Journal of Research & Development, Vol.3 (2003)
ISSN 0972-5407

Phytoplankton Dynamics in Anchar Lake, Kashmir

Shamim A. Bhat and Ashok K. Pandit

Centre of Research for Development, University of Kashmir, Srinagar - 190006, Jammu and Kashmir, India

ABSTRACT

The present investigation on Anchar Lake was undertaken during 2000-01 and deals with the general ecology of phytoplankton in the lake ecosystem. Overall 143 species of algae were reported from the lake basin. In general, the phytoplankton exhibited its peak growth during summer and a very low growth during winter. The growth and abundance of phytoplankton are closely related to physico-chemical characteristics of water besides climatic conditions especially the temperature. On the basis of phytoplankton population the lake is at present undergoing accelerated cultural eutrophication.

Keywords: Freshwaters, phytoplankton, nutrients, eutrophication, lake, Kashmir.

INTRODUCTION

The valley lakes, indispensable aquatic ecosystems, are enveloped on all the sides by the Himalayan mountains. They are irreplaceable natural waterbodies aboding a rich and diverse gene pool. These waterbodies also provide food, fodder, green manure and vegetables besides being potential sources of water and recreation. Nevertheless, some of the lakes like Anchar has shown pronounced trophic evolution due to fast growing human populations and urbanisation in the catchment of the lake (Zutshi *et al.*, 1980; Pandit, 1996, 99). Development of floating gardens for agricultural purposes and the utilisation of lake waters for navigation and disposal of sewage and sewerage from the surrounding human habitation, in addition to natural siltation and the toxic effluents coming out from Sheri-Kashmir Institute of Medical Sciences (SKIMS) complex (Bhat *et al.*, 2001) are greatly responsible for the deterioration of the lakes environment which subsequently have severely disturbed the ecology of both plant and animal communities.

Very few ecological investigations have been published on the plankton populations of freshwaters of Kashmir Himalaya (Kaul *et al.*, 1978; Pandit, 1980; Zutshi *et al.*, 1980; Kaul and Pandit, 1982; Yousuf *et al.*, 1986; Pandit, 1993, 96, 98, 2000 and Sarwar, 1999) but so far as the Anchar Lake is concerned not much information is available vis-à-vis phytoplankton dynamics. It is in this backdrop, Anchar Lake was selected and the present study, therefore, encompasses the study on species composition, seasonal variation and seasonal succession of phytoplankton communities in relation to the operative influence of physico-chemical environment. The study will help us in understanding the current trophic status of the lake.

STUDY AREA

Anchar Lake, is situated 14 km to the northwest of Srinagar city at an altitude of 1584 m a.s.l. within the geographical coordinates of 34° 20' - 34° 26' N lat. and 74.82° - 74.85° E long. The lake is connected to the Khusalsar Lake which is in turn is connected to a famous Dal Lake through a small inflow channel, Nalla Amir Khan. However, a network of channels resulting in a delta type formation from the cold water river Sind enter the lake on its western shore. The lake is also fed by a number of springs present in the basin itself and along its periphery. Towards the northeast of this water-basin is situated the complex of SKIMS draining its toxic effluents into the lake. The run-off from the surrounding paddy fields including floating gardens and sewage and sewerage from the surrounding human habitation are also drained into the lake, thereby further enhancing the nutrient levels of the lake.

The lake is heavily infested with thick macrophytic growth and the littorals, constituting the major portion of the lake, are dominated by tall growing emergents like *Phragmites australis*, *Typha angustata* and *Sparganium erectum*. However, dense patches of low growing emergents like *Myriophyllum verticillatum* are found at sites receiving waste waters. The growth of submerged plants is, in general, restricted due to silt-impregnated water and thick phytoplankton blooms resulting in algal mats. Deeper zones of the lake are mainly occupied by the sparse growth of submergeds like *Ceratophyllum demersum* and *Potamogeton crispus*. A number of floating islands (Radhs) utilized for vegetable cultivation, being developed in the margins, result in a myriad of channels which are heavily infested with thick mats of obnoxious weed complexes like *Lemna-Salvinia*. In fact, Anchar Lake has a great diversity of plant communities; wherein Zutshi (1975) reported twenty associations and Kak (1981) reported forty-two macrophytic species from this natural heritage of Kashmir.

The four sites (I, II, III, IV) selected differed on the basis on water depth, vegetation and other biotic variables (Fig. 1)

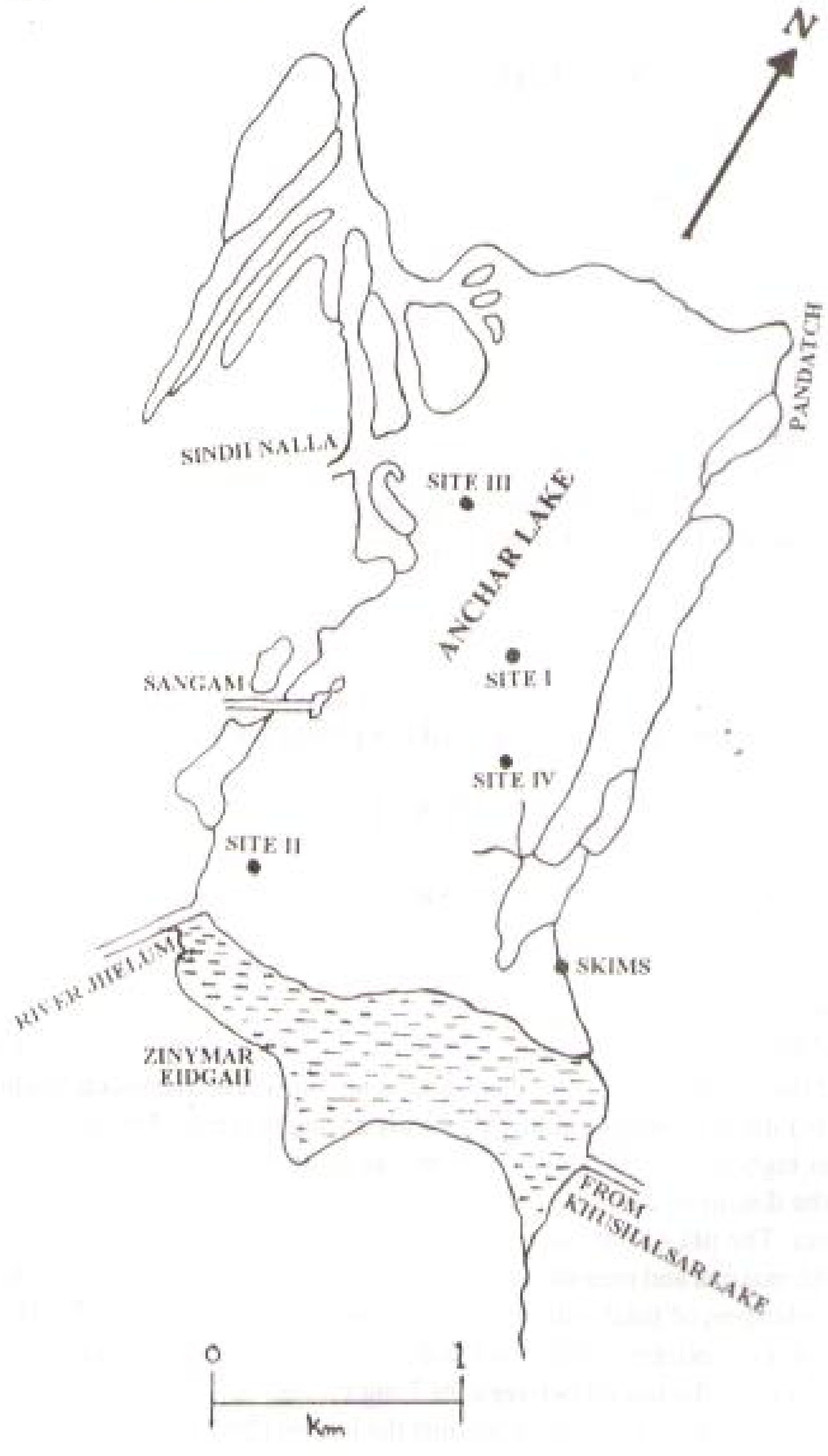

Fig.1. Map of Anchar Lake showing various sampling sites

MATERIAL AND METHODS

The sampling was carried out on monthly basis during April 2000-March 2001 and the samples were thoroughly mixed in equal proportions to form a representative sample of five litres, which was sieved through a plankton net of bolting silk (mesh size no. 20). The plankton sample thus collected was preserved in 4% formaldehyde (APHA, 1998). The quantitative estimation of phytoplankton was done under microscope, with the help of Sedgwick Rafter cell of 1 ml capacity.

The unicellular algae were counted as individuals whereas in filamentous Cyanophyceae 100 μm length of the filaments were taken as the equivalents. Similarly, the filamentous Chlorophyceae were recorded as cells while in the colonial forms like *Microcystis, Pandorina, Volvox, Gomphosphaera*, etc. the counting unit was the colony(Jumppanen, 1976).

Identification of the phytoplankton was done with the help of standard works by Fritsch (1935), Desikachary (1959), Randhawa (1959), Prescott (1970), Palmer (!980), Edmondson (1992), Cox (1996), etc. The detailed chemical analysis of water samples followed the standard methods of Golterman and Clymo (1969), APHA (1998) and Gupta (2000)

RESULTS

Physico-Chemical Characteristics of Water

The average and mean values for various physico-chemical features of lake water at different study sites are summarised in Table 1. During the present investigation there were pronounced fluctuations in the depth of waterbody with maximum depth (1.99 m) during autumn and the minimum (1.03 m) during summer. However, the secchi visibility remained high (0.64 m) during winter and low (0.43 m) during summer. The water temperature of the lake was highest (24.9°C) during summer as against the lowest (6.9° C) during winter. However, the dissolved oxygen values were more (4.4 mg l^{-1}) in spring and less (2.42 mg l^{-1}) in autumn. The pH of the water, being towards alkaline side, fluctuated between 8.14 and 8.05 with maxima and minima during summer and autumn respectively. The conductivity values, an indication of total nutrient concentration, varied from 323.2 μS cm^{-1} to 408.4 μS cm^{-1}, with two extremes being obtained during spring and autumn respectively. For calcium, the values fluctuated between 29.7 mg l^{-1} and 50.3 mg l^{-1}, with highest calcium content 50.3 mg l^{-1} during winter as against the lowest (29.7 mg l^{-1}) being recorded during summer. Magnesium followed a trend similar to that of calcium and ranged between 9.02

mg l^{-1} to 18.2 mg l^{-1}. The higher levels of sodium were found in the range from 4.8 to 15.7 mg l^{-1} as against the lower levels (2.6 to 7.3 mg l^{-1}) of potassium. Alkalinity is a measure of

Table 1 : Physico-chemical characteristics of Anchar Lake during different seasons, 2000-01

Parameters		Spring	Summer	Autumn	Winter
1. Depth(m)	A	1.38	1.03	1.99	1.07
	R	0.97-1.73	0.72-1.26	0.72-1.72	0.62-1.67
2. Transparency(m)	A	0.54	0.43	0.55	0.64
	R	0.24-0.81	0.27-0.55	0.34-0.70	0.31-0.95
3. Temperature (°C)	A	22.4	24.9	16.7	6.9
	R	22.0-22.8	24.3-25.6	16.5-16.9	6.7-7.4
4. Dissolved oxygen (mg l-1)	A	4.4	3.9	2.42	3.6
	R	3.4-5.2	3.6-4.27	1.5-4.06	3.11-4.0
5. pH	A	8.10	8.14	8.05	8.12
	R	7.90-8.19	7.97-8.41	7.94-8.15	8.02-8.21
6. Conductivity (µS cm-1)	A	408.4	332.2	323.2	330.7
	R	362.3-482.3	282.0-438.6	308.6-337.6	279.0-377.0
7. Calcium (mg l^{-1})	A	33.8	29.7	49.3	50.3
	R	31.3-37.2	27.4-33.54	45.4-52.1	47.4-52.8
8. Magnesium (mg l^{-1})	A	10.2	9.02	18.2	16.1
	R	9.16-12.9	6.62-12.1	16.06-19.8	14.6-17.9
9. Sodium (mg l^{-1})	A	-	4.8	15.7	8.7
	R	-	3.1-6.55	14.7-17.9	8.0-9.0
10. Potassium (mg l^{-1})	A	-	2.6	7.3	2.9
	R	-	1.6-3.15	6.6-7.9	2.8-3.0
11. Alkalinity (mg l^{-1})	A	311.0	135.0	347.6	298.5
	R	256.6-358.3	110.6-160.6	320.0-381.3	292.0-310.0
12. Chloride (mg l^{-1})	A	45.9	32.7	21.6	25.5
	R	40.4-52.5	18.6-40.6	20.0-23.3	19.0-29.0
13. Silicates (mg l^{-1})	A	3.1	3.15	2.1	3.98
	R	2.96-3.19	3.06-3.25	1.68-2.48	3.20-4.47
14. NH3-N (µg l^{-1})	A	240.7	221.8	491.2	407.1
	R	195.0-350.0	180.0-282.5	393.3-568.3	362.5-450.0
15. NO3-N (µg l^{-1})	A	270.3	208.3	247.2	184.3
	R	237.6-304.0	140.6-247.6	199.0-321.6	135.0-280.0
16. TOPP (µg l^{-1})	A	50.3	80.3	156.2	145.1
	R	35.3-72.6	66.6-98.0	121.6-178.3	120.0-162.0
17.TPP (µg l^{-1})	A	286.3	513.1	403.2	401.8
	R	203.3-357.6	371.6-603.3	267.6-501.6	372.5-425.0

A = Average; R = Range

buffering capacity of the water with the values greatly fluctuating from 135.0 to 347.6 mg l^{-1}. The maximum value was, however, attained in autumn and minimum in summer. For the chloride concentration the values varied greatly at regular intervals with maximum (45.9 mgl^{-1}) during spring and minimum (21.6 mg l^{-1}) during autumn. Similarly, the maximum (3.98 mg l^{-1}) silicate level was obtained in winter as against the minimum (2.1 mg l^{-1}) in autumn. For ammonical nitrogen, the maximum content (491.2 µg l^{-1}) was obtained in autumn and the minimum (221.8 µg l^{-1}) in summer. The concentration of orthphosphate phosphorus was quite low (50.3 to 156.2 µg l^{-1}) as compared to total phosphate phosphorus (286.3 to 513.1 µg l^{-1}). In general, the maximum phosphorus concentration was obtained during hotter months and minimum during the colder months of the year.

Phytoplankton

I. Species composition

The phytoplankton exhibited a great diversity in species number at four different sampling sites of Anchar Lake. During the present investigation a total of 143 phytopfankton species and sub-species were recorded from the lake, out of which 31 belonged to Cyanophyceae, 49 to Chlorophyceae, 40 to Bacillariophyceae, 14 to Euglenophyceae, and 03 each to Chrysophyceae, Dinophyceae and Xanthophyceae respectively (Table 2).

Table 2. Total number of phytoplankton species

Taxonomic groups	Total number of species
A. Cyanophyceae	31
B. Chlorophyceae	49
C. Bacillariophyceae	40
D. Xanthophyceae	03
E. Chrysophyceae	03
F. Dinophyceae	03
G. Euglenophyceae	14
Total	**143**

II. Seasonal variation in the population density

Pronounced seasonal variation occurred in the species composition and population density of phytoplankton (Table 3). There were variations in spatial distribution of various phytoplankters also.

Cyanophyceae

The most common species viz., *Oscillatoria foreani*, *O. accuminata*, *Nodularia spumigena*, *Chrococcus turgidus* and *Rivularia minutula* occurred throughout the year and showed their maximum density at the peak stages of growth in summer. However, some of the species showed only temporal variations and species like *Oscillatoria proboscidae*, *O.princeps*, *Lyngbya aestuari*, *Aphanizomenon holsaticum*, *Nodularia* sp. and *Astramoeba radiosa* were thus mostly restricted to spring and summer whereas species namely *Microcystis aeruginosa*, *Schizothrix* sp., *Oscillatoria nigra* and *Anabaena major* exhibited their mass occurrence in winter only. Of the study sites Cyanophyceae was the most dominant at site - II during summer, being mainly composed of *Oscillatoria foreani*.
Chlorophyceae

The most common species found throughout the year included: Chlorella vulgaris, *Chlorococcum* sp., *Microspora amoena*, *Ulothrix zonata*, *Uronenema elongatum*, *Dermatophyton radians*, *Oedocladium operculatum*, *Oedogonium* sp., *Spirogyra* sp., *Mougeotia* sp., *Zygnema cylindrospermum* and *Desmidium aptogonum*. However, species like *Gonium pectorale*, *Pediastrum biradiatum*, *Scenedesmus quadricauda*, *Sphaerocystis schroeteri*, S. *boryanum*, *Coleochaete scutata*, *Drapanaldiopsis* sp., *Closterium ehrenbergii*, *C. leiblenii* and *C. moniliferum* had a long growth period extending from spring to autumn while as forms like *Hormidium subtile*, *Hyalotheca* sp., *Pithophora* sp. and *Rhizoclonium* were thermophobic, loving to live in cold waters.

Among the study sites, the maximum density of green algae was registered during summer at site -I with *Chlorella vulgaris*, *Pediastrum biradiatum* and Spirogyra sp., each making 800 ind/l; thus contributing the maximum towards the population density at the study site.

Bacillariophyceae

Most of the species occurring throughout the year included: *Cymbella cistula*, *Fragilaria capucina*, *Navicula subtillisma*, *Pinnularia nobilis*, *Eunotia minor* and *Synedra*

Table 3 . Seasonal variation in the population density (ind/l) of phytoplankton at four different study sites of Anchar Lake

A. CYANOPHYCEAE	Spring				Summer				Autumn				Winter			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Anabaena major	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-	-
A. solitaria	-	-	-	-	-	-	-	-	-	-	200	-	-	-	-	-
A. oscillatorioides	-	-	-	-	-	-	-	-	-	200	-	-	-	-	-	-
Aphanizomenon holsaticum	-	200	-	300	-	200	-	100	-	-	-	-	-	-	-	-
Coccochloris stagnina	200	-	-	-	400	-	-	-	400	-	200	-	-	-	-	-
Coccochloris sp.	40	-	-	20	200	-	-	100	400	200	200	300	-	-	-	-
Chroococcus turgidus	200	100	100			200	200	100	100	20	20	-	40	-	-	-
Cylindrospermum licheniforme	-	-	-	-		100	-	-	-	-	-	-	100	-	-	-
Gomphosphaeria wichurae	-	-	-	-	300	-	-	200	-	-	-	-	-	-	-	-
Lyngbya aestuarii	-	300	400	-	-	300	200	-	-	-	-	-	-	-	-	-
Nostoc linckia	600	-	-	-	400	-	-	-	300	200	-	-	-	-	-	-
Nodularia spumigena	300	-	-	-	200	-	-	-	100	-	-	-	-	300	100	
Nodularia sp.	-	-	-	200	-	-	-	100	-	-	-	-	-		-	-
Oscillatoria acuminata	-	-	500	300	-	-	300	200	400	-	-	100	-	100	-	-
O. annae	-	-	-	-	-	100	-	-	-	-	-	-	-		-	-

Continued....

ISSN 0972-5407

O. foreaui	600	300	-	400	700	800	-	300	100	200	400	100	800	300	100	100
O. proboscidea	-	-	-	300	-	-	-	200	-	-	-	-	-	-	-	-
O. princeps	-	-	-	200	-	-	-	100	-	-	-	-	200	300	100	100
O. nigra	-	-	-	-	-	-	-	-	-	-	-	-	800	400	300	200
O. tenuis	100	-	-	-	200	-	-	100	-	-	-	100	-	-	-	-
O. stagnina	40	-	-	-	200	-	-	100	100	-	-	-	-	-	-	-
Pediastrum tetras	-	-	-	-	200	100	100	-	-	-	-	-	-	-	-	-
Radiococcus nimbatus	200	-	-	-	100	-	-	40	200	-	-	300	-	-	-	-
Schizothrix sp.	-	-	-	-	-	-	-	-	-	-	-	-	400	-	-	-
Synechoccus ambiguus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100
Trichodesmium lacustre	-	-	-	-	-	-	-	-	-	-	-	200	-	-	-	-
Spirulina major	500	300	40	-	300	100	200	-	-	-	-	-	-	-	-	200
Merismopoedia sp.	-	-	300	-	-	-	200	-	-	100	200	-	-	-	-	-
Astramoeba radiosa	40	-	-	-	200	-	-	-	-	-	-	-	-	-	-	-
Rivularia minutula	500	-	-	-	400	-	-	-	300	-	-	-	-	100	-	-
Microcystis aeruginosa		-	-	-	-	-	-	-	-	-	-	-	400	600	200	-
Total Cyanophyceae	**3320**	**1200**	**1340**	**1720**	**3800**	**1900**	**1200**	**1640**	**2400**	**920**	**1200**	**1100**	**2740**	**2200**	**800**	**700**

Continued.....

ISSN 0972-5407

B. CHLOROPHYCEAE																
(a) Volvocales																
Chlamydomonas sp	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Volvox sp	-	-	-	-	-	-	-	-	200	-	-	-	-	-	-	-
Gonium pectorale	500	300	-	-	400	200	-	-	200	100	-	-	-	-	-	-
Pandorina chakourensis	-	-	-	-	-	-	-	-	-	200	-	-	-	600	200	-
P. major	-	-	-	-	40	-	-	-	-	-	-	-	-	-	-	-
(b) Chlorococcales																
Chlorella vulgaris	600	300	200	400	800	200	300	400	600	800	400	300	-	700	-	300
Chlorococcum sp	500	-	300	-	300	-	-	-	200	-	-	-	-	100	20	20
Oocystis sp	600	-	200	700	500	-	20	200	-	-	-	-	-	-	-	-
Pediastrum chodati	-	-	-	-	-	-	-	100	-	200	100	20	-	-	-	-
P. biradiatum	400	-	-	300	800	-	-	200	200	100	-	-	-	-	-	-
Scenedesmus quadricauda	500	300	300	200	300	200	200	100	700	500	400	-	-	-	-	-
S. acutus	-	-	-	-	-	20	-	-	20	-	-	-	500	-	-	-
Sphaerocystis schroeteri	400	-	-	-	600	-	-	-	20	-	-	-	-	-	-	-
S. boryanum	-	-	-	400	500	-	-	100	-	-	100	-	-	-	-	-
Radiococcus nimbatus	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-

Continued....

Hydrodictyon sp.	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	100
Selanastrum gracile	-	-	-	-	-	20	-	-	-	200	300	-	-	-	-	-
Pediastrum ovatum	200	-	-	-	300	-	-	-	-	-	-	-	-	-	-	-
(c) Ulotricales																
Hormidium subtile	-	-	-	-	-	-	-	-	-	-	-	-	100	-	-	-
Microspora amoena	300	-	-	500	100	-	-	-	200	-	-	-	200	-	-	-
Binuclearia tetrana	20	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-
Ulothrix zonata	200	-	-	100	200	100	20	200	200	200	400	300	-	300	200	-
Uronema elongatum	-	200	-		200	100	-	-	100	200	200	-	300	100	-	-
Enteromorpha intestinalis	500	300	-	200	300	200	100	-	-	-	-	-	-	-	400	-
Hyalotheca sp.	-	-	-	-	-	-	-	-	-	-	-	-	100	-	-	-
(d) Chaetophorales																
Chaetophora incrassata	-	-	-	-	-	-	-	-	-	-	-	100	-	-	-	-
Chaetonema irregulare	-	-	200	-	-	-	-	-	-	-	-	100	-	-	-	-
Coleochaete scutata	200	-	-	100	300	-	-	-	100	100	-		-	-	-	-
Dermatophyton radians	400	300	300	500	600	200	200	300	-	-	200	100	-	300	100	-
Draparnaldiopsis sp.	100	-	100	-	400	-	-	-	200	-	200	-	-	-	-	-

Continued....

ISSN 0972-5407

(e) Oedogonales																
Oedocladium operculatum	200	400	300	500	100	200	100	100	-	-	-	100	40	200	-	100
Oedogonium sp	300	200	200	500	300	-	100	100	200	200	-	200	40	200	-	100
(f) Cladophorales																
Pithophora sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-
Rhizoclonium sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-
Cladophora glomerata	200	400	-	-	100	600	-	-	-	-	-	-	-	-	-	-
(g) Conjugales																
(i) Zygnemataceae																
Spirogyra sp	-	100	-	200	800	300	-	400	300	200	200	100	-	300	-	-
Mougeotia sp	100	-	-	300	500	200	-	-	100	300	100	200	300	200	-	-
Zygnema cylindrospermum	-	-	100	-	-	-	-	100	200	100	-	-	100	-	-	-
(ii) Desmidaceae																
Desmidium aptogonum	400	300	200	200	300	200	100	100	300	100	-	-	100	200	100	100
Cosmarium granatum	400	200	200	-	200	100	100	-	-	-	-	-	-	-	-	-
C. monomarum	100	-	-	-	200	-	-	-	-	-	-	-	-	-	-	-
C. moniliforme	-	-	-	100	-	-	-	200	-	-	-	-	-	-	-	-
C. monomazum	-	-	-	-	-	-	-	-	-	-	100	-	100	100	-	-
Closterium ehrenbergii	400	-	-	-	300	-	-	-	300	-	100	-	-	-	-	-

Continued

Penium margaritaceum	-	-	-	-	-	-	-	-	100	100	-	-	-	-	-	-
Closterium granatum	-	-	-	300	-	-	-	100	-	-	-	-	-	-	-	-
C. leibleinii	700	-	300	400	600	-	200	-	400	-	-	-	-	-	-	-
C. moniliferum	300	-	-	-	300	-	-	-	-	-	200	-	-	-	-	-
Euastrum geminatum	-	-	-	-	-	200	-	-	-	100	-	-	-	-	-	-
Total Chlorophyceae	**8560**	**3300**	**2900**	**5900**	**10340**	**3040**	**1440**	**2720**	**4880**	**3700**	**3000**	**1520**	**1880**	**3300**	**1220**	**720**
C. BACILLARIOPHYCEAE																
Bacillaria paradox	-	200	-	-	-	100	-	-	-	-	-	-	-	-	-	-
Asterionella Formosa	-	-	-	-	-	-	-	-	200	-	100	200	400	-	-	-
Amphora ovalis	-	-	-	200	-	100	-	100	-	-	-	-	200	100	-	-
Achanthes lanceolata	-	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-
Cymbella cistula	400	-	-	300	600	100	-	100	-	100	400	-	-	100	200	300
Cyclotella sp	100	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-
Cocconeis placentula	-	-	-	-	-	-	-	-	100	-	-	-	40	200	-	100
Diatomella balfouriana	300	-	300	-	600	100	200	-	100	-	300	300	-	-	-	-
Diatoma hemalis	-	-	-	-	300	-	-	-	-	-	100	-	-	-	-	-
Eunotia minor	100	-	-	-	300	-	-	-	-	-	300	200	100	-	-	-
Epithemia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	200

Continued....

Journal of Research & Development, Vol 3 (2003)
ISSN 0972-5407

Fragilaria capucina		100	-	-	-	200	100	-	200	200	300	-	-	100	400	-
Gomphonema minutum	-	-	-	-	200	-	-	-	-	-	-	-	-	-	-	-
Meridion circulare	-	-	-	-	-	-	-	-	300	200	100	100	-	-	-	-
Nedium affinis	-	200	-	-	40	100	-	-	-	-	-	-	-	200	100	-
Nitzschia acicularis	-	-	-	-	100	100	-	-	-	-	-	-	-	-	-	-
N. diversa	100	200	-	-	200	-	-	-	-	-	-	-	-	-	-	-
N. radicula	-	-	-	100	-	-	-	-	-	-	-	-	100	100	-	-
N. capitellata	-	-	-	-	-	-	-	-	-	-	-	-	100	-	-	-
Navicula radiosa	-	100	-	-	-	200	-	-	-	-	-	-	-	-	100	200
N. subtillisma	200	-	100	-	900	-	-	-	-	200	-	100	-	40	400	-
N. sancta	-	-	-	-	-	-	-	-	300	-	200	-	-	-	-	-
N. phyllepta	-	-	-	-	-	-	300	-	100	-	-	-	-	-	-	-
N. cryptocephala	-	-	-	-	100	-	-	-	-	-	-	-	100	-	-	-
Pinnularia sudetica	-	-	-	-	-	-	-	-	100	-	-	-	-	-	-	-
P. appendiculata	-	-	-	-	-	-	-	-	100	-	-	-	100	-	-	-
P. nobilis	100	-	-	-	200	-	100	-	100	100	100	-	200	100	-	-
P. cincta	-	-	-	-	-	-	-	-	-	300	200	-	400	-	-	-
Stauroneis lauenburgiana	-	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-

Continued

S. phoenicenteron	-	-	-	-	-	100	-	-	-	-	100	-	-	-	-	-
S. thermicola	-	-	-	-	-	-	-	-	-	-	100	200	-	-	-	-
Synedra ulna	100	-	100	300	3000	100	100	200	300	-	200	100	100	-	-	100
S. famelica	-	-	-	-	-	-	-	-	-	200	200	40	-	-	-	-
Tabellaria flocculosa	-	-	200	-	-	-	300	-	-	-	-	-	500	300	100	-
Melosira granulata	200	-	-	-	400	100	100	-	-	-	-	-	-	-	-	-
Meridion sp.	-	-	-	200	-	-	-	-	-	-	-	300	-	-	-	-
Surirella robusta	-	-	-	-	300	-	-	200	-	-	-	-	-	-	-	-
Tabellaria sp.	-	-	100	-	-	-	100	-	-	-	-	-	-	-	-	-
Cymbella aequalis	-	-	-	-	-	-	-	-	-	300	-	200	-	-	-	-
Gomphonema geminatum	-	-	-	100	-	-	-	200	-	-	-	-	-	-	-	-
Total Bacillariophyceae	**1600**	**800**	**800**	**1200**	**5200**	**1300**	**1300**	**800**	**1900**	**1600**	**2700**	**1740**	**2340**	**1240**	**1400**	**900**
D. XANTHOPHYCEAE																
Tribonema bombycinum	-	-	-	-	-	-	-	-	100	-	100	-	-	-	-	-
Vaucheria aversa	100	-	-	-	40	100	200	-	40	-	-	-	-	-	-	-
Botryococcus braunii	-	-	-	-	-	-	-	-	-	-	-	-	200	300	100	-
Total Xanthophyceae	**100**	-	-	-	**40**	**100**	**200**	-	**140**	-	**100**	-	**200**	**300**	**100**	-

Continued

E. CHRYSOPHYCEAE																
Dinobryon borgei	400	-	-	-	100	-	-	-	200	-	-	-	100	-	-	-
D. stipitatum	-	400	-	-	-	100	-	-	-	-	-	-	-	-	-	-
D. divergens	-	-	-	-	200		-	100	-	-	-	-	-	-	-	-
Total Chrysophyceae	**400**	**400**	-	-	**300**	**100**	-	**100**	**200**	-	-	-	**100**	-	-	-
F. DINOPHYCEAE																
Glenodinium quadridens	300	100	-	200	100	-	-	-	-	-	-	-	-	-	-	-
Peridinium sp.	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-	-
Gymnodinium aeruginosum	-	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-
Total Dinophyceae	300	100	-	300	200	-	-	-	-	-	-	-	-	-	-	-
G. EUGLENOPHYCEAE																
Astasia klebsii	-	200	100	-	-	-	-	-	-	200	300	100	100	-	100	100
Euglena deses	400	-	-	-	300	100	-	-	-	-	-	-	100	200	100	100
E. laevis	-	-	-	-	-	-	-	-	100	-	-	-	-	-	-	-
E. acus	200	-	-	-	200	-	-	-	-	-	-	-	200	-	-	-
Chlorogonium sp.	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-	200
Cryptoglena pigra	-	-	-	-	-	-	-	-	100	-	-	-	-	-	-	-
Phacus suecica	200	100	-	-	200	100	-	-	-	40	300	-	200	200	100	100
P. quinquemarginatus	100	40	-	-	40	-	-	-	-	-	400	-	-	-	-	100

Continued...

Lepocynclis acicularis	-	-	-	-	-	-	-	-	-	-	600	100	100	100	100	-
L. texta	300	200	-	-	100	40	-	-	-	-	-	-	200	200	100	200
L. ovum	-	-	200	-	-	-	100	-	-	-	-	-	-	-	-	-
Trachelomonas hispida	-	-	-	200	-	-	-	-	-	-	-	-	-	-	-	-
T. intermedia	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T. planctonica	200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Euglenophyceae	**1500**	**540**	**300**	**300**	**840**	**240**	**100**	-	**200**	**240**	**1600**	**200**	**900**	**700**	**500**	**800**

ulna. Only one species (*Diatomella balfouriana*) was reported to occur in spring, summer and autumn. However, the species namely *Pinnularia cincta, Asterionella formosa* and *Cocconeis placentula* were restricted to winter season only. Like the former group, the maximum density of diatoms was observed at site I during summer. *Navicula subtillisma* with 900 ind/l, however, was the most dominant form at the study site during the season.

Euglenophyceae

Species like *Phacus suecica* and *P. quinquemarginatus* were regularly present throughout the year. However, species like *Trachelomonas hispida, T. intermedia* and *T. planctonica* were found in greet abundance in spring while as forms like *Euglena laepis* and *Cryptoglena pigra* mostly occurred during autumn. Among the study sites I again registered the maximum population with *Euglena deses* (400 ind/l), being the most dominant species during the spring.

Chrysophyceae

The most dominant species, *Dinobryon borgei*, occurred throughout the year while as *Dinobryon divergens* was restricted to summer only. Site I and II exhibited the higher density values, with species like *Dinobryon borgei* and *D. stipitatum* each with 400 ind/l making the decisive proportions of the group during spring.

Dinophyceae

Glenodinium quadridens was the only species found during both spring and summer as against the forms like *Peridinium* sp. and *Gymnodinium aeruginosum* having restricted growth in spring and summer respectively.

Site I again depicted maximum density of the group during spring with *Glenodinium quadridens* (300 ind/l) contributing the maximum towards the population density of the group.

Xanthophyceae

Though none of the species could make its presence throughout the year yet species like *Vaucheria aversa* was found during spring, summer and autumn as against *Botryococcus braunii* being found during the winter only. Of the study sites, site II had maximum population with *Botryococcus braunii* (300 ind/l); thus contributing significantly to the winter phytoplankton.

Total phytoplankton

The phytoplankton, in general, exhibited a long growth period extending from spring to autumn, the growth being restricted during winter (cold water period). Site differences showed site I registering the highest population density of 20,720 ind/l during summer. In contrast, the minimum of the populations (3120 ind/l) were obtained during winter at site IV (Table 4).

II. Seasonal succession

The annual seasonal succession of phytoplankton based on relative density is depicted in Table 5.

Spring:

Features of spring phytoplankton were the dominance of Chlorophyceae (52.1-62.6%), followed by Cyanophyceae (18.2-25.1%), Bacillariophyceae (10.1-15.1%) and Euglenophyceae (3.2-9.5%) in a decreasing order. The order of the dominance was thus Chlorophyceae > Cyanophyceae > Bacillariophyceae > Euglenophyceae > Xanthophyceae. However, the site variations depicted site IV having maximum relative density (62.6%) of Chlorophyceae and site I having the lowest contribution of Xanthophyceae being, only 0.6%.

Summer:

Among the various groups, the Chlorophyceae was the most dominant group with relative density values ranging from 34.0 to 51.7%, followed by Cyanophyceae (18.3 to 34.9%), Bacillariophyceae (15.2 to 30.6%), Xanthophyceae (0.1 to 4.7%), Euglenophyceae (2.3 to 4.0%) and Chrysophyceae (1.4 to 1.9 %) in a declining order. Thus, the order of dominance of summer phytoplankton was Chlorophyceae > Cyanophyceae > Bacillariophyceae > Xanthophyceae >Euglenophyceae. Like spring phytoplankton, site IV registered maximum relative density for Chlorophyceae (51.7%). and, site I exhibited the minimum of Xanthophyceae (0.1%).

Table 4 . Total phytoplankton density (ind/l) at four different study sites of Anchar Lake

Taxonomic groups	Spring				Summer				Autumn				Winter			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
A. Cyanophyceae	3120	1200	1340	1720	3800	1900	1200	1640	2400	920	1200	1100	2740	2200	800	700
B. Chlorophyceae	8560	3300	2900	5900	10340	3040	1440	2720	4880	3700	3000	1520	1880	3300	1220	720
C. Bacillariophyceae	1600	800	800	1200	5200	1300	1300	800	1900	1600	2700	1740	2340	1240	1400	900
D. Xanthophyceae	100	-	-	-	40	100	200	-	140	-	100	-	200	300	100	-
E. Chrysophyceae	400	400	-	-	300	100	-	100	200	-	-	-	100	-	-	-
F. Dinophyceae	300	100	-	300	200	-	-	-	-	-	-	-	-	-	-	-
G. Euglenophyceae	1500	540	300	300	840	240	100	-	200	240	1600	200	900	700	500	800
Total Phytoplankton	**15780**	**6340**	**5340**	**9420**	**20720**	**6680**	**4240**	**5260**	**9720**	**6460**	**8600**	**4560**	**8160**	**7740**	**4020**	**3120**

Table 5 : Composition of phytoplankton on the basis of percentage density of various taxonomic groups

Taxonomic groups	Spring				Summer				Autumn				Winter			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
A. Cyanophyceae	21.0	18.9	25.1	18.2	18.3	28.4	28.3	34.9	24.6	14.2	13.9	24.1	33.5	28.4	19.9	22.4
B. Chlorophyceae	54.2	52.1	54.3	62.6	49.9	45.5	34.0	51.7	50.2	57.2	34.8	33.3	23.0	42.6	30.3	23.0
C. Bacillariophyceae	10.1	12.6	15.1	12.7	25.0	19.5	30.6	15.2	19.5	24.7	31.3	38.1	28.6	16.0	34.8	28.8
D. Xanthophyceae	0.6	-	-	-	0.1	1.5	4.7	-	1.4	-	1.1	-	2.4	3.8	2.4	-
E. Chrysophyceae	2.5	6.3	-	-	1.4	1.5	-	1.9	2.0	-	-	-	1.2	-	-	-
F. Dinophyceae	1.9	1.6	-	3.2	0.96	-	+	-	-	-	-	-	-	-	-	-
G. Euglenophyceae	9.5	8.5	5.6	3.2	4.0	3.6	2.3	-	2.0	3.7	18.6	4.3	11.0	9.0	12.4	25.6

Autumn:

The autumn phytoplankton again is characterised by the dominance of Chlorophyceae ranging between 33.3 and 57.2%, followed by Bacillariophyceae (19.5 - 38.1%), Cyanophyceae (13.9 - 24.6 %), Euglenophyceae (2.0-18.6%), Xanthophyceae (1.1-1.4%) and Chrysophyceae (zero-2.0%) in a decreasing order. The sequence of autumn phytoplankton groups recorded were thus Chlorophyceae >Bacillariophyceae > Cyanophyceae > Euglenophyceae > Xanthophyceae. Unlike spring and summer phytoplankton, during autumn the site II registered the maximum proportions of Chlorophyceae (57.2%) as against the least for Xanthophyceae (1.1%) at site III during the same season.

Winter:

During winter the proportion of Chlorophyceae was again maximum and that of Chrysophyceae the minimum. The order of dominance of various taxonomic groups was : Chlorophyceae (23.0 - 42.6%) > Bacillariophyceae (16.0-34.8%) > Cyanophyceae (19.9 - 33.5 %) > Euglenophyceae (9.0-25.6%) > Xanthophyceae (2.4 - 3.8%) > Chrysophyceae (zero - 1.2%). There were again spatial variations with site II registering the maximum relative density (42.6%) for Chlorophyceae and the site I showing minimum (1.2%) for Chrysophyceae. In general, the seasonal succession of phytoplankton thus showed the dominance of two major groups i.e., Chlorophyceae and Cyanophyceae over other various taxonomic groups.

DISCUSSION

The growth and abundance of phytoplankton are closely determined by the changes in the physico-chemical characteristics of water, besides biotic variables. The increasing concentrations of phosphorus and the optimal ratio between phosphorus and nitrogen have direct impact on the primary production and the development of phytoplankton community during the initial phase of eutrophication (Jumppanen, 1976). Similarly, Kaul *et al.* (1978) and Pandit (1980) reported that the freshwater bodies of Kashmir, rich in Calcium and Magnesium, have thick populations of plankton, especially Cyanophyceae. The authors opined that the higher amounts of Calcium and Magnesium help in the development of a rich population of the blue-greens as calcium, in the form of calcium formate is, required for the sheath formation of blue-greens while magnesium is an essential element for healthy pigmentation, particularly of chlorophyll-a which the blue-greens contain (Fogg, ,1953)

The development and abundance of blue-greens in Anchar Lake is, therefore, the outcome of higher levels of both the ions. Chlorophyceae grows vigorously at site I during the late summer when the nitrate content ranged low. Similar results have also been obtained by Pearsall (1923), Singh (1960), Zafar (1964), Munawar (1970), Kaul *et al.* (1978) and Pandit (1980, 98). The comparatively higher transparency and temperature , however, associated with low water level seems to be conductive for the dominance of filamentous forms of green algae and the overall maximum phytoplankton density (10340 ind/l) at site I during summer. These findings are in consonance with the earlier findings of Kaul *et al.*, (1978) and Pandit (1980) on Malgam Wetland in Kashmir. Dense populations of desmids were not usually observed in calcium rich water of Anchar Lake as according to Pearsall (1932) and Vass and Sachlan (1949) desmids form thick populations in water that are poor in calcium. These results are in agreement with the present study wherein the highest density of desmids (5200 ind/l) at site I were correlated with the lowest calcium level ($X=29.7\ mgl^{-1}$) during summer. The higher values of silicates as reported for site III during winter ($4.47\ mgl^{-1}$) were also held responsible for the development of diatoms at the site. These findings are also in agreement with the earlier findings of Pearsall (1932), Bailey-Watts and Lund (1973) and Khan (1985), who believe that the diatom populations are well dependent on the silicate content of water and two have a positive correlation.

Eugleninae starts emerging during late winter and showed peak development in early spring. The group then start declining gradually during summer months. The peak development in group seemed to be a function of higher amounts of both phosphorus and nitrogen brought about by floods and effluents besides the availability of key elements after decomposition. This assumption gains further support from the earlier findings of Zutshi and Vass (1982) while working on Dal Lake, and other urban valley lakes of Kashmir. The most remarkable feature of phytoplankton of Anchar Lake is the thin population of *Dinobryon borgei* (Chrysophyceae) and *Peridinium* sp. (Dinophyceae) and their almost negligible contribution towards the total algal population. The extremely low population of these species are attributed to the high phosphrous level ($513.1\ \mu g\ l^{-1}$) and its inhibitory influence on the species as also reported by Rodhe (1948) and McMurry and Olive (1975). The present study revealed, however, peak growth of phytoplankton in summer, with an average density per site 9225 ind/l, as a result of regeneration and availability of minerals due to the decomposition of organic matter in the sediments during autumn and spring seasons. Authors like Poltoracka (1963), Davis (1964), Spondniewska (1974), and Kaul *et al.* (1978) also support such a proposition . The high levels of P and N, therefore, justify the mass bursts of algal groups at their peak productive stages, especially when the light and temperature conditions are quite favourable for their growth. In conclusion, the present nutrient status and phytoplankton populations justify the placement of the Anchar Lake in the advanced stages of eutrophication.

ACKNOWLEDGEMENTS

The authors wish to thank Prof. A. R. Yousuf, Director CORD, for providing laboratory facilities.

REFERENCES

APHA, 1998. *Standard Metho ls for the Examination of Water and Wastewater*. 20th Edition. American Public Health Assoc. Washington, D. C.

Bailey - Watts, A. E. and Lund, J. W. G. 1973. Observation on a diatom bloom in Loch Leven, Scotland. *J. Linn. Soc* (London). **5** : 235-250.

Bhat, S. A., Rather, S. A. and Pandit, A. K. 2001. Impact of effluents from Sheri-Kashmir Institute of Medical Sciences (SKIMS), Soura on Anchar Lake. *Jóurnal of Research & Development* **1** : 30-37.

Cox, E. J. 1996. *Identification of Freshwater Diatoms from Live Material*. 1st Edition. Chapman & Hall, London, UK. 158 p

Davis, C. C. 1964. Evidence for the eutrophication of lake Erie from phytoplankton records. *Limnol. Oceanogr*. **1** : 47-53.

Desikachary, T. V. 1959. *Cyanophyta*. Indian Council of Agricultural Research, New Delhi. 686 p.

Edmondson, W. T. 1992. *Ward and Whipple Freshwater Biology*. 2nd ed. Intern. Books and Periodicals Supply Service New Delhi.

Fogg, G. E. 1953. *The Metabolism of Algae*. Mathuen & Co. Ltd. London.

Fritsch, F. E. 1935. *The Structure and Reproduction of Algae*. Vol.I Cambridge Univ. Press, London.

Golterman, H. Z. and Clymo, R. S. 1969. *Methods for Physical and Chemical Analysis of Freshwaters*. IBP Handbook No. 8. Blackwell Scientific Publication, Oxford, Edinburgh.

Gupta, P. K. 2000. *Methods in Environmental Analysis-Water, Soil and Air*. Agrobios Jodhpur, India. 409 p.

Jumppanen, K. 1976. Effects of waste waters on a lake ecosystem. *Ann. Zool. Fennici*. **13**:85-138.

Kak, A. M.1981. Floristic composition, structure and ecology of some high altitude lakes of Kashmir Himalayas. p. 106-108. In : *Proc. Abs. Silver Jubilee Symposium of Tropical Ecology. "Ecology and Resource Management in the Tropics"*. R. S. Ambasht and H. N. Pandey (eds.) Banaras Hindu University, Varanasi.

Kanth, T. A. and Amin, S. M. 1996. Drainage system in Kashmir Valley. p.185-197. In : *Ecology, Environment and Energy* (A. H. Khan & Ashok K. Pandit, eds.). The University of Kashmir, Srinagar-6, J&K, India.

Kaul, V., Fotedar, D. N., Pandit, A. K. and Trisal, C. L. 1978. A comparative study of plankton populations of some typical fresh waterbodies of Jammu and Kashmir State. p. 249-269. In : *Environmental Physiology and Ecology of Plants* (D. N.Sen and R. P. Bansal, eds.). B. Singh, M. Pal Singh, Dehra Dun, India.

Kaul, V. and Pandit, A. K. 1982. Biotic factors and food chain structure in some typical wetlands of Kashmir. *Poll. Res.* **1** (1-2) : 49-54.

Khan, M. A. 1985. Spatio-temporal phytoplankton variability in two Himalayan lacustrine ecosystems. *Acta hydrochim et hydrobiol.* **13** : 249-259.

Mackereth, F. J. H. 1963. *Water Analysis for Limnologists*. Freshwater Biol. Assoc., **21** : 1-70.

McMurry, G. and Olive, J. H. 1975 Summer phytoplankton photosynthesis in a north eastern Ohio glacial lake. *Ohio J. Sci.* **75** : 238-250.

Munawar, M. 1970. Limnological studies on freshwater ponds of Hyderabad, India. II. The biocenose and distribution of unicellular and colonial phytoplankton in polluted and unpolluted environments. *Hydrobiologia* **36** : 105-128.

Palmer, C. M. 1980. *Algae and Water Pollution*. Castle House Publications Ltd., USA.

Pandit, A. K. 1980. *Biotic factor and food chain structure in some typical wetlands of Kashmir*. Ph.D. Thesis University of Kashmir, Srinagar - 190006 India.

Pandit, A. K. 1993. Dal Lake ecosystem in Kashmir Himalya: Ecology and management. p 131-202. In : *Ecology and Pollution of Indian Lakes and Reservoirs*. (P.C. Mishra and R. K. Trivedy, eds.) Ashish Publishing House, New Delhi, India.

Pandit, A. K. 1996. Lakes in Kashmir Himalaya. p.1-40 In: *Ecology, Environment and Energy*. (A. H. Khan and Ashok K. Pandit, eds.). The University of Kashmir, Srinagar-190 006, J&K, India.

Pandit, A. K. 1998. Plankton dynamics in freshwater wetlands of Kashmir. p.22-68. In : *Ecology of Polluted Waters and Toxicology* (K. D. Mishra, ed.). Technoscience Publications, Jaipur, India.

Pandit, A. K. 1999. *Freshwater Ecosystems of the Himalaya*. Parthenon Publications, New York, London.

Pandit, A. K. 2000. Trophic evolution of lakes in Kashmir Himalaya, p. 213-242. In: *Natural Resources of the Western Himalaya* (Ashok K. Pandit, ed.) Valley Book House, Srinagar, J&K.

Pearsall, W. H. 1923. A theory of diatom periodicity. *J. Eol.* **11-12** : 165-183.

Pearsall, W. H. 1932. Plankton in English lakes. *J. Ecol.* **20** : 241-262.

Poltoracka, J. 1963. Phytoplankton in lakes near Wegorzewo in the light of peculiarities of environment. *Pol. Arch. Hydrobiol.* **11** : 189-217.

Prescott, G. W. 1939. Some relationships of phytoplankton to limnology and aquatic biology. *Publ. Amer. Assoc. Adv. Sci.* **10** : 65-78.

Prescott, G. W. 1970. *How to know the freshwater algae*. 348 pp.

Rodhe, W. 1948. Environmental requirements of freshwater plankton algae. Experimental studies in the ecology of phytoplankton. *Symb. Bot. Upsal.* **10** : 1-149.

Sarwar, S. G. 1999. Water quality and periphytic algal component of Anchar Lake, Kashmir. p. 237-250. In : *Inland Water Resources, India*. (M. K. Durga Prasad and P. Sankara Pitchaich eds.) Discovery Publishing House, New Delhi.

Singh, V. P. 1960. Phytoplankton ecology of the inland waters of Uttar Pradesh. *Proc. Symp. Algology. ICAR*, New Delhi, pp. 243-271.

Spondniewska, I. 1974. The structure and production of phytoplankton in Mikolajskie Lake. *Ekol. Pol.* **22** : 68-105.

Vass, K. F. and Sachlan, M. 1949. On the ecology of some lakes near Bittenzorg, Java. *Hydrobiologia* **1**: 238-250.

Yousuf, A. R., Balki, M. H. and Qadri, M. Y. 1986. Limnological features of a forest lake of Kashmir. *J. Zool. Soc. India* **38**(1&2) : 29-42.

Zafar, A. R. 1964. On the ecology of algae in certain fish ponds of Hyderabad, India. Physico-chemical complexes. *Hydrobiologia* **23** : 179-195.

Zutshi, D. P. 1975. Association of macrophytic vegetation in Kashmir lakes. *Vegetatio* **30**: 61-65.

Zutshi, D. P. and Vass, K. K. 1971. Ecology and production of *Salvinia natans* Hoffim in Kashmir. *Hydrobiologia* **38** : 303-320.

Zutshi, D. P., Subla, B. A., Khan, M. A. and Wanganeo, A. 1980. Comparative limnology of nine lakes of Jammu and Kashmir Himalayas. *Hydrobiologia* **72** (1-2) : 101-112.