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Pinnularia sikkimensis sp. nov. (Bacillariophyceae), from Eastern Himalayas and its distribution in Southeast Asia

SUDIPTA KUMAR DAS^{1,6}, CHERAN RADHAKRISHNAN^{2,3,7}, MAXIM KULIKOVSKIY^{4,8}, ANTON GLUSHCHENKO^{4,9}, J. PATRICK KOCIOLEK^{5,10} & BALASUBRAMANIAN KARTHICK^{2,3,11*}

¹ Central National Herbarium, Botanical Survey of India, Howrah-711 103, India.

² Biodiversity and Palaeobiology Group, Agharkar Research Institute, Pune, Maharashtra-411004, India.

³ Affiliated to the Department of Environmental Science, Savitribai Phule Pune University, Ganeshkind, Pune, Maharashtra-411007, India.

⁴ Timiryazev Institute of Plant Physiology of RAS, IPP RAS, 35 Botanicheskaya St., Moscow, 127276, Russia.

⁵ Museum of Natural History and Department of Ecology and Evolutionary Biology, University of Colorado, Boulder, CO 80309, USA.

⁶ [✉ sudiptaalgae@gmail.com](mailto:sudiptaalgae@gmail.com); [ORCID: https://orcid.org/0000-0002-2355-8715](https://orcid.org/0000-0002-2355-8715)

⁷ [✉ radha.cheran@gmail.com](mailto:radha.cheran@gmail.com); [ORCID: https://orcid.org/0000-0003-2698-942X](https://orcid.org/0000-0003-2698-942X)

⁸ [✉ max-kulikovsky@yandex.ru](mailto:max-kulikovsky@yandex.ru); [ORCID: https://orcid.org/0000-0003-0999-9669](https://orcid.org/0000-0003-0999-9669)

⁹ [✉ chelovek91_91@mail.ru](mailto:chelovek91_91@mail.ru); [ORCID: https://orcid.org/0000-0002-3876-3455](https://orcid.org/0000-0002-3876-3455)

¹⁰ [✉ patrick.kociolek@colorado.edu](mailto:patrick.kociolek@colorado.edu); [ORCID: https://orcid.org/0000-0001-9824-7164](https://orcid.org/0000-0001-9824-7164)

¹¹ [✉ diatomist@gmail.com](mailto:diatomist@gmail.com); [ORCID: https://orcid.org/0000-0003-4066-2458](https://orcid.org/0000-0003-4066-2458)

*Corresponding author: [✉ karthickbala@aripune.org](mailto:karthickbala@aripune.org)

Abstract

A new species of *Pinnularia* is described from a stream from Sikkim, India, falls under Eastern Himalayas biodiversity hotspot. Features that help make this species distinctive include having triundulate margin, a broad, central fascia, a central depression, and oppositely-deflected external distal raphe fissures. *Pinnularia sikkimensis* sp. nov. is compared with its morphologically similar species, such as *Pinnularia nodosa*, *P. biceps*, *P. grunowii*, *P. septentrionalis*, *P. graciloides* var. *jogensis* and *P. ferrophila*. The taxon is also recorded from two stream sites in Vietnam suggesting a wide distribution across Southeast Asia. In addition to the description of the new species, a checklist of endemic *Pinnularia* taxa from India is also presented.

Keywords: new species, *Pinnularia*, distribution, India, Southeast Asia, endemic taxa

Introduction

Pinnularia (Ehrenberg 1843: 45) is a genus of biraphid diatoms, its species characterized by having linear-lanceolate valves with wide, alveolate striae. It is one of the genera with high species numbers, with just over 720 names (Kociolek *et al.* 2020). Members of the genus are widely recorded across the salinity and moisture gradients, ranging from freshwater, marine, brackish and aero-terrestrial habitats across the globe. However, members of this genus are mostly known from the oligotrophic habitats with acidic and low conductivity waters. Species delimitation within this genus has been defined by valve shape, striae density, the orientation of the raphe, and extent and shape of the central fascia (Krammer 2000). Recently Liu *et al.* (2018) presented a detailed monograph on the diversity of *Pinnularia* from the Great Xing'an Mountains, China, reporting a total of 89 taxa, of which 19 are new to science. Nearly 105 species and 80 infraspecific taxa were recorded so far from India. Among these, 61 taxa are endemic to India (Table 1), confined to Peninsular India. However, descriptions of new species of *Pinnularia* from the Himalayan region are rare, with only one taxon, *Pinnularia viridis* var. *rectangularis* Kant & Gupta (1998: 157), which was poorly described with no information on the type material. It appears to be nomenclaturally invalid.

The Eastern Himalayas include central Nepal, Myanmar, Bhutan, south-east Tibet in China, and a part of the north-eastern region of India. Floristically, it is very rich with nearly one third of the reported species being endemic to the region (Dhar 2002). Amidst the Eastern Himalayas, Sikkim is a very small state, yet it is rich in biodiversity afforded by a wide spectrum of ecological and microclimatic conditions (Forest Department Sikkim 2007).

Diatom studies in Indian Eastern Himalayan region are rare, with only a few recent reports (Das *et al.* 2018; Wadmare *et al.* 2019). In comparison, records of diatoms from the Nepalese Himalayas (Jüttner *et al.* 2004, 2010a, 2010b, 2011, 2017, 2018; Van de Vijver *et al.* 2011; Krstić *et al.* 2013; Wetzel *et al.* 2019) are numerous. In the present study, we describe a new species of *Pinnularia* from a stream in Sikkim (Eastern Himalayas), compare it to morphologically-similar congeners and discuss its distribution in Southeast Asia.

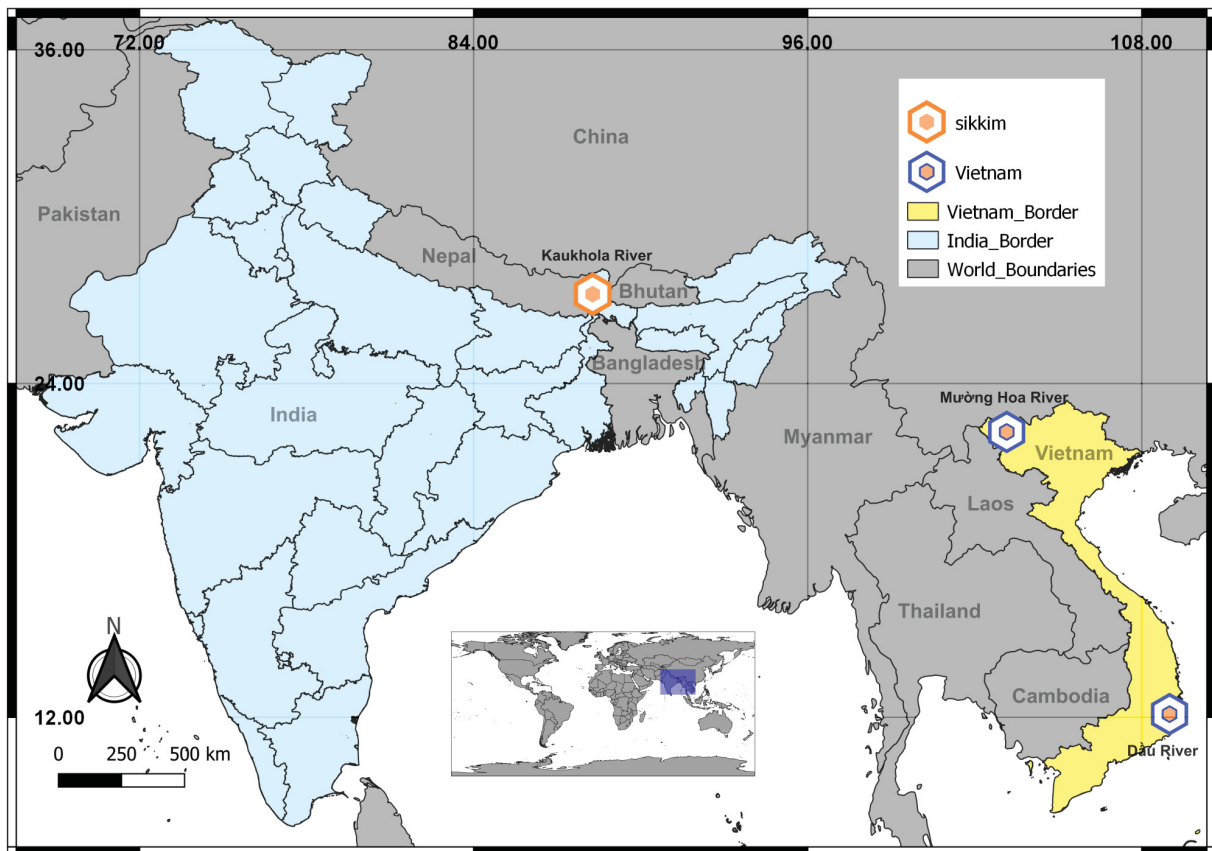
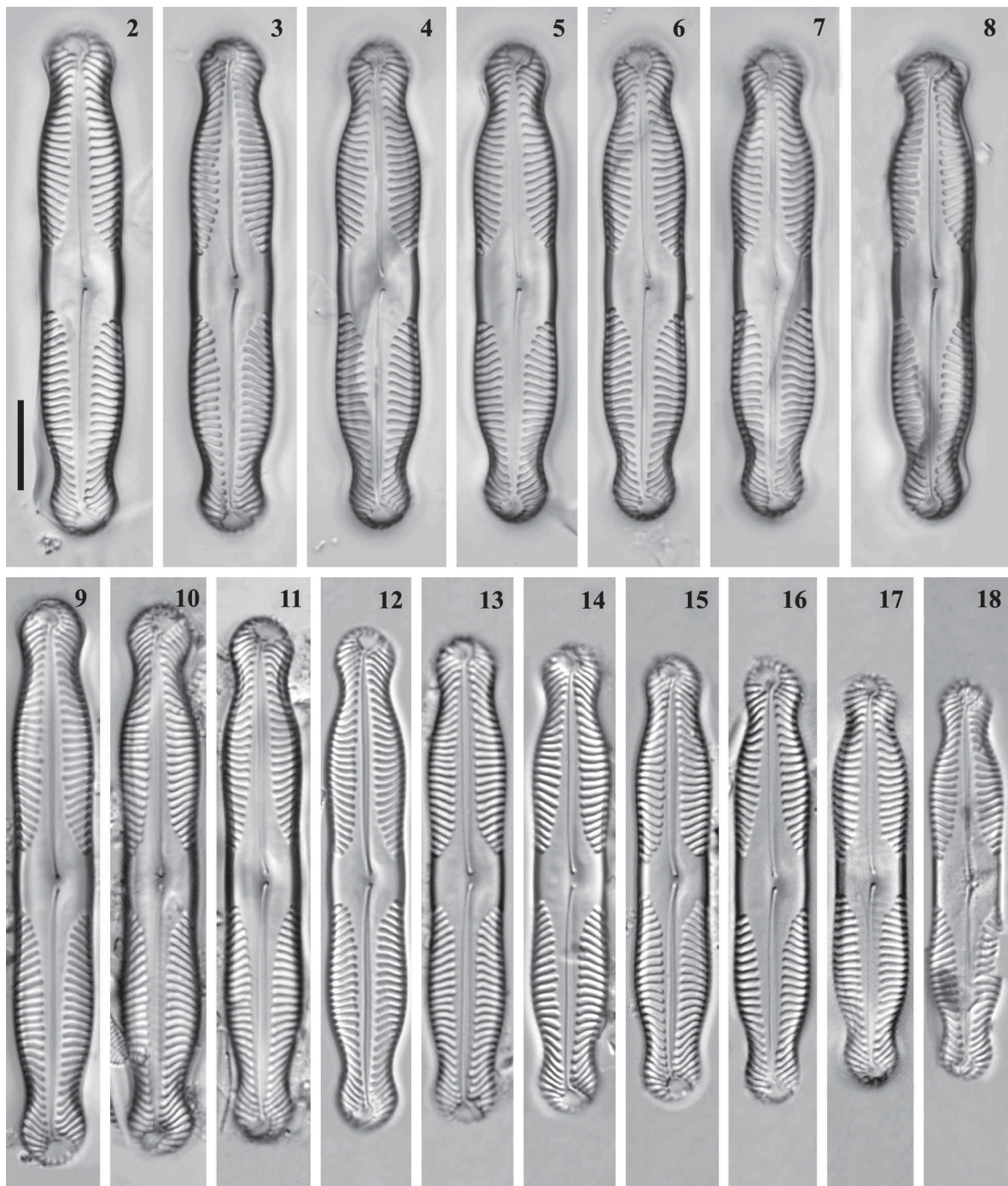


FIGURE 1. Map showing the type locality of *Pinnularia sikkimensis* sp. nov. and its distribution in Vietnam.

Materials and methods

The diatom samples were collected from epilithic habitats of partially submerged rocks near the bank of the stream near Kaukhola River, in South Sikkim district of Sikkim, India (N 27.210106, E 88.275501, 686 masl). The sampled stream is a small type-3 stream flowing across the pristine woodlands of South Sikkim until its confluence with Kaukhola River. Stones were scraped with the help of a toothbrush to remove that attached biofilm. Additional samples were collected from Vietnam by E.S. Gusev and M.S. Kulikovskiy, and designated no 00319 (Khánh Hòa Province, Hòn Bà Reserve, Dữu River, N 12.112806, E 108.998139, 2.07.2012, benthos) and 02084 (Lào Cai Province, near Sa Pa Town, Mững Hoa River (N 22.258167, E 103.148056, 10.05.2015, benthos) (Fig. 1). The collected brown materials were stored in a plastic container. In the laboratory, the samples were cleaned by boiling in concentrated nitric acid (HNO₃) to oxidize organic matter. Subsequently, the resulting material was alternately centrifuged and rinsed with distilled water several times until the sample attained a neutral pH. The cleaned suspension was air-dried onto coverslips and mounted with Naphrax® synthetic resin (refractive index 1.73). Light microscopy (LM) observations were made with an Olympus BX 53 (Tokyo, Japan), equipped with Differential Interference Contrast optics and images were captured with an Olympus DP 73 digital camera. The clean material was used for SEM observations. Cleaned diatoms were dried onto glass coverslips and affixed to aluminum stubs with double-sided carbon tape. Stubs with the cleaned material were sputter-coated with gold-palladium with an Emitech K575X sputter coater. SEM observations were performed with an EVO MA15, Carl Zeiss microscope with LaB6 filament. LM and SEM images were processed in GIMP (version 2.8.14) and plates were compiled with Inkscape (version 0.91). Cleaned material and slides are archived at the Diatom Collection at Agharkar Research Institute Herbarium (AHMA) and Central National Herbarium

(CAL), Howrah. Samples from Vietnam and slides are deposited in the public collection of Maxim Kulikovskiy at the Herbarium of the Institute of Plant Physiology of Russian Academy of Science, Moscow, Russia.



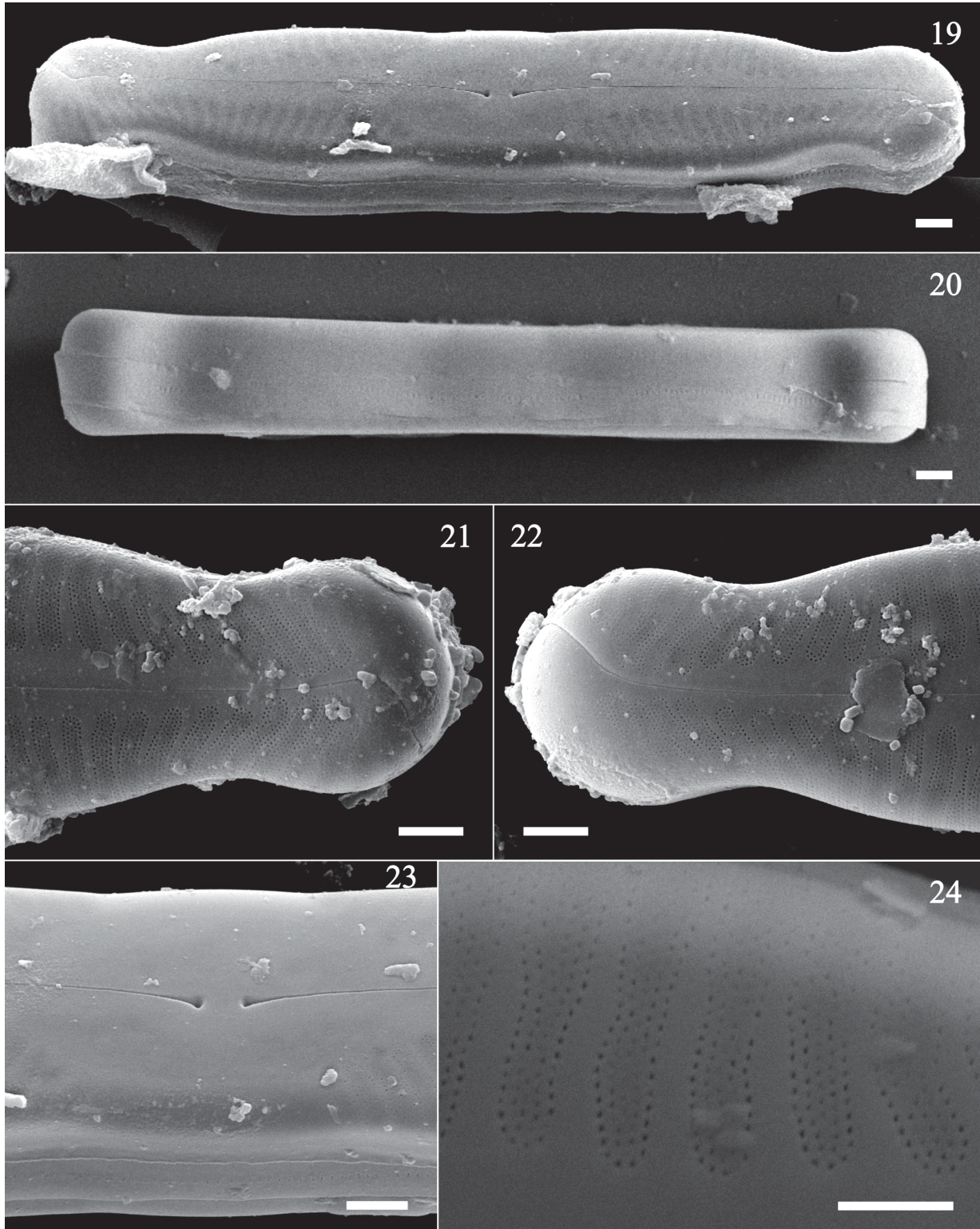
FIGURES 2–18. Light microscope images of *Pinnularia sikkimensis* sp. nov. Valve view showing the size diminution series. Figs 2–8, Samples from India. Figs 9–18, Samples from Vietnam. Figs 9, 12–14, 17 from slide no 00319; Figs 10, 11, 15, 18 from slide no 02084. Scale bar: Figs 2–18: 10 μ m.

Results

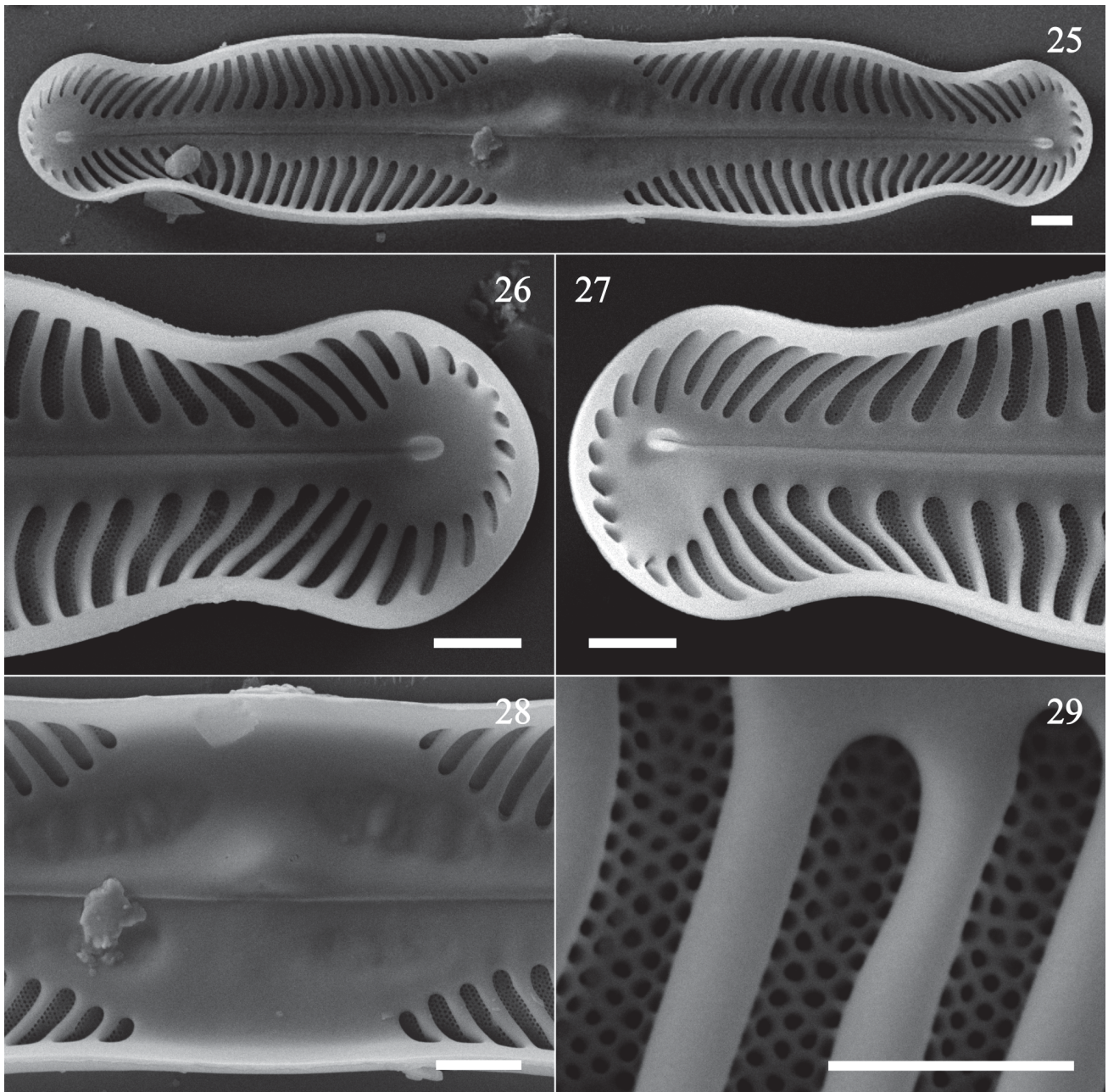
Description of new species

Pinnularia sikkimensis Sudipta K. Das, C. Radhakrishnan, Kociolek & B. Karthick sp. nov. (Figures 2–8, 19–29; holotype illustrated in Fig. 2)

LM Description (Figs 2–8):—Valves linear with triundulate margins. Central inflation is slightly narrower than other two. Apical area attenuated to capitate, rounded apices. Length 52.0–56.0 μm , breadth 9.0–9.5 μm , length/breadth ratio is 5.5–6.1. Raphe branches lateral, slightly arched. Drop-like expanded proximal raphe ends are deflected in the same direction. Distal raphe fissures deflected to opposite side and sickle-shaped, clearly discernible in LM. Axial area 1/3 width of valve, wider at center and narrower near apices. Central area rhombic with distinctly broad slightly asymmetric fascia. Striae broad, radiate in central area, convergent near apices, 9–11 in 10 μm .



FIGURES 19–24. *Pinnularia sikkimensis* sp. nov. SEM. 19. External view of the whole valve. 20. Girdle view of the whole valve. 21, 22. External view of poles showing the distal raphe endings. 23. External view of valve centre, showing the proximal raphe endings. 24. Magnified view of striae patterns showing small areolae and covered by silicified hymens. Scale bars: Figs 19, 20: 2 μm ; Figs 21–24 = 1 μm .



FIGURES 25–29. *Pinnularia sikkimensis* sp. nov. SEM. **25.** Internal view of a whole valve. **26, 27.** Internal view of poles showing the helictoglossae. **28.** Internal view of center valve showing the central depression. **29.** Magnified view of striae pattern showing the internal structure of areolae. Scale bars: Figs 25–28: 2 μ m; Fig. 29 = 1 μ m.

SEM Description (Figs 19–29):—In the SEM, external valve views show the external proximal raphe ends bent in one direction and slightly dilated (Fig. 19). Distal raphe ends are hooked in the opposite direction as that in the proximal ends (Figs 19, 21–23). Striae composed of 4–6 rows of small areolae and covered by silicified hymens (Fig. 24). Internally, the alveolus is open, with areolae 36–50 nm in diameter, 7–8 in 1 μ m (Fig. 29). Raphe branches straight (Fig. 25), terminating as helictoglossae which are placed eccentrically from the apical axis of the valve (Figs 26, 27). Central nodule is slightly raised, with several spherical to elliptical, sometimes irregularly-shaped depressions around it. The raphe is covered at the central nodule, giving the appearance of a lack of intermission (Fig. 28).

HOLOTYPE (designated here):—Slide #27–51, Sample #1326; deposited at the Diatom Collection, Agharkar Research Institute Herbarium (AHMA), Pune, India. **ISOTYPE:** CAL/ALG. 59, Central National Herbarium Botanical Survey of India, Kolkata, India.

ETYMOLOGY:—The species name refers to the name of the Indian state from where the new species is discovered: Sikkim.

TYPE LOCALITY:—India, Sikkim, South Sikkim District, stream, near Kaukhola River (N 27.210106, E 88.275701, 686 masl.).

DISTRIBUTION:—The specimens of *P. sikkimensis*, recorded from the epilithic habitat; Vietnam, Khánh Hòa Province, Hòn Bà Reserve, Dầu River (N 12.112806, E 108.998139) and Lào Cai Province, near Sa Pa Town, Mýòng Hoa River (N 22.258167, E 103.148056), benthos.

REMARKS:—Specimens observed from Dau river, Vietnam have slightly larger valve length (46.5–66.5 µm) and smaller width (7.2–9.0 µm) in comparison to the type population from the Eastern Himalayas.

Discussion

Nearly one third of *Pinnularia* taxa, recorded from India are potentially endemic (Table 1), as none of these taxa were recorded from adjoining or Southeast Asia countries. In this context, the description of a new species *P. sikkimensis* from the eastern Himalayas as well as Vietnam, suggests that some taxa are wide spread across the Southeast Asia. Foged (1976) recorded many new species described from Western Ghats from Sri Lanka and recent study by Pardhi *et al.* (in review) from India and Vietnam confirms distribution of few *Gomphonema* across both regions. The sharing of regional endemics might be extending to entire tropical Asia, which is evident from the reporting of *Kulikovskiyia* S.Roy, Kociolek, Liu *et al.* B.Karthick (2020: 83) from the Western Ghats of India and Hainan Province of China (Roy *et al.* 2020). All these observations support the claim of Asia as one of the global diatom diversity hotspots (Kociolek 2018). Among the taxa listed in Table. 1, only taxa described by Gandhi's are connected to a collection or in traceable situation. The collections associated with all other names are lost or untraceable, which makes the reassessing scenario difficult and need for the new collection from the all biogeographic zones of the Indian subcontinent.

TABLE 1. List of *Pinnularia* species endemic to India.

Name of the taxa	Type Locality	References
<i>Pinnularia acrosphaeria</i> W.Sm. var. <i>turgida</i> Bhosale <i>et al.</i>	Pond, Sangli, Maharashtra	Bhosale <i>et al.</i> 2012
<i>Pinnularia aestuarii</i> Cleve var. <i>lata</i> H.P.Gandhi	Paddy fields, Mugad, Karnataka	Gandhi 1957
<i>Pinnularia amaniensis</i> Hust. f. <i>indica</i> Sarode & N.D.Kamat	Lake, Nagpur, Maharashtra	Sarode & Kamat 1984
<i>Pinnularia borealis</i> Ehrenb. var. <i>barodensis</i> H.P.Gandhi	Pools and ditches, Baroda, Gujarat	Gandhi 1998
<i>Pinnularia borealis</i> Ehrenb. var. <i>lonavlensis</i> H.P.Gandhi	Pools and wet mosses, Lonavala, Maharashtra	Gandhi 1962b
<i>Pinnularia braunii</i> (Grunow) Cleve var. <i>amphicephala</i> (Mayer) Hust. f. <i>subconica</i> Venkataram.	Pools near Elliot beach, Chennai, Tamil Nadu	Venkataraman 1939
<i>Pinnularia braunii</i> (Grunow) Cleve var. <i>constricta</i> B.N.Prasad & M.N.Srivast.	Pond, Mile-Tilak, South Andaman, Andaman & Nicobar Islands	Prasad & Srivastava 1992
<i>Pinnularia brevicostata</i> Cleve var. <i>indica</i> H.P.Gandhi	Borivali streams and Powai lake, Mumbai, Maharashtra	Gandhi 1960b
<i>Pinnularia conica</i> H.P.Gandhi	Paddy fields and road side pools, Mugad, Karnataka	Gandhi 1957
<i>Pinnularia divergentissimoides</i> H.P.Gandhi	Jog falls, Mysore, Karnataka	Gandhi 1970
<i>Pinnularia dolosa</i> H.P.Gandhi var. <i>dolosa</i>	Pond, Andheri, Mumbai, Maharashtra	Gandhi 1960b

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TABLE 1. (Continued)

Name of the taxa	Type Locality	References
<i>Pinnularia dolosa</i> H.P.Gandhi var. <i>atpadiensis</i> Bhosale <i>et al.</i>	Pond, Sangli, Maharashtra	Bhosale <i>et al.</i> 2012
<i>Pinnularia dolosa</i> H.P.Gandhi var. <i>chariessa</i> H.P.Gandhi	Pond, Andheri, Mumbai, Maharashtra	Gandhi 1960b
<i>Pinnularia dolosa</i> H.P.Gandhi var. <i>tumida</i> Bhosale <i>et al.</i>	Pond, Sangli, Maharashtra	Bhosale <i>et al.</i> 2012
<i>Pinnularia dubiosa</i> H.P.Gandhi	Jog falls, Mysore, Karnataka	Gandhi 1966
<i>Pinnularia episcopalis</i> Cleve var. <i>elongata</i> J.Thomas & Gonzalves	Rajewadi hot spring, Ratnagiri, Maharashtra	Thomas & Gonzalves 1965b
<i>Pinnularia esox</i> Ehrenb. var. <i>capitata</i> H.P.Gandhi	Paddy fields, Mugad, Karnataka	Gandhi 1957
<i>Pinnularia esox</i> Ehrenb. var. <i>fasciata</i> H.P.Gandhi	Paddy fields, Mugad, Karnataka	Gandhi 1957
<i>Pinnularia gibba</i> (Ehrenb). Ehrenb. f. <i>undulata</i> Venkataram.	Irrigation tank, Vandalur, Chennai, Tamil Nadu	Venkataraman 1939
<i>Pinnularia graciloides</i> Hust. var. <i>jogensis</i> H.P.Gandhi	Jog falls, Mysore, Karnataka	Gandhi 1966
<i>Pinnularia interrupta</i> W.Sm. var. <i>singhai</i> S.K.Sinha & O.N.Srivast.	Pond, Ranchi, Jharkhand	Sinha & Srivastava 1989
<i>Pinnularia kalapanensis</i> B.N.Prasad & M.N.Srivast.	Pond, Mile-Tilak, South Andaman, Andaman & Nicobar Islands	Prasad & Srivastava 1992
<i>Pinnularia karnatika</i> H.P.Gandhi	Paddy fields, Mugad, Karnataka	Gandhi 1957
<i>Pinnularia kolhapurensis</i> H.P.Gandhi	Rankala tank, Kolhapur, Maharashtra	Gandhi 1958
<i>Pinnularia lacus-biwa</i> Skvortzow f. <i>minor</i> H.P.Gandhi	Borivali streams, Powai lake and Vihar lake, Mumbai, Maharashtra	Gandhi 1960b
<i>Pinnularia legumen</i> Ehrenb. var. <i>interrupta</i> H.P.Gandhi	Stream, Panhalgarh hill fort, Kolhapur, Maharashtra	Gandhi 1959a
<i>Pinnularia lonavlensis</i> H.P.Gandhi	Pools, Lonavla, Maharashtra	Gandhi 1962b
<i>Pinnularia macra</i> H.P.Gandhi	Reservoir, Ahmedabad, Gujarat	Gandhi 1961
<i>Pinnularia maharashtrensis</i> Sarode & N.D.Kamat	Stagnant surface water, Gangapur, Maharashtra	Sarode & Kamat 1984
<i>Pinnularia marathwadensis</i> Sarode & N.D.Kamat	Lake Bindusara, Pali, Maharashtra	Sarode & Kamat 1984
<i>Pinnularia mesolepta</i> Ehrenb. var. <i>indica</i> H.P.Gandhi	Pond, Wadala, Mumbai, Maharashtra	Gandhi 1960b
<i>Pinnularia mysorensis</i> H.P.Gandhi	Pools and puddles, Sagar, Karnataka	Gandhi 1959b
<i>Pinnularia nakaii</i> Skvortzow var. <i>indica</i> H.P.Gandhi	Powai lake, Mumbai, Maharashtra	Gandhi 1960b
<i>Pinnularia neglecta</i> (Mayer) Åke Berg. var. <i>interrupta</i> H.P.Gandhi	Paddy fields and road side pool, Mugad, Karnataka	Gandhi 1957
<i>Pinnularia neglecta</i> (Mayer) Åke Berg. var. <i>minor</i> Bhosale <i>et al.</i>	Pond, Sangli, Maharashtra	Bhosale <i>et al.</i> 2012

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TABLE 1 (Continued)

Name of the taxa	Type Locality	References
<i>Pinnularia neglecta</i> (Mayer) Åke Berg. var. <i>undulata</i> H.P.Gandhi	Borivali stream and Powai lakes, Mumbai, Maharashtra	Gandhi 1960b
<i>Pinnularia panhalgarhensis</i> H.P.Gandhi var. <i>panhalgarhensis</i>	Stream, Panhalgarh hill fort, Kolhapur, Maharashtra	Gandhi 1959a
<i>Pinnularia panhalgarhensis</i> H.P.Gandhi var. <i>lanceolata</i> H.P.Gandhi	Stream, Panhalgarh hill fort, Kolhapur, Maharashtra	Gandhi 1959a
<i>Pinnularia paucicostis</i> H.P.Gandhi	Jog falls, Mysore, Karnataka	Gandhi 1966
<i>Pinnularia platycephala</i> (Ehrenb.) Cleve f. <i>khanapurensis</i> Bhosale <i>et al.</i>	Pond, Sangli, Maharashtra	Bhosale <i>et al.</i> 2012
<i>Pinnularia pseudoluculenta</i> H.P.Gandhi	Borivali stream, Powai lake and Vihar lake, Mumbai, Maharashtra	Gandhi 1960b
<i>Pinnularia pseudomicrostauron</i> H.P.Gandhi	Pools and ditches, Ahmedabad, Gujarat	Gandhi 1962a
<i>Pinnularia pusilla</i> H.P.Gandhi	Stream, Panhalgarh hill fort, Kolhapur, Maharashtra	Gandhi 1959a
<i>Pinnularia sagittata</i> H.P.Gandhi var. <i>sagittata</i>	Pools and ditches, Sagar, Karnataka	Gandhi 1959b
<i>Pinnularia sagittata</i> H.P.Gandhi var. <i>bhandarensis</i> Sarode & N.D.Kamat	Lake Abkari, Bhandara, Maharashtra	Sarode & Kamat 1984
<i>Pinnularia sahyadrense</i> H.P.Gandhi	Jog falls, Mysore, Karnataka	Gandhi 1966
<i>Pinnularia santapau</i> J.Thomas & Gonzalves	Palli hot spring, Mumbai, Maharashtra	Thomas & Gonzalves 1965a
<i>Pinnularia schweinfurthi</i> H.P.Gandhi	Jog falls, Mysore, Karnataka	Gandhi 1970
<i>Pinnularia simplex</i> H.P.Gandhi	Pools, Wadala and Andheri, Mumbai, Maharashtra	Gandhi 1960b
<i>Pinnularia stomatophora</i> (Grunow) Cleve var. <i>gibbosa</i> Hust. f. <i>jogensis</i> H.P.Gandhi	Jog falls, Mysore, Karnataka	Gandhi 1970
<i>Pinnularia subgracilloides</i> H.P.Gandhi	Jog falls, Mysore, Karnataka	Gandhi 1970
<i>Pinnularia subsimilis</i> H.P.Gandhi	Jog falls, Mysore, Karnataka	Gandhi 1970
<i>Pinnularia sudetica</i> Hilse var. <i>commutata</i> (Grun. ex A.W.F.Schmidt) A.Cleve f. <i>obtusata</i> H.P.Gandhi	Stream, Panhalgarh hill fort, Kolhapur, Maharashtra	Gandhi 1959a
<i>Pinnularia surajkundensis</i> B.N.Prasad <i>et al.</i>	Reservoir, Surajkund, Haryana	Prasad <i>et al.</i> 1981
<i>Pinnularia termes</i> Ehrenb. var. <i>terminta</i> (Ehrenb.) A.Cleve f. <i>tumida</i> Bhosale <i>et al.</i>	Pond, Sangli, Maharashtra	Bhosale <i>et al.</i> 2012
<i>Pinnularia ueno</i> Skvortzow var. <i>wadalensis</i> H.P.Gandhi	Pond, Wadala, Mumbai, Maharashtra	Gandhi 1960b
<i>Pinnularia venkateswarii</i> Sarode & N.D.Kamat	Stagnant surface water, Bhandara, Maharashtra	Sarode & Kamat 1984
<i>Pinnularia vidarbhensis</i> Sarode & N.D.Kamat	Stagnant surface water, Katta, Maharashtra	Sarode & Kamat 1984
<i>Pinnularia viridis</i> (Nitzsch) Ehrenb. var. <i>curviraphe</i> H.P.Gandhi	Jog falls, Mysore, Karnataka	Gandhi 1960a
<i>Pinnularia viridis</i> (Nitzsch) Ehrenb. var. <i>rectangularis</i> Kant & P.Gupta	Stream, Ladakh, Jammu & Kashmir	Kant & Gupta 1998
<i>Pinnularia viridis</i> (Nitzsch) Ehrenb. var. <i>turgidus</i> C.S.Singh	Ganga river, Varanasi, Uttar Pradesh	Singh 1963

TABLE 2. Comparative morphological features of *Pinnularia sikkimensis* sp. nov with other similar species.

Morphological features	<i>Pinnularia sikkimensis</i> sp.nov	<i>Pinnularia nodosa</i> (Ehrenberg) W. Smith	<i>Pinnularia biceps</i> Gregory	<i>Pinnularia grunowii</i> Krammer	<i>Pinnularia septentrionalis</i> Krammer	<i>Pinnularia graciloides</i> var. <i>jogensis</i> Gandhi	<i>Pinnularia</i> <i>ferrophiila</i> Krammer
References	Present study	Krammer 2000	Krammer 2000	Krammer 2000	Krammer 2000	Gandhi 1966	Krammer 2000
Valve length (µm)	44–63	25–72	48–85	27–55	42–70	92.4–100	30–62
Valve width (µm)	8.7–10	5.3–9	11–13	6.5–9	10–15	14.3–15	8.8–10
Valve outlines	Linear	Linear to linear-lanceolate	Linear	Linear	Linear	Linear	Linear
Margin	Triundulate margin	Straight to triundulate	Straight, or very slightly triundulate	Moderately triundulate	Triundulate	Triundulate	Slightly triundulate
Valve apices	Capitate to rounded apices	Protracted or capitate	Ends capitate	Ends capitate, but broad and obtusely rounded	Capitate with broad shoulders	Rounded capitate	Rounded capitate
Central area	The central area is a Bilateral and Broad fascia	The central area is a Bilateral, sometimes unilateral, fascia	The central area is a Rhombic and irregular, small asymmetric fascia	The central area is a Rhombic and short or moderately broad fascia	Rhombic, widened to the margin as small fascia	Rhomboid, large fascia	Rhomboid and Broad fascia
Number of striae in 10 µm	9–11	8–12	9–13	11–14	10–11	8–10	9–10
Striae pattern	Striae radial in middle and more radiate towards the apices	Parallel or Slightly radiate in middle	Radiate in the middle, towards ends convergent	Radiate in the middle, strongly convergent towards the ends	Strongly radiate in the middle, convergent towards the end	Strongly radiate in the middle, convergent towards the end	Radiate in the middle, convergent at the ends
Central depression	Present. Elliptical, sometimes irregular shape	Absent	Absent	Absent	Absent	Absent	Absent
Raphe	Straight to filiform	Weakly lateral	Filiform to slightly lateral	Straight to filiform	Slightly lateral, outer fissures commonly straight	Slightly unilateral	Moderately lateral
Terminal raphe fissures	Deflected to the opposite side	Deflected to the same side	Deflected to the same side	Deflected to the same side	Deflected to the same side	Deflected to the same side	Deflected to the same side

Pinnularia sikkimensis sp. nov. is similar to several other *Pinnularia* taxa in the shape of the valves, possessing triundulate outlines. A comparative morphological account of our species with the similar ones is presented in Table 2. In comparing our new species with those considered by Krammer (1992, 2000), we should note that in neither of these monographs did Krammer consider specimens from Asia. While this might not be surprising, given one of them has the subtitle (“eine Monographie der europäischen Taxa”; Krammer 1992) and the other was published in the series “Diatoms of Europe” (Krammer 2000), the latter work includes taxa from North America, South America, New Zealand and New Caledonia. Our new species is similar in outline to *P. nodosa* (Ehrenb.) W. Smith (1856: 96), *P. septentrionalis* Krammer (2000: 103), and *P. ferrophila* Krammer (2000:107)

With respect to *P. septentrionalis*, Krammer’s (1992) view of *P. mesolepta* (Ehrenb.) W. Smith (1853: 58) was with wider valves, recognizing the species and five morphotypes. The closest of these morphotypes was his morphotype 5, encompassing the concept of *P. mesolepta* of Hustedt (1938) in his paper on Java, Bali and Sumatra. Krammer later proposed a new name for this taxon at the species level, proposing *P. septentrionalis* Krammer for Grunow’s *Navicula mesolepta* var. *stauroneiformis* (Grunow 1860: 520), but he illustrated only specimens from northern Europe. While Krammer (2000) indicated “*nov. spec.*” in the figure legends of the plate on which this species was illustrated, in this case he did not describe a new species. His designation of “*nom. nov., stat. nov.*” with the species description for *P. septentrionalis* is correct, as he was proposing a new name for recognizing this taxon at the level of species (Krammer 2000). The species from Sikkim differs from these specimens of *P. septentrionalis* illustrated from Europe by being more linear and having less pronounced undulations, in having a comparatively wider central fascia, and the presence of elliptical to irregularly-shaped depressions in the central area. *Pinnularia ferrophila* has indistinct triundulation in the valve margin and rhomboid central area which differentiates it from our described species. It is worth noting that Gandhi reported *P. mesolepta* var. *stauroneiformis* (Grunow) Cleve (1895: 76) in his treatment of diatoms from Bombay and Salsette Islands (Gandhi 1960a), which is also a triundulate species. *Pinnularia sikkimensis* differs from *P. mesolepta* var. *stauroneiformis* by rhombic central area. *Pinnularia nodosa* valves are more linear in outline than *P. sikkimensis* and also lack a broad fascia as well as central depression. The valves of *P. grunowii* Krammer (2000: 100) are 1.2–1.5 times smaller than the present species, with moderate undulations in the margin and closely distributed striae. The central area in all the taxa is rhombic, but the fascia in *Pinnularia sikkimensis* is broader compared to *P. grunowii*. Likewise, in comparison to *P. biceps* Gregory (1856: 8), our species is not only with smaller valve width, but also has distinct triundulate margin.

A recent study by Liu *et al.* (2018) recorded nearly 20% of endemism in the *Pinnularia* diversity from the Great Xing’an Mountain region. In their treatment of the genus from this locality in China, the only triundulate species they reported was *P. turbulenta* (A.Cleve) Krammer (2000: 100). As shown by Liu *et al.* (2018), this species has quite pronounced marginal undulations, which differentiates it from *P. sikkimensis*. This interpretation is aligned with the interpretation of this taxon by Krammer, based on his review of European specimens (Krammer 2000).

Gandhi (1966) described *Pinnularia graciloides* var. *jogensis* Gandhi (1966: 154), a triundulate taxon from the Jog Falls of Western Ghats region. Gandhi’s taxon differs from *P. sikkimensis* by being more linear in outline, small central area and the headpole is more protracted than what is seen in the new species from Sikkim. Another triundulate taxon described by Gandhi is *P. esox* Ehrenberg var. *capitata* Gandhi (1957: 849) from Mugad (Gandhi 1957) which is characterized by wedge shaped apices, whereas *P. sikkimensis* possess rounded apices.

Discovery of this new species from Indian subcontinent and Southeast Asia continues our comprehensive investigation of diatom floras from these regions. Well-documented studies of diatoms from these poorly-investigated regions will be important for understanding diatom biogeography and the origin and subsequent changes in the floras over time. This investigation is strengthening our knowledge of diatom diversity in these regions of Asia.

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