THE TAXONOMY AND DIVERSITY OF *PROSCHKINIA* (BACILLARIOPHYTA), A COMMON BUT ENIGMATIC GENUS FROM MARINE COASTS.

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ABSTRACT

Detailed morphological documentation in LM and SEM is provided for *Proschkinia* taxa, including the generitype *P. bulnheimii* and *P. complanata*, *P. complanatula*, *P. complanatoides* and *P. hyalosirella*, as well as six new species. All established taxa are characterized from original material from historical collections. The new species described in this paper – *P. luticola*, *P. staurospeciosa*, *P. impar*, *P. modesta*, *P. fistulispectabilis* and *P. rosowskii* – were isolated from from the Western Pacific (Yellow Sea coast of Korea) and across the Atlantic (Scottish and Texas coasts). Thorough documentation of the frustule, valve and protoplast architecture revealed the revealed the combination of characters diagnostic of the genus *Proschkinia*: a single lobed chloroplast, girdle composed of U-shaped, perforated bands, the position of the conopeate raphe-sternum relative to the external and internal valve surface, and the presence of an occluded process through the valve, termed the "fistula". Five strains of *Proschkinia* were harvested for DNA and sequenced for nuclear ribosomal SSU and plastid-encoded *rbc*L. Phylogenetic analysis recovered a clade of *Proschkinia* with *Fistulifera*, another fistula-bearing diatom genus, and these were sister to a clade formed of the Stauroneidaceae; in turn, all these were sister to a clade composed of *Parlibellus* and data from two monoraphid genera *Astartiella* and *Schizostauron*. Despite morphological similarities between *Proschkinia* and the Naviculaceae (*Navicula*, *Haslea*), these two taxa are distant in our analysis. We documented the morphology of *Proschkinia*, including variability in fistula, suggesting that fistula ultrastructure might be the key feature for species identification within the genus.

Key index words: diatoms (Bacillariophyta), *Proschkinia*, molecular phylogeny, morphology, taxonomy, biodiversity, new species, Atlantic Ocean, Adriatic Sea, Pacific Ocean

Abbreviations: n.a. – numerical aperture; FIB – Focused Ion Beam; LM – light microscope; ML – maximum likelihood; SEM – scanning electron microscope

INTRODUCTION

The genus *Proschkinia* was established by Karayeva (1978) to accommodate three taxa included in *Navicula sensu lato*, two of which had previously been included in section Microstigmaticeae Cleve (Hustedt 1962, Cox 1988). Karayeva designated *Navicula bulnheimii* Grunow the generitype of the new genus, as *Proschkinia bulnheimii* (Grunow in van Heurck) Karayeva. Taxa belonging in *Proschkinia* attracted attention from the scientific community some time ago (Brogan and Rosowski 1988, Cox 1988, Round et al. 1990, Clavero 2009, Cox 2012, Majewska et al. 2019) and continues here. The valves of *Proschkinia* exhibit a naviculoid shape and the valve exterior resembles some species of *Navicula* and *Haslea* in the presence of conspicuous longitudinal ribs. The characters shared by the taxa belonging to *Proschkinia* are:

- where known, generally a single chloroplast divided into two girdle-appressed plates, linked by a narrow bridge
- a very broad girdle, composed of numerous open U-shaped bands

- an externally conopeate raphe-sternum associated with two deep grooves between the sternum and the rest of the valve
- a row of conspicuously elongate areolae perpendicular to the internally-elevated raphe rib
- a modified process through the valve called a “fistula”, located near the center of the valve on the primary side

The chloroplasts of *Proschkinia* were studied by Mereschkowsky (1902, 1903, 1906, as“*Libellus*”). Mereschkowsky (1903) illustrated, in great detail, a single chloroplast in the form of two plates lying against opposite sides of the girdle and connected by a very narrow isthmus near the centre of the cell. The two plates are displaced in opposite directions, so that the cell contents appear diagonally symmetrical in valve view (e.g. Mereschkowsky 1903, figs 5, 6; see also the generic description in Round et al. 1990, fig. 81 in Clavero 2009, and this paper). The special process termed the ‘fistula’ was first observed and named in *Fistulifera* Lange-Bertalot (Lange-Bertalot 1997) and has subsequently been reported by Zgrundo et al. (2013) in *F. saprophila* (Lange-Bertalot and Bonik) Lange-Bertalot and by Matsumoto et al. (2014) in *F. solaris* S. Mayama, M. Matsumoto, K. Nemoto and T. Tanaka. The presence of a process in *Proschkinia* has been acknowledged far longer, but was referenced under different names. It was first detected with light microscopy, e.g. by Hustedt (1962, ‘mucilage pore’ or ‘stigma’), and then confirmed in SEM by Karayeva (1978; ‘pore’), Cox (1988 as ‘pore’, 2012 as ‘pore’ and ‘stigma’), Brogan and Rosowski (1988, ‘stigma’) and also in Round et al. (1990, ‘stigma’) and Clavero (2009, ‘stigma’). The term ‘fistula’ was not used to describe the *Proschkinia* process until Cox (2012) and Zgrundo et al. (2013), who concluded that it is of the same kind as in *Fistulifera*.and Our recent observations, illustrated in detail first by Riaux-Gobin et al. (2013), show that the fistula also occurs in one more genus: the monoraphid *Astartiella* Witkowski, Lange-Bertalot and Metzeltin in Moser et al. (1998). However, all sequenced strains of *Astartiella* fell outside of the *Proschkinia* and *Fistulifera* clade (Davidovich et al. 2017, Sabir et al. 2018, Majewska et al. 2019, this study). In general, the fistula is constituted internally of a wart-like structure covered with a finely perforated membrane (hymen) and externally as an apically oriented slit positioned close to the central nodule on the valve primary side (Lange-Bertalot 1997, Zgrundo et al. 2013, Matsumoto et al. 2014). However, although the basic structure is the same in *Proschkinia*, *Fistulifera* and *Astartiella*, there is a wider range of morphological variation in *Proschkinia*, both internally and externally (Brogan and Rosowski 1988, Cox 1988, Round et al. 1990, Clavero 2009, Cox 2012, Riaux-Gobin et al. 2013, Zgrundo et al. 2013, Majewska et al. 2019, this study).

In all *Proschkinia* species examined with electron microscope (EM), the raphe-sternum is separated from the rest of the valve surface externally by two shallow, apically oriented grooves which terminate at the apices. Furthermore, the raphe-sternum of *Proschkinia* is unique in being accompanied by a row of elongate areolae observed both internally and externally (Brogan and Rosowski 1988, Round et al. 1990, Clavero 2009, this study). The other characters of the valve surface, such as the striae, areolar occlusions and apical areolae, are shared between *Proschkinia* and several other naviculoid genera, including *Haslea*, *Navicula*, *Hippodonta*, *Craticula* and *Schizostauron*. *Haslea*, some *Navicula* and some *Craticula* share a peculiar valve face ultrastructure with *Proschkinia*, in which the stria-forming areolae are aligned longitudinally and lie between continuous longitudinal ribs (Brogan and Rosowski 1988, Round et al. 1990).

The wide breadth of *Proschkinia*'s girdle is also observed in some amphoroid diatoms e.g. *Tetramphora* (Stepanek and Kociolek 2016), though the girdle bands of *Tetramphora* are externally plain and internally perforated, but never 'U-shaped' like those in *Proschkinia*. The girdle in *Schizostauron* is also composed of 'U-shaped' bands, though the girdle of *Schizostauron* is much narrower than that of *Proschkinia*, and the bands are plain.

Round et al. (1990) included this genus in the Proschkiniaceae, a monotypic family in the suborder Naviculineae, and Zgrundo et al. (2013) noted the similarity of the fistula in *Fistulifera* to the isolated pore of *Proschkinia*, although they found no other evidence supporting a link between them and suggested that it was 'unlikely' that there was a close relationship. The genus has only recently been the subject of molecular phylogenetic studies (Gastineau et al. 2019, Majewska et al. 2019). Using a dataset of mitochondrial genes, Gastineau et al. (2019) found *Fistulifera* and *Proschkinia* to be sister to one another and this has been confirmed by Majewska et (al. 2019) with a larger molecular dataset which included nuclear and chloroplast genes

For this paper, we have been able to provide detailed SEM images of the long-established species *P. bulnheimii, P. complanata* (Grunow) D.G.Mann, *P. complanatula* (Hustedt) D.G.Mann, *P. complanatoides* (Hustedt ex Simonsen) D.G.Mann and *P. hyalosirella* (Hustedt ex Simonsen) D.G. Mann, based on original material from historical gatherings. We also isolated, successfully grew in culture, and performed molecular phylogenetic analyses on, four new species (*P. luticola*, *P. staurospeciosa*, *P. impar*, *P. modesta*) from a single region of the Korean Yellow Sea coast. We also obtained a further new species from the Korean site that we describe on the basis of morphology alone (*P. fistulispectabilis*), document one undescribed strain from Scotland (*Proschkinia* sp. 1) by sequence data and limited morphology, and describe one species (*P. rosowskii*) based on morphology from the Texas coast of the Gulf of Mexico. In the light of our present survey, the diversity of the genus *Proschkinia* seems to have been strongly underestimated.

MATERIAL AND METHODS

Historical samples

Splits of original unmounted material were obtained from the Hustedt Collection in the Alfred Wegener Institute, Bremerhaven and from the Grunow Collection in the Natural History Museum in Vienna. The samples obtained from the Hustedt Collection were the same as those used by Simonsen (1987) in the typification of Hustedt taxa. From sample As 1465, Simonsen made lectotype and iso-lectotype slides for *Navicula complanatoides*; from sample AM 2243 lectotype and iso-lectotype slides of *Navicula complanatula*; Hustedt's *Navicula hyalosirella* originated from sample AM 2214. From the Grunow Collection in the Natural History Museum in Vienna, splits were taken of samples 870 and 1123 from which *Amphora complanata* Grunow was described and sample 1720 from which the holotype of *Navicula bulnheimii* Grunow originated. From the unmounted material, permanent slides were made and suspension was also dropped onto aluminum stubs. These resources produced from unmounted material are accessible from Szczecin Diatom Culture Collection upon request (cf. Table 1). All these species have been observed by LM and SEM. Details on the geographic origins of established *Proschkinia* species are listed in Table 1, but see also Supplementary Data S1.

Sampling sites

Benthic samples were collected from the North Atlantic in Scotland in the early 2000s and from the Gulf of Mexico near Corpus Christi (Texas, USA), where the sediment from subtidal mangrove roots was sampled in December 2013 (Table 2; details of the Scottish sample have unfortunately been lost). Sampling of the Korean Yellow Sea coast was performed at Beopsan-ri, Pado-ri and Baeksajang (Table 2). The Beopsan-ri area is a mud flat, Pado-ri Beach is composed of fine gravel occurring in the rough wave zone, and Baeksajang Beach is sandy. The samples were collected from the surface of tidal flats by Petri dish in Beopsan-ri, whereas seaweeds in the Pado-ri and Baeksajang beaches were all sampled in May and December 2016.

Sampling and cultures

Isolation of *Proschkinia* cells for culture was performed directly after the samples were transferred to the laboratory. Monoclonal cultures were obtained by successive manual isolations of single cells under an inverted microscope (Nikon TS 100) using Pasteur pipettes; the cells were transferred into 24-well tissue culture plates (Corning Cell Culture Vessels). Cultures were maintained in 250 mL polycarbonate (PC) bottles with 32 PSU f/2 medium enriched with Si (Guillard 1975) at 20°C under a 16h:8h light:dark cycle, with 80 μmol $m^{-2}s^{-1}$ of white light.

Microscopical examination

Microscopical work within this study has been shared between University of Szczecin, Kunsan National University in Korea, and the Royal Botanic Garden Edinburgh. LM protocols follow Mann and Trobajo (2014) and Witkowski et al. (2014, 2015).

To observe the chloroplast morphology of live cells, clones were photographed in counting chambers using a Nikon TS300 inverted microscope (Nikon Corporation, Tokyo, Japan) equipped with a ×100 Plan Apochromatic oil immersion objective (n.a.=1.40) equipped with differential interference contrast (DIC) optics. For morphological observations of cleaned valves by LM and SEM, cell suspensions of cultures were boiled with 30% hydrogen peroxide (H_2O_2) at 150°C for a few hours. Boiled cultures and wild samples were rinsed with deionized water five times. Finally, cleaned diatom material was pipetted onto coverslips, dried and mounted on glass slides using Naphrax (Brunel Microscopes, Wiltshire, U.K.). LM observations were made with a Zeiss Axio Imager M2 (Carl Zeiss, Jena, Germany) using a ×100 PlanApochromatic oil immersion objective (n.a. =1.46) equipped with DIC. For SEM examination, a few drops of cleaned material were put onto Whatman Nucleopore polycarbonate membrane filters (Fisher Scientific, Schwerte, Germany). When the membranes were dried, they were mounted onto aluminum stubs and coated with gold-palladium or gold for ca. 3–5 minutes. SEM observations were performed at the University of Rzeszów, Faculty of Agriculture and Biology, using a Hitachi SU8010 and at the West Pomerania University of Technology in Szczecin at the Faculty of Chemical Technology and Engineering, using a Hitachi SU8020.

Nanocuts were performed on specimens of *Proschkinia complanatoides* from Coll. Hustedt by means of an FIB/SEM Hitachi NB5000 integrated system. This system consists of an ultra-high-performance focused Ga+ ion beam gun (40 kV) and high-resolution field emission scanning electron microscope (30 kV). This dual beam system enabled high-throughput specimen preparation, high- resolution imaging and analysis, as well as precision nanosectioning.

The LM and SEM protocol at Kunsan University was as follows: clonal cultures of *Proschkinia* spp. were harvested and cleaned in accordance with the Hasle and Fryxell (1970) method. Suspensions of the clones were pipetted onto cover glasses, left to dry at room temperature and mounted on glass slides with Naphrax. Prior to SEM examination, the samples were sputter coated with platinum (Pt) in an Ion Sputter coater (E-1045, Hitachi, Japan). Observations were carried out at an acceleration voltage of 5 kV by an FE-SEM (Hitachi S-4800, Japan).

DNA extraction and PCR

Kunsan University: The genomic DNA *Proschkinia* strains was extracted using AccuPrep®Geomic DNA extraction kit according to the manufacturer`s protocol (Bioneer, Daejeon, Korea). PCR amplification and sequencing were conducted targeting the small subunit ribosomal RNA (SSU rRNA), chloroplast-encoded RUBISCO gene large subunit (*rbc*L) and sequenced primers are listed in Table 3. The full-length eukaryotic SSU rRNA gene (18S rDNA) was amplified in two fragments by primers (EukA and G18R for the first fragment and 570F and EukB for the second fragment). All genes were amplified using a total 25 μL reaction mix that contained 1.0 μL DNA (20 ng), 16.35 μL distilled water, 2.5 μL 10 × Ex Taq^{TM} buffer, 2.0 μL each 2.5 mM dNTPs, 1.0 μL each 10 pmol primer and 0.15 μL DNA polymerase (5 U · μL^{-1}). PCR conditions for SSU were as follows: 3 min at 94 ℃ followed by 30 cycles of 45 s at 95°C, 1 min at 55°C, and 3 min at 72°C, with a final extension time of 5 min at 72°C. For *rbc*L the volume of each PCR was 50 μL: 2 μL (20 ng) purified DNA template; 5 μL 10× Takara Taq buffer (includes 50 mM Tris-Acetate-EDTA,); 2 μL Ultrapure dNTPs Set (2.5 mM each dATP, dCTP, dGTP, dTTP); 2 μL each primer; 0.2 μL Takara Taq DNA polymerase (5 U/μL); and ddH2O to a final volume of 50 µL. PCR conditions for *rbc*L were as follows: 3:30 min at 94°C, followed by 36 cycles of 50 s at 94°C, 50 s at 52°C, and 1:30 min at 72°C, with a final extension time of 15 min at 72°C (Thomas, 2016). PCR products were sent to Genotech company (Daejeon, Korea) for purification and sequencing.

Royal Botanic Garden Edinburgh: DNA extraction, amplification and *rbc*L sequencing of the Scottish strain (*Proschkinia* sp. 1) followed Jones et al. (2005).

Phylogenetic analysis

SSU sequences were aligned using SSU-Align (Nawrocki 2009, Nawrocki et al. 2009). A diatom covariance model was created based on the eight diatoms provided with SSU-Align, with the addition of diatom structural models from Cannone et al. (2002) available on 2/1/2019. We retained only those sites with a Bayesian Posterior Probability of correct alignment of 0.95 or better. Ends were trimmed to those columns which were 50% or more complete. SSU-Align predictions of paired and unpaired sites were used to partition the data into stems and loops.

Protein encoding sequences were aligned in Seaview 4.5.4 (Gouy et al. 2010) using MUSCLE (Edgar 2004). Ends were again trimmed to those columns which were 50% or more complete. Codon positions were assigned using Mesquite (Maddison and Maddison 2018). SSU and plastid protein encoding sequences were concatenated in Seaview 4.5.4. The concatenated data and the following partition definitions (SSU stems, SSU loops, first codon positions *rbc*L, second codon positions *rbc*L, third codon positions *rbc*L, first codon positions *psb*C, second codon positions *psb*C, third codon positions *psb*C) were read into Partition Finder (Lanfear et al. 2012) and run under the following conditions: branches were unlinked, the greedy algorithm was used, models were limited to GTR+G (see comments on our implementation of RAxML below), and the statistical criterion was AICc (the latter as recommended by the program documentation).

Phylogenetic analysis was conducted under the ML optimality criterion using RAxML 8.2 (Stamatakis 2014). Branch length estimates were unlinked, and the model employed was GTR+G as recommended by the documentation (https://cme, hits.org/excelixis/web/software/raxml/index.html: viz., as Gamma already allows for sites with very low rates, making joint estimation of both the proportion of invariant sites and Gamma difficult due to a possible "ping-pong" effect, because a change in P-Invar leads to a change in Gamma). Each of 35 RAxML runs was begun with a different random number seed for taxon addition and rapid bootstrapping. Each run incorporated 500 rapid bootstraps. The optimal tree from the 35 repetitions was used for interpretation of results.

The terminology follows Anonymous (1975), Round et al. (1990) and Cox (2012). Figure 1 provides an illustrated reference for the particular ultrastructure of *Proschkinia* discussed in this manuscript, and details particular characters of *P. staurospeciosa*, *P. impar* and nanocuts of *P. complanatoides*.

RESULTS

General description of the genus Proschkinia

Frustules rectangular in girdle view with girdle composed of numerous U-shaped open bands with hymenate internal perforations and plain exterior. Valves naviculoid with convex valve surface ornamented (in most species) with apically oriented longitudinal ribs. Raphe sternum conopeate, bordered by two grooves separating sternum from rest of valve. Internally, elevated raphe rib bordered by large transapically elongate areolae. Externally, raphe filiform with expanded proximal endings, sometimes bent to one side with apical ends strongly hooked to same side. Distal raphe ends associated with large apical areolae. Internally, raphe opens laterally along raphe rib, terminating distally in simple helictoglossae. Transapical striae composed of apically elongate hymenate areolae. Central area with fistula. Externally, fistula opening is an apically elongate slit, close to central nodule at primary side. Internally, fistula composed of domed structures of variable size, always occluded by porous membranes (hymens) like those of areolae.

Established *Proschkinia* species

Proschkinia bulnheimii (Grunow in Van Heurck) Karayeva – Figure 2

LM Morphology

Valves narrowly lanceolate to linear elliptic with more or less protracted, obtusely rounded apices, 15–30 µm long, 3–4 µm in width (Fig. 2, a–h). Raphe filiform, straight with proximal ends close to each other. Transapical striae parallel, ca. 30 in 10 µm. Small, isolated fistula associated with middle stria (Fig. 2, a–I, cf. Table 4).

SEM Morphology

Valve exterior

Valve surface slightly arched, with distinctly protracted, broadly rounded apices, ornamented with longitudinal ribs terminating shortly below apices and at valve center (Fig. 2, j–l). Raphe sternum conopeate (arrow in Fig. 2k), raphe filiform, external proximal raphe endings small, very close to each other (Fig. 2k). Distal raphe endings strongly hooked in same direction (Fig. 2l). Axial area very narrow, linear, forming a small, rhombic central area (Fig. 2, j–l). Fistula hidden underneath a small, apically oriented, oblique slit at the valve center (arrow in Fig. 2k). Transapical striae almost parallel throughout, becoming slightly convergent at apices, ranging from 28 at valve center up to 34 in 10 µm at apices. Central striae much more robust than the remaining striae (Fig. 2, j and k).

Valve interior

Valve interior flat with strongly elevated raphe-sternum and shallow mantle. Raphe slit opening laterally, internal proximal raphe endings expanded and tear-like, separated by a distinct double helictoglossa (Fig. 2, m and n). Raphe terminates at apices in simple helictoglossae (Fig. 2p). Fistula relatively large, irregular though principally oblong in shape (arrow in Fig. 2n); fistula distinctly engulfed by raphe-sternum. Transapical striae composed of rectangular apically oriented areolae depressed below virgae. Virgae narrower than areolae (Fig. 2o), 70 areolae in 10µm.

Comments: *Proschkinia bulnheimii,* selected by Karayeva (1978) as the type species of *Proschkinia,* was examined here from the holotype material, which has also been illustrated in TEM by Krammer and Lange-Bertalot (1986, fig. 56: 9) and in SEM by Cox (1998, figs 38-43). *P. bulnheimii* is a tube dwelling species described from inland saline waters in Germany and seems to be locally abundant in places. It has been observed in South Africa (Cholnoky 1963, Archibald 1983), Europe (e.g. Catalonia, by Clavero 2009; Caspian Sea, by Karayeva and Bukhtiyarova 2010) and in the Salton Sea in California (Lange and Tiffany 2002). The specimen illustrated by Wachnicka from the east coast of Florida seems to represent *P. browderiana*

Frankovich, Ashworth and M.J. Sullivan in Majewska et al. (2019) though it is similar to *P. bulnhemii* in terms of gross morphology, http://fcelter.fiu.edu/data/database/diatom/index.htm?species=3874).

***Proschkinia complanata* (Grunow) D.G.Mann (Coll. Grunow Vienna: Triest and Svety Petar Island in Croatia) – Figures 3, 4**

Syn.: Grunow 1867, Hedwigia 6, p. 25 as *Amphora complanata*; illustrated by Grunow in A. Schmidt Atlas 1874, pl. 26, fig. 45 (*Amphora complanata* Grunow; Adria; in plate legend (Erläuterungen); *Navicula complanata* (Grunow) Grunow in Cleve and Grunow 1880, p. 42; *Libellus complanatus* (Grunow) De Toni 1890, p. 971

LM Morphology

Note: our measurements are based on Coll. Grunow 870; valves in the Coll. Grunow 1123 sample were very rare and our measurements of these are given in brackets. They still fall within the size range of the species as given in the literature

Valves narrowly rhombic-lanceolate, 55.0–57.7 (35–40) µm long, 6.7–7.3 (4–6) µm wide. Transapical striae resolvable in LM, 24–25 in 10 µm, parallel in the middle. The two central striae on the valve secondary side are distant (Fig. 4, a–h). Fistula distinct, positioned on valve primary side (cf. Table 4).

SEM Morphology

Valve exterior

Frustules rectangular with girdle composed of numerous copulae, 26–28 in 10 µm (Fig. 4, a and b). Valve surface slightly convex (Fig. 3, i–l). Longitudinal ribs rather delicate, 65–70 (70–80) in 10 µm (Fig. 3i, and 4a). Raphe-sternum very narrow, flanked by two distinct grooves which terminate below the apices (arrows in Fig. 3i and 4, a and e). Proximal raphe endings somewhat expanded and rather close (Fig. 3, i–k and 4, a, c and d). Terminal raphe endings strongly hooked in same direction (Fig. 3, a and d, 4, a and e). Transapical striae parallel, becoming convergent shortly below apices. Areolae positioned within grooves larger than those positioned in the striae (arrow in Fig. 3j). External opening of fistula covered with apically elongate, somewhat elevated siliceous flap (Fig. 3, j–k and 4, a–d).

Valve interior

Internally, raphe-sternum rib somewhat elevated (Fig. 3m and 4f). Raphe opening laterally, with proximal raphe endings somewhat expanded and distant (Fig. 3n and 4g). Raphe terminates in small, simple helictoglossae at apices; long apical areolae present (Fig. 3, o). Areola occlusions hymenate (arrow in Fig. 3n). Fistula composed of many globular structures arranged in a row with two accessory pores visible (Fig. 3m and 4, f–g).

Comments: our LM and SEM images of *Amphora* (*Navicula*) *complanata* Grunow, based on a loan from Grunow Collection in Vienna originate from the same material from which the holotype presented in A. Schmidt Atlas (1875, fig. 26: 45) was obtained. The search in Vienna revealed the presence of two samples from the Adriatic Sea which have been annotated with Grunow's handwriting and line drawings as bearing *N. complanata* (cf. Supplementary data 1). These are the so-called 'Trieste sample' (coll. Grunow 1123) and Svety Petar Island in Croatia sample (coll. Grunow 870). *N. complanata* from the former sample has been illustrated, though only with a low-resolution objective, by Krammer and Lange-Bertalot (1986, fig. 56: 1, 2). The second sample is very rich in *N. complanata* and has not been illustrated thus far. Here we have observed material from both samples (1123 and 870) with SEM. Comparison of external and internal valve ultrastructure confirmed that the two samples do indeed contain the same species, *N. complanata*. Hustedt (1962) postulated that as a starting point in solving the systematic relationship and the size data of *N. complanata*, only the material from the Adriatic Sea can be considered. In this paper we did not examine slide 142 from Cleve and Möller which was illustrated by Krammer and Lange-Bertalot (1986, fig. 56:3) and Cox (1988, figs 57–61). This material was sampled by P.T. Cleve and originated from the western Baltic Sea coast of Sweden at Lysekil, which is located north of Gothenburg. Comparison of LM and SEM images from Grunow Coll. in Vienna samples with *N. complanata* illustrated from Cleve and Möller 142 shows that they are different (cf. Cox 1988), particularly in the external valve surface, which is plain in the Cleve and Möller 142 specimen but ornamented with dense longitudinal ribs in specimens from the Grunow material. In addition, the fistula is not seen, which suggests it is rather small in the former specimen, whereas it is distinct and composed of numerous globular structures in the latter. In fact, the lack of a proper, unambiguous image of the fistula in the species from Cleve and Möller 142 makes it impossible to identify it properly and we propose to keep it as „*Proschkinia* sp."

***Proschkinia complanatoides* (Hustedt ex Simonsen) D.G.Mann in Round et al. – Figure 5**

Syn.: *Navicula complanatoides* Hustedt 1962 nom. inval., p. 340, fig. 1451, *Proschkinia complanatoides* (Hustedt) Karayeva nom. inval., *Navicula complanatoides* Hustedt ex Simonsen 1987, fig. 734: 4–10,

LM Morphology

Cells rectangular in girdle view with rounded corners and numerous, very narrow bands, ca. 18 in 10 µm (fig. 6a). Valves lanceolate with slightly convex sides and acute ends, 33–60 µm long, 4.6–7.3 µm wide. Raphe straight and linear, with indistinct and very closely positioned proximal ends. Fistula positioned opposite shortened central stria (arrow in Fig. 5f). Transapical striae 17–20 in 10 µm, somewhat coarser at center, parallel to slightly radiate, then changing direction and becoming convergent at apices (Fig. 5, b–g, cf. Table 4).

SEM Morphology

Valve exterior

Frustules with broad girdle, composed of numerous copulae (Fig. 5h). Valves arched almost up to apices. Longitudinal ribs variable, well-developed (Fig. 5i) or present only in proximity to raphe-sternum below apices, 50–70 in 10 µm (Fig. 5, j–m). Raphe-sternum conopeate (see Fig. 5j), proximal raphe endings hooked towards valve primary side, distinctly expanded and somewhat apart (Fig. 5, i–l). Apical raphe endings terminate in strong hook (Fig. 5, f and g). Fistula opening in form of short undulate slit, opening obliquely towards valve center (Fig. 5, i–k). Three accessory pores present, two on valve primary side and one on secondary side (Fig. 5k).

Valve interior

Valve interior flat with elevated raphe-sternum rib. Raphe slit opening laterally, proximal endings small, apical endings terminating in small helictoglossa (Fig. 5, n, o and q). Elevated raphe-sternum rib flanked by large areola (Fig. 5o). Fistula solitary, very large, partly positioned beside raphe-sternum (Fig. 5p) and associated with three distinct accessory pores, two on valve primary side and one on secondary side (Fig. 5o). Fistula shape unique to *P*. *complanatoides* (Fig. 5p).

Comments: Hustedt marked *N*. *complanatoides* on three slides made from a Sumba (Indonesia) sample, AS1135. However, no specimen of *N*. *complanatoides* was found in the marked slides by Simonsen (1987). Likewise, our own search for *N*. *complanatoides* in slides made from sample AS1135 also failed, except for a well-preserved girdle of the species in question found by SEM. Instead of the AS1135 slides, Simonsen proposed slide N13-60 Sumba g. as the lectotype (fig. 734: 1–6) and slide 287-22B Sumba. 2. as an isolectotype (fig. 734: 7–10), made from sample AS1465 from the same location. Not surprisingly, then, we found a number of specimens in sample AS1465 received from the Hustedt Collection, which we imaged in LM and in SEM.

Zgrundo et al. (2013, figs 24, 25) illustrate external and internal views of *P*. *complanatoides* in SEM, and the details conform with our images of this species. However, *Proschkinia complanatoides* as illustrated by Karayeva 1978 (fig. 2: 1–4) is rather similar to our *P*. *rosowskii*; in a later work, Karayeva and Bukhtiyarova (2010, fig. II: 2–7) illustrate *P*. *complanatoides* from the Caspian Sea, which can be identified as *P*. *complanata*. The same conclusion applies to specimens illustrated as *P*. *complanatiodes* in Lobban et al. (2012, plate 1, figs 4–6; plate 52, fig. 6; plate 53, figs 1–4), which we identify as *P*. *complanata* based on the shape of the fistula both internally and externally (cf. our Figs 3 and 4)

***Proschkinia complanatula* (Hustedt ex Simonsen) D.G.Mann – Figure 6**

Syn.: *Navicula complanatula* Hustedt ex Simonsen

Hustedt 1962, p. 338, fig. 1450, Simonsen 1987, fig. 735: 1–10

LM Morphology

Cells rectangular in girdle view with rounded corners and numerous, fairly broad bands, ca. 7–8 in 10 µm (Fig. 6a). Valves lanceolate with acutely rounded apices, 34–58 µm long, 7.1–8.0 µm wide. Raphe straight and linear, with closely positioned proximal ends. Transapical striae parallel at center, 12–15 in 10 µm, becoming slightly convergent and denser near apices, 17–20 in 10 µm (Fig. 6, b–I, cf. Table 4).

SEM Morphology

Valve exterior

Valves slightly arched, flat at center, becoming marked by longitudinal ribs towards valve apices, 65 in 10 µm (Fig. 6, j and k). Raphe-sternum distinct, conopeate (Fig. 6k). Raphe proximal endings gently bent towards valve secondary side, somewhat expanded and close (Fig. 6k). Distal raphe endings terminate in strong hooks (Fig. 6l). Fistula opening a small depression framed by lip-like structure, associated with four accessory pores opening onto valve face central area (Fig. 6, j and k).

Valve interior

Valve interior flat with strongly elevated raphe-sternum rib (Fig. 6, m–n). Raphe slit opening laterally, proximal endings small, apical endings terminating in distinct helictoglossa. Transapical striae positioned between significantly broader virgae, parallel, becoming slightly convergent near apices. Raphe-sternum flanked by large areolae (arrowheads in Fig. 6m). Stria-forming areolae ca. 70 in 10 µm (Fig. 6n).

Solitary, large fistula slightly engulfed by raphe-sternum. The tear-like fistula shape is unique to *P. complanatula* (Fig. 6m).

Comments: *N*. *complanatula* was described by Hustedt (1962, p. 338) from the coast of the East Pacific in Charleston, Oregon, USA. The unmounted material received from the Hustedt Collection, sample AM2243, was fairly rich in *N*. *complanatula*. This species has also been observed by SEM in sample AS1465 from Sumba Island in Indonesia. Besides the holotype habitat, *P*. *complanatula* has been identified by Stidolph et al. (2012; pl. 26: fig. 105) from Academy Bay, Santa Cruz Island, Galapagos.
The identity of *Proschkinia complanatula* remains problematic due to its similarity to *P*. *poretzkajae* (Korotkevich) D.G.Mann. Based solely on LM images, the two species are almost identical in terms of valve outline, length and width; however, the stria density is 12–15 in 10 µm in *P*. *complanatula* and 16–20 in 10 µm in *P*. *poretzkajae*. Comparisons between these species by SEM are not possible at this time, as our search for the slides or unmounted material in the Komarov Institute of Botany Russian Academy of Sciences in St. Petersburg failed. The specimen illustrated by Korotkevich (1959) is characterized by a higher stria density than *P*. *complanatula* and, more importantly, have closely spaced external proximal raphe endings vs the distinctly bent and distant ones in *P*. *complanatula* (Simonsen 1987, fig. 735: 6–10, this paper).

Proschkinia hyalosirella **(Hustedt ex Simonsen) D.G.Mann – Figure 7**

Syn.: *Navicula hyalosirella* Hustedt ex Simonsen

Hustedt 1962, p. 335, fig. 1448. Simonsen 1987, fig. 735: 11–13

LM Morphology

Cells rectangular in girdle view, with rounded corners and numerous, very narrow girdle bands, ca. 20 in 10 µm (Fig. 7, a–c). Valves narrowly lanceolate with fairly acute ends, ca. 25–30 µm long, ca. 3–4.1 µm in width. Raphe straight, proximal ends positioned close together. Transapical striae resolvable in LM only at valve center, ca. 28 in 10 µm, becoming denser towards apices (cf. Table 4).

SEM Morphology

Valve exterior

Frustules very broad in girdle view with numerous copulae. Copulae with regularly distributed internal rectangular hymenate pores (Fig. 7, d–f). Valve surface arched, with slightly bent, narrowly rounded apices. Longitudinal ribs distinct near raphe sternum, becoming delicate towards valve margin, 70 in 10 µm. Raphe-sternum conopeate, raphe branches filiform, straight with closely-spaced, slightly expanded, tear-like proximal endings (Fig. 7h). Apical raphe ends strongly hooked associated with long apical areolae (Fig. 7i). Fistula opening and proximal raphe endings covered by a massive siliceous flap (Fig. 7h). Accessory pores not observed on external valve surface (Fig. 7, j–l).

Valve interior

Internal valve surface concave; raphe-sternum distinct and elevated, resembling a long rod. Raphe slit opens laterally, proximal endings slightly expanded, separated by a small double helictoglossa (Fig. 7, j, m and n). Elevated raphe-sternum flanked by elongate hymenate areolae (Fig. 7, m and n). Transapical striae parallel at center, becoming slightly radiate then strongly convergent towards apices. Stria density changes from 25–26 in 10 μm at center to 28–30 in 10 μm at apices (Fig. 7, j and k). Transapical striae composed of hymenate areolae, 70 to 80 in 10 μm. Fistula solitary, peanut-like (unique for the species), rather large, very close to raphe-sternum. Raphe sternum slightly constricted opposite fistula (Fig 7k). Fistula associated with four small accessory pores located very close to raphe-sternum and framing the central area.

Comments: *Navicula hyalosirella* was described by Hustedt (1962, p. 335) from Pass-a-Grille, St. Petersburg on Florida's west coast and illustrated with a line drawing. This species is illustrated in Simonsen (1987, p. 479, fig. 735: 11–13, slide N18-22). In unmounted material of sample AM2214 received from the Hustedt Collection, we were able to find three specimens by SEM (with some of them showing the valve interior and fistula in particular, cf. our Fig. 8i and j). However, we did not find any specimens in LM slides made from sample AM2214. Careful SEM and LM examination of another Hustedt sample of unmounted material, from Madeira, west of Lido (E10731), revealed the presence of *N. hyalosirella* in LM and SEM. The valve measurements and comparison between AM2214 and E10731 specimens positively identify *N. hyalosirella* from this sample. *Proschkinia hyalosirella* as illustrated in Zgrundo et al. (2013) has a fistula comprised of a small, solitary domed structure and does not conform with the species as illustrated here based on Hustedt's original material.

Novel *Proschkinia* species

***Proschkinia luticola* S-Y. Kim, J-G. Park, Witkowski and B-S. Kim, sp. nov. – Figure 8**

LM Morphology

Valves linear-lanceolate to linear-elliptic, (10)22–23 µm long, 4.5–6.0 µm wide (n=15). Transapical striae barely resolvable in LM, parallel at valve center (Fig. 8f). Fistula recognizable in LM, positioned close to central nodule (Fig. 8, a–f).

SEM Morphology

Valve exterior

Valves with acutely rounded, slightly bent apices. External valve surface slightly convex with indistinct longitudinal ribs. Raphe-sternum conopeate (Fig. 8i), raphe branches filiform, slightly undulate (Fig. 8, g and h). External proximal raphe endings simple, slightly bent towards valve primary side. Apical raphe endings terminate in short hooks, both oriented in same direction, terminating in distinct groove with few areolae (Fig. 8i). Transapical striae parallel throughout, 27–29 in 10 µm. Areolae aligned along apical ribs, ca. 70 in 10 µm (Fig. 8, g and h). External fistula opening in a form of irregular slit, associated with 3 to 4 pores (Fig. 8, g and h, cf. Table 4).

Valve interior

Valve surface concave, gradually elevating towards raphe internal rib (Fig. 8, j and k). Raphe slit opening laterally, with slightly expanded central raphe endings separated by a small double helictoglossa (Fig. 8, m and n). The areolae adjacent to the raphe-sternum are noticeably larger than those elsewhere in the striae (Fig. 8, k, m and n). Fistula relatively large, transapically elongate, morphologically complex, associated internally with two solitary pores occluded by domed, perforated hymenes (Fig. 8, k and l).

Holotype: Natural History Museum, London, BM 81909, derived from the material of clone KNU-B-16024 that was used to obtain sequence MK887894.

Isotype: slide no. SZCZ 26592 deposited in A. Witkowski Diatom Collection, Institute of Marine and Environmental Sciences, University of Szczecin, Szczecin, derived from same clone

Type habitat: Beopsan-ri tidal flat at the Yellow Sea coast in Korea, leg. Jong-Gyu Park and Byoung-Seok Kim, May. 2016

Etymology: the species name is derived from the type habitat, a mud flat: the Latin for mud is "lutum", hence *luticola* indicates a mud-dwelling species.

Comments: *Proschkinia luticola* is one of the smallest species thus far established in the genus. It differs from other small species such as *P. bulnheimii*, *P. lacrimula* Majewska and *P. browderiana* by the valve apices, which have protracted apices, while those of *P. luticola* are acutely rounded. Most importantly, in our species the fistula is relatively large and has a complex ultrastructure, whereas in *P. bulnheimii* and the other listed small taxa, the fistula is small and simple.

***Proschkinia staurospeciosa* S-Y. Kim, J-G. Park, Witkowski and Gastineau, sp. nov. – Figure 9**

LM Morphology

Frustules rectangular with slightly rounded corners, very broad in girdle view (Fig. 9d). Valves strictly lanceolate with very slightly offset, acute apices, 27–28 µm in length, ca. 5.0 µm in width (n=15). Transapical striae parallel at valve center, becoming increasingly convergent towards apices, 23–24 in 10 µm. Fistula small, barely resolvable in LM (Fig. 9, a–i, cf. Table 4).

SEM Morphology

Valve exterior

External valve surface slightly convex in the middle, becoming increasingly arched towards apices (Fig. 9, j and k). Longitudinal ribs not observed (Fig. 9, j–l). Raphe-sternum conopeate, raphe filiform, straight, proximal ends slightly expanded externally and bent towards valve secondary side (Fig. 9k). Apical raphe endings strongly hooked to same side and terminate on valve mantle below apices (Fig. 9l). Transapical striae composed of slit-like areolae, ca. 80 in 10 µm, somewhat narrower than virgae. External opening of fistula a simple slit (Fig. 9k). Externally, fistula associated with four accessory pores (black arrowheads in Fig. 9k).

Valve interior

Valve internal surface concave obliquely ascending towards raphe internal rib. Raphe slit opens laterally, central nodule distinct, internal proximal raphe endings slightly expanded (Fig. 9, m and n), apical raphe endings terminate in small, simple helictoglossa (Fig. 9o). Areolae aligned along raphe-sternum are larger by a few orders of magnitude than those in the striae (Fig. 10, m and n). Fistula very small, simple, somewhat elongate transapically, framed with shallow depression and associated with four accessory pores (Fig. 9n).

Holotype: Natural History Museum, London, slide BM 81912 derived from the material of clone SZCZR1824 that was used to obtain sequence MK887897.

Isotype: slide no. SZCZR1824 deposited in A. Witkowski Diatom Collection, Institute of Marine and Environmental Sciences,, University of Szczecin, derived from same clone
Type habitat: Fine gravel of Pado-ri Beach, Yellow Sea coast of Korea, leg. Jong-Gyu Park and So-Yeon Kim, Dec. 2016

Etymology: the species name refers to the central area, which is stauros-like ('stauro-') and rather well developed ('speciosa' = showy).".

Comment: *Proschkinia staurospeciosa* differs from most other species by the absence of longitudinal ribs over the valve external surface. One of the other species in which the valve face is devoid of longitudinal lines is *Navicula complanata* Grunow from Cleve and Möller 142, as illustrated in Cox (1988, figs 60, 61). The two species differ, however, in terms of stria density, which is 23–24 in 10 µm in *P*. *staurospeciosa* vs 17 in 10 µm in *N*. *complanata* Grunow *sensu* Cox (1988). The epizoic species *P. lacrimula*, *P. maluszekiana* and *P. vergostriata* (Majewska et al. 2019) also lack longitudinal lines, but are either significantly smaller than *P. staurospeciosa* (*P. lacrimula* and *P. vergostriata* < 15 um in length), while *P. maluszekiana* has a significantly more complex internal fistula ultrastructure.

Proschkinia impar S-Y. Kim, J-G. Park and Witkowski, sp. nov. – Figure 10

LM Morphology

Valves linear-lanceolate with acutely rounded apices, 34.5–36 µm long, 4.9–5.3 µm wide (n=15). Transapical striae resolvable in LM only at valve center, parallel, 26 in at center, up to 30 in 10 µm towards apices. Fistula indistinct, but easily resolvable in LM (Fig. 10, a–k, cf. Table 4).

SEM Morphology

Valve exterior

Frustules rectangular with rounded corners, girdle composed of numerous bands, 30–34 in 10 µm (Fig. 10l). External valve surface slightly convex (Fig. 10, m and n). fine longitudinal ribs only very slightly elevated above valve face (Fig. 10, m–p), 70–80 in 10 µm. Raphe-sternum conopeate, raphe filiform with slightly-expanded external proximal raphe endings (Fig 10, n and o) terminal raphe endings strongly hooked in same direction, terminating in long slits on valve mantle (Fig. 10p). External opening of fistula partially occluded by large, oblique and slightly thickened siliceous flap (Fig. 10, n and o).

Valve interior

Internally, valve face flat, ascending towards internal raphe rib (Fig. 10q). Areolae aligned along raphe-sternum larger by a few orders of magnitude than those in striae (Fig. 10, r and t). Raphe slits distinct and open laterally, proximal internal raphe endings positioned close together, separated by small double helictoglossa at center

(Fig. 10r). Fistula simple, composed of two domed structures and associated with two isolated accessory pores (Fig. 10, r and s).

Comments: this species resembles to some extent *N*. *complanatoides* as illustrated by Brogan and Rosowski (1988) and the newly described *P*. *rosowskii*. The two species differ, however, by the proximal raphe endings, which are expanded and somewhat distant in *P*. *impar* vs expanded and approximate in *P*. *rosowskii*. The two species also differ in fistula morphology, with two domed structures slightly engulfed by the raphe-sternum and two closely positioned accessory pores in *P*. *impar* vs the two simple structures without visible accessory pores positioned close to the raphe-sternum in *P*. *rosowskii*. The two species differ also in terms of external fistula structure, with large and oblique siliceous flap in *P*. *impar* vs small strictly apically oriented flap in *P*. *rosowskii*.

Holotype: Natural History Museum, London, slide BM 81908, derived from the material of clone KNU-Y-16121 that was used to obtain sequence MK887893.

Isotype: slide no. SZCZ 26593 deposited in A. Witkowski Diatom Collection, Institute of Marine and Environmnetal Sciences, University of Szczecin, Szczecin, derived from same clone

Type habitat: Fine gravel of Pado-ri Beach, Yellow Sea coast of Korea, leg. Jong-Gyu Park and So-Yeon Kim, Dec. 2016.

Etymology: the species name is derived from the development of the central area on only one side of the valve, being distinctly present on the valve primary side, whereas almost missing at the valve secondary side.

Proschkinia modesta **S-Y. Kim, J-G. Park and Witkowski sp. nov. - Figure 11**

LM Morphology

Valves linear-lanceolate with very slightly set off, acutely rounded apices, 32.5–35 µm long, 5.7–6.2 µm wide (n=16). Transapical striae in the valve middle resolvable in LM. Fistula relatively easy to resolve with LM (Fig. 11, a–k, cf. Table 4).

SEM Morphology

Valve exterior

Valve surface slightly convex with rather delicate longitudinal ribs, 70 in 10 µm (Fig. 12, l and m). Raphe-sternum conopeate with very narrow conopeum (Fig. 11n). Raphe filiform and straight, proximal endings somewhat expanded, slightly bent towards valve primary side, while apical endings hooked (Fig. 11, l and m). Transapical striae parallel, becoming slightly convergent towards apices, 29–30 in 10 µm.composed of slightly apically elongate rectangular areolae, 70–80 in 10 µm. External opening of fistula framed by apically elongate, somewhat elevated siliceous rib (Fig. 11, l and m).

Valve interior

Valve face interior with elevated raphe-sternum rib (Fig. 11o), areolae aligned along raphe-sternum noticeably larger than those elsewhere in the striae (Fig. 11, p and r). Proximal raphe endings somewhat expanded and distant (Fig. 11p), apical endings terminate in small, simple helictoglossae (Fig. 11r). Fistula composed of three isolated, domed structures associated with two domed, hymenate accessory pores (fig. 11q).

Holotype: Natural History Museum, London, slide BM 81910, derived from the material of clone KNU-Y-16122 that was used to obtain sequence MK887895.

Isotype: slide no. SZCZ 26594 deposited in A. Witkowski Diatom Collection, Institute of Marine and Environmental Sciences, University of Szczecin, Szczecin, derived from the same clone.

Type habitat: Fine gravel of Pado-ri Beach, Yellow Sea coast of Korea, leg. Jong-Gyu Park and So-Yeon Kim, Dec. 2016

Etymology: the species name is derived from its lack of obvious distinguishing characters, “modestus” in Latin means modest.

Comments: to a certain extent, *P*. *modesta* resembles *P*. *impar*, to which it is sister in our molecular phylogeny. Externally they are similar, differing only in the position of the external fistula opening, which is strictly apically oriented in *P*. *modesta* vs somewhat oblique in relation to the apical axis in *P. impar*. Internally, the two species also differ in terms of the fistula, with three domed structures positioned on somewhat elevated part of the raphe-sternum in *P*. *modesta* vs two domed structures positioned on the valve internal surface and slightly engulfed by the raphe-sternum in *P*. *impar*.

Proschkinia fistulispectabilis **S-Y. Kim, J-G. Park and Witkowski sp. nov. – Figure 12**

LM Morphology

Valves strictly lanceolate with acutely rounded apices, 52 µm long, 9.0–9.8 µm wide (n=10). Transapical striae resolvable by LM, 20–23 in 10 µm, parallel throughout, becoming slightly convergent just below apices. Fistula large, distinct in LM and positioned perpendicularly to central nodule (Fig. 12, a–f, cf. Table 4).

SEM Morphology

Valve exterior

External valve surface flat, longitudinal ribs (60–70 in 10 µm) very well developed (Fig. 12, g–j). Raphe-sternum narrow, conopeate. (Fig. 12, g-j). Raphe straight, proximal endings slightly bent to opposite sides and very close, terminal raphe endings hooked in same direction (Fig. 12g). External opening of fistula an apically elongate slit similar to the mouth of a frog (Fig. 12i).

Valve interior

Internally, elevated raphe-sternum flanked by elongate areolae (Fig. 12k). Proximal raphe endings slightly expanded and distant (Fig. 12k), apical raphe ends terminate in simple, small helictoglossae (Fig. 12, m and n). Transapical striae composed of rectangular, apically elongate areolae ca. 60 in 10 µm (Fig. 12, i-k and m). Fistula composed of numerous grape-like structures covered by finely perforated occlusions (Fig. 12l).

Holotype: Natural History Museum, London, slide BM 81907, derived from a culture KNU-Y-16100 from which we failed to harvest DNA

Isotype: slide no. SZCZ 26595 deposited in A. Witkowski Diatom Collection, Institute of Marine and Environmental Sciences, University of Szczecin, Szczecin, derived from the same clone.

Type habitat: Sand on Baeksajang Beach, Yellow Sea coast of Korea, leg. Jong-Gyu Park and So-Yeon Kim, Dec. 2016

Etymology: the species name is derived from the unusually large fistula positioned within the central area.

Comments: among the species presented here, this species is unique in terms of size and gross morphology. This species has broader valves (9.0–9.8 µm) than the largest of the established species, *P*. *complanatula* (7.1–7.8 µm), and likewise much denser striation (20–23 in 10 µm) than *P*. *complanatula* (12–15 in 10 µm). In terms of the fistula ultrastructure, it somewhat resembles *P*. *luticola*, but only in EM, as the two fistula differ in size by few orders of magnitude, with that of *P*. *fistulispectabilis* being larger. The two fistulae also differ in the external opening which in *P*. *fistulispectabilis* is a long arc, like the mouth of a frog, while in *P*. *luticola* it is a simple slit. None of the other known *Proschkinia* taxa have an internal morphology of the fistula like *P*. *fistulispectabils*.

***Proschkinia rosowskii* Chunlian Li, Witkowski, Ashworth and E.C. Theriot sp. nov. – Figure 13**

Syn.: *Navicula complanatoides sensu* Brogan and Rosowskii 1988

LM Morphology

Valves linear-lanceolate with very slightly offset, acutely rounded apices, (26)38–40 (55) µm long, (4)5.5–7.5 µm wide (n=21). Transapical striae resolvable by LM, (24)27–28 in 10 µm (Fig. 14, h–s). Fistula barely resolvable by LM. Chloroplast (Fig. 14, a–g) consisting of two large plates connected by a narrow isthmus, typical of the genus, but with contorted lobes (lying principally against opposite sides of girdle), rather than the simple flat plates illustrated in a *Proschkinia* species by Cleve (1894, p. 153), Cox (1981, 1988) in "*Navicula complanata*", and Mereschkowsky (1903b, pl. 2, figs 42–48) in "*Libellus libellus*" and "*Libellus parvulus*"; our species more closely resembles Mereschkowsky's *Libellus reticulatus* (Mereschkowsky 1903b, pl. 2, figs 34–36) and *P. hartii* (Cholnoky) Clavero and Hernández-Mariné as illustrated by Clavero (2009). In our description above, the frustule size data of Brogan and Rosowski (1988) are given in brackets (cf. Table 4).

SEM Morphology

Valve exterior

External valve surface flat with delicate longitudinal ribs, 60–70 in 10 µm. Central area a "Y-shaped" structure (Fig. 13, u and w). Raphe-sternum conopeate, raphe filiform with expanded, tear-like proximal raphe endings positioned close (Fig. 13, t and u), while terminal raphe endings are strongly hooked in the same direction, terminating in long slits on mantle (Fig. 13t). Transapical striae parallel, becoming convergent towards apices. External fistula opening partially occluded by small, apically oriented, slightly thickened flap (“elevation” in Brogan and Rosowski 1988, Fig. 8; our Fig. 13u).

Valve interior

Internally, valve surface with elevated raphe rib. Raphe-sternum flanked by elongate areolae (Fig. 13, v and w). Raphe slits straight, with simple proximal raphe endings, strongly-elevated small helictoglossae at the apical raphe endings (Fig. 13v). Fistula composed of two-three isolated pores (Fig. 13, v and w).

Holotype: Natural History Museum, London, slide BM 81911, derived from culture SZCZCH1764, from which DNA was harvested but PCR failed

Isotype: slide no. SZCZCH1764 deposited in A. Witkowski Diatom Collection, Institute of Marine and Environmental Sciences, University of Szczecin, Szczecin, from the same clone.

Type habitat: Gulf of Mexico, Texas, Corpus Christi, Fish Pass mangrove scrape, leg. Ch. Li, A. Witkowski, M. Ashworth and E. Theriot, Dec. 2013.

Etymology: the species name is dedicated to Dr. Jim Rosowski in appreciation of his contribution to research into this particular species but also in general to progress in diatomology.

Comments: *P*. *rosowskii* corresponds to *N*. *complanatoides* as characterized by Brogan and Rosowski (1988, p. 265, figs. 12, 16) in both internal and external fistula structure, the proximal external raphe endings and in the possession of the forked (Y-shaped) structure in the central area. As shown in our LM and SEM observations of *Navicula complanatoides*, the species studied by Brogan and Rosowski can no longer be considered *N*. *compalanatoides*. Besides the size dimensions, the two illustrations exhibit a major difference in the external and internal structure of fistula and the proximal external raphe endings (cf. our Fig. 5). *Proschkinia complanatoides* has a large fistula internally versus the two to three small pores in *P*. *rosowskii*. Externally, the fistula opening in *P*. *complanatoides* is formed as an apically elongate slit, whereas in *P*. *rosowskii* it is covered by a thickened flap. The proximal raphe endings are completely different between the two species -- strongly bent in *P*. *complanatoides* (Zgrundo et al. 2013, this paper) and coaxial, expanded and close each other in *P*. *rosowskii* (cf. Brogan and Rosowski 1988, this paper).

***Proschkinia* sp. 1 – Figure 14**

LM Morphology

Frustules rectangular, dorsiventral in girdle view with numerous bands (Fig. 14, a–d); more than 20 bands in epitheca, with a density of up to 28 in 10 µm measured by SEM). Valves lanceolate with acutely rounded apices, 28–31.5 µm long, 5.5–6.6 µm wide (n=12). Transapical striae delicate but resolvable by LM, ca. 22–24 in 10 µm, parallel (Fig. 14, a-h). Fistula indistinct, but well resolvable in LM (Fig. 14f, cf. Table 4).

SEM Morphology

Valve exterior

Valve surface flat with slightly depressed raphe-sternum, abruptly differentiated from hyaline mantle (Fig. 14, j and k). Longitudinal ribs almost absent at valve center, becoming regular outside central area, increasingly thinner towards valve margin, very dense, 90–100 in 10 µm (Fig. 14, j–n). Raphe-sternum conopeate, very narrow, bordering grooves barely visible. Raphe filiform, proximal external endings rather distant (Fig. 14, j–m), hooked towards valve secondary side (Fig. 14, j and m); distal endings strongly bent in same direction (Fig. 14j). External fistula opening in form of thin, bent slit (Fig. 14, j, k and m). Transapical striae dense, usually parallel at valve center, 25–26 in 10 µm (Fig. 14, m and n).

Valve interior

To date, only external valve views have been observed for this strain.

Comments: this species has been difficult to observe in the microscope due to the high salt content maintained for several years in the voucher material, which was strongly corrosive to siliceous frustules (even when they were still coated with organic material). The size morphometrics differ from those of other known species. Some similarity exists between this strain and *P. complanatoides*, especially in the shape of the external proximal raphe endings, although in *P. complanatoides* these are hooked towards the valve primary side, whereas in *Proschkinia* sp. 1 they are hooked towards the secondary side. Furthermore, the stria density is higher than in *P. complanatoides*. Due to the poor preservation of *Proschkinia* sp. 1, we refrain from naming the species and making a formal taxonomic description until new cultures can be established. Its identity is established by the *rbc*L sequence and hence we consider it worthwhile to document the existence of the species, even though some morphological data (especially concerning the internal structure of raphe and fistula) are missing. This strain originates from the Scottish coasts of the North Sea (North Atlantic).

Molecular phylogeny

Our phylogeny (Figure 15, Supplementary Fig. S1; Supplementary Table S2, Supplementary data S3) recovered *Proschkinia* and *Fistulifera* as sister taxa inside a bigger clade comprised of genera such as *Craticula*, *Sternimirus*, *Stauroneis* and *Parlibellus harffianus*; this larger clade had high bootstrap support (100%). Within *Proschkinia*, the epizoic taxon *P. vergostriata* Frankovich, Ashworth and M.J.Sullivan (Majewska et al. 2019) was sister to the remaining *Proschkinia* species sequenced (98% bootstrap support). *Proschkinia* and *Fistulifera* were recovered as reciprocally monophyletic (each clade with high bootstrap support of 100%). That clade itself received strong support (100%) with one species of *Parlibellus* (*P. harffianus* SZCZCH75) recovered as its sister species (cf. Fig.15 and Supplementary Fig. S1). The relationship of *Parlibellus harffianus* to *Proschkinia–Fistulifera* remains enigmatic, in that the remaining species of *Parlibellus* were recovered as a clade (100% bootstrap support) embedded in another clade with *Astartiella* and *Schizostauron*, though with little support (51%)

The larger clade composed of *Proschkinia*/*Fistulifera* + the Stauroneidaceae and *Parlibellus* + the monoraphid genera *Astartiella* and *Schizostauron* is sister to a strongly supported (BS 100%) clade containing *Phaeodactylum triconrnutum* and *Gomphonemopsis* cf. *pseudexigua* (clade PG in Sabir et al. 2018). This “PG clade” and the clade including *Proschkinia* and *Fistulifera* were sister, with low BS support, to a series of monophyletic clades comprising *Mastogloia*, *Tetramphora* and the Berkeleyaceae without *Parlibellus* (Fig. S1). This latter clade received variable, but usually low to modest support. Analysis of our large phylogenetic tree (Fig. S1) shows that the Naviculineae sensu Round et al. (1990, cf. also Cox and Reid 2004) is a paraphyletic suborder, with the Stauroneidaceae, Proschkiniaceae, *Parlibellus*, *Astartiella* and *Schizostauron* in one well supported, monophyletic clade and the Naviculaceae, Pleurosigmataceae, Plagiotropidaceae in another monophyletic clade distant from each other by several nodes.

DISCUSSION

In this paper we present light and electron microscopic documentation of five (out of seven) established species for which unmounted material is accessible, including the generitype, *Proschkinia bulnheimii*, from historical material obtained from the Grunow Collection in Vienna. Also from Grunow Collection in Vienna we received material and studied in LM and SEM two samples referenced as original material for *Proschkinia complanata* (Grunow) D.G.Mann. Whereas sample “Trieste 1123” has already been illustrated in low resolution LM (Krammer and Lange-Bertalot 1986), the second sample “Svety Petar 870” is illustrated in LM and SEM for the first time. From Husetdt Collection we have received and studied in LM and SEM three out ofand four described *Navicula* species included in *Naviculae* Sect. *Microstigmaticae* that have been transferred to *Proschkinia*: *N. complanatula*, *N. complanatoides*, *N. hyalosirella* excluding *N. longirostris* (Hustedt 1962). In this paper we also formally describe six *Proschkinia* species all new to science isolated from the Yellow Sea coast in Korea and the Gulf of Mexico in Texas.

Our observations of morphological characters and the recent study by Majewska et al. (2019) underlines the importance of the fistula for the proper identification of *Proschkinia* species. Furthermore, as shown in the molecular phylogeny, the fistula seems to be a shared, derived character (synapomorphy) for the *Proschkinia* and *Fistulifera* clade. However, in the light of our recent results, as well as those of Riaux-Gobin et al. (2013) this may not be the case, because *Astartiella* also contains a central process. When first describing *Astartiella* Witkowski, Lange-Bertalot and Metzeltin, Moser et al. (1998) referred to its raphe valve process as a "stigma" and Riaux-Gobin et al. (2013) did likewise in characterizing the valve morphology of *Astartiella societatis* Riaux-Gobin, Witkowski and Romero. However, with molecular markers (see also Sabir et al. 2018 and Majewska et al. 2019) *Astartiella* is often recovered in close proximity, or even sister to, the *Proschkinia*/*Fistulifera* clade. This suggests that the "stigma" may in fact be a fistula, though it only occurs on the raphid valve. So, perhaps the fistula is not a synapomorphy for the *Proschkinia–Fistulifera* clade alone but for a wider group; alternatively, fistula-like structures could have evolved several times across the raphid diatoms.

Morphological support for molecular clades?

The ML phylogeny obtained in the course of this work (cf. Supplementary Table S2, Supplementary data S3, Supplementary Fig. 1), although informative, is not totally satisfying due to the low support at some of the nodes. Our results agree with Gastineau et al. (2019) and Majewska et al (2019) in showing that *Proschkinia* is sister to *Fistulifera*. This pair also shares a clade with the genera *Craticula*, *Sternimirus*, *Stauroneis*, *Parlibellus*, *Astartiella* and *Schizostauron*, which agrees with the molecular phylogenies shown in Davidovich et al. (2017) and Sabir et al. (2018). Although *Proschkinia* and *Fistulifera* show such distinct differences in their gross morphology (large, fairly robust naviculoid cells, with structure usually resolvable by LM in *Proschkinia* and very small, delicately-silicified cells in *Fistulifera*) they do share some characters such as the fistula. Indeed, the internal structure of the fistula is similar in *P. bulnheimii*, *P. vergostriata*, *P. sulcata* and all known *Fistulifera* species, since in all it is a simple wart-like structure with a domed, finely perforated membrane internally. Externally, however, the variation in the fistula opening between the two genera is distinct. These genera also share hymenate areolae occlusions, though these are also observed in many raphid diatom taxa (Mann 1981, Zgrundo et al. 2013, Matsumoto et al. 2014).

As for the other genera in the molecular clade with *Proschkinia* and *Fistulifera*, *Craticula* resembles *Proschkinia* in the external longitudinal ribs found in some species of both genera and the raphe sternum bordered by apically oriented grooves found in *C. ambigua* and many *Proschkinia* spp. The raphe in *C. ambigua*, however, is not conopeate (Round et al. 1990, Mann and Stickle 1991, Lange-Bertalot 2001). *Schizostauron* also has U-shaped girdle bands somewhat like *Proschkinia*, but they are unperforated (Witkowski, unpublished observations). A broad girdle composed of multiple perforated bands is also present in other unrelated raphid genera e.g. *Undatella* Paddock and Sims (Round et al. 1990) and *Tetramphora* Mereschkowsky, but these are quite distant from *Fistulifera* and *Proschkinia* in the molecular phylogeny; for example, *Tetramphora* is sister to the Mastogloiales (Stepanek and Kociolek 2016), whereas *Undatella* is usually found in or near the Bacillariaceae (Ashworth et al. 2017). Furthermore, the girdle bands in *Undatella* are tube-like rather than U-shaped and the perforation is the same as that on the valve face (Round et al.

1990). Stepanek and Kociolek (op. cit.) illustrate a few general frustules of *Tetramphora*, with only their fig. 77 showing the detailed structure of a single girdle band of *T. lineolatoides* Stepanek and Kociolek. As far as it is possible to compare the girdle bands in the two genera in question, they appear different in terms of ultrastructure, as the bands in *Tetramphora* are flat and perforated only on the advalvar side (Stepanek and Kociolek 2014, 2016). We cannot see any obvious morphological character shared between *Proschkinia* and *Sternimirus* to the exclusion of the rest of the raphids; possibly the robust and somewhat elevated sternum might be such a character (cf. Witkowski et al. 2016).

Externally, the raphe-sternum of *Proschkinia* is demarcated from the remainder of the valve by two distinct grooves. Based on SEM observations by Cox (1988), Round et al. (1990), Carr et al. (2008) and Clavero (2009) and on our results, we understand the raphe system of *Proschkinia* as an externally conopeate T-shaped structure with a massive internal rib through which the raphe slits opened laterally (cf. our Fig. 2g). For now, we are unable to point to a similar raphe-sternum in other diatoms, especially in its internal development.

Our data would support the transfer of *Fistulifera* into the Proschkiniaceae (*Fistulifera* was placed in the Stauroneidaceae by Cox 2015), but it may be best to delay redrawing family boundaries until the interrelationships of *Stauroneis*, *Craticula*, *Sternimirus*, *Prestauroneis*, *Parlibellus*, *Astartiella* and *Schizostauron* (all of which are represented in molecular datasets) are clearer. The concepts of the Stauroneidaceae formulated by Round et al. (1990: *Stauroneis* plus *Craticula*) and Cox (2015: excluding *Fistulifera* from her grouping would leave *Stauroneis*, *Craticula*, *Lacunicula* and *Prestauroneis*) cannot yet be confirmed or refuted since current analyses do not give strong support for any groupings of these seven genera, apart from *Astartiella* and *Schizostauron* (see also Sabir et al. 2018).

The relationship between *Proschkinia* and *Parlibellus* has not been recognized in recent classifications (they were put in different suborders by Round et al. 1990 and Cox 2015) but much earlier, Mereschkowsky (1903a) placed the two together in the same genus ('*Libellus*'), as two informally recognized groups. Mereschkowsky saw *Libellus* as key to understanding how naviculoid diatoms evolved, occupying an intermediate position between 'archaic' forms with a single chloroplast per cell (the 'Archaidées') and the naviculoid diatoms with two entirely separate chloroplasts, one on either side of the girdle (the 'Naviculacées', e.g. *Navicula sensu stricto*, *Trachyneis*). [He wrote of *Libellus* "C'est un genre très ancient, que je regarde comme l'ancêtre commun de toutes les *Polyplacatae* (*Naviculacées*, etc) et comme le lien intermédiaire qui réunit ces dernières aux *Archaidées*": Mereschkowsky 1903a, p. 113].

Molecular phylogenies do not support Mereschkowsky's idea (e.g. Supplementary Fig. S1). Interestingly, however, the chloroplast morphology and cellular changes that formed the basis of Mereschkowsky's hypothesis – that a phase of chloroplast division that is transient in one species or group of diatoms can become the dominant phase in a related group (codified as a 'law', the 'loi de translation des stades', by Mereschkowsky 1904) – seem to be demonstrated in the wider clade containing *Proschkinia* and perhaps within *Proschkinia* itself. In the *Proschkinia* species we have examined (this paper and unpublished observations), and also those studied by Mereschkowsky (1902, 1903a, b) and Clavero (2009), cells possess a single chloroplast comprising two plates (sometimes elaborately lobed) connected by a narrow isthmus near the center of the cell. [We have not ourselves seen any examples where there are two separate chloroplasts as drawn by Cleve (1894, p. 193; the cell he showed in girdle view appears to be degraded, while the valve view shows inflections of the chloroplasts at the center suggesting an undetected bridge between them: this was also the interpretation of Mereschkowsky 1903b, pl. 2 figs 11, 12) or by Cox (1988). Further, the illustrations of small-celled *Proschkinia* by Majewska et al. (2019, their supplementary fig. S1) are not clear enough to judge the structure of interphase cells, and those of other *Proschkinia* by Brogan and Rosowski (1988) are also unclear. However, we do not claim that no *Proschkinia* species possess two chloroplasts.] Some *Stauroneis* and *Craticula* species pass transiently through such a stage during cell division (Stickle and Mann 1988, Mann and Stickle 1991), and others (e.g. *C.* cf. *halophila*) maintain a similar state for most of interphase (Mann and Stickle 1991). In *Prestauroneis protracta* (= *Parlibellus protracta*) too, an isthmus between the two chloroplast plates persists during the initial stages of chloroplast rearrangement following cytokinesis (Mann 1988). Hence a stage that occupies only a small fraction of the cell cycle in some of the Proschkiniaceae–Stauroneidaceae is the dominant phase in at least some, perhaps all *Proschkinia* species (through Mereschkowsky's 'translation des stades'). In contrast, a delay in chloroplast division is apparently always absent in some other, unrelated naviculoid diatoms with two chloroplasts, such as *Navicula sensu stricto* or *Seminavis* (e.g. Mann and Stickle 1989, Chepurnov et al. 2002). However, whether particular features of the pattern and timing of chloroplast division characterize the whole Proschkiniaceae–Stauroneidaceae group or only some clades within it is as yet unclear, as are the directions of character state transitions: currently, even basic information about chloroplast structure and division are missing for most species, and *Proschkinia* is still a mysterious diatom genus of the marine littoral in terms of understanding its evolutionary significance.

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Table 1. Diatoms from historical gatherings of *Proschkinia* species studied in this paper.

Table 2. Sites, temperature and salinity of the sampling stations from which *Proschkinia* strains studied originated.

Table 3. Primers used to amplify the SSU and *rbc*L markers used in the molecular phylogenetic analysis.

Table 4. Summary of the *Proschkinia* species studied here. Included are size dimensions and ultrastructure characters of newly described and selected established species. “ND” means data are not available.

Figure captions

Figure 1. Significant characters for distinguishing *Proschkinia* species, based on selected species illustrated in SEM. (a, c–d) *P. staurospeciosa* Kim, S-Y., Park, J-G.,

Witkowski & Gastineau sp. nov.; (b, e) *P. impar* Kim, S-Y., Park, J-G. & Witkowski sp. nov.; and (f, g) *P. complanatoides* (Hustedt ex Simonsen) D.G.Mann. (a) Valve central area external view, black arrows mark the beginning of apically elongate grooves between the raphe sternum the valve surface, white arrowheads mark the virgae, black arrowheads mark areolae, whereas the white arrow marks the fistula opening. (b) Central area exterior detailed view, white arrowhead marks the silica flap covering the opening of the fistula and white arrow with black frame marks the longitudinal rib on the valve surface, the black arrows are pointing to the conopeate raphe sternum, white arrows are showing the virgae inside the apically elongate grooves and the black arrowhead marking the external opening of the accessory pore. (c) Close up of the valve exterior note the apically oriented grooves (white arrows) and the conopeate raphe sternum (black arrowheads). (d) valve interior central part note pole like raphe rib flanked by elongate areolae (black arrowhead) delineated by the virgae (white arrow), white arrowhead marks the striae forming areolae. Black arrows are pointing to the black contour of the external opening of the grooves, whereas white arrowhead in black frame is pointing towards the internal surface of the conopeum. (e) Close up of the valve interior central area; note fistula formed by two domed structures (black arrows) and the two associated pores (white arrowheads). (f) FIB nanocut through the valve central nodule, note the external fistula opening below the siliceous flap (black arrow) and the chambered nanocut through fistula (white arrow). (g) FIB nanocut through the raphe branch middle illustrating the conopeate T-shaped raphe sternum (black arrows), the groove between the raphe sternum and the valve exterior (black arrowhead) and the raphe slit (white arrowhead).

Figure 2. *Proschkinia bulnheimii* (Grunow in Van Heurck) Karayeva (a–i) cleaned specimens in the light microscope. (j–p) SEM. (j). External view of the whole specimen, note somewhat coarser middle stria (arrow) and longitudinal ribs (arrowheads). (k) Close up of the valve centre exterior, note the expanded proximal raphe endings (white arrowheads) and the simple fistula opening (black arrowhead). (l). Close up of the apex, note the strongly hooked distal raphe end (arrow) and apical areolae. (m). Internal view of the whole valve. (n). Close up of the valve centre interior, note the simple domed fistula (white arrowhead) and the proximal raphe ends with double helictoglossa (black arrowhead). (o). Hymenate areolae occlusions (arrow). (p). Apical part of the valve interior with elevated raphe rib (arrow), and the large areolae aligned along the raphe rib (arrowhead).

Figure 3. *Proschkinia complanata* (Grunow) D.G.Mann (a–h) in light microscope. Cleaned specimens from Grunow collection in Vienna. (a–g) sample 870, (h) sample 1123. (i–o) specimens from sample 870 in SEM. (i) External valve view of the whole specimen. (j) valve centre close up, note two grooves between raphe-sternum and the valve face (arrowheads). (k) Close up of the central area with expanded proximal raphe ends (black arrowheads) note thickened siliceous flap covering the external opening of fistula (white arrowhead). (l) External apical raphe end, note the strong hook (arrow) and long apical areolae (arrowhead). (m) Valve centre internal view with elevated raphe rib (arrow) and fistula composed of numerous globular structures in a row (arrowhead). (n) areolae occluded internally with perforated hymenes (arrowhead) (o) Apical raphe ending terminating in small helictoglossa (arrowhead).

Figure 4. *Proschkinia complanata* (Grunow) D.G.Mann (Grunow sample 1123) in SEM. (a) The whole frustule (b) Close up of the girdle apical part with copulae (arrow). (c) Close up of the central area, arrows mark the grooves between the T-shaped sternum and the valve. (d) Close up of specimen illustrated in Fig. c, note expanded proximal raphe ends and the flap covering the fistula (arrow). (e) Close up of the apical valve part, note the termination of the longitudinal ribs (black arrowhead) and of the striation (white arrowhead). (f) valve centre internal view note strong pole-like raphe rib (arrows). (g) Close up of fistula composed of several globular structures in a row (arrow) with two accessory pores (arrowheads).

Figure 5. *Proschkinia complanatoides* (Hustedt ex Simonsen) D.G. Mann (a–g) cleaned material in LM. (i–q) SEM. (h). Girdle composed of U-shaped bands (arrow). (i). Valve exterior of the whole specimen. (j, k). Valve centre close up with hooked proximal raphe endings (white arrowheads) and slit-like openning of the fistula (black arrowhead), note the grooves between the raphe-sternum and the valve face (arrows). (l, m). Close up of the apex with hooked distal raphe end (arrow in Fig. m). (n). The whole valve interior, note the raphe rib (arrow). (o). Close up of the valve centre interior with fistula (arrow) and the accesory pore (arrowhead). (p). Details of the fistula. (q). Valve apex interior, note a small helictoglossa.

Figure 6. *Proschkinia complanatula* (Hustedt ex Simonsen) D.G. Mann (a–i) cleaned specimens in the light microscope. (j–n) SEM. (j). Valve exterior of the whole specimen. (k) Valve centre close up, with the fistula opening (arrow), the expanded, slightly bent proximal raphe ends (arrowheads) note valve surface lacking the longitudinal ribs. (l). Valve apex exterior, note strongly hooked distal raphe end

(arrow) and termination of the apical groove (arrowhead). (m). Central area interior close up, note the raphe rib (black arrow), peculiar fistula (white arrow) and the large areolae aligned along the raphe rib (arrowheads), see the fine striae forming areolae (black arrowhead). (n) Valve interior in its apical part.

Figure 7. *Proschkinia hyalosirella* (Hustedt) D.G. Mann. (a–c) cleaned specimen in the light microscope. Scale (a–c): 10 µm. (d–n) SEM. (d–f) Girdle details with U-shaped and perforated bands (arrows in Fig. e and arrowhead in Fig. f). (g). Valve exterior of the whole specimen. (h). Valve centre close up, with raphe proximal endings (white arrowheads) and opening of fistula (black arrowhead) note also gradually vanishing longitudinal ribs. (i) Valve apex exterior note strongly hooked raphe distal end (arrow) and long apical areolae (arrowhead). (j) Whole specimen valve interior note the raphe rib (arrow). (k, l). Valve centre interior close ups and position of the fistula (white arrowhead), with small engulfment in the raphe-sternum (arrow in Fig. l) note domed, hymenate accessory pore (black arrowhead). (m). Valve apex interior note the elevation of the raphe rib (arrow). (n) Internal raphe distal end, note the small helictoglossa (black arrowhead) and elongate areolae aligned along the raphe rib (white arrowheads).

Figure 8. *Proschkinia luticola* Kim, S-Y., Park, J-G., Witkowski & Kim, B-S. sp. nov. (a–f) cleaned specimens from the culture in the light microscope. (g–n) SEM. (g) Whole specimen valve exterior. (h) Valve centre exterior close up, note simple proximal raphe endings, and irregular slit of fistula opening (arrow). (i) Valve apex close up with strongly hooked distal raphe end (arrowhead). (j) Whole specimen valve interior. (k) Valve centre interior close up with elongate areolae aligned along the

raphe rib (arrowhead). (l) Close up of the fistula structure (arrow) with two accessory pores (white arrowheads). (m, n) Close ups of the valve apices interior with simple helictoglossa, note stria forming areolae (arrowheads).

Figure 9. *Proschkinia staurospeciosa* Kim, S-Y., Park, J-G. Witkowski & Gastineau (a–i) in the light microscope, cleaned specimens from the culture. (j–p) SEM. (j) External valve surface. (k) Close up of valve centre with apical grooves (arrows), fistula opening (white arrowhead) and openings of fistula associated pores (black arrowheads). (l) Valve apex exterior with raphe distal raphe end (arrowhead). (m) The whole valve interior with elongate areolae flanking the raphe rib (arrowheads). (n) Valve centre close up, note the small, fistula (arrow) and accessory pores (arrowheads). (o) Valve apex interior close up, note the small helictoglossa (arrowhead). (p) Separated girdle bands note numerous U-shaped open bands (arrow).

Figure 10. *Proschkinia impar* Kim, S-Y., Park, J-G. & Witkowski (a–k) in the light microscope cleaned specimens from the culture. (l–t) SEM. (l) Complete frustule with numerous U-shaped girdle bands (arrows). (m) External view of the slightly convex valve surface. (n) raphe-sternum exterior close up, note apical grooves (arrows). (o) Valve centre exterior with fistula opening (arrow). (p) Strongly hooked distal raphe end close up (arrow), and apical areolae (arrowheads). (q) Whole specimen valve interior with elevated raphe rib (arrows). (r) Valve centre interior close up note apically elongate striae forming areolae (arrowheads) and small domed fistula (arrow). (s) Close up of the fistula, note two, simple domed structures (arrows) and two isolated pores (arrowheads). (t) Apex interior close up, note the raphe end terminating in small helictoglossa (arrowhead).

Figure 11. *Proschkinia modesta* Kim, S-Y., Park, J-G. & Witkowski. (a–k) in the light microscope cleaned specimens from the culture. (l–r) SEM. (l) External valve surface. (m) Valve centre close up, note apical grooves (arrows) and fistula opening covered with thickened siliceous flap (arrowhead). (n) Apical raphe end with apical areolae close. (o) Valve interior with raphe rib (arrows). (p) Raphe rib flanked with large areolae (arrowheads). (q) Close up of fistula (arrowheads), note two domed accessory pores (arrows). (r) Internal terminal raphe end.

Figure 12. *Proschkinia fistulispectabilis* Kim, S-Y., Park, J-G. & Witkowski (a–f) cleaned specimens from the culture in the light microscope, note the large fistula (arrow in Fig. e). (g–n) SEM. (g) Valve face exterior with distinct raphe sternum (arrows). (h) Valve centre with two shallow grooves (arrows) and large central area (arrowheads). (i) Fistula external opening (arrow), with simple and approximate proximal raphe endings (arrowheads). (j) Apical valve part with hooked external terminal raphe ending (arrow), note the longitudinal ribs (arrowheads). (k) Valve centre interior close up, note raphe-sternum (white arrows), fistula (black arrow) and striae forming areolae (arrowheads). (l) Complex fistula structure. (m-n) Internal apical raphe ends terminating in simple helictoglossa.

Figure 13. *Proschkinia rosowskii* Ch. Li, Witkowski, Ashworth & Theriot, E.C. sp. nov. (a–s) in the light microscope. (a–g) Live specimens with chloroplast. (h–s) Cleaned specimens from the culture and (s–w) in SEM. (t) Whole specimen external valve view. (u) Valve centre close up, note the apical grooves (arrows) and the fistula opening (black arrowhead) close to the central nodule (white arrowhead). (v) Whole

specimen internal valve view. (w) Valve centre interior close up, note elevated raphe-sternum (white arrow), large elongate areolae (arrowheads) and the fistula (black arrow).

Figure 14. *Proschkinia* sp. 1 from Scotland. (a–h) cleaned valves from the culture in light microscope, note the fistula in fig. f. (i–n) SEM. (i) The whole frustule in girdle view, note U-shaped girdle bands (arrow). (j) Lateral view of the frustule, note the sternum (arrowheads) and strongly bent proximal raphe ends (arrows). (k) Valve face centre close up note the indistinctly raised siliceous flap covering the fistula (arrow). (l). Close up of another specimens illustrating the valve face centre with indistinct raphe sternum (arrows). (m) Valve centre close up with distinct proximal raphe ends (arrows) and the fistula (white arrowhead), note the very high density of the longitudinal ribs (black arrowheads). (n) Valve apex close up, note the U-shaped and perforated girdle bands (arrow).

Figure 15. Phylogeny of genera closely related to *Proschkinia* based on three gene (nuclear- encoded ribosomal SSU, chloroplast-encoded *rbc*L, *psb*C markers) data set.

Supplementary data S1. Detailed information on established *Proschkinia* taxa studied in this paper.

Supplementary data S2. Strains used in the phylogenetic analysis. For cultures from public collections, the ID is provided (UTEX = UTEX Culture Collection of Algae; NCMA = National Center for Marine Algae and Microbiota; CSIRO = Australian National Algae Culture Collection; MCC-NIES = Microbial Culture Collection at National Institute for Environmental Studies, SZCZ = Szczecin Culture Collection).

Raphid pennates as ingroup taxa are listed as first in the table; araphid pennates as outgroup taxa follow after table break. All taxa are listed alphabetically.

Supplementary data S3. The aligned 3-gene dataset (nuclear- encoded ribosomal SSU, chloroplast-encoded *rbc*L, *psb*C markers) used for the molecular phylogenetic analyses.

Supplementary Figure S1. Maximum Likelihood complete phylogenetic tree of *Proschkinia* based on three gene (nuclear- encoded ribosomal SSU, chloroplast-encoded *rbc*L, *psb*C markers) data set.

Table 1. Diatoms from historical gatherings studied in this paper

Taxon	Basionym	Location	Sample number	Slide in present authors collection	Collection
Proschkinia bulnheimii	*Navicula bulnheimii*	Inland saline waters in SE Germany	1720	RBG in Edinburgh	Coll. Grunow
Proschkinia complanata	*Amphora complanata*	Svety Petar, Croatia	870	SZCZ75731 in Szczecin	Coll. Grunow
Proschkinia complanata	*Amphora complanata*	Trieste	1123	SZCZ25978 in Szczecin	Coll. Grunow
Proschkinia complanatoides	*Navicula complanatoides*	Sumba Island	As1135, As1465	SZCZ25792, SZCZ25791 in Szczecin	Coll. Hustedt
Proschkinia complanatula	*Navicula complanatula*	Oregon, USA	Am2243	SZCZ25790 in Szczecin	Coll. Hustedt
Proschkinia hyalosirella	*Navicula hyalosirella*	Florida, USA Madeira	Am2214 E10731	SZCZ25921, SZCZ25789 in Szczecin	Coll. Hustedt

Table 2. Sites, temperature and salinity of the sampling stations from which the *Proschkinia* strains studied were isolated and examined.

Species	Locality	temperature	Salinity	Sampling date	Latitude	Longtitude
Proschkinia luticola	Beopsan-ri, Taean, Korea	15.7	20.6	2016.05	36˚ 45′7.15″ N	126˚ 10′59.81″ E
Proschkinia staurospeciosa	Pado-ri, Taean, Korea	12.3	33.0	2016.12	36˚ 44′15.0″ N	126˚ 07′49.7″ E
Proschkinia impar	Pado-ri, Taean, Korea	12.3	33.0	2016.12	36˚ 44′15.0″ N	126˚ 07′49.7″ E
Proschkinia modesta	Pado-ri, Taean, Korea	12.3	33.0	2016.12	36˚ 44′15.0″ N	126˚ 07′49.7″ E
Proschkinia fistulispectabilis	Baeksajang, Taean, Korea	10.1	32.8	2016.12	36˚ 34′42.94″ N	126˚ 18′49.63″ E
Proschkinia rosowskii	Fish Pass Mangrove, Corpus Christi, Texas, USA	ND	28-34	2013.12	27° 40’48.0" N	97°10’22.8" W
Proschkinia sp. 1	Scotland, North Atlantic	ND	35	Early 2000s	ND	ND

Table 1. Primers used to amplify the SSU and *rbc*L.

Name	Gene	Sequence(5'-3')	Reference
EukA	SSU	AAC CTG GTT GAT CCT GCC AGT	Medlin et al. (1988)
G18R	SSU	GCA TCA CAG ACC TGT TAT TG	Litaker et al. (2003)
570F	SSU	GTA ATT CCA GCT CCA ATA GC	Weekers et al. (1994)
EukB	SSU	TGA TCC TTC TGC AGG TTC ACC TAC	Medlin et al. (1988)
DP*rbc*L1	*rbc*L	AAG GAG AAA THA ATG TCT	Jones et al. (2005)
DP*rbc*L7	*rbc*L	AAR CAA CCT TGT GTA AGT CTC	Jones et al. (2005)

Table 1. Summary of the *Proschkinia* species studied. Included are size dimensions and ultrastructure characters of newly described and selected established species. ND means data are not available.

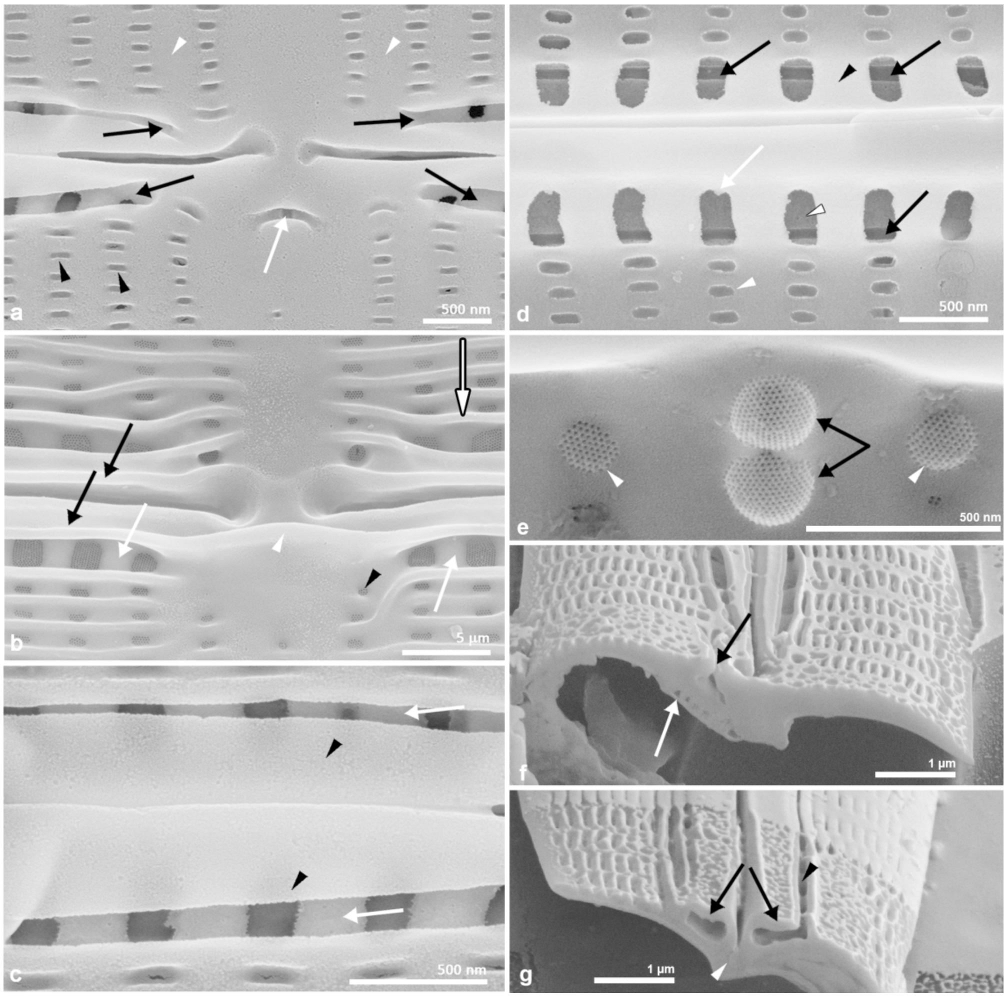
	Length	Width	Stria in 10 µm	Fistula internally	Fistula externally	Distribution	Areola in 10 µm	Longitudinal ribs in 10 µm	Distal raphe ends	Proximal raphe ends	Density of girdle bands in 10 µm
Proschkinia luticola	(10)22-23	4.5-6.0	27-29	Large, morphologically complex	Irregular slit	Beopsan-ri, Taean, Korea, Yellow Sea	70	70	Shortly hooked	Slightly bent	ND
Proschkinia staurospeciosa	27-28	Ca. 5.0	23-24	One domed structure	Simple slit	Pado-ri, Taean, Korea, Yellow Sea	80	Not observed	Strongly Hooked	Slightly bent	ND
Proschkinia impar	34.5-36.0	4.9-5.3	26-30	two domed, structures	Thickened siliceous	Pado-ri, Taean,	80	70-80	Strongly Hooked	Slightly expanded	30-34

					flap	Korea, Yellow Sea					
Proschkinia modesta	32.5-35.0	5.7-6.2	29-30	Three domed, circular structures	Somewhat elevated slit	Pado-ri, Taean, Korea, Yellow Sea	70-80	70	Hooked	Somewhat expanded	ND
Proschkinia fistulispectabilis	Ca. 52.0	9.0-9.8	20-23	Grape-like structure	Elongate slit	Baeksajang, Taean, Korea, Yellow Sea	60	60-70	Hooked	Bent	ND
Proschkinia rosowskii	38-40	5.5-7.5	27-28	Two domed structures	Apically oriented slightly thickened flap	Gulf of Mexico, Texas, Corpus Christi,	60	60	Hooked	expanded	ND

						Mangroves					
Proschkinia sp.1	28-31.5	5.6-6.6	25-26	ND	Thin strongly bent slit	The North Sea	90-100	90-100	Strongly bent	Bent	>20-28
Proschkinia bulnheimii	15-30	3-4	28-34	single, domed structure	Oblique slit	Saline inland waters in Europe, Catalan coasts, South African coasts, North America	70	70	Strongly hooked	Simple expanded	20
Proschkinia complanata (870 Coll.	55.0-58	6.7-7.3	24-25	Globular structures	Thickened elevated flap	Adriatic Sea, Pacific Ocean (Guam)	65-70	65-70	strongly hooked	Simple expanded	

Grunow Vienna)											
Proschkinia complanata (1123 Coll. Grunow Vienna)	35-40	4-6	24-25	Globular structures	Apically oriented oblique slit	Adriatic Sea, Triest	70-80	70-80	Strongly hooked	Simple expanded	26-28
Proschkinia complanatoides	33-60	4.6-7.3	17-20	Large lubricate	Short undulate slit	Indonesia, Baltic Sea	50-70	50-70	Strongly hooked	Strongly bent	18
Proschkinia complanatula	34-58	7.1-8.0	12-15	Tear-like shape	Small depression framed by a lip-like structure	Oregon, USA	70	65	Strongly hooked	Slightly bent	7-8
Proschkinia hyalosirella	25.0-30.0	3-4.1	28-30	Peanut-like structure	Massive siliceous	Gulf of Mexico,	70-80	70	Strongly hooked	Slightly expanded,	20

flap covering the central nodule	Florida West coast, Madeira		tear-like



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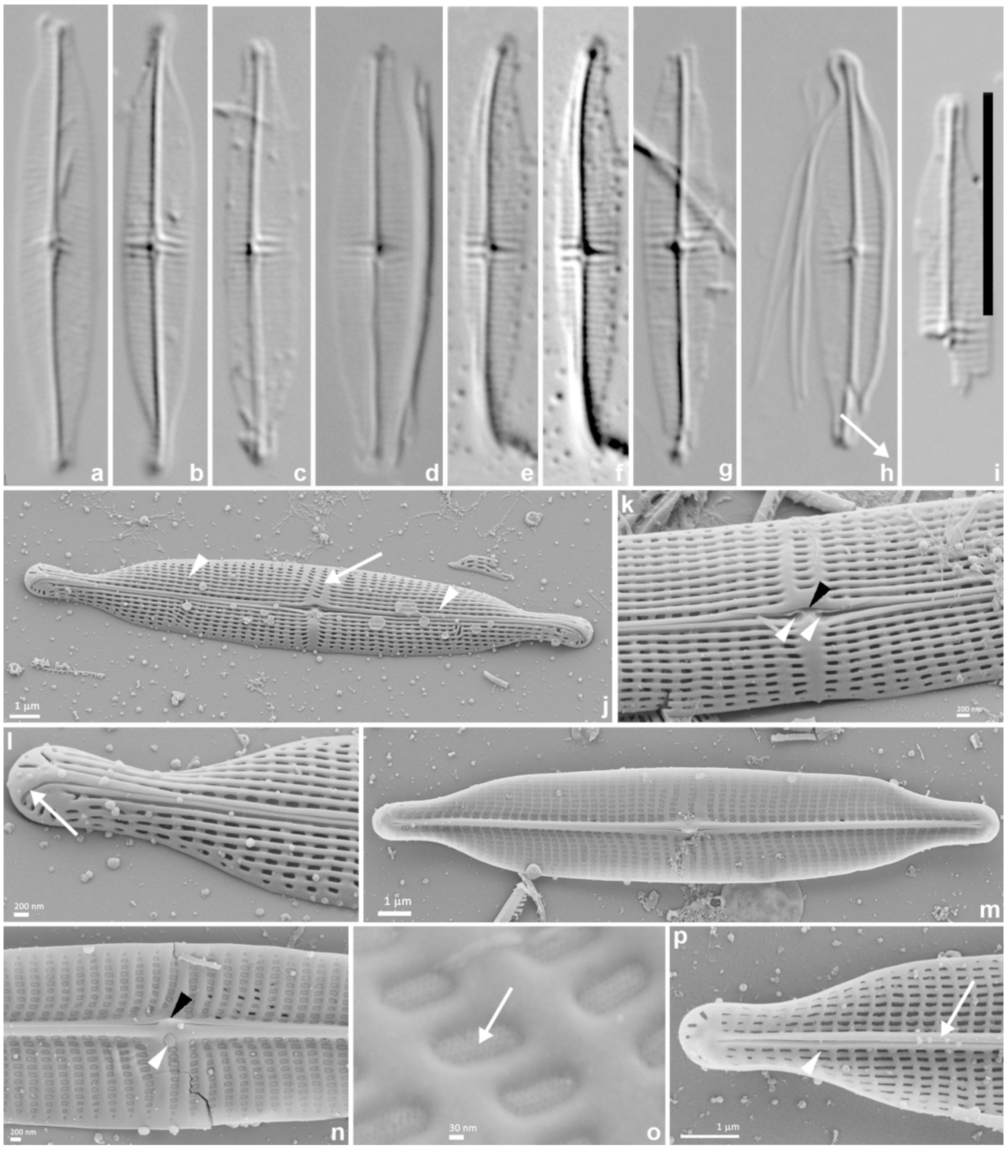

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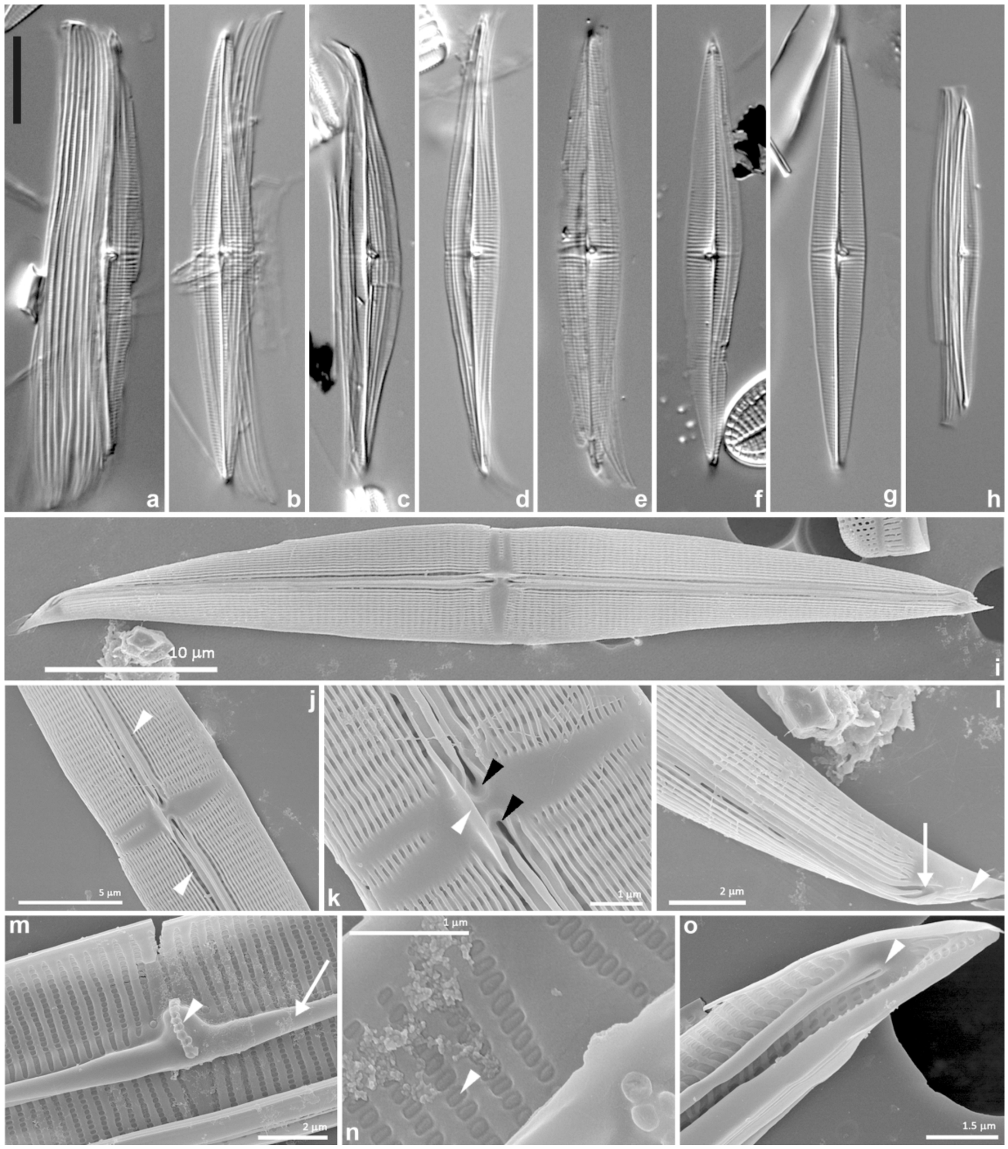

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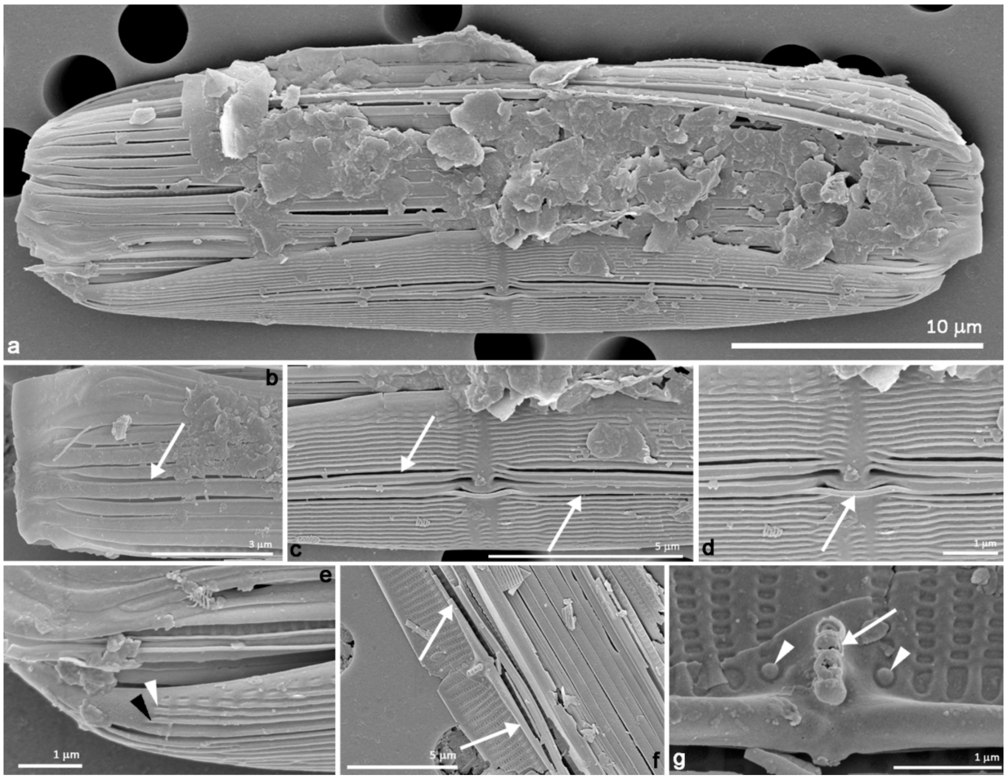
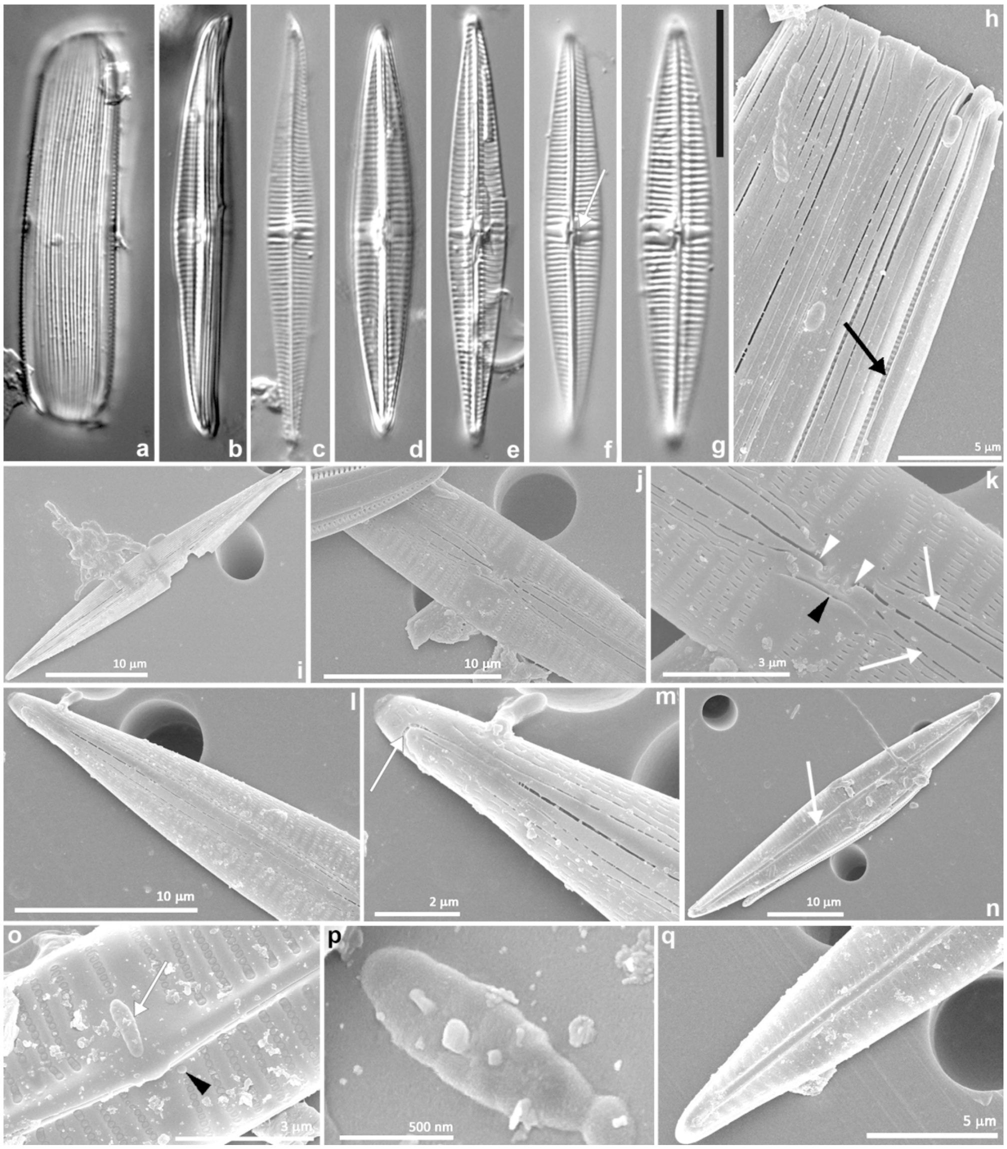
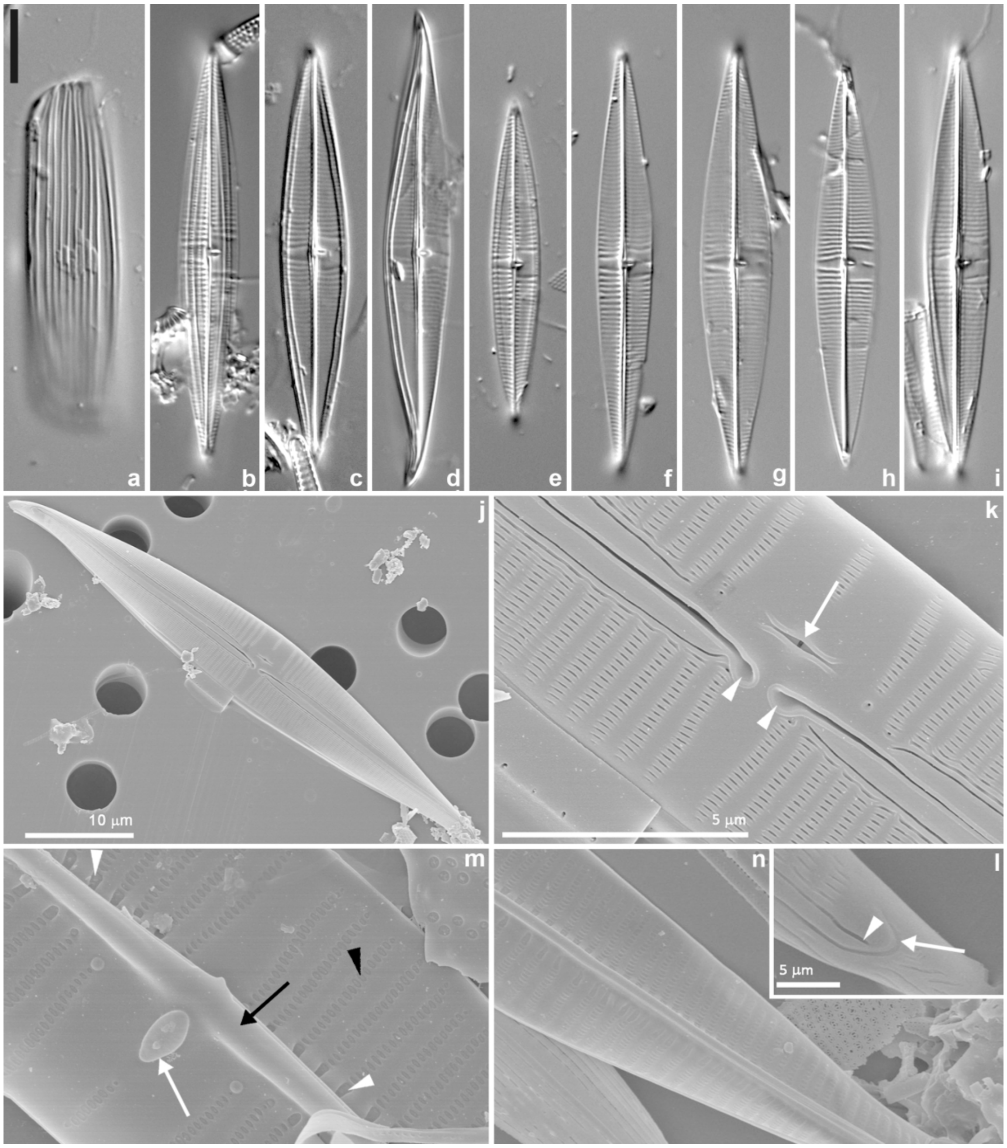


Proschkinia complanata (Grunow) D.G.Mann (Grunow sample 1123) in SEM. (a) The whole frustule (b) Close up of the girdle apical part with copulae (arrow). (c) Close up of the central area, arrows mark the grooves between the T-shaped sternum and the valve. (d) Close up of specimen illustrated in Fig. c, note expanded proximal raphe ends and the flap covering the fistula (arrow). (e) Close up of the apical valve part, note the termination of the longitudinal ribs (black arrowhead) and of the striation (white arrowhead). (f) valve centre internal view note strong pole-like raphe rib (arrows). (g) Close up of fistula composed of several globular structures in a row (arrow) with two accessory pores (arrowheads).

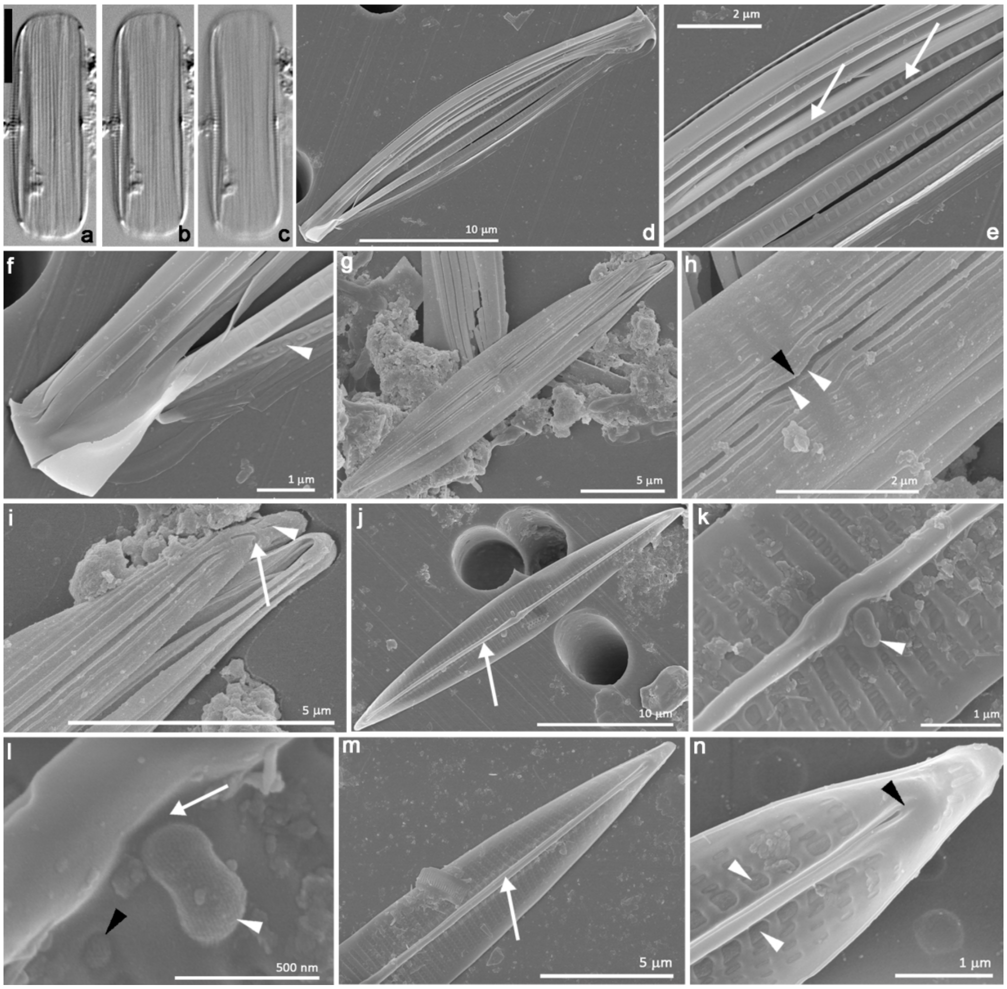
175x134mm (300 x 300 DPI)



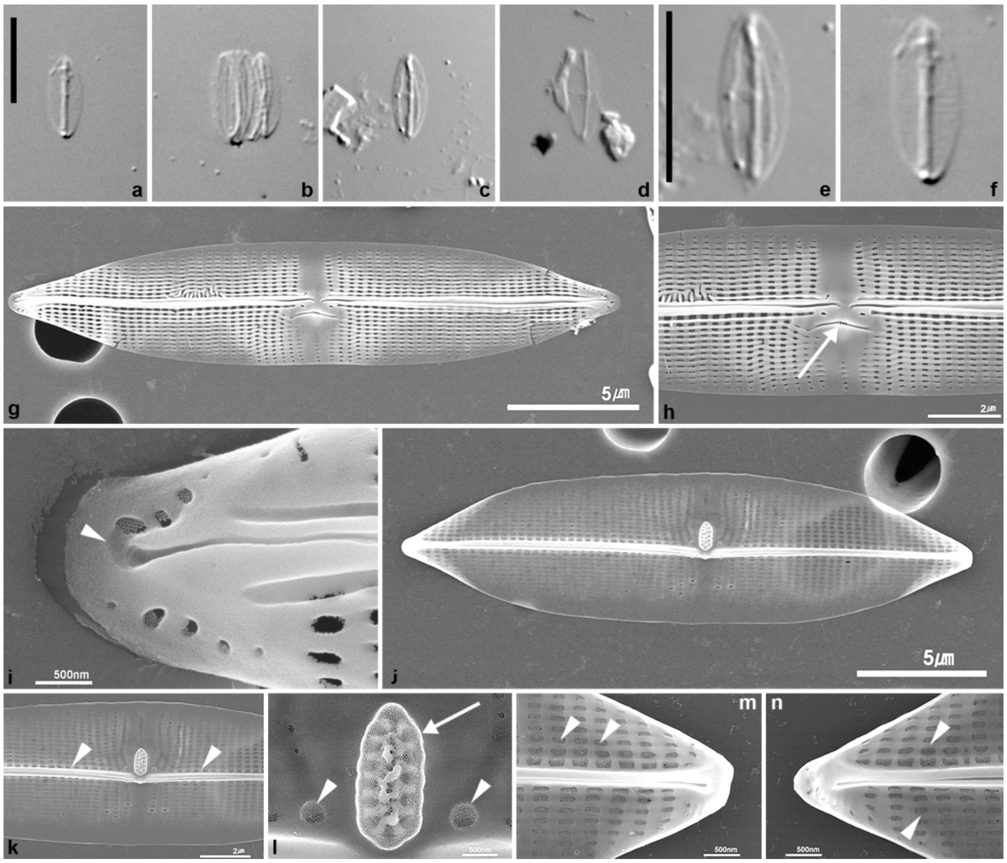
Proschkinia complanatoides (Hustedt ex Simonsen) D.G. Mann (a–g) cleaned material in LM. (i–q) SEM. (h). Girdle composed of U-shaped bands (arrow). (i). Valve exterior of the whole specimen. (j, k). Valve centre close up with hooked proximal raphe endings (white arrowheads) and slit-like openning of the fistula (black arrowhead), note the grooves between the raphe-sternum and the valve face (arrows). (l, m). Close up of the apex with hooked distal raphe end (arrow in Fig. m). (n). The whole valve interior, note the raphe rib (arrow). (o). Close up of the valve centre interior with fistula (arrow) and the accesory pore (arrowhead). (p). Details of the fistula. (q). Valve apex interior, note a small helictoglossa.



Proschkinia complanatula (Hustedt ex Simonsen) D.G. Mann (a–i) cleaned specimens in the light microscope. (j–n) SEM. (j). Valve exterior of the whole specimen. (k) Valve centre close up, with the fistula opening (arrow), the expanded, slightly bent proximal raphe ends (arrowheads) note valve surface lacking the longitudinal ribs. (l). Valve apex exterior, note strongly hooked distal raphe end (arrow) and termination of the apical groove (arrowhead). (m). Central area interior close up, note the raphe rib (black arrow), peculiar fistula (white arrow) and the large areolae aligned along the raphe rib (arrowheads), see the fine striae forming areolae (black arrowhead). (n) Valve interior in its apical part.

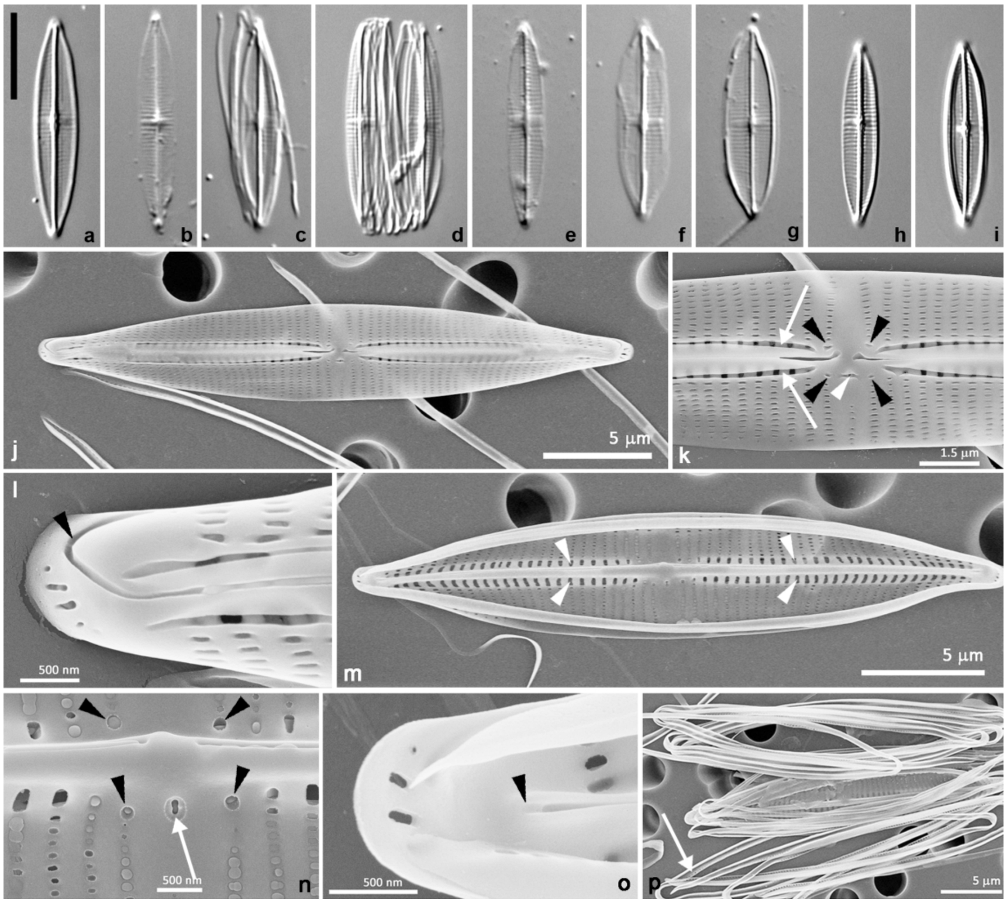


Proschkinia hyalosirella (Hustedt) D.G. Mann. (a–c) cleaned specimen in the light microscope. Scale (a–c): 10 µm. (d–n) SEM. (d–f) Girdle details with U-shaped and perforated bands (arrows in Fig. e and arrowhead in Fig. f). (g). Valve exterior of the whole specimen. (h). Valve centre close up, with raphe proximal endings (white arrowheads) and opening of fistula (black arrowhead) note also gradually vanishing longitudinal ribs. (i) Valve apex exterior note strongly hooked raphe distal end (arrow) and long apical areolae (arrowhead). (j) Whole specimen valve interior note the raphe rib (arrow). (k, l). Valve centre interior close ups and position of the fistula (white arrowhead), with small engulfment in the raphe-sternum (arrow in Fig. l) note domed, hymenate accessory pore (black arrowhead). (m). Valve apex interior note the elevation of the raphe rib (arrow). (n) Internal raphe distal end, note the small helictoglossa (black arrowhead) and elongate areolae aligned along the raphe rib (white arrowheads).

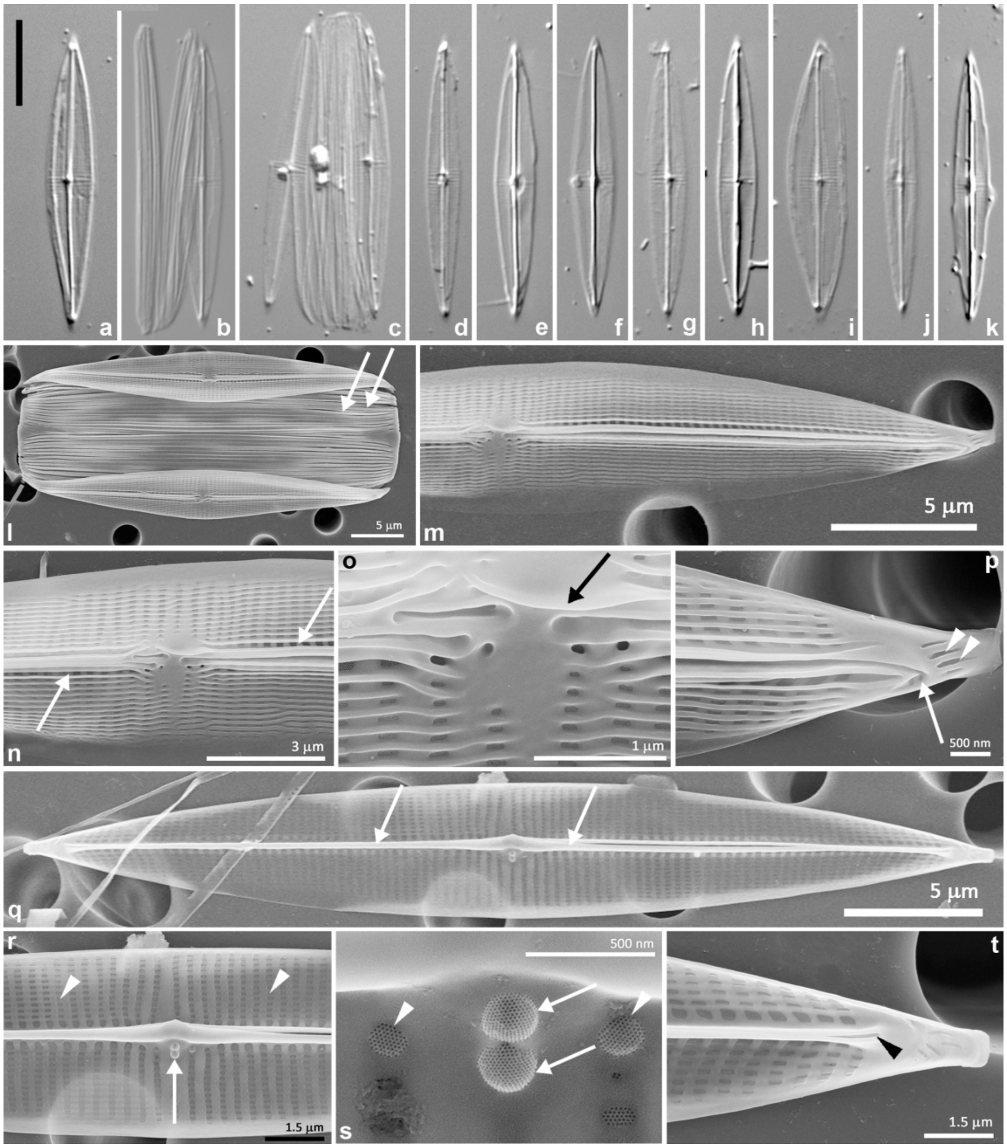


Proschkinia luticola Kim, S-Y., Park, J-G., Witkowski & Kim, B-S. sp. nov. (a–f) cleaned specimens from the culture in the light microscope. (g–n) SEM. (g) Whole specimen valve exterior. (h) Valve centre exterior close up, note simple proximal raphe endings, and irregular slit of fistula opening (arrow). (i) Valve apex close up with strongly hooked distal raphe end (arrowhead). (j) Whole specimen valve interior. (k) Valve centre interior close up with elongate areolae aligned along the raphe rib (arrowhead). (l) Close up of the fistula structure (arrow) with two accessory pores (white arrowheads). (m, n) Close ups of the valve apices interior with simple helictoglossa, note stria forming areolae (arrowheads).

175x149mm (300 x 300 DPI)

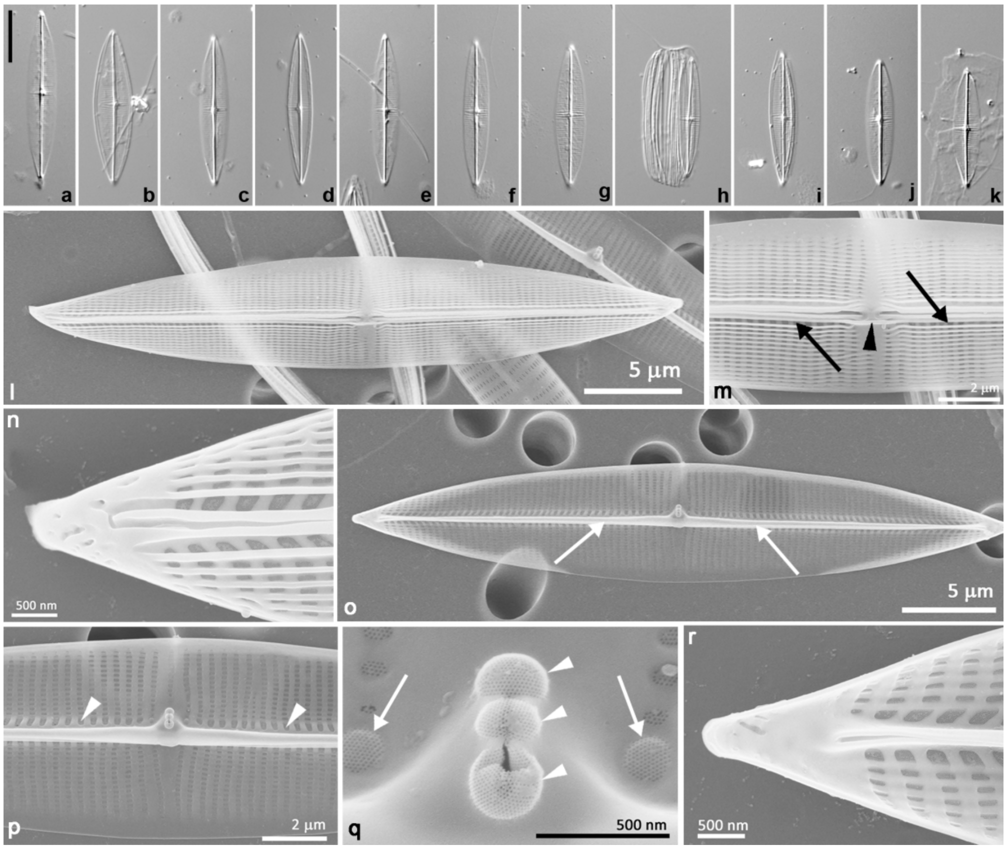


Proschkinia staurospeciosa Kim, S-Y., Park, J-G. Witkowski & Gastineau (a–i) in the light microscope, cleaned specimens from the culture. (j–p) SEM. (j) External valve surface. (k) Close up of valve centre with apical grooves (arrows), fistula opening (white arrowhead) and openings of fistula associated pores (black arrowheads). (l) Valve apex exterior with raphe distal raphe end (arrowhead). (m) The whole valve interior with elongate areolae flanking the raphe rib (arrowheads). (n) Valve centre close up, note the small, fistula (arrow) and accessory pores (arrowheads). (o) Valve apex interior close up, note the small helictoglossa (arrowhead). (p) Separated girdle bands note numerous U-shaped open bands (arrow).

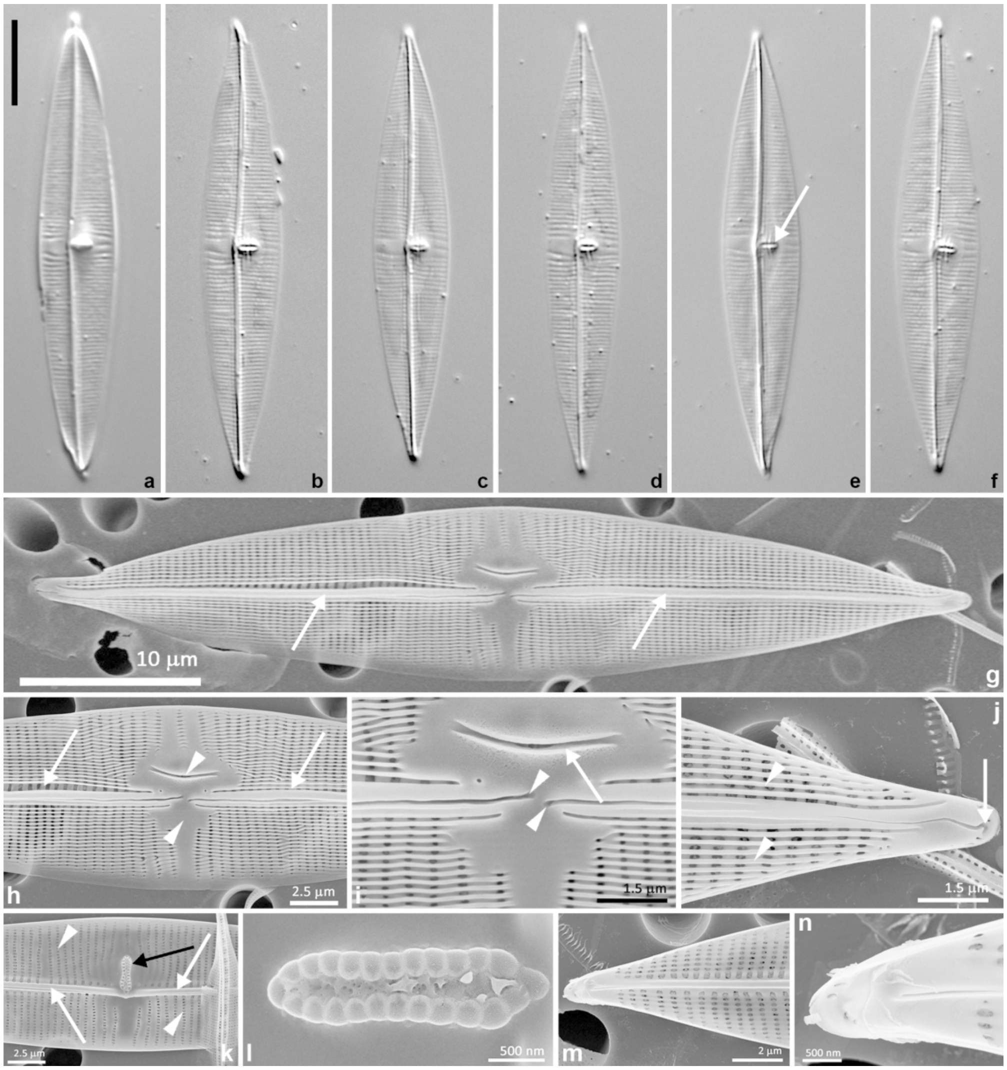


Proschkinia impar Kim, S-Y., Park, J-G. & Witkowski (a–k) in the light microscope cleaned specimens from the culture. (l–t) SEM. (l) Complete frustule with numerous U-shaped girdle bands (arrows). (m) External view of the slightly convex valve surface. (n) raphe-sternum exterior close up, note apical grooves (arrows). (o) Valve centre exterior with fistula opening (arrow). (p) Strongly hooked distal raphe end close up (arrow), and apical areolae (arrowheads). (q) Whole specimen valve interior with elevated raphe rib (arrows). (r) Valve centre interior close up note apically elongate striae forming areolae (arrowheads) and small domed fistula (arrow). (s) Close up of the fistula, note two, simple domed structures (arrows) and two isolated pores (arrowheads). (t) Apex interior close up, note the raphe end terminating in small helictoglossa (arrowhead).

175x199mm (300 x 300 DPI)

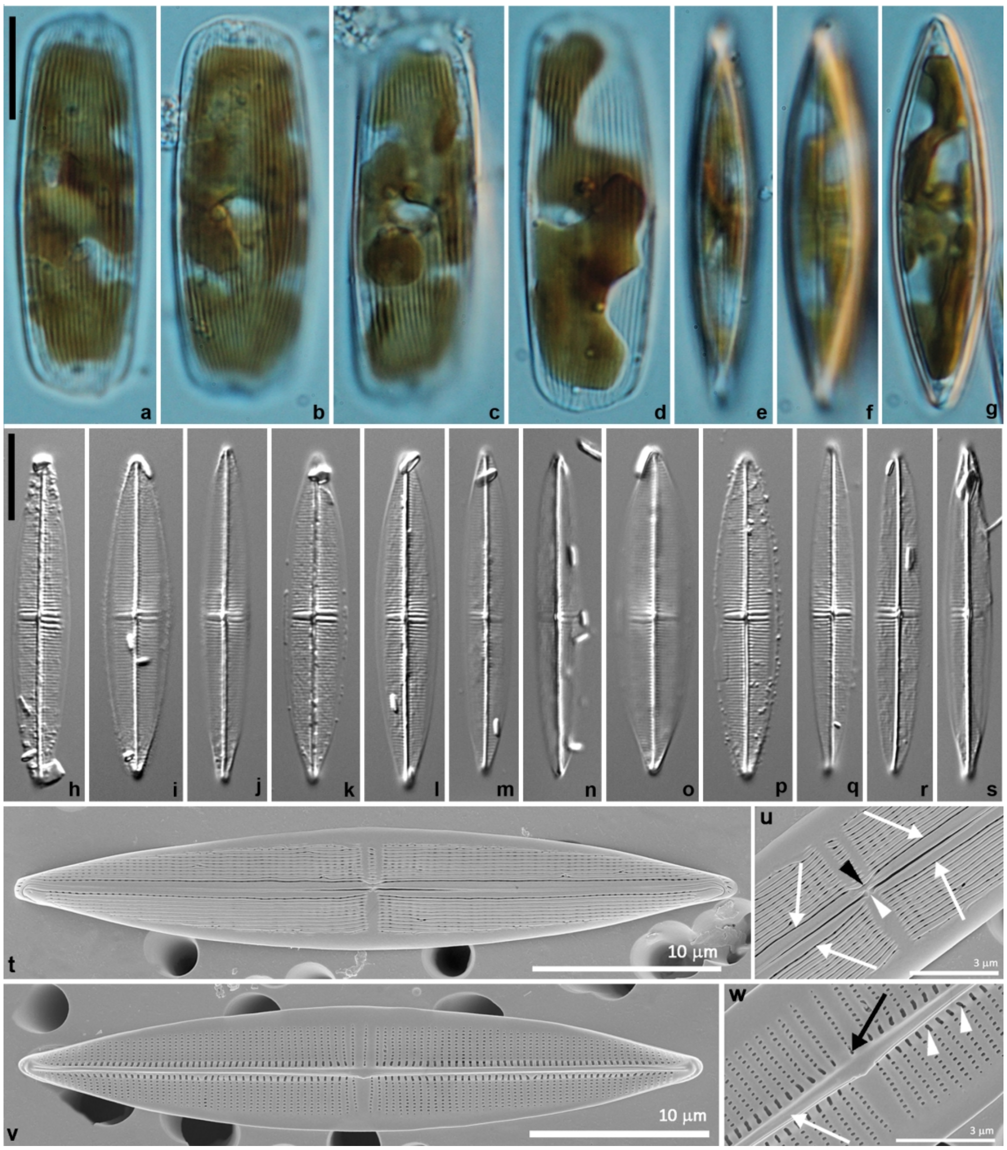


Proschkinia modesta Kim, S-Y., Park, J-G. & Witkowski. (a–k) in the light microscope cleaned specimens from the culture. (l–r) SEM. (l) External valve surface. (m) Valve centre close up, note apical grooves (arrows) and fistula opening covered with thickened siliceous flap (arrowhead). (n) Apical raphe end with apical areolae close. (o) Valve interior with raphe rib (arrows). (p) Raphe rib flanked with large areolae (arrowheads). (q) Close up of fistula (arrowheads), note two domed accessory pores (arrows). (r) Internal terminal raphe end.

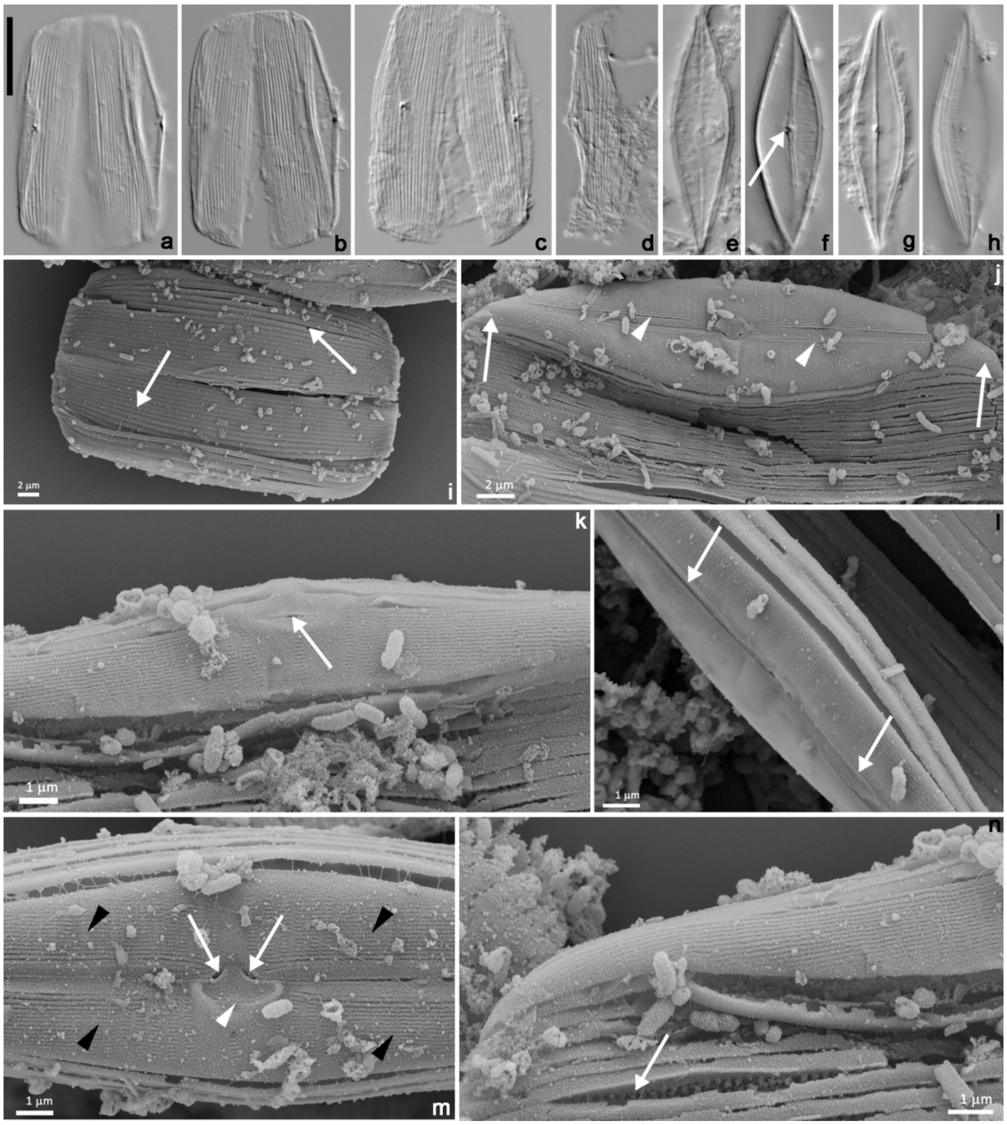


Proschkinia fistulispectabilis Kim, S-Y., Park, J-G. & Witkowski (a–f) cleaned specimens from the culture in the light microscope, note the large fistula (arrow in Fig. e). (g–n) SEM. (g) Valve face exterior with distinct raphe sternum (arrows). (h) Valve centre with two shallow grooves (arrows) and large central area (arrowheads). (i) Fistula external opening (arrow), with simple and approximate proximal raphe endings (arrowheads). (j) Apical valve part with hooked external terminal raphe ending (arrow), note the longitudinal ribs (arrowheads). (k) Valve centre interior close up, note raphe-sternum (white arrows), fistula (black arrow) and striae forming areolae (arrowheads). (l) Complex fistula structure. (m-n) Internal apical raphe ends terminating in simple helictoglossa.

175x186mm (300 x 300 DPI)

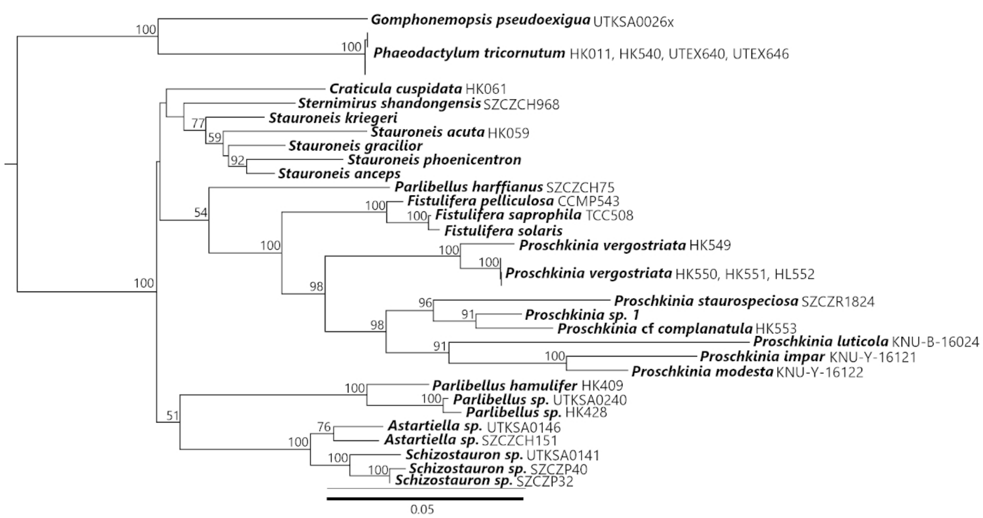


Proschkinia rosowskii Ch. Li, Witkowski, Ashworth & Theriot, E.C. sp. nov. (a–s) in the light microscope. (a–g) Live specimens with chloroplast. (h–s) Cleaned specimens from the culture and (s–w) in SEM. (t) Whole specimen external valve view. (u) Valve centre close up, note the apical grooves (arrows) and the fistula opening (black arrowhead) close to the central nodule (white arrowhead). (v) Whole specimen internal valve view. (w) Valve centre interior close up, note elevated raphe-sternum (white arrow), large elongate areolae (arrowheads) and the fistula (black arrow).



Proschkinia sp. 1 from Scotland. (a–h) cleaned valves from the culture in light microscope, note the fistula in fig. f. (i–n) SEM. (i) The whole frustule in girdle view, note U-shaped girdle bands (arrow). (j) Lateral view of the frustule, note the sternum (arrowheads) and strongly bent proximal raphe ends (arrows). (k) Valve face centre close up note the indistinctly raised siliceous flap covering the fistula (arrow). (l). Close up of another specimens illustrating the valve face centre with indistinct raphe sternum (arrows). (m) Valve centre close up with distinct proximal raphe ends (arrows) and the fistula (white arrowhead), note the very high density of the longitudinal ribs (black arrowheads). (n) Valve apex close up, note the U-shaped and perforated girdle bands (arrow).

175x195mm (300 x 300 DPI)



Phylogeny of genera closely related to Proschkinia based on three gene (nuclear- encoded ribosomal SSU, chloroplast-encoded rbcL, psbC markers) data set.

109x55mm (300 x 300 DPI)

Supplementary data S1. Detailed information on established *Proschkinia* taxa studied in this paper.

Navicula bulnheimii Grunow – type material. This material originates from Rabenhorst Algen Europa's 1301. This particular 'copy' of the *exsiccata* coming from the Grunow collection, where it is sample 1720, contained in packet 1901/1068.

Navicula complanata Grunow - 870, on the Island "S. Pietro dei Nembi" = Sveti Petar, by medical doctor Reichardt

Species list from Grunow no. 870 (according to his accession book): *Amphora complanata*, *hemisphaericum*?, *Homeocladia vidovichii*, *Berkeleya micans*, *Achnanthes longipes*, *Grammatophora oceanica*, *Cocconeis dirupta*, *scutellum*, *Orthoneis splendida*, *Orthoneis binotata*, *Stauroneis aspera*, *Actinocyclus subtilis*, *Pyxidicula dalmaticum*

Navicula complanata Grunow – 1123, Trieste, Adriatic Sea, Italy by Hauck no. 443 Schlamm auf Ulven und Gelidien

Species list from Grunow no. 1123 (according to his accession book): *Amphora complanata* [*Amphora complanata* Kützing], *decussata* [*Amphora decussata* Grunow], selten, *marina* [*Amphora marina* W.Smith], *Grammatophora gibberula* [*Grammatophora gibberula* Kützing], *oceanica* [*Grammatophora oceanica* Ehrenberg], *Pleurosigma balticum* [*Pleurosigma balticum* (Ehrenberg) W.Smith], *tenuissimum* [*Pleurosigma tenuissimum* W.Smith], *intermedium* [*Pleurosigma intermedium* W.Smith] nicht selten, […] *Striatella unipunctata* [*Striatella unipunctata* (Lyngbye) C.Agardh], *Licmophora elongata* [?]

Surirella gemma [*Surirella gemma* (Ehrenberg) Kützing), *fastuosa* [*Surirella fastuosa* (Ehrenberg) Ehrenberg], *Cocconeis scutellum* [*Cocconeis scutellum* Ehrenberg], *Nitzschia panduriformis* var. *parva* [*Nitzschia panduriformis* W.Gregory], *lanceolata* (klein, selten) [*Nitzschia lanceolata* W.Smith], *birostata* selt.[en] [*Nitzschia birostrata* W.Smith], *spathulata* var. *minuta* [*Nitzschia spathulata* Brébisson ex W.Smith], *angust* [?], *affinis m.*, [*Nitzschia affinis* Grunow], […], *Bacteriastrum curvatum* [*Bacteriastrum curvatum* G.Shadbolt], *Achnanthes longipes* selten [*Achnanthes longipes* C.Agardh], *Sceptroneis marina* var. [?], *Thalassionema nitzschioides m.* [*Thalassionema nitzschioides* (Grunow) Grunow]

Navicula complanatula Hustedt – sample AM 2243, Charlestone, Oregon, USA, Bootshafen, South Slough. 18.10.1959.

Navicula complanatiodes Hustedt – sample AS 1465 – Soemba (Sumba), am Stein, Jaag 115g Island, Indonesia

Navicula hyalosirella Hustedt – sample AM 2214 – Florida, Southend of Pass-a-Grille near St. Petersburg, USA, am Meeres-Algen (on marine seaweeds)24.12.1956.

Additional samples:

Sample As1135 Sumba, Waingapoe, auf algenbedeckten Steinen Jaag 115a from the

Soemba (Sumba) Island, Indonesia

Sample E10731 Madeira 79 westlich Lido from Madeira 79, west of Lido

54

Table S2. Taxa, strain voucher ID and GenBank accession numbers for strains used in the DNA sequence data phylogenetic analysis. Collection site for sample of original strain isolation is also included (where known); in the case of cultures from public collections, the culture ID is provided in this column (UTEX = UTEX Culture Collection of Algae; NCMA = National Center for Marine Algae and Microbiota; CSIRO = Australian National Algae Culture Collection; MCC-NIES = Microbial Culture Collection at National Institute for Environmental Studies, SZCZ = Szczecin Culture Collection). Ingroup taxa (raphid pennates) provided first in the table; outgroup taxa ("araphid pennates") follow after table break. Taxa are listed alphabetically.

Taxon	Strain Voucher	Collection Site (Locality in paretheses)	GenBank Accession (SSU, *rbc*L, *psb*C)
Achnanthes chlidanos M.H.Hohn & Hellerman			KJ658412, KJ658394, N/A
Achnanthes coarctata (Brébisson ex W. Smith) Grunow in Cleve & Grunow	HK079	FD185 (UTEX)	HQ912594, HQ912458, HQ912287
Achnanthes sp. Bory	HK303	SanNicholas1 (San Nicholas, Canary Islands)	KC309473, KC309545, KC309617
Achnanthes sp. Bory	HK309	ECT3883 (Rainbow Harbor, Long Beach, California)	KC309474, KC309546, KC309618
Achnanthes sp. Bory	HK310	ECT3911 (Long Beach, California)	KC309475, KC309547, KC309619
Achnanthes sp. Bory	HK311	ECT3684 (Achang Reef, Guam)	KC309476, KC309548, KC309620
Achnanthes sp. Bory	HK517	Azo42 (Azores)	MH063437, MH064054, MH063967
Achnanthes sp. Bory	UTKSA0263	KSA2015-16 (Al-Nawras, Jeddah, Saudi Arabia)	MH063438, MH064055, N/A
Achnanthidium minutissimum (Kützing) Czarnecki			AM502032, AM710499, N/A
Adlafia brockmannii (Hustedt) Bruder & Hinz			AM502020, AM710487, N/A
Amphipleura pellucida Kützing	HK287	ECT3568 (Lake Travis, Texas)	KC309477, KC309549, KC309621

Amphora aliformis	AMPH177		KP229525, KP229546, KP229548
Amphora caribaea	AMPH086		KJ463428, KJ463458, KJ463488
Amphora commutata	AMPH126		KP229526, KP229547, KP229549
Amphora cf. *immarginata* Nagumo	UTKSA0172	KSA2015-37 (Rabigh, Saudi Arabia)	MH063439, MH064056, MH063968
Amphora helenensis Giffen	SZCZCH704		KT943649, KT943672, KT943709
Amphora cf. *helenensis* Giffen	SZCZP12		KU179126, KU179113, KU179140
Amphora hyalina	AMPH136		KJ463432, KJ463462, KJ463492
Amphora lineolata	AMPH035		KJ463435, KJ463465, KJ463495
Amphora obtusa Gregory	UTKSA0275	KSA2015-37 (Rabigh, Saudi Arabia)	MH063440, MH064057, N/A
Amphora obtusa var. *crassa*	AMPH070		KJ463436, KJ463466, KJ463496
Amphora pediculus (Kützing) Grunow		L1030 (UTEX)	HQ912417, HQ912403, HQ912389
Amphora securicula	AMPH046		KJ463440, KJ463470, KJ463500
Amphora sp. Ehrenberg ex Kützing	HK502	PackaryChannelSediment (Mustang Island, Texas)	MH017634, MH064058, MH063969
Amphora sp. Ehrenberg ex Kützing	UTKSA0087	SA12 (Markaz Al Shoaibah, Saudi Arabia)	MH063441, MH064059, MH063970
Amphora sp. Ehrenberg ex Kützing	UTKSA0115	KSA2015-27 (Markaz Al Shoaibah, Saudi Arabia)	MH063442, MH064060, N/A
Amphora sp. Ehrenberg ex Kützing	UTKSA0153	KSA2015-37 (Rabigh, Saudi Arabia)	MH063443, MH064061, MH063971
Amphora sp. Ehrenberg ex Kützing	UTKSA0177	KSA2015-41 (Rabigh, Saudi	MH063444, MH064062,

		Arabia)	MH063972
Amphora sublaevis	AMPH135		KJ463444, KJ463474, KJ463504
Amphora subtropica	AMPH051		KJ463445, KJ463475, KJ463505
Amphora sulcata	AMPH083		KJ463446, KJ463476, KJ463506
Amphora vixvisibilis Ch.Li & Witkowski	SZCZCH967	Yellow Sea coast, Shandong Province	KT943648, KT943670, KT943706
Amphora waldeniana	AMPH011		KJ463447, KJ463477, KJ463507
Anomoeoneis fogedii Reimer		FD399 (UTEX)	KJ011610, KJ011793, N/A
Anomoeoneis sphaerophora Pfitzer		FD160 (UTEX)	KJ011612, KJ011795, N/A
Astartiella sp. Witkowski, Lange-Bertalot & Metzeltin	UTKSA0146	KSA2015-11 (Bhadur Resort, Saudi Arabia)	MH063445, MH064063, MH063973
Astartiella sp. Witkowski, Lange-Bertalot & Metzeltin	SZCZCH151		N/A, KT943613, KT943624
Auricula sp. Castracane	HK434	21IV14-4D (Rabbit Key Basin, Florida)	KX981842, KX981810, KX981789
Auricula cf. *complexa* (Gregory) Cleve	UTKSA0038	SA12 (Markaz Al Shoaibah, Saudi Arabia)	MH063446, MH064064, MH063974
Auricula cf. *flabelliformis* M. Voigt	UTKSA0071	SA12 (Markaz Al Shoaibah, Saudi Arabia)	MH063447, MH064065, MH063975
Bacillaria paxillifer (O. F. Müller) T. Marsson	HK130	FD468 (UTEX)	HQ912627, HQ912491, HQ912320
Bacillaria sp. J.F.Gmelin	HK475	GU44BK-1 (Gab Gab Beach, Guam)	MH063448, MH064066, MH063976
Bacillaria sp. J.F.Gmelin	UTKSA0009	SA27 (Jeddah, Saudi Arabia)	MH063449, MH064067, MH063977
Bacillaria sp. J.F.Gmelin	UTKSA0129	KSA2015-9 (Bhadur Resort, Saudi Arabia)	MH063450, MH064068, MH063978
Bacillaria sp. J.F.Gmelin	UTKSA0130	KSA2015-9 (Bhadur Resort, Saudi Arabia)	MH063451, MH064069, MH063979
Berkeleya hyalina (F.E.Round & M.E.Brooks) E.J.Cox	HK388	ECT3614 (La Jolla,	KJ577847, KJ577882,

		California)	KJ577917
Berkeleya rutilans (Trentepohl ex Roth) Grunow	HK154	ECT3616 (Laguna Beach, California)	HQ912637, HQ912501, HQ912330
Berkeleya rutilans (Trentepohl ex Roth) Grunow	HK389	ECT3602 (Bolinas, California)	KJ577848, KJ577883, KJ577918
Biremis sp. D.G. Mann & E.J. Cox	HK438	21IV14-2A (Duck Key, Florida)	KX981835, KX981811, N/A
Biremis sp. D.G. Mann & E.J. Cox	UTKSA0352	KSA2016-19 (Rabigh, Saudi Arabia)	MH063452, MH064070, MH063980
Caloneis lewisii Patrick	HK060	FD54 (UTEX)	HQ912580, HQ912444, HQ912273
Caloneis sp. P.T. Cleve	KSA0127	SA12 (Markaz Al Shoaibah, Saudi Arabia)	KU179135, KU179125, N/A
Caloneis sp. P.T. Cleve	HK429	SantaRosa cor.green (Costa Rica)	KU179134, KU179123, N/A
Caloneis cf. *linearis* (Cleve) Boyer	HK430	21IV14-3A (Captain's Key, Florida)	KU179132, KU179119, KU179146
Caloneis cf. *excentrica* (Grunow) Boyer	HK431	21IV14-2A (Duck Key, Florida)	KU179130, KU179117, KU179144
Caloneis sp. P.T. Cleve	HK477	GU7Y-4 (University of Guam Marine Laboratories, Guam)	MH063453, MH064071, MH063981
Caloneis sp. P.T. Cleve	HK479	GU52V-2 (Outhouse Beach, Guam)	N/A, MH064072, MH063982
Caloneis sp. P.T. Cleve	UTKSA0235	KSA2015-37 (Rabigh, Saudi Arabia)	MH063454, MH064073, MH063983
Caloneis sp. P.T. Cleve	UTKSA0252	KSA2015-42 (Rabigh, Saudi Arabia)	MH063455, MH064074, MH063984
Caloneis cf. *westii* (W. Smith) Hendey	SZCZCH1002	Yellow Sea coast, Shandong Province	KT943628, KT943654, KT943687
Campylodiscus clypeus (Ehrenberg) Kützing		L951 (UTEX)	HQ912412, HQ912398, HQ912384
Campylodiscus sp. Ehrenberg ex Kützing		ECT3613 (Tomales Bay, California)	HQ912413, HQ912399, HQ912385

Campylodiscus sp. Ehrenberg ex Kützing	UTKSA0284	KSA2015-29 (Markaz Al Shoaibah, Saudi Arabia)	MH063456, MH064075, N/A
Carinasigma minuta (Donkin) G. Reid	HK418	GU7X-6 (University of Guam Marine Lab, Guam)	KX981841, KX981812, KX981790
Climaconeis riddleae Prasad	HK178	ECT3724 (Umatac Bay, Guam)	HQ912644, HQ912508, HQ912337
Climaconeis sp. Grunow	UTKSA0040	SA26 (Jeddah, Saudi Arabia)	KX981836, KX981813, N/A
Climaconeis undulata (Meister) Lobban et al	HK218	ECT3743 (Talofofo Bay, Guam)	KC309478, KC309550, N/A
Cocconeis cf. *cupulifera* Riaux-Gobin, Romero, Compère & Al-Handal	SZCZCH662	Yellow Sea coast, Shandong Province	N/A, KT943680, KT943718
Cocconeis cf. *mascarenica* Riaux-Gobin & Compère	SZCZCH283		N/A, KT943679, KT943717
Cocconeis placentula Ehrenberg	HK077	FD23 (UTEX)	HQ912592, HQ912456, HQ912285
Cocconeis stauroneiformis (W.Smith) H.Okuno	s0230		AB430614, AB430694, N/A
Cocconeis sp. Ehrenberg	UTKSA0056	SA28 (Jeddah, Saudi Arabia)	KU179133, KU179120, KU179147
Cocconeis sp. Ehrenberg	HK312	ECT3901 (Channel #5, US-1, Florida)	KC309479, KC309551, KC309622
Cocconeis sp. Ehrenberg	SZCZP67	Indian Ocean, Mozambique coast	KT943600, KT943614, KT943625
Craspedostauros alatus Majewska & Ashworth	HK448	CCMP1120 (NCMA)	KX981860, KX981817, KX981793
Craspedostauros alyoubii J. Sabir & Ashworth	UTKSA0083	SA18 (Duba, Saudi Arabia)	KX981857, KX981814, KX981791
Craspedostauros amphoroides (Grunow) Cox	HK447	CCMP797 (NCMA)	KX981859, KX981815, N/A
Craspedostauros paradoxa Ashworth & Lobban	HK441	GU44BK-1 (Gab Gab Beach, Guam, USA)	KX981858, KX981816, KX981792
Craticula cuspidata (Kützing) Mann	HK061	FD35 (UTEX)	HQ912581, HQ912445, HQ912274
Cylindrotheca closterium (Ehrenberg) Reimann & Lewin	HK180	CCMP1855 (NCMA)	HQ912645, HQ912509, HQ912338
Cylindrotheca sp. Rabenhorst	UTKSA0079	SA12 (Markaz Al Shoaibah,	KX981848, KX981826,

		Saudi Arabia)	KX981801
Cylindrotheca sp. Rabenhorst	UTKSA0082	SA18 (Duba, Saudi Arabia)	KX981847, KX981827, KX981802
Cymatoneis sp. P.T.Cleve	UTKSA0378	KSA2016-3 (Bhadur Resort, Saudi Arabia)	MH063457, MH064076, MH063985
Cymatopleura elliptica (Brebisson ex Kutzing) W.Smith	HK215	L1333 (UTEX)	HQ912659, HQ912523, HQ912352
Cymbella aspera (Ehrenberg) Cleve		FD272 (UTEX)	KJ011615, KJ011797, N/A
Cymbella proxima Reimer			AM502017, AM710484, N/A
Cymbopleura naviculiformis (Auerswald ex Heiberg) Krammer			AM502004, AM710471, N/A
Denticula kuetzingii Grunow	HK104	FD135 (UTEX)	HQ912610, HQ912474, HQ912303
Didymosphenia geminata (Lyngbye) M. Schmidt	CH058		KJ011636, KJ011819, N/A
Diploneis cf. *cheronensis* (Grunow) Cleve	HK417	GU44AY-6 (Gab Gab Beach, Guam)	MH017637, MH064077, MH063986
Diploneis cf. *smithii* (Brébisson in W. Smith) P.T. Cleve	HK437	GU44AY-6 (Gab Gab Beach, Guam)	KX981837, KX981818, KX981794
Diploneis parca (Schmidt in Schmidt et al.) Boyer	UTKSA0267	KSA2015-49 (Duba, Saudi Arabia)	MH063458, MH064078, MH063987
Diploneis cf. *smithii* (Brébisson in W. Smith) P.T. Cleve	UTKSA0232	KSA0215-30 (Markaz Al Shoaibah, Saudi Arabia)	MH063459, MH064079, N/A
Diploneis cf. *smithii* (Brébisson in W. Smith) P.T. Cleve	UTKSA0238	KSA2015-37 (Rabigh, Saudi Arabia)	MH063460, MH064080, MH063988
Diploneis sp. (Ehrenberg) P.T. Cleve	HK435	Coz-4 (Cozumel, Mexico)	KX981839, KX981819, KX981795
Diploneis sp. (Ehrenberg) P.T. Cleve	HK436	Coz-4 (Cozumel, Mexico)	KX981838, KX981820, KX981796
Diploneis sp. (Ehrenberg) P.T. Cleve	HK483	21IV14-2A (Duck Key, Florida)	MH017638, MH064081, MH063989
Diploneis sp. (Ehrenberg) P.T. Cleve	HK484	PackaryChannelPlank (Mustang Island, Texas)	MH017639, MH064082, MH063990

Diploneis sp. (Ehrenberg) P.T.Cleve	UTKSA0190	KSA2015-14 (Bhadur Resort, Saudi Arabia)	MH063461, MH064083, MH063991
Diploneis subovalis Cleve	HK084	FD282 (UTEX)	HQ912597, HQ912461, HQ912290
Diploneis vacillans (A.W.F.Schmidt) Cleve	UTKSA0145	KSA2015-11 (Bhadur Resort, Saudi Arabia)	MH063462, MH064084, MH063992
Diploneis vacillans (A.W.F.Schmidt) Cleve	UTKSA0150	KSA2015-37 (Rabigh, Saudi Arabia)	N/A, MH064085, MH063993
Diploneis vacillans (A.W.F.Schmidt) Cleve	UTKSA0221	KSA2015-7 (Bhadur Resort, Saudi Arabia)	N/A, MH064086, MH063994
Donkinia sp. Ralfs	UTKSA0269	KSA2015-37 (Rabigh, Saudi Arabia)	MH063463, MH064087, MH063995
Encyonema norvegica (Grunow) Mayer		FD342 (UTEX)	KJ011643, KJ011826, N/A
Entomoneis ornata (Bailey) Reimer			HQ912411, HQ912397, HQ912383
Entomoneis sp. Ehrenberg	HK 135	CS782 (CSIRO)	HQ912631, HQ912495, HQ912324
Entomoneis sp. Ehrenberg	SZCZM496	Yellow Sea coast, Shandong Province	KT943630, KT943656, KT943689
Entomoneis sp. Ehrenberg	UTKSA0013	SA12 (Markaz Al Shoaibah, Saudi Arabia)	N/A, MH064088, MH063996
Entomoneis sp. Ehrenberg	UTKSA0061	SA18 (Duba, Saudi Arabia)	MH063464, MH064089, MH063997
Entomoneis sp. Ehrenberg	UTKSA0080	SA12 (Markaz Al Shoaibah, Saudi Arabia)	MH063465, MH064090, MH063998
Entomoneis sp. Ehrenberg	UTKSA0092	SA18 (Duba, Saudi Arabia)	MH063466, MH064091, MH063999
Eolimna minima (Grunow in Van Heurck) H. Lange-Bertalot			AM501962, AM710427, N/A
Epithemia argus (Ehrenberg) Kützing	CH211		HQ912408, HQ912394, HQ912380
Epithemia sorex Kützing	CH148		HQ912409, HQ912395, HQ912381

Eunotia curvata Lagerstedt	HK086	FD412 (UTEX)	HQ912599, HQ912463, HQ912292
Eunotia glacialis Meister	HK069	FD46 (UTEX)	HQ912586, HQ912450, HQ912279
Eunotia pectinalis (Kützing) Rabenhorst	HK153	NIES461 (MCC-NIES)	HQ912636, HQ912500, HQ912329
Eunotia sp. Ehrenberg	HK286	ECT3676 (Tinago River, Guam)	KC309480, KC309552, KC309623
Fallacia monoculata (Hustedt) D.G.Mann	HK082	FD254 (UTEX)	HQ912596, HQ912460, HQ912289
Fallacia pygmaea (Kützing) Stickle & D.G.Mann	HK093	FD294 (UTEX)	HQ912605, HQ912469, HQ912298
Fallacia sp. Stickle & D.G.Mann	HK482	GU52X-3 (Outhouse Beach, Guam)	MH063467, MH064092, MH064000
Fistulifera pelliculosa (Brebisson) Lange-Bertalot			AY485454, HQ337547, N/A
Fistulifera saprophila (Lange-Bertalot & Bonik) Lange-Bertalot			KC736618, KC736593, N/A
Geissleria decussis (Østrup) Lange-Bertalot & Metzeltin		FD050 (UTEX)	KJ011647, KJ011830, N/A
Gomphonema affine Kützing	HK098	FD173 (UTEX)	HQ912608, HQ912472, HQ912301
Gomphonema parvulum (Kützing) Kützing	HK081	FD241 (UTEX)	HQ912595, HQ912459, HQ912288
Gomphonemopsis cf pseudoexigua (Simonsen) Medlin	UTKSA0026x	SA18 (Duba, Saudi Arabia)	MH063471, MH064098, MH064005
Gyrosigma acuminatum (Kützing) Rabenhorst	HK085	FD317 (UTEX)	HQ912598, HQ912462, HQ912291
Halamphora catenulafalsa Witkowski & Ch. Li	SZCZCH452	Yellow Sea coast, Shandong Province	KT943646, KT943669, KT943704
Halamphora coffeaeformis (Agardh) Levkov	HK089	FD75 (UTEX)	HQ912602, HQ912466, HQ912295
Halamphora cf. *costata* (Smith) Levkov	UTKSA0195	KSA2015-22 (Markaz Al Shoaibah, Saudi Arabia)	MH063468, MH064093, MH064001
Halamphora coloradiana J.G.Stepanek & Kociolek	AMPH025		KJ463450, KJ463480,

			KJ463510
Halamphora montana (Krasske) Levkov	TCC477		KC736615, KC736590, N/A
Halamphora normanii (Rabenhorst) Levkov			AM501958, AM710424, N/A
Halamphora oligotraphenta (Lange-Bertalot) Levkov	AMPH009		KJ463451, KJ463481, KJ463511
Halamphora sp. (Cleve) Levkov	SZCZCH101	Yellow Sea coast, Shandong Province	KT943645, KT943682, KT943703
Halamphora sp. (Cleve) Levkov	SZCZCH623	Yellow Sea coast, Shandong Province	KT943647, KT943684, KT943705
Halamphora sp. (Cleve) Levkov	SZCZCH975	Yellow Sea coast, Shandong Province	KT943650, KT943673, KT943710
Halamphora veneta (Kützing) Levkov	AMPH005		KJ463452, KJ463482, KJ463512
Hantzschia amphioxys var. *major* Grunow in Van Heurck			HQ912404, HQ912390, HQ912376
Haslea cf. *howeana* (Hagelstein) Giffen	HK494	GU7Y-4 (University of Guam Marine Labs, Guam)	N/A, MH040268, MH040241
Haslea cf. *howeana* (Hagelstein) Giffen	HK496	PR6 (San Juan, Puerto Rico)	MH017640, MH040269, MH040242
Haslea cf. *howeana* (Hagelstein) Giffen	UTKSA0211	KSA2015-54 (Duba, Saudi Arabia)	MH063469, MH064094, MH064002
Haslea ostrearia (Gaillon) Simonsen	NCC158.4		N/A, HF563525, HF558667
Haslea ostrearia (Gaillon) Simonsen	NCC321		N/A, HF563527, HF558669
Haslea sp. Simonsen	KSA0102	SA4 (Durrah, Saudi Arabia)	KX981844, KX981821, KX981797
Haslea sp. Simonsen	HK493	GU52X-1 (Outhouse Beach, Guam)	N/A, MH064095, MH064003
Haslea sp. Simonsen	UTKSA0122	KSA2015-30 (Markaz Al Shoaibah, Saudi Arabia)	N/A, MH064096, MH064004
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski			AM501966, AM710432, N/A
Hydrosilicon mitra Brun	UTKSA0421	KSA2015-37 (Rabigh, Saudi Arabia)	MH063470, MH064097, N/A

Lemnicola hungarica (Grunow) Round	HK129	FD456 (UTEX)	HQ912626, HQ912490, HQ912319
Luticola goeppertiana (Bleisch) D.G.Mann ex J.Rarick, S.Wu, S.S.Lee & Edlund			AM501967, AM710433, N/A
Lyrella hennedyi (W.Smith) Stickle & D.G.Mann	UTKSA0279	KSA2015-5 (Bhadur Resort, Saudi Arabia)	MH063472, MH064099, MH064006
Mastogloia aquilegiae Grunow in Möller	UTKSA0224	KSA2015-49 (Duba, Saudi Arabia)	N/A, MH064100, MH064007
Mastogloia fimbriata (T. Brightwell) Grunow	HK485	GU52X-1 (Outhouse Beach, Guam)	MH040321, MH040270, MH040243
Mastogloia cf. *pumila* (Grunow) P.T.Cleve	HK136	29X07-6B (Mustang Island, Texas)	HQ912632, HQ912496, HQ912325
Mastogloia sp. Thwaites in W.Smith	HK314	ECT3762 (Taeleyag Beach, Guam)	KC309481, KC309553, N/A
Mastogloia sp. Thwaites in W.Smith	KSA0062	SA17 (Duba, Saudi Arabia)	MH063473, MH064101, MH064008
Mastogloia sp. Thwaites in W.Smith	UTKSA0313	KSA0216-44 (Markaz Al Shoaibah, Saudi Arabia)	MH063474, MH064102, MH064009
Mayamaea perimitis (Hustedt) K.Bruder & L.K.Medlin	TCC540		KC736630, KC736600, N/A
Meuniera membranacea (P.T.Cleve) P. C.Silva	HK313	ECT3896 (Port Aransas Jetty, Texas)	KC309482, KC309554, KC309624
Navicula cari Ehrenberg			AM501991, AM710457, N/A
Navicula cryptocephala Kützing	HK090	FD109 (UTEX)	HQ912603, HQ912467, HQ912296
Navicula hippodontofallax Witkowski & Ch. Li	SZCZCH703	Yellow Sea coast, Shandong Province	KT943636, KT943661, KT943695
Navicula perminuta Østrup	mbccc3		JQ045340, JQ432375, N/A
Navicula sp. Bory	HK486	Coz4 (Cozumel, Mexico)	MH040322, MH040271, MH040244
Navicula sp. Bory	HK487	Coz4 (Cozumel, Mexico)	N/A, MH064103, MH064010
Navicula sp. Bory	HK488	24IV14-2A (Conch Reef, Florida)	MH063475, MH064104, MH064011
Navicula sp. Bory	HK489	24IV14-3A (Pickles Reef,	MH063476, MH064105,

		Florida)	MH064012
Navicula sp. Bory	HK490	GU7Y-4 (University of Guam Marine Laboratories, Guam)	N/A, MH040272, MH040245
Navicula sp. Bory	KSA0112	SA23 (Al-Wajh, Saudi Arabia)	N/A, MH064106, MH064013
Navicula sp. Bory	UTKSA0131	KSA2015-19 (Al-Nawras, Jeddah, Saudi Arabia)	MH063477, MH064107, MH064014
Navicula sp. Bory	UTKSA0162	KSA2015-14 (Bhadur Resort, Saudi Arabia)	MH063478, MH064108, MH064015
Navicula sp. Bory	UTKSA0239	KSA2015-41 (Rabigh, Saudi Arabia)	MH063479, MH064109, MH064016
Navicula reinhardtii Grunow in P.T.Cleve & Möller			AM501976, AM710442, N/A
Navicula tripunctata (O.F.Müller) Bory			AM502028, AM710495, N/A
Navicula zhengii Witkowski & Ch.Li	SZCZCH96	Yellow Sea coast, Shandong Province	KT943632, KT943681, KT943691
Neidium affine (Ehrenberg) Pfitzer	HK064	FD127 (UTEX)	HQ912583, HQ912447, HQ912276
Neidium bisulcatum (Lagerstedt) Cleve	HK076	FD417 (UTEX)	HQ912591, HQ912455, HQ912284
Neidium productum (W. Smith) Cleve	HK063	FD116 (UTEX)	HQ912582, HQ912446, HQ912275
Nitzschia acidoclinata Lange-Bertalot			KC736632, KC736602, N/A
Nitzschia aurariae Cholnoky	SZCZCH966	Yellow Sea coast, Shandong Province	KT943639, KT943663, KT943698
Nitzschia cf. *dissipata* (Kützing) Rabenhorst	KSA0035	SA4 (Durrah, Saudi Arabia)	KU179128, KU179116, KU179143
Nitzschia draveillensis Coste & Ricard			KC736635, KC736605, N/A
Nitzschia dubiformis Hustedt			AB430616, AB430696, N/A
Nitzschia inconspicua Grunow			KC736636, KC736607, N/A
Nitzschia filiformis (W. Smith) Van Heurck	HK073	FD267 (UTEX)	HQ912589, HQ912453, HQ912282
Nitzschia cf. *frigida* Grunow	HK468	AKIce (Barrow, Alaska)	N/A, MH064110, MH064017
Nitzschia frustulum (Kützing) Grunow	TCC545		KT072974, KT072922, N/A

Nitzschia cf longissima (Brébisson in Kützing) Grunow	HK176	ECT3689 (Sala Glula, Guam)	KX981850, KX981829, KX981804
Nitzschia longissima (Brébisson in Kützing) Grunow	GenBank		AY881968, AY881967, N/A
Nitzschia longissima (Brébisson in Kützing) Grunow	UTKSA0021	SA29 (Jeddah, Saudi Arabia)	MH063480, MH064111, MH064018
Nitzschia longissima (Brébisson in Kützing) Grunow	UTKSA0124	KSA2015-9 (Bhadur Resort, Saudi Arabia)	MH063481, MH064112, MH064019
Nitzschia lorenziana Grunow			KC736637, KC736608, N/A
Nitzschia martiana (C.Agardh) Van Heurck	HK405	3VIII07 (Talofofo Bay, Guam)	N/A, KJ577899, KJ577933
Nitzschia sp. Hassall	KSA0120	SA27 (Jeddah, Saudi Arabia)	KX981849, KX981828, KX981803
Nitzschia sp. Hassall	HK469	Rincon Mangrove (Costa Rica)	MH040323, MH040273, MH040246
Nitzschia sp. Hassall	HK470	Nate Site 1 (Kona, Hawaii)	MH040324, MH040274, MH040247
Nitzschia sp. Hassall	HK472	Coz4 (Cozumel, Mexico)	MH040325, N/A, MH040248
Nitzschia sp. Hassall	HK473	GU52X-4 (Outhouse Beach, Guam)	MH040326, MH040275, MH040249
Nitzschia sp. Hassall	HK474	CCMP1698 (NCMA)	MH040327, MH040276, MH040250
Nitzschia sp. Hassall	UTKSA0053	SA19 (Al-Wajh, Saudi Arabia)	N/A, MH064113, MH064020
Nitzschia sp. Hassall	UTKSA0102	KSA2015-14 (Bhadur Resort, Saudi Arabia)	MH063482, MH064114, MH064021
Nitzschia sp. Hassall	UTKSA0106	KSA2015-49 (Duba, Saudi Arabia)	MH063483, MH064115, MH064022
Nitzschia sp. Hassall	UTKSA0107	KSA2015-49 (Duba, Saudi Arabia)	MH063484, MH064116, MH064023
Nitzschia sp. Hassall	UTKSA0109	KSA2015-16 (Al-Nawras, Jeddah, Saudi Arabia)	MH063485, MH064117, N/A
Nitzschia sp. Hassall	UTKSA0111	KSA2015-23 (Markaz Al Shoaibah, Saudi Arabia)	MH063486, MH064118, MH064024

Nitzschia sp. Hassall	UTKSA0171	KSA2015-11 (Bhadur Resort, Saudi Arabia)	MH063487, MH064119, MH064025
Nitzschia sp. Hassall	UTKSA0173	KSA2015-37 (Rabigh, Saudi Arabia)	MH063488, MH064120, MH064026
Nitzschia sp. Hassall	UTKSA0182	KSA2015-38 (Rabigh, Saudi Arabia)	MH063489, MH064121, MH064027
Nitzschia sp. Hassall	UTKSA0260	KSA2015-11 (Bhadur Resort, Saudi Arabia)	MH063490, MH064122, MH064028
Nitzschia cf. *spathulata* Brébisson ex W.Smith	UTKSA0332	KSA2016-1 (Bhadur Resort, Saudi Arabia)	N/A, MH064123, MH064029
Nitzschia cf *spathulata* Brébisson ex W.Smith	UTKSA0387	KSA2016-35 (Duba, Saudi Arabia)	MH063491, MH064124, MH064030
Nitzschia traheaformis Ch.Li, Witkowski & Yu Sh.	SZCZCH970	Yellow Sea coast, Shandong Province	KT943642, KT943666, KT943701
Nitzschia traheaformis Ch.Li, Witkowski & Yu Sh.	SZCZCH971	Yellow Sea coast, Shandong Province	KT943643, KT943667, KT943702
Nitzschia volvendirostrata Ashworth, Dabek & Witkowski	KSA0039	SA12 (Markaz Al Shoaibah, Saudi Arabia)	N/A, KU179112, KU179139
Parlibellus hamulifer (Grunow) Cox	HK409	GU44AK-4 (Gab Gab Beach, Guam)	KJ577866, KJ577903, KJ577937
Parlibellus cf. *hamulifer* (Grunow) Cox	HK428	SantaRosaCor.green (Costa Rica)	KU179137, KU179122, KU179149
Parlibellus harffianus Witkowski, Ch. Li & S.-X.Yu	SZCZCH75		KT943652, KT943686, KT943715
Phaeodactylum tricornutum Bohlin	HK011	CCMP2561 (NCMA)	HQ912556, HQ912420, HQ912250
Phaeodactylum tricornutum Bohlin	HK540	UTEX2089 (UTEX)	MH063494, MH064127, MH064033
Phaeodactylum tricornutum Bohlin	HK538	UTEX640 (UTEX)	MH063492, MH064125, MH064031
Phaeodactylum tricornutum Bohlin	HK539	UTEX646 (UTEX)	MH063493, MH064126, MH064032
Pinnularia brebissonii (Kützing) Rabenhorst	HK092	FD274 (UTEX)	HQ912604, HQ912468,

			HQ912297
Pinnularia termitina (Ehrenberg) Patrick	HK088	FD484 (UTEX)	HQ912601, HQ912465, HQ912294
Placoneis elginensis (Gregory) Cox	HK096	FD416 (UTEX)	HQ912607, HQ912471, HQ912300
Plagiotropis sp. Pfitzer	HK508	PR5 (Condado Lagoon, Puerto Rico)	MH063495, MH064128, MH064034
Planothidium frequentissimum (Lange-Bertalot) Lange-Bertalot	PF1		KJ658409, KJ658392, N/A
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot	PL2		KJ658410, KJ658393, N/A
Planothidium sp. Round & Bukhtiyarova	SZCZCH26		KT943653, KT943678, KT943716
Pleurosigma sp. W. Smith	HK495	GU52X-1 (Outhouse Beach, Guam)	MH040327, MH040276, MH040250
Pleurosigma sp. W. Smith	UTKSA0019	SA18 (Duba, Saudi Arabia)	KX981840, KX981822, KX981798
Pleurosigma sp. W. Smith	UTKSA0167	KSA2015-49 (Duba, Saudi Arabia)	MH063496, MH064129, MH064035
Pleurosigma sp. W. Smith	UTKSA0264	KSA2015-16 (Al-Nawras, Jeddah, Saudi Arabia)	MH063497, N/A, MH064036
Pleurosigma ~~sp.~~ W. Smith	UTKSA0273	KSA2015-16 (Al-Nawras, Jeddah, Saudi Arabia)	MH063498, MH064130, MH064037
Pleurosigma cf. *stuxbergii* P.T.Cleve & Grunow	SZCZCH973	Yellow Sea coast, Shandong Province	N/A, KT943674, KT943711
Proschkinia cf. *complanatula* (Hustedt ex Simonsen) D.G.Mann	HK553	24II18-1G (Half Moon Bay, California, USA)	MK736943, MK757575, MK757579
***Proschkinia impar* So-Yeon Kim, J.-G. Park & Witkowski**	**KNU-Y-16121**	**Yellow Sea coast in Pado-ri Beach, Korea**	**N/A, MK887893, N/A**
***Proschkinia luticola* So-Yeon Kim, J.-G. Park, Witkowski & B.-S. Kim**	**KNU-B-16024**	**Yellow Sea coast in Beopsan-ri Beach, Korea**	**N/A, MK887894, N/A**
***Proschkinia modesta* So-Yeon Kim, J.-G. Park & Witkowski**	**KNU-Y-16122**	**Yellow Sea coast at Pado-ri Beach, Korea**	**N/A, MK887895, N/A**

***Proschkinia* sp. 1 D.G. Mann**		**Atlantic coast of Scotland**	**N/A, MK887896, N/A**
***Proschkinia staurospeciosa* So-Yeon Kim, J.-G. Park, Witkowski & Gastineau**	**SZCZR1824**	**Yellow Sea coast at Pado-ri Beach, Korea**	**N/A, MK887897, N/A**
Proschkinia vergostriata Frankovich, Ashworth & M.J. Sullivan	HK548	CC032217a, Loggerhead turtle (Florida, USA)	N/A, MK757570, N/A
Proschkinia vergostriata Frankovich, Ashworth & M.J. Sullivan	HK549	CC032217a, Loggerhead turtle (Florida, USA)	MK736939, MK757571, N/A
Proschkinia vergostriata Frankovich, Ashworth & M.J. Sullivan	HK550	ChelMyN 26V16, Green sea turtle (Florida, USA)	MK736940, MK757572, MK757576
Proschkinia vergostriata Frankovich, Ashworth & M.J. Sullivan	HK551	ChelMyN 26V16, Green sea turtle (Florida, USA)	MK736941, MK757573, MK757577
Proschkinia vergostriata Frankovich, Ashworth & M.J. Sullivan	HK552	ChelMyN 26V16, Green sea turtle (Florida, USA)	MK736942, MK757574, MK757578
Psammodictyon constrictum (Gregory) Mann in Round, Crawford & D.G.Mann	HK440	GU7X-7 (University of Guam Marine Lab, Guam)	KX981851, KX981830, KX981805
Psammodictyon constrictum (Gregory) Mann in Round, Crawford & D.G.Mann	HK471	Nate Site 1 (Kona, Hawaii)	MH040329, MH040278, MH040252
Psammodictyon sp. D.G.Mann	UTKSA0117	KSA2015-30 (Markaz Al Shoaibah, Saudi Arabia)	MH063499, MH064131, MH064038
Psammodictyon sp. D.G.Mann	UTKSA0151	KSA2015-37 (Rabigh, Saudi Arabia)	MH063500, MH064132, MH064039
Psammodictyon sp. D.G.Mann	UTKSA0280	KSA2015-2 (Bhadur Resort, Saudi Arabia)	MH063501, MH064133, MH064040
Psammodictyon pustulatum (Voigt ex Meister) Lobban	UTKSA0298	KSA2015-38 (Rabigh, Saudi Arabia)	MH063502, MH064134, MH064041
Rhoiconeis pagoensis Lobban	HK419	GU7X-7 (University of Guam Marine Lab, Guam)	KX981846, KX981825, KX981800
Rhoiconeis sp. Grunow	UTKSA0128	KSA2015-16 (Al-Nawras, Jeddah, Saudi Arabia)	MH063503, MH064135, N/A
Rhoicosigma sp. Grunow	UTKSA0194	KSA2015-22 (Markaz Al Shoaibah, Saudi Arabia)	MH063504, MH064136, MH064042
Rhoicosphenia abbreviata (C.Agardh) Lange-Bertalot	CH030		KJ011672, KJ011854, N/A
Rhoicosphenia cf. *abbreviata* (C.Agardh) Lange-Bertalot	EWT2016.80		KU965569, KU965580, N/A

Rhopalodia contorta Hustedt		L1299 (UTEX)	HQ912406, HQ912392, HQ912378
Rhopalodia gibba (Ehrenberg) O. Müller			HQ912407, HQ912393, HQ912379
Rhopalodia sp. O.Müller	HK433	21IV14-4D (Rabbit Key Basin, Florida)	KX981843, KX981823, KX981799
Rhopalodia sp. O.Müller		ECT3678 (Tinago River, Guam)	HQ912405, HQ912391, HQ912377
Rossia sp. Voigt			EF151968, EF143281, N/A
Schizostauron sp. Grunow	UTKSA0141	KSA2015-11 (Bhadur Resort, Saudi Arabia)	MH063505, MH064137, MH064043
Schizostauron sp. Grunow	SZCZP32	Indian Ocean coast, Mozambique	KT943595, KT943606, KT943619
Schizostauron sp. Grunow	SZCZP40	Indian Ocean coast, Mozambique	KT943596, KT943607, KT943620
Scoliopleura peisonis Grunow	HK103	FD13 (UTEX)	HQ912609, HQ912473, HQ912302
Sellaphora laevissima (Kützing) D.G.Mann	THR4		EF151981, EF143309, N/A
Sellaphora minima Grunow	TCC524		KF959656, KF959642, N/A
Sellaphora seminulum (Grunow) D.G.Mann	TCC461		KF959642, KC736613, N/A
Seminavis robusta Danielidis & D.G.Mann	HK492	GU7X-7 (University of Guam Marine Laboratories, Guam)	MH040330, MH040279, MH040253
Stauroneis acuta W.Smith	HK059	FD51 (UTEX)	HQ912579, HQ912443, HQ912272
Stauroneis anceps Ehrenberg			AM502008, AM710475, N/A
Stauroneis gracilior Reichardt			AM501988, AM710454, N/A
Stauroneis kriegeri Patrick			AM501990, AM710456, N/A
Stauroneis phoenicentron (Nitzsch) Ehrenberg			AM502031, AM710498, N/A
Stauroneis sp. Ehrenberg	UTKSA0410	KSA2016-9 (Bhadur Resort, Saudi Arabia)	MH063506, MH064138, MH064044
Sternimirus shandongensis Witkowski & Ch. Li	SZCZCH968	Yellow Sea coast, Shandong Province	KT943637, KT943662, KT943696
Staurotropis americana Ashworth	HK442	FishPassMangrove (Mustang	KX981855, KX981834,

		Island, Texas)	KX981808
Staurotropis americana Ashworth	HK443	Coz4 (Cozumel, Mexico)	KX981854, KX981833, KX981807
Staurotropis khiyamii J.Sabir & Ashworth	UTKSA0047	SA18 (Duba, Saudi Arabia)	KX981853, KX981832, KX981806
Staurotropis seychellensis (Giffen) Paddock	HK172	ECT3721 (University of Guam Marine Lab, Guam)	KX981856, N/A, KX981809
Stenopterobia curvula (W.Smith) Krammer		L541 (UTEX)	HQ912416, HQ912402, HQ912388
Surirella cf. *fastuosa* (Ehrenberg) Ehrenberg	SZCZCH189	Yellow Sea coast, Shandong Province	KT943629, KT943655, KT943688
Surirella minuta Van Heurck		FD320 (UTEX)	HQ912658, HQ912522, HQ912351
Surirella ovata Kützing	HK214	L1241 (UTEX)	HQ912658, HQ912522, HQ912351
Surirella splendida (Ehrenberg) Kützing			HQ912415, HQ912401, HQ912387
Surirella sp. Turpin	UTKSA0299	KSA2015-2 (Bhadur Resort, Saudi Arabia)	MH063507, MH064139, MH064045
Tetramphora chilensis (Hustedt) Stepanek & Kociolek		AMPH132	KU665638, KU665639, KU665640
Trachyneis sp. P.T.Cleve	HK439	SantaRosaCor.green (Costa Rica)	KX981845, KX981824, N/A
Tryblionella apiculata Gregory	HK087	FD465 (UTEX)	HQ912600, HQ912464, HQ912293
Tryblionella gaoana Witkowski & Ch. Li	SZCZCH97	Yellow Sea coast, Shandong Province	KT943638, KT943683, KT943697
unidentified diploneid	UTKSA0368	KSA0216-36 (Duba, Saudi Arabia)	MH063508, MH064140, MH064046
unidentified monoraphid	HK380	ECT3899 (Pacific Grove, California)	KJ577839, KJ577874, KJ577911
unidentified monoraphid	HK427	BallenaEstRock (Costa Rica)	KU179136, KU179121, KU179148

unidentified monoraphid	UTKSA0152	KSA2015-37 (Rabigh, Saudi Arabia)	MH063509, MH064141, MH064047
unidentified monoraphid	UTKSA0158	KSA2015-37 (Rabigh, Saudi Arabia)	MH063510, MH064142, N/A
unidentified naviculoid	HK497	23X15-5B (Harbor Branch Oceanographic Institute boat launch)	MH063511, MH064143, MH064048
unidentified naviculoid	UTKSA0247	KSA2015-5 (Bhadur Resort, Saudi Arabia)	MH063512, MH064144, MH064049
unidentified stauroneid	UTKSA0220	KSA2015-7 (Bhadur Resort, Saudi Arabia)	MH063513, MH064145, MH064050
Araphid Outgroups			
Asterionella formosa Hassall	HK144	UTCC605	HQ912633, HQ912497, HQ912326
Asterionellopsis glacialis (Castracane) Round	HK107	CCMP134 (NCMA)	HQ912613, HQ912477, HQ912306
Asterionellopsis socialis (Lewin & Norris) Crawford & Gardner	HK181	CCMP1717 (NCMA)	HQ912646, HQ912510, HQ912339
Asterionellopsis socialis (Lewin & Norris) Crawford & Gardner	HK319	ECT3920 (Ft. Stevens State Park, Oregon)	JX413545, JX413562, JX413579
Astrosyne radiata Ashworth & Lobban	HK169	ECT3697 (Gab Gab Beach, Guam)	JN975238, JN975252, JN975267
Bleakeleya notata (Grunow in Van Heurck) F.E. Round	HK247	ECT3733 (Pago Bay, Guam)	HM627330, HM627327, HM627324
Castoridens hyalina Ashworth, Witkowski & Ch. Li	HK444	C1 12-7-13 (Destin-Choctawhatchee Bay, Florida)	N/A, KU851892, KU851907
Castoridens striata Ashworth, Ch. Li & Witkowski	HK385	15VI11-2A (Baffin Bay, Texas)	KJ577844, KJ577879, KJ577915
Catacombas gaillonii (Bory de Saint-Vincent) Williams & Round	s0045		KR048195, KR048217, KR048229
Centronella reicheltii Voigt	HK150	CCAP1011/1	HQ912635, HQ912499, HQ912328
Ctenophora pulchella (Ralfs ex Kützing) Williams &	HK105	FD150 (UTEX)	HQ912611, HQ912475,

Round			HQ912304
Cyclophora castracanei Ashworth & Lobban	HK243	GU44AB-6 (Gab Gab Beach, Guam)	JN975242, JN975256, JN975271
Cyclophora castracanei Ashworth & Lobban	HK395	GU44AN-7 (Gab Gab Beach, Guam)	KJ577854, KJ577889, N/A
Cyclophora cf. *minor* Ashworth & Lobban	HK461	24IV14-3A (Pickles Reef, Florida)	MH040308, MH040254, MH040230
Cyclophora tabellariformis Ashworth & Lobban	HK306	ECT3892 (Carrabelle, Florida)	JN975243, JN975257, JN975272
Cyclophora tabellariformis Ashworth & Lobban	HK460	GU44AY-6 (Gab Gab Beach, Guam)	MH040309, MH040255, N/A
Cyclophora tenuis Castracane	HK216	ECT3723 (Umatac Bay, Guam)	HQ912660, HQ912524, HQ912353
Cyclophora tenuis Castracane	HK307	ECT3854 (Kahana Beach Park, Oahu, Hawaii)	JN975240, JN975254, JN975269
Cyclophora tenuis Castracane	HK308	ECT3838 (Long Beach, California)	JN975241, JN975255, JN975270
Delphineis surirella (Ehrenberg) G.W.Andrews	HK133	CCMP1095	HQ912629, HQ912493, HQ912322
Delphineis surirella (Ehrenberg) G.W.Andrews	HK295	ECT3886 (Bald Head Island, North Carolina)	JX413544, JX413561, JX413578
Diatoma elongata (Lyngbye) C.Agardh	HK119	UTCC62	HQ912622, HQ912486, HQ912315
Diatoma tenue C.Agardh	HK078	FD106 (UTEX)	HQ912593, HQ912457, HQ912286
Dimeregramma sp. J. Ralfs in A.Pritchard	HK288	ECT3864 (MSI, Port Aransas, Texas)	JN975244, JN975258, JN975273
Dimeregramma sp. J. Ralfs in A.Pritchard	HK358	15VI11-2A (Baffin Bay, Texas)	JX401231, JX401249, JX401267
Dimeregramma sp. J. Ralfs in A.Pritchard	HK359	ECT3891 (St. George Island, Florida)	JX401232, JX401250, JX401268
Dimeregramma sp. J. Ralfs in A.Pritchard	HK376	25VI12-1C (Hunting Island, South Carolina)	KF701596, KF701605, KF701614

Dimeregramma sp. J. Ralfs in A.Pritchard	HK377	AtlanticPlankton#8 (Florida)	KF701597, KF701606, KF701615
Florella pascuensis Navarro	HK175	ECT3756 (Guam)	JN975246, JN975260, JN975275
Fragilariforma virescens (Ralfs) Williams & Round	HK132	FD291 (UTEX)	HQ912628, HQ912492, HQ912321
Glyphodesmis sp. Greville	HK357	ECT3891 (St. George Island, Florida)	N/A, JX401248, JX401266
Grammatophora macilenta W.Smith	HK368	GU44AK-4 (Gab Gab Beach, Guam)	JX401241, JX401259, JX401276
Grammatophora oceanica Ehrenberg	HK147	CCMP410	HQ912634, HQ912498, HQ912327
Grammatophora sp. Ehrenberg	HK459	Nate Site 1 (Hawaii)	MG684352, MG684323, MG684295
Grammatophora sp. Ehrenberg	UTKSA0132	KSA2015-16 (Al-Nawras, Jeddah, Saudi Arabia)	MH063514, MH064146, MH064051
Grammatophora undulata Ehrenberg	HK367	Coz-3 (Cozumel, Mexico)	JX401240, JX401258, JX401275
Grammonema striatula (Lyngbye) Agardh	HK371	ECT3897 (Pebble Beach, California)	KF701591, KF701600, KF701609
Hanicella moenia Lobban & Ashworth	HK379	GU44AK-6 (Gab Gab Beach, Guam)	KF701599, KF701608, KF701617
Hendeyella dimeregrammopsis Ashworth	HK391	Coz-1 (Cozumel, Mexico)	KJ577850, KJ577885, KJ577920
Hendeyella lineata Ashworth & Lobban	HK325	GU44AI-3 (Gab Gab Beach, Guam)	JX413547, JX413564, JX413581
Koernerella recticostata (Körner) Ashworth, Lobban & Theriot	HK242	GU44AB-8 (Gab Gab Beach, Guam)	HM627331, HM627328, HM627325
Licmophora abbreviata Agardh	UTKSA0049	SA29 (Jeddah, Saudi Arabia)	KP125882, KP125883, KP125884
Licmophora colosalis Belando, Aboal & Jiménez	HK366	ECT3907 (Rabbit Key Basin, Florida)	JX401239, JX401257, JX401274
Licmophora colosalis Belando, Aboal & Jiménez	UTKSA0066	SA29 (Jeddah, Saudi Arabia)	MG684358, MG684329,

			MG684299
Licmophora aff. *ehrenbergii* (Kützing) Grunow	HK420	GU7X-6 (University of Guam Marine Lab, Guam)	KP125876, KP125879, KP125881
Licmophora flucticulata Lobban, Schefter & Ruck		GU56-A (Cocos Wall, Guam)	HQ997923, JN975262, JN975277
Licmophora normaniana (Greville) Wahrer in Wahrer, Fryxell & Cox	HK403	26II12-1 (Mustang Island, Texas)	KJ577860, KJ577897. KJ577931
Licmophora paradoxa (Lyngbye) Agardh	HK106	CCMP2313	HQ912612, HQ912476, HQ912305
Licmophora peragallioides (Lobban) Lobban & Ashworth	HK364	GU44AL-3 (Gab Gab Beach, Guam)	JX401237, JX401255, JX401273
Licmophora cf. *remulus* Grunow	HK302	GU52-O (Outhouse Beach, Guam)	JN975248, JN975263, N/A
Licmophora sp. Agardh	HK365	Coz-2 (Cozumel, Mexico)	JX401238, JX401256, N/A
Licmophora sp. Agardh	KSA0085	SA4 (Durrah, Saudi Arabia)	MG684353, MG684324, N/A
Licmophora sp. Agardh	KSA0151	SA1 (Durrah, Saudi Arabia)	MG684354, MG684325, N/A
Licmophora sp. Agardh	UTKSA0010	SA29 (Jeddah, Saudi Arabia)	MG684355, MG684326, MG684296
Licmophora sp. Agardh	UTKSA0029	SA18 (Duba, Saudi Arabia)	MG684356, MG684327, MG684297
Licmophora sp. Agardh	UTKSA0050	SA18 (Duba, Saudi Arabia)	MG684357, MG684328, MG684298
Licmophora sp. Agardh	UTKSA0084	SA18 (Duba, Saudi Arabia)	MG684359, MG684330, MG684300
Licmophora sp. Agardh	UTKSA0191	KSA2015-14 (Bhadur Resort, Saudi Arabia)	MH063515, MH064147, MH064052
Lucanicum concatenatum Lobban & Ashworth	HK378	GU44AI-3 (Gab Gab Beach, Guam)	KF701598, KF701607, KF701616
Microtabella interrupta (Ehrenberg) Round	HK248	ECT3700 (Gab Gab Beach, Guam)	JN975247, JN975261, JN975276
Microtabella interrupta (Ehrenberg) Round	HK458	20X15-1 (Boca Chica Channel, Florida)	MH040319, MH040265, MH040238
Nanofrustulum cf *shiloi* (J.J. Lee, C.W. Reimer, & M.E.	HK056	CCMP2649	HQ912578, HQ912442,

McEnery) F.E. Round, H. Hallsteinsen, & E. Paasche			HQ912271
Neodelphineis sp. Takano	HK421	FijiBottleNY (New York)	KP125875, KP125878, N/A
Neofragilaria nicobarica Desikachary, Prasad & Prema	s0371		AB433340, KR048216 KR048228
Neofragilaria cf. *nicobarica* Desikachary, Prasad & Prema	HK375	Coz-1 (Cozumel, Mexico)	KF701595, KF701604, KF701613
Neosynedra provincialis (Grunow) Williams & Round	HK457	24IV14-3A (Pickles Reef, Florida)	N/A, MH040266, MH040239
Opephora guenter-grassii (Witkowski & Lange-Bertalot) Sabbe & Vyverman		s0263	AB436781, KR048218, N/A
Opephora pacifica (Grunow) Petit	HK296	ECT3831 (Ward Island, Texas)	JN975249, JN975264, JN975278
Perideraion elongatum Jordan, Arai & Lobban	HK411	GU44AK-6 (Gab Gab Beach, Guam)	KJ577868, KJ577905, KJ577939
Perideraion cf. *elongatum* Jordan, Arai & Lobban	UTKSA0259	KSA2015-49 (Duba, Saudi Arabia)	MH063516, MH064148, MH064053
Perideraion montgomeryii Lobban, Jordan & Ashworth	HK246	GU7 (University of Guam Marine Lab, Guam)	HM627332, HM627329, HM627326
Plagiogramma sp. Greville	HK212	ECT3776 (Taeleyag Beach, Guam)	HQ912656, HQ912520, HQ912349
Plagiogramma sp. Greville	HK324	ECT3924 (Potlatch State Park, Washington)	JX413546, JX413563, JX413580
Plagiogramma sp. Greville	HK374	25VI12-1C (Hunting Island, South Carolina)	KF701594, KF701603, KF701612
Plagiostriata goreensis Sato & Medlin	s0388		KR048198, KR048220, KR048232
Psammogramma vigoensis Sato & Medlin	s0391		KR048194, KR048215, KR048227
Psammoneis japonica Sato, Kooistra & Medlin	HK299	GU52-O (Outhouse Beach, Guam)	JN975250, JN975265, JN975279
Psammoneis obaidii Ashworth & Sabir	UTKSA0057	SA12 (Markaz Al Shoaibah, Saudi Arabia)	KR059023, KR059022, KR059024
Psammoneis sp. Sato, Kooistra & Medlin	UTKSA0250	KSA2015-42 (Rabigh, Saudi	MH063517, MH064149, N/A

		Arabia)	
Psammotaenia lanceolata Ashworth, Ch. Li & Witkowski	HK316	10X10-2 (St. George Island, Florida)	JX413543, JX413560, JX413577
Pseudostriatella oceanica Sato, Mann & Medlin	s0384		KR048197, KR048219, KR048231
Pteroncola sp. R.W.Holmes & D.A.Croll	UTKSA0078	SA29 (Jeddah, Saudi Arabia)	MG684376, N/A, MG684316
Podocystis cf. *americana* Bailey	HK453	19X15-1A (Channel #5, Florida)	MH040320, MH040267, MH040240
Podocystis cf. *americana* Bailey	HK454	19X15-1B (Channel #5, Florida)	MG684360, MG684331, MG684301
Podocystis spathulata (Shadbolt) Van Heurck	HK217	ECT3733 (Pago Bay, Guam)	HQ912661, HQ912525, HQ912354
Rhabdonema adriaticum Kützing	HK370	Coz-3 (Cozumel, Mexico)	JX401243, JX401261, JX401278
Rhabdonema arcuatum (Lyngbye) Kützing	HK304	ECT3898 (Pebble Beach, California)	JN975251, JN975266, JN975280
Rhabdonema sp. Kützing	HK369	GU44AI-1 (Gab Gab Beach, Guam)	JX401242, JX401260, JX401277
Rhaphoneis amphiceros (Ehrenberg) Ehrenberg	HK237	ECT3828 (Redfish Bay, Texas)	HQ912673, HQ912537, KC309625
Rhaphoneis amphiceros (Ehrenberg) Ehrenberg	HK373	25VI12-1A (Hunting Island, South Carolina)	KF701593, KF701602, KF701611
Serratifera varisterna Ch.Li, Ashworth & Witkowski	HK315	9X10-2 (Florida State University Marine Lab, Florida)	JX413542, JX413559, JX413576
Serratifera varisterna Ch.Li, Ashworth & Witkowski	HK424	PackaryChannelPlankton (Mustang Island, Texas)	KU851868, KU851879, KU851894
Staurosira construens Ehrenberg	HK071	FD232 (UTEX)	HQ912587, HQ912451, HQ912280
Staurosirella pinnata (Ehrenberg) Williams & Round	HK116	CCMP330 (NCMA)	HQ912620, HQ912484, HQ912313
Striatella unipunctata (Lyngbye) Agardh	HK177	ECT3648 (Asan Beach, Guam)	HQ912643, HQ912507, HQ912336

Striatella unipunctata (Lyngbye) Agardh	HK318	ECT3874 (Channel #5, Florida)	JX419383, JX419384, JX419385
Stricosus blumbergii Theriot & Ashworth	HK362	15VI11-2A (Baffin Bay, Texas)	JX401235, JX401253, JX401271
Stricosus harrisonii Lobban & Theriot	HK363	GU44AI (Gab Gab Beach, Guam)	JX401236, JX401254, JX401272
Synedra famelica Kützing	HK072	FD255 (UTEX)	HQ912588, HQ912452, HQ912281
Synedra ulna (Nitzsch) Ehrenberg	HK075	FD404 (UTEX)	HQ912590, HQ912454, HQ912283
Synedropsis hyperborea (Grunow) Hasle, Medlin & Syvertsen	HK117	CCMP1423 (NCMA)	HQ912621, HQ912485, HQ912314
Synedropsis cf. *recta* Hasle, Medlin & Syvertsen	HK110	CCMP1620 (NCMA)	HQ912616, HQ912480, HQ912309
Tabellaria flocculosa (Roth) Kützing	HK065	FD133 (UTEX)	HQ912584, HQ912448, HQ912277
Tabularia cf. *tabulata* (Agardh) Snoeijs	HK109	CCMP846 (NCMA)	HQ912615, HQ912479, HQ912308
Talaroneis posidoniae Kooistra & De Stefano	WK59		AY216905, KR048214, KR048226
Tetracyclus sp. Ralfs	HK416	B12 (Lake Baikal, Russia)	KJ577873, KJ577910, KJ577944
Thalassionema cf. *bacillare* (Heiden) Kolbe	HK361	ECT3929 (Gulf of Mexico, Texas)	JX401234, JX401252, JX401270
Thalassionema frauenfeldii (Grunow) Tempère & Peragallo	HK372	25VI12-1A (Hunting Island, South Carolina)	KF701592, KF701601, KF701610
Thalassionema cf. *nitzschioides* (Grunow) Mereschkowsky	HK360	ECT3929 (Gulf of Mexico, Texas)	JX401233, JX401251, JX401269