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Studies in selected fragilarioid diatoms of potential indicator value from Florida (USA) with notes on the genus *Opephora* PETIT (Bacillariophyceae)

Eduardo A. Morales*

Patrick Center for Environmental Research, The Academy of Natural Sciences of Philadelphia, Philadelphia, U.S.A.

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Abstract

Four araphid diatom taxa were collected from Florida streams and studied with both light microscopy (LM) and scanning electron microscopy (SEM). Three taxa, formerly in the genus *Fragilaria* LYNGBYE, are here placed in the genus *Pseudostaurosira* WILLIAMS et ROUND. On the basis of ultrastructure observed by SEM, the remaining taxon is placed in a new genus, *Sarcophagodes*. At least two of the species referred to *Pseudostaurosira* may have been confused with species of the genus *Opephora* PETIT, which may have led to misinterpretation of the ecological characteristics of the latter genus.
All the taxa treated here belong to the Family Fragilariaceae GREVILLE as delimited in current classification schemes. Two new combinations *Pseudostaurosiropsis geocollegarum* (= *Fragilaria geocollegarum* WITKOWSKI et LANGE-BERTALOT), *Pseudostaurosira neoelliptica* (= *Fragilaria neoelliptica* WITKOWSKI) and the new species *Pseudostaurosira clavatum* are presented herein. Additionally, a new genus, *Sarcophagodes*, is erected to accommodate the new species *S. delicatula*. LM and SEM details, as well as criteria delimiting these taxa are discussed. More collections and further analyses are needed to assess the distribution of both *Opephora* and *Sarcophagodes*.

Key words: Diatoms – SEM – Taxonomy – Southern Florida – NAWQA

Introduction

Small fragilarioid diatoms are an important component in the flora of brackish waters (METZELTIN & WITKOWSKI 1996; WITKOWSKI 1994; WITKOWSKI et al. 2000). Yet, these diatoms remain understudied despite efforts by regulatory agencies to protect brackish habitats (MORALES 2001; MORALES et al. 2001; SABBE & VYVERMAN 1995). Recent studies have begun to define boundaries of described species and, with that, to discover new taxa (e.g., ANDRÉN 1997; LE COHU 1988; METZELTIN & WITKOWSKI 1996; POULIN et al. 1984; RINCE 1990; SABBE & VYVERMAN 1995; WITKOWSKI 1994; WITKOWSKI & LANGE-BERTALOT 1993; WITKOWSKI et al. 1995, 2000; and others). A serious impediment in the study of small araphid diatoms is their size. Important diagnostic characters often are too small to be resolved by light microscopy, which has a negative effect on routine ecological analyses (MORALES et al. 2001). Without adequate resolution, taxa requiring SEM accumulate in

***Corresponding author:** Eduardo A. Morales, Ph.D., Research Scientist, Patrick Center for Environmental Research, The Academy of Natural Sciences of Philadelphia, 1900 Benjamin Franklin Parkway, Philadelphia, PA 19103-1195, U.S.A.; Phone: (215) 299-1102, Fax: (215) 299-1079, e-mail: morales@acnatsci.org

categories defined by LM. A likely example is the genus *Opephora* to which many clavate forms have been ascribed. Detailed SEM analyses are required to investigate the identity and affinities of taxa currently placed in *Opephora* to ensure accuracy of ecological interpretations.

To clarify the taxonomy of *Opephora*, ROUND et al. (1990) presented photomicrographs of *O. pacifica* (GRUNOW) PETIT, and diagnosed the genus as an expansion of PETIT's original description (PETIT 1888). Accepted by SABBE &VYVERMAN (1995), *Opephora* is a *bona fide* genus containing several species sharing a putative combination of features. If ROUND's interpretation is to be followed, however, several taxa described and illustrated in the literature as *Opephora* spp. must be transferred to other genera, existing or new. Studying material from wider geographical areas, of course, may mean further taxonomic changes.

The aim of the present paper is to provide additional information on the taxonomy of the genus *Opephora* and related taxa.

Materials and Methods

Study area

The samples analyzed were collected in 1997 as part of a cooperative agreement between the United States Geological Survey's National Water Quality Assessment Program (NAWQA) and The Academy of Natural Sciences of Philadelphia following methodology explained in PORTER et al. (1993). The samples corresponded to NAWQA's Southern Florida Basin Study Unit (SOFL). A total of 54 samples were analyzed using LM. Three samples were studied in detail under SEM, namely collections from: 1. Caloosahatchee River at Alva, Lee County (latitude: 26°42′48″, longitude: 81°36′38″), 2. Peace River at Arcadia, DeSoto County (latitude: 27°13′19″, longitude: 81°52′34″), and 3. Hillsboro Canal at S-6 (sugar cane plantation) near Shawano, Palm Beach County (latitude: 26°28′18″, longitude: 80°26′46″) (Fig. 1). An analysis of the geographical distribution of taxa in SOFL is in preparation. Details on geographical and land use aspects of these ecosystems can be found in the NAWQA website (http://water.usgs.gov/nawqa/). Briefly, the three sites are heavily impacted by urban and agricultural activities. Some details on the chemistry of sampling points are given in Table 1. The parameter salinity is not calculated by NAWQA, but from conductivity readings presented in Table 1 and the diatom flora present at the site (see later) it can be inferred that the Hillsboro Canal has a brackish influence.

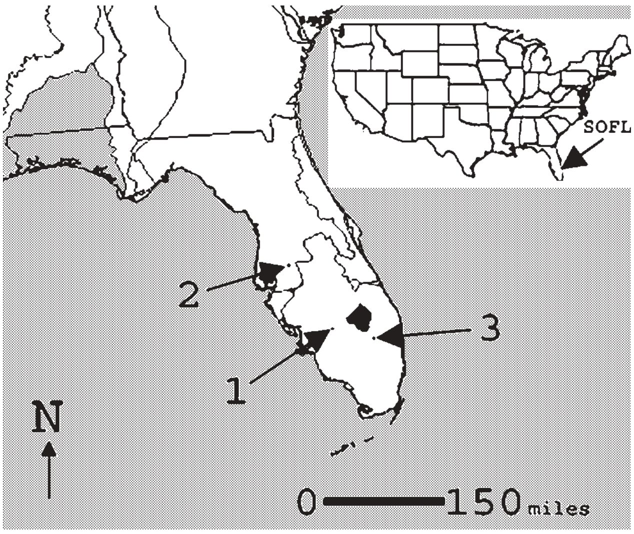

Fig. 1. Geographical location of the NAWQA Southern Florida Study Unit (SOFL) (inset) and the three sites where the samples analyzed under SEM were collected. **1.** Caloosahatchee River at Alva. **2.** Peace River at Arcadia. **3.** Hillsboro Canal at S-6 (sugar cane plantation) near Shawano.

LM and SEM studies

Permanent slides were prepared following ACKER & RUSSELL (1999a, 1999b). LM analyses were performed at a magnification of 1000X using a Zeiss Axioscope 2 microscope equipped with DIC and a Zeiss Optronics digital camera. Images were captured directly by a computer using the software program Zeiss Axiovision v. 3.0.5.

For SEM studies, a portion of acid clean material was allowed to dry at room temperature on 15 cm × 15 cm pieces of aluminum foil. Smaller pieces were then trimmed and mounted on aluminum stubs with double-sided tape. SEM samples were coated with a fine layer of gold-palladium using a Polaron sputter coater for 1 min at 1.8 kV prior to analysis. Analysis was conducted using a Leo/Zeiss DSM 982 Scanning Electron Microscope. SEM images were digitally captured on zip disks. LM and SEM plates were prepared using Adobe Photoshop v. 5.5. Morphological terminology follows ANONYMOUS (1975), BARBER & HAWORTH (1981), and ROSS et al. (1979).

Results and Discussion

SOFL samples were rich in araphid diatoms, represented mainly by species of *Fragilaria*, *Pseudostaurosira*, *Staurosira* EHRENBERG, *Staurosirella* WILLIAMS et ROUND, and *Synedra* EHRENBERG. No species were found that could be assigned to *Opephora sensu stricto*.

Of the three samples analyzed in detail under SEM, only the flora in the Hillsboro Canal sample had a strong brackish influence (Table 1). This flora was composed of species such as *Actinocyclus normanii* (GREGORY) HUSTEDT, *Hydrosera whampoensis* (SCHWARTZ) DEBY, *Pleurosira laevis* (EHRENBERG) COMPÉRE, and *Terpsinoë musica* EHRENBERG. Peace River at Arcadia was dominated by *Staurosirella berolinensis* (LEMMERMANN) EDLUND and *Pseudostaurosira brevistriata* (GRUNOW) WILLIAMS et ROUND. The Caloosahatchee River, in turn, was dominated by *Staurosirella leptostauron* var. *dubia* (GRUNOW) BUKHTIYAROVA and *Psammothidium marginulatum* (GRUNOW) BUKHTIYAROVA.

Abundance of these taxa ranged from 0.5 to 20 % of the total periphytic community. The taxa often coexist (although in varying proportions) in the same habitat, evidence of similarity in their ecological requirements (see later).

At least two taxa treated here can be confused with species in *Opephora* at the LM level. However, SEM details reveal the only common feature among the taxa is the clavate shape of the valves. Differences are conspicuous and involve a number of characters such as spine production, shape and number of the areolae, and characteristics of the closing plates (discussions for each taxon follow later).

The literature contains a number of species of *Opephora* for which both LM and SEM information are available. However, only a few species can be associated with *Opephora sensu stricto*; e.g., *O. pacifica* (ROUND et al. 1990; SULLIVAN 1979; WITKOWSKI et al. 2000) and *O. marina* (GREGORY) PETIT (ANDRÉN 1997; SNOEIJS & BALASHOVA 1998; WITKOWSKI et al. 2000). These species share characteristics that group them into a clearly definable genus. The most relevant characteristics of *Opephora* at the SEM level are the absence of spines and the presence of slit-like areolae. The latter structures lie oblique to the major axis of the valve and run from the valve face toward the valve mantle without interruption. The closing plates are extremely branched. Branches originating from the longest side of the areolar slit intertwine forming an intricate, often reticulate, pattern.

Many species that have been attributed to *Opephora*, but which do not fit the description above, should be transferred to preexisting or newly defined genera (Table 2). Taxonomic decisions about *Opephora* must be supported by combined LM and SEM analyses.

Systematics

• *Pseudostaurosiropsis geocollegarum* (WITKOWSKI et LANGE-BERTALOT) MORALES comb. nov.
(Plate 1, Figs. 1–9; Plate 2, Figs. 1–6)

Basyonym. *Fragilaria geocollegarum* WITKOWSKI et LANGE-BERTALOT in WITKOWSKI et al., 1995: Fragmenta Floristica et Geobotanica, p. 733, Figs. 16–25.

Table 1. Some chemical characteristics of the three sites studied in detail under SEM. Data have been retrieved from the NAWQA website (http://water.usgs.gov/nawqa/).

Site	pH	Conductivity µS/cm	Orthophosphate (PO_4) mg/l	Nitrogen (dissolved NO_2-NO_3) mg/l
Caloosahatchee River	7.5	458	0.105	0.323
Peace River at Arcadia	8.3	310	0.475	0.005
Hillsboro Canal at S-6 near Shawano	7.1	1120	0.039	0.300

Table 2. Some taxa currently included in *Opephora* that need to be transferred to other genera based on available SEM information. "Not available" in the second column denotes that a genus to accommodate these taxa is not available in the literature.

Taxon	Affinity with	Reference for SEM
O. burchardtiae WITKOWSKI, METZELTIN et LANGE-BERTALOT	*Pseudostaurosira*	MOSER et al. (1998)
O. guenter-grassi (WITKOWSKI et LANGE-BERTALOT) SABBE et VYVERMAN	*Staurosirella*	SABBE & VYVERMAN (1995)
O. horstiana WITKOWSKI	Not available	WITKOWSKI (1994)
O. krumbeinii WITKOWSKI, WITAK et STACHURA	Not available	LANGE-BERTALOT & GENKAL (1998), WITKOWSKI et al. (2000)
O. minuta (CLEVE-EULER) WITKOWSKI, LANGE-BERTALOT et METZELTIN	*Pseudostaurosira*	WITKOWSKI et al. (2000)
O. mutabilis (GRUNOW) SABBE et VYVERMAN	Not available	SABBE & VYVERMAN (1995)
O. naveana LE COHU	*Pseudostaurosira*	LE COHU (1988), SUNDBÄCK (1987)
O. olsenii MÖLLER	Not available	LANGE-BERTALOT & GENKAL (1998), SUNDBÄCK (1987), WITKOWSKI (1994)
O. parva KRASSKE	*Sarcophagodes* (?)[1]	WITKOWSKI (1994)

[1]The genus *Sarcophagodes* is described here as a new taxon.

MORALES (2001) suggested that *Fragilaria geocollegarum* was a possible member of *Pseudostaurosiropsis*, but required additional information. The taxon was present in NAWQA (Peace River and Hillsboro Canal), making more detailed analyses at the LM and SEM levels possible.

Morphological details of North American populations are very similar to those presented in WITKOWSKI et al. (1995). Valves are linear to elliptical with a slightly inflated central portion and forming filaments with the aid of spines (Plate 2, Fig. 6). Length: 5–16 µm, width: 2.3–3.5 µm, striae density: 14–16/10 µm (n = 30). The striae are commonly composed of two rows of areolae, one located on the valve face and the other on the valve mantle (Plate 2, Figs. 1 and 2). Sometimes two rows of areolae can be seen at the valve mantle (Plate 2, Fig. 3). A disc-like closing plate occludes each areola. The striae are interrupted at the valve edge by simple or bifurcated spines (Plate 2). Apical pore fields are absent or extremely reduced. Rimoportulae absent. Mantle plaques sometimes present at the mantle-valvocopulae junction. Cingulum composed of several open, plain, and ligulate copulae. Valvocopulae large and lacking areolae (Plate 2, Figs. 3–6). Plastids unknown.

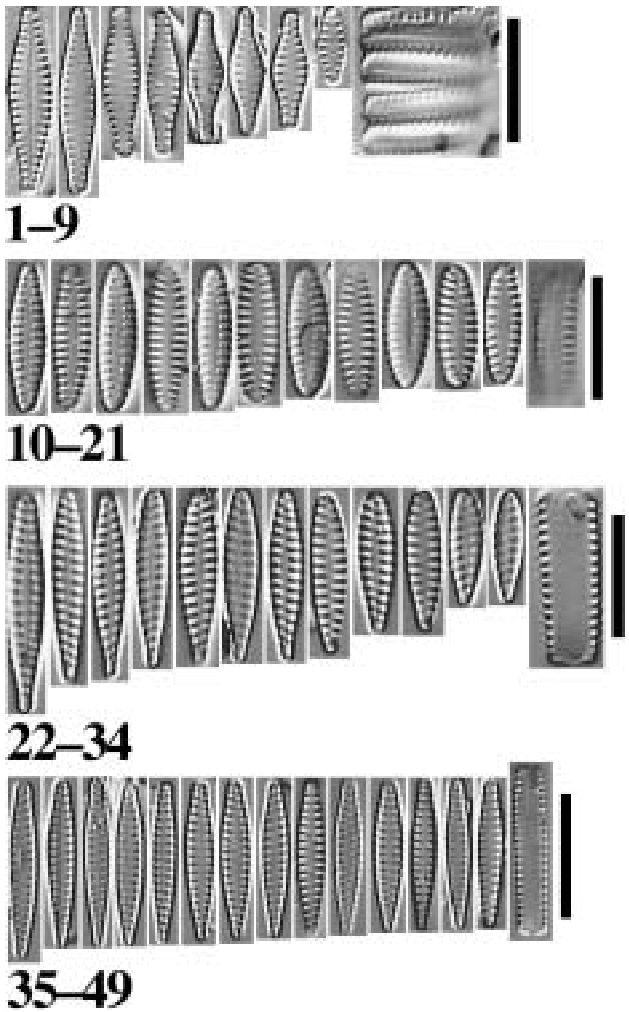

Plate 1. LM digital images of taxa treated in this work. **Figs. 1–9.** *Pseudostaurosiropsis geocollegarum* from the Hillsboro Canal, Palm Beach County. Fig. 9 depicts chain as seen in girdle view. **Figs. 10–21.** *Pseudostaurosira neoelliptica* from the Caloosahatchee River, Lee County. Fig. 21, girdle view of a single frustule. **Figs. 22–34.** *Pseudostaurosira clavatum* from the Caloosahatchee River, Lee County. Fig. 34 depicts frustule in girdle view. **Figs. 35–49.** *Sarcophagodes delicatula* from the Caloosahatchee River, Lee County. Fig. 49 shows a single frustule in girdle view. All scale bars: 10 µm.

P. geocollegarum is closely related to *P. connecticutensis*, a freshwater taxon (MORALES 2001). *P. geocollegarum*, however, seems to prefer more alkaline waters (pH 7.1–8.3), higher conductivity (458–1120 µS/cm), and more eutrophic conditions (early eutrophic to dystrophic). More studies are needed to infer the geographical distribution of the genus *Pseudostaurosiropsis*. In North America, two discrete populations have been found. The first one is described above and the other belongs to *P. connecticutensis* from lotic freshwater systems from Connecticut, USA. A third population has been observed in a sample from the NAWQA's Western Michigan Drainage Basins Study Unit, specifically from Willow Creek, Waushara County, Wisconsin, USA (latitude: 44°07′11″, longitude: 89°10′21″), but its identity remains unclear until detailed SEM studies are performed (MORALES, person. observ.).

- *Pseudostaurosira neoelliptica* (WITKOWSKI) MORALES comb. nov.
  (Plate 1, Figs. 10–21; Plate 3, Figs. 1–6)

Basyonym. *Fragilaria neoelliptica* WITKOWSKI 1994, Bibliotheca Diatomologica, Band 28, p. 128, Plate 10, Figs. 1–13.

Frustules rectangular in girdle view (Plate 1, Fig. 21), forming chains with the aid of spines. Valves broadly lanceolate to elliptical. Length: 10–14 µm, width: 3–4 µm, striae density: 12–15/10 µm (n = 30). Uniseriate striae composed of round areolae, which number varies from one to three in both valve face and mantle (Plate 3). Each areola contains finely branched closing plates similar to other *Pseudostaurosira* species (Plate 3, Figs. 4 and 6). Sternum, broadly lanceolate, but becoming narrower as the number of areolae on the valve mantle increases (Plate 3, Figs. 1, 2, and 5). Reduced apical pore fields present at both valve poles and composed of several rows of round poroids (Plate 3, Figs. 1, 2, and 4). Rimoportulae not observed. Spines spatulate, unbranched and interrupting the striae at the valve face-mantle junction (Plate 3). Mantle plaques present at the mantle-valvocopulae junction (Plate 3, Fig. 3). Cingulum up to 10 plain ligulate copulae. Valvocopulae large and lacking areolae. Plastids unknown.

This taxon resembles species in the genus *Pseudostaurosira* in almost all its features. The spines are interrupting the striae, the areolae are round with their closing plates branching in the same way as other species of this genus. Also, the apical pore fields resemble those found in *Pseudostaurosira*.

P. neoelliptica is different from *Pseudostaurosira trainorii* MORALES, a diatom that produces mainly round valves (MORALES 2001). Elliptical valves were never observed in populations of *P. trainorii*. Conversely, round forms were not observed in samples containing *P. neoelliptica*. An additional feature that separates both species is the absence of serrate spines in *P. neoelliptica*. Serrate spines in *P. trainorii* are a constant feature.

P. neoelliptica can be distinguished from *Fragilaria sapotensis* WITKOWSKI et LANGE-BERTALOT (WITKOWSKI

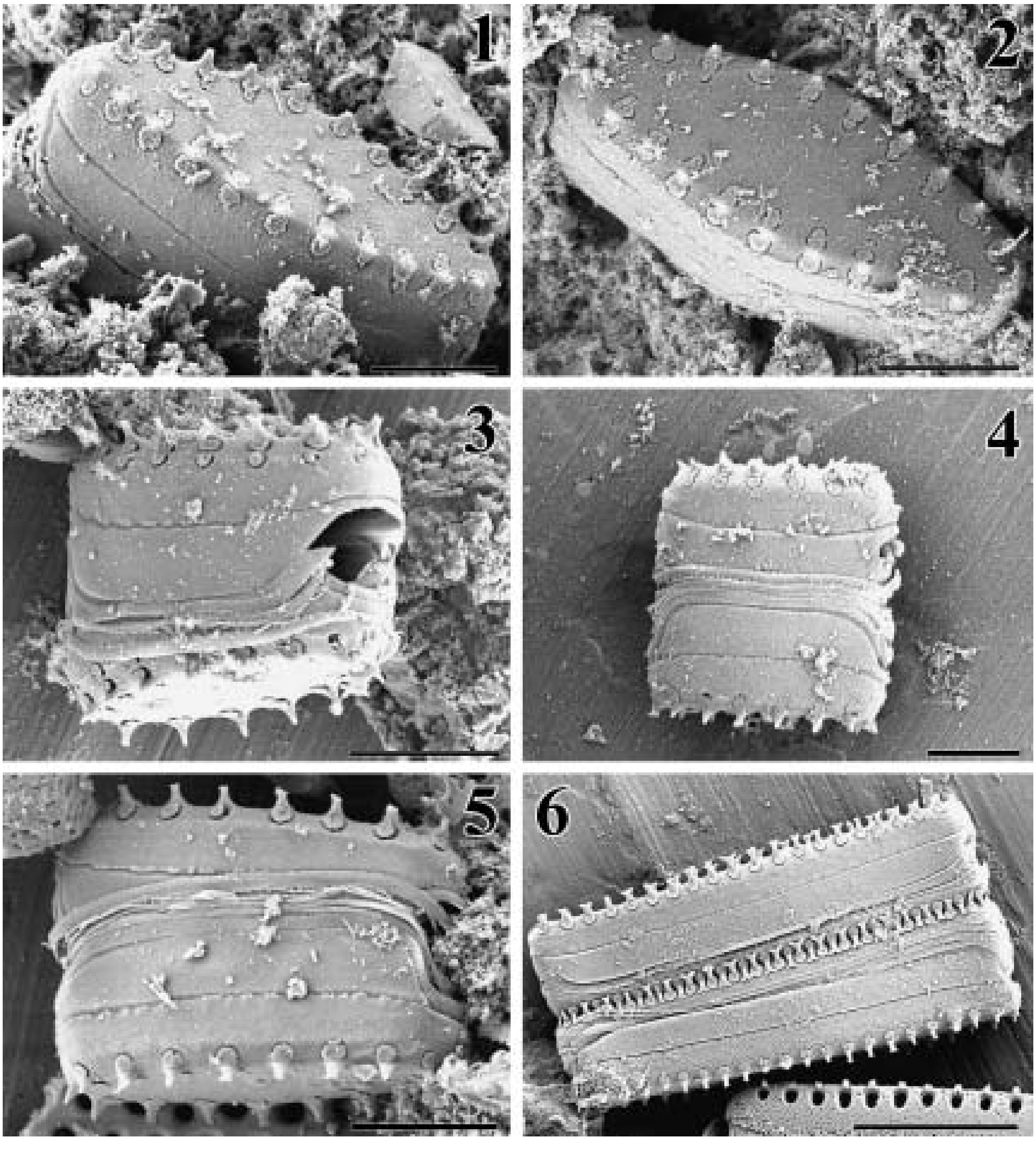

Plate 2. *Pseudostaurosiropsis geocollegarum*, SEM images. **Fig. 1**. Side view showing detail of sternum, striae, and location of spines. **Fig. 2.** Valve view showing detail of valve face and closing plates. **Figs. 3, 4,** and **5.** Side view showing detail of girdle bands, spines, and row(s) of areolae on valve mantle. **Fig. 6.** Detail of chain formation, spine structure, and girdle characteristics. 1–5, Peace River, DeSoto County; 6, Caloosahatchee River, Lee County. Scale bars: 1–5 = 2 µm; 6 = 5 µm.

& LANGE-BERTALOT 1993). *F. sapotensis* has broadly lanceolate valves, which are smaller than those of *P. neoelliptica*. The sternum is linear or narrowly lanceolate, and the density of the striae is higher in *F. sapotensis*. At the SEM level, the areolae present on the valve face are much more numerous and smaller in *F. sapotensis*. The latter taxon shows strong affinities with species in the genus *Pseudostaurosira*, thus, its transfer should be considered.

P. neoelliptica was originally described by WITKOWSKI (1994) as an attempt to solve a taxonomical problem caused by the loss of the type specimen of *Fragilaria elliptica* SCHUMANN [= *Staurosira elliptica* (SCHUMANN) WILLIAMS et ROUND]. As presented by MORALES (2001), the literature contains many records of *F. elliptica*. However, illustrations are not always compatible with each other. The same author illustrated morphs which characteristics matched the original description by SCHUMANN (1867).

WITKOWSKI (1994) suggested that *F. elliptica* could be made a synonym of *F. neoelliptica*, but I disagree. First, there are differences in the habitats collected by SCHUMANN (freshwater) and WITKOWSKI (marine/brackish). Further, there are morphological differences between specimens collected from both habitats. For example, specimens presented in MORALES (2001) have striae composed of round poroids, that are much smaller in diameter and more numerous in both valve face and mantle. Closing plates are much more robust in *F. neoelliptica*, and the apical pore fields are much more developed. The most conspicuous difference, however, is the position of the spines, which in freshwater specimens lie on the costae (not interrupting the striae). Hence, the marine/brackish water population seems to merit recognition as a separate entity. It is herein transferred to the genus *Pseudostaurosira* based on reasons stated above.

WITKOWSKI, METZELTIN, and LANGE-BERTALOT's decision [in METZELTIN & WITKOWSKI (1996)] to place *F. neoelliptica* in the genus *Opephora* (as *O. neoelliptica* WITKOWSKI, METZELTIN et LANGE-BERTALOT) must be rejected. Great differences exist between these taxa at the morphological level. The presence of spines in *F. neoelliptica* and the features of its areolae and apical pore fields support transfer. Moreover, the combination *O. elliptica* WITKOWSKI, METZELTIN et LANGE-BERTALOT is invalid. Full reference to the basyonym was not presented by METZELTIN & WITKOWSKI (1996).

WITKOWSKI et al. (2000) refer to *O. neoelliptica* as a synonym of *Pseudostaurosira perminuta* (GRUNOW) SABBE et VYVERMAN. I find differences between these two taxa. First, *P. perminuta* has a distinctly clavate shape and produces elliptical morphs only rarely (SABBE & VYVERMAN 1995). Conversely, clavate forms were not observed in *O. neoelliptica* by WITKOWSKI (confirmed by my own observations on North American populations). Valves are longer, and striae density higher in *P. perminuta*. Conspicuous differences occur at the SEM level, the most outstanding being the type of closing plate. In *P. perminuta* a volate closing plate is attached to the wall of the areola (which brings it closer to *Fragilaria sensu stricto*?), whereas in *O. neoelliptica*, the areolae possess branched closing plates. Therefore, *O. neoelliptica* (herein transferred to *Pseudostaurosira*) should not be considered as a synonym of *P. perminuta*.

P. neoelliptica was more abundant in the Caloosahatchee River at Alva. This site has a slightly alkaline pH (7.5), a conductivity of 458 µS/cm, and its trophic state is eutrophic.

• *Pseudostaurosira clavatum* MORALES sp. nov.
(Plate 1, Figs. 22–34; Plate 4, Figs. 1–6)

Holotype. G.C.103590a, Diatom Herbarium Academy of Natural Sciences of Philadelphia.
Type locality. Caloosahatchee River at Alva, Florida, USA, latitude: 26°42′48″, longitude: 81°36′38″
Diagnosis. Frustula aspectu cingulari rectangulares cateniformes spinis marginalibus. Valvae clavatae polis capitulis rostratis in exemplis grandiores. Longitudo: 8–20 µm. Latitudo: 2.5–3.5 µm. Striae density: 11–12 in 10 µm (n = 50). Striae areolae singularibus vel ovoideis. Areola una in facie valvae areola secunda (interdum tertius) in aspectu cingulari omnis lamellis claudentis ramificans. Sternum anguste lanceolatum. Areae porellarum ad apices poris rotundis. Rimoportulae nullae. Spinae spathulatae non rami duo spinulis ad infimum in margine valvae inter areolae pro maxime parte. Cingulum usque ad decem copulas apertae vel simplicibus vel ligulatis. Valvocopulae magnae non areolatae. Plasti incogniti.

Frustules rectangular in girdle view, forming chains by means of spines (Plate 4, Fig. 6). Valves clavate with rostrate head pole in larger specimens. Length: 8–20 µm, width: 2.5–3.5 µm, striae density: 11–12 per 10 µm (n = 50). Striae uniseriate composed of two round to ovoid areolae, one located on the valve face and the other on the valve mantle (Plate 4, Figs. 1, 2, 4, and 5). Rarely, two rows of areolae present on the valve mantle. Each areolae bares profusely branched closing plates (Plate 4, Figs. 1, 4, and 5). Sternum narrowly lanceolate (Plate 4, Fig. 1). Apical pore fields well developed at both valve poles and composed of several rows of round poroids (Plate 4, Figs. 1, 4, and 5). Usually mineral depositions cloud these poroids and make them appear as parallel lines, especially at the foot pole of the valve (Plate 4, Fig. 4). Rimoportulae absent (Plate 4, Fig. 2). Spines spatulate, unbranched, and with two spinules at the base (Plate 4, Fig. 6). Spines located interrupting the striae. Mantle plaques present at the mantle-valvocopulae junction (Plate 4, Fig. 3). Cingulum up to ten open, plain, ligulate copulae (Plate 4, Figs. 3, 5, and 6). Valvocopulae large and non-areolate. Plastids unknown.

Etymology. The specific epithet refers to the characteristic clavate shape of the valves.

Comments. This taxon may have been confused with taxa in the genus *Opephora* (e.g., *O. olsenii* and *O. pacifica*). However, *P. clavatum* differs from species in *Opephora* in several aspects. *P. clavatum* has spines interrupting the striae, a characteristic of several species in the genus *Pseudostaurosira* (Morales 2001; Round et al. 1990; Williams & Round 1987, 1988). Moreover, the type of areolae in *P. clavatum* differs from that in *Opephora sensu stricto* in their shape. In *P. clavatum*, areolae vary from round to ovoid in shape, and the closing plates branch in patterns that closely resemble those in species of *Pseudostaurosira*. Closing plate branches meet at the center of the areolae.

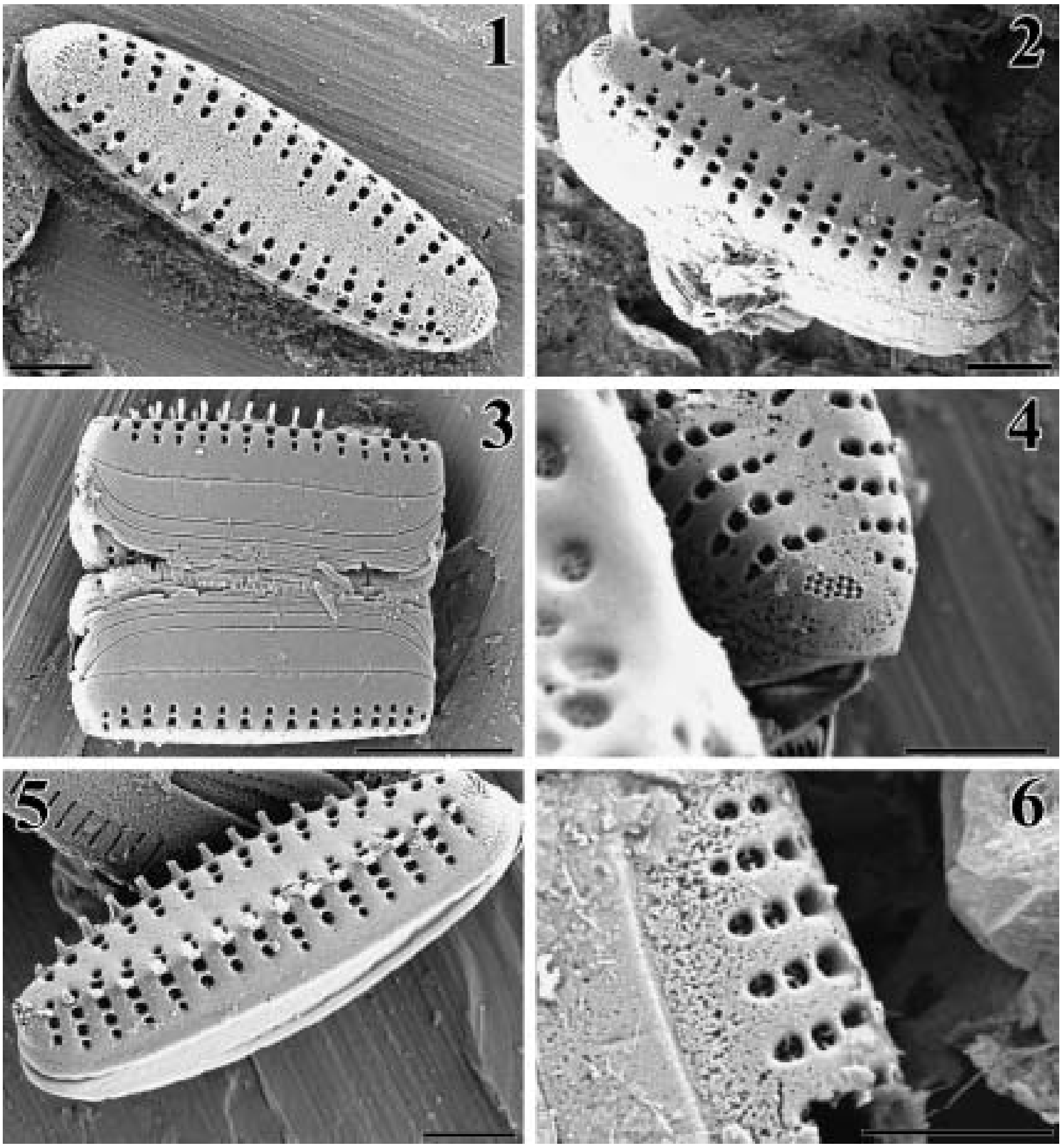

Plate 3. *Pseudostaurosira neoelliptica*, SEM details of population found in the Caloosahatchee River, Lee County. **Fig. 1.** Valve view with detail of sternum, apical pore fields, striae, and spine location. **Figs. 2** and **3.** Side views showing detail of spines, girdle bands, and rows of areolae on valve mantle. **Fig. 4.** Details of apical pore fields, areolae and closing plates. **Figs. 5** and **6.** Side views with additional details of areolae and their closing plates, as well as spines. Scale bars: 1, 2 and 4–6 = 2 µm; 3 = 5 µm.

An additional feature that distinguishes *P. clavatum* from *Opephora sensu stricto* is the presence of a single row of areolae on the valve mantle. The characteristics of these are the same as those of areolae positioned on the valve face. In *Opephora*, each areolae is a single slit that extends from the valve face onto the valve mantle without interruption. Those species currently included in *Opephora* – such as *O. olsenii* – that have striae composed of several wide and elongated areolae merit revision and probably should be accommodated in a category of their own (SUNDBÄCK 1987; MORALES, person. observ.) (Table 2). The specimens presented by SUNDBÄCK (1987) also possess spines, an additional character that warrants their separation from *Opephora* (see ROUND et al. 1990).

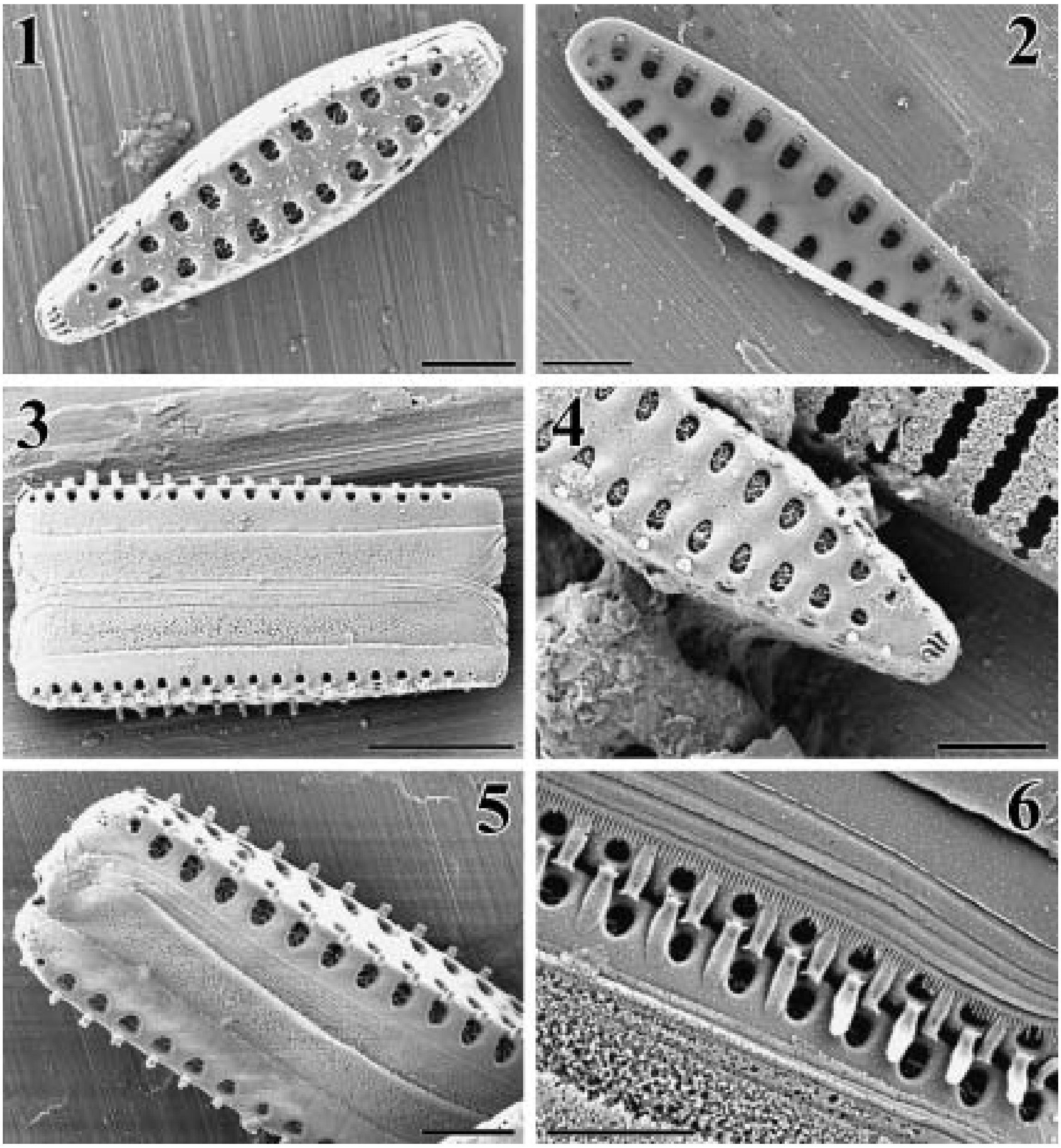

Plate 4. *Pseudostaurosira clavatum*, ultrastructure of population from the Caloosahatchee River, Lee County. **Fig. 1.** Valve view with details of valve face and associated structures. **Fig. 2.** Internal view of a single valve confirming absence of rimoportulae. **Fig. 3.** Detail of frustule in girdle view. **Fig. 4.** Detail of areolae and closing plates, position of spines and apical pore fields. **Fig. 5.** Girdle view of frustule depicting details of closing plates in the areolae at the valve mantle. **Fig. 6.** Detail of attachment of neighboring cells. Notice the presence of spinules at the base of each spine. Scale bars: 1, 2 and 3–6 = 2 µm; 5 = 5 µm.

Opephora minuta (CLEVE-EULER) WITKOWSKI, LANGE-BERTALOT et METZELTIN is closely related to *P. clavatum* (WITKOWSKI et al. 2000). However, the sternum is much wider and the areolae and associated structures are much smaller in the former. Since, *O. minuta* also presents spines interrupting the striae, its transfer to *Pseudostaurosira* is recommended.

Another species that closely resembles *P. clavatum* is *Opephora burchardtiae* WITKOWSKI, METZELTIN et LANGE-BERTALOT (in MOSER et al. 1998). Nevertheless, the central sternum is linear and the areolae are much wider in the latter taxon. The striae density is much higher, and closing plates are much more branched and robust in *O. burchardtiae*. Since the latter taxon bears

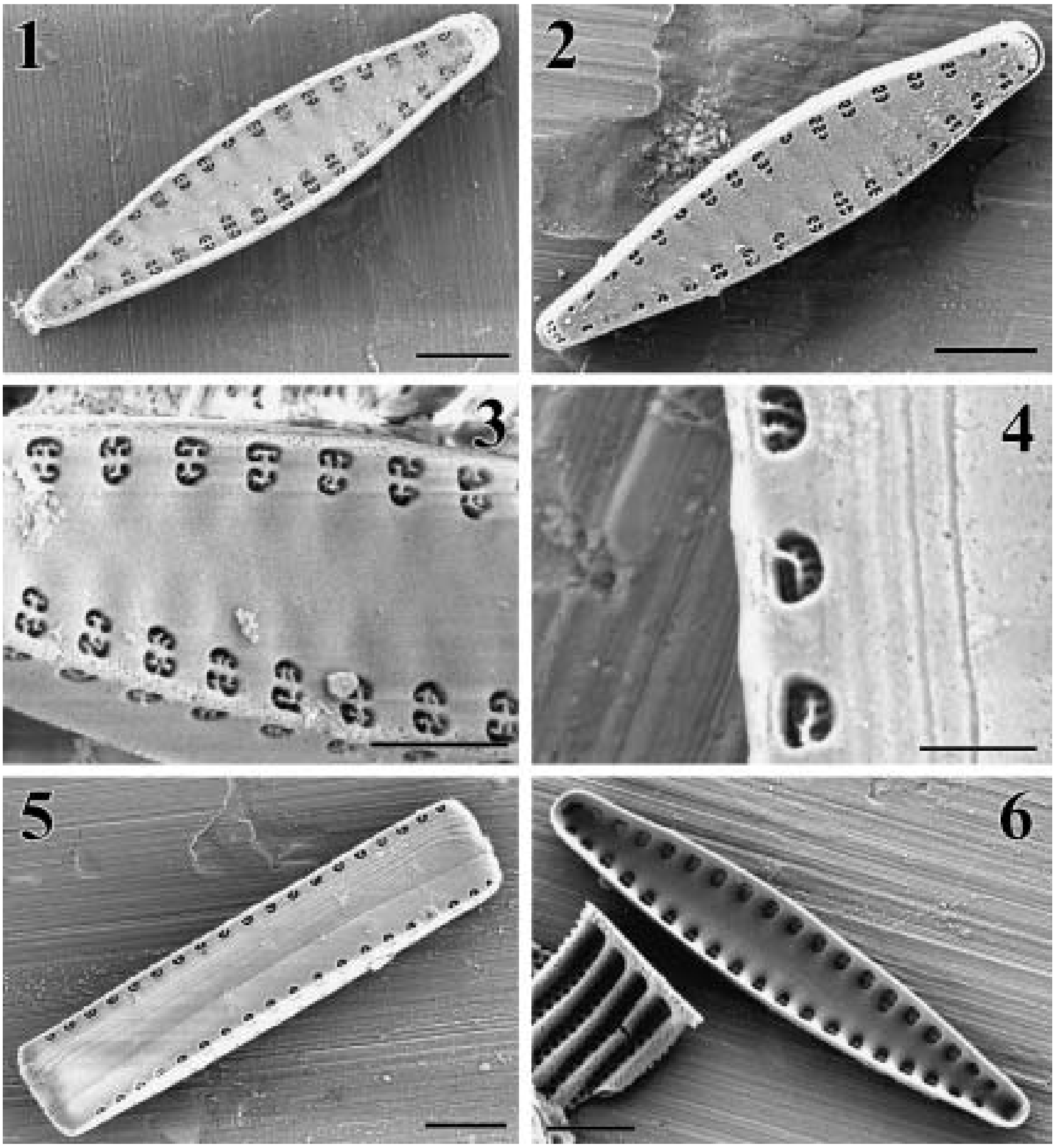

Plate 5. *Sarcophagodes delicatula*, SEM detail of population from the Caloosahatchee River, Lee County. **Figs. 1** and **2.** Valve views showing detail of valve face and its characteristics. **Figs. 3** and **4.** Detail of areolae and closing plates. **Fig. 5.** Girdle view of frustule showing characteristics of valve mantle and cingulum. **Fig. 6.** Inner surface of the valve confirming absence of rimoportulae. Scale bars: 1, 2, 5 and 6 = 2 µm; 3 = 1 µm; 4 = 0.5 µm.

spines interrupting the striae, it should be removed from *Opephora* and placed in *Pseudostaurosira*.

P. clavatum can be further characterized at the SEM level by the presence of two spinules at the base of the spines, a feature that is not present in other species of *Pseudostaurosira*. These ligulate spines are spatulate and slender and do not interlock with the spines of contiguous valves. Instead, the spines of a frustule are loosely adnate to the costae of its neighboring cells.

It could be argued that the heteropolarity of *P. clavatum* does not allow its placement in *Pseudostaurosira*. However, heteropolarity is not a stable character in many fragilarioid taxa (KRAMMER & LANGE-BERTALOT 1991; MORALES, person. observ.). Insofar, the current protologue of *Pseudostaurosira* does not preclude the placement of *P. clavatum* in this genus. Further studies of heteropolarity must be performed to determine the extent of the importance of this character in those taxa that present both isopolar and heteropolar forms e.g., *Staurosira construens* EHRENBERG and *Staurosirella pinnata* (EHRENBERG) WILLIAMS et ROUND.

P. clavatum was more abundant in the Caloosahatchee River sample, which exhibited slightly alkaline pH, medium conductivity, and eutrophic conditions (see values given for *P. neoelliptica*).

• Genus *Sarcophagodes* MORALES gen. nov.

Type species. *Sarcophagodes delicatula* MORALES sp. nov. (Plate 1, Figs. 35–49; Plate 5, Figs. 1–6)
Holotype. G.C.103590a, Diatom Herbarium Academy of Natural Sciences of Philadelphia.
Type locality. Caloosahatchee River at Alva, Florida, USA, latitude: 26°42′48″, longitude: 81°36′38″
Diagnosis. Frustula solitariae aspectu cingulari rectangulares. Valvae clavatae polis capitulis rostratis. Longitudo: 13–16 µm. Latitudo: 2–3 µm. Striae: 14–16 in 10 µm (n = 50). Striae areolis reniformibus in aspectu frontali 1 ad 3 in aspectu cingulari 1. Lamellae clausae ramificans ex transtro. Ramificatio dichotoma in aspectu cingulari detecta non nisa. Margo valvae areolis lamellatis clausae ramo principali et ramis secondaris affixis. Sternum late lanceolatum. Area porellarum ad apices poris rotundis seriatim 3 ad 4. Rimoportulae nullae. Spinae rudimentalia in margine valvae interstrias. Calli silicei nullae. Cingulum copulae (usque ad 4) reconditis simplicibus ligulatis. Valvocopulae magnae non areolatae. Plasti incognity.

Frustules solitary, rectangular in girdle view (Plate 1, Fig. 49). Valves clavate with slightly rostrate head pole. Length: 13–16 µm, width: 2–3 µm, striae density: 14–16 per 10 µm (n = 50). Striae composed of reniform areolae, whose number on the valve face varies from one to three (Plate 5). Only one row of areolae can be seen on the valve mantle (Plate 5, Figs. 1–3). Closing plates profusely branched and originating from a common crossing bar in neighboring areolae (Plate 5, Fig. 3). Dichotomous branching of closing plates detected only on valve face. Areolae located on valve mantle bear closing plates that have a main branch and several ramifications originating from it (Plate 5, Fig. 4). Sternum broadly lanceolate (Plate 5, Figs. 1 and 2). Apical pore fields developed at both valve poles and composed of three to four rows of round poroids (Plate 5, Figs. 1 and 2). Rimoportulae not present (Plate 5, Fig. 6). Rudimentary spines present at the valve edge and interrupting the striae (Plate 5, Fig. 4). Mantle plaques absent. Cingulum up to 4 closed, plain, ligulate copulae. Valvocopulae large and non-areolate (Plate 5, Figs. 4 and 5). Plastids unknown.
Etymology. The specific epithet refers to the delicate aspect of the valves of this species.
Comments. This species is rather common in samples from the type locality, where it co-occurs with *Pseudostaurosira clavatum*. At the LM level, both species can be distinguished on the bases of valve dimensions and striae density. Striae are more robust and more refractive in *P. clavatum*. An additional feature that can be used to distinguish the two taxa is the depth of the frustule (deeper in *P. clavatum*) and the presence of spines in *P. clavatum*, which can be seen in girdle view.

The species *Opephora parva* KRASSKE could belong in *Sarcophagodes*. LM and SEM illustrations of this taxon were presented by WITKOWSKI (1994). The species is different from *Sarcophagodes delicatula* in that is has a clavate shape with broadly rounded head pole, has spines and more than one row of areolae on the valve mantle. WITKOWSKI (1994) makes reference to an entity similar to *O. parva* at the LM level (referred to as *Opephora* aff. *marina*) from brackish/marine habitats in the Gulf of Gdańsk. Possibly this entity is either *Sarcophagodes delicatula* or a third taxon that needs description and placement in *Sarcophagodes*.

The genera *Sarcophagodes* and *Opephora* are different. The most conspicuous difference is the nature of the striae, which are composed of one to three distinct areolae in *Sarcophagodes*. The pattern in the arrangement of the closing plates is also different in the two genera. In *Opephora*, several profusely branched closing plates originate from the longest sides of the areolar slits and directly opposite to each other (ROUND et al. 1990). In *Sarcophagodes*, one or more closing plates originate contiguously and branch profusely toward the interior of the valve. When two areolae form a stria at the valve face, the closing plates originate from the crossing bar dividing the neighboring areolae. This pattern is not fixed, however, and often varies in other paired areolae on the same valve and when a third areolae develops within a stria.

A further difference between the genera cited above is the presence of rudimentary spines in *Sarcophagodes*. *Opephora* lacks spines.

S. delicatula also has a preference for slightly alkaline conditions, medium conductivities and eutrophic conditions (see values given for *P. neoelliptica*).

Conclusion

As stated in MORALES (2001), many of the taxonomic decisions currently made in the literature are based exclusively on the morphological species concept. It is possible that current classification schemes are affected by progress in other biological fields (e.g., biochemistry, molecular systematics, and others). Nonetheless, there is an immediate need to document and illustrate morphologically distinct populations to facilitate biogeographical and ecological assessments. The present work represents an effort to alleviate such a need.

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