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Article

Five new species of *Stauroneis* (Bacillariophyta, Stauroneidaceae) from the northern Rocky Mountains, USA

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Abstract

Five new species of *Stauroneis* are described from the northern Rocky Mountains—*S. clarkii, S. lewisii, S. sacajaweae, S. spauldingiae,* and *S. thompsonii*—for a total of 21 new *Stauroneis* species from the region. All of the new species are local or regional endemics. Water bodies supporting populations of *Stauroneis* tend to be small, remote, isolated, circumneutral, oligo- or dystrophic, and with low levels of electrolytes. These findings have implications for estimating diatom biodiversity and for conserving endemic diatom species and their habitats.

Key words: Biodiversity, conservation, diatoms, endemic species

Introduction

I recently reported 52 taxa in the genus *Stauroneis* Ehrenberg (1843: 45) from the northern Rocky Mountains, including 16 species described as new (Bahls 2010). Below I describe an additional five new species from among those reported earlier based on morphological differences from known taxa. Following this, I discuss some shared ecological factors that contribute to the observed distribution of *Stauroneis* species, as well as implications for diatom biodiversity and conservation of endemic diatom species and their habitats.

Materials and Methods

At each site, diatoms were collected from aquatic macrophytes, where available, and from the surface of rocks and fine sediments using a tablespoon or a large-bore pipette with suction bulb. Samples were preserved with Lugols (IKI) solution before transport to the laboratory, where they were treated with sulfuric acid (H_2SO_4), potassium dichromate ($K_2Cr_2O_7$), and hydrogen peroxide (H_2O_2) to remove organic matter (APHA *et al*. 1992). After several rinses in distilled water, cleaned diatom material was mounted permanently on slides using Hyrax or Naphrax and examined under light microscopy (LM) with differential interference contrast optics using a Leica DM LB2 research microscope and a Spot Insight Model 14.0 monochrome digital camera. Slides and cleaned material from these samples have been deposited in the Montana Diatom Collection (MDC) in Helena and duplicate slides, when available, have been deposited in the University of Montana Herbarium (MONTU) in Missoula (http://herbarium.dbs.umt.edu/diatoms.asp). Valve measurements were made from digital images using Spot Software (version 4.5).

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New species descriptions

Division **Bacillariophyta**
Class **Bacillariophyceae** Haeckel 1878 emend. D.G. Mann in Round et al. 1990
Subclass **Bacillariophycidae** D.G. Mann in Round et al. 1990
Order **Cymbellales** D.G. Mann in Round et al. 1990
Family **Stauroneidaceae** D.G. Mann in Round et al. 1990
Genus ***Stauroneis*** C.G. Ehrenberg 1843

Stauroneis clarkii **Bahls, *sp. nov.*** (Figs 1–4)

Type:—USA. Montana: Spring at base of Square Butte, tributary of Cowboy Creek, Chouteau County, 47.4829º N, 110.2380º W, 1400 m elevation, collected from rocks and sediment by Loren Bahls, 22 May 1999. Montana Diatom Collection (MDC) sample 179801; holotype slide MDC B1-22-5, Figs 1–4; isotype slide MDC B1-22-6.

Valves lanceolate to elliptic-lanceolate with subrostrate, broadly rounded apices. Shallow pseudoseptum occupies each apex (Fig. 4). Valve length 47–55 µm; valve width 10.0–12.3 µm. Raphe filiform, slightly sinuous, with a pronounced bend near the proximal ends, which are weakly inflated. Distal raphe ends hooked towards the same direction. Axial area c. 4 x wider than raphe, following the same contours, including the aforementioned bend. Central stauros broad, largely rectangular, scarcely wider at valve margins. Striae radiate throughout, somewhat curved, concave toward valve center, 19–20 in 10 µm. Areolae in striae 18–20 in 10 µm.

Etymology:—This taxon is named after William Clark (1770–1838), an early 19th Century Montana explorer (Jones 2004).

Observations:—*Stauroneis clarkii* was reported by Bahls (2010: 155) as *S. subhyperborea* Van de Vijver & Lange-Bertalot (2004: 72), from which it may be distinguished by its wider, less protracted apices, shallower pseudosepta, and higher areola density. It differs from *S. obtusa* Lagerstedt (1873: 36) by having subtly protracted apices and somewhat wider valves relative to their length. *Stauroneis microbtusa* Reichardt (2004: 442) has more steeply radiate striae and a central stauros that is shaped like a bow tie. *Stauroneis clarkii* is known only from the type locality, which it shares with *S. sacajaweae*.

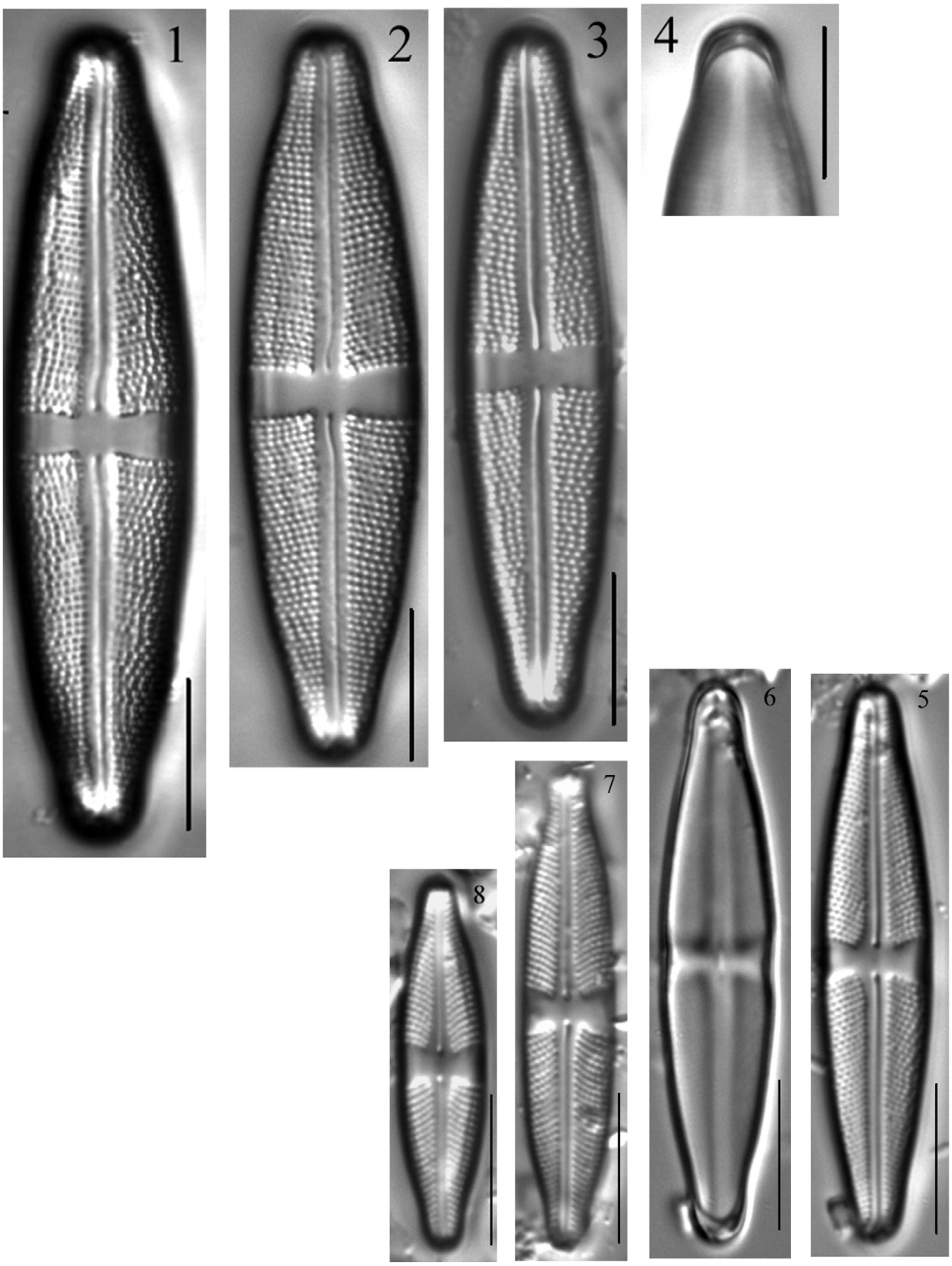
Stauroneis lewisii **Bahls, *sp. nov.*** (Figs 5–8)

Type:—USA. Montana: Blodgett Lake, Selway-Bitterroot Wilderness, Ravalli County, 46.2505º N, 114.4544º W, 2072 m elevation, collected from rocks and sediment by U.S. Forest Service personnel on 10 September 1991. MDC sample 110901; holotype slide MDC P3-4-1, Figs 5–6.

Valves narrow lanceolate to linear-lanceolate with gradually attenuated subrostrate apices. Moderately deep pseudoseptum occupies each apex (Fig. 6). Valve length 25–38 µm; valve width 6.1-7.9 µm. Raphe filiform, nearly straight with somewhat inflated proximal ends. Distal raphe ends hooked in same direction. Axial area linear c. 3 x wider than raphe, widening somewhat near central area. Central stauros broad, shaped like a bow tie. Striae strongly radiate throughout, 22–26 in 10 µm. Areolae in striae 24-26 in 10 µm.

Etymology:—This species is named after Meriwether Lewis (1774–1809), an early 19th Century Montana explorer (Danisi 2009).

Observations:—*Stauroneis lewisii* was reported by Bahls (2010: 121) as *S. pseudoschimanskii* Van de Vijver & Lange-Bertalot (2004: 57), which has elliptic-lanceolate valves with short, broadly subrostrate apices. Besides the type locality, *Stauroneis lewisii* has been collected from two other small lakes in southwestern Montana: Fred Burr Lake, Selway-Bitterroot Wilderness, Ravalli County, 46.3291º N, 114.4163º W; and Bloody Dick Pond #6, Beaverhead County, 45.1119º N, 113.4447º W.



FIGURES 1–8: *Stauroneis clarkii* and *Stauroneis lewisii*. Figs 1–4: *Stauroneis clarkii* from the type locality. Figs 5–8: *Stauroneis lewisii* from various locations. Figs 5–6: Blodgett Lake, Selway-Bitterroot Wilderness, Montana (type locality). Fig. 7: Fred Burr Lake, Selway-Bitterroot Wilderness, Montana. Fig. 8: Bloody Dick Pond No. 6, Beaverhead County, Montana.

Stauroneis sacajaweae **Bahls, *sp. nov.*** (Figs 9–15)

Type:—USA. Montana: Spring at base of Square Butte, tributary of Cowboy Creek, Chouteau County, 47.4829º N, 110.2380º W, 1400 m elevation, collected from rocks and sediment by Loren Bahls, 22 May 1999. MDC sample 179801; holotype slide MDC B1-22-5, Figs 9, 11–15.

Valves lanceolate with gradually attenuated subrostrate apices. A deep pseudoseptum occupies each apex (Fig. 15). Valve length 54–80 µm; valve width 10.8–14.7 µm. Raphe lateral, becoming filiform towards proximal ends, which are bent to one side and tipped with weakly inflated pores. Distal raphe ends hooked in a direction opposite that of proximal ends. Axial area c 3 x wider than raphe and widens gradually towards central area. Central stauros broad, shaped like a bow tie. Striae strongly radiate throughout, 23–25 in 10 µm. Areolae in striae 18–22 in 10 µm.

Etymology:—This species is named after the Lemhi Shoshone woman, Sacajawea (1788–1812?), who served as guide and interpreter for Lewis and Clark (Mann 2004).

Observations:—*Stauroneis sacajaweae* was reported by Bahls (2010: 155) as *S. subhyperborea* Van de Vijver & Lange-Bertalot (2004: 72). However, the Montana specimens have a wider stauros and distinctly higher stria and areola densities than *S. subhyperborea*. Besides the type locality—which it shares with *S. clarkii*—*S. sacajaweae* has been collected from a seep along the Going-To-The-Sun Road in Glacier National Park, Montana, 48.7381º N, 113.7456º W.

Stauroneis spauldingiae **Bahls, *sp. nov.*** (Figs 16–21)

Type:—USA. Idaho: Copper Lake, Shoshone County, 46.9422º N, 115.2664º W, 1750 m elevation, collected at 3 m depth from aquatic macrophytes by John Pierce, 29 September 1998. MDC sample 179601; holotype slide MDC P4-1-1, Figs 16–18, 20–21.

Valves lanceolate to linear-lanceolate with narrowly rostrate apices. Pseudosepta absent. Valve length 48–76 µm; valve width 12–15 µm. Raphe lateral, straight with weakly inflated proximal ends. Distal raphe ends hooked to same side. Axial area 3 x wider than raphe, expanding slightly near central area. Central stauros narrow, nearly rectangular, hardly expanding towards valve margins where shortened striae may be present. Striae radiate throughout, 19–21 in 10 µm. Areolae in striae 20-28 in 10 µm.

Etymology:—*Stauroneis spauldingiae* is named after Sarah Spaulding, a modern day explorer of diatoms, distant lands, and big rock walls.

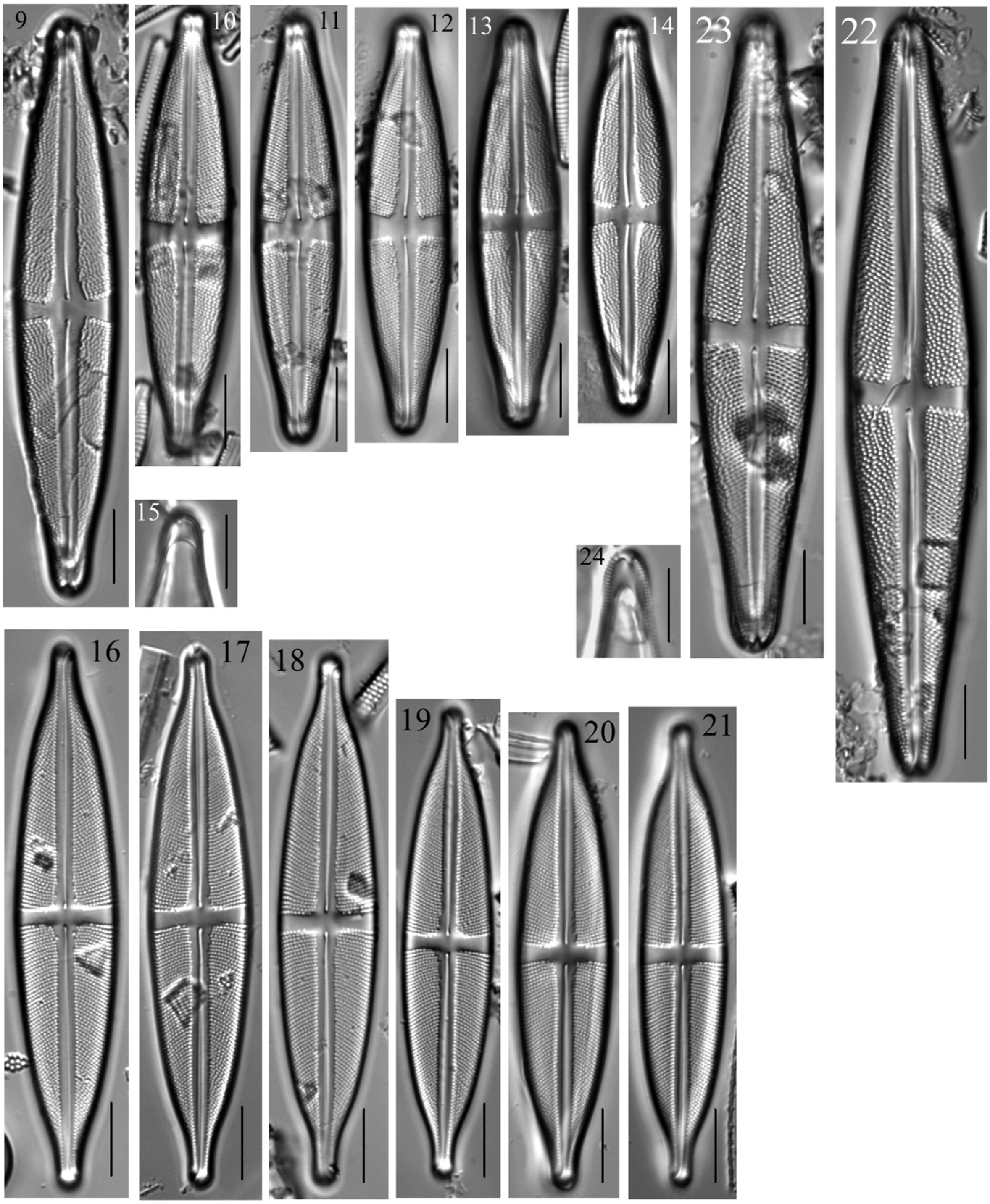
Observations:—*Stauroneis spauldingiae* was reported by Bahls (2010: 45) as *S. anceps* Ehrenberg (1843: 34). Valves of *S. spauldingiae* are somewhat larger, and have a lower stria density and a smaller, more rectangular stauros than specimens designated by Reichardt (1995: 25) as the lectotype of *S. anceps* (Sippe 1, Tafel 16, Figs 1–12). The occurrence of *S. anceps*—one of the most frequently misidentified species of *Stauroneis*—remains to be confirmed in the USA. In addition to the type locality, *S. spauldingiae* has been collected from several small lakes and ponds in western Montana and northern Idaho (Bahls 2010). These waters have circumneutral pH and very low concentrations of dissolved solids.

Stauroneis thompsonii **Bahls, *sp. nov.*** (Figs 22–24)

Type:—USA. Montana: Upper Wolverine Lake (Fig. 25), Ten Lakes Scenic Area, Kootenai National Forest, Lincoln County, 48.9705º N, 114.9221º W, 1890 m elevation, collected from rocks and sediment by Loren Bahls, 9 September 1990. MDC sample 108601; holotype slide MDC P3-3-1, Figs 22–24.

Valves lanceolate with rounded, unprotracted apices. A deep pseudoseptum occupies each apex (Fig. 24). Valve length 88–105 µm; valve width 16.3–17.5 µm. Raphe lateral with straight proximal ends, slightly inflated. Distal raphe ends hooked to same side. Axial area narrowly lanceolate, widens gradually towards central area. Central stauros nearly rectangular and placed somewhat diagonally to apical axis. Striae radiate throughout, 17–18 in 10µm. Areolae in striae 12–15 in 10 µm.

Etymology:—*Stauroneis thompsonii* is named for David Thompson (1770–1857), an early 19th Century Montana explorer and cartographer (Jenish 2003).



FIGURES 9–24: *Stauroneis sacajaweae, S. spauldingiae,* and *S. thompsonii*. Figs 9–15: *Stauroneis sacajaweae*. Figs 9, 11–15: Type locality. Fig. 10: Haystack Seep, Going-To-The-Sun Road, Glacier National Park, Montana. Figs 16–21: *Stauroneis spauldingiae*. Figs 16–18, 20, 21: Copper Lake, Shoshone County, Idaho (type locality). Fig. 19: Lily Lake, Lemhi County, Idaho. Figs 22–24: *Stauroneis thompsonii* from the type locality.

Observations:—*Stauroneis thompsonii* was reported by Bahls (2010: 61) as *S.* aff. *catharinae* Van de Vijver & Lange-Bertalot (2004: 27). However, it has significantly wider valves and lower stria and areola densities than *S. catharinae*. It is known only from the type locality, a small lake in the Galton Range in northwest Montana (Fig. 25).

FIGURE 25: Wolverine Lakes in the Galton Range, northwest Montana. Upper Wolverine Lake (foreground) is the type locality of *Stauroneis thompsonii* and typical of habitats for *Stauroneis* species in the northern Rocky Mountains. Photo by the author.

Discussion

The genus *Stauroneis* is distinguished by having two plastids, a thickened central transverse stauros, and an almost equally thickened raphe sternum (Round et al. 1990). Moreover, *Stauroneis* is restricted to freshwater (Round et al. 1990) and moist subaerial habitats (Van de Vijver et al. 2004). These features separate *Stauroneis* from similar, mostly marine and brackish-water genera that have a single plastid and/or an unthickened stauros-like central fascia: *Craspedostauros* Cox (1999: 134), *Dickieia* Berk. ex Kützing (1844: 119), *Prestauroneis* Bruder & Medlin (2008: 325), *Stauronella* Mereschkowsky (1901: 430), *Staurophora* Mereschkowsky (1903: 20), and *Stauropsis* Meunier (1910: 318). Species-rich *Stauroneis* floras are found worldwide: In the Arctic and Antarctic (Kellogg & Kellogg 2002, Van de Vijver et al. 2004); at temperate latitudes (Bahls 2010, Lange-Bertalot et al. 2003); and in the tropics (Metzeltin & Lange-Bertalot 1998, 2007).

At the habitat scale, *Stauroneis* species tend to live in small, standing or slowly moving bodies of water (lakes, ponds, pools, fens, springs, seeps), often in association with macrophytes, or on wet soils and moss (Bahls 2010, Van de Vijver et al. 2004). Moreover, *Stauroneis* habitats tend to be oligotrophic or dystrophic, circumneutral or mildly acidic, and with low dissolved solids (Bahls 2010, Van de Vijver et al. 2004). Very few *Stauroneis* species are widely distributed in larger lakes and rivers, which tend to be polluted or otherwise disturbed by human activity and have alkaline pH and elevated nutrients and conductivity (Bahls 2010). In the Northwest United States—the area covered by the Montana Diatom Collection—*Stauroneis smithii* (Grunow 1860: 564) is the only *Stauroneis* species that consistently appears in large, alkaline, and eutrophic waters (Bahls 2010). When other species are present, *Stauroneis* is a reliable indicator of clean water and the near absence of human activity.

In addition to being relatively austere environments for diatoms, *Stauroneis* habitats also tend to be in remote locations and isolated from other diatom habitats, both hydrologically and ecologically. In the Northern Rockies, *Stauroneis* habitats are typically in roadless areas at moderate to higher elevations and lack surface connections with other waters, either upstream or downstream. The Wolverine Lakes shown in Fig. 25 are typical of *Stauroneis* habitats in the region. These lakes drain internally and lack surface outflows or inflows. Water quality in such habitats is very different from water quality in disturbed and polluted habitats downstream, isolating the resident diatoms ecologically as well as hydrologically.

As floristic studies on various continents extend into these remote, isolated and undisturbed habitats, we are finding that a large number of *Stauroneis* species are (1) new to science and (2) local or regional endemics: In the Northern Rockies, 52 *Stauroneis* species were reported, of which 21 are new to science (Bahls 2010, this paper); in the Arctic and Antarctic, 63 species were reported, of which 40 were described as new (Van de Vijver et al. 2004); in Sardinia, 31 species were reported, of which 17 were described as new (Lange-Bertalot et al. 2003); in tropical South America, Metzeltin & Lange-Bertalot (1998, 2007) described 19 new species of *Stauroneis*. The great majority of these recently described species are unknown outside of their home ranges.

These findings have enormous implications regarding our understanding of *Stauroneis* diversity. For example, Patrick & Reimer (1966) described only 15 species that are currently included in the genus *Stauroneis*. This relatively small number of species can be attributed to the limited geographic scope in sampling and the rather broad species concepts that prevailed at the time. In the Northern Rockies alone, there are at least 52 distinct species of *Stauroneis* (Bahls 2010). As more of these remote regions are surveyed for diatoms and more local and regional endemics are described, we will gain a much better perspective for estimating the true extent of *Stauroneis* diversity and the diversity of other freshwater genera (see below).

These findings also underscore the importance of habitat protection for conserving diatom biodiversity. Remote, isolated and undisturbed oligotrophic waters are hotspots of diatom biodiversity, as demonstrated by Lange-Bertalot & Metzeltin (1996). This is particularly true when one considers the totality of species-rich obligate freshwater genera, including *Eunotia*, *Frustulia*, *Neidium*, *Pinnularia* and *Stauroneis*. These waters serve as regional floristic reference sites and support unique native floras in habitats that have been largely undisturbed by human activities.

From the standpoint of bioconservation, protecting these habitats and their floras should be a high priority. In the Northern Rockies, most of the habitats that support populations of endemic diatoms are remote and lack road access (personal observation). Many of these have already been protected in National Parks, Wilderness Areas, and Research Natural Areas. But others remain vulnerable, including those on public lands where "multiple use" (logging, mining, livestock grazing, recreation) is the prevailing management strategy.

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