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Research Article

On the Occurrence of Four Diatom Taxa from Eastern India with a Taxonomic Note

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Diatoms were collected from the Kotulpur area of West Bengal. Four diatom taxa, namely, *Eunotia minor* (Kützing) Grunow, *Achnanthidium minutissimum* (Kützing) Czarnecki, *Lemnicola hungarica* (Grunow) Round and Basson, and *Navicula radiosa* Kützing were observed using scanning electron microscopy (SEM) and identified in light of modern diatom taxonomic trends. Except *Eunotia minor*, all these taxa are new records to Eastern India. A note on the taxonomy of *Achnanthes pseudobiasolletiana* as described by Gandhi and *Eunotia serrata* var. *diadema* (Ehr.) R. M. Patrick as reported by Dwivedi and Misra has been added.

1. Introduction

Diatoms are a very important group of algae as they are the most common producers of organic matter in water bodies. According to Prygiel et al. [1] diatoms are good bioindicators responding quickly to environmental changes. During the 19th century, diatoms were studied for the first time in India by Ehrenberg [2]. Subsequent notable works were made by Skvortzow [3], Biswas [4], Krishnamurthy [5], Venkataraman [6], and Sarode and Kamat [7] as well as 34 papers with a book on diatom taxonomy by Gandhi [8].

Though several hundreds of papers dealing with diatom taxonomy of Indian regions were published, most of them are limited to line drawings or bright field microscopic images, which have limited information on the ultrastructural details of diatoms. Further, some of the taxa have broad species concepts and follow an old classification system. The main reason behind these taxonomic identification problems was the scarcity of ultramodern scanning and light microscopes and up to date scientific literature.

The work on Indian fresh water diatoms is still in an early stage, but breakthroughs were initiated by Karthick and Kociolek [9–11], Karthick et al. [12–14], and Alakananda et al. [15, 16] and to some extent by Wojtal et al. [17] and Roy and Keshri [18] following modern trends of diatom taxonomy.

The main purpose of this study was to examine the diatom diversity of eastern India in light of current systematic trends. Since diatom studies in eastern India were done very sporadic (Skvortzow [3], Prasad et al. [19], and Roy and Keshri [18]), this study adds new information on the diversity and taxonomy of this group in this part of the globe.

2. Materials and Methods

2.1. Study Area and Sample Collection. The study area covered small ponds of Kotulpur from Bankura district in West Bengal, India. Kotulpur is situated at 23.0125°N latitude and 87.5936°E longitude. Diatom materials were collected from Kotulpur on 24.10.2014. Epiphytic, epilithic, and episammic materials were collected and preserved in 70% ethanol.

2.2. Cleaning Techniques and Microscopy. Subsamples were cleaned using 30% hydrogen peroxide solution for removal of organic coatings. These procedures are modified from the techniques of Krammer and Lange-Bertalot [20], Taylor et al. [21], and Karthick et al. [22]. Cleaned samples were then centrifuged at 3000 rpm and alternatively rinsed with distilled water 3-4 times to remove of traces of hydrogen peroxide from samples.

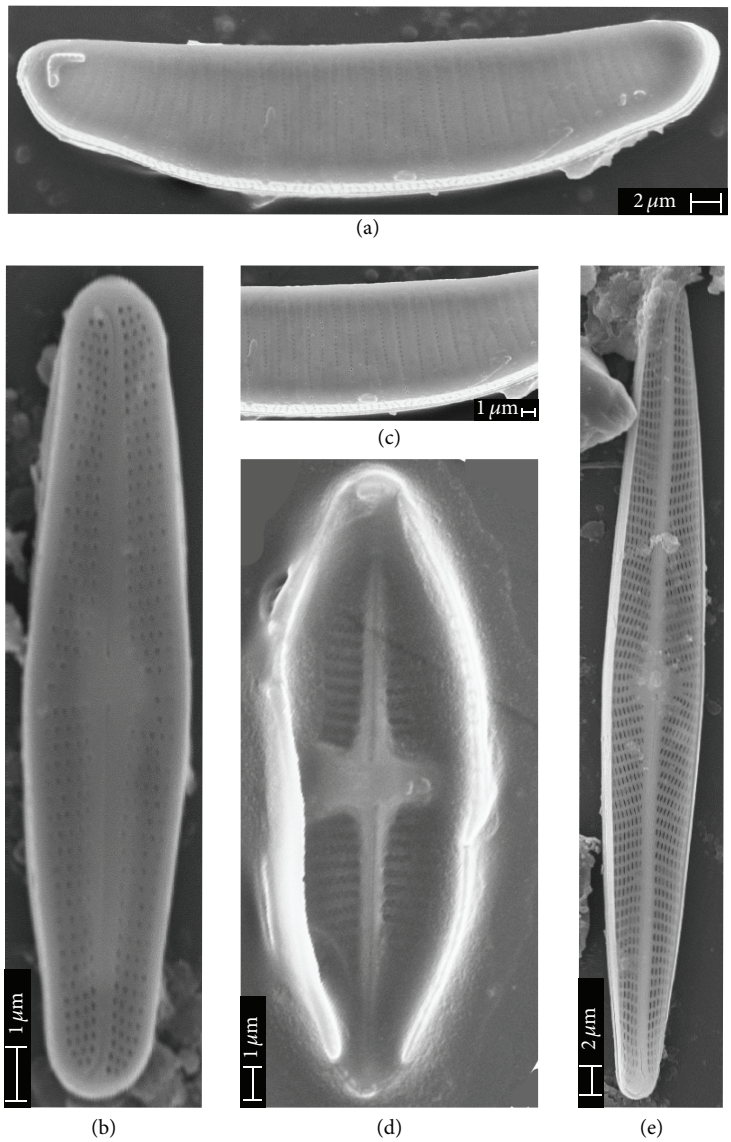

Figure 1: ((a) and (c)) *Eunotia minor* (Kützing) Grunow. (b) *Achnanthidium minutissimum* (Kützing) Czarnecki. (d) *Lemnicola hungarica* (Grunow) Round and Basson. (e) *Navicula radiosa* Kützing (scale bar shown in each SEM figure individually).

The standard protocol was followed for light microscopic and scanning electron microscope (SEM) studies. SEM studies were carried out using a LEO 430 SEM located at the Birbal Sahani Institute of Paleobotany, Lucknow.

The collected preserved materials, along with the permanent slides made up with diatom mounting medium, were stored in the Herbarium of Phycology laboratory in the department of Botany, The University of Burdwan for future study and reference purpose (BURD-JPK 2066 dated: 24.10.2014).

3. Results

Systematic descriptions and identification of the diatoms have been done using standard literature including Buczkó [23], Carneiro and de Campos Bicudo [24], Karthick et al. [25], Krammer and Lange-Bertalot [26], Patrick and Reimer [27], Lange-Bertalot [28], Lange-Bertalot and Metzeltin [29], Round and Basson [30], and Wojtal et al. [31].

According to the classification proposed by Round et al. [32] and Medlin and Kaczmarska [33] the observed diatoms belong to subdivision Bacillariophytina and class Bacillariophyceae.

3.1. Eunotia minor (Kützing) Grunow (Family: Eunotiaceae) (Figures 1(a) and 1(c)) . (Krammer and Lange-Bertalot [26], p. 196, fig. 142: 7–15; Lange-Bertalot and Metzeltin [29], p. 144, fig. 13: 18–21, fig. 103: 11; Karthick et al. [25], pl. 29).

Synonyms. *Himantidium minus* Kützing, *Himantidium pectinale* var. *minus* (Kützing) Rabenhorst, *Himantidium pectinale* var. *minus* (Kützing) Grunow, *Eunotia pectinalis* var. *minor*

(Kützing) Rabenhorst, *Eunotia pectinalis* f. *minor* (Kützing) Müller, *Eunotia pectinalis* f. *minor* (Kützing) Berg.

SEM Morphology. Convex dorsal and slightly concave or almost straight ventral margin, valve apices bluntly rounded or largely rounded, lunate shaped in valve view, striae uniseriate, taxon specific widely spaced striae present at the centre but slightly more dense towards the apices; valve length: 53.5 μm, valve breadth: 10.5–10.8 μm, striae density: 7–10/10 μm.

Distribution. Peninsular India (Karthick et al. [25]) as *E. minor* Kalimpong, West Bengal (Prasad et al. [19]); Jog Falls of Mysore, Karnataka (Gandhi [34]); Katta, Chandrapur, Bhandara, Maharashtra (Sarode and Kamat [35]) as *Eunotia pectinalis* var. *minor*.

It is common in habitats of India and almost cosmopolitan in distribution.

3.2. Achnanthidium minutissimum (Kützing) Czarnecki (Family: Achnanthidiaceae) (Figure 1(b)). (Wojtal et al. [31], p. 214, figs. 1–15; Karthick et al. [25], pl. 21).

Synonyms. *Achnanthes minutissima* Kützing, *Achnanthes microcephala* (Kützing) Grunow, *Achnanthes minutissima* var. *cryptocephala* Grunow, *Achnanthes minutissima* f. *cryptocephala* Grunow, *Achnanthes minutissima* f. *curta* Grunow, *Achnanthes cryptocephala* (Grunow) Peragallo, *Achnanthes minutissima* var. *genuine* Cleve-Euler.

SEM Morphology. Valves with bilateral symmetry. Valves are linear-lanceolate with rounded, subrostrate apices. Heterovalves flexed across the transapical axis. Raphe system present only on one valve. Raphe valves with narrow, linear-lanceolate axial area broadening in the center to form a transverse irregularly shaped central area. Raphe filiform, straight, with proximal raphe ends dilated and distal raphe endings subtly unilaterally curved. Striae moderately radiate on both valves with two shortened striae on either side of central area. Striae composed of up to 6 areolae per stria. Sometimes slit-like areola present on the valve margins. Valve length: 15.9 μm, valve breadth: 3.3 μm, and striae density: 32–34/10 μm (RV).

Distribution. Peninsular India (Karthick et al. [25]) as *A. minutissimum*. Jog Falls of Mysore, Karnataka (Gandhi [36]); Katta, Mansar, Maharashtra (Sarode and Kamat [35]) as *A. minutissima* var. *cryptocephala*. Fountain Reservoirs of Seth Sarabhai's Garden, Ahmedabad, Gujarat (Gandhi [37]) as *A. minutissima* f. *cryptocephala*. Vasna village, Ahmedabad, Gujarat (Gandhi [38]); Kolhapur, Maharashtra (Gandhi [39]); Bombay, Maharashtra (Gandhi [40]); Aurangabad, Maharashtra (Sarode and Kamat [41]) and Nagpur, Maharashtra (Sarode and Kamat [42]) as *A. minutissima*. Hirebhasgar Dam area, Mysore, Karnataka (Gandhi [43]); Bombay, Maharashtra (Gandhi [44]); Lonavla, Maharashtra (Gandhi [40]); Khamgaon, Maharashtra (Sarode and Kamat [35]) as *A. microcephala*. Hyderabad, Telengana (Johnson [45]) as *A. minutissima* and *A. minutissima* var. *cryptocephala*.

It is common in habitats of different parts of India but this is the first report of the taxon from Eastern India.

3.3. Lemnicola hungarica (Grunow) Round and Basson (Family: Achnanthidiaceae) (Figure 1(d)). (Round and Basson [30], p. 77, figs. 4–7, 26–31; Buczkó [23], figs. 2 a–k, 3 a–h,4 a, 7; Carneiro and de Campos Bicudo [24], p. 255, figs. 2–9; Karthick et al. [25], pl. 25).

Synonyms. *Achnanthidium hungaricum* Grunow, *Achnanthes hungarica* (Grunow) Grunow.

SEM Morphology. Valves with bilateral symmetry. Valves linear-lanceolate with cuneate poles with subrostrate apices. Raphe valve with often asymmetrical stauros and linear axial area. The wider part of the stauros having a "horse-shoe" depression. Raphe system present only on one valve. Terminal raphe fissures are short, slightly expanded and turned toward opposite sides. Central raphe endings are curved to opposite sides internally. Striae are biseriate and slightly radiate in the valve center but strongly radiate at the apices. Valve length: 19.5 μm, valve breadth: 7.6 μm, striae density: 16-17/10 μm (RV).

Distribution. Peninsular India (Karthick et al. [25]); Salsette island, Bombay, Maharashtra (Gonzalves and Gandhi [46]); Lonavla, Maharashtra (Gandhi [40]); Badrinath, Uttarakhand (Suxena and Venkateswarlu [47]); Kodaikanal Hill, Tamil Nadu (Suxena [48]) and Bhandara, Maharashtra (Sarode and Kamat [35]) as *A. hungarica*.

It is not very common in habitats of India and this is the first report of the taxon from Eastern India.

3.4. Navicula radiosa Kützing (Family: Naviculaceae) (Figure 1(e)). (Patrick and Reimer [27], p. 509, 560-561 figs. 48:15; Lange-Bertalot [28], p. 59, figs. 8:1–7, figs. 67:1-2).

Synonyms. *Navicula gracilis* var. *radiosa* (Kützing) Rabenhorst, *Pinnularia radiosa* W. Smith, *Navicula radiosa* var. *acuta* (W. Smith) Grunow.

SEM Morphology. Valves with bilateral symmetry. Valves are narrow and lanceolate, ends acutely rounded. Central area is rhomic. The striae are strongly radiate and are bent in the valve center and convergent near the poles. Striae composed of lineolae. Valve length: 61 μm, valve breadth: 7.7 μm, striae density: 12/10 μm, lineolae: 33–35/10 μm.

Distribution. Peninsular India (Karthick et al. [25]); Maharashtra (Sarode and Kamat [7]); Kolhapur, Maharashtra (Gandhi [39]) and Lonavla, Maharashtra (Gandhi [40]) as *N. radiosa*.

It is a common and widely spread taxon but reported for the first time from Eastern India.

4. Discussion

Except for the work of Skvortzow [3] no significant contribution has been published on the freshwater diatoms of Eastern

India. To some extent the research on the freshwater diatoms of Gujarat and Maharashtra as done by Gandhi [8] and Sarode and Kamat [7] could be mentioned, but this was limited in taxonomic scope. Since the advent of SEM that changed diatom taxonomy radically, notable contributions have been very few (Karthick and Kociolek [9–11], Karthick et al. [12–14], Alakananda et al. [15, 16], Wojtal et al. [17] and Roy and Keshri [18]). In this light the four taxa as observed under SEM from Eastern India appear to be significant because except *E. minor*, all the taxa are new records to Eastern India. From this study it also appears that the distributional records of diatoms are to be checked in light of modern diatom taxonomy, since several diatom taxa show endemism. Notably our knowledge of the diatoms of South East Asia is very poor as the published literature shows. Moreover the existing knowledge of diatoms of India should be re-evaluated in above mentioned perview. This is because in many papers, mere listing has been done, and in several other cases identifications have been done very reluctantly. This has created confusion in actual biodiversity records.

It also appears that there is the need for taxonomic revisions in many taxonomic groups. For example Gandhi [49] in his paper reported a new taxon to science as *Achnanthes pseudobiasolletiana* but from the camera lucida drawings, description, and measurements it is none other than *A. minutissimum* as appears in the light of modern taxonomy. Similarly there is confusion regarding the taxonomy of *Achnanthidium minutissimum sensu lato* as available in the literature of the works of Indian authors and abroad. *A. minutissimum sensu stricto* nowadays has a better circumscription with finer ultrastructural details, and more detailed study of Indian populations may show new taxa distinctly different from *A. minutissimum*. In one paper of Dwivedi and Misra [50] they identified taxa as *Eunotia serrata* var. *diadema* (Ehr.) R. M. Patrick but in the photographic girdle view image the taxa looks like a rectangular box which is one of the characteristic feature of *E. minor* (Karthick et al. [25]), so we propose it should be considered as *E. minor*.

Conflict of Interests

The authors of the paper declare that there is no conflict of interests regarding its publication.

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