

**Epiphytic *Eunotia* (Bacillariophyceae) on *Podostemum* from Santa Catarina, southern Brazil, including new observations on morphology and taxonomy of some rare recorded species**

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**Abstract:** *Eunotia* is a highly diverse diatom genus in the Neotropics. Considerable morphological variability of the valve showed in several species of the genus resulted in a quite confused taxonomy. Twelve *Eunotia* taxa attached to *Podostemum* spp. were investigated using the light microscopy (LM). Additionally, scanning electron microscopy (SEM) was used in order to investigate the fine morphology of most abundant taxa. Samples were collected from four rivers from the State of Santa Catarina between March 2009 and July 2010. The freshwater diatom flora from this south Brazilian state is poorly known in relation to its neighboring states. *Eunotia biseriatooides* has intermediate features between *Eunotia* and *Perinotia*, and the circumscription of these genera is discussed here. *Eunotia odebrechtiana* is very similar in morphology to *E. biseriatooides*, and the synonymy is proposed, as well as the transfer of the variety *E. odebrechtiana* var. *essequioboensis* to the species *E. biseriatooides*. The fine structure of *E. epithemioides* is showed for the first time in SEM, revealing the unusual position of the rimoportula in this genus. A new variety, *E. pseudosudetica* var. *rotundata* var. nov., was proposed and compared with the typical one. Except by *E. veneris*, all other eleven taxa presented here are new records for the State of Santa Catarina, Brazil.

**Keywords:** Diatom, Eunotiaceae, lotic systems, periphyton, taxonomy.

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**Resumo:** *Eunotia* é um gênero de diatomáceas altamente diverso na região neotropical. A considerável variabilidade morfológica encontrada nas valvas de várias espécies deste gênero resultam em uma taxonomia muito confusa. Neste estudo, 12 táxons de *Eunotia* aderidos a *Podostemum* spp. foram investigados usando microscopia óptica (MO). Adicionalmente, microscopia eletrônica de varredura (MEV) foi utilizada para investigar a morfologia ultraestrutural de táxons mais abundantes. Amostras foram coletadas em quatro rios do Estado de Santa Catarina entre março de 2009 e julho de 2010. A diatomoflora deste estado é pobremente conhecida em relação aos estados vizinhos no sul do país. *Eunotia biseriatooides* é um taxon com características intermediárias entre *Eunotia* e *Perinotia* e a circunscrição destes gêneros é discutida aqui. *Eunotia odebrechtiana* é muito similar morfológicamente a *E. biseriatooides* e a sinonimização é proposta, bem como a transferência da variedade *E. odebrechtiana* var. *essequioboensis* à espécie *E. biseriatooides*. A ultraestrutura de *E. epithemioides* é apresentada pela primeira vez em MEV, revelando a posição atípica da rimoportula dentro deste gênero. Uma nova variedade, *E. pseudosudetica* var. *rotundata* var. nov., foi proposta e comparada com a variedade típica. Com exceção de *E. veneris*, todos os outros 11 táxons apresentados aqui são novos registros para Santa Catarina.

**Palavras-chave:** Diatomácea, Eunotiaceae, perifiton, sistemas lóticos, taxonomia.

## Introduction

*Eunotia* Ehrenberg is a large periphytic diatom genus common in freshwater systems worldwide (Round et al. 1990). Diacritical features include dorsiventral valves, uniseriate striae, composed by small round poroids, raphe slits shortened lying at each pole and at least one rimoportula present near to the valve ends (Round et al. 1990). The species richness of this genus is high, and at least 1,500 species are estimated to exist throughout the world (Lange-Bertalot et al. 2011).

The diatom diversity in the Neotropics is considered rather high compared to the well-studied temperate regions of Europe and North America. Every new published flora results in dozens of new taxa proposed, some particularly endemics (e.g. Metzeltin & Lange-Bertalot 1998, 2007, Kociolek et al. 2001, Metzeltin et al. 2005). With regard to *Eunotia*, there are about 245 taxa identified to Brazilian environments (Metzeltin & Lange-Bertalot 1998, 2007, Torgan et al. 1999, Ferrari et al. 2007, Tremarin et al. 2008, 2009, Bicca & Torgan 2009, Bicca et al. 2011, Silva et al. 2011, Burliga & Kociolek 2012), of which 81 taxa were proposed as new to science (e.g. Torgan & Becker 1997, Burliga et al. 2007, Wetzel et al. 2010, 2011, Metzeltin & Tremarin 2011, Burliga & Kociolek 2012, Fuhrmann et al. 2013).

Recent studies on periphytic algae suggested that architecture of *Podostemum rutifolium* Warm. provides microhabitats for many algal species (mainly diatoms) and, therefore, is a key species in the structure of those communities. Aquatic plants are important structuring of algal communities and directly affect diversity and richness of the attached or associated microorganisms, especially in the lotic systems (Ferreira et al. 2011).

In the State of Santa Catarina, southern Brazil, there are few researches about diatoms (Souza-Mosimann 1980, Rodrigues 1984). The most of them are concentrated in littoral marine/estuarine communities, some of which recording freshwater species (Fernandes et al. 1990, Saube & Souza-Mosimann 2003, Souza-Mosimann & Laudares-Silva 2005, Souza-Mosimann et al. 2011). Epiphytic freshwater diatoms are poorly studied in this region.

Here we described 12 *Eunotia* taxa from several rheophilic environments located in Santa Catarina, based on light and scanning electron microscopies analysis. These findings contribute to knowledge of the diatom flora from Santa Catarina, as well as from Brazil.

## Material and methods

Three *Podostemum* Michaux species were collected in waterfalls of four distinct lotic systems of Santa Catarina: *P. distichum* (Cham.) Wedd from river Pelotas, *P. muelleri* Warm. from rivers Jacutinga and Irani, and *P. rutifolium* Warm. from river Correias, between March 2009 and July 2010 (Table 1).

Algal biofilm attached to the macrophytes was removed using toothbrushes and preserved in a 4% formaldehyde solution. Subsamples were cleaned following the procedure described in Simonsen (1974) and modified by Moreira-Filho & Valente-Moreira (1981). Permanent slides were mounted with Naphax resin (R.I.=1.74) for taxonomic analysis on light microscope (LM) Olympus BX-40 equipped with Olympus DP71 image capture equipment. For scanning electron microscopy (SEM), subsamples were dried directly on aluminum stubs and sputter-coated with gold. Samples were observed using JEOL JSM 6360LV microscope, operated at 15 kV and 8 mm working distance, which is housed in the Electron Microscopy Center of the Federal University of Paraná. Samples and permanent slides are stored in the herbarium of the Federal University of Paraná (UPCB, Table 1).

## Results and discussion

Eleven *Eunotia* species and one non typical variety were identified from our samples. Eleven taxa (except by *E. veneris*) represent new records for Santa Catarina. Morphological descriptions and taxonomic observations are presented below.

*Eunotia biseriatooides* Kobayasi, Ando et Nagumo var. *biseriatooides*, 1981, Proc. 6th Diat. Symp., p. 98, pl. 4, figs. 27–34.

### Figs. 1-14

**Synonyms:** *Eunotia odebrechtiana* Metzeltin et Lange-Bertalot var. *odebrechtiana*, 1998, Iconogr. Diatomol. 5, p. 71, pl. 56, figs. 1-6, 13, 14

*Eunotia monodon* var. *constricta* Hustedt (excl. typus) sensu Simonsen, 1987, Atlas and Catalogue of the Diatom Types of Friedrich Hustedt, pl. 31 figs. 2, 3 (non fig. 1).

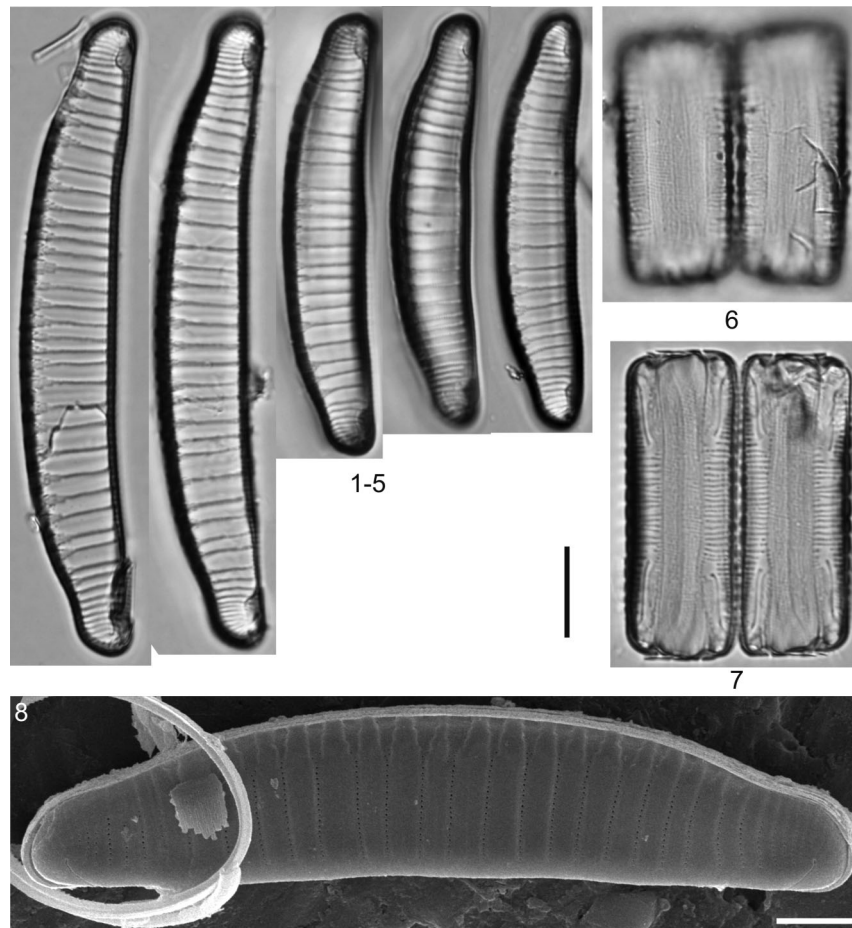
Rectangular frustules in lateral view, with longest sides undulate, caused by interfascicular thickening in the valve surface; dorsiventral valves, isopolar; dorsal margin convex, ventral margin concave, almost straight in median region; ends rounded, detached from the valve; radiate striae, denser in the ends, unisseriate, with short striae irregularly inserted around each striae at dorsal margin; delicate round areolae; terminal nodules thickened located on the ventral margin and somewhat distant from the ends; one rimoportulae per valve, located at valve extremity (Figs. 2, 5). Length 44.3–69.7 µm, width 7.6–10.7 µm, 5–7 striae (valve face) in 10 µm, 14–16 striae (ventral mantle) in 10 µm.

In SEM, areolae are simple round poroids, 33–35 in 10 µm (Figs. 8–10). Dorsal shortened striae are depressed compared to interstriae (Fig. 9). Striae are interrupted in the ventral valve-mantle junction by a hyaline edge (Figs. 9, 11, 13). Ventral valve mantle is more densely striated than valve surface (Fig. 13). External distal endings of raphe are simple, not reaching the valve center (Fig. 11). Externally, the raphe extends in oblique and slightly sinuous fissure at the ventral mantle, with simple

**Table 1.** Sampling data, with reference to local and date, host collected and register on herbarium of Federal University of Paraná (UPCB).

Herbarium Code UPCB (diatoms)	Sampling date	River	Geographic coordinates	<i>Podostemum</i> species
76020	10/07/2010	Pelotas	28°08'S; 49°37'W	<i>P. distichum</i>
76021	09/03/2010	Jacutinga	27°3'13.61"S; 51°41'54.28"W	<i>P. muelleri</i>
76022	17/03/2009	Correias	26°25'6.28"S 49°19'39.11"W	<i>P. rutifolium</i>
76024	09/03/2010	Irani	26°55'55.18"S 51°52'22.37"W	<i>P. muelleri</i>

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**Figures 1-8.** *Eunotia biseriatoides* var. *biseriatoides*. **Figs 1-5.** Specimens in valve view, LM. **Fig. 6.** Frustules in dorsal view, LM. **Fig. 7.** Frustules in ventral view, LM. **Fig. 8.** Valve overview in SEM. Scale bars: 10  $\mu\text{m}$  (Figs 1-7), 5  $\mu\text{m}$  (Fig. 8).

proximal ends (Fig. 13). Internally, the raphe ends in coarse helictoglossa (Fig. 12). Internally, the rimoportula is small, sessile (Fig. 12), often hidden by septum, when valvocopula was not detached from valve (Fig. 14). Valvocopula has delicate scalloped projections towards the internal valve surface (pars interior) on each interstriae (Fig. 10, arrowheads).

**Occurrence in the samples:** UPCB 76024

**Comments:** this species, described by Kobayasi et al. (1981), is characterized by broadly raised interstriae and short striae inserted on the dorsal side of each striae. These authors have distinguished *E. biseriatoides* from *E. biseriata* Hustedt by the “undulate dorsal margin, absence of ventral striae and more slender shape of the valve” of the former. In the light microscope, undulate dorsal margins are only detected when valves lie in girdle view (figs. 6, 7). Ventral striae are probably a reflection of ventral mantle striae, rather than projections of mantle striae reaching the valve face. This feature can be observed in the Hustedt’s iconotype of *E. biseriata*, but undiscernible in the Simonsen’s illustration of holotype (Simonsen 1987, pl. 567, figs. 9-11). Mantle striae can be observed also in *E. biseriatoides* from present study (Figs. 5, 7) and synonyms *E. monodon* var. *constricta* (Simonsen 1987, pl. 31, fig. 2) and *E. odebrechtiana* var. *odebrechtiana* (Metzeltin & Lange-Bertalot 1998, pl. 56, figs. 1, 4). These two characters do not seem to be strong criteria for differentiation. The best distinguishing feature between *E. biseriata* and *E. biseriatoides*

is the valve shape, which is slender (length/width ratio 5.1-6.9) in the latter and more robust (length/width ratio 3.4) with broadly round apices, detached from the valve, in the former (Table 2). *E. biseriata* was described in Hustedt (1952) based on a single specimen. A population-based morphometric study as well as SEM analysis of this taxon are necessary to clarify the boundaries between these taxa.

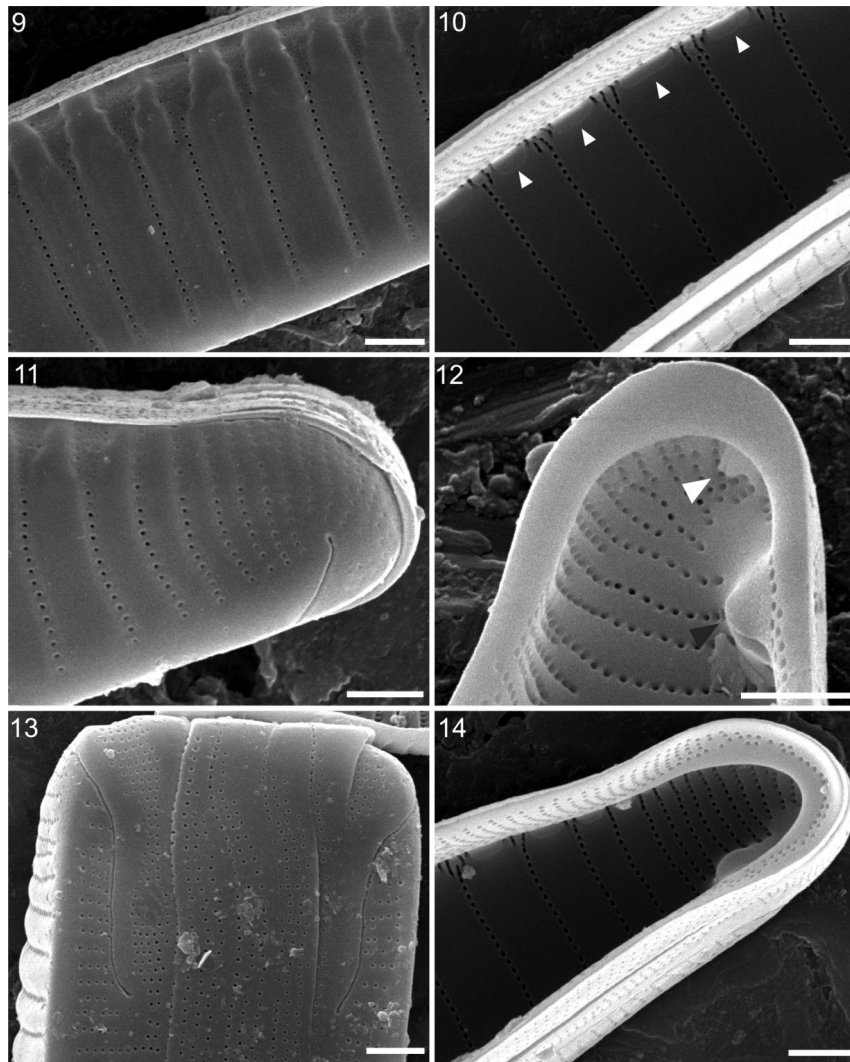
The species proposed by Metzeltin & Lange-Bertalot (1998) as *Eunotia odebrechtiana* can not be accurately distinguished of *E. biseriatoides* and, therefore, is a younger synonym from the latter. As stated by these authors, the figures 2 and 3 in plate 31 from Simonsen (1987), misidentified as isolectotype of *E. monodon* var. *constricta*, also correspond to *E. biseriatoides*.

*Eunotia odebrechtiana* var. *essequiboensis* was also proposed by Metzeltin & Lange-Bertalot (1998) based on valves with structure similar to the typical variety, but with narrower valves (6.5-8.5  $\mu\text{m}$ ) resulting in the length/width ratio of 7.8-10.2 (Table 2). Because of the typical variety is here synonymized with *E. biseriatoides*, a new combination of this variety is needed:

***Eunotia biseriatoides* var. *essequiboensis*** (Metzeltin et Lange-Bertalot) Cavalcante, Tremarin et T. Ludwig comb. nov.

**Basionym:** *Eunotia odebrechtiana* var. *essequiboensis* Metzeltin et Lange-Bertalot, 1998, Icon. Diat. 5, p. 72, pl. 57, figs. 1, 2.

The striation pattern present in *Eunotia biseriatoides* and *E. biseriatoides* var. *essequiboensis* is very similar to that found in *Perinotia* Metzeltin et Lange-Bertalot. The genus *Perinotia* was



**Figures 9-14.** *Eunotia biseriatooides* var. *biseriatooides* in SEM. **Fig. 9.** Detail of valve center, external view. **Fig. 10.** Internal view of valve center, showing valvocopula projections (arrowheads). **Fig. 11.** External view of valve end. **Fig. 12.** Internal view of valve end, showing helictoglossa (black arrowhead) and small rimoportula (white arrowhead). **Fig. 13.** Detail of ends in ventral view of an entire frustule, showing girdle bands and raphe fissure. **Fig. 14.** Internal view of valve end, with valvocopula and septum. Scale bars: 2  $\mu$ m.

described to accommodate eunotioid taxa that shows: uniseriate striae becoming multiseriate towards the dorsal side of valve, in which smaller poroids lie in deltoid depressions; internally, presence of thickened costae between each two striae; valvocopula projections on the internal dorsal valve surface. Rimoportula has not been observed in this genus. Currently, there are only two *Perinotia* species recognized (Metzeltin & Lange-Bertalot 2007, Ferrari et al. 2009).

Considering the set of diagnostic features above mentioned for *Perinotia*, *Eunotia biseriatooides* deserves to be highlighted as a species that shares features of both genera: this species possess rimoportula, like in *Eunotia*, and possess striae pattern and valvocopula projections like in *Perinotia*. However, there is no internal costa between dorsal striae.

Rimoportula is frequent in all the Eunotiaceae genera, except in *Semiorbis* Patrick. It has never been observed in *Perinotia* yet. But, this genus has a well-developed septum and a thick mantle edge, which can easily hide a small sessile labiate process. In all SEM pictures of *Perinotia* taxa recorded so far (Metzeltin & Lange-Bertalot 2007, Ferrari et al. 2009), none of them accurately

allow us to assert the lack of rimoportula. Therefore, presence of rimoportula in *Perinotia* remains to be confirmed. Moreover, the typical striae pattern and valvocopula projections of *Perinotia* plus the absence of costae in *Eunotia biseriatooides*, still allow us to raise questions concerning the consistency of *Perinotia* as currently diagnosed. Unusual striae pattern and presence of costae are presented as weak diagnostic characters to distinguish generic level in other diatom groups (eg. Reichardt 2007, 2008, Tremarin et al. 2011).

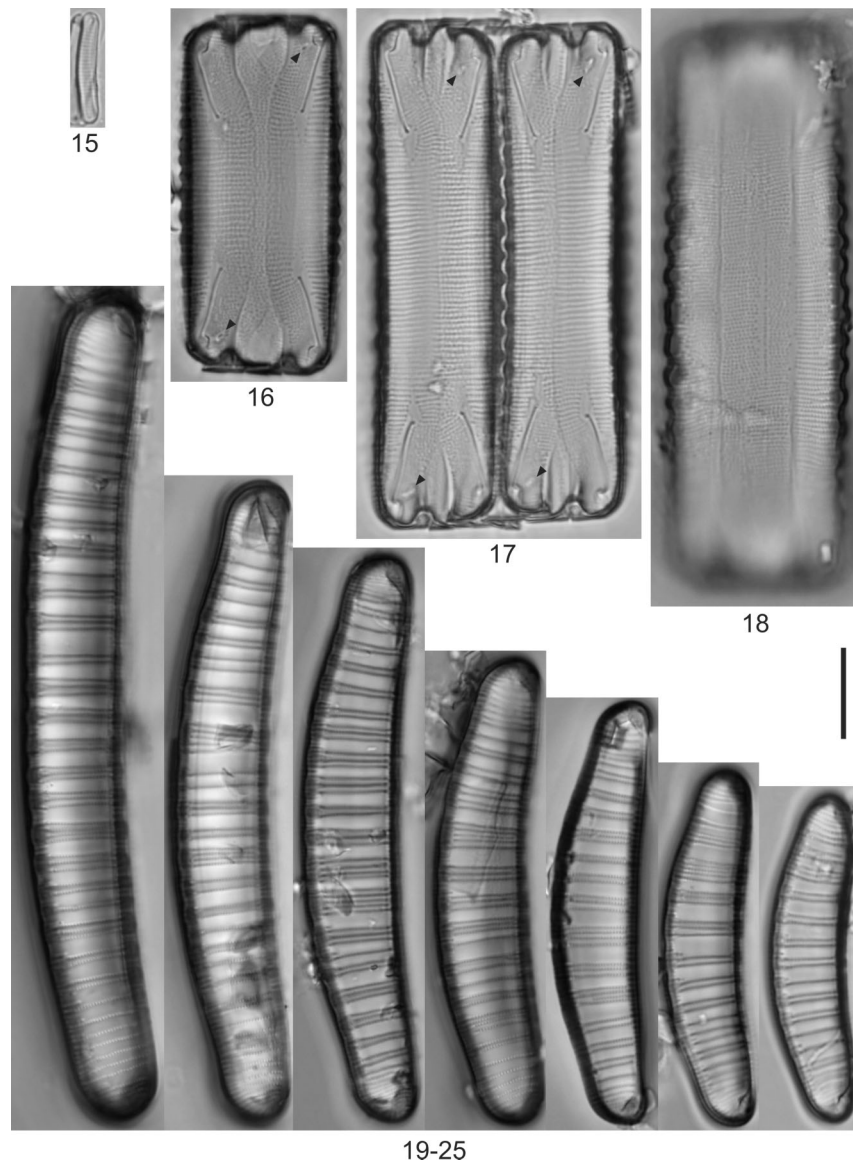
*Perinotia* taxa are poorly known, besides the frustule morphology. Plastids and chain formation, for example, have not been studied yet. Transferring *E. biseriatooides* to *Perinotia* is still premature, and requires more detailed analysis. Combined ultrastructural, molecular, and ecological investigations may provide a better elucidation about the circumscription of this taxon.

*Eunotia* cf. *botuliformis* Wild, Nörpel et Lange-Bertalot in Lange-Bertalot, 1993, Biblioth. Diat. 27, p. 29, pl. 33, figs. 2–15.

#### Fig. 15

Valve slightly dorsiventral, isopolar; dorsal margin convex, ventral margin slightly concave; ends rounded, not detached

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**Figures 15-25.** *Eunotia* spp. in LM. **Fig. 15.** *E. cf. botuliformis* in valve view. **Figs. 16-25.** *E. epithemioides*. **Fig. 16, 17.** Ventral view. **Fig. 18.** Dorsal view. **Figs 19-25.** Valve view. Scale bar: 10 µm.

from the valve; striae parallel, equidistant; areolae not discernible in LM; terminal nodules near to poles; rimoportula not observed. Length 12.1 µm, width 2.2 µm, 26 striae in 10 µm.

**Occurrence in the samples:** UPCB 76024

**Comments:** the single specimen observed in this study shows lower width and striae density than that found in the literature (width 2.7-3.8 µm, 15-22 striae in 10 µm) (Lange-Bertalot 1993; Lange-Bertalot et al. 2011). Due to the morphometric discrepancies and the rarity of this taxon in the samples, its identity cannot be accurately determined. Further studies of this population may provide clues about the precise identity of this taxon.

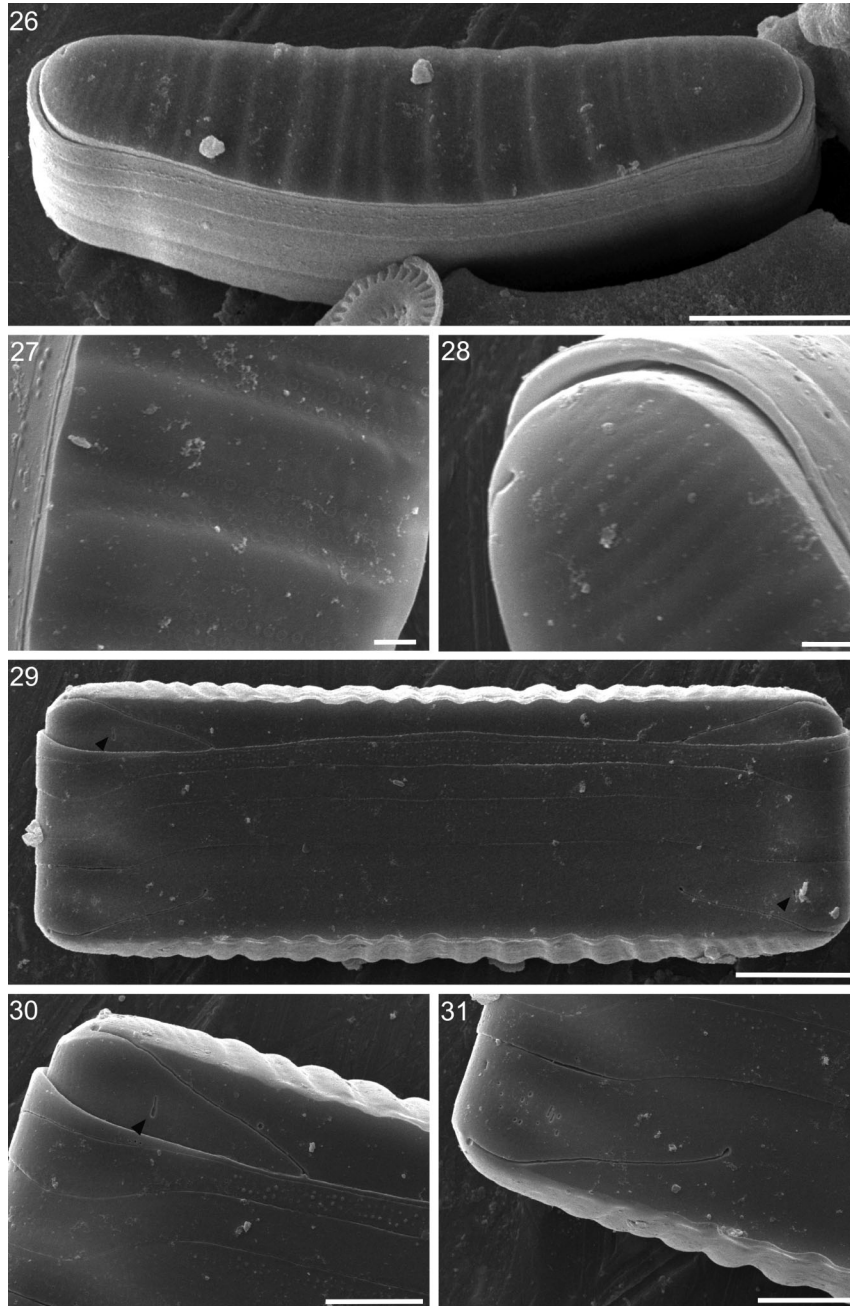
*Eunotia epithemioides* Hustedt in Schmidt 1913, Atlas Diat., pl. 287, figs. 16-19.

**Figs. 16-35**

Rectangular frustules in lateral view, with longest sides strongly undulate, caused by interfascicular thickening in the valve surface; dorsiventral valves, isopolar; dorsal margin convex, ventral margin concave; ends rounded, detached from the valve; parallel to radiate striae, arranged in irregular

fascicles with one to five striae; intercalated by short striae at dorsal margin; delicate round areolae; terminal nodules thickened near to poles; rimoportulae located at ventral mantle, one per valve, diagonally opposed in the frustule, such that can only be observed in lateral ventral view (Figs. 2, 3). Length 35.9-89.4 µm, width 7.5-10.0 µm, 9-14 striae (valve face) in 10 µm, 16-19 striae (ventral mantle) in 10 µm, 26-30 areolae in 10 µm.

In SEM, external areolae occlusions are difficult to observe (Figs. 26, 27). External distal endings of raphe are simple, not reaching the valve center (Fig. 28). Externally, the raphe extends in oblique fissure at the ventral mantle, with proximal ends dilated in pore (Fig. 31). Externally, the rimoportula aperture is slit-like, perpendicular to the apical axis of the frustule (Figs. 29, 30), and internally sessile (Figs. 34, 35). Areolae are simple poroids, striae were interrupted in ventral margin, at junction between valve surface and mantle, but not at dorsal margin (Figs. 32, 33). Mantle striae are equidistant and denser (Fig. 33) than those of valve surface. Short striae in valve surface are composed by slight projection of some mantle striae at dorsal



**Figures 26-31.** *Eunotia epithemioides* in SEM. **Fig. 26.** External valve overview. **Fig. 27.** Detail of valve center, external view. **Fig. 28.** External view of valve end. **Figs 29-31.** Frustule in ventral view, showing the slit-like external opening of the rimoportulae (arrowheads). Scale bars: 10  $\mu\text{m}$  (26, 29), 5  $\mu\text{m}$  (30, 31), 2  $\mu\text{m}$  (27, 28).

margin (Fig. 33). Pseudosepta present in the valve apices (Figs 34, 35).

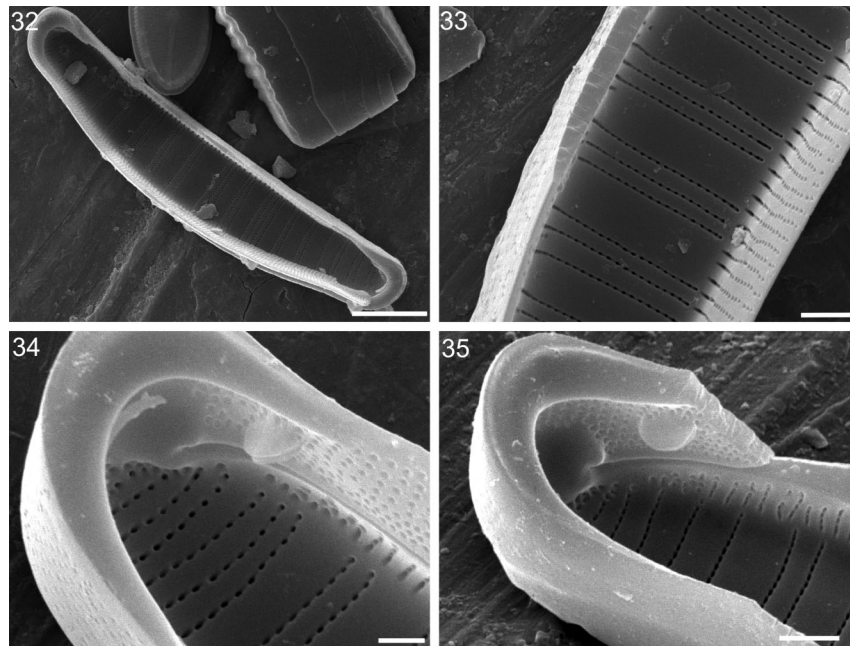
**Occurrence in the samples:** UPCB 76022

**Comments:** the analyzed population is compatible with morphometric data from the iconotypes showed by Schmidt (1913, pl. 287, length 55.5-77.8  $\mu\text{m}$ , width 9.4-11.7  $\mu\text{m}$ , 13-19 striae in 10  $\mu\text{m}$ , 27 areolae in 10  $\mu\text{m}$ ) and with the lectotype found in Simonsen (1987, pl. 34, length 54-72  $\mu\text{m}$ , width 11-12  $\mu\text{m}$ , 15-16 striae in 10  $\mu\text{m}$ , 24 areolae in 10  $\mu\text{m}$ ). However, we are expanding the ranges of valve width and striae density. We found smaller individuals than those selected as type material (we could compare only to specimens illustrated as type and we do not know, however, the morphological range of the type population).

Additionally, our specimens show fascicles with 1-5 striae, while the type material had 2-8 striae in each fascicle. This variation obviously results in lower striae density. This difference in striae density may be probably a factor affected by environmental conditions, further than a species-specific feature.

This species has not been previously documented in SEM, so morphological features as raphe and rimoportulae position were hitherto unknown. Rimoportula located in ventral mantle is not typical in *Eunotia* spp. Generally they have a single and sessile rimoportula, one per valve and lying in the valve apex (Round et al. 1990).

*Eunotia epithemioides* was originally described from a brackish lagoon of Republic of Cameroon, East Africa. The



**Figures 32-35.** *Eunotia epithemioides* in SEM. **Fig. 32.** Internal valve overview. **Fig. 33.** Detail of valve center in internal view. **Figs 34, 35.** Internal view of ends showing helictoglossa and rimoportula located in ventral margin. Scale bars: 10  $\mu\text{m}$  (32), 2  $\mu\text{m}$  (33, 35), 1  $\mu\text{m}$  (34).

species has few world records from tropical Asia and Africa (Hustedt 1949). In Brazil, it has been found only in southern region, in the state of Paraná by Lozovei & Shirata (1990), Ludwig & Flôres (1995) and Bartozek et al. (2013).

*Eunotia groenlandica* (Grunow) Nörpel-Schempp et Lange-Bertalot in Lange-Bertalot & Metzeltin 1996, Icon. Diat. 2, p. 51, pl. 17, figs. 25–27.

#### Fig. 36

Dorsiventral, isopolar valve; dorsal margin slightly convex; ventral margin slightly concave; subcapitate ends, dorsally flexed, detached from the valve; striae parallel, equidistant; areolae inconspicuous on LM; terminal nodules distinct, near to poles; rimoportula not observed. Length 22.1  $\mu\text{m}$ , width 2.2  $\mu\text{m}$ , 19 striae in 10  $\mu\text{m}$ .

**Occurrence in the samples:** UPCB 76021

**Comments:** the analyzed specimen is consistent with individuals from lectotype slide showed by Lange-Bertalot et al. (2011) except for the narrower valvae and greater density of striae (pl. 137, figs. 1-3: 2.7-4  $\mu\text{m}$  wide, 12-16 striae in 10  $\mu\text{m}$ ). However the

synonymized *E. fallax* var. *gracilima* Krasske shows similar width (2.0  $\mu\text{m}$ ) (Lange-Bertalot et al 1996).

*Eunotia meridiana* Metzeltin et Lange-Bertalot, 1998, Icon. Diat. 5, p. 67, pl. 59, figs. 7–10.

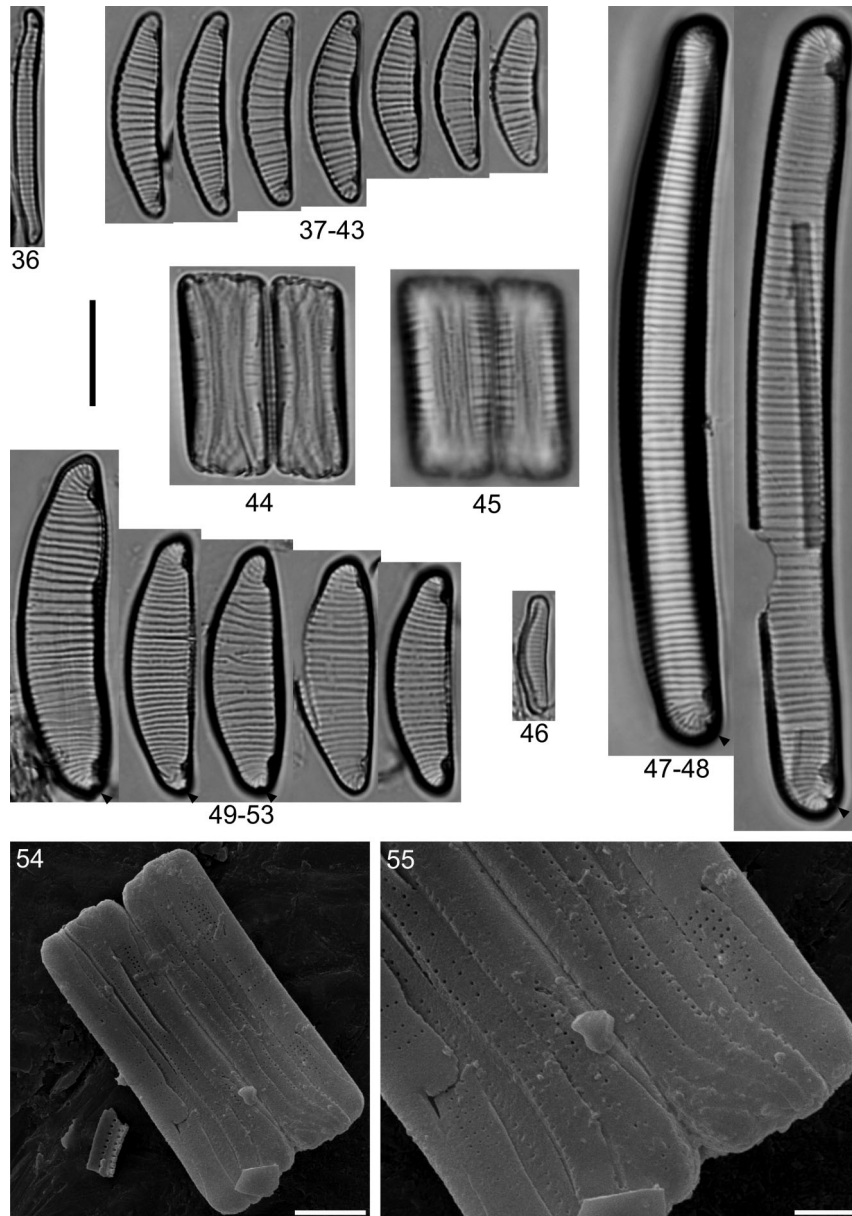
#### Figs. 37-45, 54, 55

Rectangular frustules in lateral view, joined in linear chains by overlapping of valve surfaces from adjacent cells; valve surface flat to slightly concave; dorsiventral, isopolar valves; dorsal margin convex, ventral margin straight to slightly concave in the middle; ends rounded to attenuated-rounded, not detached from the valve; radiate striae, not equidistant, with more spaced median striae; mantle striae more clearly spaced and separated from the others in lateral view (Figs. 44, 45); areolae inconspicuous on LM; terminal nodules distinct, rimoportula not observed. Length 14.4-19.3  $\mu\text{m}$ , width 4.1-4.6  $\mu\text{m}$ , 12-16 striae in 10  $\mu\text{m}$ .

In SEM, delicate areolae, punctuated. About three girdle bands per valve, ornated by one or two irregular rows of poroids. Proximal raphe endings as a simple pore.

**Table 2.** Main morphometric and distributional features of *Eunotia biseriatoides*, its synonyms, varieties and allied taxa. \*Protologue. \*\*Measured from the type illustration.

Taxon	Reference	Length ( $\mu\text{m}$ )	Width ( $\mu\text{m}$ )	Striae in 10 $\mu\text{m}$	Length/width ratio	Distribution
<i>E. biseriatoides</i>	Present study	44.3-69.7	7.6-10.7	5-7	5.1-6.9	Santa Catarina, S Brazil
	Kobayasi et al. (1981)*	37.5-57	6.5-9	4-9	7.5	Various regions of Japan
<i>E. odebrechtiana</i> var. <i>odebrechtiana</i>	Metzeltin & Lange-Bertalot (1998)*	30-85	8.5-13	4-7.5	3.2-6.5	Santos, SE Brazil.
<i>E. odebrechtiana</i> var. <i>essequiboensis</i>	Metzeltin & Lange-Bertalot (1998)*	68-73	6.5-8.5	6-7 **	7.8-10.2	Guyana
<i>Eunotia monodon</i> var. <i>constricta</i> sensu Simonsen (1987)	Simonsen (1987), pl. 31 figs 2,3	66.5	11	6	6.0	Guyana
<i>E. biseriata</i>	Hustedt (1952)*	38	11	6-10	3.4	Amazon, N Brazil



**Figures 36-55.** *Eunotia* spp. **Fig. 36.** *E. groenlandica*, LM. **Figs 37-43.** *E. meridiana*, LM. **Figs 37-43.** Valve view. **Fig. 44.** Ventral view. **Fig. 45.** Dorsal view. **Fig. 46.** *E. paludosa*, LM. **Figs 47, 48.** *E. parallela*, LM. Arrowheads indicate rimoportulae position. **Figs. 49-53.** *E. pirla*, LM. Arrowheads indicate rimoportulae position. **Figs 54, 55.** *E. meridiana* in SEM, ventral view. Scale bars: 10  $\mu\text{m}$  (36-53), 5  $\mu\text{m}$  (54), 2  $\mu\text{m}$  (55).

#### Occurrence in the samples: UPCB 76024

**Comments:** morphometric data agree with those recorded from original population (Metzeltin & Lange-Bertalot 1998) and another brazilian record (Tremarin et al. 2008). It is similar to *E. incisa* Gregory, which is usually narrower and has lower striae density and more elongated ends (Metzeltin & Lange-Bertalot 1998). Also differs from *E. pirla* Carter et Flower that shows more convex ventral margin, ends detached from the valve and denser striae (Carter & Flower 1988, Tremarin et al. 2008). Whole frustules have never been illustrated in lateral view and the striae morphology in the ventral mantle seems to be a regular criterium for identifying *E. meridiana* in this view. This is the first SEM documentation of the species.

*Eunotia paludosa* Grunow, 1862, Ver. Kais.-Königl. Zool.-Bot. Ges. Wien 12, p. 336, pl. 6, fig. 10.

#### Fig. 46

Dorsiventral, isopolar valves; dorsal margin convex, ventral margin almost straight; ends rounded, slightly detached from the valve; parallel striae, equidistant; areolae, terminal nodules and rimoportula inconspicuous in LM. Length 11.2  $\mu\text{m}$ , width 2.7  $\mu\text{m}$ , 22 striae in 10  $\mu\text{m}$ .

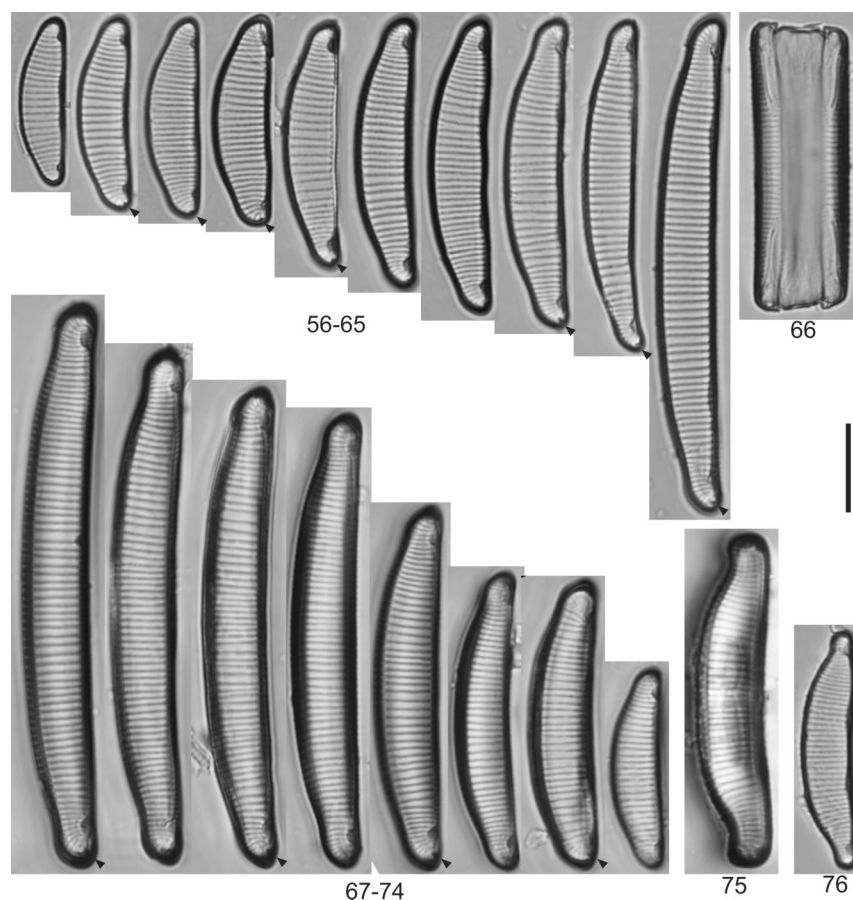
#### Occurrence in the samples: UPCB 76024

**Comments:** Krammer & Lange-Bertalot (1991) show a highly variable population for *E. paludosa*; but certainly, the specimens designated there should be reviewed. Our exemplar is especially similar to fig. 4 in plate 155 from those authors and is also in accordance to the description provided by Lange-Bertalot et al. (2011), based on lectotypified specimens of Grunow's protologue, and to the population illustrated in plate 147, figs. 24-29.

*Eunotia parallela* Ehrenberg, 1843, Abh. Kön. Akad. Wiss. Berlin, p. 414.



## Eunotia on Podostemum



**Figures. 56-76.** *Eunotia* spp. in LM. **Figs 56-66.** *E. pseudosudetetica* var. *pseudosudetetica*. **Figs 56-65.** Valve view. Arrowheads indicate rimoportula position. **Fig. 66.** Ventral view. **Figs. 67-74.** *E. pseudosudetetica* var. *rotundata* var. nov., valve view. Arrowheads indicate rimoportula position. **Fig. 75.** *E. tropico-arcus*. **Fig. 76.** *E. veneris*. Scale bar: 10  $\mu$ m.

**Figs. 47-48**

Dorsiventral, isopolar valves; dorsal margin convex, ventral margin slightly concave, margins parallel in the most of valve length; ends broadly rounded, not detached from the valve; striae parallel in the middle, becoming radiate towards the ends, not equidistant; short striae in the ends accompanying the apex curvature; areolae inconspicuous in LM; thick terminal nodules; terminal raphe fissures simple, almost reaching the apex center (Fig. 33); rimoportula visible in LM, one per valve, located between pole and ventral margin. Length 68.9-75.3  $\mu$ m, width 7.7-8.2  $\mu$ m, 11-15 striae in 10  $\mu$ m.

**Occurrence in the samples:** UPCB 76024

**Comments:** Lange-Bertalot et al. (2011) remarked the difficulty of leptotypifying *E. parallela* from Ehrenberg's (1843) syntypes. Mayama in Lange-Bertalot et al. (2011), proposed a lectotype, based on analysis of one only valve, notably observed by Ehrenberg, but without illustrations. Our specimen agrees with his morphological description (Lange-Bertalot et al., 2011), except by the lectotype is longer (ca. 130  $\mu$ m), wider (ca. 16  $\mu$ m) and has less striae density (7-8.5 in 10  $\mu$ m). Nevertheless, the "sausage-like" shape, with rounded, not protracted ends, are typical features of the species. Moreover, our data agree with *E. parallela* populations described in Patrick & Reimer (1966) and Furey et al. (2011), based in many specimens. *E. faba* Ehrenberg is a similar taxon but differs by the typical bean-like outline and shorter length (16-65  $\mu$ m) (Furey et al. 2011, Lange-Bertalot et al. 2011).

*Eunotia paralleladubia* Lange-Bertalot et Mayama also differs by being wider (8-11  $\mu$ m) and having terminal nodules closer to ends (Lange-Bertalot et al. 2011).

*Eunotia pirla* Carter et Flower, 1988, Diat. Res. 3, p. 2, figs 5-48, 51-56.

**Figs. 49-53**

Dorsiventral, isopolar valves; dorsal margin convex, ventral margin straight with irregular margin thickening (slightly triundulate); ends attenuate-rounded, detached from the valve; striae parallel in the middle, becoming radiate toward the ends, not equidistant; short striae near to dorsal margin; areolae punctuated, hardly observed in LM; terminal nodules distinct; one rimoportula per valve, located on valve extremity (Figs. 35-37). Length 20.8-32.1  $\mu$ m, width 6.0-8.3  $\mu$ m, 13-17 striae in 10  $\mu$ m.

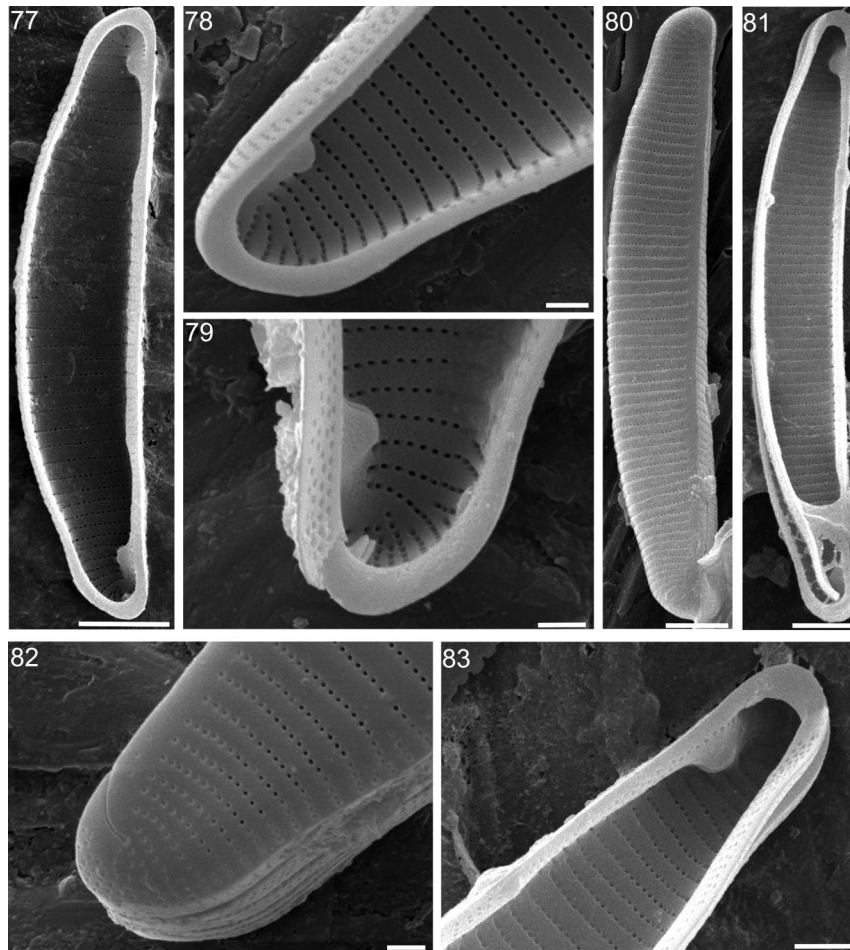
**Occurrence in the samples:** UPCB 76024

**Comments:** the type population showed by Carter & Flower (1988) and Lange-Bertalot et al. (2011) is similar to our material. Carter & Flower (1988) presented individuals with ventral margin sharply triundulate (central region of ventral margin is convex) and discussed that this feature is highly variable into this species.

*Eunotia pseudosudetetica* Metzeltin, Lange-Bertalot et García-Rodríguez var. *pseudosudetetica*, 2005, Icon. Diat. 15, p. 57, pl. 24, figs. 15-18.

**Figs. 56-66, 77-79**

Rectangular frustules in lateral view, valve surface straight; dorsiventral, isopolar valves; dorsal margin convex, ventral



**Figures 77-79.** *Eumotia pseudosudetica* var. *pseudosudetica* in SEM. **Fig. 77.** Internal valve overview. **Figs 78, 79.** Detail of valve ends in internal view, showing helictoglossa and rimoportula. **Figs 80-83.** *E. pseudosudetica* var. *rotundata* var. nov. in SEM. **Figs 80, 81.** External and internal valve overview, respectively. **Fig. 82.** Detail of valve end in external view. **Fig. 83.** Detail of valve end in internal view. Scale bars: 5  $\mu\text{m}$  (77, 80, 81), 2  $\mu\text{m}$  (83), 1  $\mu\text{m}$  (78, 79, 82).

margin straight, thickened in the median region, in the proximal raphe endings located in the mantle; ends nose-like, ventrally flexed, detached from the valve; striae parallel in the middle, radiate in the ends, not equidistant; punctuate, delicate areolae, hardly resolved in LM; terminal nodules distinct; one rimoportula per valve, close to the valve extremity (Figs. 43-51). Length 18.7-55.8  $\mu\text{m}$ , width 5.5-7.8  $\mu\text{m}$ , 11-15 striae in 10  $\mu\text{m}$ .

In SEM, areolae in round poroids, 36-38 in 10  $\mu\text{m}$ ; ventral margin thickened in the median portion (Fig. 77); helictoglossae are developed; rimoportula is small and sessile, located in the valve surface-mantle junction, and can be hidden by the thick valve wall (Fig. 77-79).

**Occurrence in the samples:** UPCB 76024

***Eumotia pseudosudetica* var. *rotundata*** Cavalcante, Tremarin et T. Ludwig var. nov.

**Figs. 67-74, 80-83**

**Diagnosis:** It differs from typical variety by the more rounded ends, less marked dorsiventrality of the valve and ventral margin without thickening.

**Description:** dorsiventral, isopolar valves; dorsal margin convex to slightly convex, ventral margin straight to slightly concave; rounded ends, detached from the valve; striae parallel, radiate in the ends, not equidistant; areolae punctuate, discernible in LM in some individuals; terminal nodules distinct; one small rimoportula per valve, near to poles.

Length 22.6-63.7  $\mu\text{m}$ , width 5.2-6.8  $\mu\text{m}$ , 11-14 striae in 10  $\mu\text{m}$ , 34-41 areolae in 10  $\mu\text{m}$ .

In SEM, areolae externally open in round poroids, 36-38 in 10  $\mu\text{m}$  (Fig. 80); terminal raphe fissures are simple, almost in the center of valve end (Fig. 82); helictoglossae are developed, septum ornated by small poroids (Fig. 83); rimoportula not observed.

**Holotype:** BRAZIL, Santa Catarina: Herval D'oeste, Irani River. UPCB 76024. Periphyton attached to *Podostemum muelleri*. 09.III.2010. A.S. Melo & A. Nuernberg. Holotype represented by fig. 67.

**Comments:** this taxon is usually recorded as *Eumotia pectinalis* (Kützing) Rabenhorst in Brazilian researches (eg. Moro et al. 1994, Raupp et al. 2006, Talgatti et al. 2007) or *E. sudetica* O. Müller (eg. Ludwig & Flôres 1995). *E. pectinalis* has undulate dorsal margins and narrower ends (Tuji & Williams 2005). Regarding *E. sudetica*, this is a taxon often illustrated with high morphological variability (eg. Krammer & Lange-Bertalot 1991, Levkov et al. 2007, Lange-Bertalot et al. 2011). As the type material of this species is unknown, it is difficult to define the original forms of *E. sudetica stricto sensu*. In contrast, *E. pseudosudetica* is a well-defined taxon (Metzeltin et al. 2005), and the population analyzed here is more similar to this taxon than to the former. Valve contour and apices are sufficient to propose this taxon as a new variety.

Our population was very similar to those determined as *E. sudetica* by Frenguelli (1933, pl. 8, figs. 8, 9), from northern

Argentina, as “*Eunotia* (?nov.) spec.” by Metzeltin & Lange Bertalot (1998, pl. 58, figs. 5, 8) from northern Brazil and as “*Eunotia* sp. 1” by Bertolli et al. (2010), from southern Brazil. All of them probably correspond to *Eunotia pseudosudetica* var. *rotundata*. *Eunotia* aff. *donato* recorded in Santos et al. (2011) is similar to this taxon, but differs by lower striae density (9–10 in 10 µm) and narrower ends.

***Eunotia tropico-arcus*** Metzeltin et Lange-Bertalot, 2007, Icon. Diat. 18, p. 123, pl. 74, figs. 1–10.

**Fig. 75**

Dorsiventral, isopolar valve; dorsal margin convex with median region almost straight; ventral margin slightly concave, especially in central region; truncate ends, dorsally flexed, detached from the valve; parallel striae, becoming radiate towards the ends, equidistant; areolae inconspicuous in LM; terminal nodules delicate, near to ends; rimoportula not observed. Length 37.4 µm, width 8.1 µm, 15 striae in 10 µm.

**Occurrence in the samples:** UPCB 76020

**Comments:** the single specimen found conforms to the protologue’s description (Metzeltin & Lange-Bertalot 2007), except for striae density (11–12 in 10 µm). However, a venezuelan taxon identified as *E. praeupta* Ehrenberg (Lange-Bertalot 1993, pl 33, fig. 5), but reinterpreted by Metzeltin & Lange-Bertalot (2007) as *E. tropico-arcus*, possesses very similar measurements to our exemplar (length 40 µm, width 9 µm, 15 striae in 10µm). Hence, we believe that the striae density may reach 15 striae in 10 µm. It differs from *E. praeupta* by the latter is wider (10–18 µm, Lange-Bertalot et al. 2011) and shows strongly convex dorsal margin. Also differs from *E. bidens* Ehrenberg especially by dorsal margin strongly biundulate and more truncate ends of the latter. Finally, *Eunotia tropico-arcus* differs from *E. arcus* Ehrenberg because the latter shows less arcuate valves, ventral margins less concave and ends narrower than central region (Metzeltin & Lange Bertalot 2007).

***Eunotia veneris*** (Kützing) De Toni, 1892, Syll. Alg. Omn. Hucusque Cogn. 2(2), p. 794.

**Fig. 76**

Dorsiventral, isopolar valve; dorsal margin convex, ventral margin almost straight, with slight central tumescence; subcapitate ends, detached from the valve; striae parallel in the middle, radiate towards the ends, equidistant; areolae inconspicuous; terminal nodules distinct; rimoportula inconspicuous. Length 26.5 µm, width 5.6 µm, 17 striae in 10 µm.

**Occurrence in the samples:** UPCB 76024

**Comments:** identification of this taxon was based on Kützing’s type material of *Eunotia veneris* illustrated in Lange-Bertalot et al. (2011). *E. veneris* had ever been cited in state of Santa Catarina, in Conceição lagoon (Souza-Mosimann 1980) and Tubarão river (Rodrigues 1984), but without illustrations.

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