Analysis of the type slide of *Stauroneis singula* J.R.Carter & Denny (*Stauroneidaceae*, *Bacillariophyta*) and a comparison with similar taxa

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Stauroneis singula J.R.Carter & Denny (Carter & Denny 1992: 202, pl. 10: fig. 5) was based on a single sample collected in 1992 from the petiole of an aquatic plant, *Nymphaea lotus* L. collected at Lake Popei, Sierra Leone. This diatom remains poorly known because it was illustrated by only a single type-specimen drawing. Williams & Reid (2002) compiled information on type specimens and slides of diatom taxa described by John Ripley Carter (1908–1993). Based on this information, we located the type slide, **BM** 81522 (Fig. 1) and obtained it on loan from the Natural History Museum, London (**BM**). Here, we detail, using LM observations, specimens from the population of *S. singula* found on the type slide. We found differences in the measurement of areolae density and the range of valve length compared to that given in the protologue (Table 1). Carter & Denny (1992) remarked on the unique character of the species as having "very discrete punctuation" of the striae. There are several other species in the genus *Stauroneis* Ehrenberg known to possess the longitudinal ribs of silica which accentuate the appearance of the longitudinal striae. These are *S. stodderi* Greenleaf (in Lewis 1865: 13, pl. 2: fig. 6), *S. staurolineata* Reimer, *S. staurolineata* var. *japonica* H.Kobayasi & Kaz.Ando, *S. zairensis* Compère and *Navicula stodderi* var. *insignis* Grunow.

Stauroneis singula resembles *S. stodderi* described from New Hampshire, USA (Lewis 1865). The former can be distinguished from the latter by its acute subrostrate apices, broader axial area, slightly higher striae and areolae density, slightly widened central area towards the valve margins, and parallel striae near the apices (compare Fig. 3 with Figs 8–14; Table 1). *Stauroneis singula* differs from *S. staurolineata* and *Navicula stodderi* var. *insignis* mainly in the absence of longitudinal ribs crossing the central area in this species (compare Figs 4 and 7 to Figs 8-14; Table 1). *Stauroneis singula* differs from *S. staurolineata* var. *japonica* mainly in its rhombic-lanceolate valve shape and slightly higher areolae density (compare Figs 5 and 15 to Figs 8–14; Table 1). A species described from Zaire, *Stauroneis zairensis* Compère (in Compère & al. 1989: 224, figs 20–6, 8–13), differs from *S. singula* by its narrow lanceolate valves, higher striae, and areolae density (compare Fig. 6 to Figs 8–14; Table 1).

Conspicuous longitudinal silica ribs transecting the central area characterises *Stauroneis staurolineata* (Reimer 1961, Polaskey 2018). *S. staurolineata* var. *japonica* lacks this feature and also has a slightly broader valve and a higher areolae density than *S. staurolineata*. Given the combined unique morphological features in *S. staurolineata* var. *japonica*, we propose to elevate this variety to species level.

Stauroneis kobayasii *nom. et stat. nov.*

Replaced synonym: *Stauroneis staurolineata* var. *japonica* H.Kobayasi & Kaz.Ando (in Kobayasi & Ando) *Japanese Journal of Phycology* 26: 15, pl. 2: figs 18, 19 (reproduced here as fig. 5), 1978.

Invalid designation: "*Stauroneis stodderi* var. *japonica*" H.Kobayasi in Ando & al. *Bulletin of the Chichibu Museum of Natural History* 16: 57–79, 1971.

Description: "Valve lanceolate with acute subrostrate ends, 95–128 µm long, 17–20.5 µm wide. Raphe linear, slightly broadened between valve center and ends, terminal fissures question mark

shaped and forking about 3 µm from the valve ends. Axial area linear and somewhat broad. Central area narrowly widened to the both margins of the valve and without crossing longitudinal ribs. Transapical striae slightly radiate, about 16–17 in 10 µm. Longitudinal ribs parallel, not undulate and interrupted at the transapical facia, about 16–20 in 10 µm." [Protologue description.]

Kobayasi (1971: 70) initially described this taxon as "*Stauroneis stodderi* var. *japonica*" bu this name is invalid as a Latin diagnosis or description was not provided. Later Kobayasi & Ando (1978) described it validly as *Stauroneis staurolineata* var. *japonica. Stauroneis staurolineata* var. *japonica* has been reported from Japan (Kobayasi & Ando 1978), Korea (Joh 2014), and is here documented for the first time from Wisconsin wetlands. The epithet is given in honor of Professor Hiromu Kobayasi (1926–1996), a former vice-president of the International Society for Diatom Research, for his contributions to diatom research. The new name is necessary because of the prior existence of *Stauroneis japonica* H.Kobayasi (Kobayasi 1986): 97, fig. 13).

Notes on the genus *Stauroneis.* Protoplast and areolae structure characterization led to the revision of the genus *Stauroneis* which now comprises only freshwater species (e.g., Stickle & Mann 1988, Round et al. 1990, Mann & Stickle 1995, Cox & Williams 2000). The presence of a transverse thickening (stauros) at the center of the valve is regarded as a homoplastic character (Cox & Williams 2000, Kociolek & al. 2019). Recent molecular studies show that taxa currently assigned to *Stauroneis* do not form a monophyletic group (Kulikovskiy et al. 2019, Kim et al. 2020). Kulikovskiy & al. (2019) further discussed the importance of the presence and absence of pseudosepta at the valve apices in distinguishing different clades within the genus *Stauroneis* which confirmed the separation of *Pleurostauron* from *Stauroneis* in the past classification scheme by Cleve (1894). Reimer (1961) proposed the transfer of *Stauroneis* taxa characterised by longitudinal ribs of silica on the valve face to a new genus. The longitudinal ribs are also present in some members of genera closely related to *Stauroneis*, such as *Craticula* and *Proschkinia* (Kulikovskiy & al. 2019, Kim & al. 2020). However, this may be a plesiomorphic character as it is shared with species in *Haslea* and *Navicula*. Members of the *Stauroneis* group with longitudinal ribs also differ from other members of *Stauroneis* in their shape, a rhombic to lanceolate valve outline with acute subrostrate ends rather than linear-lanceolate with rostrate ends as in most members of *Stauroneis*. However, circumscribing a new genus for this group requires formal systematic analysis involving protoplast structure studies and molecular data to support its monophyly and its placement within *Stauroneidaceae* (Kociolek & Williams 2015).

Table 1. Morphology of *Stauroneis singula* compared with similar species.

	Stauroneis singula	*Stauroneis stodderi*	*Stauroneis staurolineata*	*Stauroneis kobayasii comb. et. stat. nov*	*Stauroneis zairensis*	*Navicula stodderi var. insignis*
References	Carter & Denny (1992: 202, pl. 10, fig. 5)	Lewis (1865: 13–14, pl.2, fig.6), Potapova & Friedman (2021 diatoms.org)	Reimer (1961:206–207, pl. 2, fig. 3), Polaskey (2018 diatoms.org)	Kobayasi & Ando (1978: 15, pl. 2: figs 18, 19)	Compère (1989: 224, figs 2–6, 8–13)	Cleve (1894: 110, pl. III, fig. 13)
Valve shape	Rhombic-lanceolate, tapering to acute subrostrate apices.	Rhombic-lanceolate, narrowing abruptly to subrostrate apices	Lanceolate, tapering to acute apices.	Lanceolate, tapering to acute subrostrate apices.	Lanceolate, tapering to acute subrostrate apices.	Rhombic-lanceolate, tapering to subrostrate apices.
Valve length (µm)	91–120	75–97	83–125	95–128	70–110	90–110
Valve width (µm)	16–20	16–20	13.5–17	17–20.5	14–17.5	19–21

Striae in 10 µm	17–18	16–21	16–17	16–17	17–20	12–16
Striae	Slightly radiate in the middle of the valve, becoming parallel towards the apices. Areolae are coarse and appear more rounded in LM, 14–16 in 10 µm	Slightly radiate in the middle of the valve, becoming strongly radiate towards the apices. Areolae are coarse and appear rectangular in LM, 10–12 in 10 µm	Slightly radiate in the middle of the valve, becoming parallel towards the apices. Areolae are coarse and appear rectangular in LM, 9–14 in 10 µm.	Slightly radiate in the middle of the valve, becoming parallel towards the apices. Areolae are coarse and appear more rounded in 16–20 in 10 µm	Slightly radiate in the middle of the valve, becoming parallel towards the apices. Areolae are coarse and appear more rounded in LM 18–20 (24) in 10 µm	Parallel to slightly radiate throughout the valve. Areolae are coarse and appear more rounded in LM 7–9 in 10 µm
Raphe	Linear, with unilaterally hooked distal raphe ends. Proximal raphe ends are linear and not inflated.	Linear, with unilaterally hooked distal raphe ends. Proximal raphe ends are linear and not inflated.	Linear, with unilaterally hooked distal raphe ends. Proximal raphe ends are linear and not inflated.	Linear, with unilaterally hooked distal raphe ends. Proximal raphe ends are linear and not inflated.	Linear, with unilaterally hooked distal raphe ends. Proximal raphe ends are linear and not inflated.	Linear, with unilaterally hooked distal raphe ends. Proximal raphe ends are linear and not inflated.
Axial area	Somewhat broad and linear	Narrow and linear	Narrow and linear	Somewhat broad and linear	Somewhat broad and linear	Narrow and linear
Central area	Rectangular broad stauros extends to the valve margin, sometimes widen towards the valve margins, and is not transected by longitudinal ribs.	Rectangular broad stauros extends to the valve margin, sometimes widen towards the valve margins, and is not transected by longitudinal ribs.	Rectangular broad stauros extends to the valve margin, sometimes widen towards the valve margins, and transected by longitudinal ribs.	Rectangular broad stauros extends to the valve margin, sometimes widen towards the valve margins, and is not transected by longitudinal ribs.	Rectangular broad stauros extends to the valve margin, sometimes widen towards the valve margins, and is not transected by longitudinal ribs.	Rectangular broad stauros extends to the valve margin, sometimes widen towards the valve margins, and is not transected by longitudinal ribs.
Type locality	Lake Popei, Sierra Leone, West Africa	New Hampshire, North America	Bemis Lake, New Hampshire, North America	Senjoga-ike Pond, Saitama Prefecture, Japan	Fishpond in Kinshasa, Zaire	Bengal, India
Distribution	Only known from the type locality	Northeastern US (Lewis 1865, Reimer 1961, Patrick & Reimer 1966, Camburn & Charles 2000, Siver et al. 2005), Northwestern US (Bahls 2010), Alaska (Foged 1981)	Northeast and southeast US (Reimer 1961, Camburn & Charles 2000, Siver et al. 2005)	Japan (Kobayasi & Ando 1978), Yangsan-Korea (Joh 2014) Wisconsin, US (this study)	Only known from the type locality	Bengal, India (Cleve 1894), Central Siam, Lem Dan, India (Patrick 1936)

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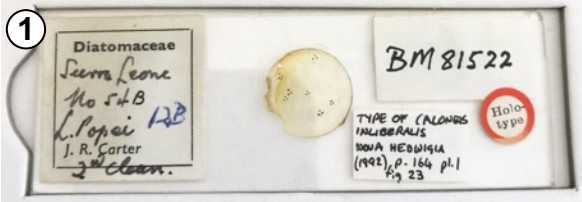
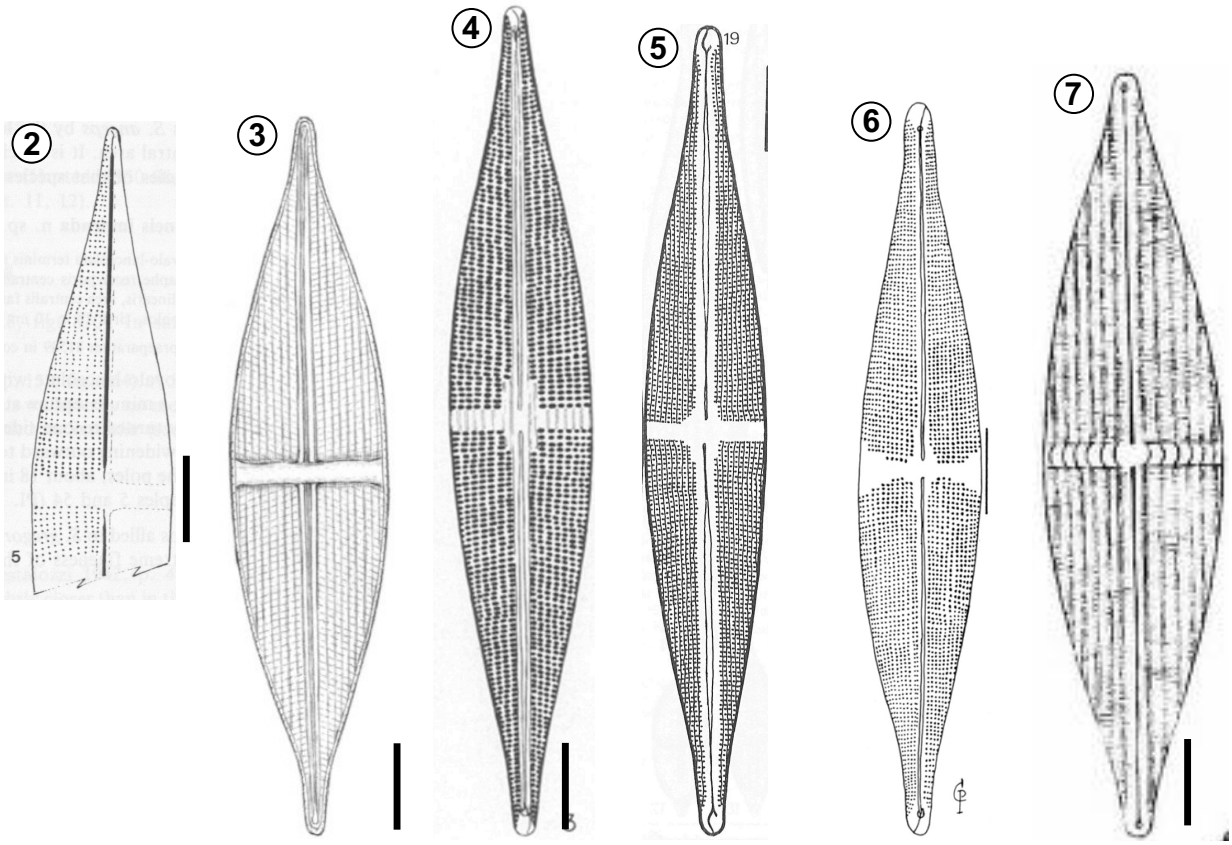
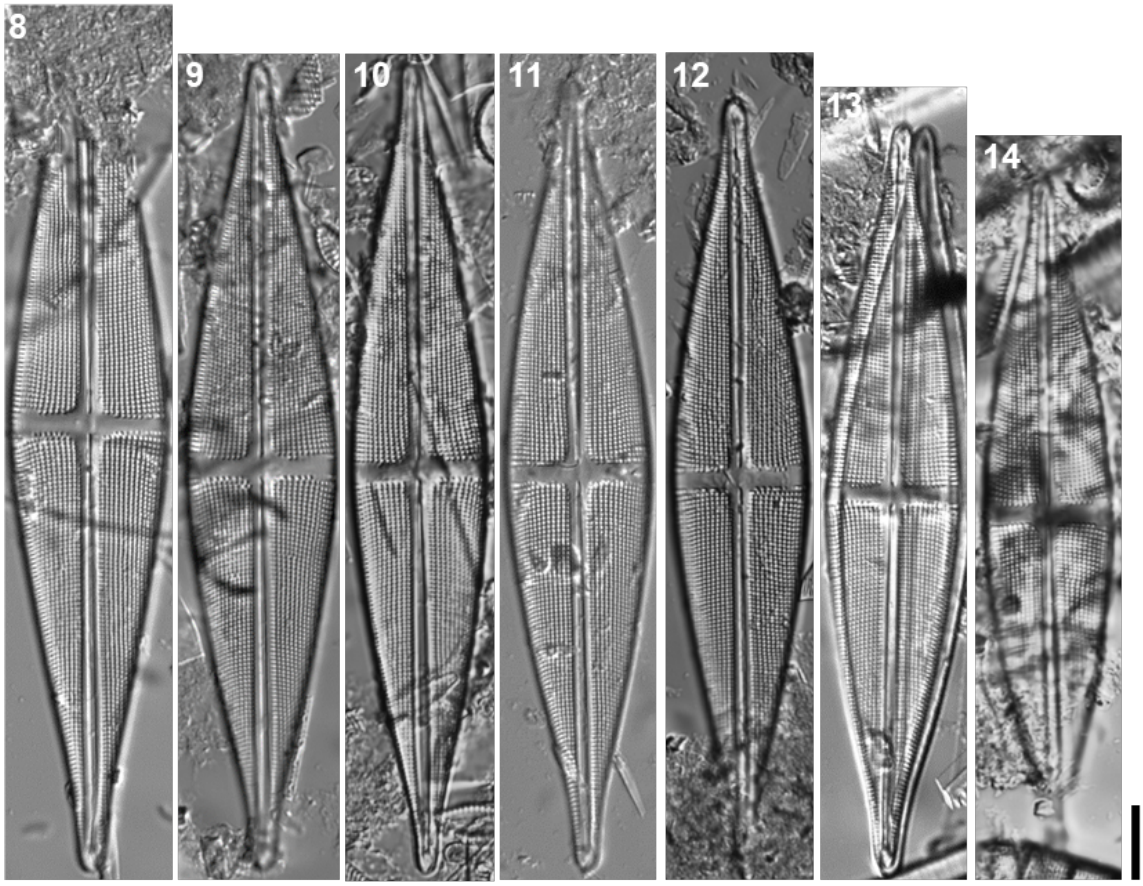


Fig. 1. Slide **BM** 81522 from Sierra Leone.



Figs 2-7. Published drawings of several species within the genus *Stauroneis* characterised by longitudinal ribs of silica on the valve face. (2) *S. singula* Carter & Denny (3) *S. stodderi* (Greenleaf) Lewis; (4) *S. staurolineata* C.W. Reimer; (5) *S. kobayasii comb. et. stat. nov*; (6) *S. zairensis* Compère; (7) *Navicula stodderi* var. *insignis* Grunow. Scale bars = 10 µm.



Figs 8-14. *Stauroneis singula* Carter & Denny. LM images taken from slide BM 81522, sample 54. Figure 10 is marked on the slide with three dots of black marker. Scale bar = 10 µm.

Fig. 15. *Stauroneis kobayasii nom. et stat. nov.* LM images taken from slide FQAB-NL109, sample is collected from a wetland in Wisconsin. Scale bar = 10 µm.