Phytoplankton: Review

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This is a comprehensive review of phytoplankton ecology in freshwater. A review study was undertaken for the better understanding of the phytoplankton distribution. The relations of phytoplankton with factors like lake temperature, sunlight exposure period, sunlight penetration, water pH, wind, transparency, seasonal variations, water characteristics, nutrient enrichment and prey-predator relation in the lakes of India. From the results, authors noticed that each lake habitat is different from other lake habitat. Finally, authors concluded that phytoplankton ecology is an indicator for the evaluation of impacts of influencing factors. These factors provide a suitable management plan for lakes. Phytoplankton ecology provides a ground for monitoring and assessing the strategies of the fresh water lake management.

Keywords: Phytoplankton ecology, Freshwater lakes, Seasonal fluctuation, Phytoplankton distribution

About four thousand million years ago, life initiated in an aquatic environment. Today, most of the taxonomic phyla dwell in an aquatic environment. In an aquatic environment, phytoplankton is most ubiquitous, unicellular and microscopic life form. Phytoplankton collectively accounted about half of the earth’s primary producers. However, light penetration, temperature, nutrient enrichment, toxic substances, mixing of water, parasites, herbivores and heterotrophic microorganism activities influenced the phytoplankton growth (Reynolds, 1987). In recent years, researchers have participated in the study of phytoplankton ecology of freshwater lakes in India.

The importance of water was realized as far back as a means of sustenance of life which was expressed in the Greek Philosopher’s Cryptic saying “Water is best”. Galileo, the great physicist of the Italian Renaissance made an attempt to study water physically. The extensive work of (Forel 1901) who is regarded as the father of Modern Limnology gave an impetus to study this subject intensively.

The discovery of plankton by (Victor Hansen, 1887) was an outstanding event in the field of Limnology. As a result of this discovery, at the end of the nineteenth century and the beginning of the twentieth century intensive work was carried out. Limnology was little known to Indian researchers until the first publication (Prasad, 1916). But it was not until 1940 that a keener interest towards this branch of science developed. An elaborate account on the distribution of the fresh water algae of North India (Rhandawa, 1936) was also of significance. Algal flora of some muddy rain water pools by(Iyengar ,1940), Periodicity of algae by (Philipose,1960), Algal ecology by (Gonzalves and Joshi,1946), Distribution of Euglenophyceae by (Suxena, 1955) and work on plankton ecology by (Singh, 1959) are all important landmarks in the study of limnology.

Algae as indicators of organic pollution (Hosmani and Bharathi, 1980) showed that species of algae at top of the pollution list were *Euglena* and *Scenedesmus*. *Euglena gracilis* was noted as an indicator of organic pollution by many researchers. *Euglena oxyuris* was stressed as an indicator of organic pollution in lakes. A detailed study on Limnlogical studies in ponds and lakes of Dharwad with comparative phytoplankton ecology (Hosmani and Bharathi, 1980) indicated that presence of diatoms was influenced by factors like calcium, iron, pH, silica, nitrates, phosphates, ox disable organic matter associated with dissolved oxygen and temperatures in lower concentrations. Diatom population in lakes was richer than in ponds. Desmids favoured lower concentration of nitrates and phosphates. Myxophyceae had a deleterious effect. *Closterium lunula* had greater tolerance capacity. *Euglena gracilis* and *Euglena elastic* and *Lepocinclis ovum* occurred as sporadic blooms in ponds while lakes were poor in Euglenophyceae. Chlorococcales occurred in all types of waters while *Franceia ovalis* occurred as a bloom. *Microcystis aeruginosa* appeared in all lakes which is indicative of the fact that it has the ability to tolerate pollution. The classification of these waters indicated that the lakes were fundamentally oligotrophic and the ponds were fundamentally eutrophic. And some factors indicated that oligotrophic nature of the lakes tends towards eutrophic nature. Using algae in classifying water bodies (Hosmani and Bharathi, 1982)**,** indicated that the Compound Quotient(CQ) values obtained for classifying water bodies showed that the lakes are weak eutrophic and show a tendency towards eutrophism where as the ponds are true eutrophic with high degree of pollution. Nitrates, phosphates and ox disable organic matter in lower concentrations coupled with high carbon dioxide supported a continuous bloom of *Spirulina nordestedtii* in a polluted lake (Puttaiah *et. al*., 1982.) The possible conditions accelerating the sporadic occurrence of *Anabaena spiroides* were increased nitrates and phosphates, low pH and lesser oxygen content. The death and decay of hydrophytes helped to a certain extent in its acceleration. Higher degree of organic pollution due to inflow of city waste also favoured the bloom (Govindappa *et al*., 1982). Euglenophyceae of polluted and unpolluted waters (Hosmani and Bharathi, 1983) indicated that some of them formed blooms while others persisted for a longer time and abruptly seized to appear. About 42 species of Euglenophyceae were reported. The report on observation of pond life with special reference to algal species diversity indices indicating water pollution (Hosmani and Mallesha, 1985) revealed that the diversity of species decreased with increase in pollution, water temperature, total nitrogen and ox disable organic matter. The diversity in the distribution of species occurred concurrent to the type of pollution. As a result, certain species tolerate pollution and appear dominantly while those that cannot tolerate pollution fail to survive in these waters. Observation on the bloom of *Euglena limnophylla* (Puttaiah *et al*., 1985) suggested that the quantity of carbonates, nitrates and free ammonia were less, while albuminoidal ammonia and phosphates rise appreciably with high alkalinity during the bloom of *Euglena limnophylia*. Biological Index of Pollution (BIP) was calculated using producers and consumers (Hosmani, 1987-88)**.** The ponds fluctuated between the zone of clean water and the zone of active decomposition. During certain seasons they shifted to the zone of moderate decomposition. A new variety of *Scenedesmus bijugatus* var. *haliyalensis* was described from the lake water (Hosmani and Bharathi, 1987). Further a new genus of *Sceneoocystis karnatakensis sp.nov* was also described from Haliyal near Karwar (Hosmani and Bharathi, 1981) *Rivularia aquatica* is known to be autotrophic as other blue greens. However it does resort to other modes of nutrition as evidenced by its parasitic nature on *Griffithella hookeriana* (Hosmani and Nagendra, 1980). A study on the calcium carbonate saturation index and its influence on phytoplankton (Hosmani and Vasanth Kumar, 1996) in sixteen lakes of Mysore were carried out. Five lakes showed a tendency of heavy scale deposition and four lakes showed a tendency of light scale deposition. Lakes that had both light scale and corrosive tendency supported the growth of phytoplankton represented by blooms of *Trachelomonas volvocine, Trachelomonas charkoweinsis, Spirulina nordestedtii*, *Phormidium fragile* and *Microcystis aeruginosa* indicating their ability to survive in waters that have a stable pH.

Early interest centred on the visible results of water-blooms (Griffiths, 1939) and of sampling in nature – originally mainly by fine plankton nets, which did not retain the smaller forms known later as nanoplankton, 'μ-algae' and picoplankton. The observations led naturally to taxonomic resolution of species, such as the common diatom *Asterionella formosa* obtained by A.H. Hassall from a London reservoir. Notable naturalists included W. West, originally a Leeds and Bradford pharmacist, whose son West, G.S. graduated from Cambridge University and contributed richly, with his father or singly, to the recognition of species in Britain (West & West, 1901, 1905, 1906a, b; G.S. West, 1904) and elsewhere, including a comparative account of the phytoplankton of three major African lakes (West, G.S. 1907). He also considered seasonal changes of phytoplankton in an Australian reservoir near Melbourne in relation to environmental factors (West, G.S.). Noteworthy of his style were accompanying photomicrographs of plankton communities in fields under low magnification. His untimely death in the influenza epidemic prevalent around 1919 was a major loss to the science.

Although algal periodicity later attracted others (Griffiths, 1923; Southern & Gardiner, 1926; Lind, 1938), limitations of sampling and counting before 1940 led to somewhat primitive measures of population dynamics and interpretations of regulating factors. Thereafter improvements followed, many introduced by Fritsch's former student J.W.G. Lund (also a skilled algal taxonomist) and his colleagues (Lund & Talling, 1958), including counts using iodine-sedimentation and the inverted microscope (Lund *et al*., 1958), a novel means of integrated sampling by vertical plastic tube (Lund, 1949), biomass assessment by chlorophyll *a*, and attention to the smallest forms (Lund, 1961; Bailey-Watts *et al*., 1968; Vincent, 1981; Happey-Wood *et al*., 1988). Biomass assessment by chlorophyll *a* developed rather late in Britain, partly due to a traditional reluctance to move from microscopy to chemical methods and partly from experience of incomplete chlorophyll extraction from algae of London reservoirs where the method was tested by Gardiner (1943a). Nevertheless, the correlative evidence obtained by Pearsall (1932) for seasonal silicate depletion by diatoms in some English lakes was a major advance that has stood the test of time. In a wide-ranging review of freshwater algal ecology, Fritsch (1931) had raised the possibility of mass-recruitment of lake phytoplankton from benthic stages. This feature was later demonstrated in work on a partially planktonic (meroplanktonic) diatom (Lund, 1954; Jewson *et al*., 1981), various cyanoprokaryotes (Cyanobacteria, 'blue-greens': Preston *et al*., 1980; Head *et al*., 1999), and a dinoflagellate (Heaney *et al*., 1983).

However, in early years, researchers reported many research studies on phytoplankton distribution and density in freshwater lakes of all over India (Ganapati, 1940; Mohan, 1987; Chaudhary & Pillai 2009; Singh & Balasingh 2011; Dakshini & Gupta 1979; Sarwar,1996, Tiwari & Chauhan 2006, Mukherjee *et al*., 2010; Jain *et al*., 1999; Chattopadhyay & Banerjee 2007; Ghosh *et al*., 2012; Jhingran, 1989; Somani *et al*., 2007; Maske *et al*., 2010). A report spanning a period of 50 years

(1947-1998) emphasized factors influence on physical, chemical and biological conditions on the Indian freshwater lake ecology system (Sugunan, 2000; Gopal & Zutshi, 1998). Further, other studies reported the distribution pattern of phytoplankton with respect to the degree of water pollution, impact of aquaculture and climatic change (Chattopadhyay and Banerjee, 2007; Pradhan *et al*., 2008), role of macrophyte's root and shoot system (Sarwar, 1996; Raut & Pejaver, 2005) and harmful and toxic effects of cyanobacteria in Indian freshwater lakes (Chaudhary & Meena, 2007; Maske *et al*., 2010). In this review, we presented an elaborative literature synthesis on the phytoplankton ecology and various factors interacted in freshwater lakes of north, south, east and west regions of India. This review may provide a better understanding of phytoplankton ecology in Indian freshwater lake scenario. It should assess qualitatively for anthropogenic changes which resulted nutrient enrichment. It provides a ground for future studies on management of freshwater lakes with phytoplankton distribution.

Indian researchers reported the several studies on the phytoplankton distribution with availability of light (Singh & Sharma, 2012), physical, chemical and biological qualities (Zafar, 1967; Munawar, 1974) in freshwater lakes. Today, Indian freshwater lakes are facing tremendous ecological stress due to raising of pollution from rapid industrialization. However, mainly seasonal changes regulated pattern of phytoplankton growth. Studies reported that the summer is the most suitable season for the growth of phytoplankton in freshwater lakes because of long duration of sunshine period, increased salinity, pH and trophotropic activities (Chaturvedi *et al*.,1999). Conversely, in late summer and monsoon season, the production of phytoplankton reduced because of heavy rainfall, high turbidity, reduced salinity, temperature, pH, overcast skies and low nutrient concentration along with consumption of phytoplankton by zooplankton and fishes etc. (Saravanakumar *et al*., 2008). During monsoon, wave action of currents and influx of rain water acts as limiting factors for phytoplankton population. The water column of the lake was remarkably stratified to large extent in heavy rainfall with high turbidity in lake water, induced due to agricultural and surface runoff and soil erosion. Subsequently, the rate of phytoplankton gradually increased in post-monsoon to the late spring. Phytoplankton community progresses a serial successions to culminate in a peak sequences with low turbidity and low wind velocity in the lakes (Chaudhary & Pillai, 2009; Sugunan, 2000). In some cases, during postmonsoon and summer, permanent bloom of phytoplankton in lakes of the southern tip of Indian peninsula appeared due to shallow depth, nutrients enrichment and adequate sunlight (Sugunan, 2000). Generally, in Indian Lakes, phytoplankton density peaks found in post monsoon and summer (Gopal & Zutshi 1998). Researchers published some accounts on phytoplankton ecology in freshwater lakes around India. Reports of phytoplankton distributions in lakes of northern India (Dakshini & Gupta 1979; Sarwar, 1996; Tiwari & Chauhan, 2006; Mukherjee *et al*., 2010), southern India (Ganapati, 1940; Sreenivasan, 1964; Sreenivasan *et al*., 1964; Abraham, 1980; Mohan, 1987; Chaudhary & Pillai, 2009; Singh & Balasingh 2011), eastern India (Sugunan & Yadava, 1991; Jain *et al*., 1999;Chattopadhyay & Banerjee, 2007; Ghosh *et al*., 2012) and western India (Jhingran, 1989; Trivedi, 1993; Somani *et al*., 2007; Maske *et al*.,2010). Authors formed these regions provisionally to consolidate the understanding of phytoplankton ecology. Details of lake studies and a summary on dominant groups of phytoplankton and factors influenced phytoplankton ecology of Indian fresh water lakes, discussed in this review study and depicted in map as distributed over four regions.

Details of freshwater lakes in India referred in the review study Lakes Dominant groups of phytoplankton Influencing factors Reference Damadama, Badkhal, Peacock lakes Blue-green algae Temperature with seasonality Dakshini & Gupta, 1979 Badua lake Blue-green algae, Diatoms Seasonal variations Verma & Munshi, 1983 Dal, Waskur lake, Anchor lakes Diatoms, green algae Hydrographic properties Sarwar, 1996 Kitham lake Green algae, Diatoms Seasonal variations Tiwari & Chauhan, 2006 Ranchi lake Blue-green algae, diatoms Organic matter Mukherjee *et al*., 2010 Bhavanisagar lake Blue-green algae Seasonal variations Sreenivasan, 1964; Sreenivasan *et al*., 1964 Red hills lake Blue-green algae Climatic factors Ganapati, 1940 Osman sagar, Miralam lakes Blue-green algae Temperature, seasonality, water chemistry Mohan, 1987 Sasthamcottah lake Green algae Water chemistry Chaudhary & Pillai, 2009. Singh & Balasingh, 2011 Nongmahir lake Green algae Nutrient enrichment Sugunan & Yadava, 1991 Khecheopalri lake Green algae Hydrology and nutrients Jain *et al*., 1999 Krishnasayer lake Diatoms Temperature, transparency, nutrients enrichment Chattopadhyay & Banerjee, 2007 Santragachi lake Blue-green algae Climatic conditions Ghosh *et al*., 2012 Ramgarh lake Diatoms Seasonality Jhingran, 1989 Dhom lake Green algae Nutrient enrichment Trivedi, 1993 Masunda lake Green algae, Bluegreen algae Seasonality, Nutrient enrichment Somani *et al*., 2007 Phutala, Ambazari lakes Blue-green algae Nutrient enrichment Maske *et al*., 2010 133 lakes West Bengal Krishnasayer Northern freshwater lakes Dakshini & Gupta (1979) reported the relation between population of phytoplankton and seasonality of three freshwater lakes of Delhi in 1976. In July and August months, dense phytoplankton decreased in all the study lakes, due to high flushing of rainwater. On the other hand, in the month of September, the phytoplankton count increased with low turbidity and wavy actions in the lakes. In Damadama, Badkhal and Peacock lakes of Delhi, *Microcystis* blooms dominated between October and December and between May and July. The authors concluded that physical, chemical and biological factors of three lakes varied from each other while, their climatic and geological conditions were same.Verma & Munshi (1983) described phytoplankton composition in Badua lake of Bihar. Phytoplankton composition dominated the blue-green algal blooms which influenced with Seasonal variations. Sarwar, 1996 presented that, the epiphytic algal flora 134 attached to Myriophyllum spicatum L. in Dal, Waskur, Anchor lakes of Kashmir. Rich and varied epiphytic algae derived moisture and nutrients from the air and rain (Sarwar,1996). Algae usually developed on Myriophyllum spicatum L. most likely due to its greater surface area. Algae dominated diatom population along with green algal blooms. According to the author, these outcomes resulted from the variations in hydrographic properties of lakes influenced the variations in epiphytic algal colonization. Tiwari & Chauhan (2006) described densities of phytoplankton in Kitham lake, Agra. Authors observed phytoplankton density in two highest peaks of winter (November to March) and summer (April to June). All the peaks dominated with green algae and diatoms (Tiwari & Chauhan, 2006). Sreenivasan presented the rich phytoplankton community in Bhavanisagar Lake, where phytoplankton communities dominated blue-green blooms, diatoms and green blooms and influenced with Seasonal variations (Sreenivasan *et al*., 1964; Sreenivasan, 1964). Mukherjee *et al*., 2010 presented details of phytoplankton dynamics of a lake in Ranchi. The distribution of phytoplankton in March, May and August was relatively least. However, in November month, all variant phytoplankton blooms occurred abundantly. Authors noted that, Ranchi lake has organic matter with high concentrations. Blue-green algae and diatom blooms were dominant phytoplankton communities in Ranchi lake. Southern freshwater lakes Ganapati in 1940 introduced the first paper on phytoplankton from the red hills lake, a water supply reservoir near Chennai in southern India. Author made foundation for Limnology in India through his significant paper. The paper served with the phytoplankton cycles with the water and climatic factors. Author reported that, by 1979, blue-green bloom diversity and addition of other algal species reduced in the lake. The authors concluded that, these events resulted from the transient eutrophication stage of the lake. In 1987, Mohan reported a two-year study (1977-1978) on diatom blooms of two tropical southern Indian lakes i.e. Osmansagar and Mir-alam lakes of Hyderabad. Population of phytoplankton in Mir-alam Lake was higher as compared to the Population of flora in Osmansagar Lake. Blue-green algal blooms were dominant in both the lakes. The author reported that, Osmansagar lake occurred more sodium, magnesium, potassium and oxygen. However, more Phosphorus, Calcium, Sodium and total solids were found only in Mir-alam Lake. The author noted that, population of diatom blooms changed with the order of concentrations of 135 cation, anions and silicates and density of diatoms changed with periodicity. Author emphasized that, temperature, seasonality of phytoplankton and chemical complexes affected the diatoms periodically (Mohan, 1987). Chaudhary and Pillai, 2009 described the relation between some physicalchemical characteristics and phytoplankton distribution of Sasthamcottah Lake during June 2006 to May 2007. All the peaks of algae dominated green alga during October and lower during June. The authors noted that, diatom flora were also affected by the pH of the lake water. During summers, green algae and dinoflagellates dominated throughout the lake when phosphates and nitrates also increased in lake water. Moreover, phytoplankton assemblages were mainly influenced by the physical, chemical and biological factors. Singh and Balasingh (2011) presented data on the phytoplankton population of the Kodaikanal Lake for a period of one year. During summer, phytoplankton dominated and declined in monsoon. Count of flora in turn increased during winter. The high nutrient concentrations with shallow depth of lake indirectly added concentrations of phosphate and nitrates, induced phytoplankton growth. Lake was predominated with green algae. In summer, the high density of algal assemblages imparted dark green color of lake. These events resulted from high temperature, pH, light intensity and low depth of the lake. freshwater lakes Small data reported on the phytoplankton of freshwater lakes of eastern region are as compared to other parts of the country. Sugunan and Yadava (1991) reported the phytoplankton distribution in Nongmahir lake, Meghalaya state.The average count of phytoplankton was 5440 units/L and dominated the chlorophyceae group. Authors concluded that the shallow depth of the lake created conditions. Jain *et al.*, 1999 presented data on the phytoplankton productivity, hydrology and nutrient dynamics of a Khecheopalri lake in the western part of the Sikkim Himalaya. The author concluded that the species of phytoplankton found in Khecheopalri lake was characteristic feature of a eutrophic stage. These outcomes resulted from agricultural activities, grazing and forest resource extraction from the watershed. Chattopadhyay and Banerjee in 2007 described the temporal changes in species composition, seasonal variation and diversity of phytoplankton community, related to some factors of water and sediment of Krishnasayer lake, Burdwan. Diatoms were dominated and factors such as temperature, transparency, dissolved oxygen, dissolved chloride, phosphate phosphorus and organic carbon positively co-related to phytoplankton. 136 Recent study of Ghosh *et al.*, 2012 reported diversity and seasonal variation of phytoplankton community. This condition related to physical-chemical components of Santragachi Lake of West Bengal between November 2009 and July 2010. Green algae were dominated and euglenoid population was in lower numbers. Authors concluded that in addition to climatic conditions, moderate level of pollution of lake affects phytoplankton growth. Western freshwater lakes The reports about composition and abundance of phytoplankton were more for western region. Jhingran (1989) gave brief description of phytoplankton population of Ramgarh lake in Rajasthan state. Dominant diatom blooms formed an average 19.08% of the total population. Author reported that events from seasonal changes in Ramgarh lake. Trivedi (1993) presented an account of phytoplankton distribution of Dhom lake in Maharashtra state. Dhom lake turned from mesotrophic to eutrophic conditions. Somani *et al*. 2007 presented the co-relation of seasonality and distribution of phytoplankton in lake Masunda, Thane (Maharashtra). Green and blue-green algal assemblages dominated the lake. Authors concluded that nutrient richness related the phytoplankton blooms in the lake. Maske *et al*., 2010 presented the outcomes of cyanobacteria in Nagpur city lakes. Cyanobacterial genera such as *Microcystis* was common in lakes of Nagpur. The lakes in Nagpur city contain diversity of cyanobacteria. The authors concluded that, more nutrient richness than temperature variations of lakes associated dominant *Microcystis* blooms in lakes. *Microcystis* blooms resulted negative allelopathic effect and affected the diversity of phytoplankton.

Thakur *et al* 2013 studied limnobiotic status of three selected lakes of Himachal Pradesh using physicochemical and biological parameters (especially phytoplankton and zooplankton) . One hundred forty-eight species belonging to nine groups of phytoplankton were identified from the lakes. Trophic level and the pollution status of the lakes were assessed upon the basis of Shannon diversity index (H′), species richness index (S), and physicochemical parameters. Plankton population size was correlated with biotic and abiotic parameters (pH, alkalinity, temperature, dissolved oxygen, transparency, phosphate, chloride, and nitrate). The present investigation revealed that the distribution of plankton species depended upon the physicochemical parameters of the environment.

Jindal *et al*. 2014 studied the seasonal variations in chlorophyll a, abundance, and species composition of plankton in relation to hydrography were studied. A total of 67 species belonging to eight groups of phytoplankton were identified. Among 67 phytoplankton species, 19 species exhibited perennial habit. Both plankton and chlorophyll a showed bimodal pattern of fluctuation with peaks in May and September.

REFERENCES :

Abraham, M.; 1980. Studies on plankton of Bhavanisagar reservoir with special reference to limnological conditions, inflow and water level. *J. Inland Fish. Soc. India*, 12: 25-37.

Bailey-Watts, A.E. (1976). Planktonic diatoms and silica in Loch Leven, Kinross: a one-month silica budget. *Freshwater Biology* 6, 203-213.

Chattopadhyay, C., Banerjee, T.C.; 2007. Temporal Changes in Environmental Characteristics and Diversity of Net Phytoplankton in a Freshwater Lake. *Turk J Bot*., 31:287-296.

Chaturvedi, R.K., Sharma, K.P., Sharma, K., Bharadwaj, S., Sharma, S.; 1999. Plankton community of polluted water around Sanganer, Jaipur. *Journal of Environment and Pollution*, 6:77-84.

Chaudhary, B.L. and Meena, L. ;2007. Environmental hazard – a case study of toxic bloom of *Microcystis* (anacystis) spp. in Udaipur lakes, Rajasthan (India). L. *Journal of Herbal Medicine and Toxicology*, 1:55 - 59.

Chaudhary, R., Pillai, R.S.; 2009. Algal biodiversity and related physicochemical parameters in Sasthamcottah lake, Kerala (India). *Journal of Environmental Research and Development*, 3:3.

Dakshini, K.M., Gupta, S.K.; 1979. Preliminary observations of limnological study of three freshwater lakes around Delhi state, India. *Proc. Indian. Nat. Sci. Acad*. B., 45: 564-570.

Forel.F.A. 1901. Hand Buch den Seckende Allgemeinc Limnologie Stuttgant 3: 249 .

Fritsch, F.E. (1931). Some aspects of the ecology of freshwater algae (with special reference to static waters). *Journal of Ecology* 19, 233-272

Ganapati, S.V.;1940. Geographical aspects of Red Hill Lake. *J.Madras geogr. Assoc*., 25:152-254.

Gonzalves E.A. and D.B. Joshi. 1946. Freshwater algae near Bombay. *J. Bom. Nat. Hist.Soc.* 46(1):154-176.

Ghosh, S., Barinova, S.,Keshri J.P.; 2012. Diversity and seasonal variation of phytoplankton community in the Santragachi Lake, West Bengal, India. *QScience Connect*. 3.

Gopal, B. and Zutshi, D.P.;1998.Fifty years of hydrobiological research in India. *Hydrobiologia*.384:267-290.

Gardiner, A.C. (1943a). Measurement of phytoplankton population by the pigment extraction method. *Journal of the Marine Biological Association* 25, 739-744.

Gardiner, A.C. (1943b). Silicon and phosphorus as factors limiting development of diatoms. *Journal of the Society of Chemical Industry of London* 60, 73-78.

Happey-Wood, C.M., Kennaway, G.M.A., Ong, M.H., Chittenden, A.M. & Edwards, G. (1988). Contributions of nano- and pico-algae to the productivity of phytoplankton and epipelic algae in an upland Welsh lake. In: *Algae and the Aquatic Environment* (ed. F.E. Round), pp. 168-184. *Biopress*, Bristol.

Head, R.M., Jones, R.I. & Bailey-Watts, A.E. (1999). An assessment of the influence of recruitment from the sediment on the development of planktonic populations of Cyanobacteria in a temperate mesotrophic lake. *Freshwater Biology* 41, 759-769.

Heaney, S.I., Chapman, D.V. & Morison, H.R. (1983). The role of the cyst stage in the seasonal growth of the dinoflagellate *Ceratium hirundinella* within a small productive lake. *British Phycological Journal* 18, 47-59.

Hosmani S.P. and S.G. Bharathi 1981. A new genus and species of alga from Karnataka.*J. Bombay. Nat. Hist Soc*. Vol.78(3):579-580.

Hosmani.S.P. and S.G. Bharathi 1982. Use of algae in classifying water bodies. *Phykos* 21:48-51.

Hosmani. S.P. 1987 Algal species diversity indices as a measure of water pollution..*Acta Botanica Indica* 15:320-322.

Hosmani S.P. and S.G. Bharathi 1987. Composite Trophy Index (CTI) as a measure of Water pollution. *Comp. Physiol. Ecol*. 12(2):71-73.

Hosmani S.P. 1988. Seasonal changes in phytoplankton communities in a fresh water Pond at Dharwad, Karnataka State, India. *Phykos.* 27:82-87.

Hosmani. S.P. and B.B. Mallesha 1985. Observation on pond life with special reference to algal species diversity indices indicating water pollution. *Plant and Nature*,3(1):41-44.

Hosmani S.P. and C.R. Nagendra 1980. *Rivularia aquatica* De Wilde as a parasite on *Griffithella hookeriana* Warm *Curr. Sci*. 49(19)751-752.

Hosmani S.P. and L. Vasanth Kumar. 1996. Calcium carbonate saturation index and its influence on phytoplankton. *Poll. Res* 15(3):285-288.

Iyengar .M.O.P.1933.Contributions to our knowledge of the colonial Volvocales of South India. *J. Lin. Soc. Bot*. 49:323-373.

Jain, S., Jain, A., Rai, S.C., Pal, J., Sharma, E.; 1999. Hydrology and nutrient dynamics of a sacred lake in Sikkim Himalaya. Hydrobiologia. 416:13-22.

Jewson, D.H., Rippey, B.H. & Gilmore, W.K. (1981). Loss rates from sedimentation, parasitism, and grazing during the growth, nutrient limitation and dormancy of a diatom crop. *Limnology and Oceanography* 26, 1045-1056.

Jhingran, A.G.; 1989. Limnology and production biology of two man-made lakes in Rajasthan (India) with management strategies for their fish yield optimisation. Final Report, IDA Fisheries Management in Rajasthan, Central Inland Capture Fisheries Research Institute, Barrackpore, India.1-63.

Jindal, R. Thakur, R, Singh, U.B. and Ahluwalia, A. S. 2014. Phytoplankton dynamics and water quality of Prashar Lake, Himachal Pradesh, India *Sustainability of Water Quality and Ecology* 4:101-113.

Lind, E.M. (1938). Studies in the periodicity of the algae in Beauchief Ponds, Sheffield. *Journal of Ecology* 26, 257-274.

Lund, J.W.G. & Talling, J.F. (1958). Botanical limnological methods with special reference to the algae. *Botanical Reviews* 23, 489-583.

Lund, J.W.G. (1949). Studies on *Asterionella formosa*. I. The origin and the nature of the cells producing seasonal maxima. *Journal of Ecology* 37, 389-419.

Lund, J.W.G. (1954). The seasonal cycle of the planktonic diatom *Melosira italica* (Ehr.) Kűtz. subsp. subarctica O. Mull. *Journal of Ecology* 42, 151-179.

Lund, J.W.G. (1961). The periodicity of micro-algae in three English lakes. *Verhandlungen der Internationalen Vereinigung für theoretische und angewandte Limnologie* 14, 147-154.

Lund, J.W.G., Kipling, C. & Le Cren, E.D. (1958). The inverted microscope method of estimating algal numbers and the statistical basis of estimations by counting. *Hydrobiologia* 11, 143-170.

Maske, S., Sangolkar L.N., Chakrabarti T.; 2010. Temporal variation in density and diversity of cyanobacteria and cyanotoxins in lakes at Nagpur (Maharashtra State), India. *Environmental monitoring and assessmen*t, 169:299-308.

Mohan, K.S.;1987. Bacillariophyceae of two tropical Indian lake of Hyderabad. *Bot. Bull. Academia Sinica*, 28:13-24.

Mukherjee, B., Nivedita, M., Mukherjee D.;2010. Plankton diversity and dynamics in a polluted eutrophic lake, Ranchi. *Journal of Environmental Biology*, 31:827-839.

Munawar, M.; 1974.Limnological studies on fresh water ponds of Hyderabad, India. *Biocenase Ibid*, 45:1-32.

Pearsall, W.H. (1932). Phytoplankton in the English Lakes. II. The composition of the phytoplankton in relation to dissolved substances. *Journal of Ecology* 20 241-258.

Philipose M.T. 1960. Fresh water phytoplankton of the Inland fisheries. *Proc. Sym. Algol*. CAR: 272-291

Pradhan, A., Bhaumik, P., Das, S., Mishra, M., Khanam, S., Hoque, B.A., Mukherjee, I., Thakur, A.R., Chaudhuri, S.R.; 2008. Phytoplankton Diversity as Indicator of Water Quality for Fish Cultivation. *American Journal of Environmental Sciences*. 4:406-411.

Prashad. B. 1916. The seasonal conditions governing pond life in The Punjab. *J. Asiat. Soc. Bengal* 12:142-145.

Preston, T., Stewart, W.D.P. & Reynolds, C.S. (1980). Bloom-forming cyanobacterium *Microcystis aeruginosa* overwinters on sediment surface. *Nature* 288: 265-267.

Ramanathan, A. L.;2007. Seasonal variation in the major ion chemistry of Pandoh Lake, Mandi district, Himachal Pradesh, India. Applied Geochemistry, 22:1736-1747.

Raut, N.S. and Pejaver, M.;2005. Survey of diversity of plankton attached to macrophytes from weed infested lakes. *J. Aqua. Biol*., 20:1-7.

Randhawa. M.S. 1936. Occurrence and distribution of the fresh water algae of North India. *Proc. Indian Acad. Sci.* 4(1):36-44

Reynolds, C.S.;1987. The response of phytoplankton communities to changing lake environment. *Schweiz Z Hydrol.*, 49:220-236.

Saravanakumar, A., Rajkumar, M., Thivakaran, G.A., Serebiah J.S.;2008. Abundance and seasonal variations of phytoplankton in the creek waters of western mangrove of Kachchh-Gujarat. *J. Environ. Biol*., 29:271-274.

Sarwar, S.G.;1996. Epiphytic algal flora attached to Myriophyllum spicatum L. in three Kashmir lakes, India. Environment and biodiversity: In the context of South Asia, 226-231.

Singh, K.K., Sharma, B.M.; 2012. Ecological productivity studies of the macrophytes in Kharungpatlake, Manipur northeast India. *International Journal of Geology, Earth and Environmental Sciences*, 2:58-71.

Singh, R.P., Balasingh, G.S.; 2011. Limnological Studies of Kodaikanal Lake (Dindugal District), in Special Reference to Phytoplankton 141 Diversity. *Indian Journal of Fundamental and Applied Life Sciences*, 1:112-118.

Somani, V., Gholba, M., Pejaver, M.; 2007. Study of phytoplankton population in lake Masunda, Thane, employing multivariate analysis. Eco. Env. & Cons. ,13: 847-848.

Sreenivasan, A.; 1964. Limnological studies and fish yield in three upland lakes of Madras State. Limnol. Oceanogr. ,8:501-516.

Sreenivasan, A., Soundar, R., Antony, F.; 1964. Limnological studies of tropical impoundments II Hydrobiological features and plankton of Bhavanisagar reservoir for 1961–62. Proc. Indian Acad. Sci., 59:51-71.

Sugunan, V.V., Yadava, Y.S.; 1991. Feasibility studies for fisheries development of Nongmahir reservoir. Central Inland Capture Fisheries Research Institute, Barrackpore. 30.

Sugunan, V.V.; 2000. Ecology and fishery management of reservoirs in India. *Hydrobiologia*, 430:121-147.

Suxena . M.R. 1955. Freshwater Euglenaceae from Hyderabad, India. *I.J. of L.B.S.* 34:430-450.

Tamot, S., Sharma, P.; 2006. Physico-chemical Status of Upper Lake (Bhopal, India) Water Quality with Special Reference to Phosphate and Nitrate Concentration and Their Impact on Lake Ecosystem. *Asian J. Exp. Sci.*, 20:151-158.

Thakur, R, Jindal,R. Singh, U.B. and Ahluwalia, A. S. 2013. Plankton diversity and water quality assessment of three freshwater lakes of Mandi (Himachal Pradesh, India) with special reference to planktonic indicators *Environmental Monitoring and Assessmen*t, 185(10):8355-8373.

Tiwari, A., Chauhan S. V.; 2006. Seasonal phytoplanktonic diversity of Kitham Lake, Agra. *Journal of Environmental Biology*, 27:35-38.

Trivedi, R.K.;1993. Water quality of Dhom reservoir Maharashtra, India. Ecology and pollution of Indian lakes and reservoirs, Ashish Publishing House, New Delhi.

Verma, P.K., Munshi, J.D.; 1983. Limnology of Badua reservoir of Bhagalpur, Bihar.-Proc. Indian Nat. Sci. Acad. B., 49:598-609. Zafar, R.; 1986. Seasonality of phytoplankton in some South Indian lakes. *Hydrobiologia*, 138: 177-18.

Victor Hansen. 1887 In Limnology by Welch .P. Mc. Grew Hill Book: 536.

Vincent, W.F. (1981). Photosynthetic capacity measured by DCMU-induced chlorophyll fluorescence in an oligotrophic lake. *Freshwater Biology* 11, 61-78.

West, W. & West, G.S. (1901). *The Alga-Flora of Yorkshire.* Transactions of the Yorkshire Naturalists Union, Botanical Series 5. 1-239.

West, G.S. (1907). Report on the freshwater algae, including phytoplankton, of the third Tanganyika expedition conducted by Dr W.A. Cunningham. *Journal of the Linnaean Society, Botany* 38 (No. 264), 81-197

West, W. & West, G.S. (1905). A further contribution to the freshwater plankton of the Scottish Lochs. *Transactions of the Royal Society of Edinburgh* 41, 477-518.

Zafar, R.; 1986. Seasonality of phytoplankton in some South Indian lakes. *Hydrobiologia*, 138: 177-218.