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Two new species of diatoms (Bacillariophyceae) from the coast of Tenerife, the Canary Islands, Spain

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Abstract

In a study of epiphytic diatoms from the coasts of Tenerife, Canary Islands, two new species, *Caloneis virgaestriata* and *Seminavis undulata,* were discovered and analyzed using light and electron microscopy. *Caloneis virgaestriata* is characterized by its small size, areolae rows that expand to cover the virgae between striae, and distal raphe ends curved in opposite directions. This last feature is present in only one other species currently placed in the genus, *C. hustedtii*. *Seminavis undulata* exhibits a novel morphological trait not previously recorded in the genus: its external proximal raphe ends are located beneath a silica flap with a wavy margin, giving the appearance of undulating raphe ends. A comparison of *S. undulata* with the morphologically similar taxa *S. delicatula* and *S. obtusiuscula* suggests that the latter two may in fact be conspecific. Both new species were found growing epiphytically on the chlorophyte *Cladophora prolifera* (Roth) Kützing collected from a sheltered tide pool. Detailed ultrastructural descriptions are provided, along with comparisons to morphologically similar species. The present work is the first report of new benthic diatom species described from the Canary Islands.

Keywords

Diatoms; Epiphytic; New species; Taxonomy; Tenerife

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Introduction

The Canary Islands comprise a marine archipelago of volcanic origin in the North-Eastern Atlantic Ocean. Most of these islands are surrounded by rocky shores and inhabited by many species of macroalgae that must contend with strong waves following tidal cycles (Polifrone *et al.*, 2020). Despite the long shores of these islands and their diverse environments, our knowledge of its planktonic and benthic diatoms is limited, as the few studies that have been published have mostly provided ecological information on diatoms attached to rocks and macroalgae (Sansón & Reyes, 1995; Gil-Rodríguez *et al.*, 2003; Ojeda Rodríguez *et al.*, 2005; Polifrone *et al.*, 2020).

The two genera dealt with in the present work are *Caloneis* Cleve (Cleve, 1894) and *Seminavis* D.G. Mann (in Round *et al.*, 1990), which both have a worldwide distribution. *Caloneis*, although containing 392 taxa (Fang *et al.*, 2025), is a genus of uncertain taxonomic standing. The high degree of morphological similarity between *Caloneis* and *Pinnularia* Ehrenberg (Ehrenberg, 1843) makes their separation controversial. Cox (1988) and Round *et al.* (1990) believe that the boundaries between the two genera are insufficient for a clear taxonomic distinction, likely a reason behind omitting *Caloneis* as a distinct genus by Round *et al.* (1990). A comprehensive discussion on the taxonomic relationship between *Caloneis* and *Pinnularia* was provided by Mann (2001), defending his earlier views on the invalidity of *Caloneis* as a distinct genus. Despite such ongoing discussions, diatomists continue to treat *Caloneis* as a distinct taxonomic entity and new species have been consistently added (Metzeltin *et al.*, 2005; Metzeltin & Lange-Bertalot, 2007; Lange-Bertalot *et al.*, 2004;

Levkov *et al.*, 2014; Fang *et al.*, 2025).

Mann in Round *et al.* (1990) erected the genus *Seminavis* to encompass *Amphora* Ehrenberg ex Kützing species that are characterized by strongly dorsiventral valves, uniseriate lineolate striae formed by apically elongated slit-like areolae, and two unequal plastids. The genus has further been revised to include more *Amphora* species by Danielidis & Mann (2003). Earlier, Sullivan (1990) in his study of a population identified as *Amphora obtusiuscula* Grunow (=*S. obtusiuscula* (Grunow) Danielidis *et* D. G. Mann), had noticed that the raphe ultrastructure and the partially chambered valve interior of this species is more related to *Navicula* sensu stricto than to *Amphora,* and suggested a new placement for this species other than *Amphora*. *Seminavis* is a small genus with 27 species documented, either transferred from *Amphora* or newly described.

During a survey of the benthic diatoms along the coasts of Tenerife, Canary Islands, two diatom species belonging to *Caloneis* and *Seminavis* were found, which could not be matched with any documented species of those genera and are described as new to science in the present work.

Material and Methods

Epiphytic diatoms were isolated from green, brown and red macroalgal specimens collected in October 2024 from rocky intertidal and shallow subtidal (<2 m depth) by snorkeling. The sampling was carried out at Las Galletas Harbor, a sheltered fishing port on the south coast of Tenerife, Canary Islands (28º00'31.6" N, 16º39'36.4" W), with an average salinity of 36 PSU. Sea surface temperature (SST) was measured at 24 °C. The intertidal and subtidal zones consist of rocky volcanic platforms and small tide pools where a large diversity of macroalgal species and cyanobacteria coexist. Macroalgal specimens were transported in seawater and dried within 2 h for further analysis.

After isolating and identifying the macroalgal specimens, small fragments of each macroalgal sample were placed in a 50 ml glass jar with deionized water and then shaken vigorously to detach diatom frustules. Approximately 20 ml of the aliquots containing diatom frustules were transferred to a beaker and boiled in 35% H_2O_2 for 15 min. The sample was left to cool at room temperature, then rinsed several times with deionized water to remove salts. One ml of the cleaned material was dried on a cover slip at ambient temperature. The coverslips with dry diatom cells were heated at 150 °C to ensure adhering of the frustules and then mounted in Naphrax®. For further examination, part of the clean aliquots containing diatoms were preserved in 4% glutaraldehyde. The two species described in this work were found epiphytic on the chlorophyte *Cladophora prolifera*.

A Zeiss Axioimager 2 microscope equipped with differential interference contrast (DIC) objectives and a Canon Powershot 14 digital camera were used for morphometric analysis and imaging of the frustules (Department of Biological and Environmental Sciences, University of Gothenburg, Sweden). For scanning electron microscopy (SEM), a few drops of the cleaned diatom material were dried on aluminum stubs, coated with gold palladium, and examined in a Zeiss Ultra 55 FEG SEM (Chalmers University, Gothenburg, Sweden). The relative abundance of the new species and associated diatom taxa was estimated according to the Utermöhl sedimentation and counting method (Utermöhl, 1931, 1958). Diatoms, other than the new species, were counted only when constituting more than 1% of the total diatom assemblages in the samples. Terminology used in the description of the new species follows Ross *et al.* (1979) and Round *et al.* (1990).

Results

***Caloneis virgaestriata* Al-Handal *et* M. J. Sullivan *sp. nov.* (Figs 1–6, 12–21)**

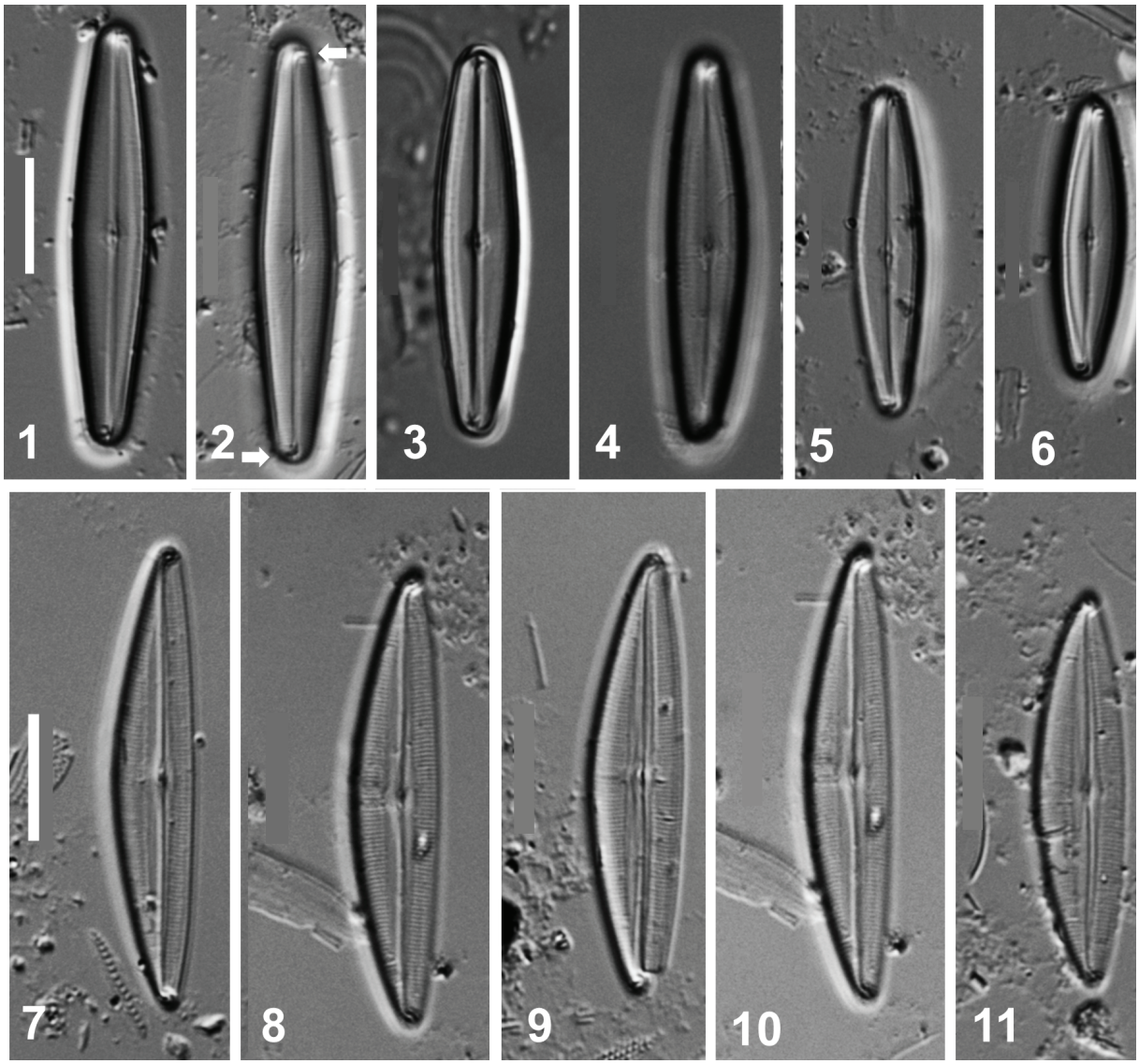
Description

LM (Figs 1–6): Valves linear-lanceolate with obtusely rounded apices. Valve length 25–39 µm, width 6–8 µm. Axial area straight, very narrow. Central area very small, slightly asymmetrical. Raphe straight, proximal ends teardrop-like, very close to each other. Distal raphe ends deflected in opposite directions (Fig. 2, white arrows). Striae very fine, not visible in LM.

SEM (Figs 12–21): Externally, central area asymmetric, a crescent-shaped flap confluent with the raphe sternum on one side, and a groove outside the raphe sternum on the other side (Figs 12, 13, 18, 19). Raphe straight, filiform, becoming lateral at the middle of valve halves (Figs 15, 16, 18). Raphe canal very narrow, becoming wider towards the poles (Figs 15, 16). Proximal raphe ends elongated, teardrop-like, raised above central area, (Figs 18, 19). Distal raphe ends wider than elsewhere, strongly deflected in opposite directions (Figs 12, 13, 15, 16). Deflected parts of distal raphe ends apically bordered by a triangular area devoid of areolae (15, 16, white arrows). Striae parallel, weakly radiate near valve poles, continuous around each pole (Figs 12, 13, 15, 16, 18). Striae very fine, 98–105 in 10 µm, formed of very small, quadrangular poroid areolae that are occluded by hymenes and arranged in a quincunx pattern. There are three transapical rows of areolae between adjacent virgae. Furthermore, the external openings of the outer areolae row of each triplet partially extend over the narrow transapical virgae (Fig. 20, white arrows). Striae terminate at valve-mantle transition, leaving a wide unperforated mantle (Fig. 21).

Internally, raphe straight, filiform (Fig. 14). Proximal raphe ends very slightly deflected in the same direction (Fig. 17); distal raphe ends terminate before poles as small helictoglossae (Fig. 14). A longitudinal row of more or less rounded alveolar openings runs close to each valve margin and is continuous around both valve poles (Figs 14, 17). The girdle consists of three copulae (Fig. 21). The valvocopula (Band 1) is broad, apparently closed, and overlaps Band 2 along its entire perimeter. Band 3 is a reduced band that fills the open end of Band 2 at one end of the frustule.

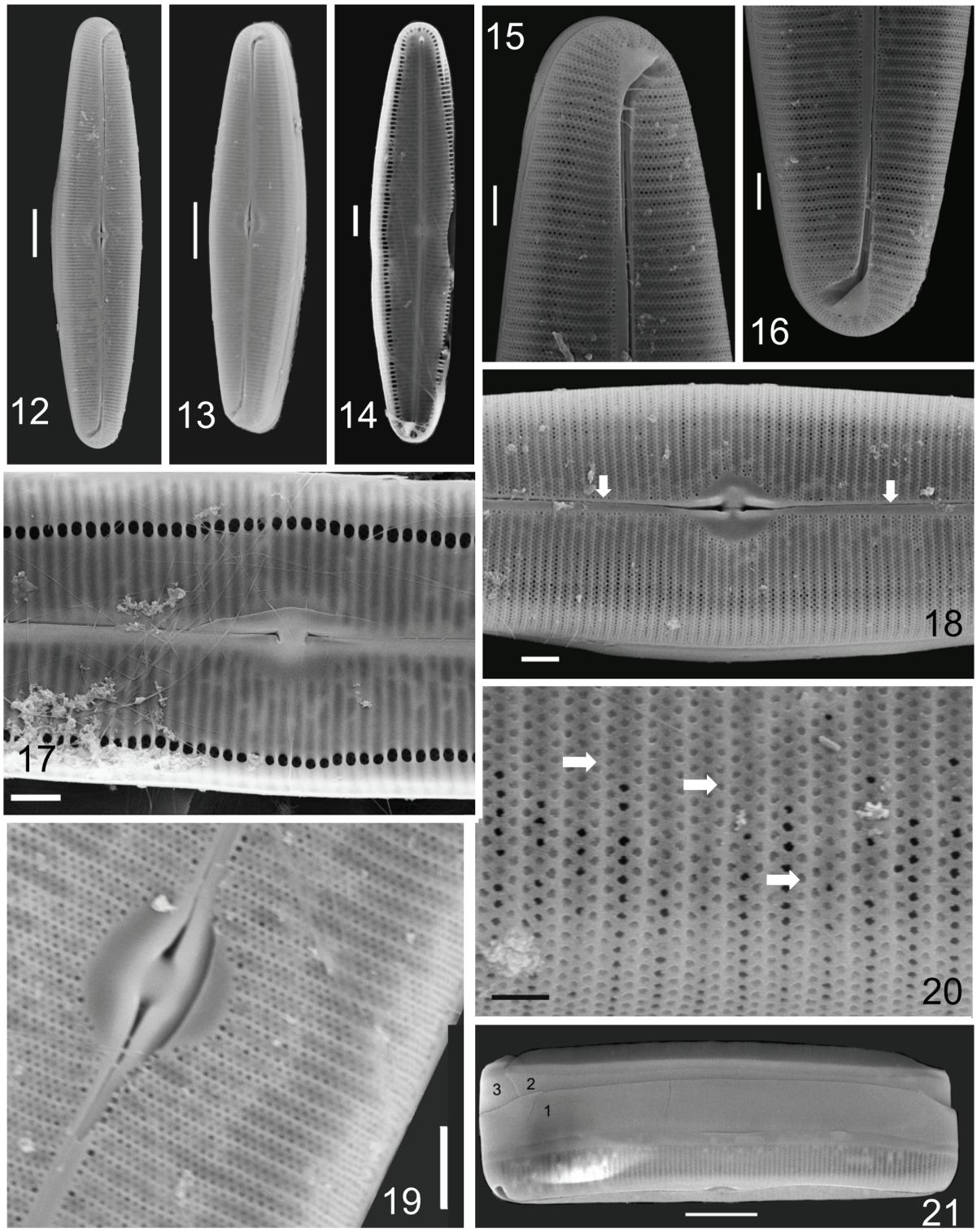
Holotype: Permanent slides and material containing specimens of *Caloneis virgaestriata* are deposited in the Herbarium Berolinense, Botanic Garden and Bo-



Figs 1–11. LM images of the new *Caloneis* and *Seminavis* species showing variation in valve outline and size. **(1–6)** *Caloneis virgaestriata*. **(2)** Distal raphe ends deflected in opposite directions (arrows). **(7–11)** *Seminavis undulata*. Scale bars 10 µm.

tanical Museum, Berlin, Germany, under accession number B 40 0046835. Fig. 2 represents the holotype. Phycobank registration: http://phycobank.org/105734.
Type locality: Muelle de Las Galletas, Tenerife Island, Spain (28º00'31.6" N, 16º39'36.4" W) epiphytic on *Cladophora prolifera*.
Ecology: *Caloneis virgaestriata* constituted 1.2% of the epiphytic diatom assemblage on *Cladophora prolifera*. The associated species were dominated by *Cocconeis* spp., which accounted for 70% of the entire assemblage. A small number of other species were encountered, including *Seminavis undulata sp. nov.* (1.5%), *Gephyra* sp. (2.2%), *Podocystis adriatica* (Kützing) Ralfs (1.7%), *Diploneis* sp. (1.4%) and *Navicula* spp. (1.9%). Due to strong wave action during high tide, only species with good adhering ability were found.
Etymology: The Latin epithet refers to the arrangement of striae that extend to partially cover the virgae on the external valve side.

Differential diagnosis: *Caloneis virgaestriata* appears similar in LM to *Caloneis minima* Hustedt (Hustedt 1955, p. 32, pl. 9, fig. 22) from Beaufort Harbor, North Carolina, USA, but can be easily differentiated by its more linear valve outline and bluntly rounded poles compared to the more elliptical valve shape and broadly rounded apices in *C. minima*. More significant is the fact that the striae of *C. minima* can easily be resolved in LM as they are 32 in 10 µm compared to 98–105 in 10 µm in *C. virgaestriata*. The distal raphe ends in *C. virgaestriata* are curved in opposite directions, while Hustedt's line drawing shows them as straight, and they unfortunately cannot be resolved in Simonsen's (1987, pl. 620, figs 4–6) images from the type slide. The proximal raphe ends of *C. virgaestriata* are noticeably further apart than those of *C. minima*. The habitats of the species differ: *C. virgaestriata* is epiphytic, while that of *C. minima* is epipelic in estuarine mud.



Figs 12–21. SEM images of *Caloneis virgaestriata*. **(12, 13)** Valve external views. **(14)** Valve internal view. **(15, 16)** Upper and lower poles of same valve showing distal raphe ends deflected in opposite directions; note the small area above deflected part of the raphe ends which are devoid of striae. **(17)** Mid-valve interior showing proximal raphe ends slightly curved to the same side and the silica flap covering half of the central area; note openings of alveoli near valve margins. **(18)** External mid-valve showing proximal raphe ends, slightly asymmetrical central area and parallel striae; note lateral displacement of raphe canal within axial area. **(19)** External central area showing proximal raphe ends, parallel transapical rows of small areolae, a clear crescent-shaped area confluent with the raphe sternum on left side, and a groove outside the raphe sternum on the right side. **(20)** External valve view showing partial extension of the areolae openings over the virgae (arrowheads). **(21)** Whole frustule in girdle view; the valvocopula (Band 1) is broad, apparently closed, and overlaps Band 2 along its entire perimeter; Band 3 is a reduced band that fills the open end of Band 2 at one end of the frustule. Scale bars 4 µm (12, 13, 14, 21), 1 µm (15–18), 0.5 µm (19), 0.4 µm (20).

***Seminavis undulata* Al-Handal, M. J. Sullivan *et* Tronholm *sp. nov.* (Figs 7–11, 22–29)**

Description

LM (Figs 7–11): Valves semi-lanceolate with obtusely rounded apices. Dorsal margin convex, ventral margin straight to weakly convex. Valve length 35–38 µm, width 6–9 µm. Axial area semi-lanceolate, gradually widening towards the indistinguishable central area. Two longitudinal lines run the length of the valve on both sides of the axial area. Raphe straight, filiform. Proximal raphe ends very close to each other, distal ends deflected dorsally. Striae parallel at mid-valve, weakly radiate towards poles, 30–36 in 10 µm.

SEM (Figs 22–29): Valve face gently curving into a shallow mantle (Figs 22, 26). Externally, raphe strongly lateral within axial area, running in a shallow raphe sternum (Fig. 22). The central area is widened slightly on the ventral part of the valve (Figs 22, 26, 28). Proximal raphe ends very small, close to each other, covered by an undulating silica flap (Figs 26, 28 white arrows). The silica flap cannot be seen in LM. Distal raphe ends strongly hooked to the dorsal side of the valve (Figs 22, 24). Striae uniseriate, weakly radiate throughout, slightly sunk into valve face, separated by narrow virgae (Figs 26, 28). Areolae with apically elongated openings (Fig. 28). Areolae density 55–62 in 10 µm.

Internally, axial area lanceolate with irregular margins due to extensions of the axial area covering small portions of the virgae (Fig. 27). Raphe strongly lateral within axial area towards valve apices, becoming central at mid-valve (Fig. 23). Proximal raphe ends simple, elongated, located on a flattened part of the raphe sternum (Figs 27 arrow, 29). Distal raphe ends ventrally bent, terminating in small helictoglossae (Fig. 25). A small chamber is present between the helictoglossae and valve apex (Fig. 25). Areolae openings slit-like, arranged in narrow foraminal rows, separated by prominent vimines (Fig. 27). The ventral striae are partially chambered due to a marginal thin layer of silica that runs the length of the valve (Figs 23, 25, 27).

Holotype: Permanent slides and material containing specimens of *Seminavis undulata* are deposited in Herbarium Berolinense, Botanic Garden and Botanic Museum, Berlin, Germany, under accession number B 40 0046834. Fig. 2 represents the holotype. Phycobank registration: http://phycobank.org/105735.

Type locality: Muelle de Las Galletas, Tenerife Island, Spain (28º00'31.6" N, 16º39'36.4" W). *Seminavis undulata* was epiphytic on *Cladophora prolifera*.

Ecology: Found on the same host and habitat as *Caloneis virgaestriata.*

Etymology: The Latin epithet refers to an undulated silica flap covering the proximal raphe ends.

Differential diagnosis: Due to its fine structure and valve outline, *Seminavis undulata* appears in LM morphologically very similar to *S. delicatula* Wachnicka *et* Gaiser (Wachnicka & Gaiser 2007, p. 442, figs 228–234) and *S. obtusiuscula* (Grunow) Danielidis *et* D. G. Mann (Danielidis & Mann, 2003, p. 32, figs 33, 34) but can be differentiated in SEM by its undulated silica flap covering the proximal raphe ends.

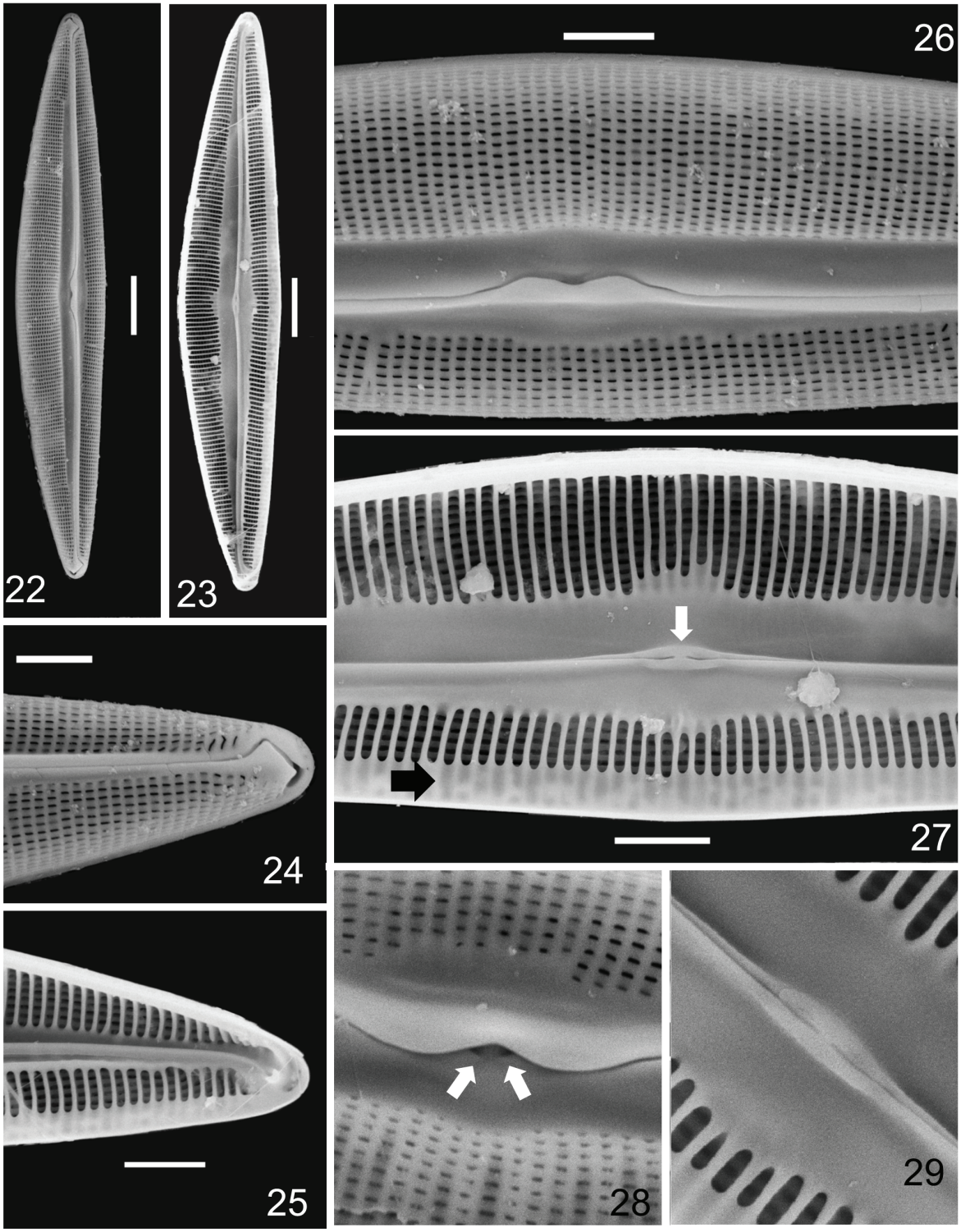
Discussion

The diminutive size of the new *Caloneis* species limits the number of comparable taxa available in the existing literature. Another species that resembles *C. virgaestriata* is *C. liber* var. *delicata* Meister (Meister 1935, p. 91, fig. 14), which was collected as an epiphyte on *Sargassum* in Honduras. Meister provided a very brief description but that taxon is close to Hustedt's *C. minima* in its valve dimensions and density of the striae (30 in 10 µm vs 32 in 10 µm) that are clearly visible in LM. Striae density is much greater in *C. virgaestriata* (98–105 in 10 µm) and is not resolvable in LM.

Park *et al.* (2018, p. 123, fig. 110) imaged a diatom collected as an epiphyte on *Padina* from Micronesia that they labeled as *Caloneis* sp. 3 which may be identical with *C. virgaestriata*. The valve shape is linear-lanceolate with obtusely rounded apices, the proximal raphe pores are very close to one another, the alveoli openings are submarginal, and the striae are not resolvable in LM in both forms. The authors did not provide any description of this taxon other than valve dimensions, which renders further comparisons moot.

The distal raphe ends, which are curved in opposite directions in *C. virgaestriata*, represent a character relatively unknown in *Caloneis* where in virtually all species they are curved in the same direction. The only exception we have been able to find is *C. hustedtii*, described by Aleem (in Aleem & Hustedt, 1951) from marine sediment in England. It seems, however, that this species has not been found or reported elsewhere since its original description. Its rhombic-lanceolate valves and striae density (30–34 in 10 µm) clearly distinguish it from C. *virgaestriata.* In the present work, we have placed our new species in the genus *Caloneis* despite the distal raphe ends being turned in opposite directions. It is worth noting that this feature is also absent in the possibly conspecific genus *Pinnularia*, as there appear to be no clear grounds for separating the two genera (Cox, 1988; Round *et al.*, 1990; Mann, 2001). In the absence of any other character of *C. virgaestriata* or *C. hustedtii* suggesting placement outside *Caloneis* we have taken a conservative approach and elected not to erect a new genus at the present time.

The striking feature seen in *C. virgaestriata* is the arrangement of the transapical striae, where some of the areolae rows are not confined to areas between virgae but partially expand to cover the virgae on the external side of the valve (Fig. 20, white arrows). In the observed specimens, it was not possible to observe if these areolae are open on the



Figs 22–29. SEM images of *Seminavis undulata.* **(22)** External view of valve. **(23)** Internal view of valve, note linear-lanceolate shape of the axial area. **(24)** External valve pole showing distal raphe end strongly deflected towards dorsal margin. **(25)** Internal valve pole showing distal raphe fissure deflected towards ventral margin and ending in a shallow helictoglossa. **(26)** External mid-valve showing the undulating silica flap covering the proximal raphe ends; note lineate nature of striae with transapically elongated areolae between the virgae. **(27)** Internal mid-valve showing slight dorsal displacement of proximal raphe ends within axial area (white arrow); note partial chambering of ventral striae (black arrow). **(28)** External view showing proximal raphe ends located beneath undulated silica flap (arrows); note their slight deflection in the same direction. **(29)** Internal proximal raphe ends close to one another and lying on flattened part of central nodule; partial chambering of ventral striae evident in bottom left-hand corner of figure. Scale bars 4 µm (22, 23), 2 µm (24–27), 0.5 µm (28, 29).

inside of the valve. A possible analogous feature has been reported in *Gomphotheca marciae* by Lobban & Prelosky (2022, fig. 12) where areolae adjacent to the massive costate fibulae may penetrate its base whereas the areolae adjacent to the virgae do not expand over the virgae. It is not yet fully understood why areolae expand to partially cover virgae or fibulae; however, studying cross-sectional fractures of valves might offer an insight into this unusual feature.

The characteristic feature of *Seminavis undulata* is its undulated silica flap which covers the external proximal raphe ends (Figs 26, 28). This structure seems to be rather unusual and is not present in any SEM image published for any species of *Seminavis*. A strong curvature of the proximal raphe ends, which have a superficial resemblance to the silica flap in *S. undulata*, is seen in *S. atlantica* Garcia (Garcia, 2007, fig. 9). However, the external proximal raphe ends of this taxon are merely ventrally deflected onto an extension of the central nodule. It should also be noted that Garcia's taxon has a completely different valve outline, lacks ventral striae opposite the central nodule, and has a much coarser striae density (11–14 in 10 µm).

LM images of *Seminavis cyrtorapha* presented by Wachnicka & Gaiser (2007, p. 444, figs 237–240) bear some similarity to *S. undulata*. The former species has less dense striae (25–27 in 10 µm) compared to 30–36 in 10 µm in our new species and a noticeably more semi-lanceolate valve shape. These authors did not provide SEM images documenting the valve ultrastructure of their new species, so it is not possible to determine whether an undulated silica flap is present in *S. cyrtorapha*.

The morphologically most similar species to *Seminavis undulata* are *S. delicatula* and *S. obtusiuscula*, as discussed in the differential diagnosis for our new species. Based on a composite analysis of the findings presented in Wachnicka & Gaiser (2007) and Danielidis & Mann (2003), the following taxa are conspecific: *S. delicatula*, a population identified as *Amphora obtusiuscula* Grunow sensu Sullivan (1990), and a population identified as *A. cymbelloides* Grunow sensu Montgomery & Miller (1978, pl. 13, figs A–H, pl. 14, figs A, B). In transferring Grunow's taxon to the genus *Seminavis*, Danielidis & Mann excluded the taxon identified as *A. obtusiuscula* by Sullivan, stating it was yet another species of *Seminavis*, and they also noted its resemblance to the original description of *A. cymbelloides*. Differences cited by Danielidis & Mann for their exclusion of Sullivan's population included a different valve shape (slightly tumid vs straight ventral margin), length to width ratio (7.2 vs 6.5), different deflections of the proximal raphe ends (both dorsal vs slightly in opposite directions), and a more central position of the raphe with respect to the valve outline in *S. obtusiuscula*. One of us (MJS) thoroughly reexamined slides containing material originally identified as *A. obtusiuscula* in Sullivan (1990) and found that the ventral margin is often slightly tumid, the proximal raphe ends were either not deflected or at least one branch was slightly dorsally deflected (however, in no case were they deflected in opposite directions), and the position of the raphe was highly variable ranging from nearly central to close to the ventral margin. The conspecific populations described and/or imaged by Wachnicka & Gaiser and Montgomery & Miller also include valves with a tumid ventral margin, a variable pattern of proximal raphe end deflection (not deflected, deflected dorsally, or turned in opposite directions), and a variable position of the raphe with respect to the valve outline. In addition, Wachnicka & Gaiser found valves with a width of 9 µm which is close to that of the valve drawn by Grunow in Schmidt's Atlas (Schmidt, 1875, pl. 25, fig. 7). Taken collectively, the populations studied by Sullivan, Montgomery & Miller, and Wachnicka & Gaiser show considerable morphological variability which included that of *S. obtusiuscula* except for its slightly larger size. Moreover, since *S. obtusiuscula* is known only from a single drawing by Grunow and there are no slides or unmounted material containing *A. obtusiuscula* in the Grunow Collection in Vienna, the variability in the morphology of this entity remains unknown. Based on these observations, we conclude that a reasonable hypothesis is that *S. obtusiuscula* and *S. delicatula* are conspecific with the caveat that a study of authenticated material of *A. obtusiuscula* in LM and SEM is needed to test this proposal adequately.

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