Three new species of the genus *Stauroneis* Ehrenberg (Bacillariophyceae: *Stauroneidaceae*) from the Northern Western Ghats, India

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Abstract: Three new species of the genus *Stauroneis* Ehrenberg are discovered from the Northern Western Ghats of India – *Stauroneis datarii* sp. nov., *Stauroneis bahlsii* sp. nov., and *Stauroneis hamiltonii* sp. nov. Based on light microscopy (LM) and scanning electron microscopy (SEM) observations, detailed morphological features are presented and each taxon is discussed in comparison with similar species within the genus. Features of linear–lanceolate valves with median constriction, rounded apices, bow–tie shaped stauros, and radiating striae characterize *Stauroneis datarii*. *Stauroneis bahlsii* has large, lanceolate valves, with obtusely–rounded apices, a bow–tie shaped stauros that may have isolated areolae in some valves. *Stauroneis hamiltonii* possesses linear–lanceolate valves, broadly rostrate apices, characteristic bow–tie shaped stauros, and radiate striae. All of the taxa share a characteristic pseudoseptum at the apices. The recent discoveries of many novel taxa from the terrestrial and semi–aquatic environments of the Northern Western Ghats highlight the role of non–aquatic habitats in unmasking the diatom diversity of the Indian subcontinent.

Key words: Bacillariophyta, Kaas plateau, new species, *Stauroneis*, taxonomy, Western Ghats

**INTRODUCTION**

The Western Ghats is a mountain range parallel to the west coast of peninsular India and represents one of the world’s most biologically diverse regions. This mountain range, combined with Sri Lanka, is recognized as one of the world’s 8th ‘hottest hotspots’ of biological diversity (Menon & Bawa 1997). The chain of mountains runs about 1600 km extending South from the Tapti River (21°N) to Kanyakumari (8 °N), interrupted by the 30 km Palghat Gap at around 11 °N (Menon & Bawa 1997). The Western Ghats can be divided into three regions: northern, central, and southern Western Ghats. The Northern area extends from Tapti in the north, running through Maharashtra and Goa’s states, to the River Kali in Karnataka about 700 km South (Shigwan et al. 2020). The diverse topography and climate create a wide range of habitats supporting a rich and unique flora and fauna. Thus, the Western Ghats is characterized by an exceptionally high biological diversity level and endemism (Groombridge 1992). Based on the present level of understanding (Gunawardene et al. 2007), endemism is highest in amphibians (78% of species reported), followed by molluscs (76%), reptiles (62%), evergreen trees (56%), fish (53%), lianas (40%), ants (20%), mammals (11%) and birds (4%). However, studies on this region’s microbial diversity are few and have only started relatively recently (Gandhi 1959, 1966, 1970; Karthick & Kociolek 2011, 2012; Suryanarayana et al. 2011; Alakananda et al. 2012; Radhakrishnan et al. 2018).

The northern parts of the Western Ghats are composed mostly of Deccan flood basalts, an igneous rock formed from the cooling of the Deccan Volcanic lava flows, which includes the bedrock of the western part of Maharashtra State. The Deccan Traps are mostly arranged in flat layers, giving rise to the Deccan plateau’s flat plains and the Western Ghats hills’ layered aspect characteristic in Maharashtra (Watve 2013). This unique geological history resulted in abundant rocky crevices. Thus, many unique aquatic habitats such as ephemeral pools on the lateritic rocky outcrop, small waterfalls, and wet walls along the mountain pass across the Northern region of the Western Ghats. These habitats are covered with algal biofilms during the southwest monsoon period (June – September). Our initial surveys in these habitats confirmed unique diatom assemblages even at the genus level, and our ongoing work has resulted in descriptions of many new taxa (Roy et al. 2019; Radhakrishnan...
et al. 2020). The current report describes three new species of the genus *Stauroneis* from the northern Western Ghats (Fig. 1), based on light (LM) and scanning electron microscopic (SEM) observations along with comparisons of similar *Stauroneis* taxa.

**Materials and Methods**

**Study Site.** The present study was conducted at two mountain passes (Kaas and Varandha Ghat sections) of India’s Northern Western Ghats.

**Sample Collection and Treatment.** Benthic diatom samples were collected by scraping substrates with spoons, transferring the algal biofilms into Whirl–Pak® storage bags, and then returning them to the lab in Pune. Water quality variables such as water temperature, pH, and electrical conductivity were measured in the field using an HQ40D portable multiparameter meter (Hach, Loveland, Colorado, USA). Nitrate and phosphate were also measured in the field, using a portable spectrophotometer DR1900 (Hach, Loveland, Colorado, USA) using Hach made chemicals (NitraVer® 6; PhosVer® 3 Phosphate). Geographical coordinates and elevation readings were taken using eTrex® 30x (Garmin®, Kansas, USA) instrument. For cleaning, a portion of each sample was mixed with equal volumes of concentrated HNO₃ and boiled to oxidize the organic matter for 90 minutes. Subsequently, the material then was alternately centrifuged at 3000 rpm and rinsed with distilled water several times until it attains a neutral pH. The cleaned material was air–dried onto glass coverslips, and the coverslips were subsequently mounted onto glass slides using Naphrax as a mounting medium (Refractive Index 1.73) for LM analysis. The slides were studied at 1000× magnification under oil immersion using an Olympus BX53 (Tokyo, Japan) microscope equipped with Differential Interference Contrast (Nomarski) optics, and images were captured with an Olympus DP 74 camera. Morphometric measurements (length, breadth, number of striae/10 μm at the centre, and apices) were noted for each species. For SEM analysis, the cleaned samples were dried onto glass coverslips (5mm × 5mm), affixed to aluminium stubs with double–sided carbon tape. Stubs were sputter–coated with gold–palladium with an Emitech K57SX sputter coater (Quorum Technologies, United Kingdom). SEM observations were performed with a Zeiss EVO MA 15 (Oberkochen, Germany) microscope with LaB₆ filament. LM and SEM images were processed in GIMP (version 2.10.24) and plates were compiled in Inkscape (version 0.92). For some LM images (Figs 25–32 and 44–51) to maintain the uniformity of the image size, cloned parts were created. Cleaned materials and slides are archived in the Diatom collection at Agharkar Research Institute Herbarium (AHMA), Pune, India. Morphological terminology follows Ross et al. (1979) and Barber & Haworth (1981).

**Results**

*Stauroneis datarii* Wadmare, Kociolek et B.Karthick sp. nov. (Figs 2–23)

**LM Description (Figs 2–13):** Valves linear–lanceolate with median area appearing very slightly constricted and apices rounded. Length 16.5–34.5 μm, breadth 3.7–5.5 μm. Axial area narrow at apices widening towards the centre to form a bow–tie shaped stauros. Raphe lateral, proximal raphe ends deflected, and distal raphe ends straight. Striae strongly radiate throughout 24–30/10 μm. Areolae distinct and dash–like. Pseudosepta evident in LM. For measurements, n = 47 valves.

**SEM Description (Figs 14–23):** Externally, valves linear–lanceolate with a narrow axial area wider at the centre (Figs 14, 15). Central stauros bow–tie–shaped without any striation (Fig. 16). Proximal raphe ends teardrop–shaped and bent slightly in the same direction (Fig. 16). Distal raphe ends sickle–shaped, continuing onto the mantle (Figs 17, 18). Striae composed of dash or hyphen–shaped areolae (Figs 14, 15).

Internally, valve mantle constricted at the central stauros (Figs 19, 20). Proximal raphe ends slightly deflected and terminating onto a well–developed, broad stauros (Fig. 21). Centre of stauros with distinct ridge present (Figs 20, 21). Distinct pseudoseptum present at each valve apex obscuring the distal raphe ends (Figs 22, 23). Hymenate occlusions bacilliform (Figs 21, 22).

**Holotype:** Specimen circled on microscope slide marked 03–67 accession #134 illustrated in Fig. 5, deposited at the Agharkar Herbarium of Maharashtra Association (AHMA) located at Agharkar Research Institute, Pune, India.

**Type Locality:** High altitude waterfall site, a cave located at Varandha Ghat road, (18.11281°N, 73.6077°E, altitude 691 meters above sea level), Maharashtra, India.

**Habitat:** Epilithic composite sample collected around the waterfall.

**Etymology:** This taxon is dedicated to Dr. Mandar Datar, Agharkar Research Institute, Pune, for his contributions in understanding the flowering plants in the Northern Western Ghats.

**Ecology:** pH – 7.17, EC (μS.cm⁻¹) – 37.33, DO (mg.l⁻¹) – 7.9, T (°C) – 24.10, N (mg.l⁻¹) – 1.4, P (mg.l⁻¹) – 0.24. The values mentioned above of the ecological parameters are single measurements corresponding to the time of collection. Various associated taxa dominate the sample belongs to *Gomphonema, Navicula, Frustulia* and *Pinnularia*.

The species that most closely resemble *Stauroneis datarii* is *Stauroneis sikkimensis N.Wadmare, S.Roy, Kociolek et B.Karthick described from moss habitats of Sikkim, India (WADMARE et al. 2019). It is differentiated from *S. datarii* by having bluntly or obtusely–rounded, non–protracted, apices, and the shape of the stauros, which is broad, and H–shaped. *Stauroneis lunndii* Hustedt, a freshwater species described from Europe, overlap valve dimensions (12–32 μm long and 4–5.5 μm broad) but has a more linear–lanceolate outline, subareolate apices and straight, non–inflated proximal raphe endings (HUSTEDT 1959). Valves of *S. atacaimae var. fuegensis Cleve–Euler, a freshwater species from Tierra del Fuego, Argentina, South America, are wider (7.0–7.5 μm), and they lack pseudosepta (CLEVE–EULER 1948). *S. distinguenda* Hustedt, described from moss habitats.
of Sumatra Island, Indonesia, is larger (42–57 μm long and 6 μm broad; HUSTEDT 1937; SIMONSEN 1987) than the new species described here. A striae density of 30–36 in 10 μm distinguishes S. datarii from S. cataractae Moser, Lange–Bertalot et Metzeltin, a freshwater species known from river habitats of New Caledonia (Moser et al. 1998). S. sphagnophila Krasske, also described from moss habitats, differs from the obtusely rounded apices as well as the stauros, which is broad, widened, and truncated towards the margin (KRASSKE 1948). Features used to distinguish Stauroneis datarii from a group of morphologically similar Stauroneis species are given in Table 1.

**Stauroneis bahlsii** Wadmare, Kociolek et B.Karthick sp. nov. (Figs 24–42)

**LM description** (Figs 24–32): Valves large, lanceolate, with blunt, obtusely-rounded apices. Length 63.5–124.5 μm, Breadth 12.0–19.5 μm. Axial area widens gradually towards the central area. Central stauros shaped like a bow–tie, widening towards the valve margin, possessing isolated areolae in some valves. Raphe filiform in the

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Fig. 1. Map showing the sampling sites of three new Stauroneis species described from the India. “Triangle” represents species from the Varandha Ghat and “Circle” from the Kass plateau region of the northern Western Ghats.

Figs 2–13. *Stauroneis datarii* sp. nov., light micrograph valve views showing size diminution series: (5) holotype specimen. Scale bar 10 μm.
Table 1. Comparison of morphological characteristics of taxa similar to Stauroneis datarii sp. nov.

<table>
<thead>
<tr>
<th>Features</th>
<th>Stauroneis datarii sp. nov.</th>
<th>S. lundii</th>
<th>S. atacamae var. fuegensis</th>
<th>S. distinguenda</th>
<th>S. cataractae</th>
<th>S. sphagnophila</th>
<th>S. sikkimensis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (μm)</td>
<td>16.5–34.4</td>
<td>12–32</td>
<td>33–40</td>
<td>42–57</td>
<td>22–28</td>
<td>16–26</td>
<td>17.9–37.6</td>
</tr>
<tr>
<td>Breadth (μm)</td>
<td>3.7–5.3</td>
<td>4–5</td>
<td>4-8-5.2</td>
<td>5</td>
<td>6</td>
<td>4,5</td>
<td>7,0-7,5</td>
</tr>
<tr>
<td>Valve shape</td>
<td>lanceolate with median depression</td>
<td>linear to linear-lanceolate</td>
<td>linear, with median depression</td>
<td>linear lanceolate, with median depression</td>
<td>linear elliptical, with slight median depression</td>
<td>linear lanceolate</td>
<td>lanceolate with median depression</td>
</tr>
<tr>
<td>Apex</td>
<td>acutely rounded</td>
<td>subrostrate</td>
<td>bluntly rounded</td>
<td>bluntly rounded</td>
<td>broadly rounded and tapered</td>
<td>obtusely rounded</td>
<td>bluntly or obtusely rounded, non-protracted</td>
</tr>
<tr>
<td>Central area</td>
<td>bowl-shaped</td>
<td>bow-tie shaped</td>
<td>expanded</td>
<td>expanded</td>
<td>strongly expanded</td>
<td>expanded</td>
<td>expanded or H-shaped</td>
</tr>
<tr>
<td>Central raphe endings, central pore</td>
<td>slightly curved</td>
<td>straight, not inflated</td>
<td>curved, small pin-point-like</td>
<td>curved, weakly expanded</td>
<td>slightly curved, small pin-point-like</td>
<td>straight, not inflated, small pin-point-like</td>
<td>slightly curved, expanded small pin-point-like</td>
</tr>
<tr>
<td>Striae (in 10 μm)</td>
<td>24-30</td>
<td>30</td>
<td>20</td>
<td>20-28</td>
<td>30-36</td>
<td>25</td>
<td>24-28</td>
</tr>
<tr>
<td>Striation pattern</td>
<td>radiate throughout</td>
<td>slightly curved, radiating</td>
<td>radiate throughout</td>
<td>radiate throughout</td>
<td>radiate throughout</td>
<td>radiate throughout</td>
<td>radiate throughout</td>
</tr>
<tr>
<td>Shape of the areolae</td>
<td>rounded</td>
<td>rounded</td>
<td>rounded to slightly elongated</td>
<td>slightly elongated</td>
<td>slightly elongated</td>
<td>rounded</td>
<td>rounded to elongated</td>
</tr>
<tr>
<td>Presence/absence of pseudosepta</td>
<td>present</td>
<td>absent</td>
<td>present</td>
<td>present</td>
<td>present</td>
<td>present</td>
<td>present</td>
</tr>
</tbody>
</table>

Figs 14–18. *Stauroneis datarii* sp. nov., SEM, external valve views: (14, 15) external view of an entire valve with distal raphe ends deflecting to the same side; (16) central stauros with teardrop–like raphe ends; (17, 18) details of apical area with sickle–shaped raphe ends. Scale bars 2 μm (14, 15), 1 μm (16–18).
centre, becoming lateral and remaining so to the distal raphe ends. Proximal raphe ends slightly dilated and curved in the same direction. Distal raphe ends curved in a direction opposite to proximal ends. Striae strongly radiate throughout, 19–23/10 μm. Areolae elongated to dash-like, distinct. Pseudo septa evident in LM. For measurements, n = 57 valves.

SEM Description (Figs 33–42): Externally, valves lanceolate with a narrow axial area that widens near the centre (Fig. 33). Central stauros broad, expanded (Fig. 34). Raphe expanded at the stauros (Fig. 34). Proximal raphe ends deflected (Fig. 34). Distal raphe ends sickle-shaped, continuing onto the mantle (Figs 35, 36). Striae composed of rounded to variously elongated areolae (Fig. 37).

Internally, the stauros is bow-tie-shaped and
expanded towards the margin (Figs 38, 40). Proximal raphe ends are slightly deflected and terminate on a well-developed, broad staurus (Fig. 40). Silica ridge present in the centre of staurus (Figs 38, 40). Distinct pseudoseptum present at each valve apex obscuring the distal raphe end (Figs 41, 42). Areolae distinct, dash- or hyphen-shaped (Fig. 39).

**Holotype:** Specimen circled on microscope slide marked 03–67 accession #134 illustrated in Fig. 28, deposited at the Agarkar Herbarium of Maharashtra Association (AHMA) located at Agarkar Research Institute, Pune, India.

**Type Locality:** High altitude waterfall site, a cave located at Varandha Ghat road, (18.11281°N, 73.6077°E, altitude 691 meters above sea level), Maharashtra, India.

**Habitat:** Epilithic composite sample collected around the waterfall.

**Etymology:** The species honours Dr. Loren Bahls from (Montana, USA) for his significant contribution to the genus *Stauroneis* in the Northern Rockies of North America.

**Ecology:** pH– 7.17, EC (µS.cm–1) – 37.33, DO (mg.l–1) – 7.9, T (°C) – 24.10, N (mg.l–1) – 1.4, P (mg.l–1) – 0.24. The values mentioned above of ecological parameters are single measurements corresponding to the time of collection. The sample is dominated by various associated taxa of *Gomphonema, Navicula, Frustulia* and *Pinnularia*.

*Stauroneis bahlsii* resembles *Stauroneis charrua* Metzeltin, Lange–Bertalot et Garcia–Rodriguez, described from Uruguay, in valve outline, but the latter taxon is broader (22–23 µm) and lacks pseudosepta (Metzeltin et al. 2005). *S. thompsonii* Bahls, a freshwater species described from rocks and sediments from Montana, USA, can be distinguished by having broader valves, (16.3–23.5 µm), rounded, non–protracted apices, and straight to weakly inflated central raphe endings (Bahls 2012). Furthermore, the valves of *S. kishinena* Bahls, another species described from Montana, are larger (122–182 µm), broader (26.33 µm), and have rounded areolae, all of which distinguish this species from *S. bahlsii* (Bahls 2010). *S. americana* Heiden differs from our species by having larger valves (136–214 µm long, 32–46 µm broad; Bahls 2010). Features used to distinguish *Stauroneis bahlsii* from a group of morphologically similar *Stauroneis* species are given in Table 2.

**Stauroneis hamiltonii** Wadmare, Kociolek et B.Karthick sp. nov. (Figs 43–59)

**LM description** (Figs 43–51): Valves linear–lanceolate with broadly rostrate ends. Length 30–61 µm, breadth 7.0–9.5 µm. Axial area linear, widening at the centre, forming a small staurus, usually bow–tie

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### Table 2. Comparison of morphological characteristics of taxa similar to *Stauroneis bahlsii* sp. nov.

<table>
<thead>
<tr>
<th>Features</th>
<th>Stauroneis bahlsii</th>
<th>S. charrua</th>
<th>S. thompsonii</th>
<th>S. kishinena</th>
<th>S. americana</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (µm)</td>
<td>63.5–124.4</td>
<td>84–110</td>
<td>122–182</td>
<td>136–214</td>
<td>126–192</td>
</tr>
<tr>
<td>Breadth (µm)</td>
<td>12.0–19.5</td>
<td>22–23</td>
<td>26.33</td>
<td>32–46</td>
<td>32–46</td>
</tr>
<tr>
<td>Valve shape</td>
<td>broadly lanceolate</td>
<td>lanceolate</td>
<td>lanceolate</td>
<td>broadly lanceolate</td>
<td>broadly lanceolate</td>
</tr>
<tr>
<td>Apex</td>
<td>blunt, obtusely rounded</td>
<td>bluntly rounded</td>
<td>rounded, non–protracted</td>
<td>rounded, subtly protracted</td>
<td>blunt, broadly rounded, non–protracted</td>
</tr>
<tr>
<td>Central area (Stauros)</td>
<td>bow–tie shaped</td>
<td>broad, expanding towards margin</td>
<td>nearly rectangular</td>
<td>rectangular</td>
<td>rectangular</td>
</tr>
<tr>
<td>Central raphe endings</td>
<td>slightly curved, deflected</td>
<td>slightly curved</td>
<td>strongly hooked</td>
<td>straight, weakly inflated</td>
<td>straight, deflected</td>
</tr>
<tr>
<td>Striae (in 10 µm)</td>
<td>19–23</td>
<td>15–16</td>
<td>11–12</td>
<td>11–14</td>
<td>11–14</td>
</tr>
<tr>
<td>Striation pattern</td>
<td>radiate throughout</td>
<td>radiate throughout</td>
<td>radiate throughout</td>
<td>radiate throughout</td>
<td>radiate throughout</td>
</tr>
<tr>
<td>Shape of the areolae</td>
<td>elongated</td>
<td>elongated</td>
<td>coarse, elongated</td>
<td>rounded</td>
<td>rounded</td>
</tr>
<tr>
<td>Presence/absence of pseudosepta</td>
<td>present</td>
<td>absent</td>
<td>present</td>
<td>present</td>
<td>present</td>
</tr>
</tbody>
</table>

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**References**

- Metzeltin et al. (2005)
- Bahls (2012)
- Bahls (2010)

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*Stauroneis hamiltonii* Wadmare, Kociolek et B.Karthick sp. nov. (Figs 43–59)

**LM description** (Figs 43–51): Valves linear–lanceolate with broadly rostrate ends. Length 30–61 µm, breadth 7.0–9.5 µm. Axial area linear, widening at the centre, forming a small staurus, usually bow–tie
shaped, rarely rectangular. Raphe filiform at the ends, lateral between the ends, with proximal raphe, ends teardrop–shaped, deflected in the same direction. Distal raphe ends deflected in the same direction. Striae strongly radiate throughout, 11–12/10 μm. Areolae are punctate to elongated, distinct in LM. Pseudosepta evident in LM. For measurements, n= 46 valves.

**SEM Description (Figs 52–59):** Externally, valves linear–lanceolate with a narrow axial area, which is wider at the centre (Fig. 52). Central stauros small, bow–tie shaped (Fig. 53). Proximal raphe ends teardrop–shaped and bent slightly in the same direction (Fig. 53). Distal raphe ends sickle–shaped, continuing onto the mantle (Figs 54, 55). Striae composed of dash–like to elongated areolae (Fig. 55).

Internally, central stauros small, thickened and expanded (Fig. 57). Proximal raphe ends slightly deflected and terminating onto a well–developed broad stauros, a distinct, longitudinally–oriented ridge present in the centre of stauros (Fig. 57). Distinct pseudoseptum present at each valve apex concealing the distal raphe end (Figs 56, 58, 59). Areolae hyphen–shaped with hymen occlusions (Figs 58, 59).

**Holotype:** Specimen circled on microscope slide marked 02–89 accession #95 illustrated in Fig. 45, deposited at the Agharkar Herbarium of Maharashtra Association (AHMA) Agharkar Research Institute, Pune, India.

**Type Locality:** Kaas plateau protected area, near Satara, (17.72635°N, 73.82249°E, altitude 1224 above mean sea level), Maharashtra, India.

**Habitat:** Benthic sample collected from a pool.

**Etymology:** The species is dedicated to Dr. Paul Hamilton (Museum of Nature, Ottawa, Canada) to acknowledge his work in diatom taxonomy.

**Ecology:** No water quality parameter observed during the collection. *Stauroneis hamiltonii* sp. nov. co–occurred with taxa of *Pinnularia, Navicula, Sellaphora* and *Adlafia. Stauroneis saprophila* M. Rybak, Noga et Ector, a saprobic species described from Poland’s anthropogenic environments, Europe, resembles *Stauroneis hamiltonii* sp. nov. in having a lanceolate outline, bow–tie shaped stauras, and a pseudoseptum. But *S. saprophila* differs in having straight central raphe endings with rounded to teardrop–shaped central pores (Noga et al. 2017). *S. pseudoschimanskii* Van de Vijver et Lange–Bertalot was found in semi–dry moss samples from South Georgia, in the sub–Antarctic region, and it resembles *S. hamiltonii* is the overall shape. This species from high southern latitudes differs, however, by having smaller valves (length 24–30 μm, breadth 6–7 μm), and much finer striae (23–24 in 10 μm) nearly twice the density as compared to the new species (Van de Vijver et al. 2004, p. 58). *S. intricans* Van de Vijver et Lange–Bertalot was described from an inland pool from Kvarossbukta, Jan Mayen, an island in the Arctic. This species is differentiated from *S. hamiltonii* by having central raphe endings that are straight and inconspicuous and much finer striae (23–27 in 10 μm; Van de Vijver et al. 2004, p. 43). *S. acidoclinata*
Figs 33–37. Stauroneis bahlsii sp. nov., SEM, external valve views: (33) external view of an entire valve; (34) broad stauros with deflected proximal raphe; (35, 36) sickle-shaped raphe continuing onto mantle; (37) view of rounded to variously elongated areolae. Scale bars 4 μm (33–36), 1 μm (37).
Figs 38-42. *Stauroneis bahlsii* sp. nov., SEM, internal valve views: (38) internal view of an entire valve; (39) hyphen–shaped areolae; (40) central area with broad stauros and silica ridge; (41, 42) Distal raphe ends obscured by distinct pseudoseptum. Scale bars 10 μm (38), 2 μm (40–42), 1 μm (39).
Lange–Bertalot et Werum, as the name suggests, is associated with acidic environments described from Bunter Sandstein, Germany. This species can be differentiated from \textit{S. hamiltonii} in having acutely–projected apices, non–deflected, central raphe endings, and finer striae (21–22/10 μm; \cite{Werum & Lange–Bertalot 2004}). Features used to distinguish \textit{Stauroneis hamiltonii} from a group of morphologically similar \textit{Stauroneis} species are given in Table 3.

### Discussion

The diatom genus \textit{Stauroneis} has been assigned over 1100 taxa and, in terms of several species and subspecific taxa, is one of the largest freshwater genera of diatoms \cite{Kociolek et al. 2020}. All of the species in \textit{Stauroneis} have thickened, an internally–elevated siliceous feature of a staurom, which lends its name to the genus and family in which these taxa occur. In terms of phylogenetic relationships, \cite{Hustedt 1952, Hustedt 1962} noted several groups within the genus based on morphological and ecological differences. Some of these groups have been recognized as distinct genera, including \textit{Capartogramma} with X–shaped central area (\cite{Ross 1963}, \textit{Schizostauron}, which includes monoraphid taxa (\cite{Grunow 1867}), \textit{Parlibellus} which includes estuarine and marine taxa (\cite{Cox 1988}), taxa possessing pseudosepta, as well as \textit{Prestauroneis}, where there is a small thickening at the central area \cite{Bruder & Medlin 2008, Liu et al. 2015}. These taxa and groups of species and the genus \textit{Craticula}, species of which do not have a staurom \cite{Spaulding et al. 2021}, have been included in the family Stauroneidae, based on formal analyses of relationships using molecular data \cite{Ashworth et al. 2017, Kulikovskiy et al. 2019}.

The material from the Northern Western Ghats reported here confirm that we observe species from several morphological groups of \textit{Stauroneis} present in the region. The three new species described here, \textit{S. datarii}, \textit{S. bahlsii}, and \textit{S. hamiltonii}, all possess pseudosepta. Pseudosepta are found in a wide range of taxa within \textit{Stauroneis}, including some very large taxa \cite[e.g., \textit{S. acuta} W. Smith, \textit{S. obtusa} Lagerstedt] and some relatively small taxa, such as the distinctive \textit{S. smithii} Grunow group \cite{Spaulding et al. 2021}. Assuming \textit{Stauroneis} is a monophyletic group, this diversity of forms within a genus found in the northern Western Ghats suggests different dispersal events of \textit{Stauroneis} taxa to the region. Alternatively, it may seem that several different lineages of diatoms have independently evolved a staurom (and thus \textit{Stauroneis} is not monophyletic;

### Table 3. Comparison of morphological characteristics of taxa similar to \textit{Stauroneis hamiltonii}

<table>
<thead>
<tr>
<th>Features</th>
<th>\textit{Stauroneis hamiltonii}</th>
<th>\textit{S. pseudoschimanskii}</th>
<th>\textit{S. intricata}</th>
<th>\textit{S. acuta}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valve shape</td>
<td>lanceolate</td>
<td>linear lancolate</td>
<td>linear lanceolate</td>
<td>elliptic lanceolate</td>
</tr>
<tr>
<td>Striation pattern</td>
<td>20–21 str</td>
<td>20–24 str</td>
<td>23–28 str</td>
<td>21–22 str</td>
</tr>
<tr>
<td>Striae (in 10 μm)</td>
<td>21–22</td>
<td>23–27</td>
<td>20–26</td>
<td>23–28</td>
</tr>
<tr>
<td>Raphe endings</td>
<td>central pore</td>
<td>central pore</td>
<td>central pore</td>
<td>central pore</td>
</tr>
<tr>
<td>Features</td>
<td>present</td>
<td>present</td>
<td>absent</td>
<td>present</td>
</tr>
<tr>
<td>Central area (Stauros)</td>
<td>moderately radiate throughout</td>
<td>straight, somewh deflected, straight, slightly incurved</td>
<td>straight, somewh deflected</td>
<td>straight</td>
</tr>
<tr>
<td>Length (μm)</td>
<td>24–30</td>
<td>24–44</td>
<td>23–75</td>
<td>21–22</td>
</tr>
<tr>
<td>Breadth (μm)</td>
<td>8.5–10.5</td>
<td>8.5–10.5</td>
<td>8.5–10.5</td>
<td>8.5–10.5</td>
</tr>
</tbody>
</table>

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see Kociolek et al. 2019), and some of these different lineages are present in the northern Western Ghats. To date, the few taxa of Stauroneis investigated in formal phylogenetic analyses confirm the genus to be monophyletic (Ashworth et al. 2017; Kulikovskiy et al. 2019; Wadmare et al., accepted). However, only a few species of the genus have been considered to date, and they do not reflect the tremendous range of morphological variation currently included in the genus. Our results attest to the diversity of unique taxa and forms present in India’s the Western Ghats. Finally, all of the taxa described here and previously (Radhakrishnan et al. 2018; Karthick & Kociolek 2011) from the Northern region of the Western Ghats originate from the semi-aquatic to terrestrial habitats, which signifies the role of the non-aquatic ecosystems in supporting the endemic biodiversity of this region.

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References
Bahls, L. (2012): Five new species of Stauroneis (Bacillariophyta, Stauroideidae) from the northern Rocky Mountains, USA. – Phytotaxa 67: 1–8. DOI: https://doi.org/10.11646/phytotaxa.67.1.1
Figs 52–55. Stauroeis hamiltonii sp. nov., SEM, external valve views: (52) external view of an entire valve; (53) small stauros with teardrop–like proximal raphe ends (54, 55) apices with sickle–shaped raphe. Scale bar 2 μm (52–55).


Karthick, B. & Kociolek, J.P. (2011): Four new centric diatoms (Bacillariophyceae) from the Western Ghats, South India. – Phytotaxa 22: 25–40. DOI: https://doi.org/10.11646/phytotaxa.22.1.2


Figs 56–59. Stauroneis hamiltonii sp. nov., SEM, internal valve views: (56) internal view of an entire valve; (57) central stauros small with distinct silica ridge; (58, 59) pseudosepta evident at the apices. Scale bar 2 μm (56–59).


