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Research article

Morphology of two *Mastogloia* species (Bacillariophyta) from Lac de Guiers (Senegal) and comparison with the type material of *M. braunii*

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Abstract. Two *Mastogloia* Thwaites ex W.Sm. taxa were found during a survey of the diatom flora of Lac de Guiers, Senegal. Based on all currently available literature, one taxon could be identified as *M. belaensis* M.Voigt, a species formerly described from Pakistan. The second species showed some resemblance to *M. braunii* Grunow. Analysis of the type of *M. braunii* revealed, however, important morphologic differences, leading to the description of a new species from the Senegal population: *M. senegalensis* Van de Vijver, Fofana, Sow & Ector sp. nov. The present paper describes this new species and discusses and illustrates the morphology of *M. belaensis* and the type of *M. braunii*. All taxa are discussed with morphologically similar taxa.

Keywords. Bacillariophyceae, *Mastogloia belaensis*, *Mastogloia braunii*, new species, Senegal, ultrastructure.

Van de Vijver B., Fofana C.A.K., Sow E.H., Cocquyt C., Blanco S. & Ector L. Morphology of two *Mastogloia* species (Bacillariophyta) from Lac de Guiers (Senegal) and comparison with the type material of *M. braunii*. *European Journal of Taxonomy* 374: 1–23. <https://doi.org/10.5852/ejt.2017.374>

Introduction

In general, the aquatic freshwater diatom flora from sub-Saharan western Africa is rather poorly known. Major taxonomic and morphologic contributions were published by Zanon (1941) (French West Africa), Pinto (1948) (Guinea-Bissau), Woodhead & Tweed (1958) (Sierra Leone), Guermeur (1954) (Senegal), Foged (1966, 1986) (Ghana and Gambia, respectively), Carter & Denny (1982, 1987, 1992) (Sierra Leone), Compère (1991) (Senegal), Ouattara *et al.* (2000) (Ivory Coast), Alfinito & Lange-Bertalot (2003) (Sierra Leone), and Compère & Riaux-Gobin (2009) (Guinea).

During a biomonitoring project using diatoms as bio-indicators in the Senegal River, a small sampling campaign was made in 2007 on the Lac de Guiers, situated in northern Senegal, south of the city of Richard-Toll. During the analysis of the collected samples, two distinct *Mastogloia* Thwaites ex W.Sm. taxa have been found, presumably belonging to '*M. sect. Sulcatae*'. The raphid genus *Mastogloia* is rather large and comprises at present more than 400 taxa, mostly observed in marine or brackish conditions (e.g., Novarino 1989; Pennesi *et al.* 2011; Lobban & Pennesi 2014). Most *Mastogloia* species have naviculoid, isopolar valves (Round *et al.* 1990). The most typical feature of this genus is the presence of a partectal ring representing a chamber-like modification of the valvocopula, running along the inner side of the girdle. Detailed information regarding the general morphology of the genus *Mastogloia* can be found in Paddock & Kemp (1990), Round *et al.* (1990), Pennesi *et al.* (2011, 2012), Lobban & Pennesi (2014) and Al-Handal *et al.* (2015). The description of most species, however, has only been based on LM observations. Morphological investigations of *Mastogloia* species based on SEM observations are scarce and only recently increased attention is given to the ultrastructure of the different species resulting in the description of a relatively large number of new taxa (Pennesi *et al.* 2011, 2012, 2013; Graeff *et al.* 2013; Lee *et al.* 2014; Lobban & Pennesi 2014; Al-Handal *et al.* 2015, 2016; Pavlov *et al.* 2016).

The objective of the present paper is to illustrate and discuss the morphology of the two *Mastogloia* taxa observed in the Lac de Guiers, using light and scanning electron microscopy observations and to compare them with the type material of comparable taxa such as *M. braunii* Grunow and *M. belaensis* M.Voigt and with illustrated records of similar (mostly recently described) species to reveal their identity. The type material of *M. braunii* was found in the Grunow collection in Vienna but, unfortunately, the search for the type of *M. belaensis* proved to be unsuccessful.

Material and methods

The Lac de Guiers is a large lake (300 km²) situated in the northern part of Senegal, south of the Senegal River, not far from the city of Richard Toll. The lake, with a length of 50 km and a maximal width of 7 km, is the main freshwater source for the Senegalese capital Dakar, located several hundreds of km to the southwest. The water from the lake is likewise used for the irrigation of rice and sugar cane cultures bordering mainly the northern shores. The lake, which bottom is at almost 2 m below sea level, is quite shallow with an average depth of 2 m, and a maximum depth of 4 m during periods of complete filling. Water level drops to less than 1.5 m during the dry season. The Ferlo River supplies the lake with freshwater in the south; in the north, the narrow Taoué canal connects the Senegal River with the lake filling the lake during periods of high water level. The canal replaces the former Taoué River which is dammed now to prevent the inflow of salt water from the Senegal delta into the lake (Dia & Reynaud 1982; Compère 1991). The lake is characterized by an alkaline pH (7.4–8.5) and a variable conductivity from 100 µm/cm in the north to 1000 µS/cm in the south, while at the end of the dry season values of 500 µS/cm in the south to 5000 µm/cm in the north were noted by Cogels and Gac in 1984 (Compère 1991).

Several samples were taken along the shore of Lac de Guiers. In one of the samples, *SEN-42*, a large population of two *Mastogloia* species has been found. The sample was collected from the surface

sediment of Lac de Guiers, close to the village of Naéré, on the western side of the lake. The sampling site was characterized by a high conductivity (3700 $\mu\text{S}/\text{cm}$). The area was vegetated with a *Typha* sp. and a *Phragmites* sp., while in the water thick masses of *Chara* sp. were floating.

For the analysis of the type of *Mastogloia braunii* the following material was used: *A. Grunow 23583* – capsule 0645 (NMW) (raw material).

Diatom samples for LM observation were prepared following the method described in Van der Werff (1955). Subsamples of the original material were oxidized using 37% H_2O_2 and heated to 80°C for approximately 1 h. The reaction was further completed by the addition of KMnO_4 . Following digestion and centrifugation (three times 10 min at 3700 \times g), the material free of organic matter was diluted with distilled water for sample mounting to avoid excessive concentrations of diatom valves and frustules on the slides. A subsample from the organic-free material was mounted in Naphrax[®] for diatom community studies. The slides were analyzed using an Olympus BX53 microscope, equipped with Differential Interference Contrast (Nomarski), and an Olympus UC30 digital camera. Morphometric data were obtained on 50 valves of *M. belaensis* and 25 valves of *M. senegalensis* Van de Vijver, Fofana, Sow & Ector sp. nov. Number of striae and number of partecta was measured from the middle towards the apices. Length and width of partecta were measured for the middle (largest) partecta and the most outer (smallest) partecta.

For scanning electron microscopy (SEM), part of the organic-free suspension was filtered through a polycarbonate membrane filter with a pore diameter of 5 μm , pieces of which were fixed on aluminum stubs after air-drying. The stubs were sputter-coated with 15 nm of Au and studied in a JEOL-JSM-7100F at 1 kV. Micrographs were digitally manipulated and plates containing light and scanning electron microscopy images were created using Adobe Photoshop 4.0[®]. Diatom terminology follows Kemp & Paddock (1989) and Paddock & Kemp (1990). A comparison was presented with *M. baldjikiana* Grunow in Schmidt (1893: pl. 188, figs 1–2, Baltshik) based on observations made from slide 545 of the Types du Synopsis des diatomées de Belgique, present in the Van Heurck Collection at the Botanic Garden Meise, Belgium (BR).

Results

Class Bacillariophyceae Haeckel emend. Medlin & Kaczmarska (Medlin & Kaczmarska 2004)

Subclass Bacillariophycidae D.G.Mann (Round *et al.* 1990)

Order Mastogloiales D.G.Mann (Round *et al.* 1990)

Family Mastogloiaceae Mereschk. (Mereschkowsky 1903)

Genus *Mastogloia* Thwaites ex W.Sm. (Smith 1856)

Mastogloia braunii Grunow

Figs 1–16

Verhandlungen der Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft in Wien 13: 156, pl. 13 fig. 2 (Grunow 1863).

Type

EGYPT: Sinäi, El-Tor, *A. Grunow 23583* – capsule 0645 (NMW) (raw material).

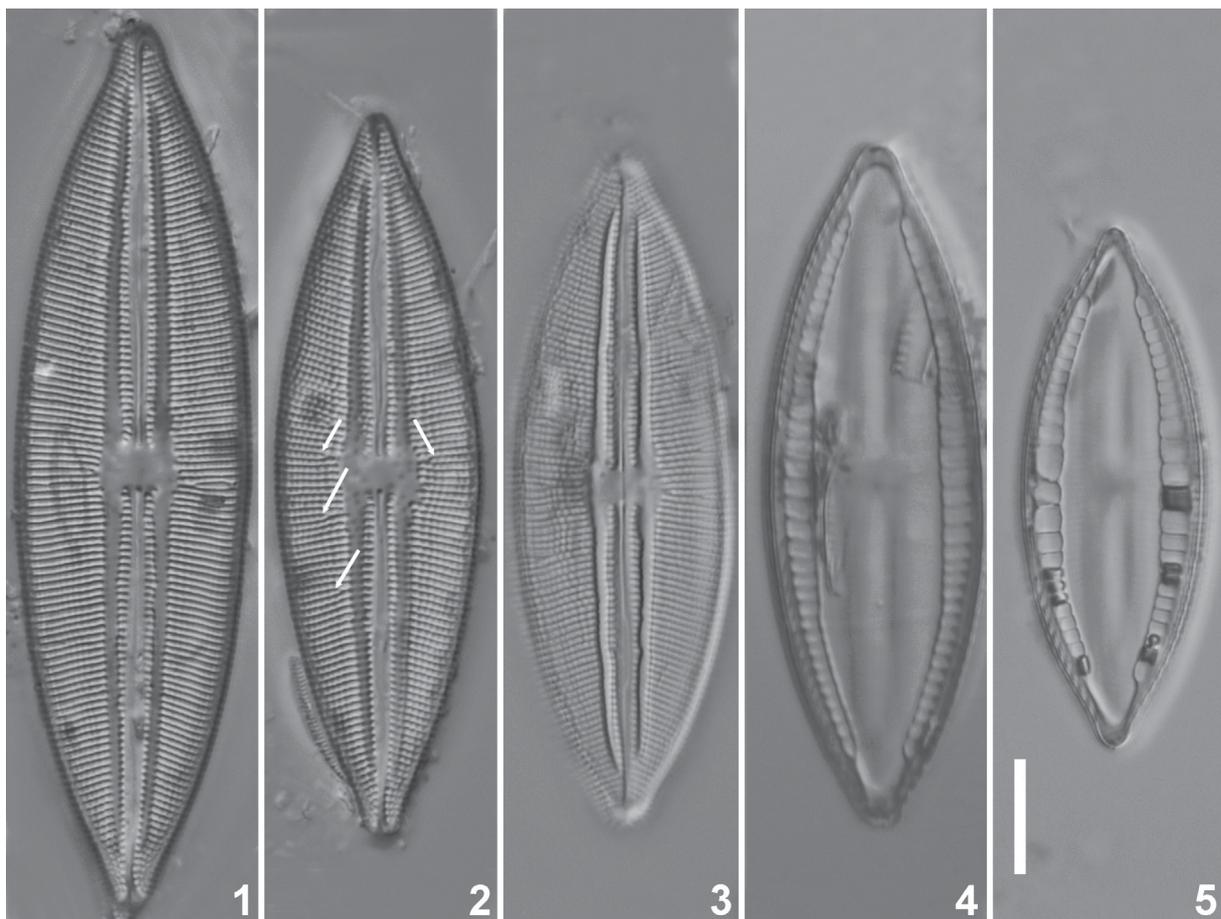
Description (type material)

Light microscopy (Figs 1–5)

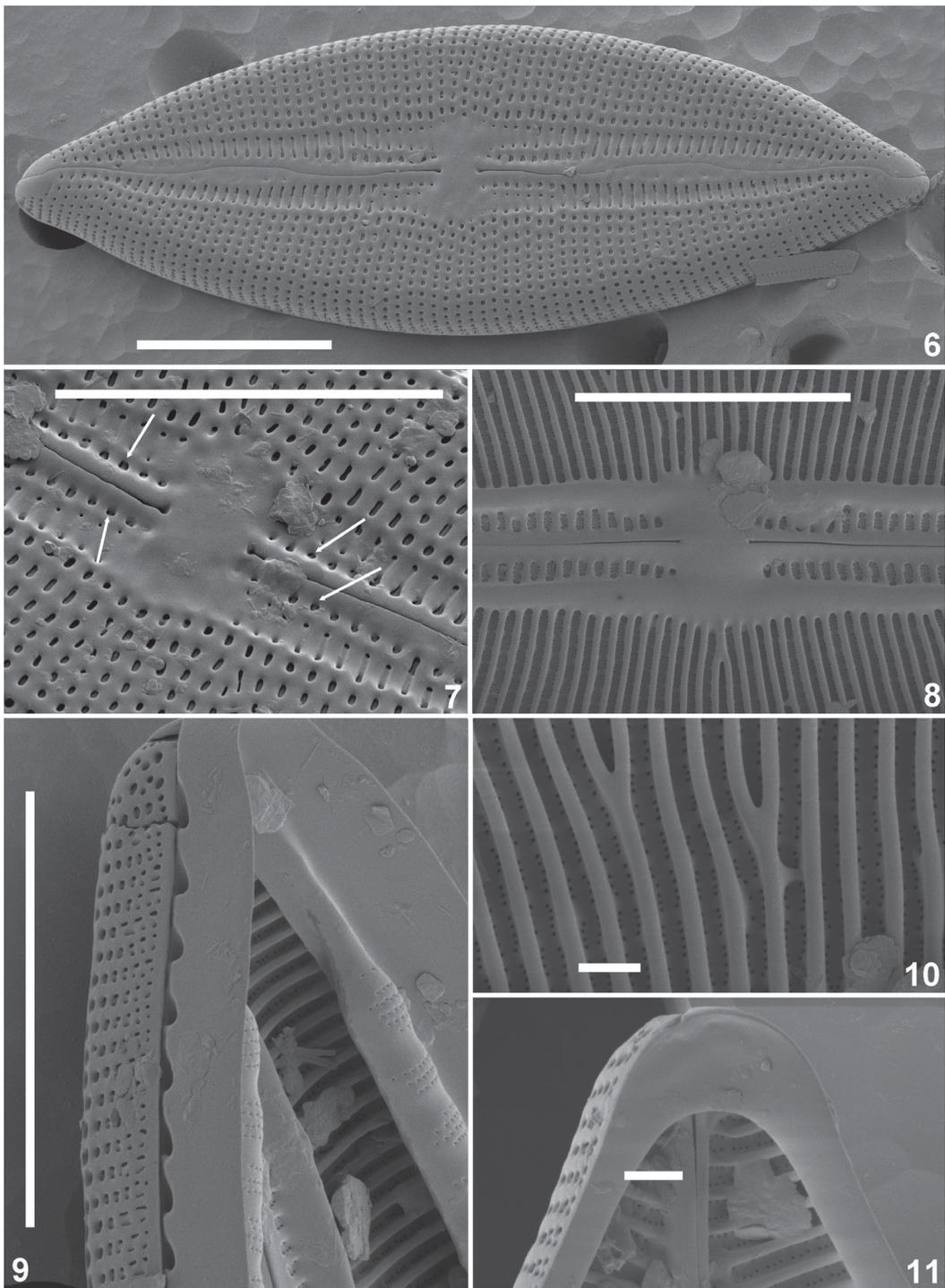
Valves elliptic-lanceolate with broadly convex margins and apiculate, cuneately protracted apices. Valve dimensions ($n = 5$): length 45–80 μm , width 16–21 μm . Axial area narrow, lanceolate, narrowing towards the apices and the central area. Lyre-shaped hyaline (rather deep) depression present parallel to and close to the axial area, separating 1–2 rows of pseudoloculi from the striae. Central area small, transapically rectangular. Raphe lateral with undulating branches. Proximal raphe endings almost not expanded, coaxial. Distal endings hooked. Striae slightly radiate mid-valve, becoming more strongly radiate towards the apices, 15–16 in 10 μm . Occasionally one to several shortened striae inserted within the normal striation pattern near the central area (Fig. 2, arrows). Pseudoloculi slightly visible in LM, ca 18 in 10 μm . Partecta distributed along the entire partectal ring, closely attached to the margins without broad flange, reaching almost the apices. Ring composed of partecta of different size (5–6 in 10 μm in the middle, 7–9 in 10 μm near the apices): the middle 6–7 partecta (length 2.4–2.6 μm , width 1.6–3.1 μm) considerable larger than the outer partecta (length 1.2–1.4 μm , width 1.4–1.6 μm).

Scanning electron microscopy (Figs 6–16)

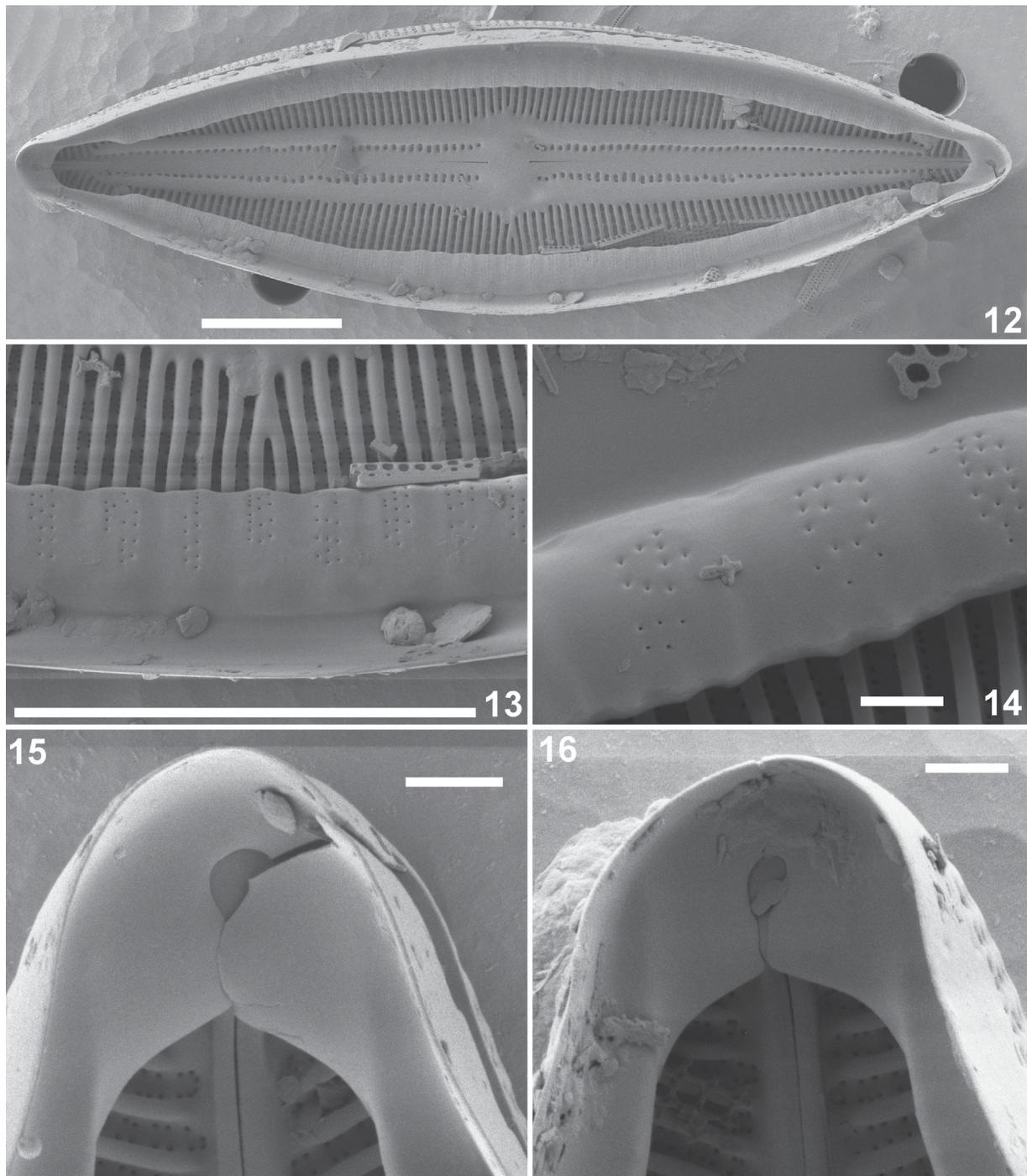
External raphe branches clearly undulating (Fig. 6). Proximal raphe endings straight, simple to very weakly expanded (Figs 6–7). Distal raphe fissures centrally crossing the terminal nodule, elongated, weakly hooked towards the same direction, continuing onto the valve mantle (Fig. 6). Marginal crest



Figs 1–5. *Mastogloia braunii* Grunow. Light micrographs (LM) of valves from the type population (Grunow 23583 – capsule 0645, Vienna, Austria). 1–3. LM views of 3 valves showing variation in valve size and shape. The arrows in Fig. 2 indicate shortened striae near the central area. 3–4. Same valve taken at different foci. 4–5. LM views of the partectal ring with the partecta. Scale bar: 10 μm .



Figs 6–11. *Mastogloia braunii* Grunow. Scanning electron micrographs (SEM) of valves from the type population (Grunow 23583 – capsule 0645, Vienna, Austria). **6.** SEM external view of an entire valve showing the shallow depressions in the axial area, the undulating external raphe branches and the terminal raphe fissures. **7.** SEM external detail of the central area. The arrows indicate one row of irregularly scattered rounded pseudoloculi. **8.** SEM internal detail of the central area. **9.** SEM detail of the valve mantle showing the mantle striae with near the mantle edge, their typical biseriolate character. **10.** SEM internal view of the striae with the arrangement of the inner areolae. **11.** SEM internal detail of the valve apex with the pseudoseptum. Scale bars: 6–9 = 10 μm ; 10–11 = 1 μm .



Figs 12–16. *Mastogloia braunii* Grunow. Scanning electron micrographs (SEM) of valves from the type population (*Grunow* 23583 – capsule 0645, Vienna, Austria). **12.** SEM internal view of an entire valve with the partectal ring and series of partectal pores. **13.** SEM internal detail of the partecta with the flange connecting the partecta with the valve margins. **14.** SEM internal detail of the partecta showing the partectal walls with 2–4 series of small, rounded pores. **15–16.** SEM internal details of the partectal ring near the valve apices showing the cleft with the lacunae. Scale bars: 12 = 1 μm ; 13–16 = 10 μm .

on the valve face/mantle junction absent (Fig. 6). Mantle striae uniseriate becoming biseriate near the mantle edge, composed of several rounded to irregularly shaped pseudoloculi (Fig. 9). Valve face clearly subdivided into two zones: an outer zone composed of a series of uniseriate striae, composed of a variable number of rounded pseudoloculi and a central zone restricted to both sides of the raphe-sternum, formed by a distinct lanceolate median depression (Fig. 6). Close to the raphe, one row of irregularly scattered rounded pseudoloculi present (Fig. 7, arrows), whereas in the depressions on both sides of the axial area, pseudoloculi transapically elongated, rectangular, diminishing in size towards the apices (Fig. 6). Central area flat, hyaline. Small hyaline area present at both apices (Fig. 6). Shallow depressions sometimes visible in the axial area (Fig. 6). Internally, hyaline H-shaped lyriform raphe sternum clearly raised (Fig. 8). Well-developed, raised costa-like interstriae interrupted by the raphe-sternum extending from the axial area towards the valve margins, separating the areolae (Figs 8, 10). Inner areolae arranged in groups of 6–8 per pseudoloculus (Fig. 10). Raphe branches straight with indistinct, almost straight proximal endings, terminating on a weakly raised central nodule (Fig. 8). Valve apices with pseudosepta (Fig. 11). Valvocopulae with typical partectal ring, opening near the apices through a series of partectal pores (Fig. 12). Partectal ring opening at the poles by a cleft, covering entirely the pseudosepta (Figs 12, 15–16). Lacunae clearly present (Figs 15–16). Partecta extending almost entirely to the valve apex, with only a small siliceous flange (Figs 12–13). Partecta subequal in size with the large ones grouped in the middle, the smaller ones nearer to the apices (Fig. 12). Partecta ornamented with several series of small, rounded areolae (Fig. 14).

Mastogloia belaensis M.Voigt

Figs 17–45

Journal of the Royal Microscopical Society ser. 3 75: 189, pl. 1 fig. 1, 5, 6, 7 (Voigt 1956).

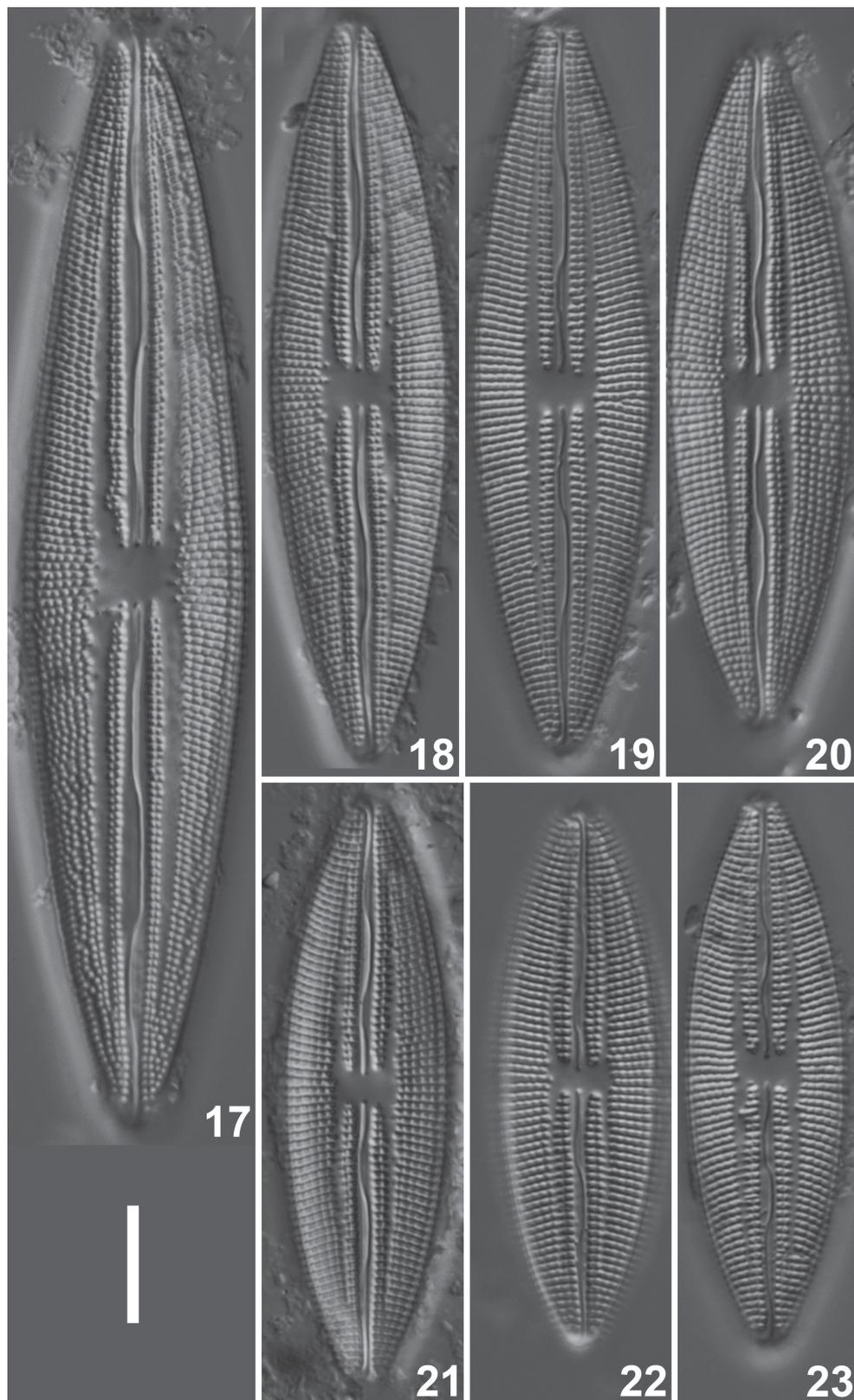
Description (Senegal population)

Light microscopy (Figs 17–32)

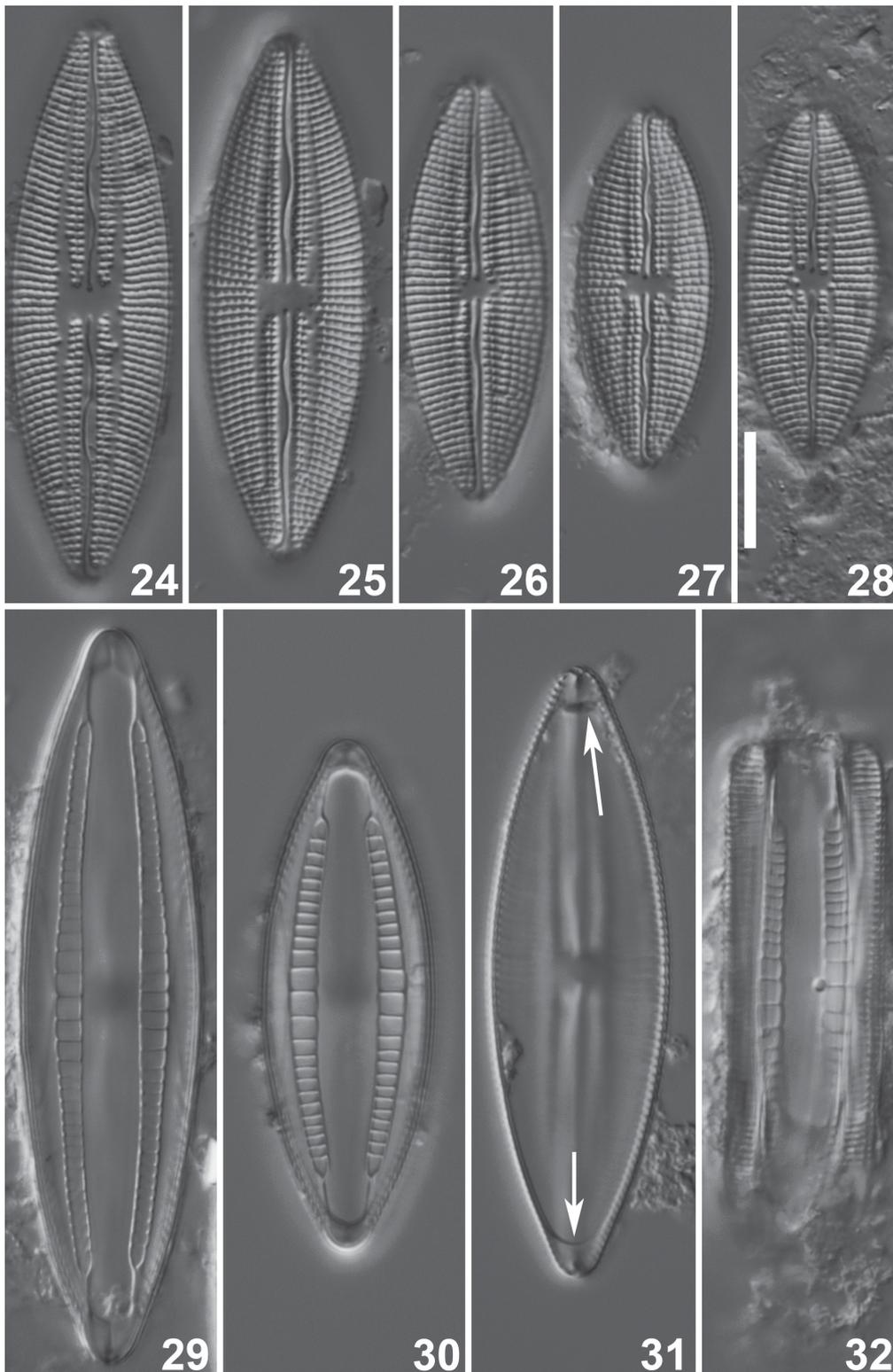
Valves lanceolate to elliptic-lanceolate with convex margins. Apices non-protracted, acutely rounded to slight protracted, substrate. Valve dimensions (n = 50): length 31–99 μm , width 11.5–20.0 μm . Axial area narrow, lanceolate, narrowing towards the apices. Lyre-shaped hyaline zone present close to the axial area, separating one row of pseudoloculi from the striae. Central area rather small, rectangular. Raphe lateral with clearly undulating branches. Proximal raphe endings indistinct, straight. Distal endings hooked towards the same direction. Striae radiate throughout, becoming less radiate and even parallel to slightly divergent (Fig. 25) towards the apices, 13–15 in 10 μm . Pseudoloculi quite large, well visible in LM, 15–20 in 10 μm . Partectal ring clearly displaced towards the middle of the valve, composed of partecta of different size (6–8 in 10 μm): the middle 4–8 partecta (length 1.9–2.9 μm , width 1.8–3.9 μm) considerable larger than the outer partecta (length 0.9–1.4 μm , width 1.2–1.8 μm).

Scanning electron microscopy (Figs 33–45)

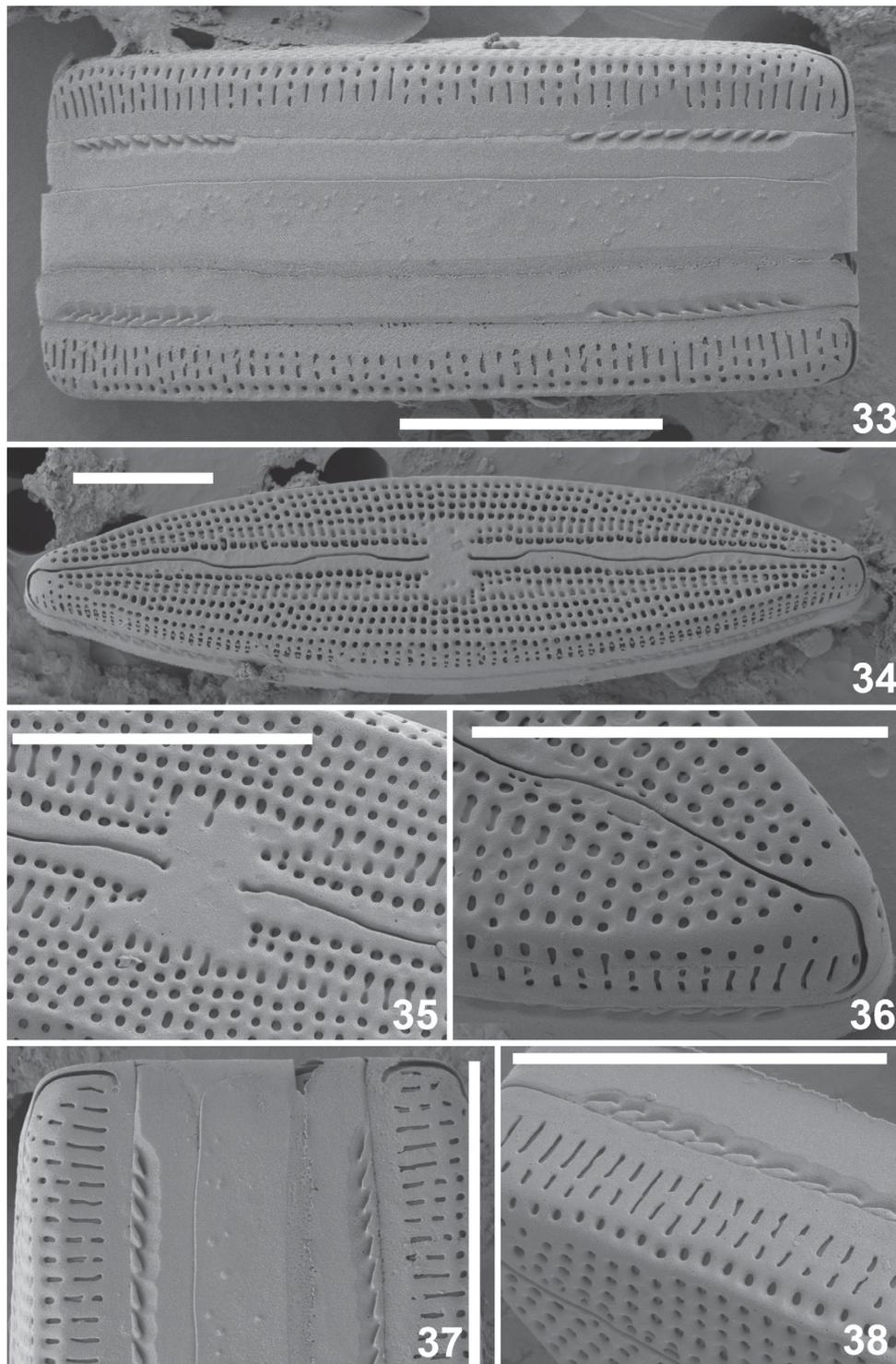
External raphe branches clearly undulating (Fig. 34). Proximal raphe endings simple, very weakly expanding, slightly deflected (Figs 34–35). Distal raphe fissures centrally crossing the terminal nodule, elongated, hooked towards the same direction, continuing onto the valve mantle, terminating almost near the mantle edge (Fig. 36). Very low, slightly thickened marginal crest visible on the valve face/mantle junction separating the striae on the valve face from the mantle areolae by a hyaline line (Fig. 34). Mantle striae entirely uniseriate, composed of several, usually transapically elongated to slit-like pseudoloculi (Figs 33–34, 36, 38). First pseudoloculi near the junction rounded (Figs 36, 38). Valve face almost flat, subdivided into two zones: outer zone composed of uniseriate striae, with up to four rounded pseudoloculi, central zone formed by one row of rounded pseudoloculi close to the axial area and one row of transapically elongated rectangular pseudoloculi (Figs 34–35). Near the central



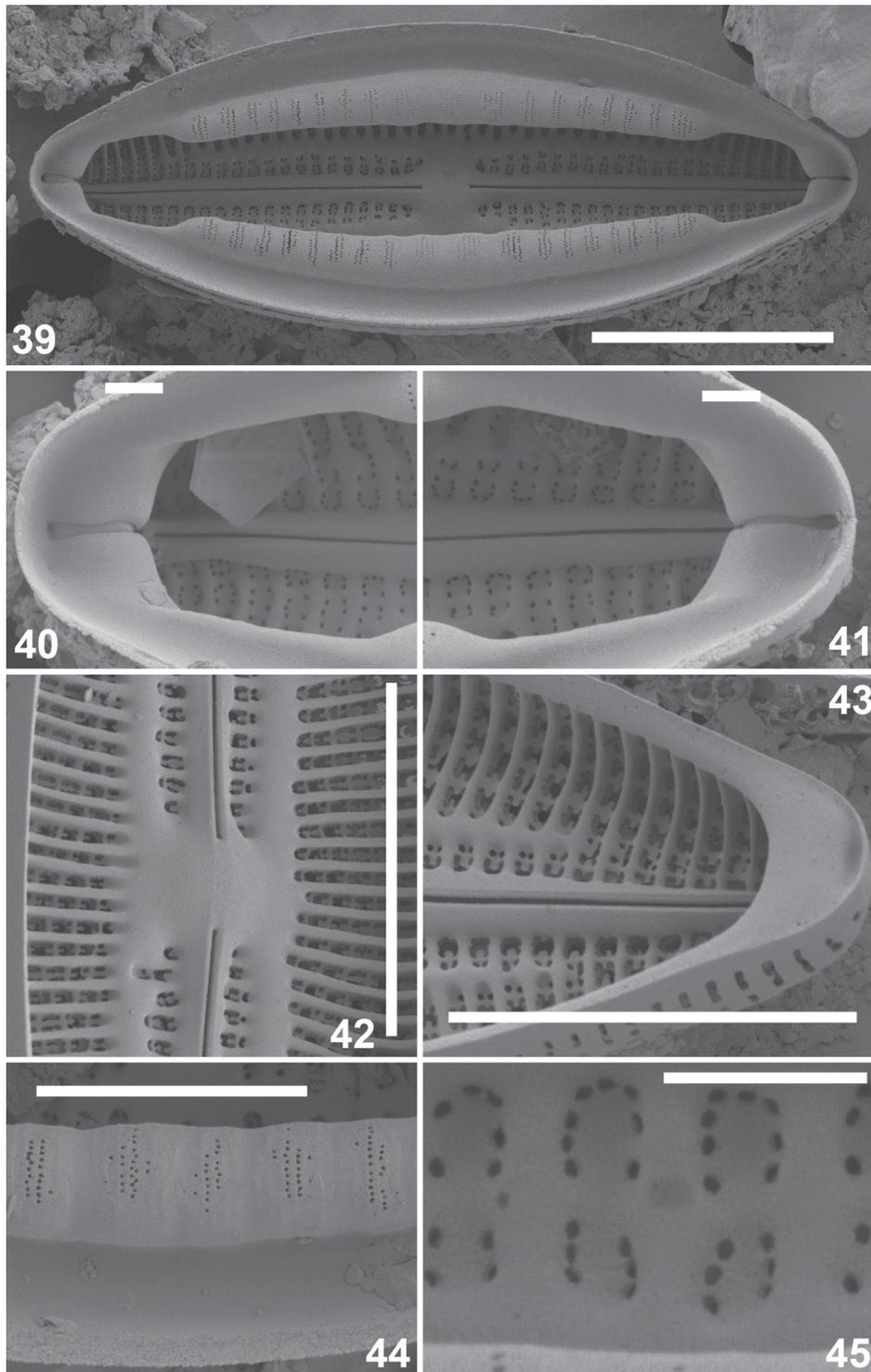
Figs 17–23. *Mastogloia belaensis* M.Voigt. Light micrographs (LM) of valves from the Lac de Guiers population (*Van de Vijver* sample *SEN-42*). LM views of several specimens showing variation in valve size and shape. Scale bar: 10 μ m.



Figs 24–32. *Mastogloia belaensis* M.Voigt. Light micrographs (LM) of valves from the Lac de Guiers population (*Van de Vijver* sample SEN-42). **24–28.** LM views of several smaller valves showing variation in valve size and shape. **29–30.** LM views of the partectal ring with the partecta. **31.** LM view of an entire valve with removed partectal ring showing the pseudosepta (arrows). **32.** Entire frustule in girdle view. Scale bar: 10 μ m.



Figs 33–38. *Mastogloia belaensis* M.Voigt. Scanning electron micrographs (SEM) of valves from the Lac de Guiers population (*Van de Vijver* sample *SEN-42*). **33.** SEM girdle view of an entire frustule showing the partectal pores and the mantle areolae. **34.** SEM external view of an entire valve with typical undulating raphe branches. **35.** SEM external detail of the central area. **36.** SEM external detail of the valve apex. **37.** SEM external detail of the apices and girdle bands of an entire frustule. **38.** SEM external detail of the valve mantle with the transapically elongated mantle areolae and the row of rounded pseudoloculi on the valve face/mantle junction. Scale bars: 10 μm .



Figs 39–45. *Mastogloia belaensis* M.Voigt. Scanning electron micrographs (SEM) of valves from the Lac de Guiers population (*Van de Vijver* sample *SEN-42*). **39.** SEM internal view of an entire valve with the typical partectal ring. **40–41.** SEM internal details of the partectal ring near the valve apices showing the cleft with the lacunae. **42.** SEM internal detail of the central area. **43.** SEM internal detail of the valve apex with the pseudoseptum. **44.** SEM internal detail of the partecta showing the partectal walls with 2–4 series of small, rounded pores. **45.** SEM internal view of the inner areolae arranged in groups of 4–8 per pseudoloculus. Scale bars: 39–43 = 10 μm ; 44 = 5 μm ; 45 = 1 μm .

area, rectangular pseudoloculi replaced by 1–2 small, rounded ones whereas near the apices, central transapically elongated pseudoloculi absent, outer zone with rounded pseudoloculi reaching the axial area (Fig. 36). Shallow depressions sometimes visible in the axial area (Figs 34–36). Hyaline areas present on each valve apex (Fig. 36). Internally, raphe sternum lyriform, slightly raised (Figs 39, 42). Raised thickened costa-like interstriae interrupted by the raphe-sternum extending from the axial area towards the valve margins, separating the areolae (Figs 42–43). Inner areolae arranged in groups of 4–8 per pseudolocus (Fig. 45). Raphe branches straight with indistinct, coaxial proximal endings, terminating on a raised central nodule (Figs 39, 42). Valve apices with clear pseudosepta covering the distal raphe endings (Fig. 43).

Girdle composed of the valvocopulae and one open, non-perforated copula (Figs 33, 37). Small siliceous papillae present on the copula (Fig. 37). Valvocopulae with typical partectal ring, opening near the apices through a series of elongated partectal pores (Figs 33, 37–38). Partectal ring open, one end closed but with a cleft forming a narrow lacuna (Fig. 40), other split with a cleft (Fig. 41), covering entirely the pseudosepta. Partecta extending to almost $\frac{1}{4}$ to $\frac{1}{6}$ from the valve apex, clearly separated from the valve margin by a siliceous flange (Fig. 39). Partecta subequal in size with the large ones grouped in the middle, the smaller ones closer to the apices (Fig. 39). Partecta ornamented with several series of small, rounded areolae, loosely aggregated in very unclear plaques and arranged inwardly (Fig. 44).

Mastogloia senegalensis Van de Vijver, Fofana, Sow & Ector sp. nov.
Figs 46–65

Etymology

The new species is named after Senegal, the country from which the new species is described.

Type

SENEGAL: Lac de Guiers, 10 Mar. 2007, *B. Van de Vijver* sample *SEN-42* (holo-: slide no. BR-4500; iso-: PLP-334; University of Antwerp, Belgium).

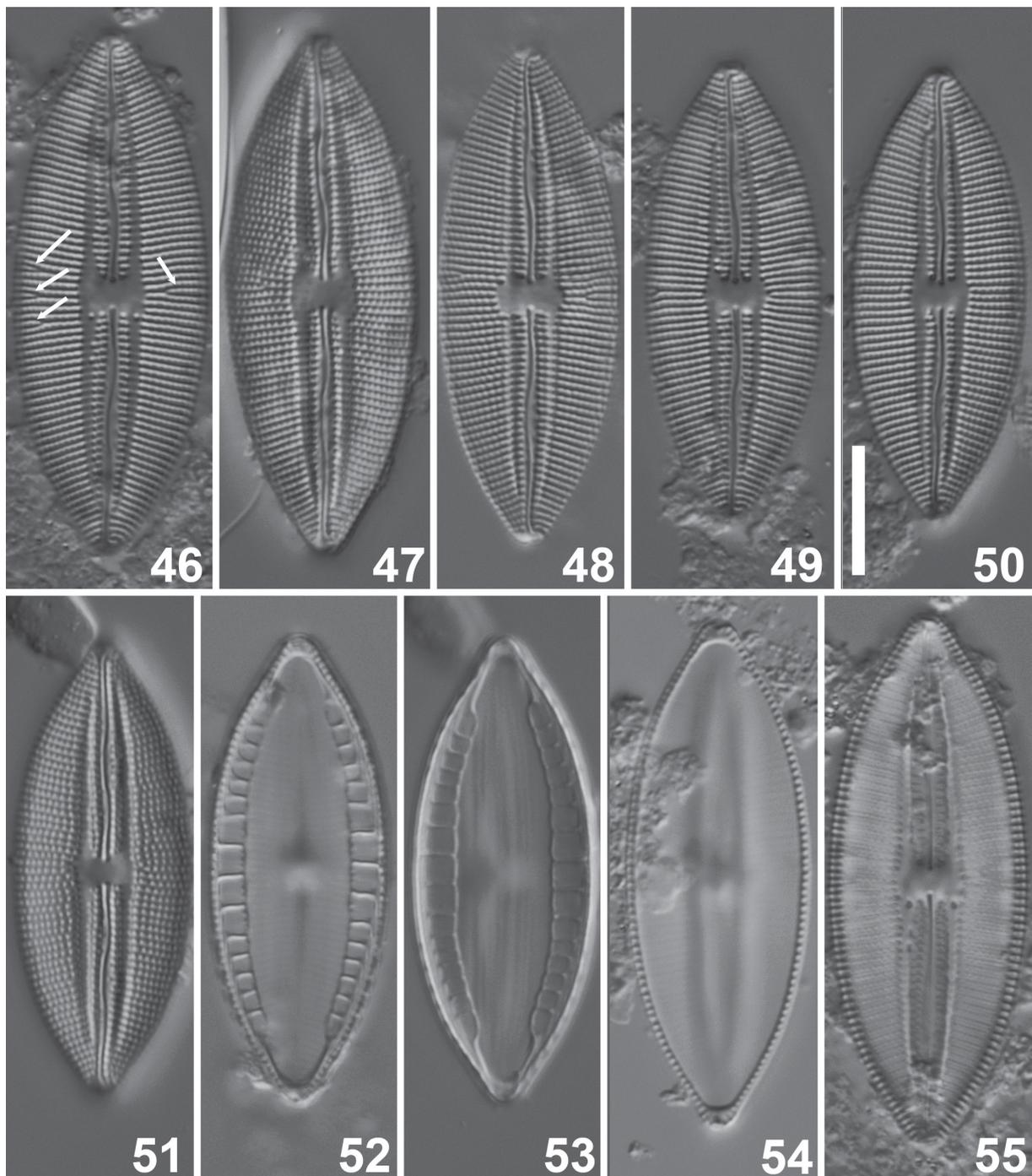
Description

Light microscopy (Figs 46–55)

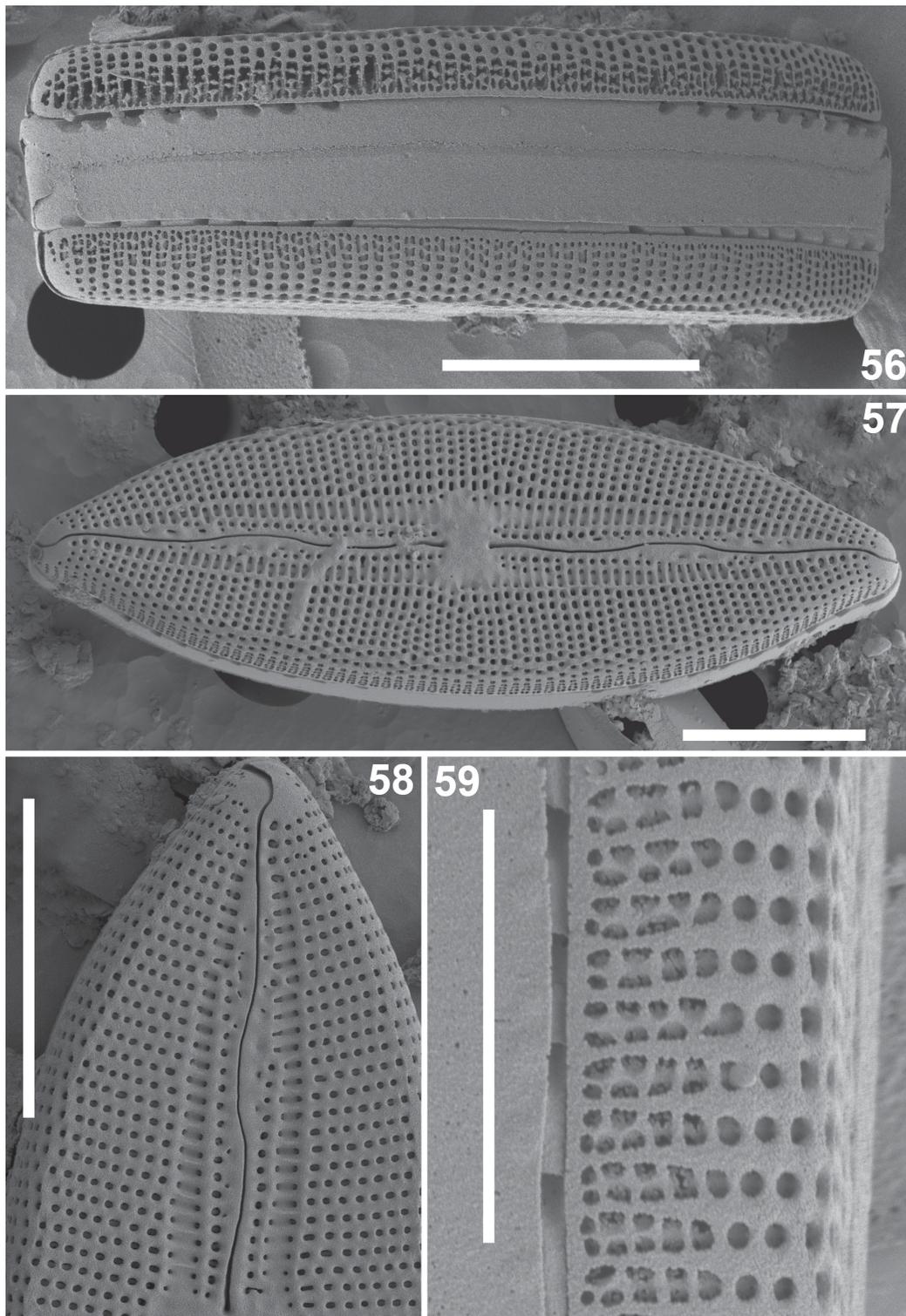
Valves elliptic-lanceolate with broadly convex margins. Apices slightly protracted, cuneately rounded, never rostrate. Valve dimensions ($n = 25$): length 26–56 μm , width 11.5–17.0 μm . Axial area narrow, linear-lanceolate, narrowing towards the apices. Lyre-shaped hyaline depression present close to the axial area, separating 1–2 rows of pseudoloculi from the striae. Central area rather small, transapically elliptical to rectangular. Raphe lateral with undulating branches. Proximal raphe endings weakly expanded, coaxial. Distal endings hooked towards the same direction. Striae slightly radiate throughout, becoming more strongly radiate towards the apices, 16–18 in 10 μm . Occasionally one to several shortened striae inserted near the central area (Figs 46, 48). Pseudoloculi well visible in LM, 15–20 in 10 μm . Partecta distributed along the entire partectal ring, closely attached to the margins without broad flange, reaching almost the apices. Partecta of different size (5–7 in 10 μm): the middle 4–5 partecta (length 1.9–3.0 μm , width 1.9–3.1 μm) considerable larger than the outer partecta (length 1.1–1.8 μm , width 1.2–2.0 μm).

Scanning electron microscopy (Figs 56–65)

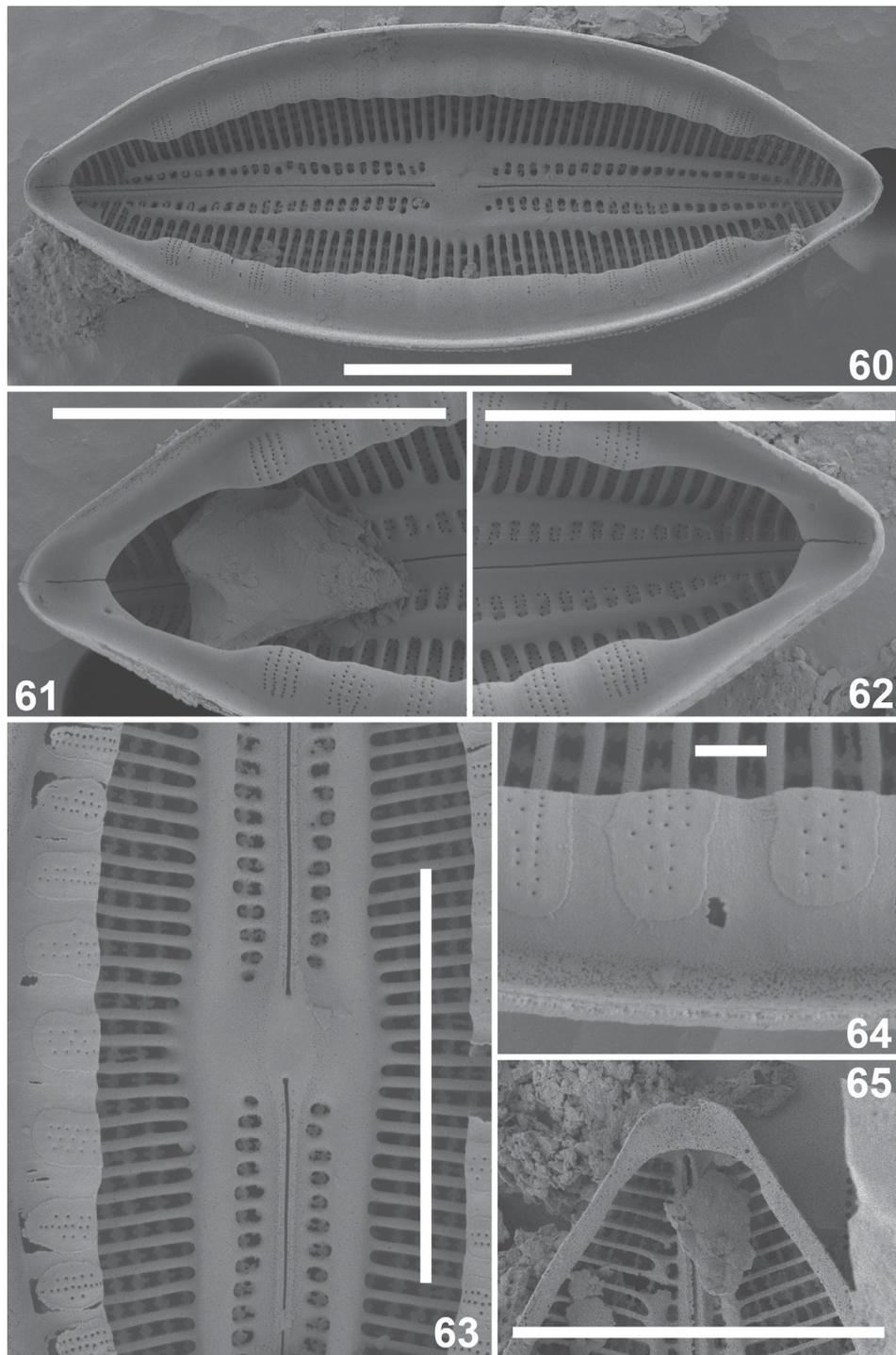
External raphe branches clearly undulating (Fig. 57). Proximal raphe endings simple to very weakly expanded, slightly deflected (Figs 57–58). Distal raphe fissures centrally crossing the terminal nodule, elongated, hooked towards the same direction, continuing onto the valve mantle (Figs 57, 58). No marginal crest on the valve face/mantle junction (Fig. 59). Mantle striae uniseriate near the valve face/



Figs 46–55. *Mastogloia senegalensis* Van de Vijver, Fofana, Sow & Ector sp. nov. Light micrographs of valves from the Lac de Guiers type population (*Van de Vijver* sample SEN-42). **46–51.** LM views of several specimens showing variation in valve size and shape (the arrows in Fig. 46 show typical bifurcating striae near the central area). **52–53.** LM views of the partectal ring with the partecta. **54.** LM view of an entire valve with removed partectal ring showing the pseudosepta. **55.** LM view of an entire valve with removed partectal ring showing the valve interior. Scale bar: 10 μ m.



Figs 56–59. *Mastogloia senegalensis* Van de Vijver, Fofana, Sow & Ector sp. nov. Scanning electron micrographs (SEM) of valves from the Lac de Guiers type population (*Van de Vijver* sample *SEN-42*). **56.** SEM girdle view of an entire frustule showing the partectal pores and the mantle areolae. **57.** SEM external view of an entire valve with typical undulating raphe branches. **58.** SEM external detail of the apex and the axial area with the depressed groove on both sides of the raphe. **59.** SEM external detail of the valve mantle. Scale bars: 10 μm .



Figs 60–65. *Mastogloia senegalensis* Van de Vijver, Fofana, Sow & Ector sp. nov. Scanning electron micrographs (SEM) of valves from the Lac de Guiers type population (*Van de Vijver* sample *SEN-42*). **60.** SEM internal view of an entire valve with the partectal ring. **61–62.** SEM internal details of the partectal ring near the valve apices showing the cleft on each apex. **63.** SEM internal detail of the central area and part of the partectal ring. **64.** SEM internal detail of the partecta showing the partectal walls with 2–4 series of small, rounded pores loosely aggregated in distinct plaques. **65.** SEM internal view of a valve apex without the partectal ring (note the small pseudoseptum). Scale bars: 60–63, 65 = 10 μm ; 64 = 1 μm .

mantle junction, biseriate near the mantle edge, composed of several rounded to irregularly shaped pseudoloculi (Fig. 59). Valve face clearly subdivided into two zones: outer zone composed of uniseriate striae, with up to 3–7 rounded pseudoloculi, central zone restricted to both sides of the raphe-sternum, formed by a shallow, but distinct lanceolate median depression (Fig. 57). Close to the raphe, one row of irregularly scattered rounded pseudoloculi present (Fig. 58), whereas in the depressions on both sides of the axial area, pseudoloculi transapically elongated, rectangular, diminishing in size towards the apices (Fig. 58). Central area slightly raised, thickened. Small hyaline areas present at the apices (Figs 57–58). Shallow irregular depressions sometimes visible in the axial area (Figs 57–58). Internally, hyaline raphe sternum H-shaped lyrifiform, clearly raised (Figs 60, 63). Well-developed, raised costa-like interstriae interrupted by the raphe-sternum extending from the axial area towards the valve margins, separating the areolae (Figs 60, 63). Inner areolae arranged in groups of 6 per pseudolocus (Fig. 62). Raphe branches straight with indistinct, slightly deflected proximal endings, terminating on a weakly raised central nodule (Figs 60, 63). Valve apices with small pseudosepta covering the distal raphe endings (Fig. 65).

Girdle composed of the valvocopulae and one open, non-perforated copula (Fig. 56). Valvocopulae with partectal ring, opening near the apices through a series of partectal pores (Figs 56, 59). Partectal ring opening at the poles by a cleft, covering entirely the pseudosepta (Figs 60–62). Lacunae never present (Figs 61–62). Partecta extending almost entirely to the valve apex, with only a small siliceous flange (Figs 60, 64). Partecta subequal in size with the large ones grouped in the middle, the smaller ones nearer to the apices (Fig. 60). Partecta ornamented with several series of small, rounded areolae, loosely aggregated in distinct plaques and arranged inwardly (Fig. 64).

Discussion

Hustedt (1933) subdivided the genus *Mastogloia* into 11 different sections mainly based on the structure, number and organization of the partecta. One of these sections, '*M. sect. Sulcatae*', presents valves with a typical median depression on both sides of the raphe sternum, often also visible internally as lateral sterna. Pennesi *et al.* (2011, 2012) revised '*M. sect. Sulcatae*' and proposed two subgroups, a first one showing external siliceous outgrowths in the median depression, and a second one only showing the median depression. It is clear that both species observed in the Lac de Guiers material belong to the '*Sulcatae* subgroup 2' as defined by Hustedt (1933) and Pennesi *et al.* (2012). The valves of *M. belaensis* showed a clear H-shaped sternum in LM although based on SEM observations the lateral hyaline zones are almost not depressed whereas the internal views clearly indicated the presence of a raised, lyre-shaped lateral sternum. Therefore, the assignment of this taxon to the '*Sulcatae* subgroup 2' is justified. Moreover, species belonging to this section have typical undulating external raphe branches, a feature clearly observed in *M. belaensis*.

Although morphologically closely related, the analysis of the Lac de Guiers material based on both LM and SEM observations, confirmed the presence of two separate taxa. Differences could be noted in the shape and structure of the partectal ring, the structure of the raphe, the structure of the mantle areolae and the structure of the valve face. *Mastogloia belaensis* showed a typical flange separating the partecta from the valve margins and the presence of a lacuna on one apex. Both features are absent in *M. senegalensis* sp. nov. Moreover, *M. senegalensis* sp. nov. showed a longer series of partecta, reaching closer to the valve apices than in *M. belaensis*, where the series of partecta terminated at about $\frac{1}{4}$ to $\frac{1}{6}$ of the valve apices. The raphe in *M. belaensis* showed more clearly undulating external raphe branches than in *M. senegalensis* sp. nov. *Mastogloia senegalensis* sp. nov. has a biseriate part in the mantle striae whereas in *M. belaensis* the mantle striae are uniseriate with transapically elongated, rectangular pseudoloculi. On the valve face in *M. belaensis*, a hyaline lyre-shaped non-depressed sternum could be observed whereas in *M. senegalensis* sp. nov., this structure presented a typical depression. Both taxa also differ in the structure of their pseudoloculi. Internally, *M. belaensis* shows an irregular number of

areolae whereas in *M. senegalensis* sp. nov., a rather constant number of six areolae per pseudolocus has been observed.

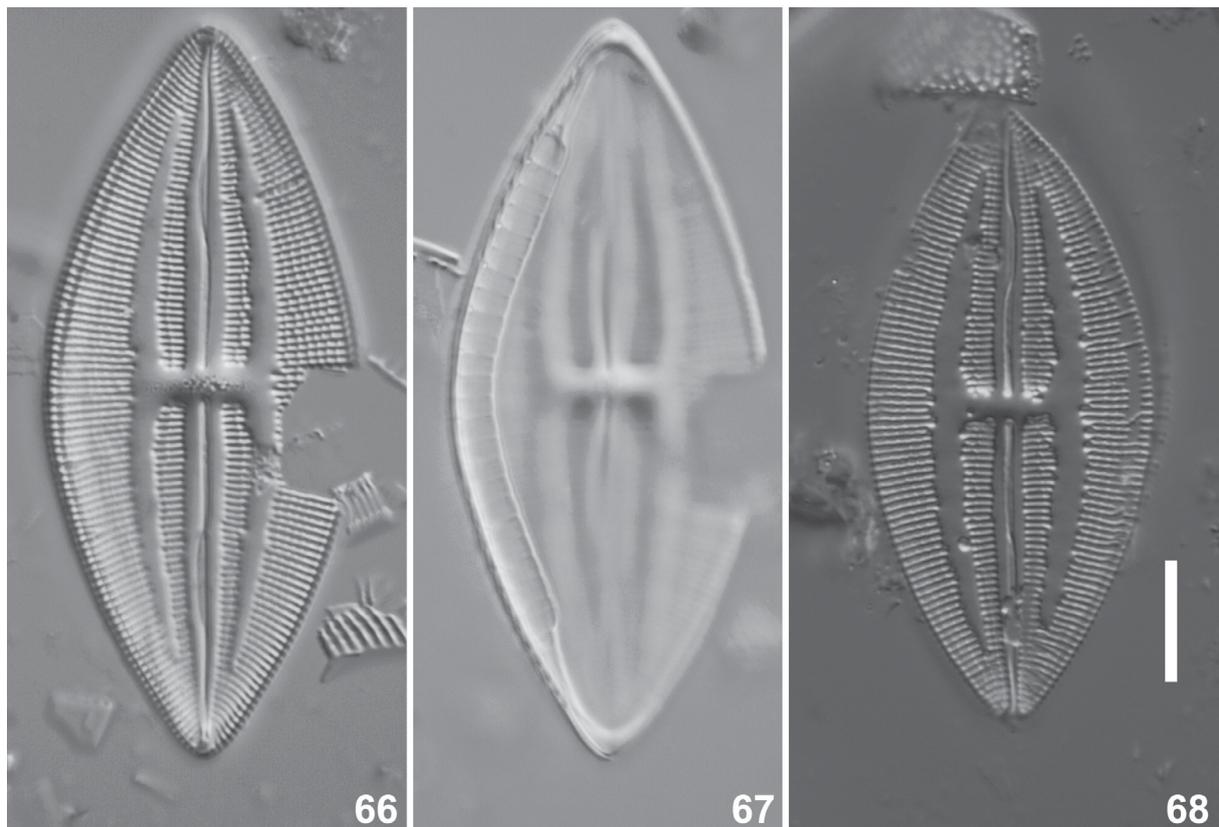
The first *Mastogloia* taxon from the Lac de Guiers could be identified as *M. belaensis*, originally described by Voigt from Pakistan in 1956 where it was found in some hot springs in the lower Hab River near Karachi (Voigt 1956). Unfortunately, the species was only illustrated by one picture. A morphological comparison with the illustration and the description in Voigt (1956) suggests an identification of valves from Lac de Guiers population as *M. belaensis*. The type material of *M. belaensis* has unfortunately never been investigated in detail using SEM techniques (Gaul *et al.* 1993; Henderson & Reimer 2003) as despite some efforts, it could not be retrieved. Although only one single LM picture was shown in Voigt (1956), there seem to be hardly any morphological differences between the valve from Pakistan and those of the Lac de Guiers population. The valve dimensions match entirely the numbers mentioned in the original description although the largest valves from the Lac de Guiers population are slightly larger (99 μm vs 92 μm) with a higher number of pseudoloci in 10 μm . The smaller valves that were observed could be identified as *M. belaensis* var. *elliptica* M. Voigt, described from the same habitats as the nominate variety (Voigt 1956). However, SEM observations of a large range of valves showed no structural differences. In the original description, Voigt (1956) indicated 9 μm as minimum valve width, a number never reached in the valves from Lac de Guiers population. Other *Mastogloia* taxa belonging to '*M. sect. Sulcatae*' all showed sufficient differences to be separated from *M. belaensis*, differing mostly in having a more developed lyre-shaped sternum (e.g., *M. braunii*, *M. vasta* Hust., *M. lyra* Lobban & Pennesi and *M. vestigiostriata* Al-Handal & Pennesi) or a different partecta-arrangement (e.g., *M. sergeiana* Pennesi & Poulin, *M. exilis* Hust. and *M. pumila* var. *papuarum* Cholnoky) (Hustedt 1933; Cholnoky 1963; Pennesi *et al.* 2012; Lobban & Pennesi 2014; Al-Handal *et al.* 2015). Two recently described *Mastogloia* taxa (*M. abnormis* Al-Handal & Pennesi and *M. descrepata* Pennesi & Al-Handal) show a close resemblance to *M. belaensis* (Al-Handal *et al.* 2016). Both taxa could be separated in being smaller with less undulating raphe branches and the absence of lacunae in the partectal ring. Moreover, the middle partecta in *M. belaensis* are larger than the other partecta whereas in *M. descrepata*, all partecta are uniform in size and shape.

Mastogloia belaensis is poorly known worldwide. Apart from the original description from Pakistan (Voigt 1956), only a few records exist. Munir *et al.* (2013) showed one LM picture of *M. belaensis* from Lake Kallar Kahar, an inland brackish water body situated in District Chakwal, Pakistan. Furthermore, only one other literature record of *M. belaensis* could be confirmed whereas another could be added after correction of the original identification. Witkowski *et al.* (2000: pl. 74 fig. 1) showed one picture from the Moroccan coast. The other population that is identified in Witkowski *et al.* (2000: pl. 84 figs 14–17) as *M. belaensis* shows a complete different partecta structure and should therefore not be identified as *M. belaensis*. A second observation was made by Gasse (1986: pl. 12 figs 4–5) from Lake Gamari (Ethiopia) who misidentified it as the more common species *M. braunii* but analysis of the published picture revealed that it should be identified as *M. belaensis*.

The second species, *M. senegalensis* sp. nov., shows some similarity with *M. braunii*, a species described by Grunow in 1863 from El Tor, Egypt. Until now, the type material of this Grunow taxon has never been analysed. All comparisons were based on other populations. Stephens & Gibson (1980) illustrated four valves of a presumable population of *M. braunii* from Florida whereas Navarro (1988) showed SEM illustrations of several valves from a population of Cabo Rojo, a municipality situated on the southwest coast of Puerto Rico. The Lac de Guiers population differs however from both published records in having a different stria structure on the mantle. The population in Stephens & Gibson (1980) presents uniseriate mantle striae with transapically elongated pseudoloci whereas the Lac de Guiers population has typically biseriate striae on the mantle. Apart from the mantle striae, several other differences could be noted. The central area in the Lac de Guiers population is larger and more rectangular in comparison

with the illustrated populations from Puerto Rico and Florida. Valves from both populations from Florida and Puerto Rico have a more slender, strictly lanceolate valve outline, whereas valves from the Lac de Guiers population has clearly elliptic-lanceolate valves.

Analysis of the type material of *M. braunii*, however, revealed that the population illustrated by Stephens & Gibson (1980) does not represent *M. braunii* s. str. and most likely should be described as a new taxon. The main difference with *M. braunii*, as it was described by Grunow (1863), consists in the structure of the mantle striae. *Mastogloia braunii* s. str. has mantle striae that are uniseriate near the valve face/mantle junction, becoming biseriate near the mantle edge, composed of several rounded to irregularly shaped pseudoloculi whereas *M. braunii* sensu Stephens & Gibson (1980) show only one elongated pseudoloculus following a small rounded one. The same applies for the Navarro (1988) population from Puerto Rico. Pennesi *et al.* (2011, 2012), Lobban & Pennesi (2014) and Al-Handal *et al.* (2015), discussing species from '*M. sect. Sulcatae*', all compared their species with *M. braunii* (as illustrated by Stephens & Gibson 1980) but none of them discussed the shape of the mantle areolae. *Mastogloia lyra* has a very shallow mantle on which the valve face striae continue as uniseriate rows of small pseudoloculi (Lobban & Pennesi 2014). *Mastogloia vestigiostriata* has a well-developed mantle with uniseriate striae composed of large pseudoloculi (Al-Handal *et al.* 2015). *Mastogloia pisculus* Cleve shows similar biseriate striae on the mantle as in the Lac de Guiers population (Pennesi *et al.* 2012). *Mastogloia sirbonensis* A.Ehrlich, described from Egypt, is somewhat similar but has



Figs 66–68. *Mastogloia baldjikiana* Grunow. Light micrographs (LM) of valves from slide 545 (Baldjick, Types du Synopsis des diatomées de Belgique, Van Heurck collection, BR). **66–67.** Same valve taken at different foci. **66, 68.** LM views of 2 valves showing variation in valve size and shape. **67.** LM view of the partectal ring with the partecta. Scale bar: 10 μm .

smaller valve dimensions (maximum width up to 14 μm whereas *M. senegalensis* sp. nov. goes up to 17 μm) and two very large middle partecta, extending out of the partectal ring, a feature never observed in *M. senegalensis* sp. nov., where the middle partecta are larger but never extending (Ehrlich 1975). The three discussed *Mastogloia* taxa show some resemblance with *M. baldjikiana*. Analysis of slide 545 from the Types du Synopsis des diatomées de Belgique, made from a sample taken at Baldjick (Baltschik), Bulgaria (Figs 66–68), revealed a large *Mastogloia* species with a lyrate hyaline structure as could be observed in the three *Mastogloia* species discussed in this paper. However, this structure is much larger and more heavily silicified in *M. baldjikiana* compared to the three taxa discussed in this paper. Moreover, the valves have a more elliptic-rhombic valve outline with a lower length/width ratio compared to *M. braunii*, *M. senegalensis* sp. nov. and *M. belaensis*. Additionally, *M. baldjikiana* possesses partecta having an equal width and length throughout the entire partectal ring, contrary to *M. braunii*, *M. senegalensis* sp. nov. and *M. belaensis* that have larger partecta in the middle compared to the ones at the end of the partectal ring. These differences exclude totally any conspecificity with all three discussed taxa.

Mastogloia senegalensis sp. nov. can be separated from *M. braunii* s. str. based on the structure of the valvocopula. The analysis of the *M. braunii* type material clearly showed the presence of two lacunae whereas the Senegal population never showed lacunae. These lacunae are one of the discriminating features according to Paddock & Kemp (1990). Based on valve dimensions, *M. braunii* is always a lot larger with a valve width often exceeding 20 μm whereas the Senegal population, despite being very large never showed valves wider than 17 μm with a higher stria density (16–18 vs 15–16 in 10 μm). The valve outline slightly differs. *Mastogloia braunii* s. str. shows more apiculate valves with acutely rounded, protracted apices whereas in the Senegal population, the apices are more truncated, less protracted, though still acutely rounded. Based on these differences and the absence of other comparable taxa, the description of the Senegal populations as a new species is justified.

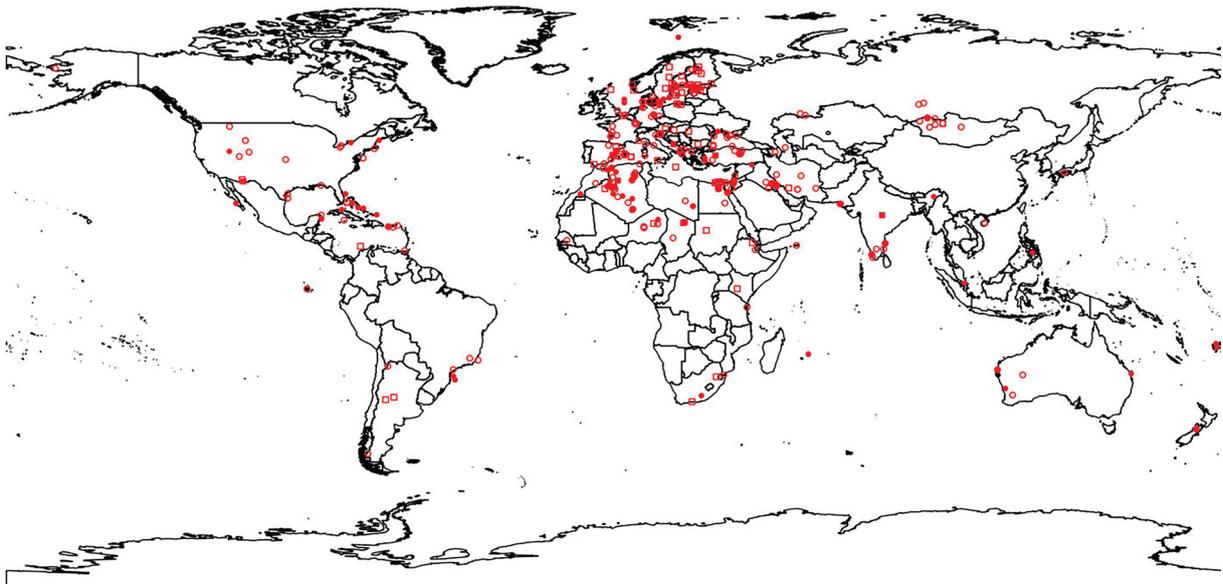


Fig. 69. World distribution of *Mastogloia braunii* s. lat. according to the literature. Circles: recent records. Squares: fossil records. Filled symbols indicate confirmed (illustrated) records. 331 locations were found based on 271 references.

Mastogloia braunii s. lat. has been reported from a large number of localities worldwide (Fig. 69). Fig. 69 shows the geographical distribution of this species based on the literature. It is clear that most records originate from the northern hemisphere, more specifically from Europe, northern Africa and the Middle East. It is, however, unclear whether all these records represent *M. braunii* s. str. or belong in fact to other, probably undescribed taxa. In Africa, the species was only rarely observed, and also these records need to be verified.

Acknowledgements

The project was financed by the Agence universitaire de la Francophonie (AUF) (project n° D-2092 RR 723). We would like to thank Dr. Anton Igersheim (Grunow Collection, Natural History Museum Vienna, Austria), for sending us the type material of *Mastogloia braunii*. Dr. Christopher S. Lobban and Dr. Chiara Pennesi are thanked for stimulating discussions. The new JEOL-JSM-7100F SEM facilities at the Botanic Garden Meise has been realized with the financial support of the IWT. Two anonymous reviewers are thanked for their comments that helped to improve this manuscript.

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Manuscript received: 11 May 2017

Manuscript accepted: 11 July 2017

Published on: 5 December 2017

Topic editor: Frederik Leliaert Ph.D., Koen Martens

Desk editor: Alejandro Quintanar

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