

Taxonomic Studies on Some Freshwater Diatoms from the Eastern Terai Region, Nepal

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Abstract

The present paper describes the morphology and distribution of 17 freshwater diatom species (Bacillariophyceae) collected from rivers, ponds, ditches and wetlands of the eastern Terai region, Nepal. They belong to the genera *Cyclotella* (1), *Ceratoneis* (1), *Fragilaria* (1), *Eunotia* (1), *Navicula* (3), *Pinnularia* (1), *Gyrosigma* (1), *Gomphonema* (2), *Cymbella* (3), *Epithemia* (1), and *Hantzschia* (2). *Cyclotella meneghiniana* Kuetz., *Ceratoneis arcus* (Ehr.) Kuetz., *Fragilaria capucina* Desmaz. var. *mesolepta* Rabenh., *Eunotia lunaris* (Ehr.) Grun., *Navicula perrotettii* Grun., *Gomphonema lanceolatum* fo. *turris* (Ehr. c.p.) Hust., and *Cymbella tumida* (Bréb.) Van. Heurck have previously been reported from the eastern Terai region but *Navicula radiosa* Kuetz., *Gyrosigma kuetzingii* (Grun.) Cl., *Gomphonema sphaerophorum* Ehr., *Cymbella aspera* (Ehr.) Cl., and *Hantzschia amphioxys* (Ehr.) Grun. var. *capitata* Muell. are new records for this area. *Navicula gastrum* Ehr., *Pinnularia viridis* (Nitzs.) Ehr. var. *intermedia* Cl., *Cymbella reinhardtii* Grun., Hust., *Epithemia sores* Kuetz. and *Hantzschia virgata* (Roper) Grun. are new records for Nepal.

Key words: Algae, Bacillariophyceae, freshwater diatoms, Terai, Nepal

Introduction

Diatoms are unicellular, sometimes colony forming eukaryotic microscopic algae, which live free floating or attached to surfaces in fresh-waters and in the oceans, or live in moist soils. Their glasslike cell wall is composed of pectic compounds usually impregnated with silica and has two overlapping halves the epivalve and the hypovalve. Diatomaceous earth accumulated in some geologic formations is mined and used for a number of industrial applications for example in filters.

The eastern Terai region of Nepal is part of the northern Indo-Gangetic plains and is located between 26°20' to 26°55'N latitude and 86°08' to 88°12'E longitude. It extends c. 192 km east-west and 16 to 40 km north-south between the Siwalik Hills and the border of India, occupying an area of about

7217 km². Its elevation ranges from 70 to 300 m amsl. It comprises the Jhapa, Morang, Sunsari, Saptari, Siraha and the southern part of the Udayapur district. The major rivers in the region are the Sapta Koshi, Mechi, Kankai, Triyuga, and Kamala which originate in the Himalayas and flow to the south. Other seasonal rivers originating in the Mahabharat and Siwalik Hills have often very low water levels during the dry season. The region has a subtropical monsoon climate with hot and wet summers and mild and dry winters. The mean temperature, annual rainfall and relative humidity are 25°C, 2169.5 mm, and 74 %, respectively.

The first investigations on diatoms in Nepal were made by Carter (1926), followed by Hirano (1955, 1963, 1969, 1984), Suxena and Venkateswarlu (1968), Suxena *et al.*

(1972), Hickel (1973a, b), Ishida (1986), Aryal and Lacoul (1996), Juettner *et al.* (1996), Rothfritz *et al.* (1997), Juettner *et al.* (2000), Cantonati *et al.* (2001), Juettner *et al.* (2003), Juettner *et al.* (2004), and Simkhada and Juettner (2006). So far 263 diatom taxa have been reported from Nepal (Baral, 1999). Most of these reports were from the high Himalaya and the mountain regions of the Middle Hills. Although the abundance of lotic and lentic habitats provide diverse habitats for algae in the Terai region, this area of the country remains poorly investigated. Only recently some studies have investigated diatoms from Biratnagar (Rai and Rai, 2005), Maipokhari lake, Ilam (Rai, 2005), and the Koshi Tappu area (Simkhada *et al.*, 2006).

Materials and methods

Between 2002-2004, thirteen samples were collected from ten localities and fixed with 4% formalin. The samples were deposited in the laboratory of the Botany Department, P.G. Campus, Biratnagar. Permanent slides were prepared following the method by Patrick and Reimer (1966) and photo micrographs were taken using a Nikon E-400 with H-III photographic attachment. Taxonomic identifications were made by consulting various literatures and monographs and the nomenclature followed Hendey (1964).

The abbreviations used in the text are: L= cell length, W= cell width, Str= striae, P= page number, Tab= table number, Pl= plate number, Fig= figure number, CN= collection number, Lc= locality, D= date of collection and Alt= altitude.

Algal Localities

Diatoms have been collected from the following localities (Map 1).

1. Satasi River, Dudhe, Jhapa: edge of shallow running water (Alt. 128 m).
2. Sukrabare, Kechana, Morang: water cannel near Kamal Pokhari (Alt. 73 m).
3. Pathari, Morang: slow running water near Mahendra Rajmarg (Alt. 140 m).
4. Biratnagar, Morang: pond at Birendra Sabha Griha (Alt. 72 m).
5. Biratnagar, Morang: ditches on both sides of Pitchhra Nahar (Alt. 72 m).
6. Tarahara, Sunsari: road side ditches in front of Agriculture Research Centre (Alt. 155 m).
7. Koshi Tappu, Sunsari: wetlands in Koshi Tappu Wildlife Reserve (Alt. 206 m).
8. Sapta Koshi River, Sunsari: plankton from the river littoral in the Koshi Tappu Wildlife Reserve (Alt. 206 m).
9. Koshi Barrage, Sunsari: water damp or reservoir west of Bhandabari (Alt. 162 m).
10. Triyuga River, Udayapur: slow running water near Gaighat (Alt. 152 m).

Observations

Class: Bacillariophyceae

Order: Bacillariales

Sub-order: Coscinodiscineae

Family: Coscinodiscaceae

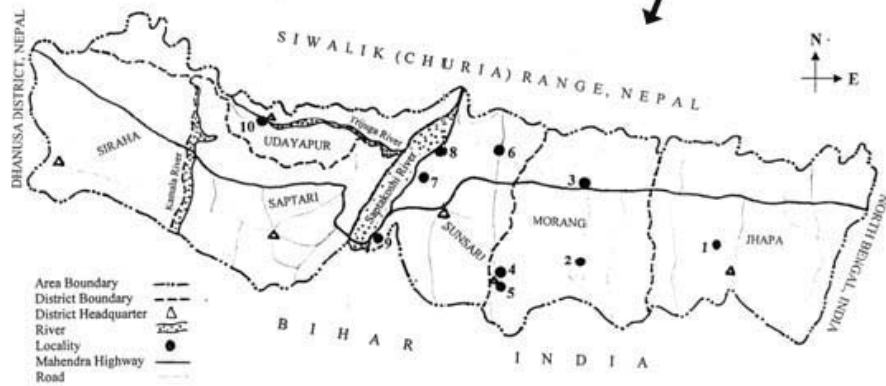
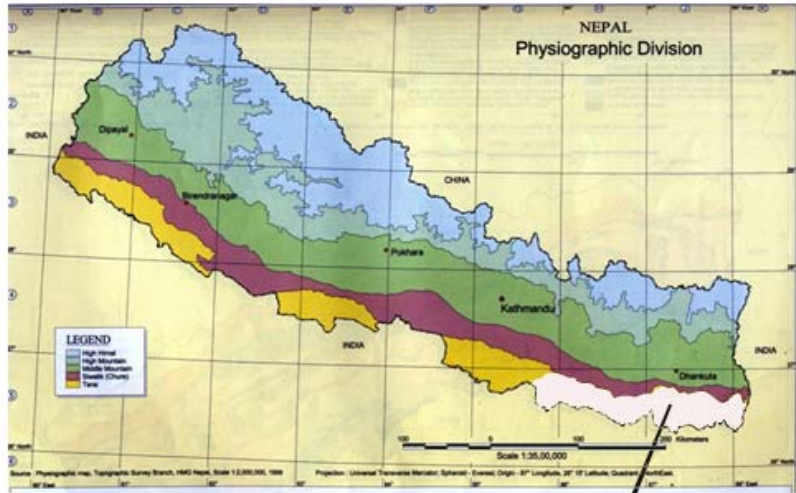
Genus: *Cyclotella* Kuetzing 1834

1. *Cyclotella meneghiniana* Kuetz. (Fig. 2)

Smith, G.M. 1950, P. 462, Fig. 371; Tiffany, L.H. and M.E. Britton 1952, P. 218, Pl. 58, Fig. 660; Prasad, B.N. and M.N. Srivastava 1992, P. 160, Pl. 24, Figs. 1-2

Valves circular; central area smooth or rarely finely punctuate; marginal striae coarse, wedge-shaped.

Diameter 13.5 μ m, Str 9 in 10 μ m, CN 75, Lc 4 and 5, D 12-01-2003.



Map 1. Eastern Terai region of Nepal

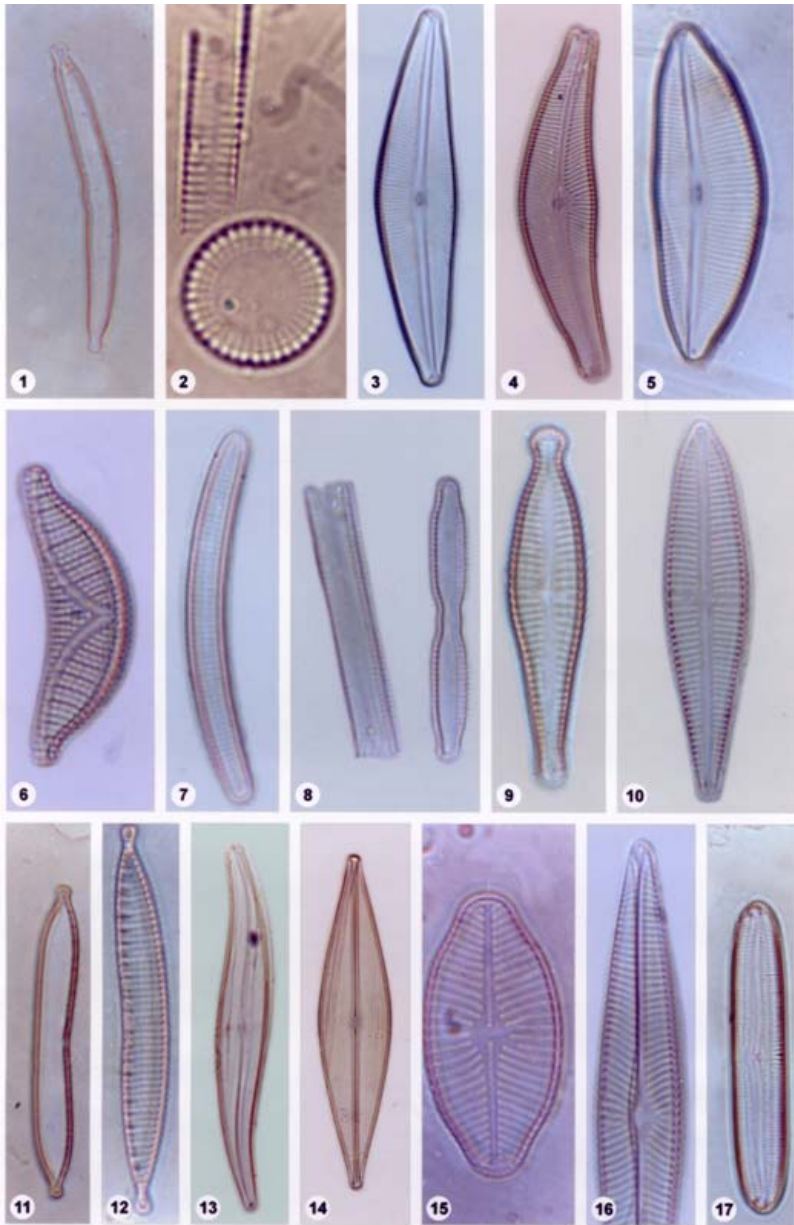


Fig. 1. *Ceratoneis arcus* (Ehr.) Kuetz. × 900; Fig. 2. *Cyclotella meneghiniana* Kuetz. × 1400; Fig. 3. *Cymbella aspera* (Ehr.) Cl. × 1100; Fig. 4. *Cymbella tumida* (Breb.) Van. Heurck. × 930; Fig. 5. *Cymbella reinhardtii* Grun., Hust. × 900; Fig. 6. *Epithemia sorex* Kuetz. × 2200; Fig. 7. *Eunotia lunaris* (Ehr.) Grun. × 2250; Fig. 8. *Fragilaria capucina* Desmaz. var. *mesolepta* Rebenh. × 2235; Fig. 9. *Gomphonema sphaerophorum* Ehr. × 2250; Fig. 10. *Gomphonema lanceolatum* fo. *turris* (Ehr. c.p.) Hust. × 2265; Fig. 11. *Hantzschia amphioxys* (Ehr.) Grun. var. *capitata* Muell. × 900; Fig. 12. *Hantzschia virgata* (Roper) Grun. × 2265; mFig. 13. *Gyrosigma kuetzingii* (Grun.) Cl. × 920; Fig. 14. *Navicula perrotettii* Grun. × 450; Fig. 15. *Navicula gastrum* Ehr. × 2245; Fig. 16. *Navicula radiosa* Kuetz. × 2250; Fig. 17. *Pinnularia viridis* (Nitzs.) Ehr. var. *intermedia* Cl. × 930.

Distribution in Nepal: pond at Dillibazar, 1300 m, Kathmandu (Hirano, 1963); Birendra Sabha Griha pond, 72 m, Biratnagar (Rai and Rai, 2005; Misra *et al.*).

Sub-order: Fragilarineae
Family: Fragilariaceae
Genus: *Ceratoneis* Ehrenberg 1840

2. *Ceratoneis arcus* (Ehr.) Kuetz. (Fig. 1)
Smith, G.M. 1950, P. 483, Fig. 391; Hustedt, F. 1959, P. 179, Fig. 684 b

Valves arcuate with a prominent tumescence in the middle of the concave side; apices rostrate-capitate; axial area narrow and towards the concave margin

L 57-60 µm, W 5-6.5 µm, Str 14-17 in 10 µm, CN 35, Lc 8 and 9, D 14-05-2002.

Distribution in Nepal: stream below Namche Bazar, 2900-4200 m, Solukhumbu (Suxena and Venkateswarlu, 1968); a stream at Kungbachen, 4150 m (Hirano, 1984); Sapta Koshi river, 206 m, Koshi Tappu, Sunsari; Rawa Khola, 720 m, Manglabare, Khotang; Gokyu lake III, 4770 m, Solukhumbu (Misra *et al.*)

Genus: *Fragilaria* Lyngbye 1819

3. *Fragilaria capucina* Desmaz. var. *mesolepta* Rebenh. (Fig. 8)
Tiffany, L.H. and M.E. Britton 1952, P. 234, Pl. 62, Fig. 699; Hustedt, F. 1959, P. 144, Figs. 659 h-i

Cells forming long chains; valves linear with pseudoraphe and more or less constricted at the centre of the valve; central area rectangular to elliptical; parallel fine striae.

L 33-35 µm, W 2-4 µm, Str 14-16 in 10 µm, CN 112, Lc 8 and 9, D 19-04-2003.

Remark: specimens found have slightly swollen constricted area at the valve centre.

Distribution in Nepal: Koshi Barrage reservoir, 162 m, Sunsari (Misra *et al.*).

Sub-order: Eunotiineae
Family: Eunotiaceae
Genus: *Eunotia* Ehrenberg 1837

4. *Eunotia lunaris* (Ehr.) Grun. (Fig. 7)
Tiffany, L.H. and M.E. Britton 1952, P. 238, Pl. 64, Fig. 730; Hustedt, F. 1959, P. 302, Fig. 769a; Prasad, B.N. and M.N. Srivastava 1992, P. 181, Pl. 25, Fig. 3

Valves crescentric to arcuate, more or less parallel sides and slightly narrower rounded apices; short raphe at the ventral margin near the poles; polar nodules small; striae parallel

L 45-46 µm, W 4-5 µm, Str 14-15 in 10 µm, CN 129, Lc 3 and 6, D 12-03-2004.

Distribution in Nepal: Bhote Koshi river, 5050 m, Solukhumbu (Suxena and Venkateswarlu, 1968); roadside ditches at Tarahara, 155 m, Sunsari (Misra *et al.*).

Sub-order: Naviculineae
Family: Naviculaceae

Genus: *Navicula* Bory 1822, emend. Cleve 1894

5. *Navicula gastrum* Ehr. (Fig. 15)
Tiffany, L.H. and M.E. Britton 1952, P. 256, Pl. 67, Fig. 786; Hustedt, F. 1961-1966, P. 799, Fig. 1771; Cholnoky, B.J. 1966, P. 34, Tab. 4, Fig. 88

Valves broadly elliptic; apices short rostrate and broadly rounded; axial area narrow, parallel; central area widened and irregular; raphe straight, median with distinct central nodules; striae radiate through, striae around the central area alternately long and short.

L 33 μm , W 15.5 μm , Str 8-11 in 10 μm , CN 227, Lc 10, D 10-12-2003.

Distribution in Nepal: new record for Nepal.

6. *Navicula perrotettii* Grun. (Fig. 14)
Hustedt, F. 1961-1966, P. 56, Fig. 1205a; Foged, N. 1980, P. 652, Pl. 8, Figs. 1-2

Valves broadly lanceolate; apices rostrate capitate or slightly rounded; axial area narrow parallel; central area moderately wide and longitudinally elongated; raphe straight with distinct central nodules; striae parallel and convergent towards the poles; areolae rectangular and perpendicular to the raphe creating longitudinal striae parallel to axial area.

L 195 μm , W 42-44 μm , transverse Str 13 in 10 μm , longitudinal Str 9-10 in 10 μm , CN 201, Lc 10, D 25-05-2003.

Distribution in Nepal: roadside ditches in front of Sent Joseph's School, 72 m, Biratnagar (Rai and Rai, 2005).

7. *Navicula radiosa* Kuetz. (Fig. 16)
Tiffany, L.H. and M.E. Britton 1952, P. 255, Pl. 67, Fig. 780; Foged, N. 1983, P. 446, Pl.

3, Fig. 18; Prasad, B.N. and M.N. Srivastava 1992, P. 212, Pl. 28, Fig. 4

Valves lanceolate; apices rounded and slightly rostrate or cuneate; axial area narrow, parallel, widening into a rhombic central area; raphe straight with central nodules deflected to one side; striae radiate and convergent towards the poles.

L 72 μm , W 10 μm , Str 10-12 in 10 μm , CN 92, Lc 7, D 21-12-2002.

Distribution in Nepal: Luitel Bhanjyang, 770 m, Gorkha; Kali Gandaki, 2600 m, Mustang; Tukucha Moor, 2640 m, Mustang; Manang Bhot Base Camp, 3500 m, Manang (Hirano, 1963); Phewa Lake, 967 m, Kaski (Nakanishi, 1986); new record for the eastern Terai.

Genus: *Pinnularia* Ehrenberg 1840

8. *Pinnularia viridis* (Nitzs.) Ehr. var. *intermedia* Cl. (Fig. 17)

Foged, N. 1982, P. 356, Pl. 8, Fig. 3

Valves linear or elliptic-linear with parallel or slightly convex sides; apices slightly pointed or broadly rounded; axial area wide, linear, c. $\frac{1}{4}$ of the valve width; large central area somewhat elliptic and slightly wider on one side; raphe broad and undulate with approximated central nodules and hooked terminal fissures; striae very coarse, punctuate, striae radiate becoming parallel convergent towards the poles.

L 92-93 μm , W 15-16 μm , Str 9-10 in 10 μm , CN 86, Lc 7, D 21-12-2002.

Distribution in Nepal: new record for Nepal.

Genus: *Gyrosigma* Hassall 1845, emend. Cleve 1894

9. *Gyrosigma kuetzingii* (Grun.) Cl. (Fig.13)

Hustedt, F. 1938, P. 410, Tab. 14, Fig. 2; Tiffany, L.H. and M.E. Britton 1952, P. 269, Pl. 66, Fig. 761

Valves sigmoid, lanceolate, tapering to narrowly rounded apices; axial area narrow, linear; small elongated elliptical central area; raphe thin, sigmoid, slightly excentric towards poles with distinct polar nodules; areolae rectangular and perpendicular to the raphe creating a transverse and longitudinal striation

L 100 µm, W 13 µm, transverse Str 21 in 10 µm, longitudinal Str 25 in 10 µm, CN 208, Lc 2, D 07-06-2003.

Distribution in Nepal: pond at Luitel Bhanjyang, 770 m, Gorkha (Hirano, 1955); new record for the eastern Terai.

Family: Gomphonemaceae
Genus: **Gomphonema** C.A. Agardh 1824

9. **Gomphonema lanceolatum** fo. **turris** (Ehr. c.p.) Hust. (Fig. 10)

Gandhi, H.P. 1959, P. 325, Fig. 47; Hadi, R.A.M. *et al.* 1984, P. 535, Pl. 5, Fig. 78; Pl. 12, Fig. 205

Valves broad, clavate with an apiculate head pole and a capitate foot pole; axial area linear, widening into a round or elliptical central area, which is wider on one side and has an isolated pore on the primary side of the central nodule; raphe straight with hooked terminal fissures; striae coarsely punctate, slightly radiate, striae shortend and wider around the central area.

L 50 µm, W 10.5 µm, Str 11-12 in 10 µm, CN 200, Lc 10, D 25-05-2003.

Distribution in Nepal: ponds in Koshi Tappu, 206 m, Sunsari (Simkhada *et al.*, 2006).

10. **Gomphonema sphaerophorum** Ehr. (Fig.9)

Tiffany, L.H. and M.E. Britton 1952, P. 272, Pl. 72, Fig. 847; Prasad, B.N. and M.N. Srivastava 1992, P. 257, Pl. 33, Fig. 10

Valves broad, clavate with capitate head pole and slightly capitate foot pole; axial area linear, narrow, and widening into a small circular central area with an isolated pore on the primary side of the central nodule; raphe straight with distinct central nodules; striae punctate and slightly radiate, wider at the centre of the valve

L 44 µm, W 9 µm, Str 11-12 in 10 µm, CN 202, Lc 10, D 25-05-2003.

Distribution in Nepal: pond near Phewa Lake, 967 m, Pokhara (Hirano, 1955); pond near police station, Mahendranagar, Kanchanpur (Habib, 1997); new record for the eastern Terai.

Genus: **Cymbella** C.A. Agardh 1830

11. **Cymbella aspera** (Ehr.) Cl. (Fig. 3)
Tiffany, L.H. and M.E. Britton 1952, P. 279, Pl. 73, Fig. 858; Hadi, R.A.M. *et al.* 1984, P. 534, Pl. 5, Fig. 74; Pl. 11, Fig. 195

Valves asymmetric, semi-lanceolate, dorsal side convex and ventral side almost straight and slightly expanded at the centre of the valve; apices slightly rostrate and broadly rounded; axial area broad and widening into an elliptic central area; raphe located slightly closer to the ventral valve margin, very slightly curved; striae radiate.

L 136 µm, W 30 µm, Str 7-10 in 10 µm, CN 196, Lc 10, D 25-05-2003.

Remarks: present specimen differs as it has slight constriction below the truncately

rounded poles and radiate transverse striation.

Distribution in Nepal: pond at Thaple Himal, 4000 m, Manang (Hirano, 1955); new record for the eastern Terai.

12. *Cymbella reinhardtii* Grun., Hust. (Fig. 5)
Hustedt, F. 1938, P. 424, Tab. 24, Figs. 27-28

Valves only slightly semilanceolate almost lanceolate, dorsal and ventral sides convex; apices very slightly rostrate and rounded; axial area narrow widening into a small rhombic central area; raphe slightly undulate; striae radiate

L 80 μm , W 26 μm , Str 8-9 (dorsal) and 10 (ventral) in 10 μm , CN 196, Lc 10, D 25-05-2003.

Distribution in Nepal: new record for Nepal.

13. *Cymbella tumida* (Bréb.) Van. Heurck. (Fig. 4)

Tiffany, L.H. and M.E. Britton 1952, P. 278, Pl. 74, Fig. 860; Gandhi, H.P. 1999, P. 20, Pl. 1, Figs. 24-26; P. 91, Pl. 1, Figs. 19-20

Valves semilanceolate with a convex dorsal margin and almost straight or slightly convex ventral margin with a slight expansion in the centre of the valve; apices rostrate and broadly rounded; axial area narrow, widening into a large round central area with a single pole on the ventral side; raphe slightly curved, with distinct central nodules located slightly closer to the ventral valve margin; striae coarse, punctuate and radiate.

L 97 μm , W 20.5 μm , Str 9-10 in 10 μm , CN 76, Lc 5, D 25-03-2003.

Distribution in Nepal: pond at Arughat Bazar, 710 m, Gorkha (Hirano, 1955; 1984); roadside ditches, Mahendranagar (Habib, 1997); Pitchhra pond, 72 m, Biratnagar (Rai and Rai, 2005).

Family: Epithemiaceae

Genus: *Epithemia* Brébisson 1838

14. *Epithemia sorex* Kuetz. (Fig. 6)

Tiffany, L.H. and M.E. Britton 1952, P. 281, Pl. 75, Fig. 881; Foged, N. 1983, P. 441, Pl. 6, Fig. 7; Hadi, R.A.M. *et al.* 1984, P. 536, Pl. 5, Fig. 83; Pl. 12, Figs. 213-214.

Valves crescentic with convex dorsal margin and concave ventral margin; apices capitate and broadly rounded; raphe biarcuate, bending towards the dorsal edge at the centre; costae distinct and radiate with two to three alveoli between the costae

L 35 μm , W 9.5 μm , Costae 5-6 in 10 μm , Str 13 in 10 μm , CN 128, Lc 9, D 28-03-2003.

Distribution in Nepal: new record for Nepal.

Family: Bacillariaceae

Genus: *Hantzschia* Grunow 1880

15. *Hantzschia amphioxys* (Ehr.) Grun. var. *capitata* Muell. (Fig. 11)

Tiffany, L.H. and M.E. Britton 1952, P. 289, Pl. 75, Fig. 887; Prasad, B.N. and M.N. Srivastava 1992, P. 313, Pl. 31, Fig. 6

Valves slightly reniform, convex dorsal valve margin, raphe located at concave ventral margin; apices subcapitate and rounded; fibulae distinct wider spaced at the centre of the valve; striae parallel, slightly radiate towards the apices.

L 67 μm , W 7-8 μm , keel punctae 7-8 in 10 μm , CN 217, Lc 3, D 07-06-203

Distribution in Nepal: Maipokhari lake, 2150 m, Ilam (Rai, 2005); new for the eastern Terai.

16. *Hantzschia virgata* (Roper) Grun. (Fig. 12)

Sinnu, N.A. and L.E. Squires 1985, P. 314, Pl. 18, Fig. 163

Valves reniform, convex dorsal valve margin, raphe located at concave ventral margin; apices capitate and rounded; fibulae distinct wider spaced at the centre of the valve; striae parallel, slightly radiate towards the apices.

L 49 µm, W 5.5-6 µm, keel punctae 7 in 10 µm, Str 13 in 10 µm, CN 227, Lc 1, D 10-12-2003.

Distribution in Nepal: new record for Nepal.

Conclusion

In the present study 17 diatom species belonging to 11 genera were recorded from a variety of freshwater habitats in the eastern Terai of Nepal. *Navicula radiosa*, *Gyrosigma kuetzingii*, *Gomphonema sphaerophorum*, *Cymbella aspera*, and *Hantzschia amphioxys* were first records for this area. *Navicula gastrum*, *Pinnularia viridis* var. *intermedia*, *Cymbella reinhardtii*, *Epithemia sorex*, and *Hantzschia virgata* were new records for the diatom flora of Nepal.

Taxonomic investigations on the diatom flora of Nepal are still very limited and most studies were performed in mountainous areas. The Terai plain with its hot and humid climate as well as rich lotic and lentic aquatic habitats requires a more extensive exploration and documentation of its algal flora. The establishment of a diatom database would be an essential contribution to the conservation of Nepal's aquatic biodiversity.

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