Seminavis recta comb. nov. et stat. nov.: morphology and distribution in salt marshes from southern Brazil

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Abstract: *Cymbella (Encyonema) grossestriata* var. *recta* was studied based on analysis of the type material from Argentina and newly collected material from southern Brazil. In light microscopy the taxon presents dorsiventral valves, asymmetric and expanded central area, striae slightly radiate at the ends, becoming strongly radiate, and sigmoid in the center of valve. In scanning electron microscopy it is possible to observe features that are similar to the *Navicula* genus, such as slit–like areolae, accessory rib in the primary side, which is wider (expanded) at the center and valves with a marked virgae. Beyond these features the presence of two chloroplasts per cell definitively excludes the taxon from the Cymbellales group and allows us to transfer it to the genus *Seminavis*. *Seminavis recta* comb. et stat. nov. was found associated to *Spartina* and *Scirpus* species and living in the sediment of salt marshes in oligo to mesohaline zones, in a wide range of temperature and pH. This species is rare, and has been reported only to South America until now.

Key words: brackish water, *Cymbella* (*Encyonema*) *grossestriata* var. *recta,* diatom, epiphyton, *Navicula norae*, sediment

Introduction

Seminavis, described by Mann in Round et al. (1990) has valves semi–lanceolate and strongly dorsiventral. This genus is different from *Amphora* Ehrenberg ex Kützing *sensu lato* by containing two elongated plastids of unequal size and uniseriate striae, which have apically elongate areolae (slit–like). *Cymbella* C. Agardh *sensu lato* and *Encyonema* Kützing *sensu lato* present the same valvar shape. However, *Seminavis* has neither stigmata nor pore fields and it has both proximal and distal raphe ends dorsally deflected.

The morphology of the plastids, the internal raphe sternum with lateral fissure, the presence of accessory rib, and slit–like areolae are the main features that approach *Seminavis* to *Navicula* Bory *sensu stricto*, both genera are separated by dorsiventral lateral symmetry (Cox & Reid 2004).

After the initial description of *Seminavis,* eighteen species were combined and discovered in this genus occurring in marine and brackish waters (Round et al. 1990; Danielidis & Mann 2002, 2003; Cox & Reid 2004; Danielidis et al. 2006; Garcia 2007; Wachnicka & Gaiser 2007; Witkowski et al. 2000). Up to now, the species recorded from Brazil are *S. atlantica* Garcia by Garcia (2007) and Souza–Mosimann et al. (2011), *S. robusta* Danielidis et Mann (as *Amphora angusta* Gregory and *Amphora angusta* var. *ventricosa* (Gregory) Cleve) by Moreira–Filho (1959), Moreira–Filho & Kutner (1962) and Fernandes et al. (1990), and *S. strigosa* (Hustedt) Danielidis et Economou–Amilli by Silva et al. (2010).

The low number of *Seminavis* species found in Brazil is probably related to the few taxonomic studies performed on the coast and probably due to the little attention given to rare taxa. The review of similar genera like *Amphora* and *Cymbella* can increase the species number and contribute to delimitate the S*eminavis* genus (Danielidis & Mann 2003; Cox & Reid 2004).

Cymbella (Encyonema) grossestriata O. Müller var. *recta* Frenguelli was originally illustrated by Frenguelli (1938, plate I, fig 20) based on material from the Matanza river estuary (Argentina). Metzeltin et al. (2005) found this variety in Laguna Rocha (Uruguay) and proposed a new name to the taxon (*Navicula norae* Metzeltin, Lange–Bertalot et Garcia–Rodriguez), justi-fying that this variety could not be combined intra–specifically with *Cymbella grossestriata* O. Müller since it does not belong to the genera *Cymbella* C. Agardh or *Encyonema* Kützing. The epithet "*recta"* was not used because it

was already established as the species *Navicula recta* BRUN et HERIBALD. Afterwards the taxon was recorded as *Cymbella grossestriata* by SILVA et al. (2010) for southern Brazil. However, when specimens found in salt marshes from Brazil and the type material of *Cymbella (Encyonema) grossestriata* var. *recta* from Dr. J. Frenguelli Collection (LP, Museo de La Plata, Argentina) were analyzed in light and electron microscopy, we observed that both do not belong either to *Cymbella* (or *Encyonema*) or to *Navicula*, but rather to the *Seminavis* genus. Therefore, the transfer of this taxon to *Seminavis* is proposed.

MATERIALS AND METHODS

Samples were gathered from surficial sediment and from stems of herbaceous plants (see list in Table 1) in three sites located in the salt marshes of the Patos Lagoon estuary (31º57'S, 52º06'W) in southern Brazil (Fig. 1). The sampling was carried out in September 2010 (winter) and February 2011 (summer).

For the analysis of the epipelon the surficial sediment was collected with a core (10 cm of diameter; 2 cm of depth) and at the same time the pH, salinity and temperature were measured in the interstitial water using pH meter (PHTEK®), salinometer (YSI® 30) and thermometer (Incoterm®). In laboratory, live motile diatoms were isolated from sediment by the "Trapping method" adapted from Eaton & Moss (1966) and Laudares–Silva & Cimardi (1989).

Epiphyton was scraped from plant stems using a metal blade. The scraped sections corresponded to the 5 cm portions of the stem adjacent to the ground which were submerged at the moment of sampling. The material was fixed with formaldehyde (4%) after collection.

Epipelic and epiphytic samples were processed using nitric acid and mounted on slides using Naphrax®. For light microscopy (LM) analysis we used a Zeiss Axioplan LM with a Axiocam ERc 5s camera. For scanning electron microscopy (SEM) a Jeol JSM–5200 (20 mm working distance, 15 kV) and a Jeol JSM–6060 (10 mm working distance, 20 kV) were used. Permanent slides are held at the Diatom Collection of Herbarium HAS (accession numbers 6242–6264; 6497–6517), Museu de Ciências Naturais, Fundação Zoobotânica do Rio Grande do Sul, Porto Alegre, Brazil.

The investigated material included five slides and raw material from the type of *Cymbella* (*Encyonema*) *grossestriata* var. *recta* from the Herbarium of the División

Table 1. Distribution of the *Seminavis recta* on epipelon and epiphyton along the sites [(IP) Ilha da Pólvora, (SS) Saco do Silveira and (SJN) São José do Norte] in winter 2010 and summer 2011, and physical and chemical data of the interstitial water.

Samples	Epipelon	Epiphyton	Sanility	Temperature	pH	Plants
winter						
IP 1A	X	X	3.4	16.7	7.3	*Scirpus maritimus* L.
IP 1B	X	X	3	15.4	7.2	*Spartina densiflora* BRONGN.
IP 1C	X	X	1.5	15.9	6.8	*S. maritimus*
SS 2A	0	0	0.1	20.6	8.8	*Juncus kraussii* HOCHST.
SS 2B	0	0	0.3	21.2	7.8	*J. kraussii*
SS 2C	0	0	0.3	20.4	7.1	*S. densiflora*
SJN 3A	0	0	1.2	17	7.2	*Spartina alterniflora* LOISEL.
SJN 3G	0	0	1.9	19.1	7.7	*S. alterniflora*
SJN 3i	0	0	1.9	21.5	7.7	*S. densiflora*
summer						
IP 1A	X	X	14	28	8.6	*S. alterniflora*
IP 1C	X	X	8	29	6.6	*S. maritimus*
IP 1K	0	0	19.5	25	—	*S. alterniflora*
SS 2A	0	0	15	27	7.9	*J. kraussii*
SS 2D	0	0	16	25	7.5	*J. kraussii*
SS 2F	0	0	15	26	6.8	*S. densiflora*
SJN 3D	0	0	35	27	7.3	*S. alterniflora/ J. kraussii*
SJN 3G	0	0	30	27	—	*S. alterniflora*
SJN 3i	X	X	15	28	7.4	*S. alterniflora*

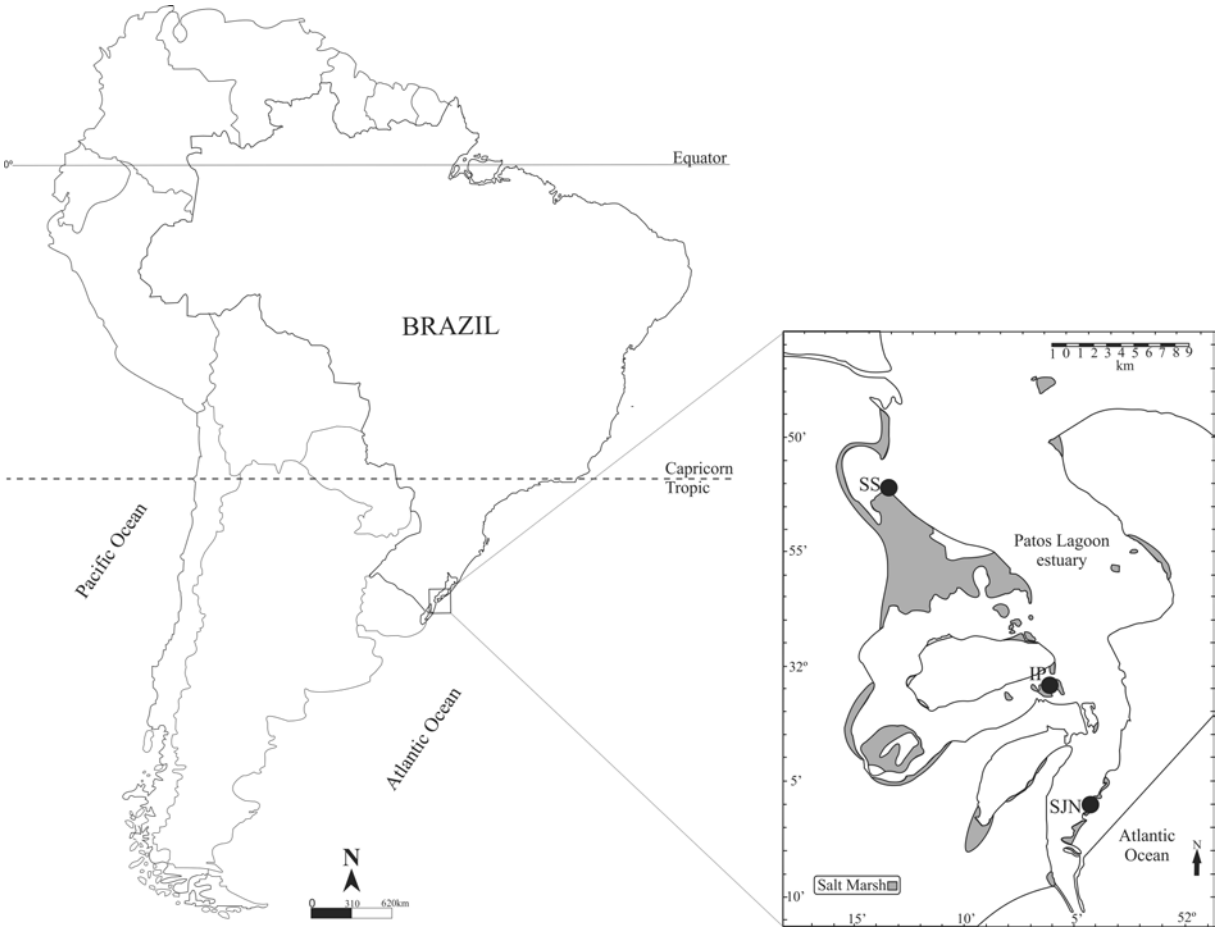


Fig. 1. Location of sampling sites [(SS) Saco do Silveira; (IP) Ilha da Pólvora and (SJN) São José do Norte] in salt marshes at Patos Lagoon estuary, southern Brazil. Modified from Costa (1998).

Ficología of the Faculdad de Ciencias Naturales y Museo (LP), collection Dr. J. Frenguelli (series 403). The slides were observed using a Leica DM 2500 with DIC (Differencial Interference Contrast) and camera Leica DFC 420 C located at the Faculdad de Ciencias Naturales y Museo de La Plata, Argentina. Small portion of raw sample were prepared and mounted on stubs to observe under SEM.

Morphological terminology follows Anonymous (1975), Barber & Haworth (1981), Round et al. *(*1990) and Danielidis & Mann (2002). All figures were assembled using Corel Designer X6®.

Results and Discussion

***Seminavis recta* (Frenguelli) Talgatti et Torgan comb. et stat. nov. (Figs 3–44)**

Basionym: *Cymbella* (*Encyonema*) *grossestriata* O. Müller var. *recta* Frenguelli 1938. *Revista del Museo de La Plata*, nueva serie 1, Paleontologia 5, p. 303, lam. I, fig. 20.

Synonym: *Navicula norae* Metzeltin, Lange–Bertalot & García–Rodríguez 2005. Diatoms of Uruguay, Iconographia Diatomologica, Volume 15, p.138, figs 43: 1–5.

Original description: "*Valvis asymmetrice lanceolatis, apicibus rectis, subcuneato–rotundatis; 90–93 µ longis, 20 µ latis: striis transversis transverse lineolatis, validis, radiantibus, in valvae medio 4–5, ad apices 7 in 10 µ, lineolis 16–17 in 10 µ. Ceterum ut in typo.*"

Type locality: Argentina, Matanza river estuary in Buenos Aires, 12 February 1928 (LP 403).

Morphology

Light microscopy: The valves are dorsiventral, semilanceolate with dorsal margin arched and ventral margin slightly convex. The ends are rounded to cuneate and slightly arched to straight towards the center of the valve (Figs 3–35). The cell contains two plastids, one lying along each side of the girdle, which in valvar view shows long strips next to the border of the dorsal and ventral side; the dorsal plastid is larger than the ventral (Fig. 8). The central area is expanded and asymmetric, from circular to elliptic (Figs 17, 20) or not expanded but widening on the dorsal side following the axial area and on the ventral side it is rounded (half circle) (Figs 15, 28, 35). The striae are slightly radiate at the ends, becoming strongly radiate, and sigmoid in the center of the valve (Figs 7b, 13, 16,

32, 35). In some specimens at the valve center there are one or two shortened striae that can be at the dorsal or ventral side (Figs 7b, 11, 16, 18). Length 61.8–110.94 µm, width 12.5–18.3 µm. Dorsal central striae 5–7 in 10 µm, ventral central striae 5–8 in 10 µm, at the ends 7–8 in 10 µm.

Electron microscopy: In external view, the raphe is filiform and straight until near the middle of the valve, where it is slightly deflected to the ventral side (Fig. 38). The proximal and distal raphe ends are dorsally deflected to secondary side, where the Voigt fault is. (Figs 36–40). The proximal raphe ends are slightly expanded and drop–like (Fig. 38). The distal raphe ends are strongly hooked onto the secondary side (Figs 40, 42). The axial area is narrow and slightly raised (Fig. 38, 39). The areolae are apically elongate, slit–like (22–24 in 10 µm) starting on the mantle margin and following until the axial area, except at in the center of dorsal and ventral side where shortened striae are usually found (Figs 39, 41, 44).

In internal view, the proximal raphe ends appear continuous. The distal raphe ends terminate in the helictoglossa (Fig. 43). The raphe canal is accompanied by an accessory rib in the primary side, which is wider (expanded) at the center and is not interrupted (Fig. 44). A simple pore is observed at the apices (Fig. 43). The valves have a marked virgae (Fig. 44). The areolae are elliptical, occluded and together with vimines are strongly lower than the virgae (Fig. 44).

Comparison with the type material

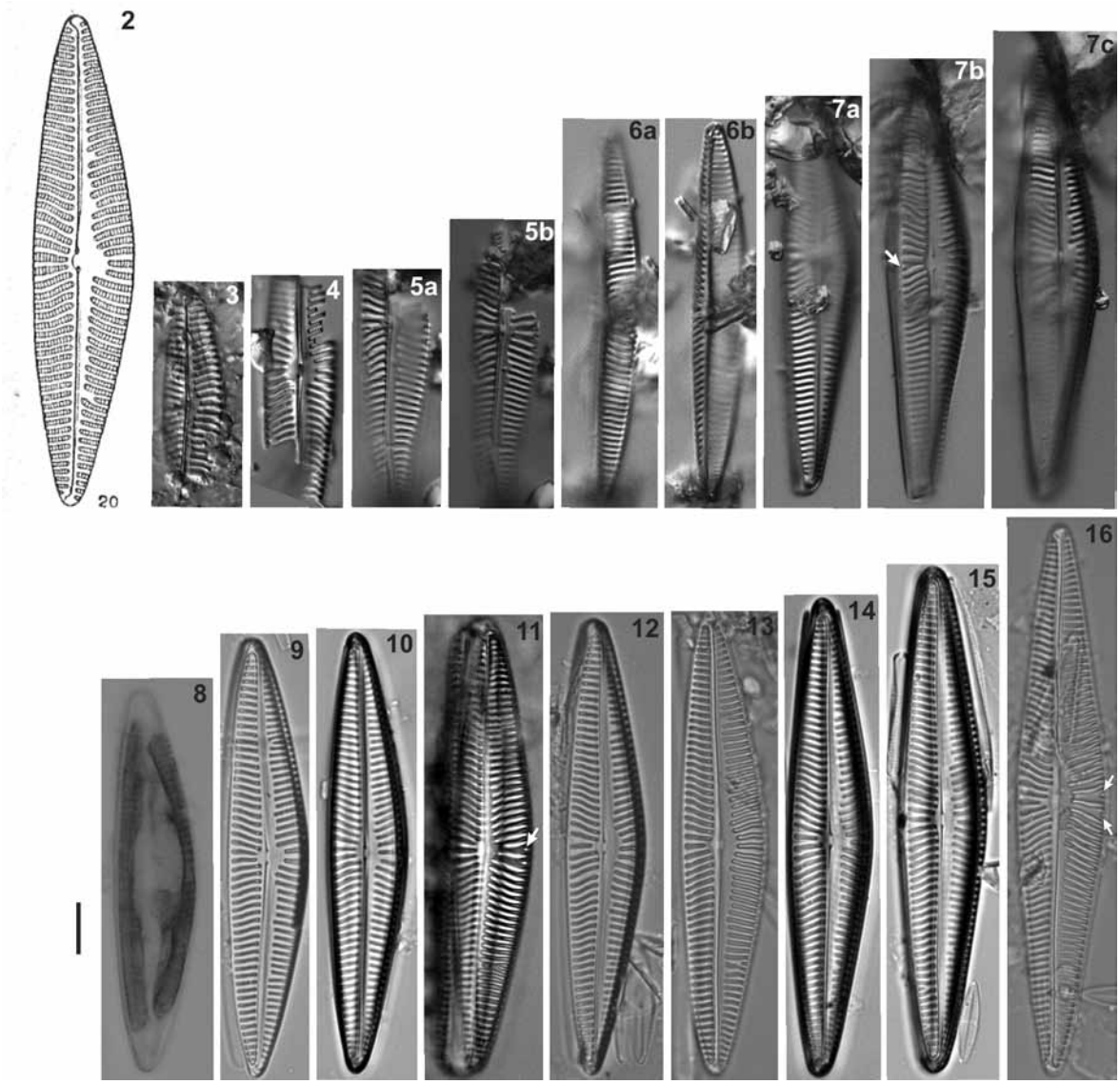
FRENGUELLI (1938) when described *C. grossestriata* var. *recta* compared this taxon with other varieties of the species and concluded that the differences between them were the apices and the ventral side shapes. *Cymbella grossestriata* var. *obtusiuscula* MÜLLER and *C. grossestriata* var. *javanica* HUSTEDT have oblique apices and ventral side with straight or gibbous edges, whereas *C. grossestriata* var. *recta* has apices gradually cuneate (never rostrate) and convex edge in ventral side (Figs 3–35).

The rare specimens found in the sample number 403 from Frenguelli Collection (Figs 3–7c) were broken, but it was possible to relate them to the authors's drawing (Fig. 2). We also found smaller specimens in this Collection (Table 2), with a higher number of the striae and lineolae than those recorded by FRENGUELLI (1938). Such specimens have similar dimensions and shape to those of Brazilian (Figs 8–35) and Uruguayan material (Table 2). However, some specimens from the Frenguelli Collection have shortened striae at the center of the valve, like the specimens from the Brazilian salt marsh, which can be viewed using light microscope (Figs 5b, 7b, 11, 16, 18). In the specimens showed by METZELTIN et al. (2005; plate 43, figs. 1–4) the presence of these shortened striae is not clear. The observation of these striae probably is related with the position of

Table 2. Morphometric features of *Seminavis recta* (new and type material) and comparison with similar taxa of *Cymbella* and *Seminavis*.

Features	***Cymbella grossestriata***	***Cymbella (Encyonema) grossestriata* var. *recta***		***Navicula norae***	***Cymbella pusilla***	***Seminavis atlantica***	***Seminavis recta***	***Seminavis robusta***	***Seminavis strigosa***
	MÜLLER (1905)	FRENGUELLI (1938)	Frenguelli Collection (n =5)	METZELTIN et al. (2005)	SCHIMIDT (1874–1959)	GARCIA (2007)	This study (n=35)	DANIELIDIS & MANN (2002)	DANIELIDIS & MANN (2003)
Length (µm)	58	90–93	69.09–96	86–107.5	30–36*	64.5–100	61.8–110.94	34–68	21–38
Breadth (µm)	22	20	13.6–16.2	17.5–20	6–7.5*	7–12	12.5–18.3	6.5–9.5	3.5–6.2
Dorsal striae (10 µm)	5	4–5	6	4–5	12–13*	11–14	5–7	17–20.7	17.5–24.5
Ventral striae (10 µm)	3–4	4–5	6–7	4–5	13–14*	11–14	5–8	16–19.3	16–23
Poles striae (10 µm)	8–9	7	8	6	14*	11–14	7–8	—	20–35*
Areolae (10 µm)	—	16–17	22–24	18	—	60–70*	18–24	20–24	~50–70*

* measured in the illustrations.



Figs 2–16. LM images of *Seminavis recta* comb. nov et stat. nov.; (2) iconotype of the *Cymbella grossestriata* var. *recta* by Frenguelli (1938, fig. 20) showing specimen in valvar view; (3–7c) images of specimens from the Frenguelli Collection (type, sample 403, LP); (7b) arrows indicate shortened striae in ventral side; (8–16) epipelic specimens from Brazilian salt marshes; (8) image showing cell containing two plastids; (11) arrows indicate shortened striae in dorsal side. Scale bar 10 μm.

the valve on the slide, nevertheless during the analysis of the individuals on SEM it was possible to visualize that these shortened striae are on the valve mantle (Fig. 41). Our efforts to observe unmounted material from the type collection of *C. grossestriata* var. *recta* in SEM was unsuccessful because the material was rare in the sample, as mentioned also by Frenguelli (1938).

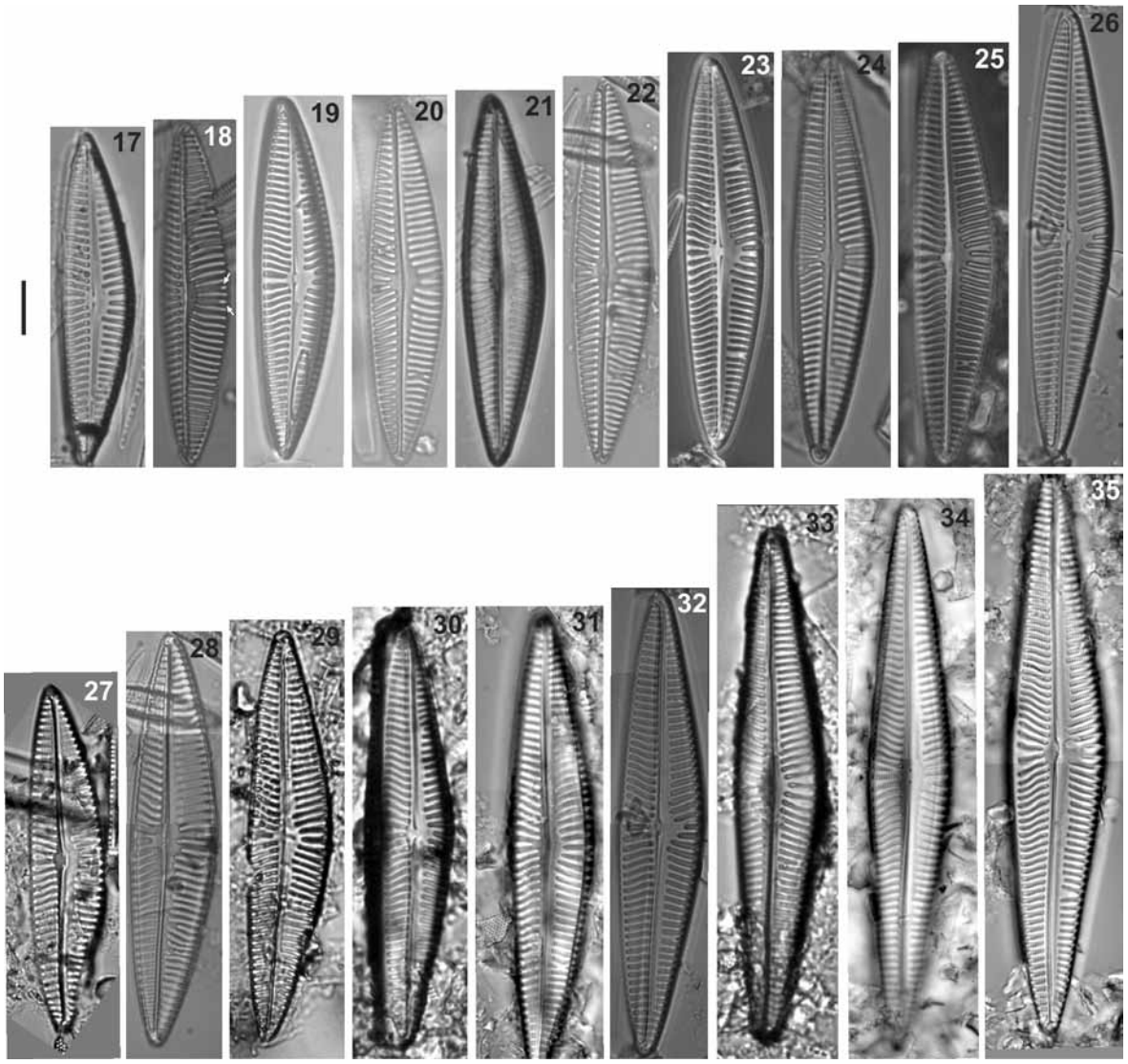
Comparison with similar taxa

Cymbella grossestriata Müller differs morphologically from *Seminavis recta* by shorter length, greater breadth, ventral side with gibbous edge, dorsal and ventral striae strongly divergent and poles narrowly rounded (Table 2).

Cymbella pusilla Grunow (in Schimidt 1874–1959) was illustrated in electronic microscopy by Cox (1979), and it was transferred to *Seminavis* by Cox & Reid (2004) based on a cladistic analysis. *Seminavis pusilla* (Grunow) Cox et Reid and *S. recta* have a similar shape, however the first one shows smaller dimensions and more delicate striations (Table 2).

Seminavis atlantica Garcia can be distinguished from *S. recta* by denser striae and areolae and a different valve outline (see Garcia 2007; fig. 10). In *S. atlantica* the ventral margin is slightly concave and the dorsal margin is convex–linear, while in *S. recta* the ventral margin is slightly convex and the dorsal margin is strongly arched.

Seminavis robusta Danielidis et Mann presents smaller dimensions and higher striae density (16–19.3 striae in 10 μm) than *S. recta*. Furthermore, *S. robusta* has a broad axial area at the dorsal side and internally does not have expanded accessory rib at the center of the valve (see Danielidis et Mann 2002; figs 49, 51).



Figs 17–35. LM images of *Seminavis recta* comb. nov et stat. nov.; (17–35) specimens from Brazilian salt marshes; (17–26) images of the specimens from the epipelon; (17) arrows indicate shortened striae in ventral side; (27–35) images of the specimens from the epiphyton. Scale bar 10 μm.

Seminavis strigosa (HUSTEDT) DANIELIDIS et ECONOMOU–AMILLI presents shorter dimensions and has a higher striae and areolae density than *S. recta* (Table 2). Furthermore, the first species shows a straight ventral margin and central area more expanded.

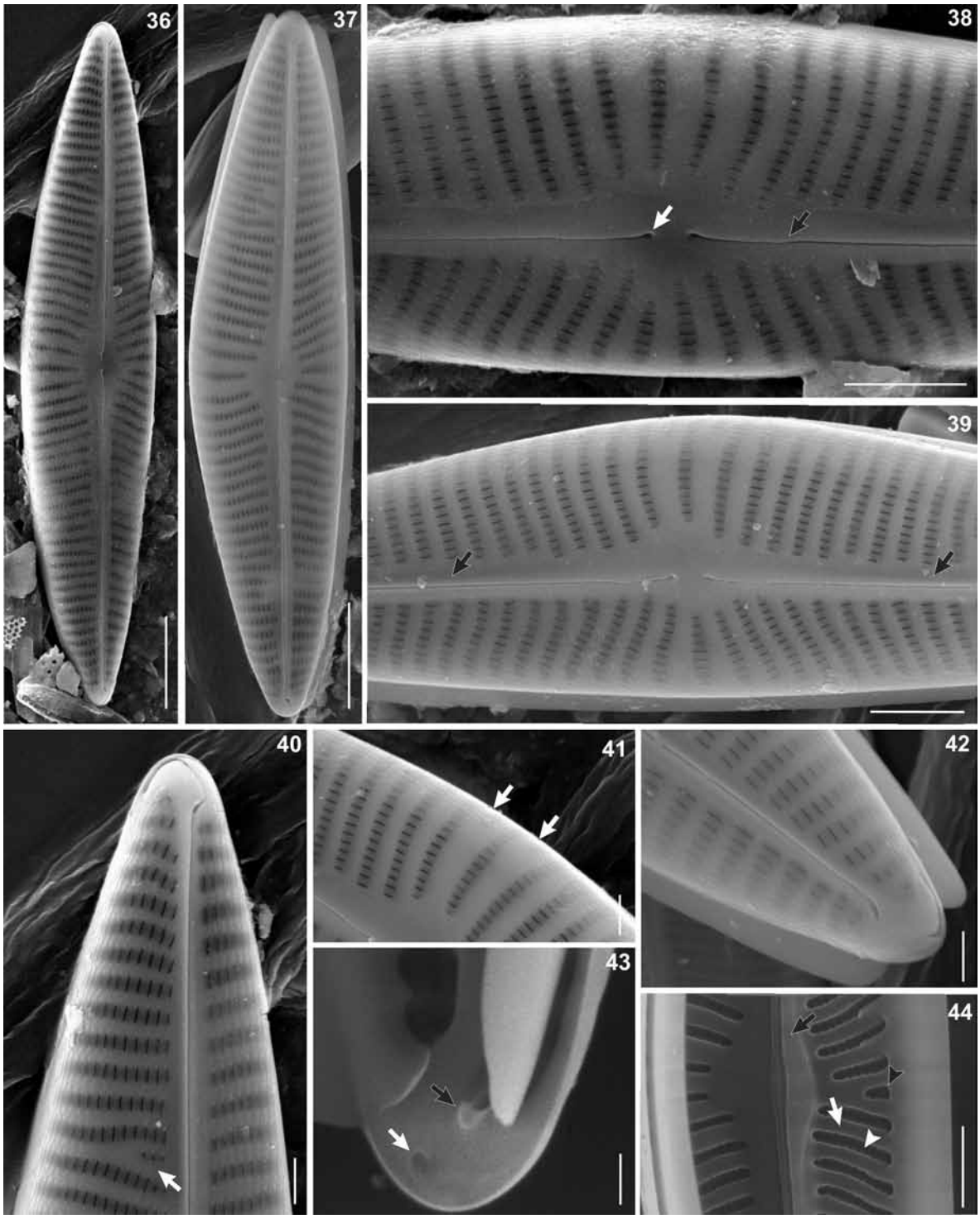
Ecology and distribution

Seminavis recta occurred concomitantly in the epipelon and epiphyton (Table 1). The species was found alive in temperatures between 15.4 °C and 29 °C, pH between 6.6 and 8.6, and in oligo to mesohaline zone (salinity between 1.5 and 15) (Table 1). It is important to point out that *S. recta* did not show specificity with any kind of plant, occurring in association with *Spartina alterniflora* LOISEL., *S. densiflora* BRONGN. and *Scirpus maritimus* L. (Table 1).

Seminavis recta from Brazilian salt marshes was found in sediment composed by sand and clay. In the estuary of Matanza river (Argentina) where the species was first described, and in Laguna Rocha (Uruguay) a shallow lagoon with a wide salinity range (METZELTIN & GARCÍA–RODRIGUEZ 2003) the sediment is also composed by clay and sand.

Afterwards, SILVA et al. (2010) recorded *S. recta* (as *Cymbella grossestriata*) for the salt marshes of Patos Lagoon estuary. The authors found this species in summer and autumn, in the oligohaline zone (salinity= 5), with temperature ranging between 24.1 °C and 27.1 °C and the pH between 5.3 and 7.3 (personal communication).

The occurrence of living individuals of *S. recta* in a wide range of salinity and simultaneously in the epipelon and epiphyton should be related to the system's dynamics. The salt marshes of the Patos Lagoon estuary endure a constant variation of the water level and of salinity which depends on the



Figs 36–44. SEM images of *Seminavis recta* comb. nov et stat. nov. (material from Brazilian salt marshes): (36, 37) external view of the valve; (38) external view of the center of the valve showing the raphe slightly deflected to ventral side (black arrow) and proximal raphe ends slightly expanded and drop–like (white arrow); (39) shape of central area, striae pattern and axial area slightly raised (black arrow); (40) apice of valve showing distal raphe ends strongly hooked onto secondary side and Voigt fault (white arrow); (41) detail of the center of the dorsal side showing two shortened striae onto the valve mantle (white arrow); (42) detail of distal raphe ends deflected to dorsal side; (43, 44). Internal view of the valve; (43) distal raphe ends terminated in helictoglossae (black arrow) and apical simple pore (white arrow); (44) center of valve showing accessory rib expanded to ventral side and no interrupted (black arrow), a thickened virgae (white arrow), vimines (white arrow head) and shortened stria in the ventral side (black arrow head). Scale bars 10 μm (36, 37); 5 μm (38, 39, 41); 2 μm (40, 42); 1 μm (43, 44).

meteorological conditions (direction of wind and pluviosity) in the region.

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