Observations and typification of *Fragilaria cyclopum* (Brutschy) Lange-Bertalot (*Fragilariaceae, Bacillariophyta*)

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Adolf Brutschy (1885–1955) described in 1922 (Brutschy 1922: 284, figs 11-13) a curved diatom species he observed living on the carapaces and legs of the copepod *Cyclops strenuus* Fischer, 1851 (Family *Cyclopidae,* Subphylum *Crustacea,* Phylum *Arthropoda*) (Fig. 1) and occasionally also in the plankton of two Swiss lakes (Baldeggersee and Hallwilersee, Kanton Luzern & Kanton Aargau, Switzerland). Brutschy (1922), however, used two different names for the same taxon in his paper: *S. cyclopum* and *S. helveticum*. This can be seen for instance in the legend for his fig. 12 (see our Fig. 1). These can be accepted as alternative names. One of the names should be chosen as its valid published name (ICN Art. 36.3, Turland & al. 2018). Although Brutschy (1922: 286) provided a Latin description for the name *S. helveticum*, it is more logical to use *S. cyclopum* as it is the most widely recognised of the two; and later, some infraspecific names were added to *S. cyclopum* (for instance: *Synedra cyclopum* var. *robusta* P.Schulz, 1931). In his description, Brutschy (1922: 286) clearly indicated the curved valve outline ("*valvis linearibus arcuatis*") and the growth habitus in small bundles on the carapaces of copepods ("*Frustulis in fascis radiatos conjunctis in corpore animialium* Cyclops *O. F. M. generis sedentibus*"). In his discussion, Brutschy (1922: 286) also mentioned a possible second species growing on copepods in the Schliersee (Germany): *Eunotia lunaris* var. *planctonica* Lemmermann (Lemmermann 1910: 328, figs 22, 23). Hustedt (1930: 164) considered this latter taxon a synonym of *Synedra cyclopum* and extended the distribution of the species by adding records from lakes from Germany, Switzerland, Austria and Poland.

Three varieties of *Synedra cyclopum* were later described, usually based on slight differences in valve outline. In 1931, Schulz described *Synedra cyclopum* var. *robusta* showing a more robust outline than the nominate variety. A second variety, *Synedra cyclopum* var. *gibbosa* Moghadam from Flathead Lake, Montana, was described by Moghadam (1969: 178, pl. 1: fig. b) and distinguished by the shape of the central area, extending to the valve margins and attenuate poles (Moghadam (1969: 178). A third variety, *S. cyclopum* var. *incisa* G.A.Cunningham (in Cunningham & Whitson 1978: 528, fig. 1), was described in 1978 from Lake West Okoboji (Iowa, USA) and shows a slight constriction in the ventral margin at the central area (Cunningham & Whitson 1978). In 1953, Cleve-Euler (1953: 67–68, fig. 388 b, c) separated the nominate form as "f. *typica"* (*nom. inval.*) from valves showing a more inflated central part as *Synedra cyclopum* f. *ventralis* Cleve-Euler. In the epitype population of the nominate forma from the Greifensee (see below), larger and

more robust valves were found that could be identified as *Synedra cyclopum* var. *robustum* P.Schulz, but the population analysis showed, however, a continuum with the smaller valves that are more characteristic for the nominate variety. Constricted or slightly deformed valves (*Synedra cyclopum* var. *incisa* G.A.Cunningham) regularly occur in species of the genus *Fragilaria* and can be considered teratological forms without any taxonomic significance (Falasco & al. 2009, 2021). Our analysis of material collected in the 1990s from Lake Okoboji (slides **ANSP** GC 61500 and 61501) showed no differences with the observations presented in this paper (Gaiser & Bachmann 1994). As both varieties show no additional morphological differences, there is no reason to keep them separate from the nominate variety and therefore they should be considered as heterotypic synonyms. This was already suggested by Lange-Bertalot (1980: 752) and later confirmed by Krammer & Lange-Bertalot (1991: 134, pl. 117: figs 15, 16). At present, ventrally inflated valves have not been observed, so it is unclear how to classify *Synedra cyclopum* f. *ventralis*, but it is most likely these forms are simply part of the outline variability of the nominate forma. A fourth variety, *S. cyclopum* var. *nipponica* Skvortzow (1936: 19, pl. 13, fig. 37) was described from Kizaki Lake (Honshu, Japan), but the valve illustrated shows no similarity to *F. cyclopum*, making it unlikely that this variety is actually related to *F. cyclopum*. Analysis of the original material will be needed to confirm its taxonomic identity.

In 1981, *Synedra cyclopum* was transferred by Lange-Bertalot (1981: 752) to the genus *Fragilaria* as *F. cyclopum* (Brutschy) Lange-Bertalot, unfortunately without illustrating the type material. Krammer & Lange-Bertalot (1991, pl. 117: fig. 15), however, illustrated a single valve from an original slide made by Brutschy from the Hallwilersee. Unfortunately, original Brutschy material was no longer available in collections worldwide (Bernauer & Hürlimann, pers. obs.) but in the Hustedt collection (**BRM**, Bremerhaven, Germany), a slide made by Brutschy has been conserved. This slide (No. K1-26) was collected from the plankton of the Hallwilersee on 26.IV.1916 and prepared by Brutschy. Although a few valves could be photographed using light microscopy on the slide (Figs 2–6), it was impossible to analyse the species using scanning electron microscopy, making it difficult to determine the correct taxonomic identity of the species. The slide is designated as lectotype for the species (see below) and to allow a better observation of the population variability and ultrastructure of the species, new copepod plankton was collected in April 2021 from two lakes: Hallwilersee and Greifensee (Kanton Zürich, Switzerland). Both lakes are very near to each other. In the first sample, only a very low number of valves could be retrieved but the population in the Greifensee is quite abundant and allowed for a good SEM observation. Therefore, the sample is designated below as the epitype of the lectotype in accordance with ICN Art. 9.9 (Turland & al. 2018).

Morphological analysis confirmed the taxonomic position of the species within the genus *Fragilaria*, in spite of the curved valve outline. A transfer to the genus *Hannaea* seems less appropriate, although most taxa in the latter genus typically possess curved valves (Bixby & Jahn 2005). *Hannaea* taxa are also characterized by a distinct buttressed ventral inflation lacking striae (Bixby & Jahn 2005) which is clearly absent in *F. cyclopum*.

Here, we detail observations on specimens of *F. cyclopum* from the Brutschy slide conserved at **BRM** and a slide prepared from the Greifensee sample collected at on April 15th 2021, conserved at **BR**, using light and scanning electron microscopy. The Brutschy slide in **BRM** is designated as lectotype and the material from the Greifensee is designated as epitype for the designated lectotype.

Fragilaria cyclopum (Brutschy) Lange-Bertalot, *Nova Hedwigia* 33: 752, 1981 (Figs 2–33)
Basionym: *Synedra cyclopum* Brutschy, *Internationale Revue der gesamten Hydrobiologie* 10: 284, figs 11–13, 1922.
Synonyms: *Eunotia lunaris* var. *planctonica* Lemmermann, 1910, *Synedra cyclopum* var. *robustum* P.Schulz 1931, *S. cyclopum* var. *incisa* G.A.Cunningham (in Cunningham & Whitson) 1978

Lectotype (here designated): slide K1-26, Hallwilersee, Kanton Aargau, Switzerland, leg. A. Brutschy, coll. date 26.IV.1916, slide present in **BRM**. The lectotype is represented by Figs 2–6.
Epitype (here designated for the above lectotype of *Synedra cyclopum* Brutschy): slide **BR**-4665 (**BR**, Meise Botanic Garden); sample Greifensee (Kanton Zürich, Switzerland, coll. date 15.IV.2021, leg. Silvana Käser); the epitype is here represented by Figs 7–33.
Registration: http://phycobank.org/102822
Description: Frustules rectangular, solitary, grouped in bundles growing on the legs and carapaces of small, planktonic copepods (Fig. 27). Ribbon-like colonies not observed. Girdle bands perforated, open (Fig. 28). Valves linear, distinctly curved with a convex dorsal and concave ventral side. Apices weakly protracted, subrostrate to broadly rounded. Valve dimensions (n=25): valve length 30–120 µm, valve width 3.5–4.5 µm. Sternum narrow, linear. Central area formed by a large, irregularly shaped hyaline zone, bordered by several shortened striae. Striae parallel, uniseriate (Figs 29–31), composed of small, rounded to weakly apically elongated areolae. Stria density: 15–17 in 10 µm. Ghost striae visible in the central area (Fig. 31). Apical pore field large, covering the entire apices, composed of up to 7 long rows of small, rounded pores (Figs 28, 30). Rimoportula large, transapically elongated, replacing the areolae in one of the last striae before the apex (Fig. 30). Internally rimoportula large, straight (Fig. 32).

Hoff & Lange-Bertalot (2011: 443, figs 2–33) described a second curved *Fragilaria* species from the Sredinny Range (Срединный хребет) of the Kamchatka Peninsula (Russian Far East): *Fragilaria flexura* U.Hoff & Lange-Bertalot. Although both taxa share the typical curved valve outline, they can be separated based on the shape of the apical pore field. In *F. flexura*, this pore field is restricted to the ventral valve side whereas in *F. cyclopum*, the pore field occupies the entire apex. Hoff & Lange-Bertalot (2011: 448) reported as the main difference between both taxa the lower valve dimensions in *F. flexura* (max. length 20 µm) although the species overlap in valve width (2–4.5 µm in *F. flexura* and 3.5–4.5 µm in *F. cyclopum*) and stria density (14–20 vs 15–17 in 10 µm). Additionally, *F. cyclopum* possesses a larger rimoportula (e.g., Hoff & Lange-Bertalot 2011, fig. 25).

Based on literature data and our observations, *Fragilaria cyclopum* appears to be a Holarctic species. Populations in North America do not differ morphologically from the type population in Europe (see Bahls 2012). The species has been recorded from lakes and reservoirs (and rivers that drain lakes and reservoirs) across the western United States, including Montana (Bahls 2012). Chiavelli & al. (1993) discussed the occurrence of *F. cyclopum* in Oneida Lake, New York: it appeared to be most abundant when water transparency was high and *Daphia* populations increased. In a study of the phototrophic epibionts in the region of Krasnoyarsk (Russia), the species was found to prefer colder water as it had a positive effect on the population sizes of their host, a large *Daphnia* species (Dubovskaya & al. 2005).

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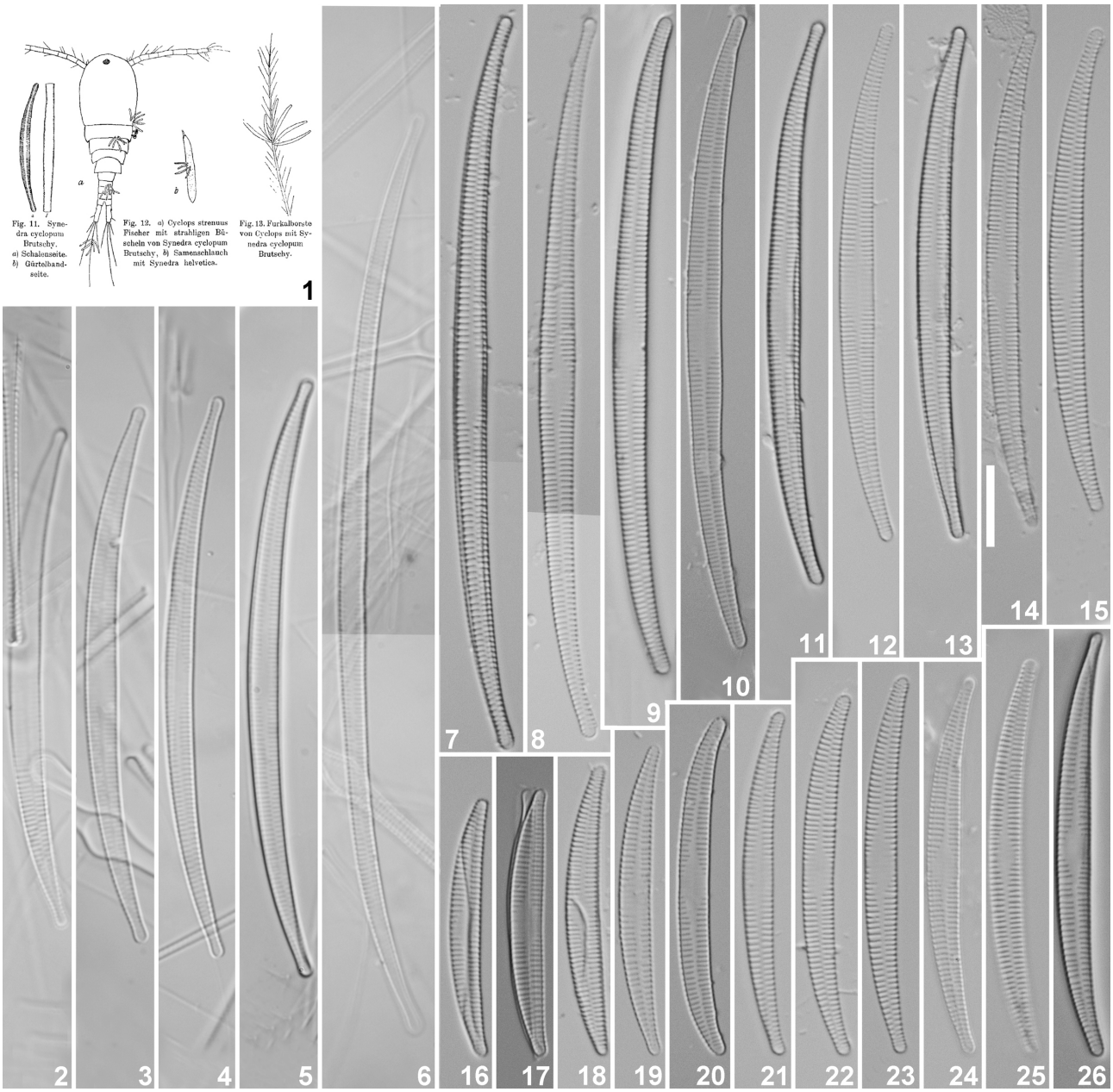
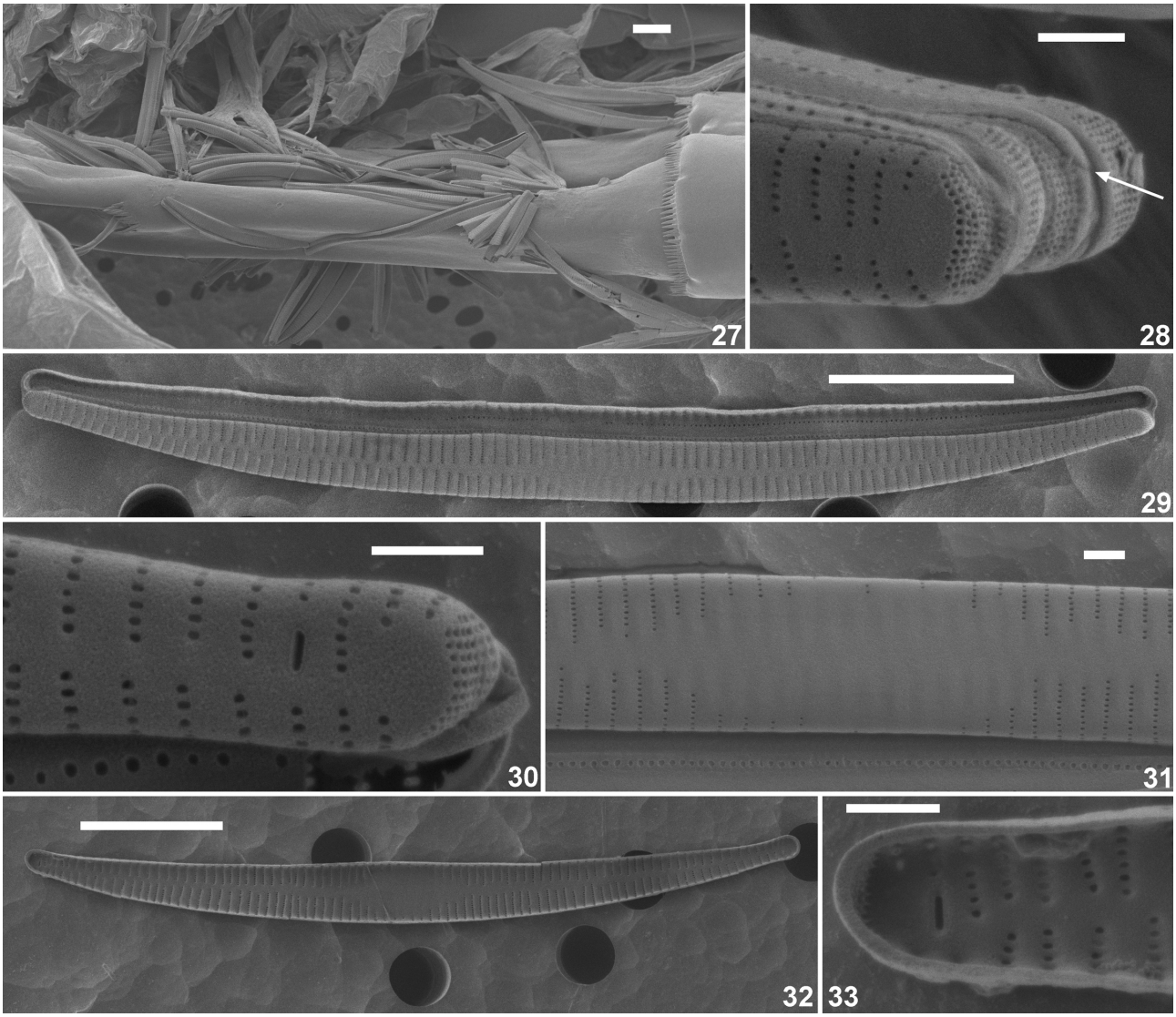


Figs 1–26. ***Fragilaria cyclopum*** **(Brutschy) Lange-Bertalot.** LM pictures taken from lectotype (Figs 2–6) and epitype (Figs 7–26) material. **Fig. 1.** Original illustrations from Brutschy (1922). **Figs 2–6**. Five valves from the lectotype slide K1-26 (Hallwilersee, **BRM**). **Figs 7–26.** Cell diminution series cycle of *Fragilaria cyclopum* from the epitype slide (Greifensee, **BR**-4665). Scale bar = 10 µm.



Figs 27–33. ***Fragilaria cyclopum*** **(Brutschy) Lange-Bertalot.** SEM pictures taken from epitype material. Fig. 27. Several frustules attached in bundles to the legs of a copepod. **Fig. 28.** SEM external detail of the valve apex of two frustules. Note the open girdle band (arrow). **Fig. 29.** SEM external view of an entire valve. **Fig. 30.** SEM external detail of the valve apex showing the apical porefield and the large, slit-like rimoportula. **Fig. 31.** SEM external detail of the central area with ghost striae and irregularly shortened striae bordering the central area. **Fig. 32.** SEM internal view of an entire valve. **Fig. 33.** SEM internal detail of a valve apex showing the large rimoportula. Scale bars = 10 µm (Figs 27, 29 & 32) and 1 µm for all other figures.