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We bow in reverence to the beautiful creator of the universe who is almighty ALLAH (Subhana–Wa–Tallah) for inspiration and for every success, and whose benediction gave us all required zeal for the completion of this book.

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PREFACE

Algae are immense and varied group of simple plants ranging from unicellular to multicellular form. Algae are found in fresh and marine waters, as well as in lentic and lotic habitats. They are broadly categorized into blue green algae, green algae, brown algae, red algae and other multifarious diatoms. In addition to playing a significant role in photosynthesis, algae are also being used as food products and as a source of antioxidants. Some microalgal species have tremendous potential for **biodiesel production** and also possess antimicrobial activities. The Kashmir Valley of Jammu and Kashmir, India, is bestowed with number of world-famous lentic water bodies, and Dal Lake is one such important aquatic ecosystem. The lake lies between 34º6'N -34º10'N latitude and 74º50'E-74º54'E longitude and is situated at an altitude of about 1,584 m above mean sea level. Though significant work has been carried out to study the algal diversity in this Himalayan lake, until now, no **detailed digital microphotography** using advanced software has been carried out. In order to fill this gap, the **main objective of the book** is to provide a comprehensive morphological and taxonomic description of the algal flora with detailed description supported by authentic literature for the benefit of researchers, students, and biologists, as well as anyone else interested in the subject. The seasonal and locational distribution of algal species is also observed, keeping in view the different pollution loads of the various sites in and around the lake. The authors have noted all of the species recorded here in their own collections and have made an attempt to present their observations and findings in the light of the most recent literature available in the subject. The authors believe that such an extensive analysis of the algal flora of Dal Lake will stimulate interest in the phycological (algal) science both locally and at the global level.

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Parents are the most precious gifts of God to Mankind. We have no words to express our heartfelt gratitude to our beloved and affectionate parents who are the tower of strength and source of inspiration and who dedicated their entire lives for our success. We believe that, without their blessings, love and support, we would have never reached this stage.

Place: Kashmir
J. A. Lone, F. A. Lone and K. Toppo
Date: July, 2021

CHAPTER 1

INTRODUCTION

Algae are a large and diverse group of simple plants ranging from unicellular to multicellular forms. They lack leaves, roots, and other organs that characterize higher plants. The branch of science that deals with the study of algae is called Phycology or Algology. The term Phycology is derived from two Greek words (Phycos-sea weeds; logos-discourse). The group includes simplest and most primitive members of thallophyta that exhibit a wide range of reproductive characteristics ranging from simple, asexual cell division to complex forms of sexual reproduction. These are considered as the first autotrophic (i.e., photosynthetic or holotrophic) plants of the planet. They comprise nearly one third of world plant biomass of the earth.

Algae are ubiquitous, that occur in almost all habitats, ranging from marine and freshwater to desert sands and from hot springs to snow. They occur as very small, single celled to complex multicellular forms, such as the giant kelps of eastern Pacific Ocean that grow to more than 60 meters in length and form dense marine forests. The habitats occupied by fresh water algae are divided into lotic (running) and lentic (stagnant) water types. The lotic water includes rivers, streams, canals, waterfalls and rivulets, while lentic water includes ditches, puddles, pools, ponds, lakes, agricultural fields and moist surface of soil, rock, stone, tree trunk, air, ice etc.

Due to the growth of algae in different habitats, they may be classified as variable and highly diversified group of green plants i.e., phytoplanktonic (free floating), benthos (attached to sediments), epiphytic (on plants), epilithic (on stones), epipelic (on sand), endophytic (inside the plant), epizoic (on shells), and endozoic (inside sponge).

Algae are placed at the lowest rung of evolution and serve as a base model for origin of land plants. They have enormous economic importance, not only as primary producers and pollution indicators (Prasad and Singh, 1996), but also as a source of several natural products, biofertilizers and

fine chemicals. They are an inseparable part of environment and also help in its purification. The early accumulation of oxygen in the earth's atmosphere was due to photosynthesis of ancient algal forms. It is estimated that algal photosynthesis contributes nearly 90 per cent of oxygen release in the earth's atmosphere. Globally, algae are considered to fix 50 per cent of CO_2, and are the primary producers of oxygen in aquatic habitat supporting food chains (Misra *et al.,* 2001).

Most algal species exist as a single cell in aqueous habitats, but some are organized in simple, filamentous colonies. Scientists have estimated the total number of algal species to over 50,000 in the world, but only 30,000 species are identified and examined (Frac *et al.,* 2010). Even a few species have been found to be of biotechnological importance in the industry. The photosynthesis in algae is similar to that found in all plants, but algae are especially effective in converting carbon dioxide and other nutrients into organic compounds. An algal facility could be sited next to a power plant or industry that burns fossil fuels and the former could recycle part of the carbon dioxide from flue gases into liquid fuels, thereby help to reduce its emissions in the atmosphere and combating climate change.

The Kashmir valley is one of the divisions of Jammu and Kashmir, India, which is bestowed with a number of world famous lentic water bodies, and Dal Lake is one such important water body of the Himalayan ecosystem. This urban lake is of fluviatile origin, having been formed from the ox-bows of the river Jhelum situated on the north-east of Srinagar, Kashmir at the foothills of Zabarwan mountains. The lake lies between 34°6'N - 34°10'N latitude and 74°50'E-74°54'E longitude at an altitude of about 1,584 m above mean sea level (Najar and Khan, 2012). The main source of water for this lake is rainfall (Khan *et al.,* 2012). The lake is also mainly fed by a large perennial inflow stream called as Telbal Nallah that contributes about 80 per cent of the total inflow to the lake (Enex, 1978; Zutshi and Vass, 1978; Trisal, 1987), while a number of other small streams, viz., *Peshpaw*, *Shalimar*, *Merakhsha* and *Harshikul* around the shoreline (Najar and Khan, 2012) also contribute to the total inflow. However, the lakebed abounds in a number of natural springs.

The lake is divided into four basins: Hazratbal, Bod Dal, Nagin and Gagribal which differ markedly in their area, volume, depth and shoreline development indices etc. The Nagin basin is the deepest basin (maximum depth of about 6 m), and Gagribal basin the shallowest (maximum depth 2.5 m). The total water surface area of the lake is 11.50km², of which 4.1km² is under floating gardens, 1.51km² is submerged land and 2.25km²

is under marshy land (Jeelani and Shah, 2006). The Telbal Nallah with other small streams enter the lake at Hazratbal basin, then passes through Bod Dal basin, and finally drains into the river Jhelum from Gagribal basin side at the Dal Gate (Jeelani and Shah, 2006). The Nagin basin also receives water from the Hazratbal basin and leaves through the marshy area without any prominent outlet. Being an urban lake, the Dal Lake is surrounded by developed land, and most of the lakeshore is occupied by houses, hotels, restaurants and houseboats.

The lake always remains in an eutrophic state during the summer season, with highest standing crop of algae in spring-summer interphase, and which gets diminished during winter. The early ecological studies conducted in the lake by many researchers (Kant and Kachroo, 1971; Kant and Kachroo, 1974; Zutshi *et al*., 1980; Mir and Kachroo, 1982; Rather, 1994; Jeelani *et al.,* 2008; Singh *et al.,* 2008) have revealed that the lake is having a great diversity and abundance of algae, especially microalgae. The important phytoplankton found in this Himalayan Lake are *Chlamydomonas* spp., *Chlorella* spp., *Nitzschia* sp., *Navicula* sp., *Scenedesmus* spp., *Spirogyra* spp., *Spirulina* and *Microcystis* spp., etc.

CHAPTER 2

PHYCOLOGICAL STUDIES: AT A GLANCE

This part of the book emphasizes upon work done on the biological diversity of fresh water algae, around the globe and in India with special emphasis on Kashmir valley of Jammu and Kashmir, India.

2.1 Algological Studies - Global Scenario

The progress of algological studies around the globe has been reviewed for over five decades. The work has been extensively done on Chlorophyceae, Cyanophyceae, Bacillariophyceae and Rhodophyceae.

The 19th century witnessed a great spurt in algal studies: From 1817-1824, Agardh carried out a study on the algal flora of Scandinavia. Ralfs (1848) studied desmids of Britain. A great contribution came from Kuetzing (1845-1849) who authored a greater number of genera than any phycologists before, and described many species. Afterwards, from 1891 Borge carried out an extensive research on the algal flora of Germany, as well as on the collections received from China and Paraguay. West and West (1895, 1897-1898) have given a detailed taxonomical enumeration of fresh water algae from Madagascar, North America and Singapore. A monograph of British Desmidiaceae was prepared by West *et al.,* in 1923. The freshwater algae of South Africa particularly from Natal and Transvaal cape colony were studied by Fritsch and Rich (1924, 1937).

The freshwater algal flora of Ceylon was reported by Crow (1923). Handa (1927 a, b) has made an important contribution to the fresh water algae from Rangoon. Prescott (1931, 1935, 1936 a, b and 1937) reported desmid flora of Iowa, New England, the Western United States, Gatun Lake, Panama canal, Isle and Michigan. Prescott and Magnotta in 1935 gave notes on Michigan desmids.

A study of algal flora of Britain was carried out by Lund (1942-1960) who recorded species like *Chlamydomonas, Scenedesmus* and a few new forms.

The structure and reproduction of algae were explored by Fritsch (1945). Some freshwater algae from North America were reported by Prescott *et al.* (1949). Prescott and Scott (1945) and Prescott (1951) carried out extensive work on the fresh water algae of the United States of America. The algae of Illinois were reported by Tiffany and Britton (1952).

Indonesian fresh water algae received considerable attention from Scott and Prescott (1956, 1958 and 1960) who prepared notes on them. Coesel (1975, 1979, 1984, 1988, 1989 and 1993) made significant contributions to Dutch desmid flora, and Coesel (2000) also studied the desmid flora of Thailand. Pham *et al.* (2011) prepared a checklist of the algae of Singapore. Freitas and Lover de-Oliveira (2013) prepared a checklist of green algae for the State of Mato Grosso, Central Brazil.

2.2 Phycological Research in India

In the eighteenth and nineteenth centuries, great advances were made in the field of Algology, especially on Cyanophyceae, Chlorophyceae, Bacillariophyceae and Rhodophyceae throughout the Indian subcontinent. During the last 60 years, several standard publications on morphology and taxonomy of various algal groups were credited to prominent algologists like Desikachary (1959) on Cyanophyta, Randhawa (1959) also added new dimensions to the study of Zygnemataceae. Ramanathan (1964) on Ulotrichales, Philipose (1967) on Chlorococcales while Iyengar and Desikachary (1981) on Volvocales, Gonzalves (1982) on Oedogoniales. Likewise, Anand (1989) came up with publications on blue green algae.

Ehrenberg (1854) was the first worker who studied the geographical distribution of various species of Diatoms, particularly from Bengal in India. Turner (1892) published a memoir of the East Indian freshwater algae. Turner in his work incorporated 22 species of Myxophyceae, 542 species of desmids and 60 species of Chlorophyceae, exclusive of desmids. West and West (1902) described 7 species of Rhodophyceae, 49 species of diatoms, 33 species of Myxophyceae, 246 species of desmids and 34 species of Chlorophyceae from Ceylon. West and West (1907) recorded 58 species of diatoms and 148 species of desmids as well as 53 species of blue green algae from Madras and Burma. Ghose (1923, 1927b) has given systematic and ecological accounts of blue green algae from Lahore, Shimla and Rangoon. Bharadwaja's (1928-64) notable contribution was on the Cyanophycean flora of Uttar Pradesh, India. The distribution of Ulotrichales algae in India was extensively studied by Ramanathan (1964) in his monographic work. Randhawa (1934, 1936b, c,

1938, 1940, 1941b, 1943, 1958, 1959) extensively studied and made significant contributions on Zygnemataceae and Chaetophoraceae. The occurrence of Oedogoniales taxa in India has been reported by Singh (1936), Gonzalves and Sonnad (1961) from Mysore, Goyal (1964b) from Rajasthan, Bharati and Pai (1972b) from Mysore, Karnataka. Misra (1937) reported Zygnematales members from Kashmir valley of Jammu and Kashmir. The Cladophorales were recorded from different places of India by Balakrishnan (1954), Randhawa and Venkataraman (1961). Goyal and Venkataraman (1964) have described cultural variations in the morphology of *Anabaena cycadeae* Reink. Chaturvedi and Pandey (1976) have listed 52 taxa of Cyanophyceae and Chlorophyceae from Rohilkhand, Uttar Pradesh, India. Pandey and Pandey (1980) have studied 33 taxa under 15 genera of Bacillariophyceae from Allahabad, Uttar Pradesh, India. Mukhopadhyay and Chatterjee (1981) have compiled the description of 57 taxa of blue green algae from Howrah district, West Bengal. Dickie (1882) described few interesting algae from Sikkim Himalayas. In 1984, Sankaran discovered a new species of genus *Batrachospermum* Roth named as *B. desikacharyi* from Tamil Nadu. Prasad *et al.* (1986) enumerated 22 taxa of Cyanophyceae from Panchmarhi, Madhya Pradesh. Desikachary *et al.* (1990, 1998) prepared a detailed account of Indian Rhodophycean algae from fresh as well as marine water habitats. A pioneering work on Chlorococcalean flora was done by Kaushik *et al.* (1991) from Madhya Pradesh. Kant and Gupta (1998) have reported 171 species of Cyanophyceae from Ladakh (Jammu and Kashmir). In the same year, they made an extensive survey of algal forms of Ladakh and recorded 286 genera, 848 species, 155 varieties, 27 forms and 6 combinations. Habib (2000) studied 25 taxa of diatoms from 10 genera from the foothills of Garhwal Himalayas, Uttaranchal. Habib (2001) has studied some Chlorococcalean taxa from the foothills of Kumaun Himalayas. Suseela and Dwivedi (2001) reported 4 taxa of Chaetophoralean members from Bundelkhand region of Uttar Pradesh. Suseela and Dwivedi (2002) have made a great contribution to fresh water algal flora of class Bacillariophyceae from Bundelkhand region, Uttar Pradesh. In the same year, Pattanaik and Adhikary (2002) reported 16 taxa under 8 genera of Cyanophyceae from some archaeological sites and monuments of India. Khare and Suseela (2004) have enumerated 31 taxa of Cyanophyceae, Chlorophyceae and Bacillariophyceae from Nainital (Uttaranchal). Misra *et al.* (2004) studied 17 taxa of 15 genera in Cyanophyceae, Chlorophyceae and Bacillariophyceae from Sant Kabir Nagar, Uttar Pradesh. Suseela and Toppo (2007) enumerated the desmid flora of Sikkim Himalayas. Toppo and Suseela (2009) enumerated

Scenedesmus species in Chhattisgarh State. Suseela and Toppo (2010) enumerated the occurrence of rare desmids and their addition to Indian algal flora. Suseela and Toppo (2011) studied the occurrence and diversity of *Staurastrum* species in lentic water bodies of Chattisgarh State. Kumar *et al.* (2013) studied the Cyanophycean flora of Kangra district of Himachal Pradesh.

2.3 Algal Investigations in Kashmir Himalayan Valley

The pioneering studies on the Lakes of Kashmir were initiated with the work of Kant and Kachroo (1973) who reported the peak population for Myxophyceae in October, Chlorophyceae in August, and Bacillariophyceae in January and February, and Cryptomonadineae in September-October, and Dinophyceae and Euglinineae in August-September. Bacillariophyceae had a secondary peak population in October, and monthly distribution of dominant genera was represented graphically.

Mir and Kachroo (1982) reported that in the Dal and Nagin lakes of the Kashmir Himalayas, the main bulk of the phytoplankton comprises Bacillariophyceae, with highest standing crop in spring-summer being interphase and eliminate being lowest in the winter. They found that local meteorological disturbances and the shallowness of the lake cause erratic fluctuations in physical-chemical parameters of the lake water and alter its biological balance.

Zutshi and Vass (1982) studied the phytoplankton crop of the lake and reported that, in general the lake has phytoplankton belonging to Chlorophyceae, Bacillariophyceae and Cyanophyceae. They also found significant site variation with regard to plankton distribution.

Wanganeo and Wanganeo (1991) have revealed that lakes in Kashmir showed a marked change in algal assemblage with change in physical and chemical environment.

Khan (2002) consolidated the first series on phycological studies in Kashmir and recorded a total of 889 algal species representing various groups and distributed in diverse freshwater habitats.

Iqbal *et al.* (2008) assessed the impact of effluents on 134 species of phytoplankton population in four different basins of Dal Lake during Dec. 2001 to Nov. 2002. The seasonality of phytoplankton depicted a definite seasonal succession, being dominated by diatoms during spring, green

algae during summer, blue-green algae during autumn and diatoms again during winter. Species like *Asterionella formosa*, *Pediastrum tetras* and *Tetraedron regulari* restricted their presence only near the regions receiving sewage outfalls, and species like *Pediastrum ovatum*, *Merismopedia glauca* and *Trachelomonas* sp. were found only at open water sites.

Shafiq-ur-Rehman (2009) found that the Dal Lake is polluted due to the presence of a new species identified as *Euglena shafiqii,* which forms a red bloom on the surface of the lake The nutrients in the lake were found to be an important factor for the periodicity and aggregation of the species, since during the bloom period the quantity of nutrients in the lake was reduced, presumably because they were utilized by the organisms for growth.

Ganai *et al.* (2010) carried out studies on Wular Lake located at a distance of 34 km from Srinagar city of Kashmir valley and identified a total of 64 phytoplankton spp. Bacillariophyceae was found to be the most dominant group at the selected site. The most abundant species in terms of population density were *Amphora spp., Cyclotella* spp*., Longissimae longatum, Navicula* spp. and *Nitzschia* spp. Chlorophyceae was the second most dominant group of phytoplankton, with *Chlorella* spp., *Pediastrum* spp*., Spirogyra* spp. and *Volvox* spp. as the most abundant species. Amongst Cyanophyceae, *Anabaena* spp. was found to be the most dominant species at the selected site. Euglenophyceae formed the least represented group of phytoplankton which showed the peak population in spring. Chlorophyceae and Cyanophyceae showed a positive correlation with water temperature at the selected site, whereas Bacillariophyceae and Euglenophyceae showed a negative correlation.

CHAPTER 3

RESEARCH TECHNIQUES ADOPTED

A comprehensive research programme was chalked out to characterize the algal diversity of Dal Lake as per the following technical details:

3.1 Survey and Preservation of Algal Samples

For monitoring, systematic field study and regular collection of algal samples, six permanent sampling sites were selected in the Dal Lake (Plate1). These sites were selected according to differences in degrees of human interferences within different parts of the lentic ecosystem, and also as zones of special ecological interests. These sites were designated as Dal Lake Sites (DLS)-DLS-I (Nehru Park), DLS-II (Bren Laam), DLS-III (Char Chinar), DLS-IV (Hazratbal), DLS-V (Nagin), and DLS-IV (Ranawari).

Fresh algal samples were collected separately from the six different sampling sites of Dal Lake between 8:30 and 13:30 hrs in sample collection bottles made of polyethylene and polypropylene (100 ml), with four replicates for each sample. Sampling was done during the four seasons of a year i.e., spring (April), summer (July), autumn (October), and winter (January). Samples were collected from the Lake between the 15th and 20th of every month from January 2012 to December 2012. The fresh algal samples were collected with the help of sample collecting spoons, forceps etc. and were immediately fixed by using a suitable preservative (7% formaldehyde) for the biodiversity studies (Wetzel and Lickens, 2000).

3.2 Algal Identification using Advanced Microscopy

Each of the 100 ml samples collected with four replicates was immediately preserved and phytoplanktons were studied for the biodiversity details. The identification of microalgae was carried out by using an advanced microscope (LEICA DM 500, U.K) connected to a computer with a digital image analyzer and associated software (LAS EZ 1.8.0). Microphotographs were also used with an attached camera (LEICA EC3). The identification

of the microalgae was also authenticated based upon standard keys given by Desikachary (1959) for blue green algae; Tiffany (1952) for blue green, green algae and diatoms; Prescott (1970) for blue green and green algae; Phillipose (1967) for green algae etc. for morphological characteristics. The attributes recorded for morphological parameters through microscopic examination were size and shape of vegetative cells, spines, flagella, heterocyst and colour of thallus.

CHAPTER 4

MORPHO-TAXONOMIC DESCRIPTION OF ALGAL DIVERSITY

This chapter embodies the results obtained from research programme conducted at Division of Environmental Sciences, SKUAST-Kashmir and Algology laboratory of NBRI-Lucknow, India.

In the present comprehensive research programme, fresh water algal flora of Himalayan Dal Lake ecosystem have been studied with the help of digital photo imagery, and using advanced Leica software for measurements. A total of ninety six algal samples during the four seasons of the year were collected for biological studies from six different sites of Dal Lake. During the study, a total of 91 algal genera were identified comprising 217 species, 41 varieties and 8 forma, and their class-wise representation during the four seasons at six different sites of Dal Lake is presented in Table 1. The digital micro photo imagery and measurements were performed at X 630, except in a few species where the magnification has been mentioned.

Table-1: Class-wise representation of fresh water algal flora

S. No.	Class	Genera	Species	Varieties	Forma
1	Chlorophyceae	56	149	30	08
2	Cyanophyceae	16	28	02	-
3	Bacillariophyceae	14	30	05	-
4	Eugleanophyceae	04	09	04	-
5	Rhodophyceae	01	01	-	-
	Total	**91**	**217**	**41**	**08**

The taxa have been arranged in various orders of each class, namely Chlorophyceae, Cyanophyceae, Eugleanophyceae, Bacillariophyceae and Rhodophyceae. The orders of Chlorophyceae and Eugleanophyceae have been arranged according to Fritsch (1935), orders of Cyanophyceae have been arranged according to Fritsch (1945) and Desikachary (1959), and the orders of Bacillariophyceae have been arranged according to Hendey (1964) and also updated according to the AlgaeBase. The diversity and distribution of each Class (Chlorophyceae, Cyanophyceae, Eugleanophyceae, Bacillariophyceae and Rhodophyceae) at six different sites of Dal Lake during four seasons of a year are presented in the Tables 2, 3, 4 and 5. The Chlorophycean algae of Dal Lake were best represented in summer and autumn and their abundance were lowest in the winter followed by spring season. Bacillariophyceae showed their peaks of standing crop during winter, while Cyanophyceae showed their peak abundance during summer and autumn seasons, and in case of Euglenophyceae, autumn season was favourable. The species of each genus are alphabetically arranged and, in some cases, only variety or forma of a particular species was encountered. The description has been given for each taxon and is followed by list of references (for comparison), collection number and accession number.

Table-2: Diversification of Chlorophyceaen algae in Dal Lake Ecosystem

Phytoplanktons	Winter						Spring						Summer						Autumn				
	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V
Actinastrum hantzschii	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	+	++	++	-	++	-	+++	-
Actinastrum fluviatile (=*Actinastrum hantzschii* var. *fluviatile*)	-	-	-	-	-	-	-	-	-	-	-	-	++	+	+	+	-	-	++	-	-	-	+
Actinastrum lagerh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	++	-	++	+++	-	-	++
Ankistrodesmus falcatus	-	-	-	-	-	-	-	-	-	-	-	-	++	+	+	++	-	+++	-	+	-	++	+
Ankistrodesmus falcatus var. *radiatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	++	-	-	+++	-	-	++
Monoraphidium contortum (=*Ankistrodesmus falcatus* var. *spirilliformis*)	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	++	-	-	+++	-	-	+	++
Ankistrodesmus spiralis	-	-	-	-	-	-	-	-	-	-	-	-	++	++	-	-	-	-	+++	-	-	-	-
Staurodesmus octocornis (=*Arthrodesmus octocornis*)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	+++	-	-

Table-2 Contd….

Phytoplanktons	Winter						Spring						Summer						Autumn				
	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V
Closterium lunula var. *biconvexum* (=*Closterium lunula* forma *biconvexum*)	-	-	-	-	-	-	-	-	-	-	-	-	+++		++	-	-	-	-	++	-	+	-
Closterium moniliferum	-	-	-	-	-	-	-	-	-	-	-	-	+	++	-	-	-	++	+	-	-	-	+++
Closterium idiosporum var. *punctatum* (=*Closterium punctulatum*)	-	-	-	-	-	-	-	-	-	-	-	-	+	+	++	+	++	++	++	-	-	++	-
Closterium parvulum	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	++	++	-	+++	-	++	-	-
Closterium venus	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+++	-	++	++	+
Coelastrum microporum	-	-	-	-	-	-	-	-	-	-	-	-	++	+	-	+++	+	++	+	++	-	++	+
Coelastrum sphaericum	-	-	-	-	-	-	-	-	-	-	-	-		+++	+	++	+	+	+	-	-	-	+++
Coenococcus planctonicus	-	-	-	-	-	-	-	-	-	-	-	-	+	++	-	+	+	+	+++	-	+	+	+
Radiococcus polycoccus (=*Coenococcus polycoccus*)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+++	-	-	-	-
Cosmarium auriculatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	++	+	+	-	+	-	++
Cosmarium botrytis	-	-	-	-	-	-	-	-	-	+	-	-	+	+	++	+	-	-	+++	-	-	-	
Cosmarium botrytis	-	-	-	-	-	-	-	-	-		+	-	-	-	-	-	++	-	-	-	+	-	++

Table-2 Contd….

Phytoplanktons	Winter						Spring						Summer						Autumn				
	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V
Cosmarium moniliforme							+	+		-	-	-	+	+	+++	-	+	-	++	+	-		+
Cosmarium pachydermum	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	-	+	-	-	-	++	+
Cosmarium pardalis	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	++		-	++	-
Cosmarium perfissum	-	-	-	-	-	-	-	-	-	-	-	-	+	++	-	+	+	-	+++		+	+	
Cosmarium phaseolus var. *omphalum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	++	-	++
Cosmarium Polygonum	-	-	-	-	-	-	-	-	+	-	-	-	-	+	+	+	+	+	+	+	+	-	++
Cosmarium portianum	-	-	-	-	-	-	-	-	-	-	-	+	-	-	++	-	-	-	++	-	+	-	-
Cosmarium pseudobroomei	-	-	-	-	-	-	-	-	-	-	-	-	-		+	+	+++	+	+	+	-	-	-
Cosmarium pseudogranatum	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	++		++	-	-	+	+
Cosmarium punctulatum	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	+	+	-	+++	-	++
Cosmarium reniforme	-	-	-	-	-	-	-	-	-	-	+	+	-	+	+	+	+	+	+	+	+++	-	+
Cosmarium pygmaeum	-	-	-	-	-	-	-	-	-	-	-	-	++	++	-	-	++	-	-	-	++	-	-
Cosmarium quadrum	-	-	-	-	-	-	-	-	-	-	-	-	+	+	++	-	+	-	-	-	-	+	++
Cosmarium retusiforme	-	-	-	-	-	-	-	-	-	-		-	-	++	++	-	++	-	-	-	-	-	+
Cosmarium subgranatum var. *borgei*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	+	+	++
Cosmarium subimpressulum	-	-	-	-	-	-	-	-	-	-	-	-	+	++	+	+	=	-	++	-	-	-	-
Cosmarium subtumidum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	++	-
Cosmarium subundulatum	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	++	-	-	+++	-	-	-	-

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Table-2 Contd….

Phytoplanktons	Winter						Spring						Summer						Autumn				
	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V
Cosmarium turpinii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+++	-	+
Cosmarium vermae	-	-	-	-	-	-	-	-	-	++	-	-	+	+	+	++	-	-	++	-	+	-	-
Willea crucifera (=*Crucigenia crucifera*)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	+++
Willea rectangularis (=*Crucigenia rectangularis*)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+++	-	-	-	-	+	-	-	-
Crucigenia tetrapedia	-	-	-	-	-	-	-	-	-	-	-	-	+++	-	-	-	-	-		+	+	-	-
Cylindrocapsa conferta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+		-		-
Cylindrocapsa geminella var. *minor*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-	-
Desmidium bengalicum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	++	-	+++
Dichotomosiphon tuberosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mucidosphaerium pulchellum (=*Dictyosphaerium pulchellum*)				+		+	-	+	+	+	+	+	+	+	+	+	+	+	+++	+	++	+	+
Dictyosphaerium reniforme forma *major*	-	-	-	-	-	-	+	+	-	-	-	+++	+	-	+	+	++	+	+	+	++	+	+

Table-2 Contd….

Phytoplanktons	Winter						Spring						Summer						Autumn				
	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V
Gloeotaenium loitlesbergerianum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	++
Golenkinia radiata	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	++	-	-	-	-	-
Gonium pectorale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-
Hydrodictylon reticulatum	-	-	-	-	-	-	-	-	-	-	-	-	++	-	+	++	-	-	+++	-	-		+
Raphidocelis danubiana var. *elegans* (=*Kirchneriella contorta* var. *elegans*)	-	-	-	-	-	-	-	-	-	-	-	-	+++	-	-	++	-	-	-	-	++	++	-
Kirchneriella lunaris	-	-	-	-	-	-	-	-	-	-	-	-		-	++	-	-	-	+++	-	-	-	-
Lagerheimia wratislawiensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Micractinium pusillum	-	-	-	-	-	-	-	-	-	-	-	-	+	-		-	-	++	-	-	-	-	+
Micractinium pusillum var. *elegans*	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	++	-
Micrasterias pinnatifida	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	++	-	-	+	-
Micrasterias radians	-	-	-	-	-	-	-	-	-	-	-	-		-	-	+	-	-	++	-	-	-	+
Monoraphidium griffithii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	++	-	-	-	+
Nephrocytium agardhianum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	++

Table-2 Contd….

Phytoplanktons	Winter						Spring						Summer						Autumn				
	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V
Eremosphaera gigas (=*Oocystis gigas*)	-	-	-	-	-	-	-	-	-	-	+	-	+	+	-	-	-	-	++	+	+	-	-
Oocystis lacustris	-	-	-	-	-	-	-	-	-	-	+	-	++		-	-	-	-	-	+	+	-	-
Neglectella solitaria (=*Oocystis solitaria*)	-	-	-	-	-	-	-	-	-	-	++	-	+	+	-	-	-	-	-	+	+	-	-
Chloroidium saccharophilus (=*Palmellococcus saccharophilus*)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		+	-	+
Pandorina morum	-	-	-	-	-	-	-	-	-	-	-	++	-	-	++	-	+	-	+	+	+	-	++
Pediastrum angulosum	-	-	-	-	-	-	-	+	-	-	+	-	-	++	-	-		-	+	-	-	-	-
Pseudopediastrum boryanum var. *longicorne* (=*Pediastrum boryanum* var. *longicorne*)	-	-	-	-	-	-	-	+	-	-	-	-		++	+	+	+	+	++	-	-	-	+
Pediastrum duplex (=*Pediastrum duplex* var. *clathratum*)	-	-	-	-	-	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+++
Pediastrum duplex (=*Pediastrum duplex* var. *reticulatum*)	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+		+++	-	-	-	+
Stauridium tetras (=*Pediastrum tetras*)	-	-	-	-	-	-	-	-	-	-	-	-	-	++	+	+	+	-	-	+	+	+	+++