 78: 32, pl. 13, figs 15-19, pl. 14, figs 9-14. 2014.
Figures 27-31

Morphometry: L: 34.0-55.6 µm; W: 1.6-2.5 µm; S: 19-21 in 10 µm; L/W: 19.3-30.7.

Table 1. Dimensions, herbarium access number, habitat and trophic status occurrence for diatoms of the Billings Complex well distributed in Brazil. D: diameter; L: length; H: mantle height; W: width; L/W: length/width ratio; A: areolae; C: alar canals; F: fibulae; S: striae. F: phytoplankton, P: periphyton, SS: surface sediment. TSI: Trophic State Index. Taxa preceded by two asterisks represent new records for the State of São Paulo.

Taxa	Dimensions (µm) and striae density (in 10 µm)	Habitat	TSI	Herbarium access number (SP)
Thalassiosiraceae				
Spicaticribra rudis (Tremarin *et al*.) Tuji *et al.* (figures 2-4)	D: 11.7-15.3	F	Eutrophic	401581
Stephanodiscaceae				
Cyclotella atomus Hustedt (figures 5-7)	D: 5.1-5.7	SS	Eutrophic	401574
Cyclotella meneghiniana Kützing (figures 8-9)	D: 5.6-21.0; S: 9-13	F, P, SS	Mesotrophic to supereutrophic	401582, 427912, 401586
Discostella pseudostelligera (Hustedt) Houk & Klee (figures 10-11)	D: 4.1-11.0; S: 18-22	F, P, SS	Mesotrophic to supereutrophic	401577, 427907, 401586
Discostella stelligera (Cleve & Grunow) Houk & Klee (figure 12)	D: 6.3-16.0; S: 15-16	F, P, SS	Mesotrophic to supereutrophic	401575, 427912, 401593
Aulacoseiraceae				
Aulacoseira ambigua (Grunow) Simonsen (figures 15-16)	H: 6.0-13.2; D: 3.5-9.1; S: 15-23	F, P, SS	Mesotrophic to supereutrophic	401564, 427910, 401588
Aulacoseira granulata var. *granulata* (Ehrenberg) Simonsen (figure 17)	H: 8.0-36.3; D: 3.8-10.5; S: 9-16	F, P, SS	Mesotrophic to supereutrophic	401560, 427898, 401591
Aulacoseira granulata var. *angustissima* (O. Müller) Simonsen (figure 18)	H: 10.8-17.3; D: 2.0-3.5; S: 15-21	F, P, SS	Mesotrophic to supereutrophic	401566, 427900, 401590
Aulacoseira granulata var. *australiensis* (Grunow) Moro (figure 19)	H: 15.6-20.9; D: 14.6-16.3; S: 9-11	F	Mesotrophic	401560
Aulacoseira pusilla (F. Meister) Tuji & Houki (figures 20-22)	H: 3; D: 5.5-7.0	SS	Mesotrophic to eutrophic	401592
Aulacoseira tenella (Nygaard) Simonsen (figures 23-25)	H: 1.5-2.0; D: 5.5-6.0	F, SS	Mesotrophic to supereutrophic	401581, 401589
Fragilariaceae				
***Ctenophora pulchella* (Ralfs *ex* Kützing) D.M. Williams & Round (figure 26)	L: 33.1-43.5; W: 5.0-5.5; S: 15; L/W: 7.1	P	Eutrophic	427905

continue

Table 1 (continuation)

Taxa	Dimensions (µm) and striae density (in 10 µm)	Habitat	TSI	Herbarium access number (SP)
Fragilaria billingsii Wengrat *et al*. (figures 54-56)	L: 67.8-76.0; W: 2.5-2.7; S: 20-21; L/W: 27.6-29.8	F, P	Mesotrophic to eutrophic	401572, 427906
***Fragilaria crotonensis* var. *oregona* Sovereign (figures 32-34)	L: 73.5-93.3; W: 2.9-3.6; S: 14-15; L/W: 26.3-28.3	F, SS	Eutrophic	401581, 401586
Fragilaria gracilis Østrup (figures 35-37)	L: 37.5-50.0; W: 2.0-3.5; S: 19-21; L/W: 18.7-18.8	F, P, SS	Mesotrophic to supereutrophic	401560, 427898, 401584
Ulnaria ulna (Nitzsch) Compère (figure 53)	L: 178.0-194.2; W: 4.9-5.1; S: 11; L/W: 38.1	F	Mesotrophic to eutrophic	401574
Eunotiaceae				
Eunotia bilunaris (Ehrenberg) Schaarschmidt (figures 63-65)	L: 13.5-35.7; W: 3.1-3.3; S: 17-19; L/W: 4.6-11.5	P	Mesotrophic to eutrophic	427902
Eunotia genuflexa Nörpel-Schempp (figure 66)	L: 132.9-135.6; W: 2.5-3.0; S: 20-21; L/W: 44.7-51.9	P	Mesotrophic	427902
Eunotia incisa W. Gregory (figures 67-69)	L: 16-42; W: 3.2-4.5; S: 17-21; L/W: 5.5-9.6	F, P	Mesotrophic to eutrophic	401562, 427909
Eunotia mucophila (Lange-Bertalot & Nörpel) Lange-Bertalot (figures 70-71)	L: 27.3-31.0; W: 2.4-2.7; S: 26-27; L/W: 11.3-11.5	P	Mesotrophic	427902
Eunotia naegelii Migula (figures 72-73)	L: 62.5- 90.9; W: 2.2-2.5; S: 24-27; L/W: 29.5-37.0	F, P	Mesotrophic	401565, 427902, 401589
Eunotia veneris (Kützing) De Toni (figures 78-80)	L: 13.6-39.4; W: 4.2-5.1; S: 16-19; L/W: 5.2-8.2	F, P, SS	Mesotrophic	401565, 427909, 401589
Cymbellaceae				
Cymbopleura naviculiformis (Auerswald *ex* Heiberg) Krammer (figures 88-89)	L: 22.7-27.9; W: 6.8-7.3; S: 15; L/W: 3.3-3.7	F, SS	Mesotrophic	401565, 401589
Encyonema acquapurae Wengrat *et al.* (figures 90-91)	L: 22.0-25.5; W: 5.4-5.7; S: 11-12; L/W: 4.1-4.5	SS	Mesotrophic	401589
Encyonema neogracile Krammer (figures 92-94)	L: 23.6-34.6; W: 4.6-5.2; S: 15-16; L/W: 5.3-6.0	P	Mesotrophic	427909

continue

Table 1 (continuation)

Taxa	Dimensions (µm) and striae density (in 10 µm)	Habitat	TSI	Herbarium access number (SP)
Encyonopsis sanctipaulensis Wengrat *et al.* (figures 95-97)	L: 20.2-25.9; W: 5.5-5.8; S: 10-11; L/W: 4.0-4.6	F, SS	Mesotrophic	401565, 401589
Encyonopsis subminuta Krammer & Reichardt (figures 98-99)	L: 14.7-19.5; W: 3.6-4.1; S: 23-26; L/W: 4.7-4.8	F, P	Mesotrophic	401576, 427908
Gomphonemataceae				
Gomphonema auritum Braun *ex* Kützing (figures 100-102)	L: 25.2-28.7; L: 4.4-5.0; S: 15-17; L/W: 5.3-5.9	F	Eutrophic	401562
Gomphonema lagenula Kützing (figures 106-108)	L: 15-26; W: 5.0-6.7; S: 12-16; L/W: 3.3-4.4	P	Eutrophic	427900
Gomphonema pseudoaugur Lange-Bertalot (figures 109-110)	L: 22.2-29.0; W: 7.3-8.0; S: 14-16; L/W: 3.4-3.9	P	Eutrophic	427900
***Gomphonema pumilum* (Grunow) Reichardt & Lange-Bertalot (figures 111-113)	L: 13.3-31.3; W: 3.8-5.4; S: 11-15; L/W: 4.4-5.8	P	Eutrophic	427911
Achnanthidiaceae				
Achnanthidium catenatum (J. Bílý & Marvan) Lange-Bertalot (figures 114-116)	L: 8.9-19.1; W: 2.8-3.7; striae inconspicuous; L/W: 4.6-5.8	F, P, SS	Mesotrophic to supereutrophic	401571, 427906, 401583
Achnanthidium minutissimum (Kützing) Czarnecki (figures 117-119)	L: 9.0-18.4; W: 2.5-3.3; S: 25-29; L/W: 3.8-6.1	F, P, SS	Mesotrophic to supereutrophic	401576, 427908, 401583
Achnanthidium saprophilum (H. Kobayasi & Mayama) Round & Bukhtiyarova (figures 120-122)	L: 7.1-11.0; L: 2.6-3.1; striae inconspicuous; L/W: 2.5-3.3	F, P, SS	Mesotrophic to supereutrophic	401569, 427904, 401584
Achnanthaceae				
Lemnicola hungarica (Grunow) Round & Basson (figures 126-127)	L: 11-35; W: 4.5-8.0; S: 20-25; L/W: 4.8-4.9	P	Mesotrophic to supereutrophic	427900
Amphipleuraceae				
Frustulia crassinervia (Brébisson) Lange-Bertalot (figure 128)	L: 29.4-41.6; W: 8.2-9.3; striae delicate; L/W: 4.1	F, P, SS	Mesotrophic to eutrophic	401568, 427909, 401589
Brachysiraceae				
Brachysira brebissoni R. Ross (figures 129-131)	L:11.6-19.1; W: 4.0-5.3; S: 24-33; L/W: 2.4-4.1	F, SS	Mesotrophic to eutrophic	401565, 401589

continue

Table 1 (continuation)

Taxa	Dimensions (µm) and striae density (in 10 µm)	Habitat	TSI	Herbarium access number (SP)
Sellaphoraceae				
Sellaphora nigri (De Notaris) C.E. Wetzel & Ector (figures 136-138)	L: 5.9-9.0; W: 3.1-3.8; S: 24-26; L/W: 2.0-2.2	P	Mesotrophic to eutrophic	427911
Sellaphora sagerresii (Desmazières) C.E. Wetzel & D.G. Mann (figures 139-141)	L: 8.0-15.6; W: 3.5-4.4; S: 20-22; L/W: 2.7-3.7	P	Eutrophic	427911
Naviculaceae				
Navicula cryptocephala Kützing (figure 147)	L: 19.0-32.6; W: 5.1-6.2; S: 15-18; L/W: 4.6	P	Mesotrophic to eutrophic	427900
Navicula cryptotenella Lange-Bertalot (figure 148)	L: 15-29.3; W: 4.5-6.5; S: 14-18; L/W: 4.4	P	Eutrophic	427911
Navicula notha Wallace (figure 149)	L: 21.6-36.9; W: 4.0-5.5; S: 15-18; L/W: 6.4	F, P, SS	Mesotrophic to supereutrophic	401576, 427899, 401589
Kobayasiella parasubtilissima (H. Kobayasi & Nagumo) Lange-Bertalot (Figures 153-154)	L: 27.2-32.5; W: 4.0-5.3; striae inconspicuous; L/W: 5.3-7.1	F, P	Mesotrophic to eutrophic	401568, 427902, 401589
Bacillariaceae				
Hantzschia amphioxys (Ehrenberg) Grunow (figure 155)	L: 22.7-23.6; W: 4.1-4.3; striae inconspicuous; F: 15; L/W: 5.6	F	Supereutrophic	401574
Nitzschia palea (Kützing) W. Smith (figures 156-158)	L: 12.1-36.7; W: 2.5-4.2; S: 13-17; F: 14-15; L/W: 5.7-9.0	P	Eutrophic to supereutrophic	427912
Surirellaceae				
Stenopterobia delicatissima (F.W. Lewis) Brébisson *ex* Van Heurck (figure 166)	L: 51.7-96.0; W: 3.7-5.0; striae inconspicuous; C: 6-8; L/W: 19.1	F, P	Mesotrophic	401565, 427902
***Stenopterobia planctonica* Metzeltin & Lange-Bertalot (figure 167)	L: 88.1-97.3; W: 4.8-5.0; striae inconspicuous; C: 7; L/W: 19.3	F	Mesotrophic	401565

Specimens found in Billings Complex have linear valves with a slight bilateral swelling in the median region and a rimoportula visible in LM in each subcapitate apex. They agree with type material of *Fragilaria aquaplus*, despite having a lower striae density (22-24 in 10 µm, Lange-Bertalot & Ulrich 2014). It is similar to *Fragilaria gracilis*, from which is differentiated by the slightly narrower valves (3.6 µm wide, Tuji 2007), by the median swelling, and rimoportulae. According to Tuji (2007), the rimoportula is present in one of the valve apices in *F. gracilis* and there is no median swelling in the illustrations of type material.

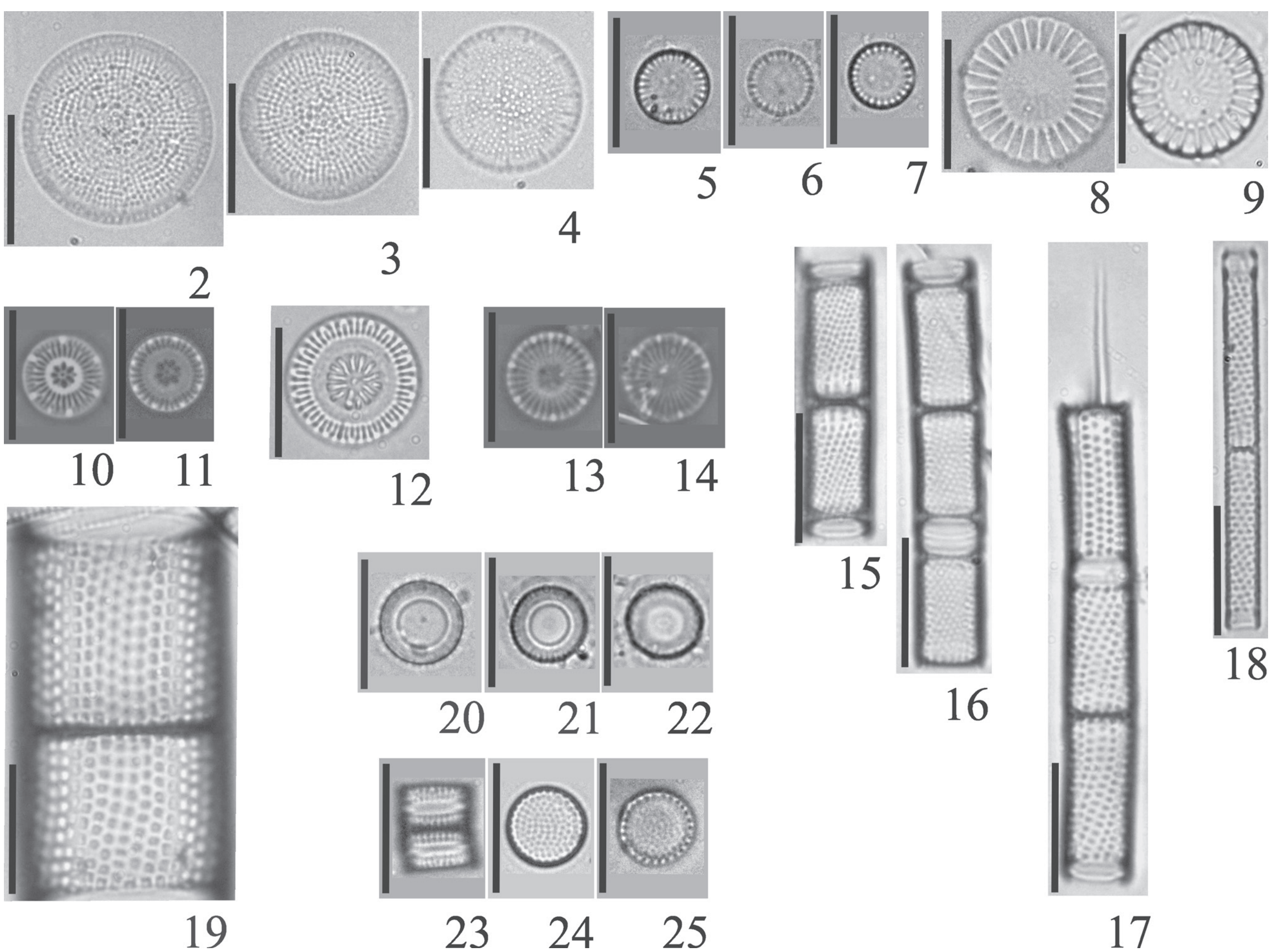
The species is cited here for the first time in Brazil. It was found in phytoplankton and surface sediment of all Billings Complex sites as well as in the periphyton of Rio Grande Reservoir, and from mesotrophic to eutrophic conditions.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Rio Grande, 11-II-2011, *S. Wengrat & D.C. Bicudo* (SP401574, SP427907); 5-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP401586).

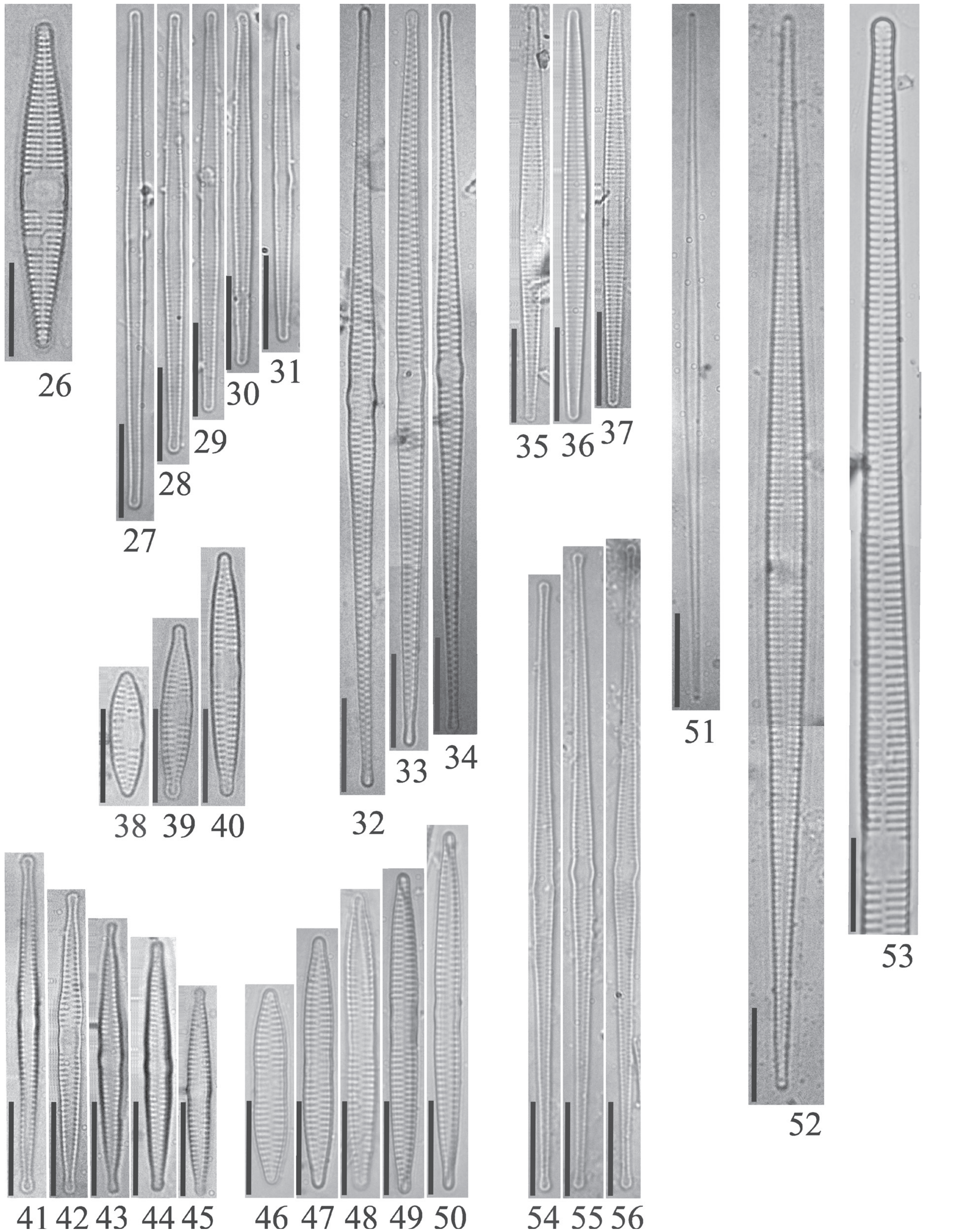
****Fragilaria perminuta*** (Grunow) Lange-Bertalot *in* Krammer & Lange-Bertalot, Süßwasserflora von Mitteleuropa 2/3: 125, pl. 109, figs 1-5. 1991.
Figures 38-40

Morphometry: L: 12.3-26.1 µm; W: 2.8-4.0 µm; S: 14-19 in 10 µm; L/W: 3.9-8.8.

The taxon agrees with the lectotype presented by Tuji & Williams (2008a). It differs from *Fragilaria*



Figures 2-25. Diatoms of the Billings Complex. 2-4. *Spicaticribra rudis* (Tremarin, Ludwig, Becker & Torgan) Tuji, Leelahafriengkrai & Peerapornpisal. 5-7. *Cyclotella atomus* Hustedt. 8-9. *Cyclotella meneghiniana* Kützing. 10-11. *Discostella pseudostelligera* (Hustedt) Houk & Klee. 12. *Discostella stelligera* (Cleve & Grunow) Houk & Klee. 13-14. *Stephanodiscus minutulus* Cleve & J.D. Möller. 15-16. *Aulacoseira ambigua* (Grunow) Simonsen. 17. *Aulacoseira granulata* var. *granulata* (Ehrenberg) Simonsen. 18. *Aulacoseira granulata* var. *angustissima* (O. Müller) Simonsen. 19. *Aulacoseira granulata* var. *australiensis* (Grunow) Moro. 20-22. *Aulacoseira pusilla* (F. Meister) Tuji & Houki. 23-25. *Aulacoseira tenella* (Nygaard) Simonsen. Scale bars = 10 µm.



Figures 26-56. Diatoms of the Billings Complex. 26. *Ctenophora pulchella* (Ralfs *ex* Kützing) D.M. Williams & Round. 27-31. *Fragilaria aquaplus* Lange-Bertalot & Ulrich. 32-34. *Fragilaria crotonensis* var. *oregona* Sovereign. 35-37. *Fragilaria gracilis* Østrup. 38-40. *Fragilaria perminuta* (Grunow) Lange-Bertalot. 41-45. *Fragilaria* sp. 1. 46-50. *Fragilaria* sp. 2. 51. *Fragilaria spectra* P.D. Almeida & C.E. Wetzel. 52. *Ulnaria ferefusiformis* Kulikovskiy & Lange-Bertalot. 53. *Ulnaria ulna* (Nitzsch) Compère. 54-56. *Fragilaria billingsii* Wengrat, C.E. Wetzel & E. Morales. Scale bars = 10 μm.

vaucheriae (Kützing) J.B. Petersen, a similar species, which has wider valves of 4-5 µm and lower striae density of 9-14 in 10 µm (Krammer & Lange-Bertalot 1991). In addition, it is also similar to *F. recapitellata* Lange-Bertalot & Metzeltin, which has capitated apices and longer valves of 20-39 µm (Tuji & Williams 2008a as *Fragilaria capitellata*) than *F. perminuta*.

The species is cited here for the first time in Brazil. It was found in all compartments of the reservoir, occurring in the phytoplankton, periphyton, and surface sediment samples, and from mesotrophic to supereutrophic conditions.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Rio Grande, 5-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP401560); Taquacetuba, 7-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP427905, SP401593).

Fragilaria spectra P.D. Almeida & C.E. Wetzel *in* Almeida *et al*., Phytotaxa 243(6): 174, figs 54-84. 2016.
Figure 51

Morphometry: L: 73-75 µm; W: 1.6-2.2 µm; striae inconspicuous; L/W: 48.9.

The population found was characterized by long needle-like valves, attenuated apices and inconspicuous striae. Resembles *Fragilaria tenera* (W. Smith) Lange-Bertalot, which has greater width (2-3 µm) and conspicuous striae (17-20 in 10 µm, Krammer & Lange-Bertalot 1991). It is also similar to *F. sepes* Ehrenberg, which however presents very conspicuous striae as seen in the illustrations of type material in Tuji (2004).

The species was recently described from oligo- to mesotrophic environments in the State of São Paulo, occurring mainly in phytoplanktonic samples (Almeida *et al*. 2016). In Billings Complex, it occurred in phytoplanktonic samples from the Rio Pequeno branch in mesotrophic conditions.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Rio Pequeno, 6-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP401563).

Fragilaria sp. 1
Figures 41-45

Morphometry: L: 23.8-41.0 µm; W: 2.1-2.9 µm; S: 17-19 in 10 µm; L/W: 8.8-17.0.

This taxon is similar to *Fragilaria crotonensis* Kitton (L: 40-170 µm; W: 2-4 µm; S: 15-18 in 10 µm, Patrick & Reimer 1966) in its central swelling, but differs by having more capitated apices, smaller length and higher striae density. It also resembles *Fragilaria parva* (Grunow) Tuji & D.M. Williams (Tuji & Williams 2008b) and *Synedra rumpens* var. *scotica* Grunow (Patrick & Reimer 1966), differing by the presence of short striae with more pronounced axial area in *Fragilaria* sp. 1. Most valves examined showed deformation, hindering the identification of the population. The examined individuals differ from all known taxa in their particular set of morphological features.

The species was found in phytoplankton and surface sediment of the central body and Taquacetuba branch in both eutrophic and supereutrophic conditions.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Central body, 11-II-2011, *S. Wengrat & D.C. Bicudo* (SP401578); Taquacetuba, 11-II-2011, *S. Wengrat & D.C. Bicudo* (SP401580, SP401581).

Fragilaria sp. 2
Figures 46-50

Morphometry: L: 18.7-82.7 µm; W: 3.2-4.3 µm; S: 14-16 in 10 µm; L/W: 6.2-13.0.

The taxon resembles *Fragilaria fragilarioides* (Grunow) Cholnoky in the valve format, presenting linear to linear-lanceolate valves with a subrostrate to rostrate apex and a bilaterally swollen central area. Patrick & Reimer (1966) separated *Synedra rumpens var. fragilarioides* Grunow, the basionym from other varieties mainly by the coarser striae (10-12 in 10 µm). Despite Brassac & Ludwig (2003) increasing the range of striae density for *F. fragilarioides* (10-17 in 10 µm), the decision was made to retain *Fragilaria* sp. 2 as a distinct taxon because of the importance of this diagnostic feature, as mentioned by Patrick & Reimer (1966).

The species was found in periphyton from Rio Grande Reservoir, the central body, and the Taquacetuba branch, from eutrophic to supereutrophic conditions.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Rio Grande, 5-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP427900); Central body, 7-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP427903); 11-II-2011, *S. Wengrat & D.C. Bicudo* (SP427910).

Ulnaria (Kützing) Compère

****Ulnaria ferefusiformis*** Kulikovskiy & Lange-Bertalot, Fottea 16(1): 36, figs 1-13. 2016.
Figure 52

Morphometry: L: 105-190 µm; W: 3.9-4.8 µm; S: 13-15 in 10 µm; L/W: 28.4.

The analyzed population presents fusiform valves with attenuate to subcapitate ends. Type population in Kulikovskiy *et al*. (2016) presents only subcapitate ends but all the other morphometric features are in accordance with present population. The original authors differentiated *Ulnaria ferefusiformis* from *U. acus* (Kützing) Aboal by the non-fusiform valve outline in the latter as represented by Lange-Bertalot & Ulrich (2014) in their restudy of the type material. The species also differs from *U. pilum* Kulikovskiy & Lange-Bertalot, another fusiform taxon, in the longer and wider valves of the latter (218-295 µm long, 5.6-6.3 µm wide, Kulikovskiy *et al*. 2016).

The species is cited here for the first time in Brazil. It was found in phytoplankton from the central body and Taquacetuba branch and in periphyton from the Rio Pequeno branch of Billings Complex. The distribution of the species ranges from mesotrophic to supereutrophic conditions.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Central body, 6-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP401566); Taquacetuba branch, 11-II-2011, *S. Wengrat & D.C. Bicudo* (SP401580, SP401581, SP401582); Rio Pequeno branch, 6-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP427901).

Eunotiaceae

Actinella Lewis

Actinella leontopithecus-rosalia Costa, Iheringia, Série Botânica 46: 64, fig. 18. 1995.
Figures 57-59

Morphometry: L: 22.5-46.6 µm; W: 2.7-3.6 µm; S: 18-20 in 10 µm; L/W: 7.1-12.3.

Kociolek *et al*. (2001) differentiated this species from *A. lange-bertalotii* Kociołek by the shorter and narrower valves and the lower striae density of the latter taxon (L: 19-87 µm; W: 3.5-4.5 µm; S: 15-16 in 10 µm). However, Tremarin *et al*. (2016) restudied the Brazilian type material of *A. leontopithecus-rosalia* and showed overlapping measurements (L: 18.1-90.3 µm; W: 2.6-4.6 µm; S: 16-19 in 10 µm). In this way, the taxa were synonymized and our population agrees with the illustration and morphometric characteristics of type material.

The species was described and reported in States of Rio de Janeiro (Costa 1995, Menezes & Dias 2001), Paraná, Mato Grosso and Rio Grande do Sul (Tremarin *et al*. 2016). In the state of São Paulo, it was already reported as *A. lange-bertalotii* (Faustino *et al*. 2016). It occurred in planktonic samples from the Taquacetuba branch with eutrophic conditions.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Taquacetuba, 7-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP401568).

Actinella **sp.**
Figures 60-62

Morphometry: L: 69.8-135.6 µm; W: 4.0-5.2 µm; S: 16-20 in 10 µm; L/W: 22.4-24.5.

The population found is most similar to *Actinella crawfordii* Kociolek, but has higher striae density than the 12-14 in 10 µm of *A. crawfordii* (Kociolek *et al*. 2001). Furthermore, although the apical pole of both species is morphologically similar, the basal pole differs by being swollen in the population from Billings and narrow in *A. crawfordii*. The characteristic basal pole also distinguishes *Actinella* sp. from *A. brasiliensis* Grunow, which has an attenuated-rounded basal pole.

The species was only found in periphytic material from the mesotrophic area of the Rio Pequeno branch.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Rio Pequeno, 6-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP427902).

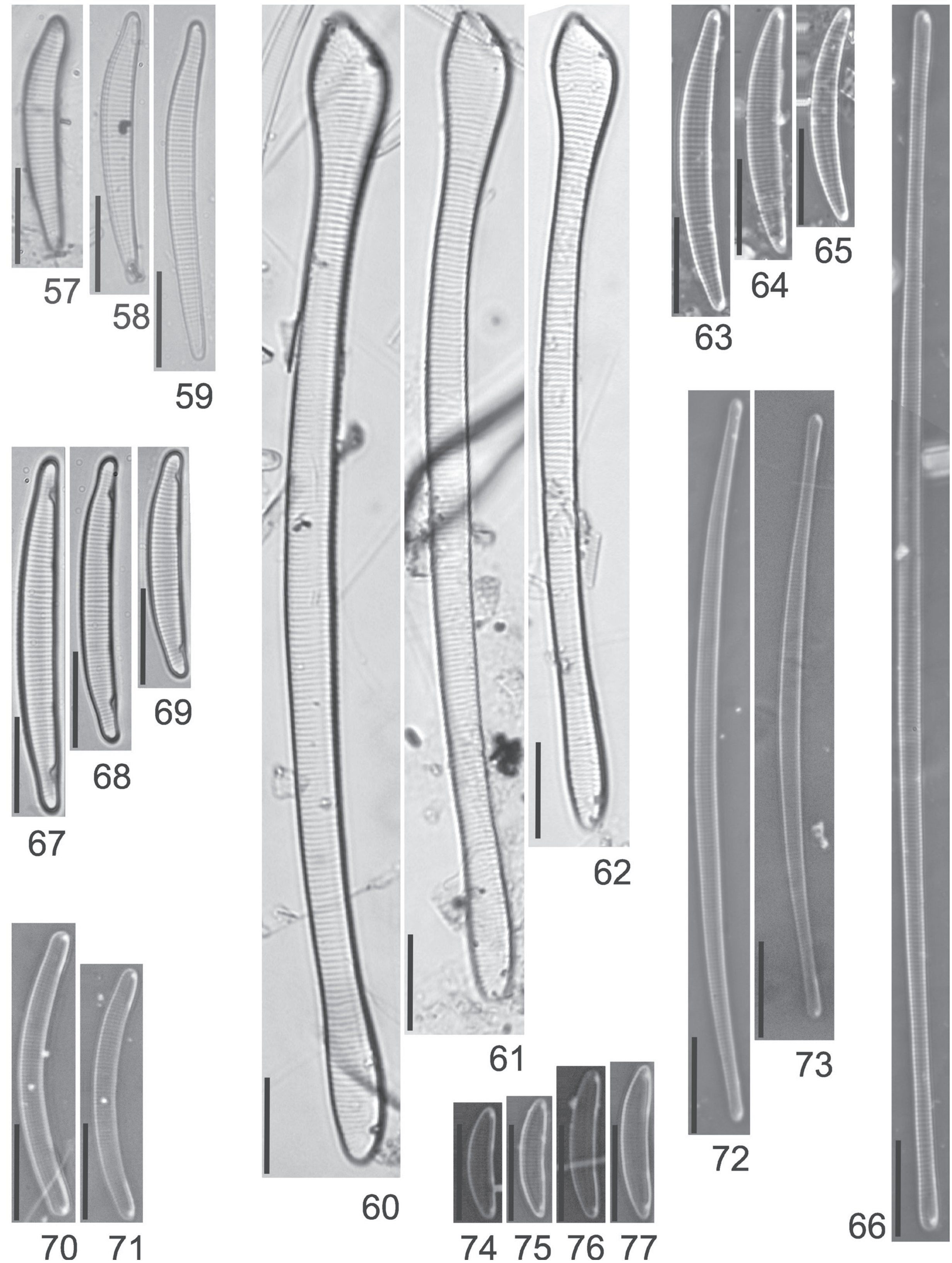
Eunotia Ehrenberg

Eunotia botulitropica C.E. Wetzel & L.F. Costa *in* Costa *et al*., Bibliotheca Diatomologica 64: 14, pl. 58, figs 11-46. 2017b.
Figures 81-83

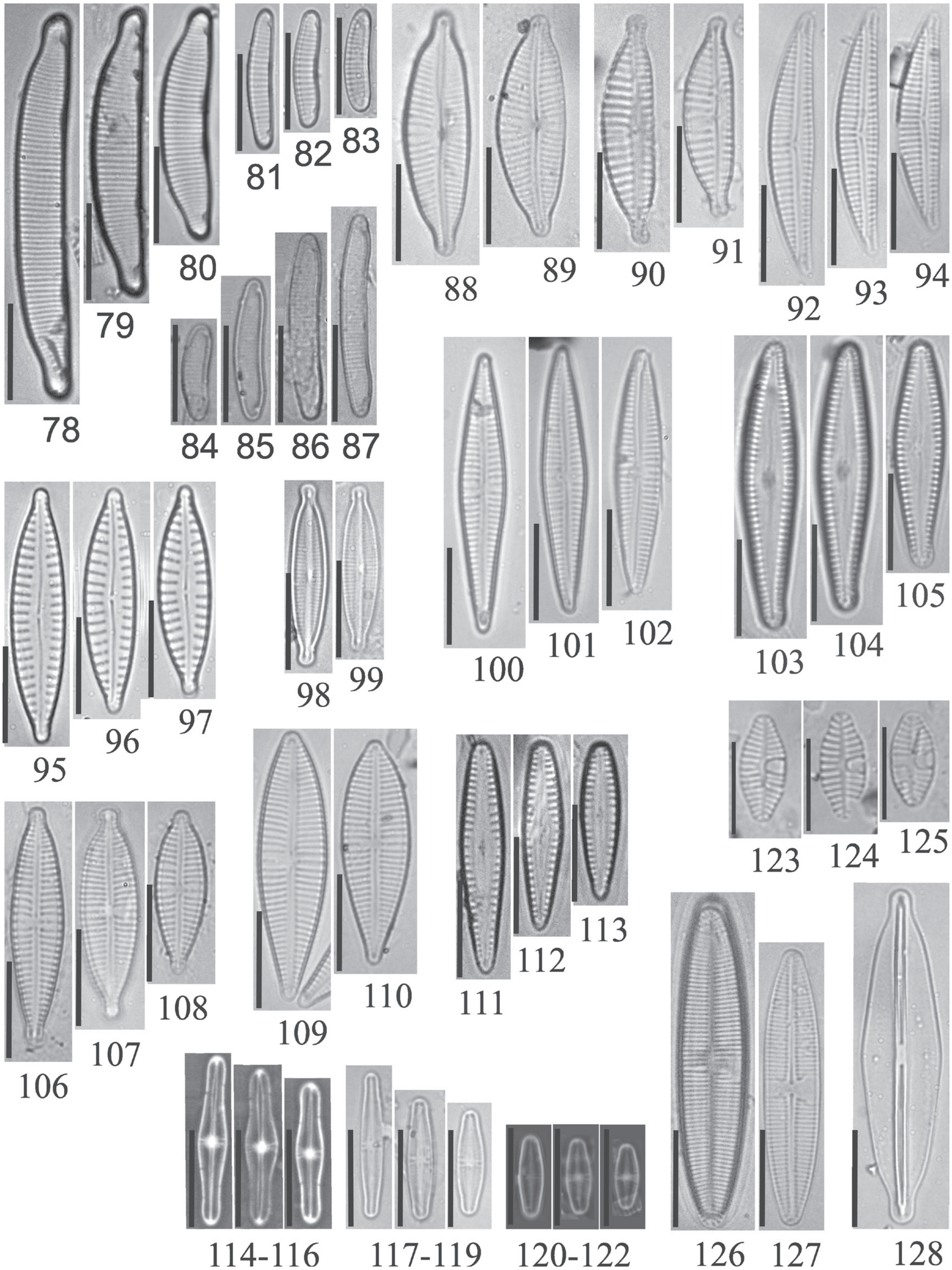
Morphometry: L: 10.6-14.2; W: 2.4-2.5; S: 18-19 in 10 µm; L/W: 4.2-6.0.

The taxon resembles *Eunotia botuliformis* Wild, Nörpel & Lange-Bertalot, however presents narrower valves (3.0-3.8 µm wide) and more acute apices (Lange-Bertalot 1993). It is also similar to *E. rhomboidea* Hustedt, which has more frequent isopolarity and greater width (2-4 µm wide, Hustedt 1950). In the State of São Paulo, a very similar specimen was cited as *E. faba* Ehrenberg (Bicudo *et al*. 1999).

The species was described from surface sediment in São Paulo State (Costa *et al*. 2017b). In our material,



Figures 57-77. Diatoms of the Billings Complex. 57-59. *Actinella leontopithecus-rosalia* Costa. 60-62. *Actinella* sp. 63-65. *Eunotia bilunaris* (Ehrenberg) Schaarschmidt. 66. *Eunotia genuflexa* Nörpel-Schempp. 67-69. *Eunotia incisa* Gregory. 70-71. *Eunotia mucophila* (Lange-Bertalot & Nörpel) Lange-Bertalot. 72-73. *Eunotia naegelii* Migula. 74-77. *Eunotia subarcuatoides* Alles, Nörpel & Lange-Bertalot. Scale bars = 10 µm.



Figures 78-128. Diatoms of the Billings Complex. 78-80. *Eunotia veneris* (Kützing) De Toni. 81-83. *Eunotia botulitropica* C.E. Wetzel & L.F. Costa. 84-87. *Eunotia* sp. 88-89. *Cymbopleura naviculiformis* (Auerswald *ex* Heiberg) Krammer. 90-91. *Encyonema acquapurae* Wengrat, Marquardt & C.E. Wetzel. 92-94. *Encyonema neogracile* Krammer. 95-97. *Encyonopsis sanctipaulensis* Wengrat, Marquardt & C.E. Wetzel. 98-99. *Encyonopsis subminuta* Krammer & Reichardt. 100-102. *Gomphonema auritum* Braun *ex* Kützing. 103-105. *Gomphonema curvipedatum* H. Kobayasi *ex* Osada. 106-108. *Gomphonema lagenula* Kützing. 109-110. *Gomphonema pseudoaugur* Lange-Bertalot. 111-113. *Gomphonema pumilum* (Grunow) Reichardt & Lange-Bertalot. 114-116. *Achnanthidium catenatum* (J. Bílý & Marvan) Lange-Bertalot. 117-119. *Achnanthidium minutissimum* (Kützing) Czarnecki. 120-122. *Achnanthidium saprophilum* (H. Kobayasi & Mayama) Round & Bukhtiyarova. 123-125. *Planothidium frequentissimum* Lange-Bertalot. 126-127. *Lemnicola hungarica* (Grunow) Round & Basson. 128. *Frustulia crassinervia* (Brébisson) Lange-Bertalot. Scale bars = 10 µm.

it was distributed in phytoplankton from Rio Grande Reservoir and the Taquacetuba branch in mesotrophic to eutrophic conditions.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Taquacetuba, 7-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP401568); Rio Grande reservoir, 5-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP401559).

Eunotia subarcuatoides Alles, Nörpel & Lange-Bertalot, Nova Hedwigia 53(1-2): 188, pl. 4, figs 1-36. 1991.
Figures 74-77

Morphometry: L: 12.2-16.7 µm; W: 2.7-3.1 µm; S: 25-27 in 10 µm; L/W: 5.7-4.2.

The analyzed population presents acute rounded apices, raphe nodes near the apices, and numerous delicate striae. The species differs from *E. bilunaris*, which has more arched valves and lower striae density (17-19 in 10 µm), as well as from *E. seminulum* Norpel-Schempp & Lange-Bertalot, which also presents more arched valves (Alles *et al*. 1991).

The species was already reported in the States of Rio Grande do Sul and São Paulo (Bicca & Torgan 2009, Costa *et al.* 2017b). In our material, it occurred only in a periphytic sample from the mesotrophic area of the Rio Pequeno branch.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Rio Pequeno, 6-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP427902).

Eunotia sp.
Figures 84-87

Morphometry: L: 10.0-20.9 µm; W: 2.6-2.9 µm; S: 24-25 in 10 µm; L/W: 7.5-8.0.

The population analyzed has slightly arcuate linear valves with rounded apices as well as numerous and delicate striae. The most similar species found in the literature is *E. intermedia* (Krasske *ex* Hustedt) Nörpel & Lange-Bertalot, which has lower striae density (14-19 in 10 µm) and greater width (3.5-5.5 µm). Furthermore, it is possible to compare the species with *E. rhomboidea*, which presents some slightly heteropolar valves and coarser and lower striae density than the population found at Billings Complex.

The species was already reported in São Paulo state as *Eunotia* sp. 1 (Costa *et al.* 2017b). In our material, it was distributed in phytoplankton and surface sediment from the Rio Pequeno branch in mesotrophic conditions.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Rio Pequeno, 6-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP401565, SP401589).

Gomphonemataceae

Gomphonema Ehrenberg

Gomphonema curvipedatum H. Kobayasi *ex* Osada, Atlas of Japanese Diatoms based on electron microscopy 1: 10, pl. 122, figs 1-13. 2006.
Figures 103-105

Morphometry: L: 24.5-31.2 µm; W: 5.0-6.5 µm; S: 15-17 in 10 µm; L/W: 4.5-5.3.

Specimens very similar to those found in Billings were observed in southern Brazil, but identified at genus level (*Gomphonema* sp. 1) by Bertolli *et al*. (2010) and Silva *et al*. (2010). The taxon is characterized by having curved subcapitate apices, differing from *Gomphonema hawaiiense* E. Reichardt which has attenuated apices. The latter taxon also has longer (32.6-55.0 µm) and wider (6.3-9.5 µm) valves (Tremarin *et al*. 2009) than the specimens found in Billings Complex. The examined population agrees with Kobayasi *et al.* (2006) despite having slightly curved apices, the most obvious feature on the type material.

The species was reported in the first time in the state of São Paulo in mesotrophic conditions (Faustino *et al*. 2016). In our material, it was found in periphyton from the Taquacetuba branch, a eutrophic environment.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Taquacetuba, 11-II-2011, *S. Wengrat & D.C. Bicudo* (SP427911).

Achnanthidiaceae

Planothidium Round & Bukhtiyarova

*******Planothidium frequentissimum*** (Lange-Bertalot) Lange-Bertalot, Iconographia Diatomologica 6: 282. 1999.
Figures 123-125

Morphometry: L: 10.3-11.5 µm; W: 4.6-5.1 µm; S: 15-17 in 10 µm; L/W: 2.1-2.4.

The population observed agrees with all morphometric features from the basionym in Krammer & Lange-Bertalot (1991): *Achnanthes lanceolata* subsp. *frequentissima* Lange-Bertalot. The taxon differs from other representatives of the genus by having a hood as well as in the shape and dimensions of the valve. Among the species with hood, *P. frequentissimum* differs from *P. biporomum* (M.H. Hohn & Hellerman) Lange-Bertalot and *P. rostratum* (Østrup) Lange-Bertalot in presenting valves lanceolate to elliptic with rounded or slightly protracted apices (Potapova 2010). Furthermore, while Potapova (2010) mentions the lack of distinction between the raphid lanceolate valve of *P. frequentissimum* and *P. lanceolatum* (Brébisson *ex* Kützing) Lange-Bertalot, identification is possible by the hoodless araphid valve of the latter species. *Planothidium frequentissimum* also differs from *P. bagualensis* Wetzel & Ector, which has bluntly rounded apices never rostrate and a higher valve width of 6.7-9.5 µm (Wetzel & Ector 2014).

The species was reported in the state of Paraná as *Planothidium rostratum* (Östrup) Round & Bukhtiyarova in periphytic samples (Bertolli *et al*. 2010). In our material, it occurred in surface sediment samples from the Rio Pequeno branch in mesotrophic conditions.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Rio Pequeno, 6-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP401587).

Brachysiraceae

Brachysira Kützing

Brachysira microcephala (Grunow) Compère, Bulletin du Jardin Botanique de Belgique 56(1/2): 26-28, fig. 94. 1986.
Figures 132-135

Morphometry: L: 10.9-23.0 µm; W: 4.1-5.0 µm; striae inconspicuous; L/W: 2.7-4.8.

Wolfe & Kling (2001) commented on the nomenclatural confusion of *Brachysira microcephala* and *B. neoexilis* Lange-Bertalot, mainly in response to Lange-Bertalot & Moser (1994), who published the same species of Compère (1988) as *B. neoexilis*. The species is cited as *B. neoexilis* in southern Brazil (*e.g.*, Bertolli *et al*. 2010, Silva *et al*. 2010), however Wolfe & Kling (2001) was followed here, adopting the oldest name validly published.

The species has been reported in the State of São Paulo in oligo- to eutrophic conditions (Faustino *et al*. 2016). In our material, it was distributed in phytoplankton from Rio Grande Reservoir and the Rio Pequeno branch, and in periphyton from the Rio Pequeno branch, in mesotrophic to eutrophic conditions.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Rio Grande, 5-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP401562); Rio Pequeno, 10-II-2011, *S. Wengrat & D.C. Bicudo* (SP427908, SP427909).

Pinnulariaceae

Caloneis Cleve

Caloneis sp.
Figures 142-143

Morphometry: L: 15.1-18.3 µm; W: 4.4-4.8 µm; S: 30-34 in 10 µm; L/W: 3.7-4.2.

The population analyzed has elliptic valves with rounded apices. It is similar to *Caloneis bacillum* (Grunow) Cleve, however, the latter presents smaller fascia and lower striae density of 25-29 in 10 µm (Kociolek 2011b). *Caloneis vasilyevae* Lange-Bertalot, Genkal & Vekhov has more similar measurements (30 striae in 10 µm, Lange-Bertalot *et al*. 2004) resembling *Caloneis* sp., though differing in its acute apices. The species found in Billings Complex also differs from these taxa by its proximal raphe ends being more distant from each other.

The species occurred only in periphyton from the Taquacetuba branch in eutrophic conditions.

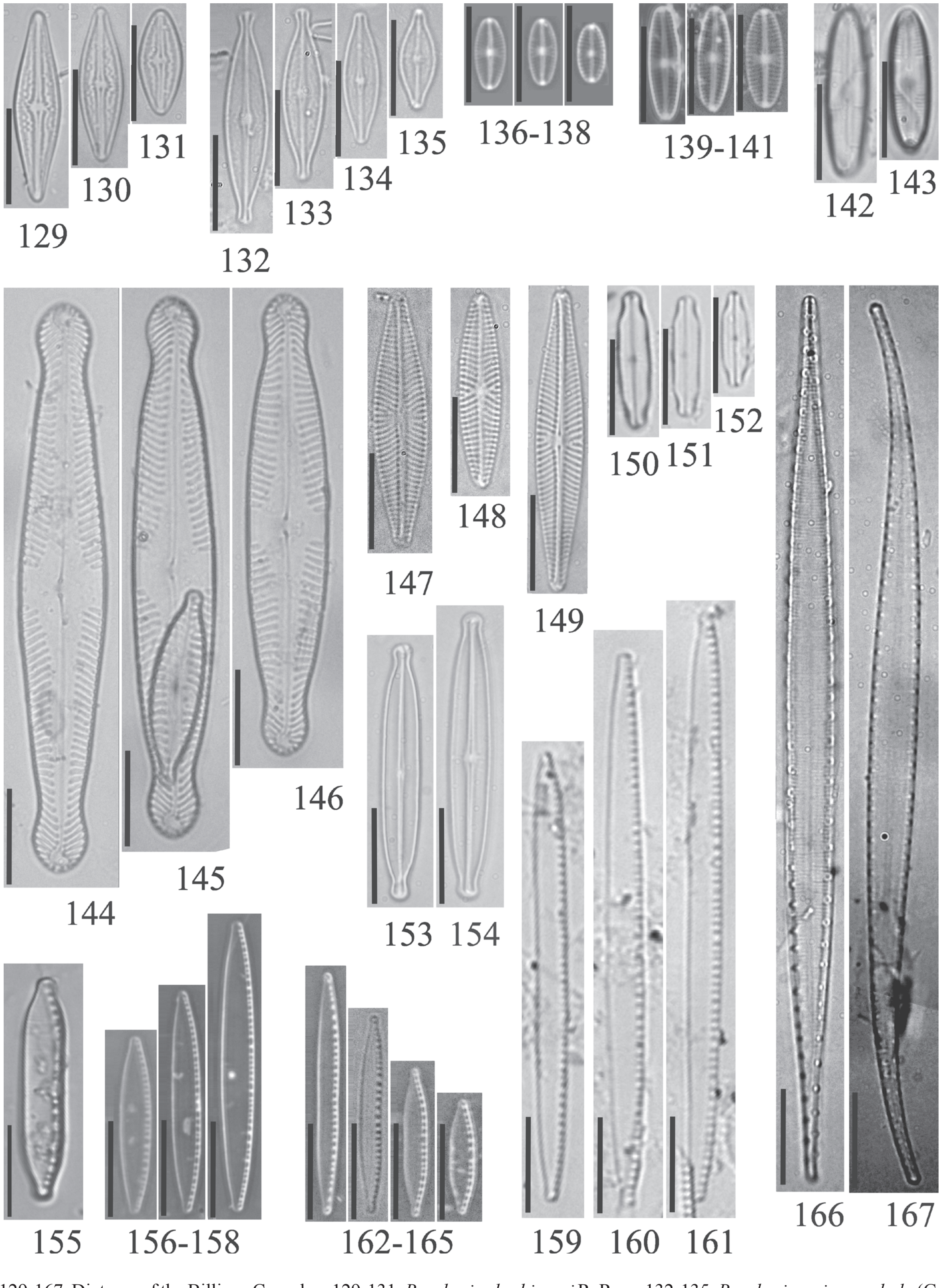
Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Taquacetuba, 7-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP427904).

Pinnularia Ehrenberg

Pinnularia sp.
Figures 144-146

Morphometry: L: 48.5-60.2 µm; W: 8.8-9.3 µm; S: 12 in 10 µm; L/W: 5.7-6.8.

The species has linear-lanceolate valves with subcapitate to capitate apices. Therefore, it differs from *P. subanglica* Krammer which has linear valves with parallel margins as well as from *P. brauniana*



Figures 129-167. Diatoms of the Billings Complex. 129-131. *Brachysira brebissoni* R. Ross. 132-135. *Brachysira microcephala* (Grunow) Compère. 136-138. *Sellaphora nigri* (De Notaris) C.E. Wetzel & Ector. 139-141. *Sellaphora sagerresii* (Desmazières) C.E. Wetzel & D.G. Mann. 142-143. *Caloneis* sp. 144-146. *Pinnularia* sp. 147. *Navicula cryptocephala* Kützing. 148. *Navicula cryptotenella* Lange-Bertalot. 149. *Navicula notha* Wallace. 150-152. *Adlafia triundulata* Tusset, Tremarin & Ludwig. 153-154. *Kobayasiella parasubtilissima* (H. Kobayasi & Nagumo) Lange-Bertalot. 155. *Hantzschia amphioxys* (Ehrenberg) Grunow. 156-158. *Nitzschia palea* (Kützing) W. Smith. 159-161. *Nitzschia fruticosa* Hustedt. 162-165. *Nitzschia* sp. 166. *Stenopterobia delicatissima* (F.W. Lewis) Brébisson *ex* Van Heurck. 167. *Stenopterobia planctonica* Metzeltin & Lange-Bertalot. Scale bars = 10 µm.

(Grunow) Studnicka, which presents narrower valves ranging from 7.3-8.5 µm (Krammer 2000), more constricted apices, and more lanceolate valves.

The taxon was found in surface sediment samples from Rio Pequeno branch in mesotrophic conditions.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Rio Pequeno, 6-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP401589).

Naviculaceae

Adlafia Moser, Lange-Bertalot & Metzeltin

******Adlafia triundulata*** Tusset, Tremarin & Ludwig *in* Tusset *et al*., Phytotaxa 306(4): 269, figs 81-97. 2017.
Figures 150-152

Morphometry: L: 10.4-14.7 µm; W: 2.8-3.8 µm; striae inconspicuous; L/W: 3.7-4.6.

The population analyzed has linear valves with slightly undulating margins and rostrate to subcapitate apices. It is comparable to some species of *Navicula* recently transferred to *Sellaphora* in Wetzel *et al.* (2015). It differs from *Sellaphora tridentula* (Krasske) C.E. Wetzel, which presents evident undulations; from *S. difficillima* (Hustedt) C.E. Wetzel, Ector & D.G. Mann, which has slightly rostrate apices; and from *S. pseudoarvensis* (Hustedt) C.E. Wetzel & Ector, which shows shorter valve lengths. Beyond the above differences, the latter two species possess valve margins without undulations. *Adlafia bryophila* (J.B.Petersen) Lange-Bertalot also differs from *A. triundulata* by the valve outline without undulations.

The species was described from Mato Grosso do Sul State in carbonate waters (Tusset *et al*. 2017) and a similar specimen was reported as *Navicula tridentula* Krasske in the State of Paraná (Bertolli *et al.* 2010). In our material, it occurred only in periphyton from the Taquacetuba branch in eutrophic conditions.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Taquacetuba, 7-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP427904).

Bacillariaceae

Nitzschia Hassal

Nitzschia fruticosa Hustedt, Abhandlungen des Naturwissenschaftlichen Verein zu Bremen 34(3): 349, figs 81-82. 1957.
Figures 159-161

Morphometry: L: 49.5-64.6 µm; W: 3.3-3.9 µm; striae inconspicuous; F: 14-16 in 10 µm; L/W: 15.0-19.2.

Populations found resemble *N. palea* (Kützing) W. Smith in valve form, subcapitate apices, and difficult-to-discern striae. However, they differ mainly in the slightly heteropolar valves of the analyzed population. Aside from the longer valves found in the Billings samples, our specimens agreed with other Brazilian populations (Moro & Fürstenberger 1993, Laux & Torgan 2011).

The species was already reported for the State of São Paulo in subfossil assemblages mainly in the eutrophic phase (Faustino *et al*. 2016). In our material, it occurred in periphytic samples from Rio Grande Reservoir and in phytoplankton from the Taquacetuba branch, also in eutrophic conditions.

Examined material: BRASIL. São Paulo: São Paulo, Billings Complex, Taquacetuba, 11-II-2011, *S. Wengrat & D.C. Bicudo* (SP401580); Rio Grande, 11-II-2011, *S. Wengrat & D.C. Bicudo* (SP427907).

Nitzschia sp.
Figures 162-165

Morphometry: L: 11.2-31.0 µm; W: 2.2-3.3 µm; striae inconspicuous; F: 11-15 in 10 µm; L/W: 4.5-11.2.

The species resembles *Nitzschia perminuta* (Grunow in Van Heurck) Peragallo, which has conspicuous and finely punctuated striae (Kociolek 2011a) while the studied population presents inconspicuous striations in optical microscopy. Silva *et al.* (2010) reported a very similar specimen to that found in Billings for the state of Paraná as *N. perminuta*.

The species occurred in periphyton from Rio Grande Reservoir, the central body, and the Taquacetuba branch, in eutrophic to supereutrophic conditions.

Examined material: BRASIL, São Paulo: São Paulo, Billings Complex, Rio Grande, 5-VIII-2009, *S. Wengrat & D.C. Bicudo* (SP427900); Central body, 11-II-2011, *S. Wengrat & D.C. Bicudo* (SP427910); Taquacetuba, 11-II-2011, *S. Wengrat & D.C. Bicudo* (SP427911).

Final Remarks

Overall, 67 taxa from 28 genera were found in Billings Complex, of which four are new reports for Brazil (*Stephanodiscus minutulus*, *Fragilaria aquaplus*, *F. perminuta* and *Ulnaria ferefusiformis*) and beyond those, six others are new records for the state of São Paulo (*Adlafia triundulata*, *Ctenophora pulchella*, *F. crotonensis* var. *oregona*, *Gomphonema pumilum*, *Planothidium frequentissimum* and *Stenopterobia planctonica*).

Concerning the different habitats, periphyton accounted for 68.65% (46 taxa) of the total diatom diversity, followed by phytoplankton (59.7%) and surface sediments (40.3%). Periphyton assemblages also contributed the highest number of exclusive taxa (21), followed by phytoplankton (9) and surface sediment (6). These results highlight that the type of habitat analyzed could directly influence the local biodiversity, and more than one habitat should be included to improve the total local biodiversity. In this study, therefore, if only one community were analyzed, 30-60% of diatom biodiversity would be overlooked.

Furthermore, the eutrophic and natural mesotrophic regions of Billings Complex presented the richest flora with 47 and 41 taxa, respectively, contrasting with the supereutrophic (central body) and artificial mesotrophic region (Rio Grande Reservoir), which presented only 22 species each. The highest number of exclusive taxa were found in mesotrophic environments (18 taxa) with the occurrence of Cymbellaceae and Surirellaceae. The eutrophic regions accounted for 12 exclusive taxa, including representatives of Gomphonemataceae and Thalassiosiraceae. The supereutrophic region did not present exclusive taxa.

To summarize, this study contributes to the knowledge of diatom biodiversity in tropical regions, particularly in urban reservoirs, adding new records for Brazil and the state of São Paulo. Furthermore, present findings highlight the inclusion of different habitats and environments for improving the knowledge of local biodiversity.

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