Observations on the type material of *Fragilaria construens* [var. *binodis*] f. *borealis* Foged (*Fragilariaceae, Bacillariophyta*)

Bart Van de Vijver, *Meise Botanic Garden, Research Department, Nieuwelaan 38, 1860 Meise, Belgium & University of Antwerp, Department of Biology – ECOSPHERE, Universiteitsplein 1, B-2610 Wilrijk, Belgium* (correspondence: bart.vandevijver@plantentuinmeise.be)

The taxonomy of a group of species around *Pseudostaurosira pseudoconstruens* (Marciniak) D.M.Williams & Round (1988: 278) is unclear, particularly due to the absence of a thorough analysis of the original material of the species of this group. Currently, the following European *Pseudostaurosira* taxa can be included within this group: *P. pseudoconstruens*, *P. robusta* (Fusey) D.M.Williams & Round (1988: 278) and *P. borealis* (Foged) M.L.García & al. (2017: 112). Apart from these (transferred) taxa, several other taxa should be included but their taxonomic position is uncertain. Marciniak (1982) for instance described two varieties under *Fragilaria pseudoconstruens*: var. *bigibba* Marciniak (1982: 164) and var. *rhombica* Marciniak (1982: 164). The former is now considered to be a younger, heterotypic, synonym for *P. robusta*, whereas the latter was recombined as *Pseudostaurosira marciniakiae* Ector & al. (in Morales & al. 2019: 276, as '*marciniakae*'). The group shares a set of features that separates them from other *Pseudostaurosira* taxa. It comprises small-celled fragilarioid taxa with an inflated or cruciform outline bearing the following morphological features: a usually flat valve face, small apical pore fields on both apices, a lack of rimoportulae, striae composed of 2–3 square to rounded areolae, internally occluded by small volae, well-developed marginal, spatulate linking spines located on the virgae and, open, plain girdle bands (Williams & Round 1988, Morales & al. 2019).

Apart from *Pseudostaurosira robusta,* the morphology of which was recently studied [Van de Vijver & Kusber 2022, although these authors created an illegitimate name for this taxon, *Pseudostaurosira undulata* Van de Vijver & Kusber, as it included *Pseudostaurosira robusta* as a synonym], the original material for the other taxa has never been properly investigated and all information of these taxa is based on a single LM illustration (see Foged 1974, plate III: fig. 6) or SEM photograph (see Marciniak 1982, pl. 1: figs 1–6) and a short description. Given the morphological variability of these small-celled fragilarioid species and the high similarity between them, separating the different taxa is quite difficult and blurred by an incomplete iconography (Van de Vijver, pers. obs.). Analysis of the type material of *Fragilaria construens* [var. *binodis*] f. *borealis* Foged (1974: 56), the basionym for *P. borealis*, revealed a high morphological diversity and underlined the confusion in identifying the observed valves. A thorough revision of this group will be necessary to clear this situation. The original material Barbara Marciniak used for the description of her species, has been located but still needs to be studied in detail (Carlos E. Wetzel, pers. comm.).

With the present contribution the morphology is examined for one of the species in this group, *P. borealis*, with a description and illustration of the diversity in valve outline observed in the type material, aiming to offer important information on its morphological variability.

Pseudostaurosira borealis was originally described as "*Fragilaria construens* var. *binodis* f. *borealis*" from a sample Niels Foged (1906–1988) collected on 15.VII.1954 from stones covered with moss and green algae in the outflow from a small lake near Thingvellir on the road between Reykjavik and Thingvalla, north of Mosfellsheidi (Iceland) (sample 29/1954, holotype originally deposited in coll. N. Foged in Odense and now conserved in **C**, the herbarium of the Natural History Museum of Denmark in Copenhagen). Foged illustrated his new taxon with only an LM photograph and added the following description: "*Marginibus leviter concavis et striis crasse*

punctatis a Fragilaria construens *var.* binodis *differet* [differs from *Fragilaria construens* var. *binodis* by only slightly concave margins and distinctly punctate striae]". For its valve dimensions Foged noted: length 16 µm, width 5 µm, 14 striae in 10 µm, most likely indicating he did only study one (or a very low number) of specimens.

In 2004, the taxon was observed in material from the Faeroe Islands and based on the observations in that study, it was subsequently transferred to the genus *Staurosira* and raised to species level as *Staurosira borealis* (Foged) Witkowski & al. (in Witon & al. 2004: 127). Recently, García & al. transferred it to the genus *Pseudostaurosira*, solely based on the analysis of "*sufficient published information*" but without having seen the original material (García & al. 2017, p. 112).

The species is very rarely observed and seems to be restricted to northern Europe and Greenland as only records from Iceland, Sweden, Greenland, and the Faeroe Islands could be found (Foged 1974, Witon & al. 2004, and unpublished observations).

Witon & al (2004: 129) very briefly discussed the difference between *P. borealis* (as *Staurosira borealis*) and *P. pseudoconstruens* [as *S. pseudoconstruens* (Marciniak) Lange-Bertalot (in Krammer & Lange-Bertalot 2000: 587)], based on their own observations from the Faeroe Islands. Their illustrated valves of *P. pseudoconstruens* show a large morphological intravariability, almost larger than the differences with *P. borealis*. Moreover, they did not show any external views and presented only 2 LM pictures of *P. borealis* valves having an identical size.

The original material Foged used to describe his taxon was retrieved from **C** during a short Synthesys+ visit to Copenhagen in February 2023. During the analysis of the type population of *P. borealis*, a large morphological variability was observed, mainly with regard to valve outline (Figs 1–61). As currently we have no idea about the exact morphological idea of the species described by Barbara Marciniak in 1982, it is virtually impossible to decide how many taxa are actually present in the sample. The following description is based on careful analysis of the observed valves separating those populations that do not present a morphological continuum based on valve outline, shape of the apices and dimensions. Whether some of the latter belong to *P. borealis*, *P. pseudoconstruens* or a different, probably undescribed species, cannot at present be determined. It is not even possible to eliminate the possibility that *P. borealis* and *P. pseudoconstruens* are conspecific. A preliminary analysis of the original Marciniak material of *P. pseudoconstruens* resulted in the observation, by means of SEM, of several valves that could be identified as *P. borealis* (Carlos E. Wetzel, unpubl. res.). By documenting and discussing the morphological variability of the observed *Pseudostaurosira* valves in the Foged material, in relation to the presumed type population of *P. borealis*, the morphological knowledge of this species will greatly increase.

Pseudostaurosira borealis (Foged) M.L.García & al., 2017 (Figs 1–21, 62–68)
Basionym: *Fragilaria construens* [var. *binodis*] f. *borealis* Foged, *Bibliotheca Phycologica* 15: 56, pl. III: fig. 6, 1974.
Homotypic synonym: *Staurosira borealis* (Foged) Witkowski & al. (in Witon & al. 2004)
Holotype: Foged sample 29/1954, **C**!
Type locality: outflow from a small lake near Thingvellir, Iceland, sample 29, coll. date 15.VII.1954, leg. N. Foged
Description: Frustules rectangular, connected to each other forming long, ribbon-like chains using marginal, spatulate interlocking spines (Figs 62 & 63). Spines located on virgae at valve face/mantle junction (Figs 64 & 65). Stipules absent. Valves rectangular in their middle part with often very weakly constricted valve margins, and clearly protracted, elongated rostrate to weakly

subcapitate apices. Valve dimensions (n=50): length 11–20 µm, width 4–5 µm. Valve face flat, although very weak undulation occasionally observed (Fig. 65, arrows). Sternum broad, linear to lanceolate. Central area lacking. Striae composed of 1–3 large rounded to squarish areolae and one areola on the valve mantle, 14–16 striae in 10 µm. Small volae arising mesh-like from the areolar opening, projecting inwards. Scattered pattern of very small siliceous papillae present around areolae (Figs 64 & 66). Apical pore fields present on both apices, composed of at least 2 rows of relatively large, rounded pores. Mantle edge bearing dense row of siliceous mantle plaques (Fig. 63). Girdle bands numerous, open, plain (Figs 62 & 63), often with small fimbriate edge (Fig. 63, arrow). Internally, virgae weakly raised with broad striae sunken between them (Fig. 67). Areolae covered by internal, elliptical depositions. End wall thickened with a recessed apical pore field (Fig. 68)

Most of the observed valves in the original material could be assigned to *P. borealis* (Figs 1–21) or *P. robusta* (Figs 42–55), the latter characterised by a typical deeply undulating valve outline. However, several populations showed either an intermediate valve outline between *P. borealis* and *P. robusta* (Fig. 56–61) having an asymmetrically constricted, concave central part with one valve margin being more convex or straight. Most likely these valves should be considered to belong to *P. robusta,* but this is not straightforward for each of the illustrated valves. Van de Vijver & Kusber (2022) showed the original type population for *P. robusta* and also illustrated several valves with these intermediate features (see their figs 12–15). More problematic, however, are on one hand the observed groups of valves with clearly convex, often rounded margins (Figs 22–30), smaller valve dimensions and a more cruciform valve outline (Figs 31–37) and on the other hand narrower, more linear valves with weakly concave margins (Figs 38–41). The first two groups show some resemblance with the 4 illustrated valves of *P. pseudoconstruens* in Witon & al. (2004, figs 18–21) and the two valves illustrated in Marciniak (1982, pl. I: figs 1, 2), belonging to the type of *P. pseudoconstruens*. As the original material of *P. pseudoconstruens* has not been properly investigated at present, it remains unclear whether these groups represent *P. pseudoconstruens* or whether the population now identified as *P. borealis* should be considered as being part of a highly variable *P. pseudoconstruens*, giving priority to the latter name as it is the oldest name in the species rank.

This research received support (Bart Van de Vijver) from the SYNTHESYS project (www.synthesys.info), financed by the H2020 Research Infrastructures Programme, to visit **C**. Dr Christian Lange and Prof. Dr Nina Lundholm, my hosts, are thanked for their help in the Foged collection. Dr Carlos E. Wetzel and Dr Agata Wojtal are thanked for their help with the original material from the Barbara Marciniak collection.

Foged, N. (1974). Freshwater diatoms in Iceland. *Bibliotheca Phycologica* 15: 1–118.

Garcia, M.L., Maidana, N.I., Ector, L. & Morales, E.A. (2017). *Staurosira patagonica* sp. nov., a new diatom (Bacillariophyta) from southern Argentina, with a discussion on the genus *Staurosira* Ehrenberg. *Nova Hedwigia Beiheft* 146: 103–123.

Krammer, K. & Lange-Bertalot, H. (2000). Bacillariophyceae, 3. Teil: Centrales, Fragilariaceae, Eunotiaceae. pp. 1–578, Ergänzungen 579–596, 167 pls (2188 figs). Heidelberg: Spektrum Akademischer Verlag.

Marciniak, B. (1982). Late glacial and Holocene new diatoms from a glacial lake Przedni Staw in the Piec Stawów Polskich Valley, Polish Tatra Mts. *Acta Geologica, Academiae Scientiarum Hungariacae* 25(1–2): 161–171.

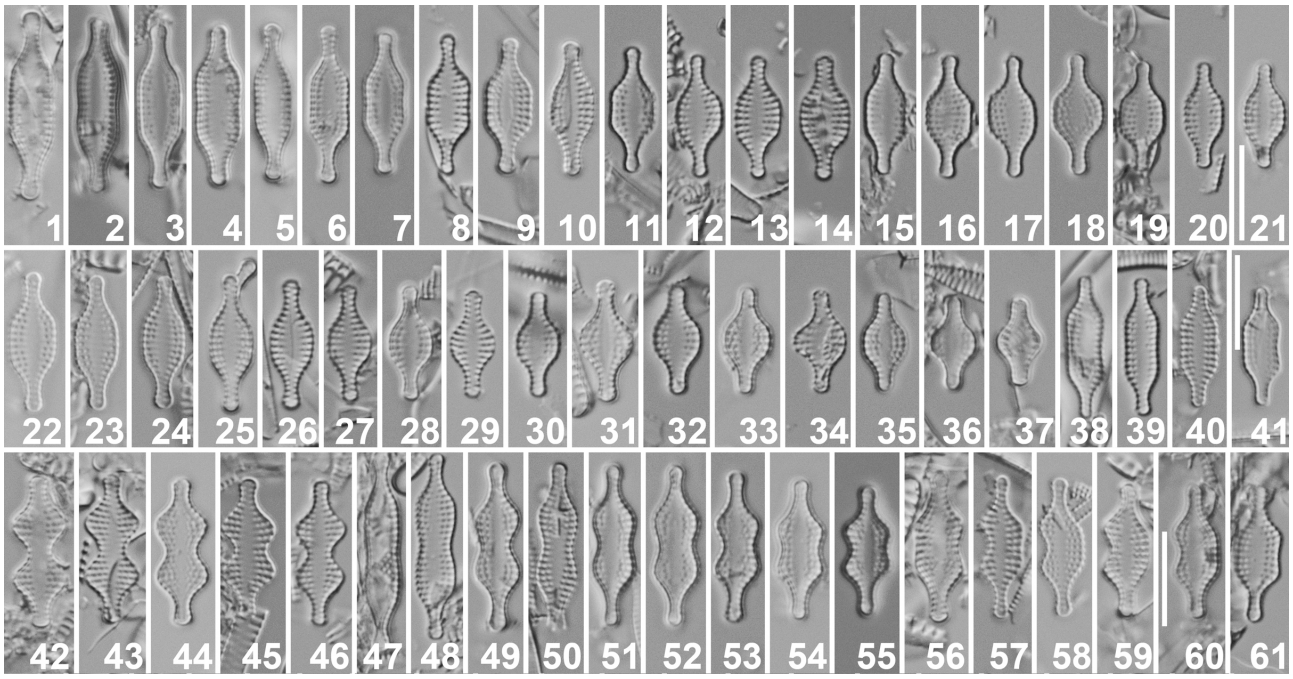
Morales, E.A., Wetzel, C.E., Novais, M.H., Buczkó, K., Morais, M.M. & Ector, L. (2019). Morphological reconsideration of the araphid genus *Pseudostaurosira* (Bacillariophyceae), a

revision of *Gedaniella*, *Popovskayella* and *Serratifera*, and a description of a new *Nanofrustulum* species. *Plant Ecology and Evolution* 152(2): 262–284.

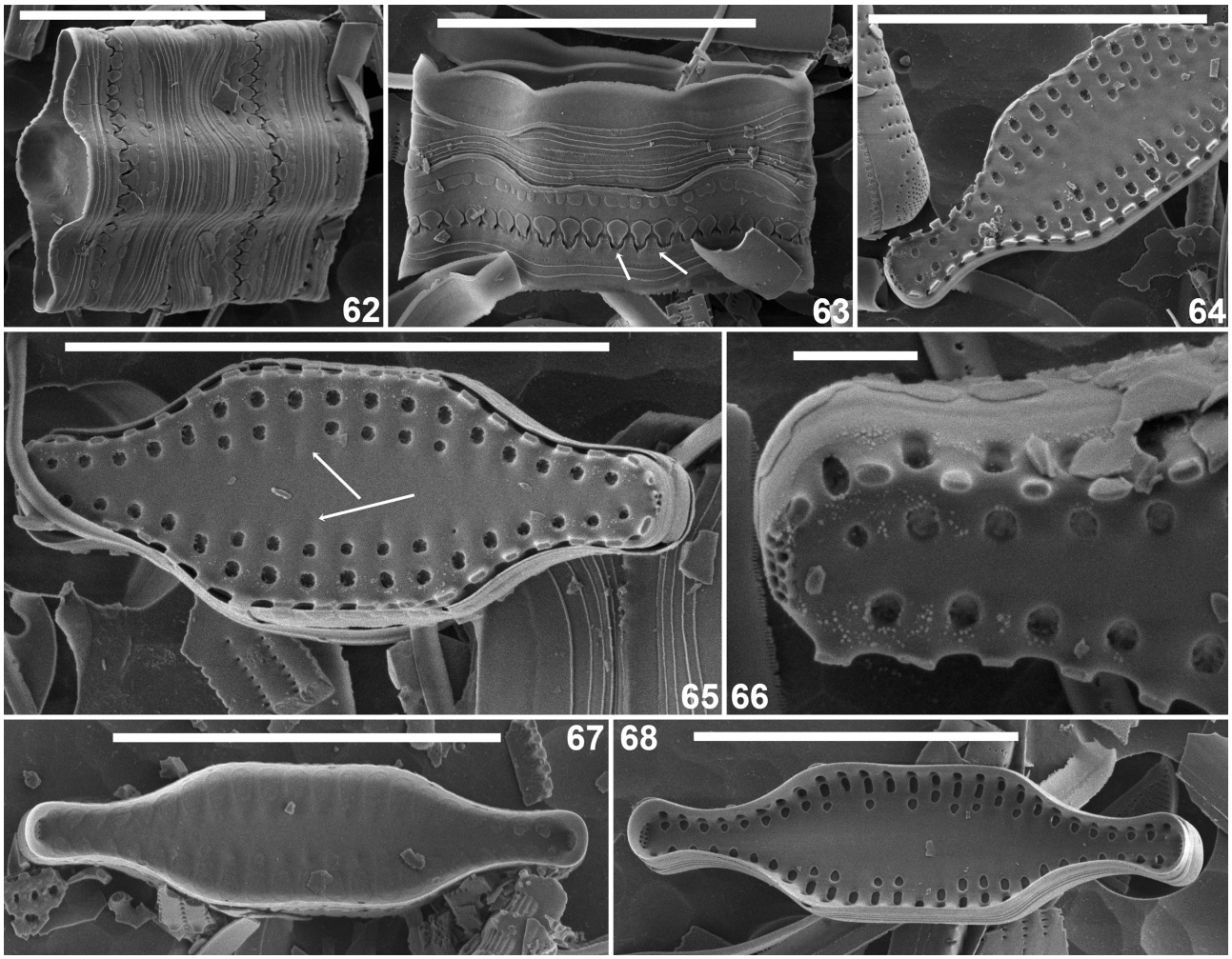
Van de Vijver, B. & Kusber, W.-H. (2022). Typification and transfer of *Fragilaria undulata* C.E.Cramer to the genus *Pseudostaurosira* (Staurosiraceae, Bacillariophyta) with some notes on the diatom species described by Carl E. Cramer. *Notulae Algarum* 225: 1–5.

Williams, D.M. & Round, F.E. (1988 '1987'). Revision of the genus *Fragilaria*. *Diatom Research* 2: 267–288.

Witon, E., Witkowski, A. & Lange-Bertalot , H. (2004). *Hippodonta subcostulata* (Hustedt) Lange-Bertalot, Metzeltin et Witkowski and some fragilarioid diatom taxa from the Holocene lacustrine sediments of the Faeroe Islands. *Diatom Research* 19(1): 123–134.



Figs 1–61. *Pseudostaurosira borealis* (Foged) García & al. and related taxa. LM pictures taken from the holotype material (Foged 29/1954, Iceland). LM pictures of valves in valve face view in decreasing valve length. Figs 1–21. *Pseudostaurosira borealis*, holotype population. Figs 22–30. *Pseudostaurosira* sp., population showing convex, clearly rounded valve margins. Figs 31–37. *Pseudostaurosira* sp., population showing smaller, more cruciform valves. Figs 38–41. *Pseudostaurosira* sp., population showing more linear, narrower valves with weakly concave margins. Figs 42–55. *Pseudostaurosira robusta* (Fusey) D.M.Williams & Round. Figs 56–62. *Pseudostaurosira* sp., population showing valves with intermediate undulated margins between *P. robusta* and *P. borealis*. Scale bars = 10 µm.



Figs 62–68. *Pseudostaurosira borealis* (Foged) García & al. SEM pictures taken from the holotype material (Foged 29/1954, Iceland). Fig. 62. Colony of several valves linked with their spatulate, interlocking spines. Fig. 63. Two frustules connected to each other. The arrows indicate the fimbriate edge of the copulae. Figs 64, 65. External view of two valves showing the areolae with the volae, the weakly undulating valve face surface (white arrows) and the position of the marginal spines. Fig. 66. External detail of the valve apex with the apical pore field, the small siliceous papillae around the areolae and the volae in the areolae. Fig. 67. Internal view of an entire valve showing the weakly raised virgae and the internal, elliptical depositions. Fig. 68. Internal view of an entire valve with the internal depressions removed. Scale bars = 10 µm except for Fig. 66 = 1 µm.