



Cymatosirella Dąbek, Witkowski & Sabbe *gen. nov.*, a new marine benthic diatom genus (Bacillariophyta) belonging to the family Cymatosiraceae

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Abstract

We present a new marine benthic diatom genus *Cymatosirella gen. nov.* The genus belongs to the family Cymatosiraceae and has been assigned to the subfamily Extubocelluloideae on the basis of ultrastructural cell wall features. It has isovalvate cells with undulate valves and is characterized by the absence of tubular processes and the occurrence of hollow spines which are observed for the first time in the Cymatosiraceae. The new genus contains four species, two of which are transferred from the genus *Cymatosira*, viz. *Cymatosirella capensis comb. nov.* and *Cymatosirella minutissima comb. nov.*, and two which are new to science, viz. *Cymatosirella benguelensis sp. nov.* and *Cymatosirella taylorii sp. nov.* *Cymatosirella capensis* is chosen as the generitype. The new genus includes a group of very small taxa inhabiting the intertidal zone of the Atlantic Ocean with three species in South Africa and one in Europe. *C. capensis* was originally described by Giffen from Langebaan Lagoon (a shallow marine inlet in the southern part of Saldanha Bay, Western Cape Province), on the basis of light microscopy only, and has to date only been illustrated by line drawings. *C. minutissima*, so far only known from the Westerschelde estuary (The Netherlands), has previously been documented in more detail using both light and electron microscopy. Here, we present the results of detailed light and electron microscopical investigations of *C. capensis*, both from its original type material and from recently collected samples from the type locality and neighboring littoral areas in the Western Cape Province, and of the new species *C. benguelensis* and *C. taylorii*, also from Western Cape localities. All species are compared with similar small taxa belonging to the Cymatosiraceae, subfamily Extubocelluloideae.

Key words: *Cymatosirella*, diatoms, Giffen, marine littoral, new genus

Introduction

The diatom family Cymatosiraceae Hasle, von Stosch & Syvertsen (1983) comprises bipolar centric taxa that belong to 13 extant genera and 5 fossil genera, divided into two subfamilies, the Cymatosiroideae and the Extubocelluloideae (Table 1). The fundamental difference between these two subfamilies is that Cymatosiroideae have heterovalvate cells with process on one valve and pili on the other, whereas Extubocelluloideae are isovalvate, which means that the process occurs or is observed very rarely (Hasle *et al.* 1983). Moreover, features like marginal spines, marginal ridge or pili, which are characteristic for Cymatosiroideae, are absent in Extubocelluloideae. Representatives of the family Cymatosiraceae are present in the fossil record since the Eocene (Witkowski *et al.* 2011). Some authors have suggested a relationship with pennate diatoms (Medlin & Kaczmarek 2004, Sorhannus 2004, 2007, Williams 2007, Witkowski *et al.* 2011). The Cymatosiraceae have been the subject of detailed taxonomic and ultrastructural studies during the last decades (cf. Salah 1955, Hasle *et al.* 1983, Takano 1985, Nakata 1987, Gardner & Crawford 1993, Riaux-

Gobin & Chrétiennot-Dinet 2000, Sabbe *et al.* 2010, Sato 2010). New species and genera are still being discovered and the potential for new discoveries remains high (A. Witkowski & A. Gomes, pers. comm.).

The history of benthic marine diatom research on the west coast of South Africa is inherently linked with Professor Malcolm Hutchinson Giffen (1902–1986). In the 1970s and 1980s, Giffen either collected material or received samples from numerous coastal localities including Sea Point near Cape Town (Giffen 1970) in the south, and from St. Helena Bay (Giffen 1973), Langebaan Lagoon (Giffen 1975), Saldanha Bay (Giffen 1976) and Port Nolloth on the west coast of Namaqualand (Giffen 1984). Numerous new marine diatom taxa were described, and many of these appear to be distributed globally in the marine littoral. For example, *Dimeregramma inane* Giffen (1970: 91 [= *Pteroncola inane* (Giffen) Round in Round, R.M. Crawford & D.G. Mann 1990: 390]), *Amphora helenensis* Giffen (1973: 33), and *Navicula viminoides* Giffen (1975: 88) have been shown to be abundant in numerous marine littoral sites worldwide, including the Baltic Sea (Snocijs & Potapova 1995, Snocijs & Balashova 1998, Witkowski *et al.* 2000).

TABLE 1: List of genera belonging to the family Cymatosiraceae.

	Name, authority, year	Recent/Fossil	Number of species*
	<i>Arcocellulus</i> Hasle, von Stosch & Syvertsen 1983	R	2
	<i>Bogorovia</i> Jouse ex Yanagisawa 1995b	F	16
	<i>Brockmanniella</i> Hasle, von Stosch & Syvertsen 1983	R	1
	<i>Campylosira</i> Grunow ex Van Heurck 1885	R/F	9
	<i>Cymatosira</i> Grunow 1862	R/F	29
Cymatosiroideae	<i>Hyalinella</i> Witkowski, Lange-Bertalot & Metzeltin 2000	R	1
	<i>Kisseleviella</i> Scheschukova-Poretzkaja 1962	F	8
	<i>Koizumia</i> Yanagisawa 1994	F	3
	<i>Lennoxia</i> Thomsen & Buck 1993	R	1
	<i>Leyanella</i> Hasle, von Stosch & Syvertsen 1983	R	1
	<i>Minutocellus</i> Hasle, von Stosch & Syvertsen 1983	R	3
	<i>Papiliocellulus</i> Hasle, von Stosch & Syvertsen 1983	R	2
	<i>Plagiogrammopsis</i> Hasle, von Stosch & Syvertsen 1983	R	6
	<i>Praecymatosira</i> Strelnikova 1979	F	1
	<i>Rossiella</i> Desikachary & Maheshari ex Yanagisawa 1995a	F	18
Extubocelluloideae	<i>Extubocellulus</i> Hasle, von Stosch & Syvertsen 1983	R	2
	<i>Pierrecomperia</i> Sabbe, Vyverman & Ribeiro 2010	R	1
	<i>Pseudoleyanella</i> Takano 1985	R	1

* according to Catalogue of Diatom Names, California Academy of Sciences, On-line Version updated 19/08/2011. Compiled by Elisabeth Fourtanier & J. Patrick Kociolek. Available online at <http://research.calacademy.org/research/diatoms/names/index.asp>; visited on 11/05/2013.

Recently, a small species of *Cymatosira* Grunow, *C. minutissima* Sabbe & Muylaert (Sabbe *et al.* 2000: 246, figs 17–20, 28–31), was described from the intertidal zone of the Westerschelde Estuary in the Netherlands. It was assigned to *Cymatosira*, mainly on the basis of negative features, i.e. it lacked features which are diagnostic of other genera in the Cymatosiraceae. However, it also lacked a number of features characteristic of the genus *Cymatosira*, such as a subcentral rimoportula, heterovalvy and a marginal ring of distinct spines. The absence of these features was attributed to the minute size of the species when compared

with typical representatives of *Cymatosira* (Sabbe *et al.* 2010). As the authors pointed out, *Cymatosira minutissima* showed some resemblance to *Cymatosira capensis* described by Giffen (1975: 79, figs 36–39) as a “small, faintly silicified and difficult to resolve even under phase contrast” species from Langebaan Lagoon. His early description, however, included only line drawings and thus knowledge regarding its exact morphology and ultrastructure remained limited. In addition, *C. capensis* has never been reported outside the type locality. The species was assigned to the genus *Cymatosira* on the basis of its general resemblance (in the light microscope) to *Cymatosira belgica* Grunow in Van Heurek (1881: pl. 45, figs 38–41; 1885: 157).

In the present study, we examined the type and recent materials of *Cymatosira capensis*, a small marine benthic species described by Giffen (1975) from South Africa. We also report the discovery and provide formal descriptions of two new species from the marine littoral of the west coast of South Africa, which appear to be closely related to *C. capensis*, but also to *C. minutissima*. All four species consistently display a unique combination of features (e.g. isovalvy, absence of processes, pili, marginal ridges, fascia and/or pseudosepta) which hitherto have not been reported for any genus in the family Cymatosiraceae. We therefore propose a new genus, *Cymatosirella* Dąbek, Witkowski & Sabbe to accommodate these four species. Below, the new genus and the new species, viz. *Cymatosirella benguelensis* Dąbek & Witkowski *sp. nov.* and *Cymatosirella taylorii* Dąbek & Witkowski *sp. nov.*, are described in detail using light (LM), scanning electron (SEM) and transmission electron microscopy (TEM). In addition, we provide a detailed description of the type and recent material of *Cymatosirella capensis* (Giffen) Dąbek, Witkowski & Archibald *comb. nov.*

Material and Methods

Slides studied included dried oxidized samples made from the original Giffen materials collected from the Langebaan Lagoon (Giffen 1975), these are: SZCZ 6849 = G628, SZCZ 6850 = G629, SZCZ 6851 = G630/7, SZCZ 6853 = G633. Malcolm H. Giffen slides are component of the South African Diatom collection previously housed in the CSIR Durban laboratories but now transferred to the North-West University, Research Unit for Environmental Sciences, Potchefstroom, South Africa. The South African Institute for Aquatic Biodiversity (SAIAB), Grahamstown, South Africa is the custodian of this international collection. In addition, we examined a Giffen slide from the collection in the British Museum (BM 80509, made from Giffen sample G630/2) and recent freshly collected material obtained in February 2011 from intertidal flats and beaches composed of sand, rocks and macroalgae from various localities on the west coast of South Africa (Fig. 1, Table 2).

Samples collected by the authors and splits of the original Giffen samples were treated with 10 % hydrochloric acid (HCl) to remove calcium carbonate particles and, after thoroughly washing, were boiled in 37 % hydrogen peroxide (H₂O₂) to remove organic matter. The final suspensions were washed several times with distilled water and drops of each were placed onto cover slips and left to evaporate overnight at room temperature. Permanent preparations were then made with Naphrax® mountant.

The slides were examined using Nikon Eclipse E600 and Zeiss Axio Scope A1 light microscopes. Morphometric measurements were performed using ImageJ software. SEM was performed at J.W. Goethe University in Frankfurt am Main, Germany with a Hitachi S4500 microscope. TEM and SEM were performed at Warsaw University of Technology using Hitachi S5500 and Hitachi S8000 microscopes. The Hitachi S5500 enables examination of diatom valves under both scanning and transmission modes.

Terminology follows Anonymous (1975), Hasle, von Stosch & Syvertsen (1983), Ross *et al.* (1979) and Round *et al.* (1990).

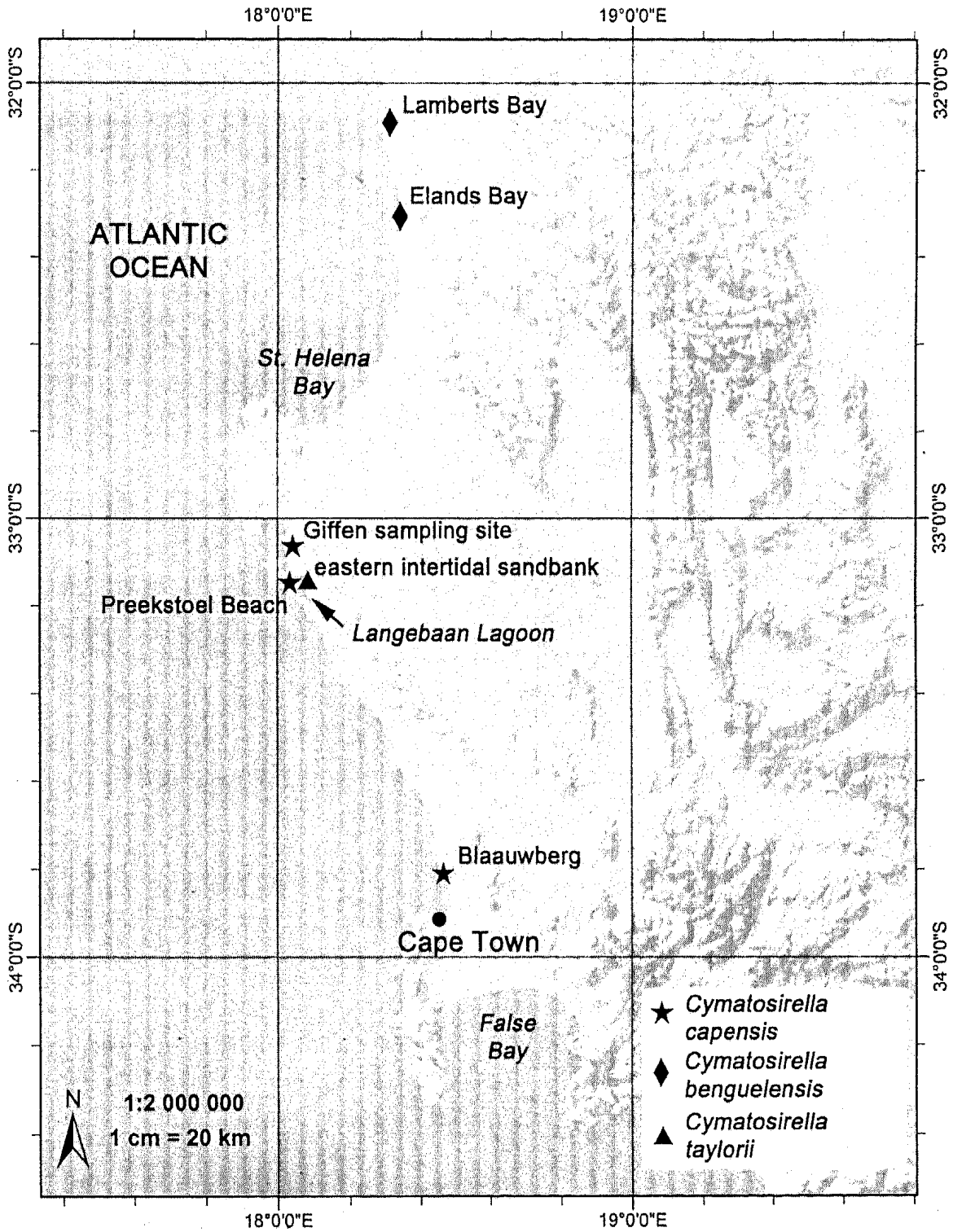


FIGURE 1: Sampling sites map, west coast of South Africa.

TABLE 2: Samples used during investigation (slides bear the corresponding numbers, except the BM slide).

Location	Sample number	Relative abundance [%]	Type of material
<i>Cymatosirella capensis</i> (Giffen) Dąbek, Witkowski & Archibald <i>comb. nov.</i>			
Langebaan Lagoon, Western Cape Province, South Africa; GPS: 33°5'S, 18°2' E	G628	3,7	brown masses of <i>Melosira nummuloides</i> and <i>Berkeleya rutilans</i> filaments
	G629	6,3	
	G630/7 holotype	10,3	<i>Enteromorpha</i> sp. mats
	G630/2 BM80509	not counted	
	G633	1,7	<i>Berkeleya</i> filaments together with <i>Enteromorpha</i> sp. and <i>Ectocarpus</i> sp.
Preekstoel Beach, Langebaan Lagoon, Western Cape Province, South Africa. GPS: 33°8'855" S; 18°1'863" E	SZCZ 17537	0,7	sand from shallow water in intertidal area
Blaauwberg, Western Cape Province, South Africa. GPS: 33°45'078" S; 18°26'468" E	SZCZ 17589	2	sand from beach with algae
<i>Cymatosirella benguelensis</i> Dąbek & Witkowski <i>sp. nov.</i>			
Lamberts Bay, Western Cape Province, South Africa. GPS: 32°5'179" S; 18°18'701" E	SZCZ 17497 holotype	18,7	sand from intertidal flat
Elands Bay, Western Cape Province, South Africa. GPS: 32°18'930" S; 18°19'951" E	SZCZ 17518	0,33	sand from rocky intertidal flat
<i>Cymatosirella taylorii</i> Dąbek & Witkowski <i>sp. nov.</i>			
Eastern part of Langebaan Lagoon, Western Cape Province, South Africa. GPS: 33°6'788" S; 18°2'631" E	SZCZ 17582 holotype	5,3	sand from intertidal flat

G—Giffen Collection, North-West University, Research Unit for Environmental Sciences, Potchefstroom, South Africa; BM—British Museum, London, UK; SZCZ—Szczecin University Collection, Poland.

Taxonomic results and species description

Division: **Bacillariophyta**

Class: **Mediophyceae** (Jouse & Proshkina-Lavrenko) Medlin & Kaczmarska 2004

Subclass: **Cymatosiropheycidae** Round *et al.* 1990

Order: **Cymatosirales** Round & Crawford in Round *et al.* 1990

Family: **Cymatosiraceae** Hasle, von Stosch & Syversten 1983

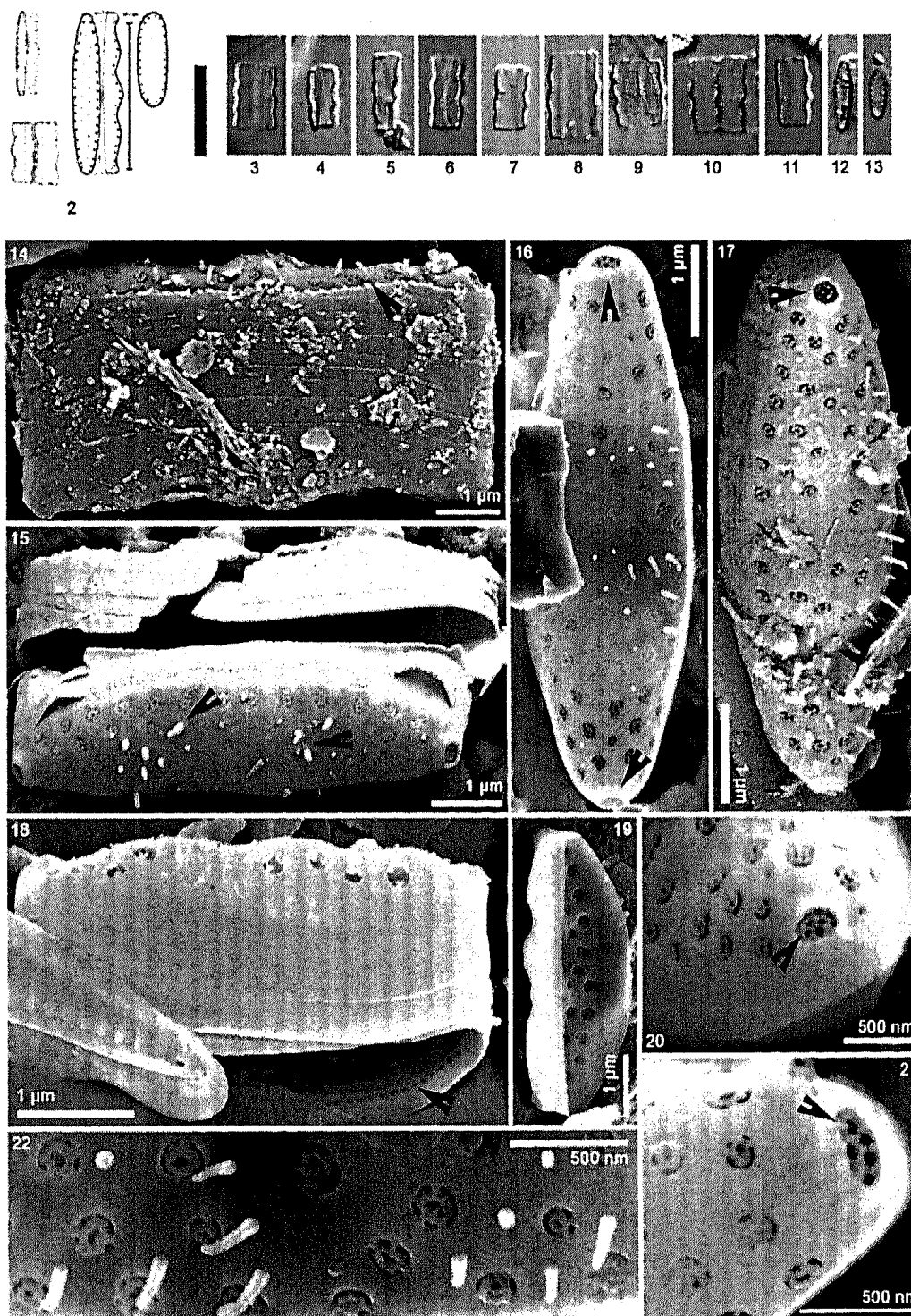
Subfamily: **Extubocelluloideae** Hasle, von Stosch & Syversten 1983

Cymatosirella Dąbek, Witkowski & Sabbe *gen. nov.* (Figs 2–58)

Typus generis: *Cymatosirella capensis* (Giffen) Dąbek, Witkowski & Archibald *comb. nov.*

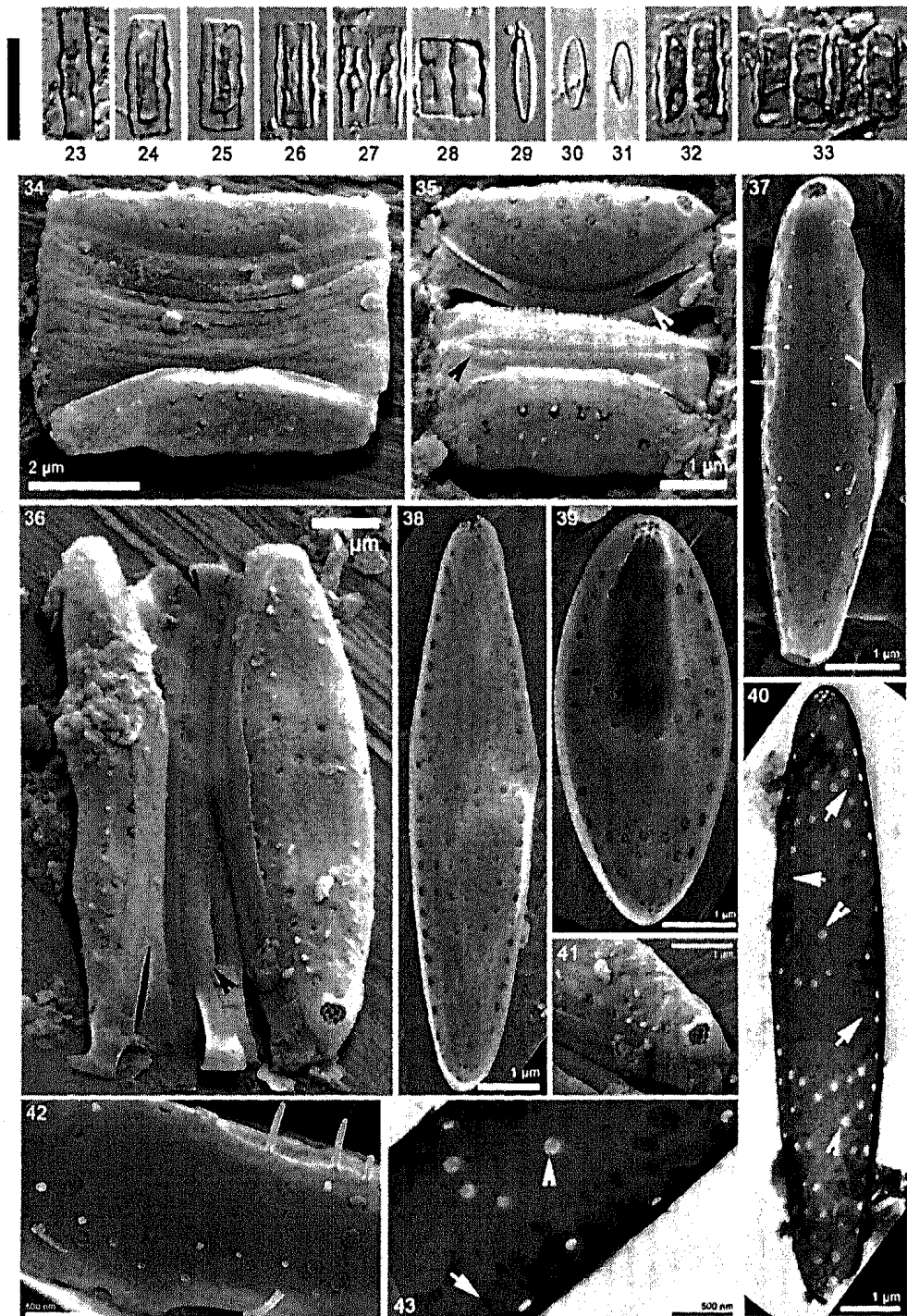
Cells rectangular and undulate in girdle view, single or a few cells joined together in short ribbon-like colonies, one plastid per cell. Frustules isovalvate without processes. Cingulum composed of numerous bands, each with one row of poroids. Valves elliptical to lanceolate, with rounded apices. Valve face undulate and areolate. Both apices bearing ocelluli, surrounded by an unperforated rim; porelli sometimes with spines in-between. Valve mantle deep without perforations. Areolae closed by cribra, volae or apparently without occlusions. Spines few, scattered on the valve face. Processes, marginal spines, marginal ridges, pili, pseudosepta or fascia are absent.

Etymology:—The generic name refers to the resemblance of this new genus to *Cymatosira* and to its very small size.



FIGURES 2–22: *Cymatosirella capensis* (Giffen) Dąbek, Witkowski & Archibald *comb. nov.*, Langebaan Lagoon, South Africa. Following images originate from: slide G630/2 (figs 10–15, 17), G628 (figs 3,4), G629 (figs 5–9), SZCZ 17582 (figs 18–21), SZCZ 17589 (figs 16, 22). Fig. 2: Original drawings of Malcolm H. Giffen of *Cymatosira capensis* (Giffen 1975). Figs 3–13: LM images. Scale bar = 10 µm. Figs 14–22: SEM images. Figs 14, 15: Frustule in girdle view with distinctly undulated outline and spines (arrowhead). Figs 16, 17: Valve view, each elevation bearing an ocellulus (arrowhead) surrounded by unperforated rim. Note the areolae with external cribra. Fig. 18: External view of the mantle and cingulum. Girdle bands are perforated by the one row of poroids (arrowhead). Fig. 19: Internal view of the mantle and areolae. Figs 20, 21: External view of ocelluli composed of porelli with small spines (arrowhead). Fig. 22: Valve surface view with hollow spines and areolae with external cribra.

Cymatosirella capensis (Giffen) Dąbek, Witkowski & Archibald *comb. nov.* (Figs 2–13 [LM], Figs 14–22 [SEM])
 Basionym: *Cymatosira capensis* Giffen (1975: 79, figs 36–39).
 Type:—SOUTH AFRICA. Western Cape Province: Langebaan Lagoon, Saldanha Bay (Giffen slide G 630/7, holotype!).



FIGURES 23–43: *Cymatosirella benguelensis* Dąbek & Witkowski *sp. nov.*, Lamberts Bay, South Africa. All images originate from the holotype slide SZCZ 17497. Figs 23–33: LM images. Scale bar = 10 µm. Figs 32, 33: Living cells with plastids. Figs 34–39, 41, 42: SEM images. Figs 40, 43: TEM images. Figs 34–36: Frustule in girdle view with complete cingulum. Bands with one row of poroids (arrowhead). Fig. 37: External view of valve. Note the simple occlusions closing areolae and spines on the valve face. Figs 38, 39: Internal view of the valve and ocelluli. Fig. 40: Valve with occlusions (arrowhead) and spines (arrow). Fig. 41: Ocellulus composed of 13 porelli (3 central porelli). Figs. 42, 43: Central, bulged part of the valve face surrounded by one row of poroids and spines. Fig. 43: Detail of valve showing occlusions (arrowhead) and spines (arrow).

Frustules rectangular and distinctly undulate in girdle view, valve mantle deep and unperforated. Valves elliptical to lanceolate with cuneate to rounded apices, 4.5–11 µm long, 2–3 µm wide. Valve surface areolate, areolae arranged either in a quincunx pattern or irregular, ca. 15–18 in 10 µm.

Habitat:—Atlantic Ocean, Langebaan Lagoon, rocky tidal flat overgrown by macroalgae mats. Langebaan Lagoon is a part of Saldanha Bay, located around 100 km north of Cape Town. This area is strongly influenced by water masses of the Atlantic Ocean and the cold, nutrient-rich Benguela Current. Langebaan Lagoon is sheltered from the coast, therefore sea surface temperature and salinity is much higher. The difference in the water temperature could be even more than 10°C between the open coast and Langebaan Lagoon, while the salinity is slightly higher than 35 ‰.

Observations:—The frustules are rectangular and distinctly undulate in girdle view, (Figs 2–11, 14). Cells are solitary or 2–4 cells joined together in short ribbon-like colonies (Fig. 10). The girdle is composed of numerous bands, each with one row of poroids (Figs 14, 15, 18). The valves are elliptical (smaller specimens) to lanceolate (larger specimens) with cuneate to slightly rounded apices, 4.5–11 µm long, 2–3 µm wide (Figs 12, 13, 16, 17). The valve surface is perforated by areolae externally closed by cribra; the areolae are more or less arranged in a quincunx pattern (cf. Giffen 1975) or irregularly, ca. 15–18 in 10 µm (Figs 16, 17); the areolae are easily visible in LM. Each valve bears two slightly elevated ocelluli (Figs 14–17), which are surrounded by an unperforated rim. The ocelluli are composed of 12–15 porelli with small spines set in-between (Figs 20, 21); there are four central porelli (Figs 17, 20). The valve mantle is deep and unperforated (Figs 18, 19). Spines are irregularly placed on the valve face but mainly occur around the centre of the valve (Figs 15–17); they are hollow and tapered (Fig. 22). Processes, pili nor fascia have not been observed.

Ecology and geography:—*Cymatosirella capensis* was found only in tidal and intertidal samples from the west coast of South Africa. It was most abundant in samples with sand (SZCZ 6849 = G628, SZCZ 6850 = G629, SZCZ 17537) and with seaweeds e.g. species of *Enteromorpha* and *Ectocarpus* (SZCZ 6851 = G630/7, SZCZ 6853 = G633) in the Langebaan Lagoon (Giffen 1975). A few specimens were also identified in a sandy sediment sample from Blaauwberg beach near Cape Town (SZCZ 17589). *Cymatosirella capensis* is most probably an epipsammic and/or epiphytic intertidal diatom species.

Cymatosirella benguelensis Dąbek & Witkowski *sp. nov.* (Figs 23–33 [LM], Figs 34–43 [SEM])

Frustules rectangular in girdle view with undulate outline. Valves lanceolate, 4–12 µm long and 1–4 µm wide. Valve surface areolated with a ring of areolae present along the valve margin, 15–26 in 10 µm; some areolae irregularly scattered over valve face.

Type:—SOUTH AFRICA. Western Cape Province: Lamberts Bay, sand from the intertidal flat (32°5'179"S; 18°18'701"E), collected on 16th February 2011, by Dąbek, Witkowski & Archibald (SZCZ 17497, holotype!).

Habitat:—Lamberts Bay is located about 280 km north of Cape Town and is influenced by Atlantic Ocean water masses, part of the Benguela Current upwelling zone. Coastal water temperature rarely exceeds 19°C, salinity is ca. 35 ‰. Beaches are sandy, occasionally with rocky outcrops and tidal pools. Climate is moderate with hot and dry summers and wet, rainy and cold winters.

Etymology:—Named after the Benguela Current (Atlantic Ocean) which washes the west coast of South Africa.

Observations:—The frustules are rectangular in girdle view with an undulate outline (Figs 23–28, 34–36). There is a single, large plastid per cell (Figs 32, 33). Cells solitary or forming small ribbon-like colonies with 2–4 cells (Figs 27, 32, 33). The girdle is composed of 8–11 bands each with a single row of poroids (Figs 34–36). The valves are lanceolate (Figs 29–31, 36–40), 4–12 µm long and 1–4 µm wide. A marginal ring of areolae (15–26 in 10 µm) is present along the valve margin; other areolae are irregularly scattered across the valve face but less so in around the slightly raised centre of the valve (Figs 37–40). The areolae are more densely packed near the apices. Externally, the areolae are closed by simple volate occlusions (Figs 40, 42, 43). The ocelluli are composed of 12–14 porelli in the largest specimens and 6–8 in the smallest, with 3 central porelli (Figs 36, 39, 41). Hyaline rings around ocelluli are present (Figs 37, 41). Spines are probably

hollow and tapered and are located in the central part of the valve and along the valve margin (Figs 40, 42, 43). Processes, pili, pseudosepta nor fascia have not been observed.

Ecology and geography:—*Cymatosirella benguelensis* was most abundant in a sand sample from Lamberts Bay (SZCZ 17497) from an intertidal pool located close to rocky outcrops. A few valves were also observed in a sample from Elands Bay (SZCZ 17518). *Cymatosirella benguelensis* most probably belongs to the epipsammon.

***Cymatosirella taylorii* Dąbek & Witkowski sp. nov.** (Figs 44–51 [LM], Figs 52–58 [SEM])

Frustules rectangular in girdle view with undulated outline. Valves lanceolate to elliptical, 4–13 µm long and 1–4 µm wide. Central part of valve face and apices elevated. Valve surface areolated, with ca. 50 areolae in 10 µm. Areolae distributed over the whole valve face.

Type:—SOUTH AFRICA. Western Cape Province: eastern part of Langebaan Lagoon, Saldanha Bay, sandy sediment from the intertidal sandbank (33°6'788"S; 18°2'631"E) collected on 19th February 2011 by Dąbek, Witkowski & Archibald (SZCZ 17582, holotype!).

Habitat:—The eastern part of Langebaan Lagoon is a shallow, sandy tidal pool. High and low tide occur twice a day. Sea surface water temperature exceeds 18° C

Etymology:—Named after and dedicated to our friend and prominent South African diatomologist Dr. Jonathan Taylor (North-West University, Potchefstroom, South Africa).

Observations:—The frustules are rectangular in girdle view with an undulated outline (Figs 44–47, 52). Cells are predominantly solitary, but occasionally two cells were found joined together (Fig. 44). The girdle is broad, and composed of numerous bands bearing one row of fine puncta (Fig. 52). The valves are lanceolate to elliptical, 4–13 µm long and 1–4 µm wide (Figs 48–51, 53). The central part of the valve face and apices are elevated (Figs 54, 56). The valve surface is strongly ornamented with areolae, ca. 50 in 10 µm (Figs 53–56). Near the central elevation, areolae are randomly distributed; further towards the apices they are arranged in longitudinal rows (Figs 53, 55, 56). Occlusions have not been observed. Each valve bears two ocelluli, composed of 7–10 porelli, with 1–2 central ones (Figs 57, 58). The ocelluli are surrounded by a hyaline ring of silica (Figs 53, 55, 57). No areolae occur near the ocelluli (Figs 53, 57). Spines were observed only rarely. Processes, pili, fascia nor pseudosepta have not been observed.

Ecology and geography:—*Cymatosirella taylorii* has been found in only one sandy sample (SZCZ 17582, the holotype) from an intertidal sandbank in the eastern part of the Langebaan Lagoon. Only a dozen valves have been found. This species most probably belongs to the epipsammon.

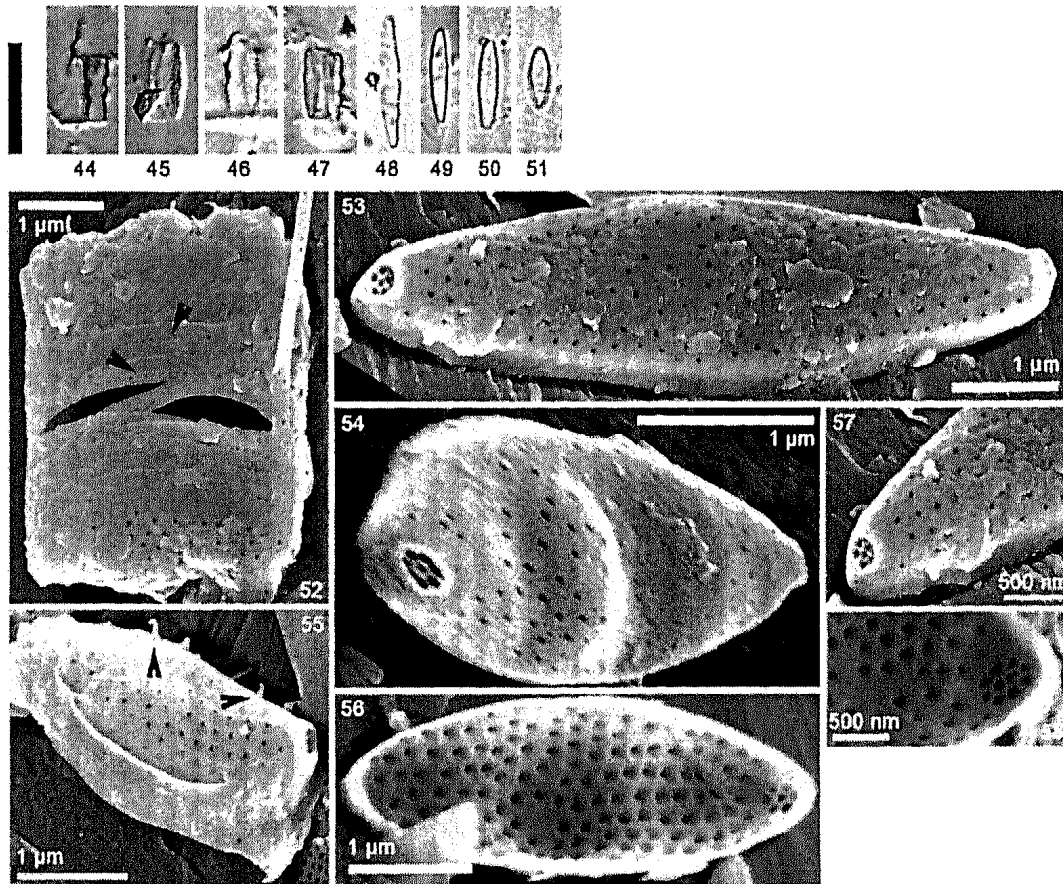
***Cymatosirella minutissima* (Sabbe & Muylaert) Dąbek, Witkowski & Sabbe comb. nov.**

Basionym: *Cymatosira minutissima* Sabbe & Muylaert in Sabbe, K., Vanelslander, B., Ribeiro, L., Witkowski, A., Muylaert, K. & Vyverman, W. (2010: 246, figs 17–20, 28, 31).

For a detailed description of this species, see Sabbe *et al.* (2010).

Key to LM identification of the species

1. Frustules rectangular and undulated in girdle view, valve face elliptical to lanceolate, arched with distinct elevation in the middle and near apices, lacking processes, fascia, pili, pseudosepta, marginal spines *Cymatosirella*
 - 1a. Valve face fully areolate (15–18 in 10 µm), areolae relatively large and prominent under LM *Cymatosirella capensis*
 - 1b. Frustules smaller (2,5–10 µm long, 1,5–2,5 µm broad) and less undulate than *Cymatosirella capensis*, valve face areolate (18,5–24 in 10 µm), areolae prominent under LM..... *Cymatosirella minutissima*
 - 1c. Valve face densely areolate (ca. 50 in 10µm), but areolae poorly visible only as small points, under LM *Cymatosirella taylorii*
 - 1d. Large areolae positioned along valve margin and prominent under LM (ca. 15–26 in 10µm), scattered areolae in the central part of the valve face poorly visible *Cymatosirella benguelensis*



FIGURES 44–58: *Cymatosirella taylorii* Dąbek & Witkowski *sp. nov.*, Langebaan Lagoon, South Africa. All images originate from the holotype slide SZCZ 17582. Figs 44–51: LM images. Scale bar = 10 µm. Figs 52–58: SEM images. Fig. 52: Frustules in girdle view with complete cingulum, girdle band perforated by one row of poroids (arrowhead). Figs 53–55: Valve face view. Note the poroids on the valve surface without oclusions and ocelluli surrounded by the rim. Fig. 55: Valve with spines (arrowhead). Fig. 56: Internal view of the valve. Fig. 57: Ocellulus in external view, composed of 8 porelli (1 central), surrounded by an unperforated rim. Fig. 58: Ocellulus in internal view, composed of 10 porelli (2 central).

Discussion

In this study, we present data on the morphology, ultrastructure, habitat and geographical distribution of four species in the newly established genus *Cymatosirella*. Three of the four species are found in marine littoral habitats of the west coast of South Africa, the remaining one from the Westerschelde Estuary (The Netherlands). A comprehensive summary of the most important morphological features of the four *Cymatosirella* species, alongside some similar species, is documented in Table 3.

SEM observations on specimens from the type locality of *C. capensis*, the two new species and *Cymatosirella minutissima* clearly show that they belong to the family Cymatosiraceae: the valves are bipolar, but lack the typical pennate valve face pattern, and possess the typical polar elevations with slightly offset ocelluli perforated by porelli. The areolae are occluded by vela and the cingulum is composed of numerous bands (Hasle *et al.* 1983: 14–16, Nakata 1987: 42, Round *et al.* 1990).

We believe that *Cymatosirella* should be placed into the subfamily Extubocelluloideae. Unlike the genera belonging to the subfamily Cymatosiroideae, species in *Cymatosirella* lack characters typical for this subfamily, such as a pseudoseptum and/or fascia (typical for *Plagiogrammopsis* and *Brockmanniella*, Hasle *et al.* 1983: 30, 35, Sato 2010), hair-like pili (characteristic for *Plagiogrammopsis*, *Minutocellus*, *Leyanella* and *Arcocellulus*, Hasle *et al.* 1983: 30, 38, 52, 55, Sato 2010) and marginal spines or a marginal ridge (as in *Cymatosira*, *Campylosira* and *Papiliocellulus*, Hasle *et al.* 1983: 16, 64, Gardner & Crawford 1992: 247).

TABLE 3: Comparison between morphological features of *Cymatosirella capensis*, *Cymatosirella minutissima*, *Cymatosirella benguelensis*, *Cymatosirella tayorii* and other similar Cymatosiraceae taxa.

Subfamily & Species	Length [µm]	Width [µm]	Shape in the girdle view	Valve shape	Areolae in 10 µm	Porelli	Process	Spines	Girdle band	Other	Ecology & Geography
<i>Cymatosirella capensis</i> (Griffen) Dabek, Witkowski & Archibald	4.5-11	2-3	distinctly undulated	elliptical to lanceolate, undulated	15-18, external cribrum	12-15 with small spines	not observed	few in the middle of the valve, hollow and tapered	numerous bands, each with one row of poroids	quincunx pattern	benthic, known only from the West Coast, South Africa
<i>Cymatosirella minutissima</i> (Sabbe & Myrjaert) Dabek, Witkowski & Sabbe	2.5-10	1.5-2.5	slightly undulated	elliptical to lanceolate, undulated	18.5-24, external cribrum	2-4 central porelli, total ca. 8-15*	not observed	rare, marginal	numerous bands	smaller, less undulated and more densely areolated than <i>Cymatosirella capensis</i>	benthic, described from Westerschelde estuary, The Netherlands
<i>Cymatosirella benguelensis</i> Dabek & Witkowski	4-12	1-4	undulated, central area and apices bulged	elliptical to lanceolate, undulated	15-26, simple vela	12-14 in the bigger specimens, 6-8 in the smaller	not observed	few, along valve margin and in the middle of the valve, hollow and tapered	8-11 bands observed, each with one row of poroids	areolae rim along valve margin, around central elevated area and apices	benthic, known only from Lambers Bay, West Coast, South Africa
<i>Cymatosirella tayorii</i> Dabek & Witkowski	4-13	1-4	distinctly undulated	elliptical to lanceolate, undulated	ca. 50, occlusions not observed	7-10, 1-2 central porelli,	not observed	rare	numerous bands, each with one row of poroids	valve face fully covered by poroids without occlusions	benthic, known only from Langebaan Lagoon, West Coast, South Africa
<i>Extraboccellatus cribriker</i> Hasle, von Stosch & Syvertsen	2.2-3.4	2.2-2.7	rectangular and obovate	elliptical to oval	broad, closed by cribrum	7-10 with well developed spikes	tubular, occasionally observed	few spines on the valve face without basal knob	ca. 12 open bands, some with poroids	quasifract bands, one single plastid per cell	planktonic and benthic species, known from Heligoland, North Sea
<i>Extraboccellatus spinifer</i> (Hargr. & Grull.) Hasle, von Stosch & Syvertsen	2.1-3.6	1.5-3.0	rectangular in broad view, oblong in narrow view	elliptical to oval	ca. 50, without occlusions	7-10 with blunt spikes	tubular, occasionally observed	few scattered on the valve face with globular base, sometimes branched	ca. 14 or more open bands	quasifract bands, one single plastid per cell	planktonic and benthic, cosmopolitan
<i>Pterocomperia catenuloides</i> Sabbe, Vyverman & Ribeiro	5.7-15.6	2.2-3.5	rectangular	semi-elliptical to semi-arcuate, flat to curved	23-29, irregularly distributed, occluded by vela	1-2 central porelli	not observed	linking spines present along valve margin, sometimes bifurcate	4 open bands, finely porous	one plastid per cell, ribbon-like colonies up to 8 cells	benthic, known from the Westerschelde and Tagus estuaries (NE Atlantic)
<i>Pseudolygarella lunata</i> Takano	6-55(?)	2.2-3.5	rectangular	lunate to sublunate, flat	12-16, occluded by rotae	no information	not observed	no information	no information	net-like marginal ridges use for forming ribbon-like colonies	benthic, known from the Mikawa Bay, Japan
<i>Cymastira belgica</i> Grunow	10-40	3-5	valves convex in the middle and depressed near elevations	lanceolate to oblong, flat	9-12, broad areolae with cribrum	20-30 with spines	labiate, situated in the middle of the valve, submarginal	no information	5-7 bands with scattered poroids	middle part of the valve devoid of areolae	planktonic and benthic, cosmopolitan
<i>Brockmanniella brockmannii</i> (Hustedt) Hasle, von Stosch & Syvertsen	4-36	3-5	distinctly undulated, central part and apices elevated	lanceolate with rounded apices, undulated	13-15	20-25 with spines	labiate, one per cell, submarginal	one marginal row, few scattered in the middle and between apices	10-15 bands with scattered poroids, ca. 10-50 in 10 µm	prominent fascia with scattered spines, one large plastid in middle	planktonic and benthic, cosmopolitan

* suggestion

Like other genera in the subfamily Extubocelluloideae, *Cymatosirella* cells are isovalvate and do not possess processes, which is the main distinguishing feature between the two subfamilies (Hasle *et al.* 1983: 68). In *Extubocellulus*, tubular processes either do not occur or are only very rarely observed (cf. Hasle *et al.* 1983: 69, Nakata 1987, Riaux-Gobin & Chretiennot-Dinet 2000, Martin-Cereceda *et al.* 2007, Rivera *et al.* 2010). Differences with *Extubocellulus* include a different pervalvar/apical axis ratio and the structure of the cingulum, which in *Extubocellulus* is composed of quasifract bands (cf. Hasle *et al.* 1983: 69, 71). *Extubocellulus* species are also less undulate in girdle view and are obovate, unlike *Cymatosirella* species which have a rectangular girdle view. The four species of *Cymatosirella* appear to be able to build small ribbon-like colonies supported by undulations of the valve face (such that the expanded area of one valve fits the depressed area of the adjacent valve) and by small spines scattered over the valve face (our figs 10, 32, 33), unlike in species of *Extubocellulus*, which can form long chains connected mainly by linking spines (Hasle *et al.* 1983: 70, figs 364, 365, 369, 374). Unlike *Pierrecomperia* or *Pseudoleyanelia*, the cells in species of *Cymatosirella* are not sublunate (Hasle *et al.* 1983, Takano 1985, Sabbe *et al.* 2010). While *Pierrecomperia* has simple linking spines along the valve margin (Sabbe *et al.* 2010: 251, figs 37, 38), *Cymatosirella* does not possess marginal linking spines. A mesh-like marginal ridge (Takano 1985: 31, figs 4, 6–9, 18, 19) is characteristic for *Pseudoleyanelia* but absent in *Cymatosirella*. The hollow spines observed in *C. capensis* and *C. benguelensis* (Figs 22, 42) have hitherto never been reported in any other species belonging to the Cymatosiraceae (cf. Hasle *et al.* 1983). For a complete overview of all distinguishing morphological features of *Cymatosirella* species, see Table 3.

Giffen compared *Cymatosirella capensis* to *Cymatosira belgica* and *C. elliptica* Salah (1955: 92, 18–21). These comparisons were based solely on LM examinations of the material studied. Giffen provided evidence to justify the distinction of *C. capensis* from other established species in the genus *Cymatosira*. Hasle *et al.* (1983) proposed that *Cymatosirella capensis* should be considered a synonym of *Brockmanniella brockmannii* (Hust.) Hasle, von Stosch & Syvertsen. Their conclusions, however, were based upon comparisons only of the line drawings of *C. capensis*. Sabbe *et al.* (2010: 245) questioned the synonymy of *C. capensis* with *B. brockmannii* and offered the opinion that a reinvestigation of the type material of *C. capensis* was necessary to assess its proper identity. Here, we confirm that *C. capensis* clearly differs from *B. brockmannii* which possesses a prominent fascia and labiate process (cf. Hasle *et al.* 1983, figs 134–136). The main similarity between *Brockmanniella brockmannii* and *Cymatosirella capensis*, and which can be noted in LM, is the frustule outline in girdle view: both have frustules with an undulating outline in girdle view (Giffen 1975: figs 36–38; Hasle *et al.* 1983: 35, fig. 5, figs 132, 133; our figs 3–11, 14). It is also possible to distinguish the two species when they are observed in chains. The undulations are symmetrical in *Brockmanniella brockmannii*, i.e. the depressions and elevations on the two neighbouring valves in a chain mirror each other (Hasle *et al.* figs 132, 133), whereas in *C. capensis* the elevations of one valve fit into the depressions of its neighbouring valve (cf. our fig. 10). The two species also have different areolar occlusions (cf. Hasle *et al.* figs 142, 143 for *B. brockmannii* and our figs 16, 17 for *C. capensis*). *Cymatosirella capensis* closely resembles *Cymatosira belgica*, one of the most characteristic and geographically widespread species of the family Cymatosiraceae but (like *C. benguelensis*, *C. taylorii* and *C. minutissima*) has no process.

Cymatosirella benguelensis and *C. taylorii* are similar to *C. capensis* but differ in some important respects (Table 3). *C. benguelensis* has volate occlusions, while *C. capensis* has cribrate occlusions. This type of volae has to date not been previously observed in members of Cymatosiraceae (Hasle *et al.* 1983) but also occurs in *Solium exsculptum* Heiberg (1863: 52; see Ross & Sims 1987: 272, 273, 299, fig. 2, 5, 6) and in some *Gomphonema* species (see e.g. Reichardt 1999). In addition, the shape of the frustule is less undulate in *C. benguelensis*, and its valves are more slender and elongate than *C. capensis*. In EM, the valves of *C. capensis* are fully areolate with areolae arranged in quincunx pattern, while in *C. benguelensis* valves possess one ring of areolae along the valve margin and one surrounding the central elevation. *Cymatosirella taylorii* also resembles *Cymatosirella capensis* and *C. benguelensis* in LM. However, the valve face of *Cymatosirella taylorii* is fully areolate, unlike *C. benguelensis*, and the number of areola is up to 50 in 10 µm, much higher than in *C. capensis* and *C. benguelensis*.

Cymatosirella benguelensis and *C. taylorii* are also similar of *Minutocellus pseudopolymorphus* Hasle, von Stosch & Syvertsen (1983: 43, figs 190–219). However, *M. pseudopolymorphus* has a single process in the middle of the valve (Hasle *et al.* 1983, fig. 201). In addition, *M. pseudopolymorphus* is curved in girdle view, rather than undulate, as in *C. benguelensis* and *C. taylorii*, and has a different valve shape, with one valve being convex and the other concave. Moreover, the striae in the valve centre are arranged in a horseshoe pattern, in contrast to *C. taylorii* which has a fully areolate valve face.

The three South African species of *Cymatosirella* strongly resemble *C. minutissima* (Sabbe *et al.* 2010: 246) from the Westerschelde Estuary in Western Europe. The latter species, however, has cribrate occlusions, unlike *C. benguelensis* and *C. taylorii*, a different areolar density and less distinctly undulated margin in girdle view compared to *C. capensis*.

Giffen's observations (1975), and our own, demonstrate that *C. capensis* has a limited geographic distribution and is found only in Langebaan Lagoon and the Saldanha area in South Africa. Only a few specimens of *C. capensis* have been observed outside Langebaan Lagoon in a sand sample from Blaauwberg beach (SZCZ 17589) near Cape Town, an observation supported by Giffen (1976, 1984) from surveys of this part of the South African coast. Giffen (1975) described *C. capensis* from a sample which originated from an *Enteromorpha* sp. However, it was also abundant on an *Ectocarpus* sp. and in sandy sediments, all of which were sampled from the Langebaan Lagoon. Its occurrence in this area may indicate its preference for warmer and sheltered waters with elevated salinity like bays or lagoons.

It is noteworthy that in his research on littoral diatoms of the South African west coast, Giffen (1970, 1973, 1975, 1976, 1984) never encountered *Cymatosira belgica*, a fairly widespread diatom species, sometimes even considered cosmopolitan (Hustedt 1955, Hendey 1964, Witkowski *et al.* 2000). Likewise, in our research along the South African west coast *Cymatosira belgica* has never been found.

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