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Diatoms from the Colombian Amazonia

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Abstract — As part of an ongoing study of the diatom flora of the Colombian Amazonia, we discuss here 21 taxa that are recorded for the first time in Colombia and one in the Colombian Amazon. Each taxon, studied with light and/or electron microscopy, is described and illustrated. The taxonomic portion is supplemented with distributional information and ecological requirements.

Amazonia / Colombia / diatoms / freshwater microalgae / taxonomy

Résumé — Vingt et une espèces et variétés nouvelles pour la flore des Diatomées de la Colombie et une espèce nouvelle pour celle de l'Amazonie colombienne sont présentées dans ce travail. Les taxons, étudiés au microscope optique et/ou au microscope électronique à balayage, sont décrits et dessinés. Les informations taxinomiques sont complétées par des éléments biogéographiques et écologiques.

Amazonie / Colombie / diatomées / microalgues d'eau douce / taxinomie

INTRODUCTION

Taxonomic studies of diatoms from the Amazon catchment area are largely restricted to Brazil (Hustedt, 1965; De Souza-Mosimann *et al.* 1997, Metzeltin & Lange-Bertalot, 1998) and Ecuador (De Oliveira & Steinitz-Kannan, 1992). In addition, there are some references to diatoms in phytoplankton papers from the Brazilian Amazon basin (Uherkovich, 1976, 1981; Uherkovich & Schmidt, 1974; Uherkovich & Rai, 1979; Uherkovich & Franken, 1980). In contrast, for the Colombian Amazon basin there is only one published paper (Sala

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et al., 1999). Taxonomic investigations in this area have principally dealt with other algal groups: Euglenophyta, Chlorococcales, Desmidiaceae and Cyanophytes (Duque, 1998).

Here we present a floristic study of planktonic and benthic diatom taxa recorded in Colombia. Some of these species have been found in other Amazonian aquatic environments (Putz & Junk, 1997; De Souza-Mosimann *et al.*, 1997) while others are recorded for the first time in Amazonia.

MATERIALS AND METHODS

The study was carried out in six lakes and two creeks belonging to the basins of the upper Solimões (Amazonas) River and Japurá (Caquetá) River, located in Colombian Amazon Basin (Fig. 1 and Tab. 1). According to Duque *et al.* (1997), these two basins have different limnological characteristics. In the upper Solimões, type I black waters are found, which have a higher degree of mineralization relative to the type III black waters environments of the Japurá basin, which are influenced by the Guyana shield (Tab. 2).

The benthic diatoms of the upper Solimões basin live over floating meadows of the angiosperms *Paspalum* spp., *Polygonum* spp. and *Pistia stratiotes* (Jiménez, 1994). In the Japurá basin, there are no floating meadows due to low conductivity, and benthic diatoms were collected from the flooded Igapó forests.

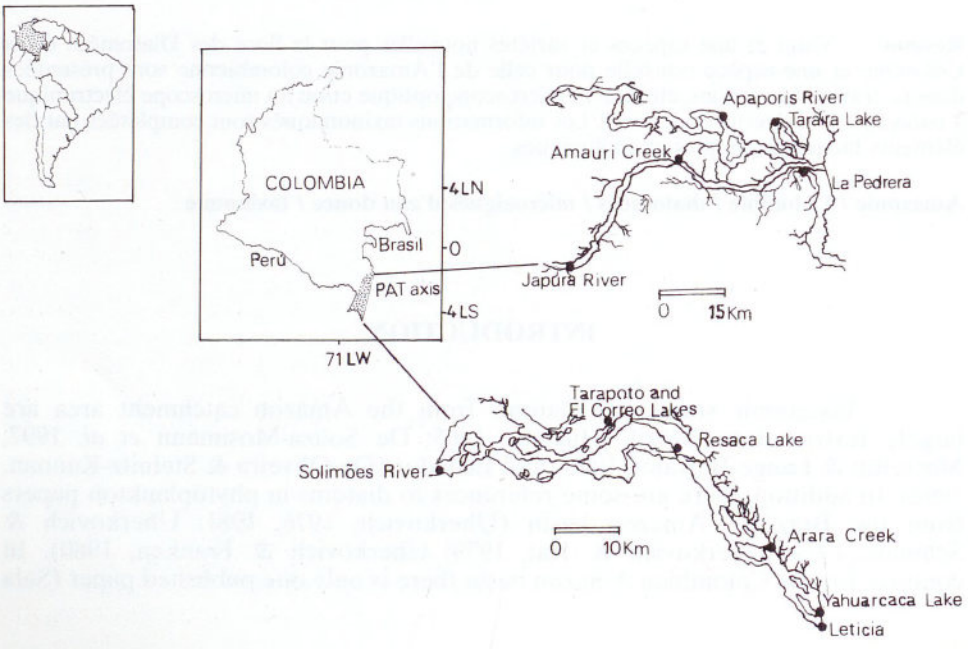


Fig. 1. Location of study sites in the Solimões and Japurá River basins (Colombian Amazon).

Tab. 1. Limnological conditions of the studied lakes and creeks.

Collection Number	*Sampling sites*	*pH*	*Specific conductivity ($\mu S\ cm^{-1}$)*	*Transparency (m)*	*Surface Temperature (°C)*
159	Tarapoto Lake	6.0	84.0	0.50	32.0
163	Arara Creek	6.6	106.0	0.65	26.5
257	El Correo Lake	6.7	135.0	0.85	26.0
261	Tarapoto Lake	7.1	160.0	1.00	29.0
270	Resaca Lake	7.4	180.0	1.50	30.0
300	Yahuarcaca III Lake	6.6	99.0	0.30	29.5
312	Amauri Creek	4.8	10.0	0.60	29.0
329	Taraira I Lake	4.6	5.0	1.67	29.0

Tab. 2. Aquatic environmental classes of the Solimões and Japurá River basins in the Colombian Amazon (classification according to Duque *et al.*, 1997).

Parameters	*Type I black waters (Upper Solimões River)*	*Type III black waters (Upper Japurá River)*
pH	5.10-7.40	4.60-5.00
Conductivity ($\mu S\ cm^{-1}$)	20.00-220.00	5.00-10.00
Transparency (m)	0.20-1.50	0.30-1.67
Turbidity (NTU)	6.30-59.60	0.90-11.70
Total cations (meq l^{-1})	0.17-2.12	0.03-0.08
Total anions (meq l^{-1})	0.18-2.20	0.11-0.22
Suspended solids (mg l^{-1})	3.1-57.00	2.70-19.40
Chlorophyll *a* ($\mu g\ l^{-1}$)	2.30-3.60	0.01-0.04

The samples analysed were collected during 1993 and 1994. Horizontal and vertical tows were made with a plankton net (mesh size = 24 µm) at different depths of the photic zone. Benthic diatoms were sampled by squeezing macrophytes and by scraping natural substrates. Samples were fixed with Transeau solution and were treated to eliminate organic matter following 1) the method described by Hasle & Fryxell (1970) and/or 2) put in muffle furnace at 500 °C during 10 minutes. Samples for light microscopy (LM) were mounted in Hyrax and samples for scanning electron microscopy (SEM) were mounted on glass stubs and then metalized with gold-palladium. Observations were carried out with a Wild M20 LM and a Jeol TM 100 SEM.

All materials are deposited in the Collection Ficoteca Amazónica at the Universidad Nacional de Colombia with the following numbers:
159: Tarapoto Lake, Amazonas River – Colombia. 9 January 1993. Phytoplankton.
163: Arara Creek, Amazonas River – Colombia. 2 March 1993. Epiphytes.
257: El Correo Lake, Amazonas River – Colombia. 14 August 1994. Phytoplankton.
261: Tarapoto Lake, Amazonas River – Colombia. 13 August 1994. Epiphytes.

270: Resaca Lake, Amazonas River – Colombia. 15 August 1994. Epiphytes.
300: Yahuarcaca III Lake, Amazonas River – Colombia. 3 November 1994. Phytoplankton.
312: Amauri Creek, Japurá River – Colombia. 7 November 1994. Epiphytes.
329: Taraira I Lake, Japurá River – Colombia. 9 November 1994. Periphyton.
Cleaned and uncleaned subsamples and permanent slides are deposited at the Herbario Nacional Colombiano (COL) and at the Departamento Científico Ficología del Museo de Ciencias Naturales de La Plata.

Terminology follows Anonymous (1975) and Ross *et al.* (1979).

OBSERVATIONS

Actinella brasiliensis Grunow *in* Van Heurck 1881: 35/19.
Krammer & Lange-Bertalot 1991: pl. 160, figs 2-3.
Metzeltin & Lange-Bertalot 1998: pl. 6, fig. 6; pl. 7, figs 9-15; pl. 62, figs 1-2.
(Figs 25, 28-31)

Frustules cuneate in girdle view. Valves heteropolar with one end swollen and slightly pointed. A row of spines on the union of the valve face and mantle, and a large spine at the broader end of the valve. Striae uniseriate, parallel along the valve face, radiate at the ends. Girdle bands open with several rows of poroids. Dimensions: length: 34-100 µm; breadth: 3-7 µm; striae in 10 µm: 14-19; areolae in 10 µm: 46 (only one specimen measured); spines in 10 µm: 14 (only one specimen measured).

Collection localities: 159, 329.

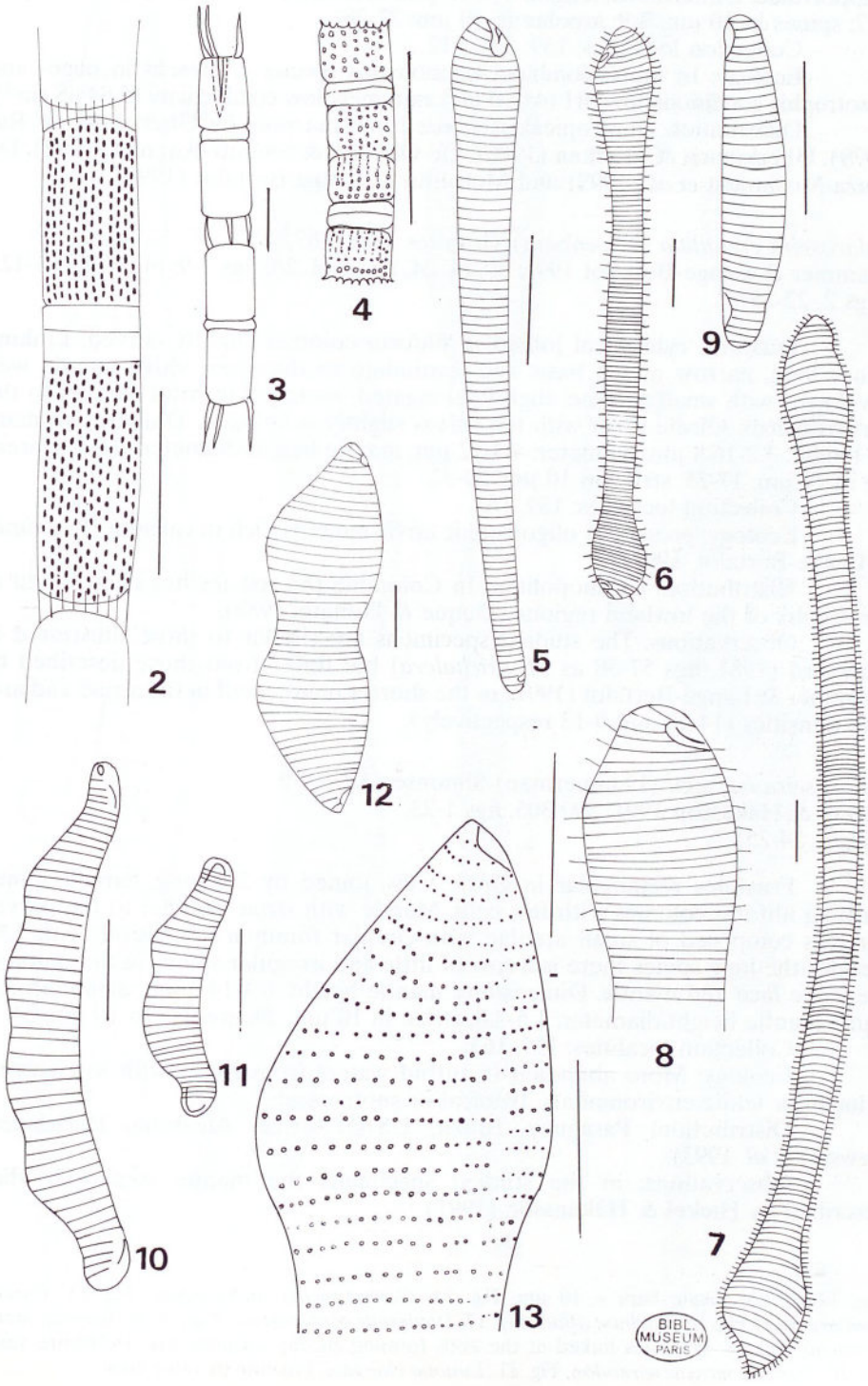
Ecology**:** In the Colombian Amazon this species is present in oligo and mesotrophic conditions, with pH 3.7-8.8 and conductivity 5-84 µS cm^{-1}.

Distribution: Pantropical. Recorded in Amazonia by Uherkovich (1981), Uherkovich & Rai (1979), Uherkovich & Franken (1980), De Oliveira & Steinitz-Kannan (1992), De Souza-Mosimann *et al.* (1997) and Metzeltin & Lange-Bertalot (1998).

Actinella guianensis Grunow *in* Van Heurck 1881: pl. 35, fig. 17.
Metzeltin & Lange-Bertalot 1998, pl. 4, figs 6-11; pl. 5, figs 1-7, pl. 8, figs 1-2 and pl. 63, fig. 6.
(Figs 6-8, 32-33)

Valves heteropolar, slightly curved; one end club shaped and the other one swollen with a protuberance on one side. A row of spines at the junction of valve face and mantle. Striae uniseriate, parallel along the valve face, strongly radiate at the ends. Raphe developed on the valve face, large helictoglossae and

Figs 2-13. LM. Scale bars = 10 µm. Fig. 2. *Aulacoseira crenulata.* Frustule in girdle view. Fig. 3. ▶ *Aulacoseira herzogii.* Frustule in girdle view. Fig. 4. *Aulacoseira* cf. *pfaffiana.* Colony in girdle view. Fig. 5. *Actinella brasiliensis.* Figs 6-8. *Actinella guianensis.* Figs 6-7. Entire valve. Fig. 8. Detail of valve end. Fig. 9. *Eunotia* cf. *sudetica.* Valve view. Figs 10-11. *Eunotia camelus.* Figs 12-13. *Eunotia pileus* var. *guianense.* Fig. 12. Entire valve. Fig. 13. Detail of striae and apical nodule.



rimoportulae. Dimensions: length: 84-193 µm; breadth: 5.6-9.6 µm; striae in 10 µm: 1-17; spines in 10 µm: 7-9; areolae in 10 µm: 27-28.

Collection localities: 159, 329, 312.

Ecology: In the Colombian Amazon this species is present in oligo- and mesotrophic conditions, low pH (4.6-6) and extremely low conductivity (5-84 µS cm^{-1}).

Distribution: Pantropical. Recorded in Amazonia by Uherkovich & Rai (1979), Uherkovich & Franken (1980), De Oliveira & Steinitz-Kannan (1992), De Souza-Mosimann *et al.* (1997) and Metzeltin & Lange-Bertalot (1998).

Aulacoseira crenulata (Ehrenberg) Thwaites 1848: 167,11/8.
Krammer & Lange-Bertalot 1991: 30, pl. 24, fig. 2; pl. 26, figs 1-9; pl. 27, figs 1-12.
(Figs 2, 22-23)

Frustules cylindrical joined in filiform colonies slightly curved. Linking spines long, narrow at the basis and spathulate to the apex. Valve mantle well developed with small areolae, slightly elongated, arranged in rows parallel to the pervalvar axis. Girdle short with the sulcus slightly developed. Dimensions: mantle height: 3.2-16.8 µm; diameter: 4.4-12 µm; mantle height/diameter: 0.6-2.8; areolae in 10 µm: 17-25; striae in 10 µm: 24-32.

Collection localities: 159, 163.

Ecology: present in oligotrophic environments, rich in calcium (Krammer & Lange-Bertalot, 1991).

Distribution: Cosmopolitan. In Colombia the species has been found in Reservoirs of the lowland regions (Duque & Donato, 1988).

Observations: The studied specimens are similar to those illustrated in Crawford (1981, figs 57-58 as *M. orichalcea*) but differ from those described by Krammer & Lange-Bertalot (1991) in the shorter mantle and in the striae and areolae densities (14-19 and 9-13 respectively).

Aulacoseira herzogii (Lemmerman) Simonsen 1979: 59.
Hickel & Häkasson 1991: 300-305, figs 1-23.
(Figs 3, 24-25)

Frustules rectangular in girdle view, joined by 2-4 long, curved spines, forming filiform colonies with few cells. Mantle with striae parallel to the pervalvar axis composed of small areolae with circular foramen not visible with LM. Besides the long spines there is a row of little and irregular spines in the union of the valve face and mantle. Dimensions: mantle height: 6.4-14.3 µm; diameter: 3.2-8 µm; mantle height/diameter: 1.5-2.8; striae in 10 µm: 29; areolae in 10 µm: 34.

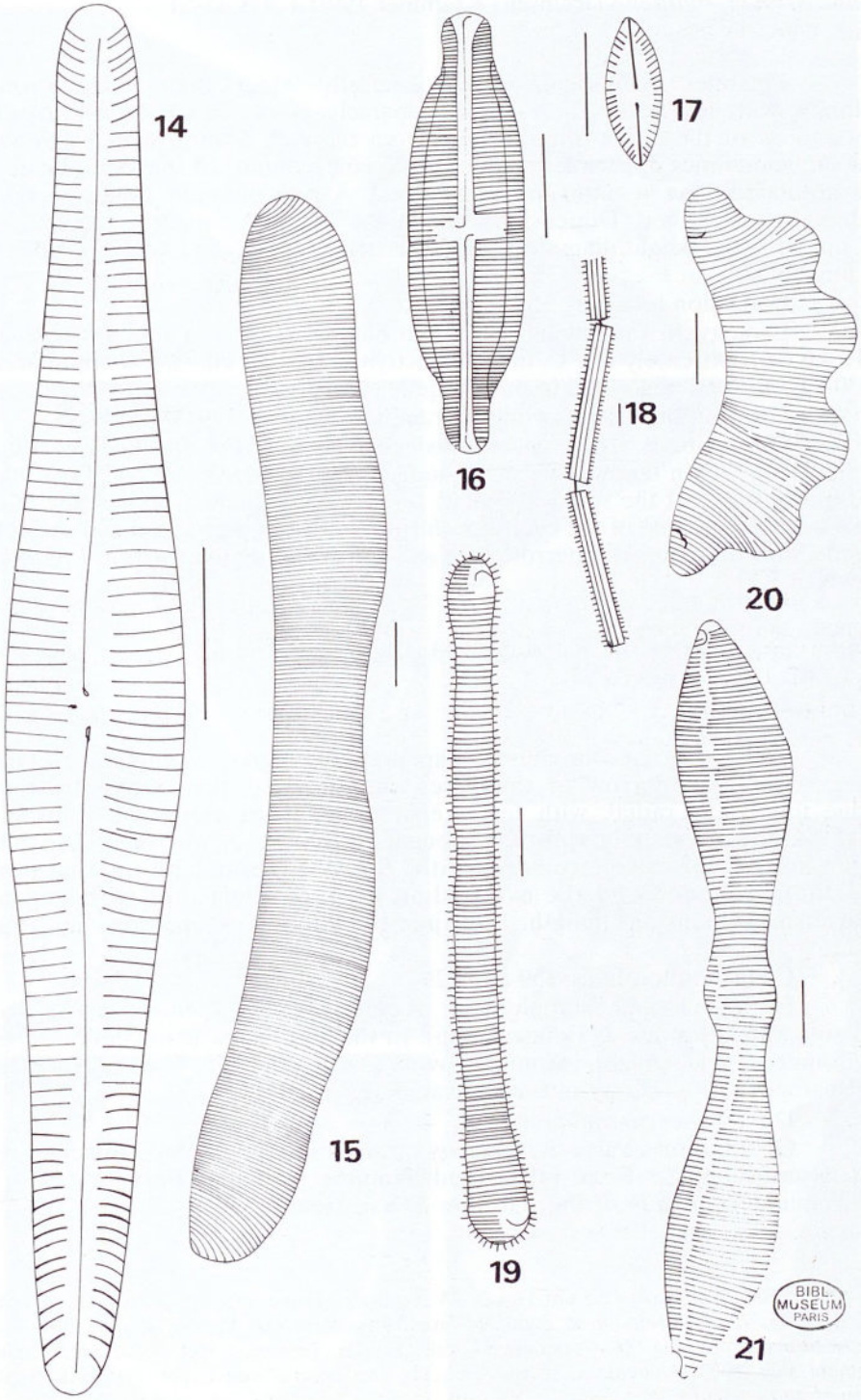
Collection localities: 159, 163.

Ecology: More abundant in turbid waters from rivers with low current velocity or lentic environments. Tropical or subtropical.

Distribution: Paraguay, Brazil, USA, Africa, Australia, Bangladesh (Jewson *et al.* 1993).

Observations: in the studied specimens the mantle is shorter than described by Hickel & Håkansson (1991).

Figs 14-21. LM. Scale bars = 10 µm. Fig. 14. *Gomphonema archaevibrio*. Fig. 15. *Eunotia anamargaritae*. Fig. 16. *Neidium affine*. Fig. 17. *Diadesmis confervaceae*. Figs 18-19. *Eunotia rabenhorstiana*. Fig. 18. Frustules linked at the ends forming zig-zag colonies. Fig. 19. Entire valve. Fig. 20. *Eunotia serra* v. *tetraodon*. Fig. 21. *Eunotia elongata*. Frustule in valve view. ▶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Aulacoseira cf. *pfaffiana* (Reinsch) Krammer 1991: 4, figs 45-54.
(Figs 4, 26-27)

Frustules cylindrical, valves generally wider than taller, forming colonies with few cells. Valve surface coarsely areolate; areolae in irregular rows, those of the outer ring different from the rest. Mantle with 2-3 rows of areolae sometimes 5, parallel to the apical axis; 'collum' of the same height as the areolated area, without 'pseudo sulcus'. A row of blunt spines serves to link valves together. Dimensions: diameter: 4-10 µm; mantle height: 1.14-5.7 µm; mantle height/diameter: 0.21-0.9; striae in 10 µm: 16-20; areolae in 10 µm: 20-22.

Collection localities: 159, 300, 329.

Ecology: In Colombian Amazon it has been found in acid environments (pH 4.6-6.6), extremely low to low conductivity (5-99 µS cm^{-1}), low transparency (0.30-1.67 m) and oligo- and in mesotrophic conditions.

Distribution: Cosmopolitan (Krammer & Lange-Bertalot, 1991).

Observations: The studied specimens differ from those described by Krammer (1991) in the number of striae (12-15 in 10 µm versus 16-20 in 10 µm) and in the shape of the spines (pointed versus blunt). In adition, in some of our specimens the areolae of the centre of the valve are not perforated and the collar is wide, while in others it is narrow as in *Aulacoseira distans* var. *nivalis* (W. Smith) Haworth.

Diadesmis confervaceae Kützing 1844: 109, pl. 30, fig. 8.
Le Cohu 1985: 6, figs 25-27.
(Figs 17, 50-51)

Frustules joined in ribbon-shaped colonies. Valves elliptical to lanceolate. Axial area narrow at the poles and widened towards central area. Striae uniseriate, radial, with few areolae (elongated along the transapical axis). Mantle striae only with one elongated areolae. A row of broad spines at the junction of valve face and mantle. Raphe filiform, with internal proximal ends expanded and the external straight. Girdle bands with one row of areolae. Dimensions: length: 15-21 µm; breadth: 5.5-8 µm; striae in 10 µm: 18-21.

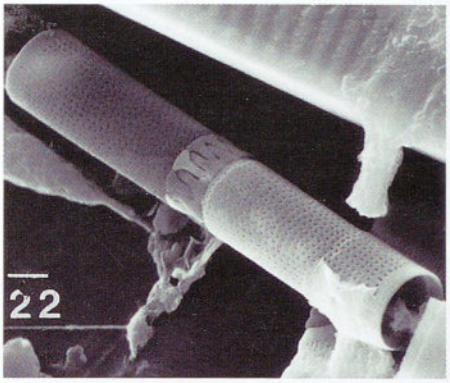
Collection localities: 159 and 329.

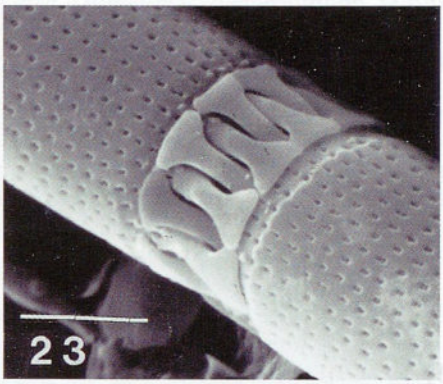
Ecology: Usually aerophytic or in quiet waters; it seems to prefer warm and soft water (Patrick & Reimer, 1966). In the study area it was found in acid environments (pH 4.6-6.0), extremely low to low conductivity (5-84 µS cm^{-1}), low transparency (0.50-1.67 m) and warm waters (29-32 °C).

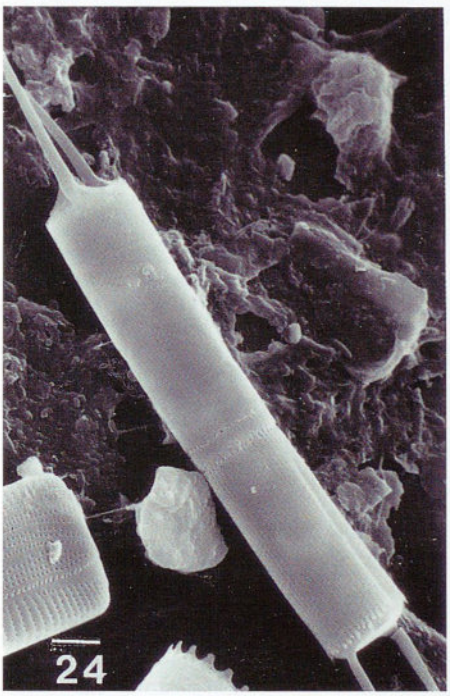
Distribution: Cosmopolitan.

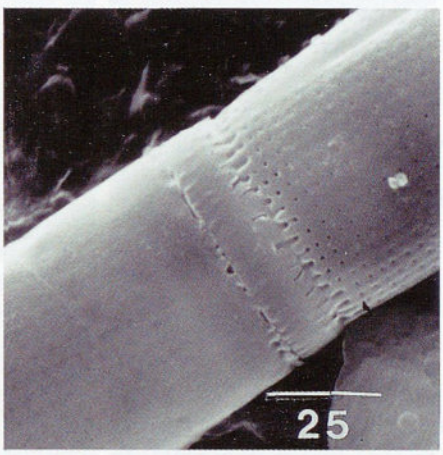
Observations: Valve morphology of the studied specimens coincides with that described by Le Cohu (1985) and Krammer & Lange-Bertalot (1986) as *Navicula confervacea* (Kützing) Grunow *in* Van Heurck.

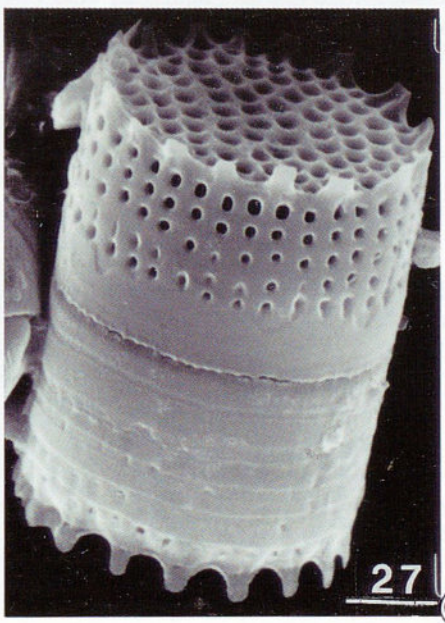
Figs 22-27. SEM. Scale bars = 2.5 µm. Figs 22-23. *Aulacoseira crenulata*. Fig. 22. Two valves linked ▶ together. Fig. 23. External view, detail of mantle areolae and linking spines. Figs 24-25. *Aulacoseira herzogii*. Fig. 24. Complete frustule. Fig. 25. External view, detail of striae and cingulum. Figs 26-27. *Aulacoseira* cf. *pfaffiana*. Fig. 26. External valve view. Fig. 27. Complete frustule.

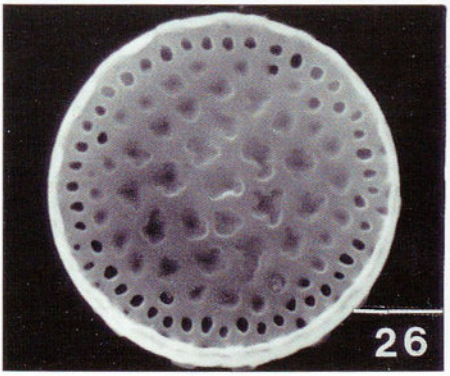












Eunotia anamargaritae (Hustedt) Metzeltin & Lange-Bertalot 1998: 51, pl. 37, fig. 9.
(Fig. 15)

Valves with the ventral margin slightly concave and the dorsal one with two undulations; ends barely differentiated from the rest of the valve. Raphe indistinguishable in the studied material. Striae uniseriate, parallel or slightly radiate at valve centre and strongly radiate at the ends. Areolae visible with LM. Dimensions: length: 178 µm; width: 17 µm; striae in 10 µm: 17.

Collection localities: 312.

Ecology: In Colombian Amazon it was present in Amauri Creek with low pH (4.6) and low electrolyte concentration (10 µS cm^{-1}).

Distribution: River Demerara, Guyana (Krammer & Lange-Bertalot, 1991) and Brazilian Amazonian Region (Metzelin & Lange-Bertalot, 1998).

Observations: The studied specimens differ from the type material (photographed in Simonsen, 1987) in size, number of striae and shape of the dorsal margin with undulations less pronounced.

Eunotia bilunaris (Ehrenberg) Mills 1934: 675.
Krammer & Lange-Bertalot 1991: 179, pl. 137, pl. 138, figs 10-24.
(Figs 34-36)

Valves slightly curved, narrowed at the poles. Striae parallel along the valve face, radiate at the poles. Raphe well developed on the valve face. Dimensions: length: 35-43 µm; width: 3.6-4.8 µm; striae in 10 µm: 16-17; areolae in 10 µm: 45-50.

Collection localities: 159 and 329.

Ecology: Epiphytic on other algae or macrophytes. In acid, lentic or lotic water bodies with low electrolytic content (Krammer & Lange-Bertalot, 1991). In the study area it was found in acid environments (pH 4.6-6.0), extremely low to low conductivity (5-84 µS cm^{-1}), low transparency (0.50-1.67 m) and warm waters (29-32 °C).

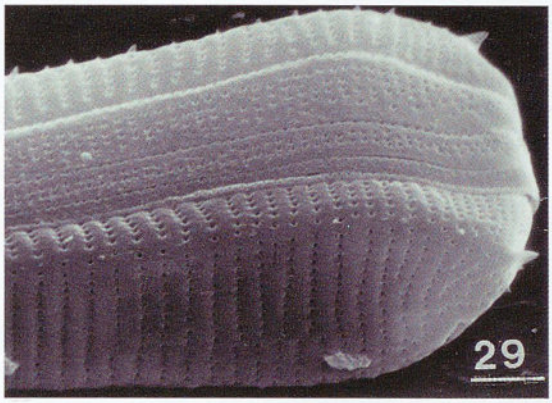
Distribution: Cosmopolitan.

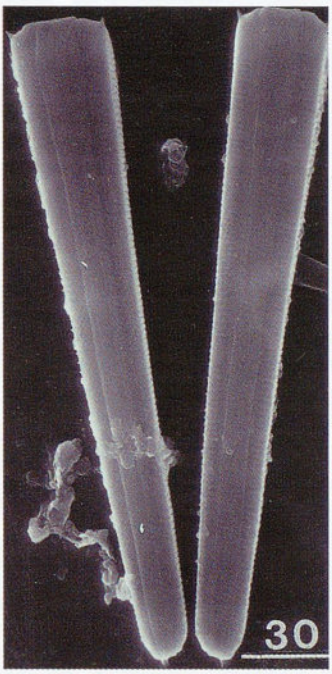
Eunotia camelus Ehrenberg 1841 (1843): 125 (413), 2/1, fig. 1.
Krammer & Lange-Bertalot 1991: pl. 160, figs 10-11.
(Figs 10-11)

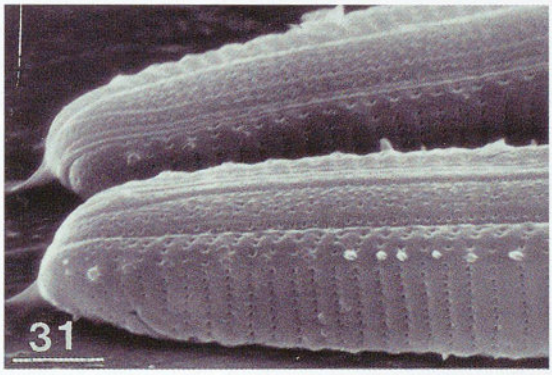
Valves slightly curved, dorsal margin with four undulations and ventral side slightly concave; ends of the valve subrostrate, dorsally bent. Striae parallel only at the centre and slightly radiate on the rest of the valve face. Girdle bands with several rows of poroids. Dimensions: length: 17.5-52 µm; breadth: 5-8 µm; striae in 10 µm: 9-13 at the valve face and 20 at the mantle.

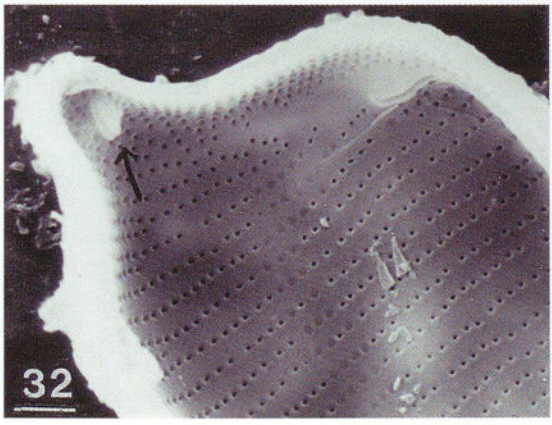
Collection localities: 159, 163 and 312.

Figs 28-33. SEM. Scale bars: Fig. 28 = 10 µm; Figs 29-33 = 0.25 µm. Figs 28-31. *Actinella brasiliensis*. ▶ Fig. 28. Two complete frustules. Fig. 29. External view of one end of the frustule. Fig. 30. Frustules in girdle view. Fig. 31. Detail of ends and cingulum. Figs 32-33. *Actinella guianensis*. Fig. 32. Internal valve view showing the rimoportula (arrow) Fig. 33. External valve ends, note the marginal raphe (arrow) and spines.









Ecology: In Colombian Amazon it was found in lentic and lotic environments with a low pH (4.8-6.6), low to medium electrolytic concentration (10-106 μs cm^{-1}) and high temperature (26.5-32 °C).

Distribution: Pantropical. Recorded in Amazonia by De Oliveira & Steintz-Kannan (1992) and De Souza-Mosimann *et al.* (1997).

Observations: The valve length of the studied specimens is greater than that described by Reichardt (1995) and agrees with the forma *denticulata* (Brébisson) Grunow. However, considering the great variability of this taxon, shown in Schmidt *et al.* (1874-1959: pl. 273, figs 8-9, pl. 274, figs 19-21 and pl. 289, figs 5-8) we identified our material as the nominate form.

Eunotia diodon Ehrenberg 1837: 45.
Metzeltin & Lange-Bertalot 1998: pl. 21, figs 6-9; pl. 46, figs 2-5.
(Figs 37-38)

Valves slightly arcuate, dorsal margin with two smooth undulations and ventral one concave, apices subcapitate. Striae parallel on valve centre, radiate at the ends. Raphe fissures well developed on valve face. Dimensions: length: 60 μm; breadth: 7 μm; striae in 10 μm: 12 (centre) and 16 (poles).

Collection localities: 312.

Ecology: Acidophilus preferring cool water (Patrick & Reimer, 1966). In the study area it was found in acid environment (pH 4.8), low conductivity (10 μS cm^{-1}), low transparency (0.60 m) and warm waters (29 °C).

Distribution: Cosmopolitan? (Krammer & Lange-Bertalot, 1991). Recorded in Amazonia by De Souza-Mosimann *et al.* (1997) and Metzeltin & Lange-Bertalot (1998).

Observations: The studied specimens coincide with those illustrated in Metzeltin & Lange-Bertalot (1998), and are also similar in valve outline to *E. praerupta* Ehrenberg but differ from this species in striae density.

Eunotia elongata (Grunow) Metzeltin & Lange-Bertalot 1998: 59, pl. 20, figs 1-5.
(Fig. 21)

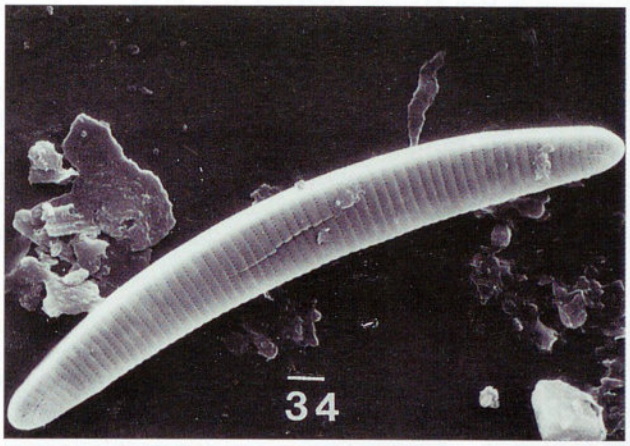
Valves curved, trilobate with ends club-shaped and centre inflated. Striae parallel at valve centre, radiate at the ends. Areolae not visible with LM. Dimensions: length: 151-165 μm; breadth: 15-17 μm; striae in 10 μm: 7-(central) and 8-10 (poles).

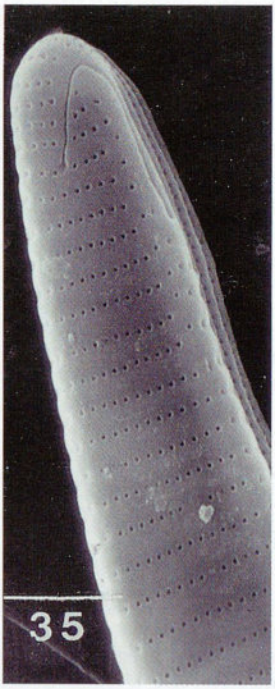
Collection localities: 163.

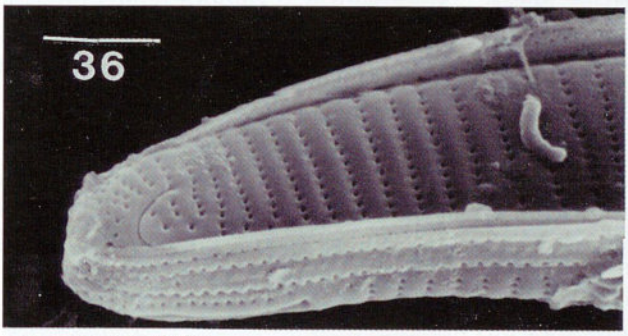
Ecology: Present in acid waters (Hustedt, 1937). In the study area it was found in Arara Creek with circumneutral pH (6.6), moderate conductivity (106 μS cm^{-1}), low transparency (0.65 m) and warm waters (26.5 °C).

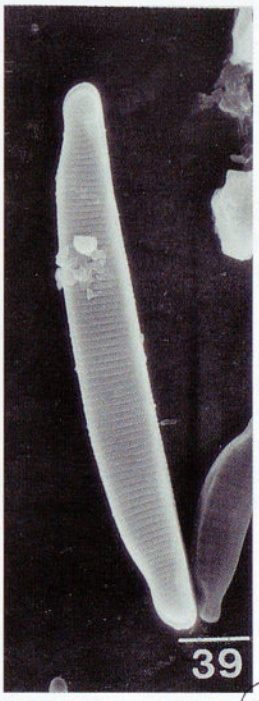
Distribution: Tropics of America and Asia (Hustedt, 1937), in Amazonia recorded by Metzeltin & Lange-Bertalot (1998).

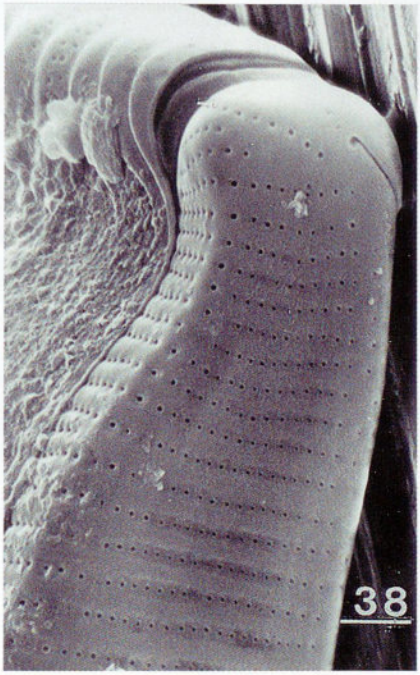
Figs 34-39. SEM. Scale bars: Figs 34-36 = 2.5 μm; Figs 37-39= 10 μm. Figs 34-36. *Eunotia bilunaris*. ▶ Fig. 34. External valve view. Fig. 35. External view, detail of striae and raphe. Fig. 36. External view of frustule end showing cingulum. Figs 37-38. *Eunotia diodon*. Fig. 37. Complete frustule. Fig. 38. External view of valve end showing striae and the distal end of raphe. Fig. 39. *Eunotia minor*. External valve view.











Eunotia minor (Kützing) Grunow *in* Van Heurck 1881: 33, figs 20-21.
(Figs 39-41)

Valves slightly arcuate with the dorsal margin convex and the ventral one straight. Apices subacute, narrower than the rest of the valve. Striae parallel at the valve centre and radiate at the ends, interrupted at the junction of the valve face and mantle on the ventral side. Raphe well developed on the valve mantle and short on the valve face. Girdle bands open with 3-4 rows of poroids. Dimensions: length: 48 µm; breadth: 6 µm; striae in 10 µm: 16 (centre) and 19 (poles), areolae in 10 µm: 28.

Collection localities: 312

Ecology: Found in acid and circumneutral water, tolerates more calcium than many species of *Eunotia* (Patrick & Reimer, 1966). In the study area it was found in acid environments (pH 4.8) with low conductivity (10 µS cm^{-1}), low transparency (0.60 m), and warm waters (29 °C).

Distribution: Cosmopolitan.

Eunotia pileus var. *guianense* (Ehrenberg) Reichardt 1995: 31, lam. 5, figs 1-8 and pl. 24, figs 9-10.
(Figs 12-13)

Valves bilobate, slightly arcuate with subacute ends. Striae parallel alongside the valve face, radial at the poles, interrupted at the ventral margin. Dimensions: length: 42-64 µm; width at the centre: 10.4-13.6 µm; width at the ends: 13.6-20 µm; striae in 10 µm: 9-12 (centre); areolae in 10 µm: 20-22.

Collection localities: 159.

Ecology: in the study area was found in a lake with pH 6, conductivity of 84 µS cm^{-1}, low transparency (0.50 m) and high temperature (29 °C).

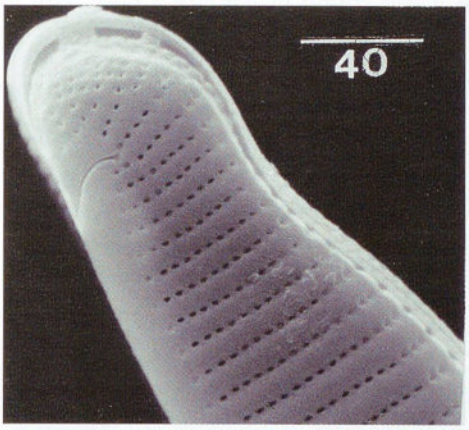
Distribution: North and South America.

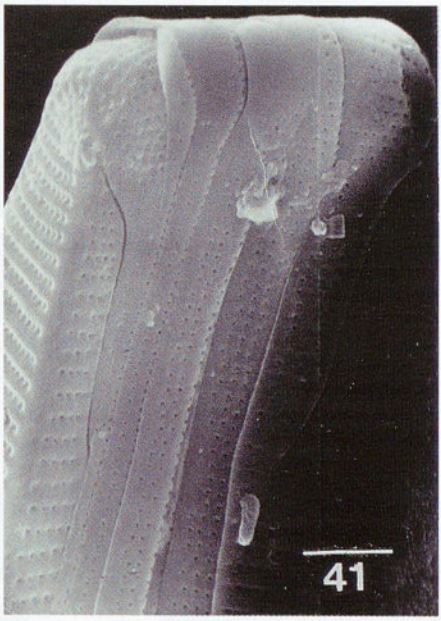
Eunotia rabenhorstiana (Grunow) Hustedt 1949: 72.
Metzeltin & Lange-Bertalot 1998: pl. 10, figs 1-13.
(Figs 18-19, 42-43)

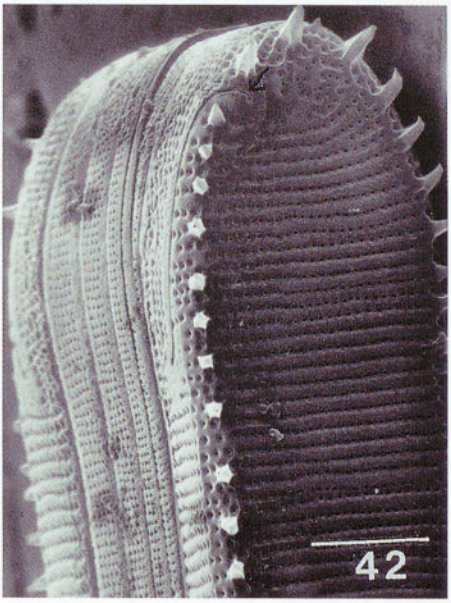
Frustules united at the poles forming zigzag colonies. Valves slightly curved, symmetrical to the transapical axis with large swollen ends. Striae parallel along the valve face, radial at the ends, interrupted by a hyaline area near the ventral margin. A row of spines at the junction of the valve face and mantle. Raphe lying mostly on the mantle, slightly developed on the valve face. Girdle bands with several rows of poroids. Dimensions: length: 85-236 µm; breadth: 5,6-8 µm; striae in 10 µm: 15-19; spines in 10 µm: 6-8.

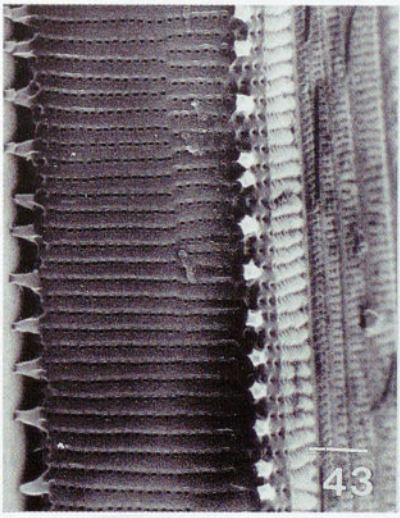
Collection localities: 312.

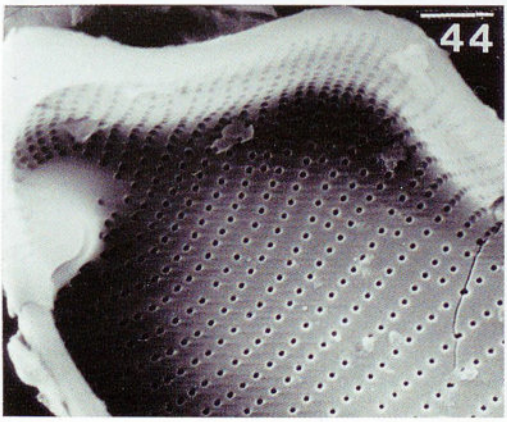
Figs 40-45. SEM. Scale bars: Fig. 40, Fig. 45 = 10 µm; Figs 41-43 = 2.55 µm; Fig. 44 = 0.25 µm. ▶
Figs 40-41. *Eunotia minor*. Fig. 40. External valve view showing striae and distal raphe end. Fig. 41. Frustule end showing cingulum and raphe. Figs 42-43. *Eunotia rabenhorstiana*. Fig. 42. External view frustule end showing raphe (arrow); marginal spines and detail of the cingulum. Fig. 43. External view of frustule showing striae pattern. Figs 44-45. *Eunotia serra* var. *tetraodon*. Fig. 44. Internal view of valve end. Fig. 45. Internal view of the valve.











Ecology: In Colombian Amazon it was found in Amauri Creek with low pH (4.8), low conductivity 10 μS cm^{-1}, low transparency (0.60 m) and high temperature (29 ºC).

Distribution: Pantropical. Recorded in Amazonia by Metzeltin & Lange-Bertalot (1998).

Eunotia tetraodon Ehrenberg 1838: 192, 21/25.
Krammer & Lange-Bertalot 1991: 220, pl. 146, fig. 5 (as *Eunotia serra* var. *tetraodon*) and Lange-Bertalot 1993: 40.
(Figs 20, 44-45)

Ventral margin of the valve concave and dorsal margin with four undulations. Ends subacute. Striae radiate on valve face, with foreshortened striae on the mantle and dorsal side of valve face. Raphe slit slightly visible on valve face, helictoglossae well developed. Dimensions: length: 3-67 μm; breadth: 1-16 μm; ventral striae in 10 μm: 7-12; areolae in 10 μm: 25-26.

Collection localities: 312.

Ecology: Present in oligotrophic or dystrophic waters, usually cool with low electrolytic content. Often in bogs and swamps (Krammer & Lange-Bertalot, 1991). In the study area it was found in Amauri Creek with low pH (4.8), low conductivity 10 μS cm^{-1}, low transparency (0.60 m) and high temperature (29 ºC).

Distribution: Pantropical.

Eunotia subarcuatoides. Alles, Nörpel & Lange-Bertalot *in* Krammer & Lange-Bertalot 1991: 214, pl. 138, figs 1-9.
(Figs 46-47)

Valves with the ventral margin nearly straight and the dorsal one convex with ends little differentiated from rest of the valve. Striae parallel at valve centre, radiate toward poles. Raphe poorly developed at valve face. Dimensions: length: 34 μm; width: 4 μm; length/width: 6.5 μm; striae in 10 μm: 20; areolae in 10 μm: 42.

Collection localities: 329.

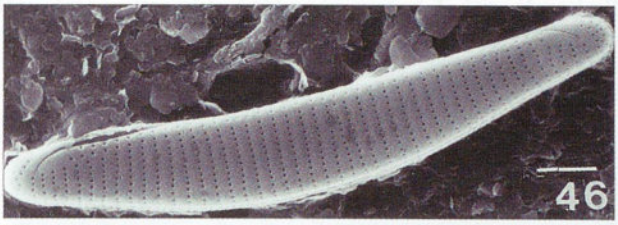
Ecology: Present in oligotrophic waters with low electrolytic content and acid pH (3.7-5.2) (Krammer & Lange-Bertalot, 1991). In the study area it was collected in a lake with acid waters (pH 4.6) and extremely low conductivity (5 μS cm^{-1}).

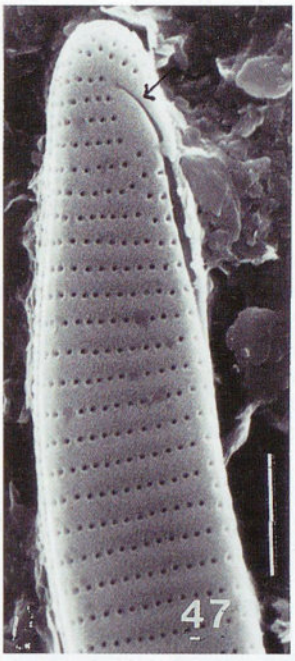
Distribution: Cosmopolitan (Krammer & Lange-Bertalot, *op. cit.*).

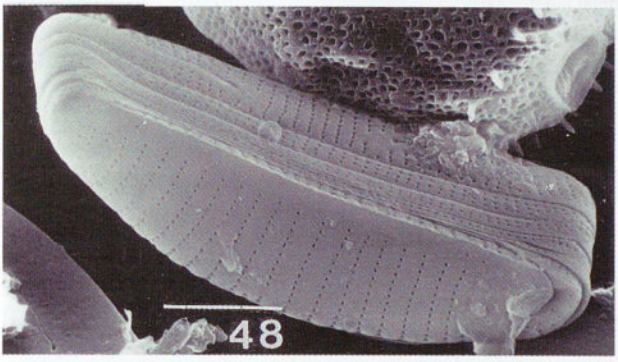
Eunotia cf. *sudetica* O. Müller 1898: 12, pl. 3, figs 25-26.
(Figs 9, 49)

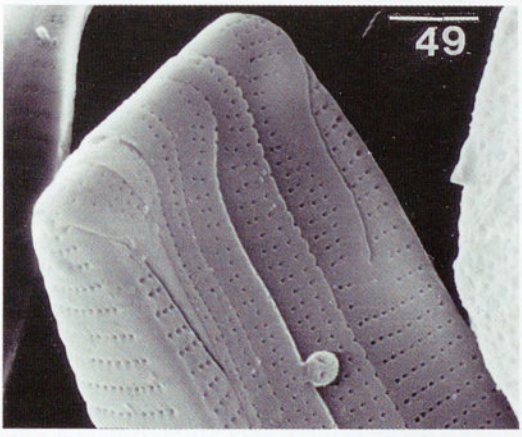
Frustules rectangular in girdle view. Valves with the ventral margin straight or slightly concave and the dorsal margin convex; ends subrostrate or not differentiated from the rest of the valve. Striae slightly radiate, interrupted at the junction of valve face and mantle. Raphe slightly curved, raphe fissures well devel-

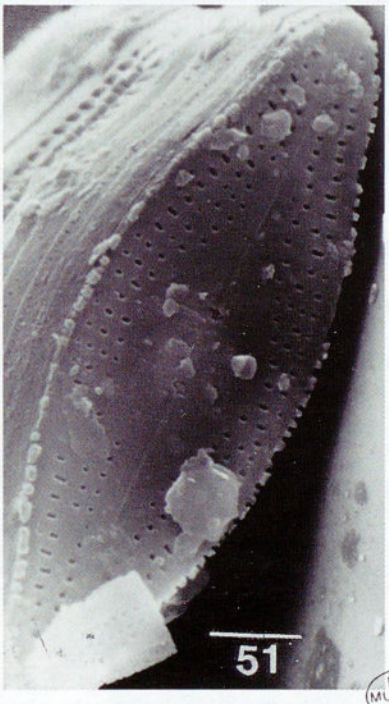
Figs 46-51. SEM. Scale bars: Figs 46, 48 = 0.25 μm; Figs 47, 49-51 = 2.5 μm. Figs 46-47. *Eunotia subarcuatoides*. Fig. 46. External valve view. Fig. 47. External view of valve end showing raphe (arrow). Figs 48-49. *Eunotia* cf. *sudetica*. Fig. 48. Complete frustule. Fig. 49. External view of frustule showing cingulum and two raphe branches. Figs 50-51. *Diadesmis confervaceae*. Fig. 50. Complete frustule. Fig. 51. Two frustules linked by marginal spines. ▶

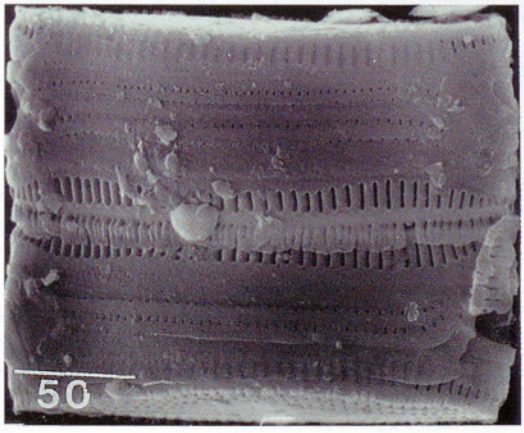












oped on the valve face. Girdle bands with 2-4 rows of poroids. Dimensions: length: 16-35 µm; width: 3-6 µm; striae in 10 µm: 9-19; areolae in 10 µm: 28-36.

Collection localities: 159, 257, 261, 312, 329.

Ecology: Present in small lentic water bodies. In Colombian Amazon it was found in lentic and lotic environments with acid to neutral pH (4.6-7.1), extremely low to moderate conductivity (5-160 µS cm^{-1}), low transparency (0.5-1.67 m) and high temperature (26-32 °C).

Distribution: Cosmopolitan.

Observations: Some of the studied specimens differ from those described by Krammer & Lange-Bertalot (1991) in their smaller width and the position of the terminal raphe fissures. We cannot with certainty state that this material corresponds to *E. sudetica* because there is no information about fine valve morphology of the species. Considering that in the LM our species is similar to *E. pirla* Carter & Flower, *E. incisa* Gregory and *E. subarcuatoides* Alles, Norpel & Lange-Bertalot, we think that a detailed analysis of the ultrastructure of the type materials is needed.

Gomphonema archaevibrio Lange-Bertalot & Reichardt *in* Reichardt, 1995: 32-33; fig. 26/8 (9?) 10-11, fig. 27/1-7, fig. 28/1-6.
Metzeltin & Lange-Bertalot 1998: pl. 160, figs 1-3.
(Figs 14, 52-55)

Valves narrow, lanceolate, slightly asymmetrical to transapical axis. Axial area narrow, slightly widened at central area. Stigma with the external opening round and the internal one elongated. Raphe lateral, external proximal ends slightly enlarged and internal ones hooked towards same side. Internal distal raphe ends with large helictoglossae. Uniseriate striae parallel or slightly radiate. Areolae with external foramen apically elongated and internal one round. Dimensions: length: 77-121 µm; breadth: 8.5-12 µm; striae in 10 µm: 10-11; areolae in 10 µm: 11.

Collection localities: 329.

Ecology: In Colombian Amazon it was found in Taraira Lake, oligotrophic with low pH (4.6), extremely low electrolyte concentration (5.0 µS cm^{-1}).

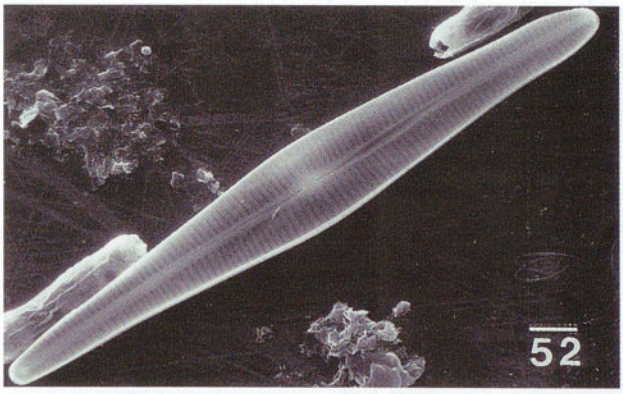
Distribution: Tropics of South America (Brazil and Venezuela), recorded in Amazonia by Metzeltin & Lange-Bertalot (1998).

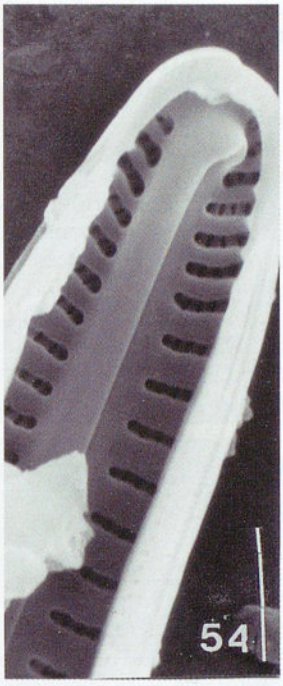
Observations: Valve morphology revealed with SEM coincides with the description and illustrations given in Reichardt (1995) and Metzeltin & Lange-Bertalot (1998).

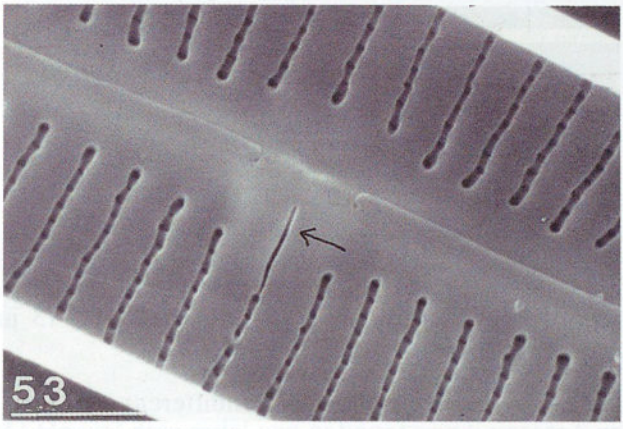
Navicula cf. *kuelbsii* Lange-Bertalot in Krammer & Lange-Bertalot, 1985: 77, figs 25: 4-7.
(Fig. 56)

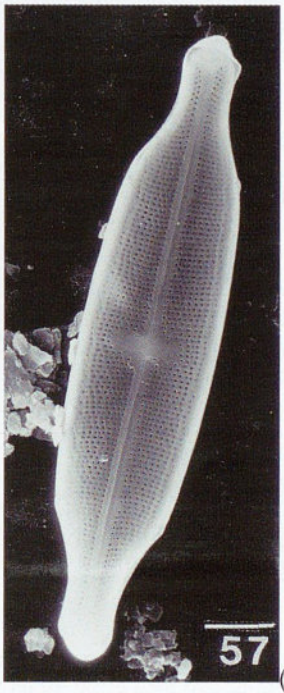
Valves elliptic. Axial area straight delimited by two depressions, and central area delimited by shortened central striae. Raphe filiform, on a longitudinal

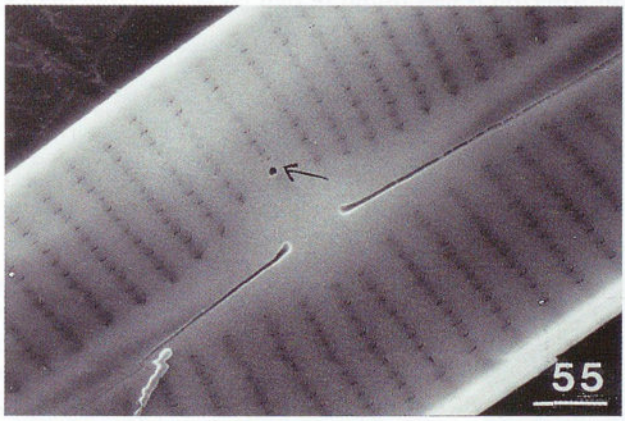
Figs 52-57. SEM. Scale bars: Figs 52, 57 = 10 µm; Figs 53-56 = 2.5 µm. Figs 52-55. *Gomphonema archaevibrio*. Fig. 52. External valve view. Fig. 53. Internal view of valve centre showing proximal raphe ends, striae and stigma (arrow). Fig. 54. Internal view of valve end showing the conspicuous helictoglossa. Fig. 55. External view of valve centre showing proximal raphe ends and stigma (arrow). Fig. 56. *Navicula kuelbsii*. External valve view. Fig. 57. *Neidium affine*. External valve view. ▶

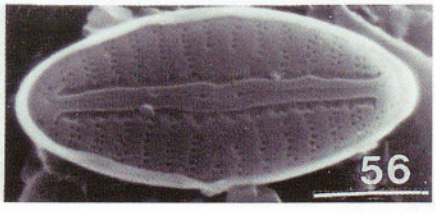












costa proximal raphe ends enlarged and distal ones twisted to the same side. Striae uni-biseriate, radiate. Dimensions: length: 7 µm; width: 3 µm; striae in 10 µm: 20-23.

Collection localities: 159.

Ecology: In Colombian Amazon it was present in a lake with low pH (6) and low specific conductivity (84 µS cm^{-1}).

Observations: The striae density in our specimens is less than that described by Lange-Bertalot (1985). While the striae structure is difficult to see in Lange-Bertalot (op. cit.), there are differences in striae morphology, clearly biseriate in our specimens and apparently uniseriate in *N. kuelbsii*. On the other hand, according to the modern concept of the genus *Navicula* this species should be transferred to *Sellaphora* Mereschkowsky. However, the studied material differs from the description of the genus given by Round *et al.* (1990) in the type of striae (sometimes biseriate). Taking into account that we have analysed only a few specimens we follow a classic criterion and treat it as *Navicula* until it is possible to analyse in more detail the valve structure of this taxon.

Neidium affine (Ehrenberg) Pfitzer 1871: 39.
Krammer & Lange-Bertalot 1986: 280, pl. 106, figs 8-10.
(Figs 16, 57-58, 60)

Valves linear-lanceolate, with margins parallel to slightly convex, with subcapitate to rostrate ends. Axial area straight and narrow; central area variable, sometimes asymmetric, transapically elongated, rectangular o elliptic. Raphe filiform, proximal ends curved, at opposite 90° angles and terminal ends straight. Longitudinal lines conspicuous, visible in LM. Striae uniseriate, parallel over much of valve, convergent at poles. Dimensions: length: 31-60 µm; width: 6.5-13 µm; striae in 10 µm: 20-26; areolae in 10 µm: 20.

Collection localities: 159, 329.

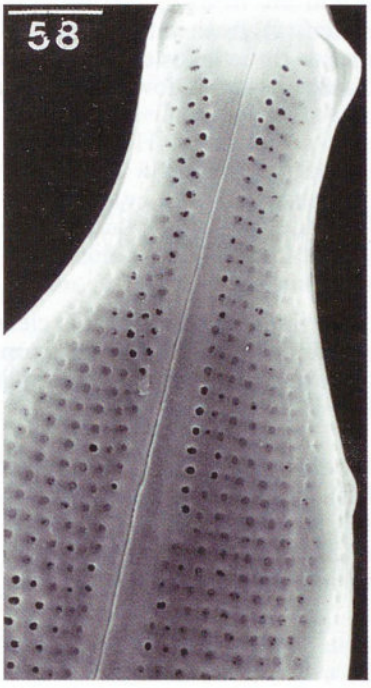
Ecology: Frequent in quiet water bodies, pH indifferent (Patrick & Reimer, 1966). In Colombian Amazon it was found in two lakes with low pH (4.6-6.0), extremely low to low conductivity 5-84 µS cm^{-1} , transparency of 0.50-1.67 m and high temperature (29-32 °C).

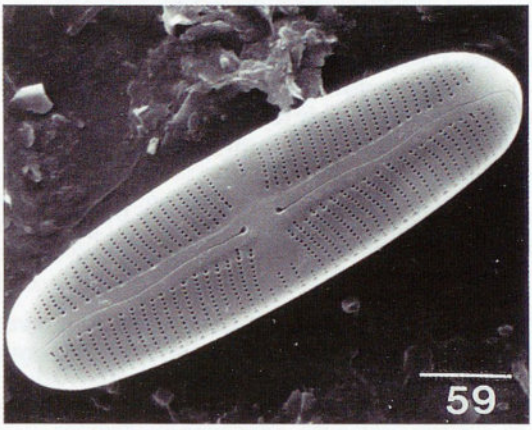
Distribution: Cosmopolitan.

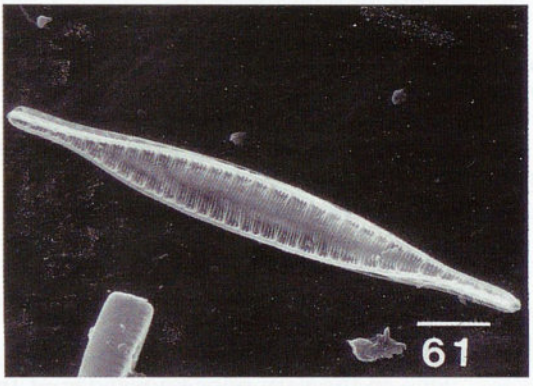
Sellaphora laevissima (Kützing) D.G. Mann 1989
Round *et al.* 1990: 552.
Krammer & Lange-Bertalot 1986: pl. 67, figs 6-10 (as *Navicula laevissima* Kützing)
(Fig. 59)

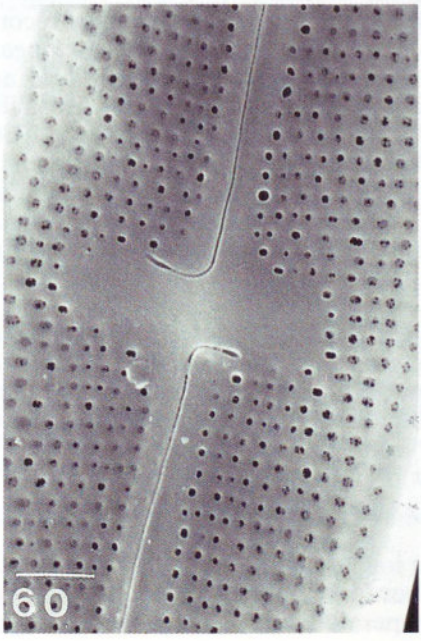
Valves elliptical with margins slightly convex. Striae uniseriate radiate, sometimes convergent at the ends. Axial area straight, slightly broader at valve centre, central area irregular, delimited by the reduction of the central striae. Raphe filiform, somewhat undulated, with the distal ends curved in the same direction. Dimensions: length: 16-39 µm; width: 6-9.5 µm; striae in 10 µm: 16-23; areolae in 10 µm: 46-55.

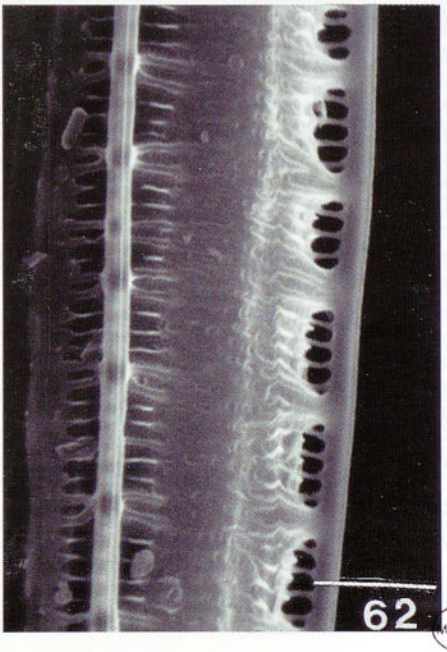
Figs 58-62. SEM. Scale bars: Figs 58, 60 = 2.5 µm; Fig. 59 = 0.25 µm; Figs 61-62 = 10 µm. Figs 58, 60. ▶ *Neidium affine*. Fig. 58. External view of valve end showing striae and distal raphe end. Fig. 60. External view of valve centre showing strongly deflected proximal raphe ends. Fig. 59. *Sellaphora laevissima*. External valve view. Figs 61-62. *Stenopterobia delicatissima*. Fig. 61. External valve view. Fig. 62. External view of valve margin showing winged alar canal.











Collection localities: 159, 270, 329.

Ecology: Widely distributed in circumneutral freshwater (Patrick & Reimer, 1966). In Colombian Amazon it was found in three lakes of low pH (4.6-7.4), extremely low to moderate conductivity (5-180 μS cm^{-1}), low transparency (0.5-1.67 m) and high temperatures (29-32 °C).

Distribution: Cosmopolitan

Stenopterobia delicatissima (Lewis) Brébisson *ex* Van Heurck 1896: 374.
Krammer & Lange-Bertalot 1988: pl. 170, figs 5, 6; pl. 173, figs 1-8; pl. 174, figs 1-12.
(Figs 61-62)

Valves isopolar with straight or convex margins and narrow ends clearly differentiated from the rest of the valve. Raphe channel on a slightly developed keel. Striae parallel, axial area irregular, slightly developed. Dimensions: length: 51 μm; width: 5.8 μm; fibulae in 10 μm: 60; striae in 10 μm: 29.

Collection localities: 159.

Ecology: Present in oligotrophic water bodies with medium or low electrolytic content (Krammer & Lange-Bertalot, 1988). In Colombian Amazon it was found in Tarapoto Lake with circumneutral pH (6), low conductivity (84 μS cm^{-1}), low transparency (0.50 m) and high temperature (32 °C).

Distribution: Cosmopolitan. Mentioned in Amazonia by Metzeltin & Lange-Bertalot (1998).

DISCUSSION

Due to the very poor knowledge of the diatom flora from Colombia, all of the taxa included in this paper (except *Aulacoseira crenulata*) are new records for this country. *Actinella brasiliensis, A. guianensis, E. camelus, E. elongata, E. diodon, E. rabenhorstiana, E. anamargaritae, Gomphonema archaevibrio* and *Stenopterobia delicatissima* were recorded in Ecuadorian and/or Brazilian Amazonia by Uherkovich & Rai (1979), Uherkovich & Franken (1980), Uherkovich (1981), De Oliveira & Steinitz-Kannan (1992), de Souza-Mosimann *et al.* (1997) and Metzeltin & Lange-Bertalot (1998). *Aulacoseira crenulata, A. herzogii, A. pfaffiana, Eunotia minor, E. pileus* var. *guianense, E. serra var. tetraodon, E. subarcuatoides, E.* cf. *sudetica, Diadesmis confervacea, Navicula kuelbsii, Neidium affine, Sellaphora laevissima are* recorded for the first time in the Amazonian region.

Of the studied taxa, ten are cosmopolitan while *Aulacoseira herzoguii, Actinella brasiliensis, A. guianensis, Eunotia camelus, E. elongata, E. rabenhorstiana* and *E. serra* var. *tetraodon* are pantropical; *E. anamargaritae, Gomphonema archaevivrio* and *Navicula kuelbsii* are distibuted only in tropical areas of South America, and *Eunotia pileus* var. *guianense* seems to be endemic to America.

Comparing the valve morphology of the studied specimens with the descriptions in the literature we found only small differences, mostly related to dimensions.

The study area is characterised by a low to neutral pH (4.6-7.6), low conductivity sometimes with extremely low values (5-180 μS cm^{-1}), low transparency (Secchi disk depth: 0.3-1.67 m) and high temperatures (26-32 °C). The ecological

characteristics given in the literature for *Aulacoseira herzogii*, *Eunotia bilunaris*, *E. elongata*, *E. diodon*, *E. minor*, *E. serra* var. *tetraodon* and *Stenopterobia delicatissima* agreee with our observations. For some species we found no previous information. We therefore present new data for eight tropical species:

Actinella guianensis, *A. brasiliensis* and *Eunotia camelus* were collected in waters with pH 4.6-6.0 and a of conductivity 5-84 μS cm^{-1}. *E. pileus* var. *guianense* and *Navicula kuelbsii* in waters with pH 6 and conductivity of 102 μS cm^{-1}. *Eunotia rabenhorstiana* and *E. anamargaritae* were found only in Amauri Creek, with low pH (4.8) and low conductivity (10 μS cm^{-1}). Finally, *Gomphonema archaevibrio* was collected in Taraira Lake, with low pH (4.6); extremely low conductivity (5 μS cm^{-1}); high transparency and oligotrophic conditions.

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REFERENCES

ANONYMOUS, 1975 — Proposals for a standardization of diatom terminology and diagnosis. *Beihefte zur Nova Hedwigia* 53: 523-354.

CRAWFORD R.M., 1981 — The diatom genus *Aulacoseira* Thwaites: its structure and taxonomy. *Phycologia* 20 (2): 174-192.

DE OLIVEIRA P.E. & STEINTZ-KANNAN, M., 1992 — The diatom flora (Bacillariophyceae) of the Cuyabeno Faunistic Reserve, Equadorian Amazonia. *Nova Hedwigia* 54 (3-4): 515-552.

DE SOUZA-MOSIMANN R.M., TAVARES, A.S. & FREITAS, V.P., 1997 — Contribução ao conhecimento da diatomoflórula do conteúdo estomacal de algumas espécies de peixes da Amazônia. 1 – *Myleus* sp. (Pacu) do Lago Do Prato, Am., Brasil. *Acta Amazonica* 27 (1): 9-26.

DUQUE S.R., 1998 — Estudio de humedales en la Amazonia colombiana. En Guerrero E. (ed.). *Una aproximación a los humedales en Colombia*. Fondo FEN Colombia – UICN. Santafé de Bogotá, pp. 73-91.

DUQUE S. R. & DONATO, J.CH., 1988 — Estudio del fitoplancton durante las primeras etapas de llenado de la Central Hidroeléctrica de Betania. Huila-Colombia. *Revista Facultad Ciencias Universidad Javeriana* (1) 2: 29-52.

DUQUE S.R., RUIZ J.E., GÓMEZ J. & ROESSLER E., 1997 — Limnología. En IGAC (ed.). *Zonificación ambiental para el plan modelo colombo-brasilero (eje Apaporis-Tabatinga: PAT*). Editorial Linotipia, Santafé de Bogotá, pp. 71-136.

EHRENBERG C.G., 1837 — Über ein aus fossilen Infusorien bestehendes, 1832 zu Brod verbacknes Bergmehl von der Grenzen Lapplands in Schweden. Bericht über die zur Bekkanntmachung geeigneten Verhandlungen der königl, preuss. *Akademie der Wissenschaften zu Berlin*, pp. 43-45.

EHRENBERG C.G., 1838 – *Die Infusionsthierchen als vollkommene Organismen. Ein Blick in das tiefere organische Leben der Natur.* Leipzig, Leopold Voss, pp. I-XVII + 1-548, pls 1-64 (Atlas).

EHRENBERG C.G., 1841 (1843) — Verbreitung und Einfluss des mikroskopischen Lebens in Süd und Nord-Amerika. *Abhandlungen der königlichen Akademie der Wissenschaften zu Berlin*, pp. 139-144.

HASLE G.R. & FRYXELL G.A., 1970 — Diatoms: cleaning and mounting for light and electron microscopy. *Transactions American Microscopy Society* 89 (4): 469-474.

HICKEL B. & HÅKANSSON H., 1991 — The freshwater diatom *Aulacoseira herzogii*. *Diatom Research* 6(2): 299-305.

HUSTEDT F., 1937 — Systematische und ökologische Untersuchungen über die Diatomeen 'Flora von Java, Bali und Sumatra nach dem Material des Deutschen Limnologischen Sundo-Expedition'. *Archiv für Hydrobiologie*, Suppl. Bd. 15 (Tropische Binnemgewässer, Band 7), pp. 131-177, pls 9-12; pls 21-28 and pls 36-43.

HUSTEDT F., 1949 — *Süsswaser-Diatomeen aus dem Albert-Nationalpark in Belgisch-Kongo in Mission H. Damas (1935-1936). Exploration du Parc National Albert, Institut des Parcs Nationaux du Congo Belge*. Hayez, Bruxelles, 199 p., 16 pls.

HUSTEDT F., 1965 — Neue und wenig bekannte Diatomeen: IX. Susswaserdiatomeen aus Brasilien, inbesondre des Amazonasgebietes. *International Revue der gesamten Hydrobiologie* 50: 391-410.

JEWSON D.H., KONDKER M., RAHMAN M.H. & LOWRY S., 1993 — Auxosporulation of the freshwater diatom *Aulacoseira herzogii* in Lake Banani, Bangladesh. *Diatom Research* 8 (2): 403-418.

JIMENEZ L.F., 1994 — *La comunidad íctica presente en la zona de los gramalotes ubicados sobre el margen colombiano del río Amazonas*. Tesis Universidad Nacional de Colombia. Santafé de Bogotá, 63 p.

KRAMMER K., 1991 — Morphology and Taxonomy of some taxa in the genus *Aulacoseira* Thwaites (Bacillariophyceae), I. *Aulacoseira distans* and similar taxa. *Nova Hedwigia* 52 (1-2): 89-112.

KRAMMER K. & LANGE-BERTALOT H., 1985 — *Naviculaceae. Neue und wenig bekannte taxa, neue Kombinationen und Synonyme sowie Bemerkungen zu einigen Gattungen*. Bibliotheca Diatomologica 9. Berlin Stuttgart, J. Cramer, 230 p., 43 pls.

KRAMMER K. & LANGE-BERTALOT H., 1986 – Bacillariophyceae 1. Teil: Naviculaceae. Band 2/1 von: *Süsswasseflora von Mitteleuropa*. (ETTL H., GERLOF J., HEYNIG H. & MOLLENHAUER D., eds), Jena, Gustav Fisher, 875 p.

KRAMMER K. & LANGE-BERTALOT H., 1988 — Bacillariophyceae 2. Teil: Bacillariaceae, Epithemiaceae, Surirellaceae. Band 2/2 von: *Süsswasserflora von Mitteleuropa*. (ETTL H., GERLOFF J., HEYNIG H. & MOLLENHAUER D., eds) Stuttgart, Gustav Fisher, 600 p.

KRAMMER K. & LANGE-BERTALOT H., 1991 — Bacillariophyceae 3.Teil: Centrales, Fragilariaceae, Eunotiaceae. Band 2/3 von: *Süsswasserflora von Mitteleuropa*. (ETTL, H., GERLOFF J., HEYNIG H. & MOLLENHAUER D., eds) Jena, Gustav Fisher, 576 p.

KÜTZING F.T., 1844 — *Die kielschaligen Bacillarien oder Diatomeen*. Nordhausen, 152 p., 30 pls, Auflage 2, 1865.

LANGE-BERTALOT H., 1996 – 85 New taxa and much more than 100 taxonomic clarifications supplementary to Süss wasserflora von Mitteleuropa Vol. 2/1-4. *Bibliotheca Diatomologica Band 27*, Berlin-Suttgart : J. Cramer, 454 p.

LE COHU R., 1985 — Ultrastructure des Diatomées de Nouvelle-Calédonie. *Annals Limnology* 21 (1): 3-12.

MANN D.G., 1989 — The diatom genus *Sellaphora*: separation from *Navicula*. *British Phycological Journal* 24: 1-20.

METZELTIN D. & LANGE-BERTALOT H., 1998 — *Tropical Diatoms from South America I*. Iconographia diatomológica vol.5. Königstein, Germany, Koeltz Scientific Books, 695 p., 220 pls.

MILLS F.W., 1934 — *An index to the genera and species of the Diatomaceae and their synonyms*, 1816-1932; pp. 527-1480.

MÜLLER 0., 1898 — *Bacillariales aus den Hochseen des Riesengebirges*. Forschungsber. aus dem Biologische Station zu Plön, Teil 6, p. 1-40, pl. 183.

PATRICK R. & REIMER CH.W., 1966 — *The Diatoms of the United States exclusive of Alaska and Hawaii. Vol 1. Monographs of The Academy of Natural Sciences of Philadelphia* nº 13, 688 p., 64 pls.

PFITZER E., 1871 — *Untersuchungen über Bau und Entwicklung der Bacillariaceen (Diatomaceen)*. Botanische Abhandlungen aus dem Gebiet der Morphologie und Physiologie, Heft. 2, Bonn, 189, 6 pls.

PUTZ R. & JUNK W.J., 1997 — Phytoplankton and periphyton. *In:* Junk, W. J. (ed.). *The central amazon floodplain. Ecology of a pulsing system*. Berlin, Germany, Springer, pp. 207-219.

REICHARDT E., 1995 — *Die diatomeen (Bacillariophyceae) in Ehrenberg´s Material von Cayenne, Guyana Gallica* (1843). Königstein, Germany, Koeltz Scientific Books, 107 p.

ROSS R., COX E.J., KARAYEVA N.I., MANN D.G., PADDOCK T.B.B., SIMONSEN R. & SIMS P.A., 1979 — An emended terminology for the siliceous components of the diatom cell. *Nova Hedwigia, Suppl.* 64: 513-533.

ROUND F.E. & CRAWFORD R.M. & MANN D.G., 1990 — *The diatoms. Biology and morphology of the genera.* Cambridge, Cambridge University Press, 747 p.

SALA S.E., DUQUE S.R., NUÑEZ-AVELLANEDA M. & LAMARO A.A., 1999 — Nuevos registros de Diatomeas (Bacillariophyceae) de la Amazonia Colombiana. *Caldasia* 21 (1): 26-37.

SCHMIDT A., SCHMIDT M., FRICKE F., HEIDEN H., MÜLLER O. & HUSTEDT F. 1874-1959 — *Atlas der Diatomaceen* , Leipzig, Kunde, O. R. Reisland, 472 pls.

SIMONSEN R., 1979 — The Diatom System: Ideas on Phylogeny. *Bacillaria* 2: 9-71.

SIMONSEN R., 1987 — *Atlas and catalogue of the diatom types of Friedrich Hustedt.* Vol 1, Stuttgart, J. Cramer, 525 p.

THWAITES G.H.K., 1848 — On the diatomaceae. *Annals and Magazine of Natural Hist*ory 2: 161-172.

UHERKOVICH G., 1976 — Algen aus den Flussen Rio Negro und Tapajós. *Amazoniana* 5: 465-515.

UHERKOVICH, G., 1981 — Algen aus enigen Gewässern Amazoniens. *Amazoniana* 7: 191-219.

UHERKOVICH G. & FRANKEN, M., 1980 — Aufwuchsalgen aus zentralamazonischen Regenwaldbachen. *Amazoniana* 7 (1): 49-79.

UHERKOVICH G. & RAI H., 1979 — Algen aus dem Rio Negro und seinen Nebenflüssen. *Amazoniana.* 6 (4): 611-638.

UHERKOVICH G. & SCHMIDT G.W., 1974 – Phytoplanktontaxa in dem Zentralamazonischen Schwemmlandsee Lago do Castanho. *Amazoniana* 5: 243-283.

Van HEURCK H., 1881 — *Synopsis des Diatomées de Belgique*. Atlas, pls 31-77.

Van HEURCK H. 1896 — *A treatise on the Diatomaceae*, London, 558 p., 35 pls.