Limnology: A Critical Review

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ABSTRACT

The word Limnology is derived from Greek limne-marsh, pond and evaluates how physical, chemical and biological environment regulates these relationships. The type of life which is supported by lentic communities will depend greatly on biotic components of the fresh water ecosystems. Phytoplankton’s are microscopic plants which obtain their energy via photosynthesis. They are important to the ecosystem because they are part of the primary producing community and assist in recycling of elements such as carbon and sulphur. A biotic factors are essentially non living components that affect the living organisms of fresh water communities. Most biological assessments have dealt with conditions arising out of organic pollution since chemical conditions are rather difficult to monitor. Therefore both biological and chemical parameters are essential to monitor pollution. Curiosity prompted researchers to ascertain facts regarding limnology and hence publications on the ecology of freshwater biota have occurred quite occasionally. 233 references are quoted in the present text. The review literature indicates that publications were high during 1980-1989 (29.4%) and 1990-1999 (26.5%). In the present paper an attempt has been made to give an extensive review of literature related to limnology.

Key words: Limnology, Phytoplankton, Biotic, Abiotic. Review.

INTRODUCTION

The importance of water was realized as far as back as 640-546 B.C. as a means of substance of life, which was expressed in the Greek Philosophers, “Thales of Miletus” Cryptic saying “Water is best”. The extensive work of Forel (1901) who is regarded as the father of modern limnology gave an impetus to study this subject intensively. Fritsch (1888) established the first mobile biological station to study the various lakes, and with the establishment of the Fresh Water Biological station, limnology flourished both in Europe and America (Hosmani 1975). Limnology is the study of the structural and functional interrelationships of organisms of inland waters as their dynamic physical, chemical, and biotic environments affect them. Freshwater biology is the study of the biological characteristics and interactions of organisms of fresh waters. This study is largely restricted to the organisms themselves, such as their biology, life histories, populations, or communities.

The first use of the term Plankton is widely attributed to the German Biologist Hensen Victor (1887). “Plankton” includes all organic particles, which float freely and involuntarily in open waters, independent of shores and bottom (wandering). Plankton of fresh waters includes representatives of several groups of algae and bacteria. Plankton therefore are microscopic organisms that live suspended in the water environment, and form a very important part of the fresh water community; they move via convection or wind induced currents in almost every habitat of a fresh water ecosystem,
thousands of these organisms can be found, and due to their small size and simplicity, they are capable of occupying large expanse of water and multiplying at an exponential rate.

Abiotic factors are essentially non-living components that affect the living organisms of the fresh water community. When an ecosystem is barren and unoccupied, new organisms colonizing the environment rely on favourable environmental conditions in the area to allow them to successfully live and reproduce. When a variety of species are present in an ecosystem, the consequent action of these species can affect the lives of fellow species in the area, and these factors are deemed biotic factors. The angle of incidence at which sun light strikes the surface of water, the cloud cover, season and location are all important and this sort of variance greatly affects what type of organisms would occupy fresh water ecosystems.

Review

Limnology as it flourished as a different branch of science chiefly concerns with ecology of fresh waters. The factors that govern the algal growth include the physical and chemical conditions and their interrelationship. The discovery of plankton by Victor Hensen (1887) (60) was an outstanding event in the field of limnology and opened up a new vista. Fritsch (1907) (62) was the pioneer worker who studied the algal periodicity of small ponds, Fritsch and Rich (1932) (63) published a series “Studies on the occurrence and reproduction of British Fresh Water Algae in Nature.” Other contributions to the study were those of West (1912) (223), West and West (1907) (232), Pearsall (1921) (161), Hodgetts (1921) (86) gave a detailed account of the factors controlling the periodicity of fresh water algae, Rao (1955) (175) reported the distribution of fresh water algae in small ponds. Storm (1924) (203), Howland and Lucy (1931) (111), Hutchinson (1932) (112) and Yoshimura (1932) (235) studied fresh water lakes. Objectionable algae and their control in lakes were dealt by Prescott (1938) (167); Bailey (1938) (16) studied the ecology of phytoplankton of Lake Michigan, chloride of surface waters were recorded by Thresh, et al., (1944) (213) attributed higher amounts of chloride to pollution. Ecology of temple tanks was extensively studied by Ganapathi (1940) (67), 1943 (64), 1955 (60) and 1960 (66). Various aspects such as diurnal variations in certain physico-chemical parameters of biological significance in temporary ponds and temple tanks; ecology of tropical waters with reference to bloom forming algae were done. Gonzales and Joshi (1946) (70) worked on the seasonal occurrence of algae in a tank at Bandra, Mumbai. Patrick (1948) (159) observed the factors affecting distribution of diatoms, Rao (1955) (175) discussed the distribution of algae in a group of six small ponds of Hyderabad, Krishnamurthy (1954) (126) worked on the diatomic flora of south Indian lake; Gandhi (1955) (69) studied fresh water diatoms of Pratagbad, Rajasthan, Philipose (1960) (165) worked on fresh water phytoplankton of inland fisheries, Singh (1960) (186) recorded the phytoplankton ecology of inland waters of Uttar Pradesh. George (1966) (71) made a comparative study of plankton ecology of fish tanks. Similar contributions to the ecology of algae were by Munnawar and Zafar (1967) (144) studied the distribution pattern of phytoplankton of polluted and unpolluted lakes of Hyderabad. They pointed out the importance of chemical parameters and their impact on algal growth. Zaffar (1955) (237, 1967) (236) studied various aspects on the ecology of freshwater ponds of Hyderabad. Munnawar (1970) (145) made an extensive survey the distribution of unicellular and colonial phytoplankton in polluted and unpolluted environments while Muzino and Mori (1970) (146) made a preliminary hydro biological survey of some Asian Inland waters. Verma and Shukla (1968) (227) studied the ecological characteristics of temple tank, in Deoband; Phytoplankton studies were done by Vyas (1968) (225) in Pichola Lake, while Zafar (1969) (236) made and extensive study of algae in ponds of Hyderabad.

Several ecological studies were made during the years 1970 to 1980. Descy (1979) (52) made a novel approach to water quality estimation using diatoms. Water pollution and periodicity of algae were related by Venkateshwarlu (1970) (225) while studying the ecological aspects of river Moosi of Hyderabad. Plankton composition in fresh water lakes was studied by Seenayya (1971) (188) while Munnawar (1972) (143) was the first person to report Euglenophyceae as indicators of organic pollution. Other works on fresh water that followed were those of Bharathi and Hosmani (1973) (23) who made an extensive survey of hydrobiology of ponds and lakes of Dharwad. Some of the important observation
was that, heavily polluted ponds showed decreased production during summer, when different species of algae appeared as blooms; further Bharathi and Hosmani (1974) reported that the total algal production increases with increase in the number of species. These ponds were disturbed by animal and human population. Dellon and Rigler (1975) related total nitrogen to phosphorous and indicated that the ratio was important as a growth limiting factor. Further he pointed out that a ratio of 12 indicates that phosphorous becomes a limiting factor, while a ratio of less than 12 indicated that nitrogen becomes a limiting factor. Studies on bloom forming algae especially *Francea ovalis*, were made by Bharathi and Hosmani (1976) who reported that increased phosphates, calcium, ox disable organic matter, albuminooidal ammonia, low pH and high degree of organic pollution followed by death and decay of Cyanophyceae, accelerated the bloom of *Francea ovalis*. The ionic composition of sixteen lakes of Hassan and Chitradurga districts were made by Bharathi and Hosmani (1977) Shannon and Brenzoic (1972) developed a trophic state criterion by using multivariate approach and compared it to Sakamato (1966). This approach was quite significant. According to the values of 0-4 indicated oligotrophic waters; 4-10 indicate mesotrophic and values greater than 10 indicate eutrophic water. According to Dobson (1974) there is a slight variation in the range of these values. 0-4.3 is considered oligotrophic, 4.3 – 8.8 is mesotrophic and greater than 8.8 are considered as eutrophic. However these values are based on the determination of chlorophyll (mg/m²). While investigating the distribution of phytoplankton in three lentic water bodies of Brasilia (Italy), Santini and Salvatore (1979) reported profound effects of the levels of phosphorous on the Chlorophyll content of algae. Other significant contribution to fresh water ecology were those Singh and Swarup (1979) who studied Lake Surah (Ballia) with special reference to the periodicity of sewage contamination on fresh water ecosystems. Hosmani and Bharathi (1980) reported algae as indicators of pollution using Palmers Pollution Indices, while Hosmani and Bharathi (1977) describe the occurrence of Euglena sanguine in a pond at Dhanwad.

Significant research was done during the period from 1981 to 1990. Heinon (1980) made an extensive study on the quantity and composition of phytoplankton of Finish Inland waters. Archibald and Lee (1981) studied the ratio of inorganic nitrogen to orthophosphorous as a limiting factor and Singh (1982) studied the physico-chemical aspects of Nainital Lake. Round (1991) suggested that the information of algal diversity in fresh waters is important to understand the factors influencing the change in algal population. The effect of anthropogenic activity also has an important bearing on the ecosystem. Descy and Costae (1991) developed test methods for assessing water quality based on diatoms. The central Amazon Lakes were classified by Rai and Hill (1982) by using the physico-chemical and microbiological parameters. They were classified as oligotrophic and eutrophic, based on the bacterial density, electrical conductivity, pH, dissolved, oxygen, silica and phosphate content. Lake Lemend (France) was studied by Barroin et al., (1982) who examined the physico-chemical aspects of the eutrophic lake. Other important works during this period were those of Gurudev et al., (1983) who reported the Desmid flora of fresh waters of Savandurga (Karnataka), Hosmani and Bharathi (1982) classified water bodies using various algal populations; Prasad and Singh (1982) reported indicator organisms of water pollution; Mohanty (1983) also worked on algal as indicators of pollution. There were many publications related to lentic water bodies during this period. To mention a few, Kaul and Siddarth (1983) worked on Lalpuri Talab (Rajkot); Bharathi and Hegde (1983) on Desmids of Karnataka, Schroeder et al., (1983) recorded the biogenic calcium carbonate production in an oligotrophic lake at Austria, Forsyth et al., (1983) studied the liminological aspects of Roangaio Lake (New Zealand); Koschel et al., (1983) studying lake Breiber (Germany) pointed out that calcite precipitation decreases the phytoplankton population, dissolved oxygen and total phosphate. Raina et al., (1984) made a detailed study of water quality and pointed out that biological oxygen demand values indicated that the water was not heavily polluted, but it was the nutrient elements that played an important role in determining the trophic status of water bodies. Studies on the sewage pollution and eutrophication of lower lakes of Bhopal were made by Bhatnagar (1984); Low content of dissolved oxygen in Dal Lake was related to enhance microbial activity Zutshi et al., (1984), 1988,
further the low content of dissolved oxygen may be related to the increased rate of decomposition in the organic matter and conversion of related carbon dioxide into carbonic acid. Chandra et al., (1984) reported total absence of plankton which may be due to acute toxicity of the combined effluents having toxic constituents of chlorine and Mercury. Dakshini and Gupta (1984) made an ecological survey of three lakes of Delhi. Chan (1985) studied the effects of water pollution on organisms of a fresh water pond of Aligarh. He reported that members of Chlorophyceae were dependent on nitrates, diatoms were controlled by phosphates, while the excess growth of Microcystis aeruginosa stimulated the growth of Euglenophyceae. These organisms indicate eutrophic nature of the pond. Hosmani and Mallesha (1985) reported algal species as indicators of water pollution. Kanugo et al., (1985) made observations on the physico-chemical characteristics of some ponds of Raipur city. Chaturvedi (1985) Sharma et al., (1985) Hegde and Bharathi (1986) while studying fresh water ecosystems reported the presence of various species of algae. Sharma et al., (1986) Chitranshi and Bilgram (1986) investigated lentic ecosystems stressing on the importance of physico-chemical parameters in relation to the distribution pattern on phytoplankton. They stressed upon the physico-chemical parameters that play a significant role in controlling the plank tonic groups in different water bodies..Sladeck(1986) described the use of diatoms as indicators of pollution.

Singh (1987) investigated the primary production in Ox-bow Lake and concluded that high temperature coupled with higher concentrations of phosphorous enhanced the rate of reproduction of Microcystis aeruginosa. Puttaiah and Somasheker (1987) pointed out that high concentrations of carbon dioxide and low concentrations of oxygen significantly contributed to the abundance of Euglenoids in fresh waters of Mysore. Some of the other significant studies during this period were those of Singh and Mahajan (1987) studied the role of temperature, nitrate and phosphorous on phytoplankton variations in a Lake of Himachal Pradesh. Similarly Kurata et al., (1987) studied seasonal changes of various physico-chemical parameters in Lake Notoro Hokkaido, Japan. Some of the common observations made by Zutshi and Khan (1988), Anand (1988), Bhattacharya (1988) and Saifulla et al., (1988) were that the physico-chemical characters of water significantly affect the algal population. They stressed upon the importance of pH, total alkalinity and carbon dioxide on the succession of phytoplankton leading to eutrophication. Hosmani (1988) studied changes in phytoplankton community in fresh waters and found that blooms of Francea ovalis, Euglena elastica, Euglena gracilis and Trachelomonas charkowensis had a significant effect in reducing the number of species in ponds.

Tripathy and Pandey (1989) recorded diatom population to be high during summer, Khatavar et al., (1989) found a close relation between phytoplankton and some nutrients, especially during summer months. The concentration of chloride, sulphate and organic carbon plays a vital role in accelerating blooms; also phosphorous concentration has a profound effect on bloom formations. Such observations were made by Ahluwalia (1989), Srivastava et al., (1989), Gosh and George (1989) and Varadaraj and Ayyappan (1989). Gast and George (1989) made an attempt to study the abiotic factors that are causative factors of pollution in urban reservoirs, while Tripathy(1989). Although there were many studies related to fresh water ecosystems during 1991, most of them were diverted mainly towards algal systematics. Few of the reports were those of Naik and Hegde (1990) from the Sharavathi estuary, Tripathi and Pandey (1990), Mathur and Pathak (1990) from rock shelters, Srivastava and Othawani (1990) from semiarid region of Rajasthan. Ashok Kumar and Patil (1990) reported Desmids of Gujarath. Some of the ecological studies related to phytoplankton were also made by Singh (1990) who correlated physio-chemical parameters with primary production of plankton, Goviathan (1990) studied seasonal succession of algal flora of waste stabilization ponds; Ibrahim Banat (1990) studied algal productivity in waste water treatment plants. Ikommiko (1990) pointed out the problem of toxic pollution of Ladoge Lake in Russia and suggested that increased discharge of toxic substances into the lake has caused water quality deterioration, changes in species composition and other deleterious effects on the aquatic ecosystem, Trifonova (1990) outlined
the ecology and succession of phytoplankton, His work was related to phytoplankton biomass and chlorophyll levels. Certain inland lakes of Mysore were studied by Naganandini and Hosmani (1990) (147). They reported that cyanophycean bloom was dominated by Microcystis aeruginosa and the bloom was influenced by dissolved organic matter, carbon dioxide, phosphorous, calcium, dissolved oxygen coupled with the death and decay of Spirulina nordestedtii. These observations were supported by Swarnalatha and Narasing Rao (1991) (206) who were of the opinion that Cyanophycean blooms are indicators of water pollution. Surendra Kumar and Sharma (1991) (204) pointed out that the trophic level of water rises due to high electrical inductance, pH, total alkalinity and nitrates. Lakes of central Ontario were studied by Molot and Dillon (1991) (142) who stressed upon nitrogen and phosphorous ratio related to chlorophyll production in lakes of central Ontario. The distribution of phytoplankton and water chemistry was studied by Sarwar and Wazir (1991) (184). Periodicity of planktonic algae was studied by Kaushik et al., (1991) (121). Sagar and Richman (1991) (179) discussed functional interaction between phytoplankton and zooplankton in Green Bay Lake, Michigan. The seasonal diversity of Desmids were studied by Nygard (1991) (153) in lakes of Denmark. Higler (1991) (85) used diatoms in ecological management.

The conditions controlling the blooms of Cyclotella were discussed by Jyothi et al., (1992) (118) who reported that during the bloom chlorides, phosphates and organic matter were in higher concentrations. Vaisya and Adoni (1992) (223) inferred that lake Sagar had become hyper eutrophic due to unbalanced physical and chemical factors. The lake had lower transparency whenever it turned alkaline. On the contrary Chatterjee (1992) (40) while investigating lake Mandan Kannan reported that the major constituents controlling the lake ecology were organic and inorganic matter from outside the lake. Borker et al., (1992) (35) investigated the physico-chemical parameters in a lake at Goa. They reported that dissolved oxygen, free carbon dioxide, pH, chloride and total alkalinity in higher concentration accelerated the pollution rate in the lake. Adhakari and Sahu (1992) (1) studying Chilka lake concluded that temperature above 20°C along with an alkaline pH was responsible for Trichodesmium bloom during summer months. Biswas (1992) (32) recorded phytoplankton periodicity in Ogulebe lakes, Nigeria and reported maximum density of Desmids during summer; Besare et al., (1992) (22) studied the numerical and volumetric variation in a polymictic lake in Bhopal. Dixit et al., (1992) (55) suggested the use of Diatoms as indicators of biological condition of lakes. They can be used to address a wide variety of environmental issues including lake acidification, eutrophication as well as climate changes. Optimum diversion rates of pH and temperature had a profound influence on Diatoms as stated by Choudary (1991) (45) using the algal bioassay method while Mohaptra and Mohanty (1992) (141) determined water quality of lakes. They found that Chlorella was more efficient than Anabaena in reducing pollution and nutrient load. Agbeti(1992) (3) made a comparative study of the relationship between diatom assemblages and trophic variables and compared his data to newer approaches. Parvateesan and Mishra (1993) (158) studied algal of Pushker Lake that could be used as indicators of pollution. They recorded various groups of algae that showed a definite correlation between physico-chemical parameters and abundance. Rao et al., (1993) (177) classified Ooty lake as eutrophic, based on the nutrients status and phytoplankton production. Banjera Lake of Hyderabad was extensively studied by Swarnalatha and Narasing Rao (1993) (206) who described the various factors responsible for appearance of a bloom of Microcystis aeruginosa. Heckey (1993) (82) suggests that nutrient loads to lakes are associated mainly with atmospheric deposition and land run off together accounting for approximately 90% phosphorous and 94% nitrogen input into the lake. Bootsman and Heckey (1993) (33) concluded that domestic inputs are negligible.

Eutrophication usually affects physical and chemical environment and can lead to significant changes in the phytoplankton community structure. Flores and Barone (1994) (58), Uku and Mavuli (1994) (219) opine that generally this process results in zooplankton community dominated by rotifers and small bodied Cladocerous. Lehman et al., (1994) (128) observed increase in chlorophyll a concentration of algal blooms during rainy season. Shaji and Patel (1994) (189) highlighted phytoplankton ecology of a polluted pond at Anand (Gujarat) and stressed upon the physico-chemical parameters; Khan and

Phosphorous inputs in lakes result in frequent blooms of blue green algae that liberates toxins (Bratli, 1994) as observed in lake Frylandswatn (Norway). McCormick and Cairns (1994) studying water bodies of Florida reported that algae can respond rapidly and predict the presence of a wide range of pollutants that can be potentially used as early warning signals of water quality determination. Miyajima et. al., (1994) concluded that the diatom population and biogenic composition of silica were higher in eutrophic lake Biwa, Japan. Swarnalatha and Norasingh Rao (1994) studying two ponds, reported that one experienced a continuous bloom of Cyanophyceae was more polluted than the other pond that supported more Desmids and was less polluted. Goel et. al., (1994) reported that phosphorous nitrogen ratio is dependent on blue green algae dominance. Bairagi and Goswami (1994) made similar observations.

There were a few reports during the year 1995 which included those of Lorson et. al., (1995) and Agbeti and Smol (1995) who studied physico-chemical and biological characteristics of high mountain lakes; Verma and Moanty (1998) reported a direct relation between pH and phytoplankton, while Pandey et. al., (1995) studied the seasonal abundance of phytoplankton in rivers.

Anna-Lisa Holopainen et. al., (1996) studied the trophic level status of lake Ladoga and their relation to phytoplankton. Boris et. al., (1996) reported toxicity of cyan bacteria blooms in the same lake. He reported Anabaena circinalis, A. flos-aquae, A.lemmemani, Gliotrichia cichilitata and Microcystis aeruginosaas toxic algal blooms. Algal blooms occurrence was found to be positively related to total nitrogen and phosphorous by James and Hewens (1996). Lenoir and Cste (1996) studied the occurrence of Euglena sanguinea and reported that temperature above 26°C, high pH, carbon dioxide, albuminoiodal ammonia, phosphate with low concentrations of carbonates, nitrates and free ammonia accelerated the bloom. Other such reports were those of Swrnalatha and Narisangh Rao(1998), Pandey et. al., (1998) who are of the opinion that inflow of nutrients and consequent algal growth deteriorates the water quality. The importance of phosphorous in eutrophication of fresh waters and production of abundant autotrophs, mainly Cyanophyceae was discussed by Correl (1998). Pollution tolerant species of algae were reported by Tarar et. al., (1998) and Agarkar(1998) assed the water quality of Sakegan Reservoirs, Gandhi revived the freshwater diatoms of central Gujarat and reported many new species. Trophic structure of some phytoplankton communities of tropical wetlands were reported by Pandit(1999). Zandbergen et.al(1998) formulated the British Colombia Water Quality index for watershed management which was an useful index for similar waters elsewhere. Dhanapathi(2000) made notes on the occurrence of Rotifers and their relation to other parameters. Eloranto and Goiniuen(2002) evaluated the fresh water diatoms of Finnish waters using benthic diatoms. Wani (1998) studied the seasonal dynamics of phytoplankton in Himalaya lakes and reported that diatoms were the most represented species; lakes of Amaravathi district were studied by Seema et. al., (1999) while other works related to coastal aquaculture were those of Chidambaram (1999). Variations in the correlations of the physico-chemical parameters and phytoplankton were reported by Rajendra Nair(1999). Agarkar(1998) made an assessment. Publications on the ecology, limnology and the phytoplankton communities continued to appear in abundance during the years following 2000.

Borse and Bhave (2000) reported that dissolved carbon dioxide was maximum in summer and minimum in winter and was dependent on carbonates and bicarbonates in water, Carbon
dioxide and pH of water also had an impact. Trophic State Indices for lakes of Mysore were calculated by Hosmani (2006) who inferred that values of 40-50 were considered mesotrophic (moderate pollution), more values than 50 were eutrophic (highly productive) and values less than 40 were considered oligotrophic. Thomas and Deviprasad (2006) studying the lakes of Mysore inferred that sunshine, phosphates, nitrates, oxygen and CO₂ have a significant effect on the growth of Myxophyceae. They reported that members of Chlorococcales had the capacity to tolerate extreme concentrations of nutrients. Mahadev and Hosmani (2004) assessed water quality based on the Langier’s index and concluded one of the lakes had a tendency of hard water with light scale deposition, while the other had a tendency of heavy scale deposition. Hosmani and Vasanth Kumar (1996) made a study on the biochemical aspects of water pollution and inferred that Kukkarahalli lake is highly productive in terms of biochemical products whereas Dalvoi lake is productive in terms of plankton productivity. Nandan et al., (2001) studied seasonal fluctuation in Hentala lake of Jalgaon and reported abundance of blue green algae was due to higher concentration of dissolved carbon dioxide, carbonates, total alkalinity, phosphates and chlorides, Noor Alam (2001) worked on physico-chemical parameters of a pond at Hatwah, Bihar, and recorded significant variations and suggested measures to prevent deterioration. Seasonal distribution of plankton in a fresh water pond of Pollachi (Tamil Nadu) was studied by Rajkumar (2001) who reported that minimum number of phytoplankton occurred in winter months. Variations in the level of phosphorous and carbon dioxide in Ambegosale lake were studied by Madhuri Pejava et al.,(2002), Anil Kumar et al., (2001) studied the important factors of organic pollution on primary productivity in wetlands of Jarkhand, Nagarathna and Hosmani (2002) studied the factors influencing the bloom of Nitzschia obtusa in a polluted lake. Correlation matrix and cluster analysis indicated that most of the physico-chemical parameters were inversely proportional to the growth of the Diatom. The appearance of few species of Desmids indicated that the water was polluted; Mamata Rawath and Jaikhar (2002) made a limnobiological study of few reservoirs of Jodhpur, Rajasthan and reported that they had low DO and the quality was very poor using advanced monitoring techniques, while Gomez (2001) developed the IDP index for streams and rivers. Many of the researchers during 2001 developed diatom based indices. Gevrey et al.(2001) made an extensive study of Langier’s index and its relation to fresh waters. Their observations were that the phytoplankton growth in saturated waters had a tendency of changing the pH of the water. Further Chlorococcales and blue green algae dominated waters that had a tendency of light scale deposition. These findings confirmed the levels of organic pollution. Cude (2001) developed an effective water quality index for management of lakes. Bate et al. (2002) made an extensive study on diatoms as indicators of pollution, Chinmoy and Razuiuddin(2002) reported the water quality index of degraded waters of industrial areas. Hosmani and Lingnaiah (2002) studied the causative factors of fish kills due to algal blooms and Hosmani(2002) also described the interrelationships of phytoplankton and zooplankton. Mahadev and Hosmani (2002) used the Langier’s index as a factor for the distribution of phytoplankton. Hariprasad and Ramakrishnan(2003) used algal assay for determination of organic pollution. Juttner et al.(2003) used diatoms as indicators of stream water quality. Ahmed (2004) described an innovative index for evaluating water quality of streams. De la Rey et al.,(2004) also applied diatoms as indicators of water quality. Nandan and Aher (2005) assessed the water quality of Haranbareae dam (Maharashtra) using algal communities and recorded pollution tolerant genera of various groups. The most pollution tolerant species were those of Navicula, Oscillatoria and Euglena. The Principal Component Analysis (PCA) was extensively used. Algal biodiversity in fresh waters and the related physico-chemical parameters were studied by Veeresh Kumar and Hosmani (2006). They concluded that Desmids occurred in fairly good numbers. These observations suggest that the lakes are oligotrophic but are tending to become eutrophic. They were also dependent on high temperature, pH and bicarbonates; Ranjan et al., (2007) studied physico-chemical characters of Ghariyarwara pond (Nepal) and observed dominance of Chlorophyceae throughout the year and seasonal variations in the other phytoplankton. Bhuiyan and Gupta (2007) made hydro biological...
study of Barak pond (Assam). They reported that highest dissolved oxygen and neutral pH in them was due to diverse plankton population. Euglenophyceae dominated the ecosystem; Tas and Gorulol (2007) (211) observed that lake Cemek (Turkey) supported abundant phytoplankton. Tiwari and Shukla (2007) (214) studying temporary water bodies of Kanpur observed high values of alkalinity, phosphates, ammonia and chloride which indicated eutrophic waters. Yogendra and Puttaiah (2007) (234) considered that BOD and COD demand decreases with increased nitrogen due to nitrification. The conclusion that was drawn by Venkata Subramani et al., (2007) (224) while studying lakes of Bodham was that chloride indicated pollution and increase in sulfate in water was due to discharge of sewage into it. Dissolved oxygen levels in water constantly changed due to organic matter (Khare et al., 2007) (124); High sodium levels contribute to salinity problems and can interfere with Mg++ and Ca++ availability, Smitha et al., (2007) (200).

Hosmani (2008) (92) studied the ecology of Euglenophyceae from Dharwad and reported that they responded to high temperature, ox disable organic matter and low concentration of dissolved oxygen; Jayashankara et al. (2010) (116) described microbial diversity of temple tanks of Udapi district while earlier Louis-Laclareq (2008) (130) developed the diatom index of saprobity. Basavarajappa et al., (2009) (13) studied the water quality parameters of four fresh water lakes of Mysore based on the CCME-WQI. In most cases the quality of water was threatened and its condition often deviated from the normal; Arivind Kumar and Varma (2009) (13) studied the spectrum of plankton abundance in certain lotic systems of Jharkhand, India. The quantitative and qualitative information on the seasonal variation of Zooplankton and selected physico-chemical variables based on the nutrient data was indexed. Sawanth et al., (2010) (185) made a limnological study of Atyal pond in Kolhapur, Maharashtra and reported that the pond is rich in nutrients and has become eutrophic. Ajayaz et al., (2010) (7) studied the diversity index of algal flora in Wular lake, Kashmir. They reported that diversity was significantly correlated with physico-chemical parameters. There was a positive correlation with conductivity, carbon dioxide, hardness and nitrate; Shinde et al., (2010) (186) studied seasonal variations in physico-chemical characteristics of Harssooli, Aurangabad and demonstrated that the water was suitable only for fish culture. Hosmani (2010) (98) made an extensive study on phytoplankton diversity in lakes of Mysore district and reported that the algal species were uniformly distributed, but diversity within the population was low. Bhosale et al., (2010) (30) dealt with the diversity of plankton in water bodies of Miraj Tashie (Maharashtra). There were great variations in the physico-chemical complexes as well as the phytoplankton population.

During recent years a large number of publications related to limnological studies appeared, especially in the southern regions of Karnataka. The techniques form normal general descriptions were switched to modern statistical explanations and multivariate analysis were used. Basavarajappa et al. (2011) (20) made an attempt to evaluate fresh water diatoms as indicators of water quality in some lakes of Mysore. All the lakes studied were alkaliphilic, and nitrogen eutrophic tolerant species were present. The water quality ranged from alpha mesotrophic to polysaprobic. The study suggested that diatoms are an excellent source of ecological indicators.. Hosmani et al. (2011) (99) while studying water quality index for protection of aquatic life used the CCME-WQI, and reported that the water quality of many lakes was always endangered and the conditions in it were always deviated from normal situations.. The lake waters were unable to support and protect aquatic life.. The structure and dynamics of biological communities and their relation to biological stress is of importance to develop conservation strategies in lake ecosystems. Nestedness is a measure of the order in ecosystem referring to the order in which the number of species is related to the area or other factors. Hosmani (2011) (101) while reporting nestedness patterns of fresh water diatom assemblages in lakes of Mysore found that Synedra ulna and Nitzschia obtusata to be perfectly nested, while the idiosyncratic species was Caloneis permagma. Diatoms of hierarchical range were Gomphonema sumatrane, Gomphonema baltonis, Gyrosigma kuetzingii, Nitzschia virudla and Navicula gracilis. Hosmani (2011) (102) using the National Sanitation Foundation-Water Quality Index rated water quality of lakes as medium to bad. The water quality and oxygen saturation levels had a major impact on the water quality.
Hosmani and Mruthunjaya (2012)\(^{(107)}\) applied the one way ANOVA to the data of fresh water ecology. The results indicated that carbon dioxide and dissolved oxygen content were the most significant parameters operating in the lakes. Desmids were at their optimum during certain months, indicating the pristine nature of water. Multivariate analysis for distribution of Euglenophyceae were applied by Hosmani (2012)\(^{(106)}\) Hierarchical associations were observed between *Peranema trichosporium* and *Phacus tortus*. Hosmani (2012)\(^{(108)}\)also used benthic diatoms in lake water quality monitoring. Many of the plankton species were indicators of anthropogenic pollution which was mainly due to cattle raring in the surroundings of the lakes. The ionic composition of fresh waters and its implication on aquaculture was studied by Hosmani (2012)\(^{(104)}\). Residual Sodium Carbonate and sodium content were high. The Sodium Absorption Ratio could be used for reclamation of lake waters. However the lakes were not suitable for aquaculture. Hosmani and Mruthunjaya (2013)\(^{(109)}\) studied the distribution of phytoplankton in lakes of T. Narasipura taluka. Cyanophyceae were the most abundant compared to Bacillariophyceae. Euglenophyceae were less and Cyanophycean blooms were common (*Microcystis aeruginosa*). Hosmani and Mruthunjaya (2013)\(^{(109)}\) studied the distribution of phytoplankton diversity on the water quality index. Very few plankton species dominated the lakes of T. Narasipura and had no impact on the water quality. Total Nitrogen played a major role while species of *Navicula*, *Nitzschia* and *Gomphonema* significantly appeared during the study period.

Hosmani (2013)\(^{(110)}\) made a comparative study of various methods of algae as indicators of water quality. The ISDE/5 Index, Palmers Index and ranking of the lakes according to Garrett Ranking were made. Nestedness of species indicated that the matrix fill was low (59.59\%) and the system temperature was high (32.22\%), indicating a poor distribution of algal species in the lakes.

**CONCLUSION**

One of the greatest difficulties in reviewing the amount of work done on a particular type of study is the availability of research journals and the research publications. A vast number of journals are published throughout the country and the world. However based on the records that could be procured through various agencies, as well as referring to various literatures available on the subject, it has been possible to accumulate the present data. It provides sufficiently high percent of references to constitute the review of literature. Avoiding the too early data and taking into account the references available from (1900) to the present day (2013); the review has been prepared.

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