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Ecological Status of Some Floodplain Lakes Within Jhelum River basin, Kashmir

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ABSTRACT

The paper analyses attribute of plankton communities and macrophytes along with environmental variables of five floodplain lakes within Jhelum River basin, during various seasons of the year 2005-2006. The Bacillariophyceae dominated Chlorophyceae and Cyanophyceae in all the lakes whereas zooplankton communities were predominated by rotifers except for the deepest lake Manasbal, where copepods were the dominant group. A close association of *Ceratophyllum-Myriophyllum* and less frequently with *Nymphoides* was observed in all the lakes. The waters of all the studied lakes were alkaline and well buffered. The high content of chloride is indicative of presence of organic matter while progressive increase in nitrogen and phosphorus in all the lakes could be attributed to anthropogenic pressure and sewage contamination. The chemical parameters in all the lakes are on higher side when compared to earlier records.

INTRODUCTION

Floodplain lakes are among the most productive life support systems in the world and are of immense socioeconomic and ecological importance to mankind. They are of critical importance for the survival of biodiversity and support high concentration of birds, mammals, fish and invertebrate species. By virtue of natural functioning, they play an important role in water quality improvement, sediment control, oxygen production, nutrient recycling, flood control, aquifers recharging and ground water discharge. Floodplain lakes are among the most altered landscapes worldwide and they continue to disappear at an alarming rate as their conversion is much higher than that for most other landscape types; as a consequence their biodiversity and water quality has declined rapidly. The primary indirect drivers of degradation and loss have been population growth and increasing economic development while the primary direct drivers of degradation and loss include infrastructure development, land conversion, water withdrawal, pollution, overharvesting and overexploitation, and the introduction of invasive species.

The River Jhelum (N lat. 33°,30'; E long. 75°25') is the only river which dissects the valley of Kashmir into two halves. The origin of the river is from foot hills of Pir Panchal mountain range which sprouts in the form of a famous octagonal spring, Verinag. The river is 241 km long and crosses to other side of Kashmir. On its journey, number of freshwater oxbow type of lakes exist on its floodplains which are mostly formed due to meandering of River Jhelum. They play an enormous role in maintaining the hydrological regimes of the entire valley (Fig. 1). Jhelum being the lifeline of Kashmir with number of lakes, directly or indirectly connected to it, are of great tourist attraction due to their scenic beauty. Among these, Dal lake has received a lot of attention and is the main tourist attraction of the valley. Anchar, Manasbal, Gilasar, Ahansar, Waskur and Wular lakes have been grossly ignored despite their rich biodiversity and significant role in hydrography of Kashmir. The lakes with their associated wetlands support rich biodiversity and provide important habitats for migratory water birds within Central Asian Flyway. These lakes serve as the largest fisheries resource in Kashmir valley supporting livelihoods of large human population living along their fringes. Regulation of hydrological regimes of the basin through Wular lake and its associated wetlands protects the Kashmir valley from floods as well as maintains flows to support agriculture and hydropower generation. The present paper deals with limnological studies of five floodplain lakes, and an attempt has been made to evaluate their current ecological status.

DESCRIPTION OF SITES

Khushalsar lake: The lake is situated in the northwest of Srinagar city at a distance of about 8.5 km from the city centre. In 19th century, the lake formed one continuous water body but during 20th century a narrow path turned into a road and got the lake separated into two smaller water bodies called Khushalsar and Gilsar. The surface area of Khushalsar is 16.6 ha with an average depth of 3.6 m. Khushalsar lake is receiving an effluent load of 465 MLD form its immediate catchment with an estimated quantity of 2MT phosphorus and 1.71 MT inorganic nitrogen (Kundangar 2002), resulting in serious weed infestation and deterioration of water quality.

Anchar lake: Anchar lake is situated at a distance of 14 km in northwest of Srinagar at an altitude of 1584m within the geographical coordinates of Lat. 34°20' N and Long. 74°82' E. It is a single basined lake connected on the eastern side of Dal lake through an inflow channel 'Nallah Amir Khan' via Gilsar and Khushalsar. The lake, though close to Srinagar city, constitute both rural and urban characteristics in a typical rural environment. In recent years significant encroachments have been noticed within the lake. According to Lawrence (1895) the area of the lake in 1893-1894 was 19.54 km^2, which has now been reduced hardly to 6.8 km^2 of which 3.6 km^2 is marsh. The lake is under tremendous biotic pressure and receives large quantities of domestic sewage from its immediate catchment.

Ahansar-Waskur lakes: The twin lakes on the floodplain of River Jhelum are situated about 26 km towards north of Srinagar within geographical coordinates of 34°18' N lat. and 74°39' E long., at an average altitude of 1583 m. The water surface area of Ahansar lake is 17 ha and its maximum depth is 5 m. The Waskur lake is 1 km off the Ahansar and comparatively larger and deeper with surface area of 38 ha and maximum depth of 6 m. Both the lakes are semi-drainage type with perennial outflow channels which are manually controlled to regulate water supply from the river during high floods.

Fig. 1: Location of floodplain lakes along Jhelum river.

Manasbal lake: It is situated 32 km to the north-northwest of Srinagar city at Safapur village within geographical coordinates of 34°15 N and 74°40° E at an altitude of 1584 m. The surface area of the lake is 280 ha of which 25 ha is marshy. The lake is oblong in outline and extends in a northeast, southwest direction with a maximum length and breadth of 3.5 km and 1.5 km respectively. It is the deepest of all valley lakes; in some parts it is 12.5 m deep and perhaps the only lake which develops summer stratification. The volume of water has been estimated as 12.8×10^6 m^3. The lake water derives chiefly from internal springs besides upland runoff. The lake is connected to the Jhelum river by a 1.6 km channel called Nunnyar nallah, which enters the river near Sumbal village. The lake receives an estimated load of 4.36 tonnes of phosphorus and 39.42 tonnes of nitrogen every year (Kundangar et al. 1997) and as a result the water body is virtually chocked up with submerged weeds particularly during summer which is also the high tourist season. The deep water becomes anoxic with considerable accumulation of hydrogen sulphide.

Wular lake: Wular is one of the largest wetlands of Asia and an internationally accepted Ramsar site, located between north latitude 34°16' to 34°26' and east longitude 74°33' to 74°42'. The Wular is a shallow lake, with a maximum depth of 5.8 m. The lake area has not been properly investigated although several estimates exist. As per the Directory of Wetlands in India (MoEF), the area has been reported to be 189 sq. km. The Survey of India maps indicate the lake area to be only 58.7 sq. km in winter (1978). Taking into consideration, the highest flood level of 1579 m, the lake area has been computed to be 173 sq. km. The revenue records, however, indicate the lake area to be 130 sq. km. As per the recent study the lake area has reduced from 157.74 sq. km to 58.71 sq. km from 1911 to 2007. Thus, there is a reduction of 45 percent mainly by conversion for agriculture (28 percent) and due to plantation (17 percent) within the lake. The stupendous problems the lake is facing, include human incursions due to unabated encroachments, rapid siltation and depletion of some endemic and endangered plants.

MATERIALS AND METHODS

The sampling was done on monthly basis during forenoon (9000-1200 hrs) and usually composite samples were considered for physico-chemical analysis and plankton enumeration. pH was measured with microprocessor based pH meter ELE (England). For rest of the parameters methods given in APHA (1997), Trivedy et al. (1995) and Mackereth (1963) were followed using DR4000 UV- Spectrophotometer (HATCH, USA). Phytoplankton enumeration was done by filtering 1 litre of lake water through plankton net (mesh size 64 mµ), while for zooplankton 10 litres of water was sieved through plankton net, keeping in view the low density of zooplankton population. The filtered plankton samples were preserved with 1% acidified Lugol's solution and enumerations were done in 1 mL Sedgwick Rafter counting cell. Identification of plankton was done after consulting Kiefer (1939), Smith (1950), Desikachary (1959), Ward & Whipple (1959), Subba Raju (1963), Suxena & Venkateshwarlu (1966), Phillipose (1967) and Weber (1971).

RESULTS

Khushalsar has been regarded as a satellite lake of Dal lake. Plankton analysis depicted about 70 phytoplankton species of which the predominant were *Scenedesmus bijugatus, S. arcatus, S. quadricauda, Tetraedon* sp., *Ankistrodesmus falcatus, Pediastrum tetras, Pediastrum* sp., (Chlorophyceae), *Fragilaria crotonensis, Navicula* sp., *Nitzchia acicularis, Synedra ulna, Amphora* sp., *Cocconeis placentula, Diatoma elongate* (Bacillariophyceae), *Microcystis aeruginosa, Oscillatoria* sp. and *Merismopedia punctata* (Cyanophyceae), *Euglena* sp., *Phacus* sp.

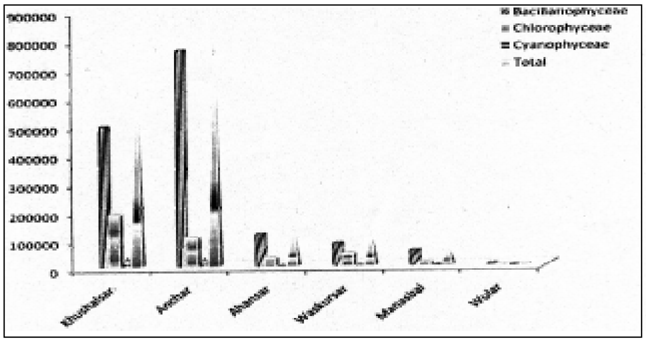

Fig. 2: Phytoplankton in different lakes.

(Euglenophyceae). However, Chlorophyceae was dominant group among all other classes. The Chrysophyceae and Dinophyceae were represented by sole members of *Dinobryon* and *Peridinium*, which were observed during spring and winter months only. The zooplankton species comprised of *Keratella coclearis, Brachinous* sp., *B. quadridenta, Asplanchna* sp., *Filinia* sp., *Rotaria* sp., (Rotifera), *Chydorus sphaericus* (Cladocera), *Cyclops* sp. (Copepoda).

The total phytoplankton population was recorded as 715.5 × 10^3 individuals/L (IL^{-1}). The Bacillariophyceae population was 493.7 × 10^3 IL^{-1} followed by Chlorophyceae and Cyanophyceae representing 186 × 10^3 and 35.7 × 10^3 IL^{-1} respectively (Fig. 2).

The Rotifera were as usual predominant contributing 78.8% to the zooplankton mass. The cladocerans and copepods contributed 12.6 % and 8.6 % respectively (Fig. 3). The chemistry of Khushalsar waters is indicative of highly enriched waters due to chloride, calcium, nitrogen and phosphate contents (Table 1).

Aquatic vegetation comprises mainly of the emergent plant species *Typha angustata* and *Phragmites communis* which are the chief occupants of the littoral zones. Rooted floating leaf macrophytes dominated by *Nelumbo nucifera, Nymphaea alba, Nymphoides peltata* occupy about 45.5% of the total area forming large associations. Of free floating macrophytes, *Salvinia natans* and *Lemna* species are distributed particularly in stagnant and sheltered zones. Submerged macrophytes due to their aggressive capacity cover the maximum area in the lake. This life form class is dominated by *Ceratophyllum demersum, Myriophyllum spicatum, Potamogeton* species, occupying about 50% of the total area.

167 taxa of phytoplankton, representing six classes of algae, were recorded from the Anchar lake. Bacillariophyceae was the predominant group, followed by Chlorophyceae. The dominant genera were *Navicula, Nitzchia, Amphora, Cymbella, Melosira, Epithemia, Fragilaria, Closterium, Ankistrodesmus, Scenedesmus, Cosmarium, Pediastrum, Oscillatoria, Chroococus, Microcystis,*

Table 1: Chemical characteristics of lake waters.

Parameters	Units	Khushalsar	Anchar	Ahansar	Waskur	Manasbal	Wular
pH		7.7	8.6	8.2	8.4	8.3	8.4
Cl	mg/L	44	38	15	20	15	35
Ca	mg/L	52	43.4	41	41.7	44	36.5
Mg	mg/L	13.4	10.5	12.7	14.7	10.7	5.8
Tot. Alk.	mg/L	105	153	150	146	117	170
Fe	µg/L	231	537	55	63	145	222
NH_4-N	µg/L	155	323	89	72	340	330
NO_3-N	µg/L	219	517	88	114	416	452
PO_4-P	µg/L	178	114	25	61	39	54
Tot. P	µg/L	880	735	649	402	413	187

Gymnodinium, Euglena, and *Phacus.* 93 zooplankton species were recorded of which 64 belonged to Rotifera, 20 to Cladocera and 9 to Copepoda. The dominant species include ***Keratella coclearis, Polyarthra vulgaris, Lepadella ovalis, Lecaneluna*** (Rotifera); ***Chydorus sphaericus, Alona rectangula, Acroperus harpae*** (Cladocera); ***Cyclops bicuspidate, Diaptomous*** sp., ***Nauplii*** larvae (Copepoda).

In this lake the total phytoplankton population was 894.7×10^3 IL^{-1} of which the Bacillariophyceae was predominant with a population of 759.7×10^3 IL^{-1}, followed by Chlorophyceae (10.2×10^3 IL^{-1}) and Cyanophyceae (3.7×10^3 IL^{-1}) (Fig. 2).

The Rotifera were dominating with a percentage contribution of 73.6 % (Fig. 3). The contribution of Cladocera and copepods was 22.4 % and 4% respectively. The chemistry of water reveals that the pH ranged between 7.7 and 9.7 with an average value of 8.6. The average concentration of calcium and magnesium in Anchar waters was 43.4 mg/L and 10.5 mg/L respectively, while the average concentration of ammonical nitrogen and nitrate nitrogen was 323 µg/L and 517 µg/L respectively. The iron content (537 µg/L) in Anchar lake was very high as compared to other lake waters. The concentration of phosphorus (PO_4-P = 114 µg/L; T.P. = 735 µg/L) was also higher than other lake waters. The total alkalinity (153 mg/L) indicated moderately hard water (Table 1).

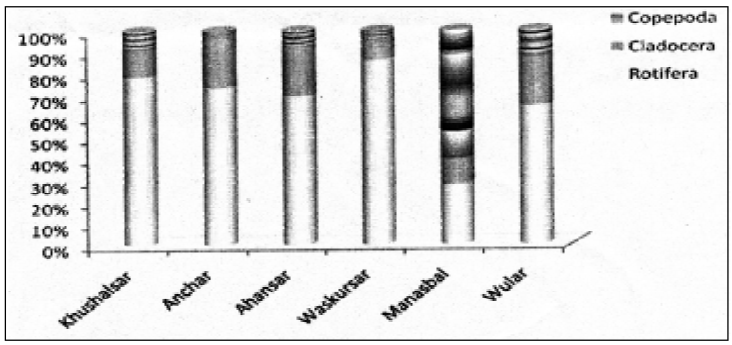

Fig. 3: Phytoplankton in different lakes.

The lake supports large stands of macrophytes mostly represented by ***Potamogeton crispus, P. natans, Ceratophyllum demersum, Myriophyllum spicatum, Nymphoides peltata, Nelumbo nucifera, Polygonum*** sp. and ***Salvinia natans***. ***Myriophyllum spicatum, Ceratophyllum demersum*** and ***P. natans*** exhibited constancy in their population density throughout the study period. The emergent macrophytes have colonized the littoral zones while mats of *Salvinia natans* and *Lemna* have occupied the channels and boat ways. 127 species of phytoplankton were recorded from twin lakes (Ahansar and Waskur). Of these 68 represented Chlorophyceae, 39 Bacillariophyceae, 16 Cyanophyceae, 3 Dinophyceae and only 1 representative from Chrysophyceae. The dominant species were *Closterium* sp., *Ankistrodesmus spiralis, Desmidium* sp., *Scenedesmus bijugatus, Fragilaria crotonensis, Fragilaria capucina, Fragilaria* sp., *Navicula radiosa, Nitzchia accicularis, Synedra ulna, Eunotia undulata, Microcystis aeruginosa, Oscillatoria proteus, Merismopedia punctata, Dinobryon divergens,* and *Ceratium hirundinella*. However, Bacillariophyceae dominated the other algal groups. Among the zooplankton, the most common forms encountered were those of *Asplanchna multiceps, Brachionus caudata, Keratella quadrata, K. cochlearis, Euchlonis dilalata, Lecane* sp., *Trichocera procellus, Cyclops* sp., *Diaptomus* sp., *Nauplii* larvae, *Bosminia longirostris, Chydorus spharicus, Alona rectangula* and *Daphnia* sp.

In Ahansar lake, the total phytoplankton population was recorded as 146.2×10^3 IL^{-1}, of which the Bacillariophyceae was 112.5×10^3 IL^{-1}. The population of Chlorophyceae was 28.25×10^3 IL^{-1} while the Cyanophyceae was 5.5×10^3 IL^{-1}. In Waskur lake, the population of phytoplankton was

132.5×10^3 IL^{-1}, followed by Chlorophyceae (4.5×10^3 IL^{-1}) and Cyanophyceae (8.0×10^3 IL^{-1}) respectively.

In both the lakes the Rotifera were dominating among the zooplankton communities contributing about 69.4% and 86.2% respectively (Fig. 3). The cladocerans contributed 23 % and 8.4 % respectively. The copepods were 7.6 % in Ahansar while in Waskur lake their percentage was 5.4 %. The lake waters were alkaline with little difference in their hydrogen ion concentration. Alkalinity was mainly of bicarbonate type with little difference between the two. The nitrate nitrogen was higher in Waskur lake while in Ahansar the annual means of total phosphorus was much higher than Waskur. The values for calcium, magnesium, chloride and iron were generally higher in Waskur lake.

Macrophytic vegetation in Ahansar and Waskur lakes comprise of emergent species viz., *Phragmites communis* and *Juncus effuses* particularly in the silted regions where water depth is shallow. Among the important floating rooted species in the lakes are *Nymphoides peltata, Nelumbo nucifera, Potamogeton natans, Nymphaea alba* and *Trapa natans*. These species cover large water area close to lake shore and in some cases the plants extend up to the centre of the lake depending upon the water depth and turbidity. The deepest parts were colonized by *Ceratophyllum-Myriophyllum* community. Other important species were *Potamogeton lucens, P. crispus, P. pucillus, Hydrilla verticillata,* and *Najas* sps.

The Manasbal waters revealed 125 species of phytoplankton of which 55 belonged to Chlorophyceae, 45 to Bacillariophyceae, 17 to Cyanophyceae while rest to other algal classes. However, Bacillariophyceae were dominant in the lake water. The most dominated forms were *Nitzchia acicularis, Fragilaria crotonensis, Navicula radiosa, Synedra ulna, Cymbella ventricosa, Cocconeis placentula, Cyclotella comensis, Cosmarium constrictum, C. reniformae, Scenedesmus bijugatus, Merismopedia elegans, M. punctata, Ceratium hirundinella, Peridinium* sp., and *Dinobryon* sp. The zooplankton population was comprised of about 132 species of which 83 were rotifers, 36 cladocerans and 13 copepods. The dominant forms being *Colurella obtuse, C. uncinate, Keratella cochlearis, Trichocera* sp., *Lepadella ovalis, Polyarthra vulgaris, Chydorus sphaericus, Alona rectangula, Acroperus harpae, Daphnia laevis, Mesocyclops leuckarti, Achanthodiaptomus denticornis, Cyclops scutifer.*

In Manasbal lake the total phytoplankton of 68.4×10^3 IL^{-1} was recorded of which Bacillariophyceae, Chlorophyceae and Cyanophyceae contributed 53.5×10^3 IL^{-1}, 10.0×10^3 IL^{-1} and 0.48×10^3 IL^{-1} respectively (Fig. 2).

Unlike other lake waters quantitatively the copepods formed the dominant group contributing about 60 % to the zooplankton mass. The Rotifera and Cladocera contributed 28 % and 11.6 % respectively (Fig. 3).

The chemistry of the lake waters depict alkaline nature with an average pH value of 8.3 (Table 1). However, calcium and other biologically important nutrients like nitrogen and phosphorus show significant enrichment than earlier records of Zutshi & Wanganeo (1984).

In Manasbal lake, the peripheral zones are infested by emergent macrophytes viz., *Phragmites australis, Typha angustata, Nelumbo nucifera, Euryle ferox* and *Cyperus* sp., while slightly deeper zones are inhabited by *Nymphoides peltata, Ceratophyllum demersum, Myriophyllum spicatum, Hydrilla verticilata* and *Chara* sp. In recent years, the lake area under *Ceratophyllum demersum* has increased tremendously and has developed into dense mono-specific stands.

In Wular lake, 82 algal taxa were recorded of which *Navicula radiosa, Synedra ulna, Amphora* sp., *Fragilaria crotonensis, Scenedesmus* sp., *Pediastrum* sp., *Pandorina* sp., *Oedogonium* sp., *Anacystis* sp., *Microcystis aeruginosa, Oscillatoria proteus, Anabaena* sp., *Spirulina* sp., *Euglena* sp., and *Phacus* sp. were common. Among the zooplankton, 55 species were recorded of which 37 belonged to Rotifera, 9 to Cladocera and 4 to Copepoda. The predominant species being *Keratella cochlearis, Polyarhra vulgaris, Ascomorpha* sp., *Brachionus quadridentata, Filinia longseta, Monostyla bulle, Chydorus sphaericus, Alona costata, Bosminia longirostris, Cyclops scutifer, Paracyclops affinis* and *Nauplii* larvae.

In Wular lake, the total algal population was 6.7×10^3 IL^{-1} of which Bacillariophyceae was 5.34×10^3 IL^{-1}. The population of Chlorophyceae and Cyanophyceae was 0.95×10^3 IL^{-1} and 0.40×10^3 IL^{-1} respectively.

Rotifera in this lake too dominated other groups. The contribution of the Rotifera was 64.5 % while cladocerans and copepods contributed 23.2% and 12.3 % respectively.

The chemistry of Wular lake waters is alkaline in nature with increasing trend of chloride, calcium, total alkalinity, iron, nitrogen and phosphorus.

In Wular lake, extensive areas are colonized by submerged, floating and emergent macrophytic species such as *Ceratophyllum demersum, Myriophyllum spicatum, Nymphoides peltata, Nelumbo nucifera, Trapa bispinosa* and *Phragmites communis* on the south eastern margin of the lake where the Jhelum river forms a large deltic tract. According to Kundangar et al. (1993) the general sequence of various growth forms in the Wular lake was *Ceratophyllum demersum-Myriophyllum spicatum-Nymphoides peltata-Nympheae alba-Potamogeton crispus-P. natans* and *Trapa natans*. The authors have reported variation in marcophytic species and have attributed it to physical environmental conditions prevailing in the lake.

DISCUSSION

The predominance of diatom species like *Navicula, Pinnularia, Nitzschia* in the lake waters depict higher trophic levels. Munawar (1970) is of the view that such diatom species develop profusely in waters rich in pollution of animal origin. Williams (1969), Stockner & Benson (1967), Holland & Beeton (1972), Richardson (1968) and Sommerfeld et al. (1975) regard *Fragilaria, Nitzschia* as an indicator of sewage pollution and eutrophy. According to Munawar (1970) the rise in nitrate and phosphate may accelerate the growth of algal forms other than Cyanophyceae, particularly diatoms and green algae. It has also been suggested that maximum taxonomic richness of herbivores should tend to occur at a higher productivity level than that for plants (Huston 1994). Although this has been confirmed by a study of plankton in 33 mainly large North American lakes (Dodson et al. 2000), our results also suggest the same pattern. This may well represent a general pattern for shallow lakes, as a recent Danish study of 71 mainly shallow lakes using TP as productivity indicator also suggests that phytoplankton diversity has an optimum at high TP levels (Jeppesen et al. 2000).

In all the studied lakes, the Rotifera were the most predominant group among the zooplankton. According to Sampath et al. (1979), the increase in the abundance of rotifers, both by species and individuals, is due to the increase in total alkalinity and total hardness values. However, Prasad (1956) and Byars (1960) are of the view that temperature is the most important factor determining the seasonal abundance of plankton and controls the quality and the quantity of the zooplankton in the lake. Michael (1964) correlated the abundance of loricate forms such as *Brachionus* sp., *Anuraeopsis* and *Keratella* to higher total alkalinity and temperature conditions. Yousuf et al. (1986)

suggested that in eutrophic lakes the number of these species is limited but the population of these species which do occur is very high and usually there appear blooms of species. In most of the floodplain Kashmir lakes, the dominance of rotifers among zooplankton has been attributed to selective predation of planktivorous fish which results in shifting of zooplankton communities (Brooks & Dodson 1965 and Kundangar & Zutshi 1985). The predominance of copepods in Manasbal lake, unlike other lakes may be due to the thermal stratification. According to Yousf (1988), all the planktonic forms of zooplankton occur in high densities in thermocline region of water column during stratification. During stratification abrupt changes in the density of water in thermocline slow down the sinking velocity of seston in this layer and result in attracting of filter-feeding rotifers which in turn not only attract the carnivores plankton but increase the concentration of copepods. The present studies reveal that the waters of all the lakes are alkaline and well buffered. The average chloride content of the studied lake waters ranged from 15 mg/L (Ahansar) to 44 mg/L (Khushalsar) which are quite higher than earlier records (Kaul 1977, Mir 1977, Yousuf et al. 1986, Kundangar et al. 1994, 1995, 1997). Thresh et al. (1944) suggested that high chloride contents indicate the presence of organic matter, presumably of animal origin which has undergone oxidation, but this may increase the nitrate content. Moyle (1956) and Ghose & Sharma (1986) attributed the higher values of chloride to pollution while Mathew et al. (2000) related the elevated chloride to flow of sewage. The Kashmir lakes have been termed as calcium rich lakes because of these being basically marl lakes. The average calcium content in the investigated lakes ranged between 36.5 mg/L (Wular lake) to 52 mg/L (Khushalsar) which are quite higher than earlier records (Zutshi & Khan 1988). The high levels of calcium in waters and presence of marl on the leaves and stems of most of the macrophytes almost in all the studied lakes may absorb labile organic substances and thereby limit the plankton growth. The direct relationship between bicarbonates and calcium has been observed by Pearsall (1923) and Zafar (1964), whereas the inverse relationship between the bicarbonates and carbonates has been noted by Ganapati (1940). In comparison to calcium, the average magnesium content in the studied lakes was very low and ranged between 5.8 mg/L (Wular Lake) to 14.7 mg/L (Waskur). This is perhaps due to the fact that waters with high dissolved organic content are alkaline in nature and magnesium salts are more soluble in them. The average total alkalinity values varied from 105 mg/L (Khushalsar) to 170 mg/L (Wular Lake) which is indicative of moderately hard waters. The alkalinity was of bicarbonate type. Freiser & Fernando (1966) stated that when total alkalinity is high the bicarbonate system prevails and the pH is usually on the alkaline side, which seems to be the case with the studied lake waters.

The iron content in the studied lake waters ranged between 55 µg/L (Ahansar) and 537 µg/L (Anchar Lake). According to Lund (1965), the availability of the iron from certain brown coloured Norwegian freshwaters is in the ferrous state and presumes that it exists as organic complexes and refers to work showing that ferric oxides are dissolved and reduced by extracts of plant residues. On the other hand Jumppanen (1976) attributes the increase of iron content to oxygen deficit. The progressive increase in phosphorus and nitrogen content in all floodplain lakes is obvious from the Table 1 as they are frequently (1-2 a year) inundated and fed by nutrient rich river water, which has been found to be the main culprit in changing the trophic status of these water bodies at a rapid scale. Hutchinson (1957) reported the increase of phosphorus as a result of sewage contamination. According to McCaull & Crossland (1974), the most important factors responsible for eutrophication of freshwater lakes are phosphorus (PO_4-P) and nitrogen (NO_3-N). Phosphorus has been singled out for attention because it is believed to be nutrient most frequently controlling eutrophication (Schindler et al. 1971, According to Lund (1965) and Einsele (1936), evidence from the addition of fertilizers to fish ponds and from what is known about the eutrophication of lakes by sewage support the view that phosphorus plays a major role in production.

In all the investigated lakes a close association of *Ceratophyllum-Myriophyllum* and less frequently with *Nymphoides* was observed which is in agreement with Zutshi (1975). The excessive growth of *Ceratophyllum* and *Myriophyllum* in almost all the lakes may be due to shallow depth, higher transparency of the waters, enrichment of lake sediments and higher levels of calcium. According to Kundangar & Zutshi (1987) in Kashmir lakes, the longer photoperiods and higher water temperature during summer and autumn seasons may be responsible for optimum growth, flowering and biomass of macrophytes. The authors opine that during winter, the lakes support very low macrophytic density as majority of the species disappear completely and a few are under the process of senescence, resting or decay. The low temperature prevailing during winter may be acting as a limiting factor for the vegetative phase in this region. Since large members of macrophytic species are chance introductions and once seed, vegetative fragments, turions, diaspore, etc. reach a favourable niche, they immediately colonize and become quite aggressive. The condition that have favoured establishment of the present macrophyte communities as the studied lakes are shallow basined, high water residence time, moderate to high nutrients levels and organic rich sediments.

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