

FRESHWATER CYANOPHYCEAE FROM EAST NEPAL

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Abstract

A total 51 taxa of cyanophycean algae belonging to 28 genera have been enumerated from different lotic and lentic freshwater bodies of east Nepal during October, 2002 to June, 2004. Of these, 19 taxa were new additions to the cyanophycean flora of Nepal and 39 were new records for the study area. *Coelosphaerium* Nägeli, *Fischerella* (Bornet *et* Flahault) Gomont and *Myxosarcina* Printz were the first time describing genera for the country. *Oscillatoria* Vaucher *ex* Gomont has the maximum species observed in the study and were frequent in most of the samples too. The distribution pattern of cyanophycean algae according to different topography were as Terai>Mountain> Himalaya.

Introduction

Eastern Development Region (26°20'-28°08'N and 86°08'-88°15'E) lies in the eastern part of Nepal between Sikkim and Darjeeling in the east, Janakpur zone of Nepal in the west, Bihar in the south and Tibet of China in the north occupying an area of about 28,456 sq. km. On the basis of topography, it is divided into 3 geographical regions from south to north as Terai with hot and humid sub-tropical climate, Mountain with warm and cold temperate climate and Himalaya with Alpine and Tundra types of climate. In general, its average winter (January) temperature ranges from below -30°C to 18°C but in summer (July), the southern belt, *i.e.*, Terai plain experiences very hot weather with average temperature from 27°C to 30°C. The eastern wetter region receives up to 3000 mm rainfall whereas the hill and Terai receives average 1000-2000 mm annually. About 80% of the total annual rainfall occurs during monsoon in the month of June, July and August. The region has extremely variable elevation above mean sea level (MSL) that ranges from 56-8848 m (Kechana Kawal to Mt. Everest, the highest peak in the world). Thus, its diverse climates favour to have an amazing wealth of cyanophycean algae in this small area.

Freshwater cyanophycean algae of east Nepal has not been studied so far properly. Hence, very little information is available regarding their taxonomy and diversity. The contribution on the cyanophycean flora of Nepal has been made by Hirano (1955, 1969), Kusel-Fetzmann (1969), Watanabe (1995), Hickel (1973), Joshi (1979), Upadhyaya (1979), Shrestha and Manandhar (1983), Nakanishi (1986), Baral *et al.* (1988), Watanabe and Komarek (1994), Komarek and Watanabe (1998), Sahay *et al.* (1993), Das and Verma (1996), Prasad (1996), Habib (1997) and Jha and Kargupta (2001).

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Kusel-Fetzmann (1969) has reported *Oscillatoria acutissima* Kufferath and *Scytonema myochros* (Dillwyn) Agardh ex Bornet et Flahault from Khumbu area. Komarek and Watanabe (1990, 1998) have recognized 8 new species, i.e., *Coleodesmium sagarmathae*, *Chamaesiphon palssahtiae*, *Clastidium nepalense*, *Cyanobacterium epiphyticum*, *Gloeocapsopsis ferruginea*, *Mantellum himalayense*, *Schizothrix flammea* and *Xenococcus luteoviolaceus* from different localities in Sagarmatha National Park. Watanabe and Komarek (1994) have also described 21 cyanophycean forms from the same park including further 5 new species, i.e., *Woronchinia kuselae*, *Eucapsis himalayensis*, *Chlorogloea simplex*, *Entophysalis rubra* and *Schizothrix radius-solis*. All these studies were concentrated to the high altitude localities in the Himalaya region. In Terai, Jha and Kargupta (2001) have described 24 taxa from Sapta Koshi Basin out of which 15 taxa were new records for Nepal. Recently, Jha and Kargupta (2006) have also reported 14 taxa of genus *Oscillatoria* from the same localities including four new records (*O. acuta* Bruhl et Biswas, *O. obscura* Bruhl et Biswas, *O. ornata* Kützing ex Gomont and *O. vizagapatensis* Rao) for the country.

As no extensive exploration of blue-green algae through Terai to Himalaya of eastern Nepal has been carried out hitherto, it was felt desirable to study the cyanophycean flora of this region. The present paper describes the morphology and distribution of 51 taxa of blue green algae in east Nepal. All these taxa were observed by the authors in the course of studies on freshwater algal diversity of eastern Nepal.

Materials and Methods

Algal samples were collected from different geographical localities in east Nepal during October, 2002 to June, 2004. Generally, periphytes were collected by squeezing submerged plants and plankton by plankton net (mesh size 0.5 mm) in the plastic bottles (250 ml). All the collections were preserved in 3-4% formalin (aqueous solution of formaldehyde) immediately in the field. For detailed laboratory study, the cyanophycean forms were stained with methylene blue and mounted in glycerine then observation and photomicrography were done with the help of Nikon E-400 microscope with H-III photomicrographic attachment. All these collections have been deposited in the Algal Repository of Phycology Research Laboratory, Botany Department, University of Lucknow, India. Accession numbers of these collections are same as those of the collection numbers.

Taxonomic identification were made by consulting Geitler (1932), Prescott (1951), Tiffany and Britton (1952), Desikachary (1959), Prasad and Srivastava (1992) and some other literatures. The classification followed after Komarek and Hauer (2009). The literature references below the taxon's name indicate the illustration considered to be closest to our specimen and used as a basis for identification. The distribution of the taxa in Nepal has also been recorded. Abbreviations and symbols used in the text are as DN =

distribution in Nepal, (*) asterisk = new record for east Nepal and (**) double asterisk = new record for Nepal.

Results and Discussion

In the present study, taxonomy of 51 taxa (belonging to 28 genera and 9 families) of blue green algae has been described from 8 districts of eastern Nepal. It includes 3 genera (*Coelosphaerium* Nägeli, *Fischerella* (Born. et Flah.) Gom. and *Myxosarcina* Printz.) newly reported for Nepal, 19 taxa new records for the country and 39 taxa new for eastern Nepal.

The maximum number of species observed under *Oscillatoria* Vaucher which was also occurred frequently in most of the other samples. Genera *Aphanocapsa*, *Aphanothece*, *Coelosphaerium*, *Woronichinia*, *Merismopedia*, *Eucapsis*, *Chlorogloea*, *Myxosarcina*, *Arthrospira*, *Cylindrospermum*, *Nostoc*, *Tolypothrix*, *Calothrix*, *Rivularia*, *Nostochopsis*, *Hapalosiphon* and *Fischerella* have monotypic species. *Microcoleus chthonoplastes*, *M. sociatus*, *Nostoc commune*, *Phormidium ambiguum* and *P. subfuscum* were found on damp soils where as *Calothrix castellii* var. *somastipurensense* and *Fischerella epiphytica* were found as epiphytic on decaying leaves of *Euphorbia pulcherrima* Willd. and *Scytonema stuposum* on the bark of *Acacia auriculiformis*. Similarly, the taxa found in rice fields were *Anabaena iyengarii* var. *tenuis*, *A. volzii*, *Aphanothece naegelii*, *Coelosphaerium dubium*, *Merismopedia elegans* and *Microcoleus chthonoplastes*. The topographical distribution pattern of the algae were as Terai > Mountain > Himalaya. More than 50% blue green algae were recorded from Terai region because the hot and humid climate favours them for luxuriant growth. *Scytonema burmanicum*, *Stigonema mamillosum* and *Stigonema ocellatum* were recorded only from Himalaya region. There are still many blue green algae in the samples which remain to be identified. The distribution of cyanophycean algae (Table 1) and a systematic enumeration of the species have been presented below.

Systematic enumeration

Order **Chroococcales**; Family **Chroococcaceae**; Genus **Chroococcus** Nägeli 1849

1. Chroococcus minutus (Kützing) Nägeli **(Pl. 1, Fig. 5)**

(Geitler 1932, 232, 112a & 113c; Prescott 1951, 449, 100: 9; Desikachary 1959, 103, 24: 4; 26: 4 & 15)

Colonies 33.5 µm long, 27.5 µm broad; cells 9-10 µm long, 7.5 µm broad.

DN = A stream at Tukucha moor, 2600 m, Mustang (Hirano, 1955); Bakeya and Chandi river, Chandranigahpur, Rautahat (Sahay *et al.*, 1993); a shallow lake near Kongma La, 5300 m, Solukhumbu (Watanabe and Komarek, 1994); on dead tree in the south shore of Rara lake, 2970 m, Mugu (Watanabe, 1995); a ditch at Narayanghat,

Chitwan (Das and Verma, 1996); Kusaha and Madhuban, Sunsari, Eastern Nepal (Jha and Kargupta, 2001).

2. ***C. schizodermaticus* W. et G.S. West (Pl. 1, Fig. 6)
(Geitler 1932, 232, 111b; Desikachary 1959, 103, 26: 17; Prasad and Srivastava 1992, 31, 5: 6)
Colonies 28 µm long, 23 µm broad; cells 7.5-8.5 µm in diameter.

Family **Microcystaceae**; Genus **Microcystis** Kützing *ex* Lemmermann 1907

3. **Microcystis aeruginosa* (Kützing) Kützing (Pl. 1, Fig. 1)
(Geitler 1932, 137, 59d; Prescott 1951, 456, 102: 1-4; Tiffany and Britton 1952, 336, 91: 1053 & 1054; Desikachary 1959, 93, 17: 1; 18: 10)
Solid colonies 30-140 µm in diameter; elathrate colonies 100-470 µm (given figure 180 µm) in diameter; elongated colonies 100-600 µm long, 30-100 µm broad; cells 4-8 µm in diameter.
DN = Lakes of Pokhara valley, Kaski (Hickel, 1973a; Nakanishi, 1986); Chhapkaiya pond, Birganj, Parsa (Prasad, 1996).

4. ***M. incerta* Lemmermann (Pl. 1, Fig. 4)
(Prescott 1951, 457, 102: 5; Tiffany and Britton 1952, 336, 91: 1055)
Colonies 530 µm long, 430 µm broad; cells 1-2.5 µm in diameter.

5. **M. robusta* (Clark) Nygaard (Pl. 1, Figs 2-3)
(Geitler 1932, 135, 58; Desikachary 1959, 85, 17: 7-10)
Irregular colonies 250 µm long, 195 µm broad; spherical colonies 290 µm in diameter; cells 3-9 µm in diameter.
DN = A pond at Pimbahal, 1300 m, Lalitpur (Joshi, 1979).

Family **Cyanobacteriaceae**; Genus **Aphanothece** Nägeli 1849

6. **Aphanothece naegelii* Wartmann in Rabenhorst (Pl. 1, Figs 9-10)
(Geitler 1932, 172; Desikachary 1959, 141, 22: 7)
Cells slightly elongate, 6.5-7.5 µm long, 5 µm broad.
DN = On damp bank by roadside at Godawari, 1400 m, Lalitpur (Watanabe and Komarek, 1988).

Family **Entophysalidaceae**; Genus **Chlorogloea** Wille 1900

7. *Chlorogloea simplex* M. Watanabe *et* Komárek (Pl. 1, Fig. 15)
(Watanabe and Komarek 1994, 12, 13; 3: 1-2; 4: 1)
Cells 3-6 µm in diameter.

Notes: Present specimen has slightly elongated and larger cells. Short pseudo-filaments look like budding of cells.

DN = Under a moist clift at Phakdingma, 2700 m, Sagarmatha National Park, Solukhumbu, Eastern Nepal (Watanabe and Komarek, 1994).

Family **Xenococcaceae**; Genus **Myxosarcina** Printz 1921

8. ****Myxosarcina spectabilis** sensu Vasistha (Pl. 2, Fig. 1)
(Desikachary 1959, 178, 30: 1-5; 31: 17-22)
Colonies up to 50 μm in diameter; cells 9 μm in diameter.

Notes: This algae was found as macroscopic, thick, slimy, spongy, leathery, green (young), hyaline (old) thallus attached on large, submerged rocks of river specially where water stream flows rapidly.

Order **Oscillatoriales**; Family **Oscillatoriaceae**; Genus **Oscillatoria** Vaucher *ex* Gomont 1892

9. ****Oscillatoria amoena** (Kützing) Gomont var. **non-granulata** Ghose (Pl. 2, Fig. 6)
(Geitler 1932, 969; Tiffany and Britton 1952, 344, 93: 1073; Desikachary 1959, 230, 39: 6-7)
Trichomes 5 μm broad; cells 2.5-4 μm long.

10. ***O. anguina** (Bory) Gomont (Pl. 2, Fig. 7)
(Prescott 1951, 485, 108: 24; Desikachary 1959, 210, 38: 11)
Trichomes 6-7 μm broad; cells 1.3 μm long.

DN = On concrete dam at Taudaha lake, 1350 m, Kathmandu (Watanabe and Komarek, 1988).

11. ****O. cortiana** Meneghini *ex* Gomont (Pl. 2, Fig. 8)
(Geitler 1932, 971, 619c; Desikachary 1959, 233, 38: 14)
Trichomes 6-7 μm broad; cells 3.7-7.5 μm long; terminal cells 10 μm long.

12. **O. limosa** Agardh *ex* Gomont (Pl. 2, Fig. 9)
(Geitler 1932, 944, 598d; Prescott 1951, 489, 109: 17; Desikachary 1959, 206, 42: 11; Sant'anna and Azevedo 1995, 40, 83)
Trichomes 11 μm broad; cells 2.5 μm long.

DN = Moist soil and hot spring water at Tatopani, 700 m, Sindhupalchok (Joshi, 1979); Kathmandu (Shrestha and Manandhar, 1983); Chandi river at Chandranigahpur, Rautahat and Kara river at Hetauda, Makawanpur (Sahay *et al.*, 1993); main dam of Khageri Khola at Tikauli, Chitwan (Das and Verma, 1996); Kusaha, Haripur, and

Madhubani of Sunsari, Eastern Nepal (Jha and Kargupta, 2001); Saradanagar, Rampur, Chitwan; paddy field at Khumaltar, Lalitpur; Thimi, Bhaktapur (Prasad and Prasad, 2001).

13. *O. princeps* Vaucher ex Gomont (Pl. 2, Figs 10-11)

(Geitler 1932, 947, 598a & 601 c-g; Desikachary 1959, 210, 37: 1, 10-11, 13-14; Prasad and Srivastava 1992, 67, 8: 8 & 10; Sant'anna and Azevedo 1995, 42, 88)

Trichomes 28.5-38 μm broad; cells 5-5.5 μm long.

DN = A pond at Patan Dhoka, 1300 m, Lalitpur (Hirano, 1963); Narayani river, Narayanghat, Chitwan (Upadhyaya, 1979); Kara river at Hetauda, Makawanpur and Malangwa, Sarlahi (Sahay *et al.*, 1993); main dam of Khageri Khola at Tikauli, Chitwan, and Jayshree Khola at Gaindakot, Nawalparasi (Das and Verma, 1996); Paddy and Sugarcane fields, Birganj, Parsa (Prasad, 1996).

14. **O. proboscidea* Gomont (Pl. 2, Fig. 12)

(Geitler 1932, 948, 598b; Desikachary 1959, 211, 38: 9; Sant'anna and Azevedo 1995, 42, 89)

Trichomes 9 μm broad; cells 3.7 μm long.

Notes: The trichome breadth is narrower than the type.

DN = Hot spring at Tatopani, 1500 m, Mustang (Upadhyaya, 1979); damp cliff by roadside at Chobhar, 1350 m, Kathmandu (Watanabe and Komarek, 1988); Roadside ditches at Mahendranagar, Kanchanpur (Habib, 1997).

15. *O. sancta* (Kützing) Gomont (Pl. 2, Fig. 13)

(Geitler 1932, 943, 598c; Desikachary 1959, 203, 42: 10; Sant'anna and Azevedo 1995, 45, 98-102)

Trichomes 18.5 μm broad; cells 3 μm long.

DN = Kaparphori ditch at Tikauli, Chitwan (Das and Verma, 1996); Kusaha, Haripur, and Madhuban, Sunsari, Eastern Nepal (Jha and Kargupta, 2001).

16. **O. splendida* Greville ex Gomont (Pl. 2, Fig. 14)

(Geitler 1932, 972, 611 m-o; 620 d-f; Desikachary 1959, 234, 37: 7-8; 38: 10; 40: 11; Sant'anna and Azevedo 1995, 45, 104)

Trichomes 2.5 μm broad; cells 4-5 μm long; end cells 12 μm long.

DN = A stream at Lirum glacier, 3900 m, Rasuwa (Hirano, 1969).

Family **Oscillatoriaceae**; Genus **Lyngbya** C. Agardh *ex* Gomont 1892**17. *Lyngbya birgei** G.M. Smith (Pl. 2, Fig. 18)

(Geitler 1932, 1048, 663; Desikachary 1959, 296, 50: 7-8; Sant'anna and Azevedo 1995, 23, 7)

Filaments 22.5-25 μm broad; sheath 1-1.5 μm thick; trichomes 19.5-20 μm broad; cells 3.7-4 μm long.

Notes: Cells are slightly longer than the type.

DN = Sundarijal, 1300 m, Kathmandu and Patan, 1300 m, Lalitpur (Shrestha and Manandhar, 1983).

18. *L. hieronymussi Lemmermann (Pl. 2, Fig. 17)

(Geitler 1932, 1047, 656a; Desikachary 1959, 297, 48: 4; Yacubson 1980, 288, 6: 83)

Filaments 16-18 μm broad; sheath 1-3 μm thick; trichomes 15 μm broad; cells 3.6-4 μm long.

Notes: The filaments are slightly broader than the type.

DN = Pond near Sharada river at Mahendranagar, Kanchanpur (Habib, 1997).

19. **L. majuscula (Dillwyn) Harvey *ex* Gomont (Pl. 2, Fig. 19)

(Geitler 1932, 1060, 672 c-d; Desikachary 1959, 313, 48: 7; 49: 12; 52: 10; Sant'anna and Azevedo 1995, 25, 18)

Filaments 14-16 μm broad; sheath 1.5-3 μm thick; trichomes 10-11 μm broad; cells 2-3 μm long.

Family **Phormidiaceae**; Genus **Phormidium** Kützing *ex* Gomont 1892**20. *Phormidium ambiguum** Gomont (Pl. 2, Fig. 15)

(Geitler 1932, 1015, 647e; Prescott 1951, 493, 3: 1; Desikachary 1959, 266, 44: 16; 45: 5-8)

Filaments 6.5 μm broad; trichomes 4.5-5 μm broad; cells 2.5 μm long.

DN = A pond at Bouddha, 1300 m, Kathmandu (Hirano, 1963); paddy fields at Kathmandu (Baral *et al.*, 1988).

21. **P. subfuscum Kützing *ex* Gomont (Pl. 2, Fig. 16)

(Geitler 1932, 1022, 652 d-g; Desikachary 1959, 273, 44: 22-23; Sant'anna and Azevedo 1995, 52, 157-160)

Trichomes 7.5-8 μm broad; cells 2.5 μm long.

Genus **Arthrospira** Stitzenberger *ex* Gomont 1892

22. ****Arthrospira khannae** Drouet et Strickland (Pl. 2, Fig. 2)
(Desikachary 1959, 189, 35: 12)
Spirals 25-27 μm distant, 15-20 μm broad; trichomes 3 μm broad; end cells 2-2.3 μm broad.
Notes: The distance between the spirals are slightly longer than the type mentioned by Desikachary (1959).

Genus **Microcoleus** Desmazières *ex* Gomont 1892

23. ***Microcoleus chthonoplastes** Zanardini *ex* Gomont (Pl. 2, Fig. 20)
(Geitler 1932, 1133, 739; Desikachary 1959, 343, 60: 7-9; Prasad and Srivastava 1992, 104, 12: 3 & 7)
Filaments up to 100 μm broad; trichomes 5 μm broad; cells 4 μm long.
DN = Khair Kholra at Tandi, Chitwan (Das and Verma, 1996).
24. ****M. sociatus** W. et G.S. West (Pl. 2, Figs 21-22)
(Geitler 1932, 1141, 746; Desikachary 1959, 346; Sant'anna and Azevedo 1995, 29, 32-33)
Filament 25 μm broad; trichomes 9-13 or more, 4-5 μm broad.

Order **Synnechococcales**; Family **Merismopediaceae**; Genus **Merismopedia** Meyen 1839

25. ***Merismopedia elegans** A. Braun in Kützing (Pl. 1, Fig. 13)
(Geitler 1932, 265, 129e; Prescott 1951, 459, 101: 1; Desikachary 1959, 156, 29: 9; Yacubson 1980, 287, 6: 73; Rath and Adhikary 2005, 44, 6: 3; 15: 110)
Whole colony 99 μm long, 78 μm broad; cells 8 μm long, 5.7 μm broad.
DN = Phewa lake, 967 m, Pokhara, Kaski (Nakanishi, 1986); Chandi river at Chandranigahpur, Rautahat and Rapti river at Hetauda, Makawanpur (Sahay *et al.*, 1993).

Genus **Aphanocapsa** Nägeli 1849

26. ***Aphanocapsa grevillei** (Berkeley) Rabenhorst (Pl. 1, Figs 7-8)
(Geitler 1932, 159, 71; Prescott 1951, 454, 101: 15-16; Tiffany and Britton 1952, 331, 90: 1047; Desikachary 1959, 134, 21: 9)
Cells spherical, 3.5-5 μm in diameter.
DN = A pond at Luitel Bhanjyang, 770 m, Gorkha (Hirano, 1955); Langtang Kholra, 200 m, Rasuwa (Hirano, 1969); on brick wall at Balaju Water Garden, 1300 m, Kathmandu (Watanabe and Komarek, 1988).

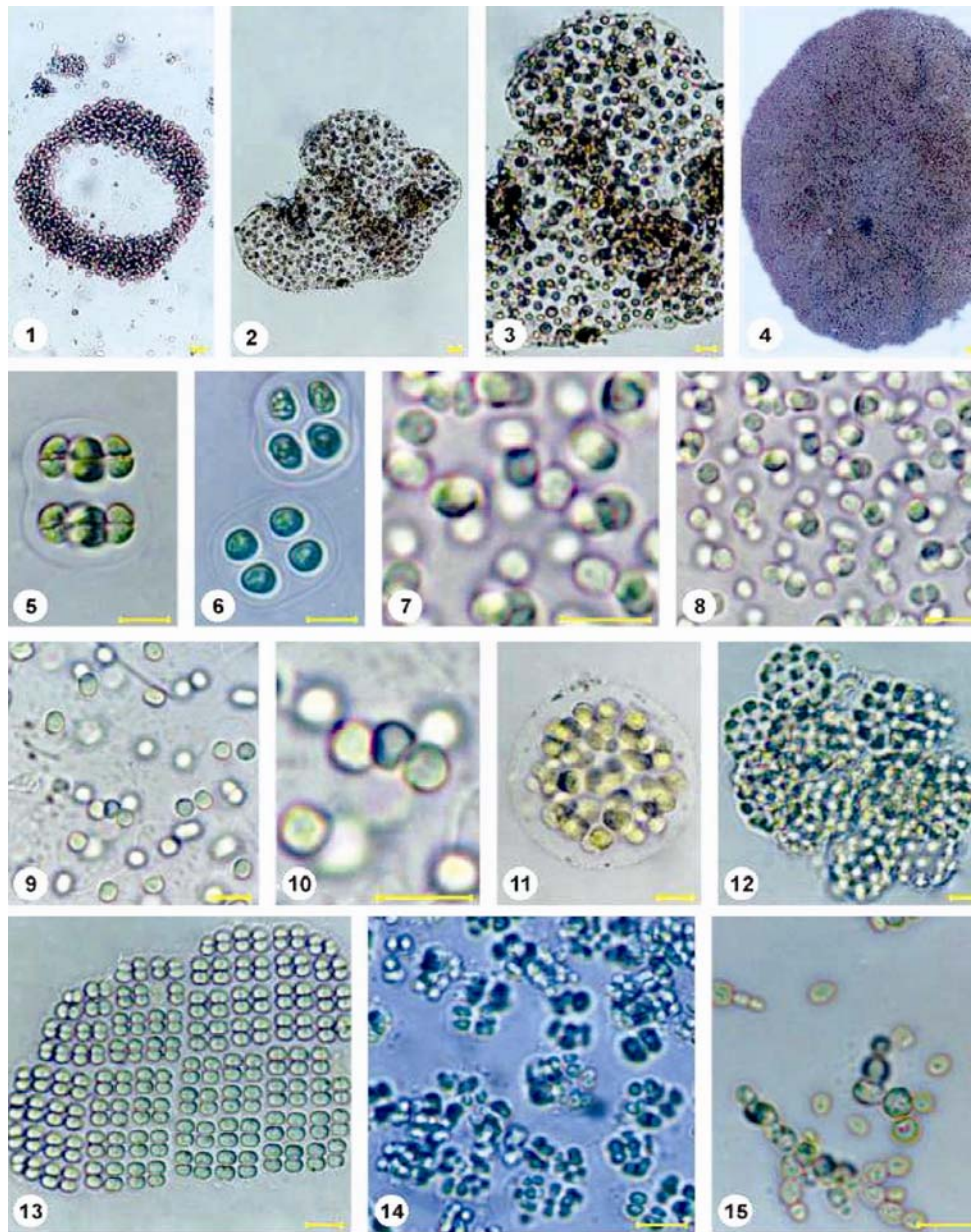


Plate 1

Fig 1-15: 1. *Microcystis aeruginosa* Kütz.; Figs. 2-3. *Microcystis robusta* (Clark) Nygaard; Fig. 4. *Microcystis incerta* Lemm.; Fig. 5. *Chroococcus minutus* (Kütz.) Näg.; Fig. 6. *Chroococcus schizodermaticus* W. West; Figs. 7-8. *Aphanocapsa grevillei* (Hass.) Rabenh.; Figs. 9-10. *Aphanothece naegelii* Wartm.; Fig. 11. *Coelosphaerium dubium* Grun.; Fig. 12. *Woronichinia kuselae* Watn. et Kom.; Fig. 13. *Merismopedia elegans* A. Br.; Fig. 14. *Eucapsis himalayensis* Watn. et Kom.; Fig. 15. *Chlorogloea simplex* Watn. et Kom.

Genus **Eucapsis** Clements et Shantz 1909**27. Eucapsis himalayensis** M. Watanabe *et* Komárek (Pl. 1, Fig. 14)

(Watanabe and Komarek 1994, 6, 7-8; 2: 1-4)

Colonies up to 20 μm in diameter; cells 3.5-5 μm long, 2.5 μm broad.*Notes:* Cell dimension is slightly smaller than the type given.

DN = Under a moist clift at Phakdingma, 2700 m and in a shallow lake near Kongma La, 5300 m, Solukhumbu, Eastern Nepal (Watanabe and Komarek, 1994).

Genus **Coelosphaerium** Nägeli 1849**28. **Coelosphaerium dubium** Grunow in Rabenhorst (Pl. 1, Fig. 11)

(Geitler 1932, 254, 121f & 122a; Prescott 1951, 470, 106: 1; Desikachary 1959, 147, 28: 10)

Colonies 58-59 μm in diameter; colonial mucilage 5-8 μm thick; cells 6-8 μm in diameter.Genus **Woronichinia** Elenkin 1933**29. Woronichinia kuselae** M. Watanabe *et* Komárek (Pl. 1, Fig. 12)

(Watanabe and Komarek 1994, 6, 6; 2: 7-10)

Complex colonies 75-95 μm , individual colonies 20-25 μm in diameter; cells 3-5 μm broad.*Notes:* Cell dimension is larger than the type specimen.

DN = A shallow lake near Kongma La, 5300 m, Solukhumbu, Eastern Nepal (Watanabe and Komarek, 1994).

Order **Pseudanabaenales**; Family **Pseudanabaenaceae**; Genus **Spirulina** Turpin *ex* Gomont 1892**30. *Spirulina major** Kützing *ex* Gomont (Pl. 2, Fig. 3)

(Prescott 1951, 480, 108: 11; Tiffany and Britton 1952, 354, 97: 1124; Desikachary 1959, 196, 36: 13; Prasad and Srivastava 1992, 51, 7: 12)

Spirals 2.9-3 μm distant, 3.5-4 μm broad; trichomes 1.5 μm broad.DN = Bagmati river at Karmaiya and Paddy field at Malangwa, Sarlahi (Sahay *et al.*, 1993).**31. S. princeps** W. *et* G.S. West (Pl. 2, Fig. 4)

(Geitler 1932, 931, 593d; Prescott 1951, 480, 108: 13; Desikachary 1959, 197, 36: 7)

Spirals 9.5-10 μm distant, 10-11 μm broad; trichomes 4-4.7 μm broad.DN = Fish pond at Hetauda, Makawanpur (Sahay *et al.*, 1993); Kusaha, Madhuban and Haripur, Sunsari, Eastern Nepal (Jha and Kargupta, 2001).

32. *S. subsalsa* Oersted. ex Gomont (Pl. 2, Fig. 5)

(Geitler 1932, 927, 593a; Prescott 1951, 480, 108: 14; Desikachary 1959, 193, 36: 3 & 9; Prasad and Srivastava 1992, 54, 7: 10-11)

Spirals 1.4 μm distant, 5.5 μm broad; trichomes 2.7 μm broad.

DN = Bagmati river at Karmaiya and Paddy field at Malangwa, Sarlahi (Sahay *et al.*, 1993); Kusaha and Madhuban, Sunsari, Eastern Nepal (Jha and Kargupta, 2001).

Order **Nostocales**; Family **Nostocaceae**; Genus **Nostoc** Vaucher *ex* Bornet *et*
Flahault 1886

33. **Nostoc commune* Vaucher ex Bornet et Flahault (Pl. 2, Fig. 24)

(Geitler 1932, 845, 536-537; Prescott 1951, 523, 119: 13; Desikachary 1959, 387, 68: 3)

Trichomes 4-4.5 μm broad; cells 4-5 μm long; heterocysts 5 μm long, 5.5 μm broad.

DN = Water tank and paddy and sugarcane fields at Birganj, Parsa (Prasad, 1996); Parwanipur, Bara (Prasad and Prasad, 2001).

Genus **Anabaena** Bory *ex* Bornet *et* Flahault 1886

34. *Anabaena iyengarii* Bharadwaja (Pl. 2, Fig. 25)

(Desikachary 1959, 406, 78: 2)

Trichomes 6 μm broad; heterocysts 9.5 μm long, 7.5 μm broad; akinets 15-25 μm long, 8-11 μm broad.

DN = Chandi river at Chandranigahpur, Rautahat (Sahay *et al.*, 1993); a pond near Sharada dam, Mahendranagar, Kanchanpur (Habib, 1997).

35. *A. iyengarii* Bharadwaja var. *tenuis* Rao (Pl. 2, Fig. 26)

(Desikachary 1959, 408, 76: 1; Prasad and Srivastava 1992, 115, 13: 4-5)

Trichomes 4-4.5 μm broad; cells 2.5-4 μm long; heterocysts 6.8-7 μm long, 6.5-7 μm broad; akinets 9-12.7 μm long, 6.5-7.5 μm broad.

DN = Kusaha and Haripur, Sunsari, Eastern Nepal (Jha and Kargupta, 2001).

36. **A. volzii* Lemmermann [Syn.: *Anabaena unispora* Gardner] (Pl. 2, Fig. 27)

(Geitler 1932, 901; Desikachary 1959, 403, 77: 1; Prasad and Srivastava 1992, 119, 13: 17, 19-20).

Trichomes 5-5.5 μm broad; cells 5-7.5 μm long; heterocysts 14 μm long, 7 μm broad; akinets 26 μm long, 12.5 μm broad.

Notes: Cells are shorter and akinets are smaller in dimension than the type.

DN = A puddle along Khair Khola at Belchi, Tandhi, Chitwan (Das and Verma, 1996).

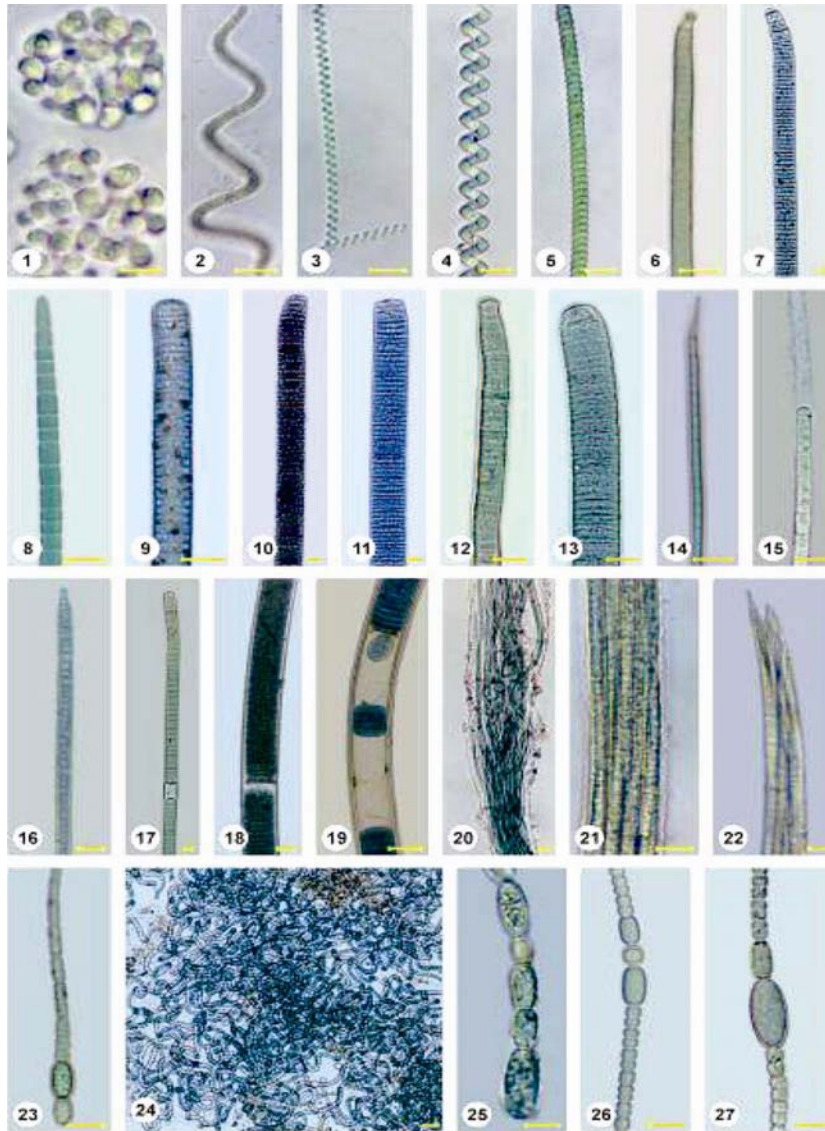


Plate 2

Figs 1-27: 1. *Myxosarcina spectabilis* Geitler; Fig. 2. *Arthrospira khannae* Drouet et Strickland; Fig. 3. *Spirulina major* Kütz. ex Gom.; Fig. 4. *Spirulina princeps* W. et G.S.West; Fig. 5. *Spirulina subsalsa* Oerst. ex Gom.; Fig. 6. *Oscillatoria amoena* (Kütz.) Gom. var. *non-granulata* Ghose; Fig. 7. *Oscillatoria anguina* (Bory) Gom.; Fig. 8. *Oscillatoria cortiana* Menegh. ex Gom.; Fig. 9. *Oscillatoria limosa* Ag. ex Gom.; Figs. 10-11. *Oscillatoria princeps* Vauch. ex Gom.; Fig. 12. *Oscillatoria proboscidea* Gom.; Fig. 13. *Oscillatoria sancta* (Kütz.) Gom.; Fig. 14. *Oscillatoria splendida* Grev. ex Gom.; Fig. 15. *Phormidium ambiguum* Gom.; Fig. 16. *Phormidium subfuscum* Kütz. ex Gom.; Fig. 17. *Lyngbya hieronymussi* Lemm.; Fig. 18. *Lyngbya birgei* G.M. Smith; Fig. 19. *Lyngbya majuscula* Harv. ex Gom.; Fig. 20. *Microcoleus chthonoplastes* Thur. ex Go; Figs. 21-22. *Microcoleus sociatus* W. et G.S.West; Fig. 23. *Cyndrospermum stagnale* (Kütz.) Born. et Flah. f. *variabilis* Prasad; Fig. 24. *Nostoc commune* Vauch. ex Born. et Flah.; Fig. 25. *Anabaena iyengarii* Bharadwaja; Fig. 26. *Anabaena iyengarii* Bharadwaja var. *tenuis* Rao; Fig. 27. *Anabaena volzii* Lemm.

Genus **Cylindrospermum** Kützing *ex* Bornet *et* Flahault 1886

- 37. **Cylindrospermum stagnale** (Kützing) *ex* Bornet *et* Flahault f. **variabilis** Prasad
(Desikachary 1959, 363, 64: 1) **(Pl. 2, Fig. 23)**
Trichomes 4-5 μm broad; cells 4-6 μm long; heterocysts 12 μm long, 6.5-7 μm broad; akinets 10 μm long, 6.5 μm broad.
Notes: Present specimen has small spores.

Family **Scytonemataceae**; Genus **Scytonema** Agardh *ex* Bornet *et* Flahault 1886

- 38. **Scytonema burmanicum** Skuja **(Pl. 3, Figs 1-2)**
(Desikachary 1959, 460, 97: 1-9)
Filaments 14 μm (above)-15.5 μm (below) broad; trichomes 11.5-12 μm broad; cells 6-9 μm long; heterocysts 13-14 μm long, 12 μm broad.
- 39. **S. javanicum** (Kützing) Bornet *ex* Bornet *et* Flahault **(Pl. 3, Fig. 4)**
(Geitler 1932, 765, 490; Desikachary 1959, 461, 100: 4)
Filaments 12.5 μm broad; trichomes 8.5-9.5 μm broad; cells 2.5-3.5 μm long; heterocysts 7 μm long, 8.5 μm broad.
- 40. **S. stuposum** (Kützing) Bornet *ex* Bornet *et* Flahault **(Pl. 3, Fig. 3)**
(Geitler 1932, 756, 482; Desikachary 1959, 459, 93: 4; Tiwari 1979, 135, 2: 3)
Filaments 16 μm broad; trichomes 8-12 μm broad; cells 5-7 μm long; heterocysts 5-6 μm long, 10 μm broad.
Notes: The present specimen has slightly smaller dimension.

Family **Microchaetaceae**; Genus **Tolypothrix** Kützing *ex* Bornet *et* Flahault 1886

- 41. *Tolypothrix distorta** Kützing *ex* Bornet *et* Flahault **(Pl. 3, Fig. 6)**
(Geitler 1932, 719, 460; Prescott 1951, 537, 125: 5-6; Desikachary 1959, 495, 102: 1)
Filaments 15 μm broad; trichomes 11.3 μm broad; cells 11 μm long.
DN = A small pond south of Rara lake, 3030 m, Mugu (Watanabe, 1995).

Family **Rivulariaceae**; Genus **Rivularia** (Roth) Agardh *ex* Bornet *et* Flahault 1886

- 42. *Rivularia minutula** (Kützing) Bornet *et* Flahault **(Pl. 3, Fig. 7)**
(Prescott 1951, 556, 136: 9)
Filaments 330-440 μm long, 10-12 μm broad at base; trichomes 7.5-8.5 μm broad at base; cells 5-5.5 μm long; heterocyst 10 μm long.
DN = Nagarjun, 1300 m, Kathmandu (Shrestha and Manandhar, 1983).

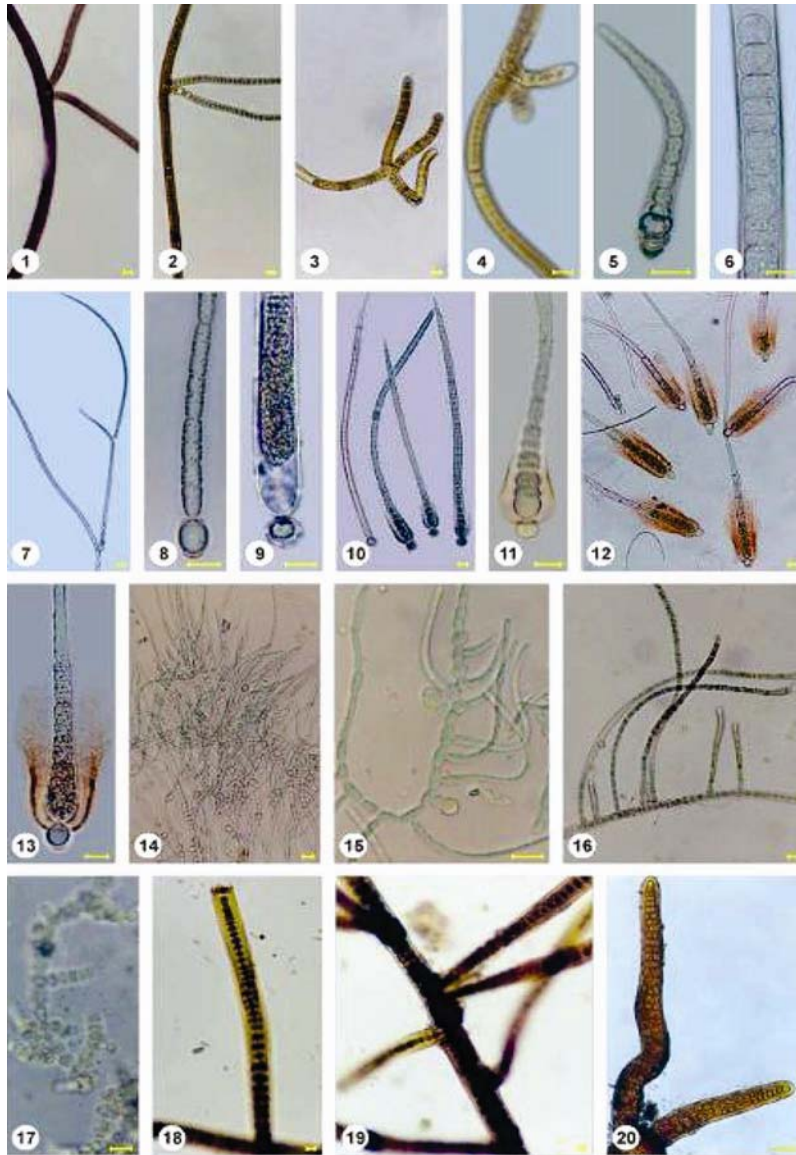


Plate 3

Figs 1-20: 1-2. *Scytonema burmanicum* Skuja; Fig. 3. *Scytonema stuposum* (Kütz.) Born. ex Born. et Flah.; Fig. 4. *Scytonema javanicum* (Kütz.) Born. ex Born. et Flah.; Fig. 5. *Calothrix castellii* (Massal.) Born. et Flah. var. *somastipurense* Rao; Fig. 6. *Tolypothrix distorta* Kütz. ex Born. et Flah.; Fig. 7. *Rivularia minutula* (Kütz.) Born. et Flah.; Figs. 8, 12-13. *Gloeotrichia raciborskii* Wolosz. var. *kashiense* Rao; Fig. 9. *Gloeotrichia intermedia* (Lemm.) Geitler var. *kanwaensis* Rao; Figs. 10-11. *Gloeotrichia echinulata* (J.E. Smith) Richt. var. *berhampurense* Rao; Figs. 14-15. *Nostochopsis lobatus* Wood em. Geitler; Fig. 16. *Hapalosiphon fontinalis* (Ag.) Born.; Fig. 17. *Fischerella epiphytica* Ghose; Figs. 18-19. *Stigonema ocellatum* (Dillw.) Thur. ex Born. et Flah.; Fig. 20. *Stigonema mamillosum* (Lyngb.) Ag. ex Born. et Flah.

Genus *Calothrix* Agardh *ex* Bornet *et* Flahault 1886

43. ** *Calothrix castellii* (Massal.) Bornet *et* Flahault var. **somastipurensis** Rao
(Desikachary 1959, 531, 113: 11-14; Tiwari 1979, 141, 5: 3) (Pl. 3, Fig. 5)
Filaments 10 μm broad at the base; trichomes 7 μm broad at the base; cells 3.2-5 μm long; heterocysts 6.5 μm long, 9.5 μm broad.
Notes: The present specimen does not bear distinct trichome hair.

Genus *Gloeotrichia* J. Agardh *ex* Bornet *et* Flahault 1886

44. ** *Gloeotrichia echinulata* (J.E. Smith) P. Richter var. **berhampurensis** Rao
(Desikachary 1959, 556, 118: 13; Tiwari 1979, 144, 7: 3) (Pl. 3, Figs 10-11)
Filaments 180-350 μm long; trichomes 7-9 μm broad; cells 6-9 μm long; heterocysts 8.5-9.5 μm long, 10-12 μm broad; akinets 14-15 μm long, 10-11 μm broad.
45. ** *G. intermedia* (Lemmermann) Geitler var. **kanwaensis** Rao
(Desikachary 1959, 560, 118: 9-11; Tiwari 1979, 145, 7: 5) (Pl. 3, Fig. 9)
Trichomes 10-11.5 μm broad at base, 5 μm broad higher up; cells 2.5 μm long at the base, 5-7 μm broad higher up; heterocysts 10 μm in diameter; akinets 50-57.5 μm long, 12.5 μm (without sheath) to 15-17.5 μm (with sheath) broad; sheath 1.5 μm thick.
46. ** *G. raciborskii* Woloszynska var. **kashiense** Rao (Pl. 3, Figs 8, 12-13)
(Desikachary 1959, 563, 117: 2-6)
Trichomes 7-10 μm broad at the base, 6-6.5 μm broad higher up; cells 7.5-9 μm long at the base, upto 10 μm long higher up; heterocysts 12.5 μm long, 10-11.3 μm broad; akinets 30 μm long, 14.6 μm broad (30-45 μm broad with sheath).

Family *Hapalosiphonaceae*; Genus *Hapalosiphon* Nägeli *ex* Bornet *et* Flahault 1886

47. * *Hapalosiphon fontinalis* (Agardh) Bornet (Pl. 3, Fig. 16)
(Geitler 1932, 535, 332; Desikachary 1959, 592, 130: 3; Tiwari 1979, 146, 8: 1)
Main filaments 10.5-12 μm broad, branch filaments 7.5-9 μm broad; trichomes 7-9.5 μm broad; cells 5-8 μm long; heterocysts 9 μm long, 7.5 μm broad.
DN = A small pond south of Rara lake, 3030 m, Mugu (Watanabe, 1995).

Genus *Nostochopsis* Wood *ex* Bornet *et* Flahault 1886

48. * *Nostochopsis lobatus* Wood em. Geitler (Pl. 3, Figs 14-15)
(Geitler 1932, 475, 28 & 285-286; Desikachary 1959, 570, 120: 1-8)
Thallus up to 4 cm in diameter; cells 4-10 μm long, up to 5 μm broad; heterocysts 6-7.5 μm long, 5.5-6.5 μm broad.

Table 1. Distribution of Cyanophycean algae in Eastern Nepal.

CN, DC	BGA	Locality	AL (m)	D	ER
EN 15, 23.08.2002	3	P.G. Campus pond, Biratnagar	72	M	T
EN 20, 29.08.2002	26	Morang Campus pond, Biratnagar	72	M	T
EN 25, 30.08.2002	8	Sera Khola, Panchakanya	430	S	Mt
EN 34, 01.09.2002	23	Paddy field at Sawane-Thingabari, Panchakanya	500	S	Mt
EN 42, 05.09.2002	10	Malaya roadside ditches, Biratnagar	72	M	T
EN 56, 19.09.2002	13	” ” ” ” ”	”	”	”
EN 45, 07.09.2002	44,45	Mawa river, Madhumalla	230	M	T
EN 54, 18.09.2002	40	Epiphyte on bark of <i>Accasia auriculiformis</i> at P.G. Campus, Biratnagar	72	M	T
EN 82, 16.12.2002	14	Sarochia pond, Biratnagar	72	M	T
EN 101,21.12.2002	29,34	Titrigachi pond, Koshi Tappu, Kusaha	206	S	T
EN 129,29.03.2003	1	” ” ” ” ”	”	”	”
EN 104,28.12.2002	18	Birendra Sabha Griha pond, Biratnagar	72	M	T
EN 113,11.01.2003	15	Raja Rani lake, Bhogateni	700	M	Mt
EN 154,11.05.2003	25	Paddy field & damp soil around a tap, Hongchur	850	K	Mt
EN 156,11.05.2003	30	Rawa Khola, Manglabare	720	K	Mt
EN 158,12.05.2003	20	Damp soil around a tap at Makpa	1440	K	Mt
EN 170,14.05.2003	9,11	Dharapani Pandhero, Damku	1690	K	Mt
EN 192,24.05.2003	6,28,35,36,44	Paddy field at Phoksiltar near Sun Koshi river	400	U	Mt
EN 211,07.06.2003	5,31	Kamal Pokhari, Sukrabare, Kechana	73	M	T
EN 226,13.08.2003	38,51	Sabha Pokhari	4100	SS	H
EN 232,18.01.2004	12	Ditches at Nahar Chowk, Shivaganj	128	J	T
EN 235,21.01.2004	16,37,46	Chimdi lake	73	S	T
EN 252,29.04.2004	43,49	Epiphyte on decaying leaves of <i>Euphorbia pulcherrima</i> in Malaya road ditches, Biratnagar	72	M	T
EN 253,12.05.2004	22,32	Pitchhra pond & canal, Biratnagar	72	M	T
EN 257,14.05.2004	17	Betana wetland, Belbari	123	M	T
EN 315,17.11.2004	19	” ” ”	”	”	”
EN 259,28.05.2004	4	Hattisar Campus pond, Dharan	511	S	Mt
EN 260,02.06.2004	50	Gokyu lake III, Khumjung	4777	SK	H
EN 261,08.06.2004	7	Gupha Pokhari, Nundhaki	2950	SS	Mt
EN 263,17.06.2004	2, 27	Mechi Campus pond, Bhadrapur	93	J	T
EN 267,17.06.2004	41,42	Mechi Pokhari, Mahespur, Bhadrapur	80	J	T
EN 278,19.06.2004	33,47	Mai Pokhari	2150	I	Mt
EN 280,19.06.2004	24	Damp soil by roadside at Jasbire	2010	I	Mt
EN 286,20.06.2004	21	Roadside drains at Ilam Bazar	1208	I	Mt
EN 302,10.09.2004	39	Roadside ditches at Itahari	120	S	T
EN 316,17.11.2004	48	Attached on outlet canal at Betana wetland	123	M	T

CN = Collection number, DC = Date of collection, BGA = Name of blue-green algae according to enumeration number in the text, AL = Altitude, D = District name, ER = Ecological region, T = Terai, Mt = Mountain, H = Himalaya, M = Morang, S = Sunsari, SS = Sankhuwasabha, K = Khotang, U = Udayapur, J = Jhapa, SK = Solukhumbu, I = Ilam, Khola = River, Pokhari = Pond.

DN = A pond at Godawari, 1400 m, Lalitpur (Shrestha and Manandhar, 1983); streamlet connecting fish pond at Godawri, 1400 m, Lalitpur (Watanabe and Komarek, 1988).

Genus **Fischerella** (Bornet *et* Flahault) Gomont 1895

49. **Fischerella epiphytica Ghose (Pl. 3, Fig. 17)

(Geitler 1932, 485, 292; Desikachary 1959, 601, 130: 2)

Main filaments up to 20 μm broad, branch filaments up to 15 μm broad; cells up to 10 μm in diameter.

Family **Stigonemataceae**; Genus **Stigonema** Agardh *ex* Bornet *et* Flahault 1886

50. *Stigonema mamillosum Agardh *ex* Bornet *et* Flahault (Pl. 3, Fig. 20)

(Geitler 1932, 520, 320-324; Prescott 1951, 547, 130: 1-3; Desikachary 1959, 613, 135: 3-6)

Branch filaments 55-60 μm broad; cells 15-17 μm in diameter.

DN = A glacier lake at Langtang Himal, 3700 m, Rasuwa (Hirano, 1969).

51. S. ocellatum (Dillwyn) Thuret *ex* Bornet *et* Flahault (Pl. 3, Figs 18-19)

(Geitler 1932, 504, 305-307; Prescott 1951, 548, 130: 5-6; Desikachary 1959, 607, 138: 2)

Main filaments 30-40 μm broad, branch filaments up to 32 μm broad at tips; cells up to 16 μm long, up to 30 μm broad.

DN = A glacier lake at Langtang Himal, 3700 m, Rasuwa (Hirano, 1969); Khumbu, 4180 m-5000 m (Kusel-Fetzmann, 1969); small pond south of Rara lake, 3030 m, Mugu (Watanabe, 1995).

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