Phytoplankton Dynamics in Hokarsar Wetland, Kashmir.

Shabir A. Rather and Ashok K. Pandit

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

ABSTRACT

The present limnological study on Hokarsar wetland was undertaken during 2000-2001. The water depth ranged between 13 and 65 cms. The pH of the water was always on alkaline side and the wetland depicted the usual cation progression: Ca > Mg > Na > K known for freshwaters. In all 138 species of phytoplankton were identified from four different sampling stations. The phytoplankton, in general, showed two growth periods, one in spring and other in autumn. A clear dominance of Chlorophyceae over Bacillariophyceae and Euglenophyceae was observed throughout the year. Parameters like conductivity, nitrogen and phosphorus showed a positive correlation with Bacillariophyceae, Chlorophyceae and Euglenophyceae while as dissolved oxygen and secchi disc transparency indicated an inverse relationship with most of the phytoplankton.

Keywords: Freshwater, phytoplankton, water chemistry, wetland, Kashmir.

INTRODUCTION

In the Western Himalaya the picturesque high altitude valley of Kashmir abounds in diverse types of freshwater bodies like rivers, streams, lakes, springs, ponds and wetlands which are of great ecological and economic interest. Among these waterbodies wetlands have received little attention and most of them are treated as wastelands excepting Hokarsar, a queen wetland of Kashmir. Hokarsar wetland occupies a special status as it is maintained by the state government as the biggest bird Reserve in Kashmir.

The wetland is facing a serious threat of encroachment due to anthropogenic pressures resulting in its gradual eutorphication and degradation. The planktonic communities because of their short life cycles respond quickly to the environmental changes particularly the planktonic algae being sensitive to chemical changes, especially fluctuations in nitrogen and phosphorus content (Kaul, *et al.*, 1978). Though some information on various ecological aspects of Hokarsar wetlands is available upto 1980's (Handoo ; 1978, Kaul and Pandit 1980;

Pandit and Kaul 1981; Pandit and Fotedar 1982; Shah *et al.*, 1984), yet hardly any limnological investigation has been conducted on this wetland since then. The aim of the present study, therefore, is to provide current trophic status of the wetland on the basis of water chemistry and phytoplankton population which is believed to have changed over the years due to growing anthropogenic pressures in the catchment area and within the wetland itself.

STUDY AREA

Hokarśar is permanent shallow wetland, situated 10 km to the west of Srinagar on Srinagar-Baramullah highway at an altitude of 1, 584 m (a s. l). The famous wetland is fed by perennial Doodganga stream that originates from Doodganga watershed in Pir Panjal range of the Himalaya and Sukhṇag stream from the west. Hokarsar is a well protected Wetland Reserve which harbours thousands of migratory birds (ducks, geese, rails etc.) during winter besides providing breeding ground to a host of resident and non-resident summer visitors from Indian plains.

The wetland is surrounded by a number of villages (Fig. 1). On the north side lies Lawaipora and on the northwest is Zainakot. On the west are Khushipora and Hajibagh while on the south lie Soibogh and Dharmuna and on the southwest is Gotapora hamlet. The total population of these villages was about 61,300 in 2000 while the total cattle population had been estimated to be about 20,433. The catchmant of the wetland is comprised of flat arable land under intense paddy

Fig.1. Map of Hokarsar,wetland showing study sites.

cultivation besides little cattle grazing. The wetland is surrounded by a thick canopy of willow (*Salix* sp.) trees besides some poplar (*Populus* sp.) trees. The wetland drains into river Jhelum on the northwest by a small stream near village Sozeith. The high anthropogenic pressures especially by drainage, filling, unregulated silt ladden water of Doodganga stream and encroachment for agricultural and housing development have adversely affected the wetland and as a result its maximum depth has reduced from 120cm during 1980's to 63cm in 2001. Similarly the wetland has considerably shrunk over the years from its actual area of 13.75 km^2 in early 1960 to about 5 km^2 at present (Pandit, 1999).

MATERIAL AND METHODS

The water samples were collected, during March 2000 – Febraury 2001 on monthly basis, between 10.00 and 15.00h from four sampling stations in one litre polyethylene bottles. Some of the parameters including temperature, pH, D.O., conductivity, water depth and transparency were analysed at the sampling stations while the other chemical parameters were determined in the laboratory within 24h. The analysis was done according to the standard methods (Mackreth, 1963; Golterman and Clymo, 1969; APHA, 1998).

Plankton samples were collected by filtering wetland water through a planktonic net of bolting silk. The sieved residue was collected in a bottle and preserved with 4 percent formaline (APHA, 1998). The plankton count was done with the help of Sedgewick-Rafter cell of 1ml capacity. The unicellular algae were counted as individuals while in filamentous Cyanophyceae, 100µm length of the filament was taken as the equivalents. Similarly the filamentous Chlorophyceae were recorded as cells while in colonial forms like *Volvox, Pandorina, Microcystis,* etc. the counting unit was a colony (Jumppanen, 1976).

Identification of the plankton was done with the help of standard works by Prescott (1939, 1951), Pennak (1978), Edmondson (1992), Cox (1996) and APHA (1998).

RESULTS

Physico-Chemical Characteristics of Water

The seasonal fluctuations for various physico-chemical characteristics of water are depicted in Table 1.

Table 1. Seasonal fluctuation in the physico-chemical characteristics of water at different sites in Hokarsar wetland

Parameters	Unit	Site	Seasons			
			Spring	Summer	Autumn	Winter
Depth	cm	I	38.00	19.00	32.00	40
		II	63.00	28.00	53.00	56
		III	29.00	15.00	37.00	52
		IV	42.00	25.00	45.00	47
Transparency	cm	I	26.00	15.00	24.00	29
		I!	30.00	18.00	28.00	47
		III	19.00	13.00	23.00	43
		IV	27.00	16.00	27.00	42
Temperature	0°C	I	16.97	28.50	14.05	7.45
		II	17.47	29.00	14.90	8.20
		III	17.05	27.25	15.00	8.15
		IV	18.65	29.05	15.20	6.95
Dissolved Oxygen	$mg.l^{-1}$	I	4.89	4.15	7.90	12.50
		II	4.47	3.25	83.00	10.35
		III	4.20	3.00	6.10	11.50
		IV	5.35	2.25	4.95	8.00
pH	---	I	7.80	8.01	8.56	8.69
		II	7.73	7.94	8.28	8.46
		III	7.55	7.75	8.23	8.48
		IV	7.87	7.80	8.03	8.69
Conductivity	$\mu s\ cm^{-1}$	I	413	355	305	227
		II	438	380	320	246
		III	467	357	316	236
		IV	470	403	315	245

Table 1 continued

Calcium	mg.l^{-1}	I	30.53	42.73	43.88	38.76
		II	35.88	37.95	37.80	30.47
		III	36.90	45.23	45.88	33.59
		IV	34.67	33.04	38.79	40.42
Magnesium	mg.l^{-1}	I	9.01	12.62	13.69	12.21
		II	10.20	10.76	11.82	10.84
		III	11.10	12.21	16.26	10.02
		IV	10.12	9.43	12.91	12.75
Sodium	mg.l^{-1}	I	2.92	3.12	3.88	2.56
		II	4.86	5.20	4.65	2.95
		III	3.20	3.40	6.42	4.12
		IV	4.10	4.85	3.95	2.15
Potassium	mg.l^{-1}	I	1.03	1.27	1.40	0.52
		II	1.50	1.70	2.10	1.06
		III	1.30	1.85	2.65	1.67
		IV	1.37	2.02	1.80	0.63
Alkalinity	mg.l^{-1}	I	80.00	147	235	290
		II	74.00	138	300	318
		III	68.00	146	352	277
		IV	88.00	120	325	311
Chloride	mg.l^{-1}	I	32.00	27.00	12.00	17.00
		II	24.00	21.00	10.00	20.00
		III	19.00	23.00	15.00	13.00
		IV	27.00	18.00	13.00	15.00
Silicate	mg.l^{-1}	I	2.75	1.90	3.50	2.80
		II	2.90	3.25	2.72	1.75
		III	3.00	2.80	2.37	1.70
		IV	3.15	2.80	2.92	1.52

Table 1 continued

Nitrate nitrogen	$\mu g.l^{-1}$	I	240	355	235	332
		II	285	397	287	225
		III	186	405	235	268
		IV	370	420	342	202
Ammonical nitrogen	$\mu g.l^{-1}$	I	156	150	83	217
		II	395	220	95	166
		III	145	197	83	210
		IV	258	207	107	225
Ortho-phosphate	$\mu g.l^{-1}$	I	92	148	90	57
		II	109	161	60	51
		III	71	94	50	44
		IV	115	150	78	55
Total phosphate	$\mu g.l^{-1}$	I	227	324	192	117
		II	250	353	170	113
		III	135	252	165	158
		IV	288	373	253	200

Water level

Water level plays an important role in governing the water quality. The depth of the water showed large fluctuations. Among the sampling sites maximum water level (63cm) was recorded at site II during spring and minimum (15cm) at site III during the summer. There were large fluctuations in water depth of the wetland due to the manipulation of water level.

Transparency

The water, in general, was turbid except during winter season. The water transparency varied between 13cm at site III during summer and 56cm at site II during winter.

Temperature

Temperature of the water depends upon water depth besides solar radiations, climate and topography. In general, the behaviour of surface temperature at the study sites showed a close relationship with that of the atmospheric temperature. In Hokarsar wetland the water temperature fluctuated between 6.95°C in winter and 29°C in summer.

Dissolved oxygen

A great variety of gases are found dissolved in natural waters. Out of these gases, oxygen is the most significant one because it is a regulator of metabolic processes of the organisms and also the community as a whole. The amplitude of dissolved oxygen was great and ranged from 2.25mg l^{-1} to 12.50mg l^{-1}. The maximum dissolved oxygen content was, however, registered during winter at site I and minimum during summer at site IV. The oxygen values estimated for the present study sites showed an inverse relationship with temperature.

pH

In the present investigation the pH of the wetland water was always on alkaline side and ranged between 7.55 in spring and 8.69 in winter.

Conductivity

The conductivity was found to be fluctuating from 227 to 470 µS cm^{-1}, the highest being observed during spring at site IV and the lowest in winter at site I. The high conductivity values estimated during the present study are indicative of enhanced eutrophication of the wetland.

Alkalinity

Alkalinity is a measure of buffering capacity of the water. Alkalinity is important for aquatic life in freshwater system because it equilibrated pH changes that occur naturally as a result of photosynthetic activity of the chlorophyll bearing vegetation. Both the carbonates and bicarbonates form the components of alkalinity. Total alkalinity of wetland water fluctuated greatly from 68mg l^{-1} to 352mg l^{-1}. The maximum value was, however, obtained during autumn and minimum during spring.

Total hardness

The total hardness is not a specific constituent of water but is a variable and complex mixture of cations and anions and is predominantly contributed by calcium and magnesium. Hardness of wetland water was almost high for all the months. Calcium value ranged between 30.47mg l^{-1} and 45.88mg l^{-1}, the maximum being recorded during autumn at site III and minimum during winter at site II. Magnesium followed a trend similar to that of calcium and fluctuated from 9.01 to 16.26 mg l^{-1}.

Sodium and potassium

In general, the concentration of sodium and potassium was lower when compared to calcium and magnesium. However, the range of sodium (2.56-6.42 mg l^{-1}) was comparatively higher as compared to potassium (0.63-2.65 mg l^{-1}) at all the study sites. The lowest value for both the ions was noted during winter at site IV and highest during autumn at site III.

Chloride and silicates

Chloride in waters is generally due to the salts of sodium, potassium and calcium. It may be contributed by sewage discharges, contamination from reflux leachates, discharge of effluents and irrigation drainage into natural waters. In the present case, chloride concentration ranged between 10.00mg l^{-1} and 32.00mg l^{-1} being high in spring and low in autumn.

Silica is an essential macro-nutrient for the growth of diatoms. The maximum (3.50 mg l^{-1}) silicate level was obtained in autumn as against the minimum (1.52mg l^{-1}) in winter.

Nitrogen (Nitrate nitrogen and ammonical nitrogen)

In Hokarsar wetland NO_3-N was relatively higher (186-405ug l^{-1}) as compared to NH_3-N depicting a range of 82-395 µg l^{-1}. However, the concentration of former were higher during summer as against the latter which recorded its peak in spring only. Both the nutrients were minimum in winter.

Phosphorus (Total phosphate phosphorus and orthophosphate-phosphorus)

Phosphorus, necessary for the fertility is generally recognized as another key nutrient in the productivity of water. The concentration of orthophosphate phosphorus was quite low (44 to 161 µg l^{-1}) as compared to total phosphate phosphorus (113 to 373 µg l^{-1}). The maximum phosphorus concentration was, however, registered at site II during summer as against the minimum at site III during winter.

Phytoplankton

Species composition

One hundred and thirty eight species of phytoplankton were recorded in Hokarsar wetland during the present study. (Table 2). Of these 50 belonged to Chlorophyceae, 43 to Bacillariophyceae, 24 to Cyanophyceae, 15 to Euglenophyceae, 3 to Xanthophyceae, 2 to Chrysophyceae and one to Dinophyceae in a decreasing order.

The most common phytoplankton species obtained during the present investigation were:

Cyanophyceae

Anabaena affinis, A. solitaria, Cylindrospermum lichniforme, Gleotricha echinulata, Nodularia spumigena, Nostoc linkia, Oscillatoria annae, O. foreani, O. limnetica and *Rivularia minutata.*

Chlorophyceae

Chlamydom onas sp., *Gonium pectorale, Pandorina morum, Volvox monance, Chlorella vulgaris, Chlorococcum hemicula, Crucigenia lauterbornei, Pediastrum boryanum, Scenedesmus ecornis, S. quadricularia, Sphaerocystis schroeteri, Ulothrix zonata, Coleocheate scutata, Oedocladium operculatum, Oedogonium* sp; *Cladophora glomeruta, Closterium ehrenburgi, Cosmarium monomazum, Mougetia transeanii* and *Spirogyra* sp.

Bacillariophyceae

Amphora ovalis, Anomoeoneis sphaerophora, Astronella formosa, Coconeis placentula, Cymbella cistula, C. cymbiformis, C.turgida, Fragilaria capucina, Melosira granulata, Navicula cincta, N. cuspidata, N. subtillisma, Nitzschia chaurli, N. diversa, Pinnularia nobilis, Synedra acus, Synedra ulna and *Tabellaria floculosa.*

Euglenophyceae

Chlorogonium sp., *Euglena acus, E. deses, E. viridis, Lepocynclis ovum, L. texta* and *Phacus caudatus minor.*

Seasonal variation in the population density

Cyanophyceae

Anabaena affinis and *Oscillatoria foreani* appeared in spring and existed throughout the year. Surprisingly *Anabaena affinis* showed its maximum development at site III during winter season only. However, *Anabaena spiroides* was recorded only during the spring season at sites II and IV. *Cylindrospermum licheniforme* showed its maximum development during spring and summer but disappeared during autumn and winter. The species showed its presence at site II during autumn season. *Lyngbya aestuarii*, being a stenothermal species, was observed during spring at all the study sites while in winter it was registered at sites I and II. *Oscillatoria tenius, Radiocystis germinata, Microcystis flos-aquae* and *M. aeruginosa* were restricted to autumn season. However, *Westiella* sp., being stenothermal, was registered at site II during spring and winter seasons. Seasonal variation of the group revealed its peak development in spring against the minimum obtained in winter.

Chlorophyceae

The group is comparatively more important in so for its species richness and contribution to the total phytoplankton production are concerned. Out of 138 phytoplankton species recorded from Hokarsar wetland, 50 alone belonged to Chlorophyceae which assumed different shapes and sizes.

(i) ***Volvocales:*** *Chlamydomonas* sp. is the most common representative and was present throughout the year with a fall in winter and summer. *Volvox monance* and *Pandorina morum* had a long growth period beginning in spring and continuing to occur throughout summer and autumn. *Eudorina elegans* was restricted to spring season only, being present at all the study sites excepting site I.

(ii) ***Chlorococcales:*** *Chlorella vulgaris* and *Chlorococum humicula* were recorded throughout the year. However, the growth for both the taxa was comparatively maximum in summer and minimum in winter. *Pediastrum duplex* was registered during spring season at sites I and II while as *P. tetras* was noted only at site II during winter season. *Scenedesmus quadricauda* made its appearance in spring and lasted upto autumn at all the study sites.

iii) ***Ulotrichales:*** *Ulothrix zonata* was the most dominant species among Ulotrichales and was found throughout the year at all the study sites excepting sites I and IV during autumn. *Hormidium subtile* was obtained in summer season while *Microspora amoena* was noted at site I during autumn.

(iv) ***Chaetophorales:*** *Coleochate scutata* was most dominant Chaetophorale which showed its maximum population in spring and minimum in winter. Individuals of *Dermetaphyton radians* were noted in spring and summer while as *Chaetophora incrassata* were registered only during spring thus loving to live in moderate to high temperatures.Chaetophorales, in general, could hardly be noticed during winter season. *Draparnaldia* sp. was an exception, being a cold stenothermal species, showing its maximum density during cold months.

(v) ***Ulvales:*** It was represented by *Enteromorpha intestina* alone and had a limited distribution, being maximum in winter as against most of the chlorophycean species.

(vi) ***Oedogoniales:*** *Oedogonium* sp. and *Oedocladium operculatum* were the representatives of Oedogoniales found in Hokarsar. Both the species showed their maximum density in spring season. However, *Oedocladium operculatum* was completely absent during autumn while *Oedogonium* sp. was noticed at site I during winter.

(vii) ***Cladophorales:*** *Cladophora glomerata* was found to occur throughout the year with its peak density in spring. However, *Pithophora* sp. had sporadiac occurrence and was registered during winter season at sites II and III only.

(viii) ***Zygnemales:*** *Closterium ehrenburgii*, *Mougetia transeaui* and *Spirogyra* sp. were the most dominant taxa among Zygnemales and exhibited their occurrence throughout the year. *Cosmarium granatum* was noted during spring and summer seasons at sites II and IV while *C. moniliforme* was registered at sites I and II during spring season. *Zygnema* sp. was almost present throughout the year, being rare in spring and showing its maximum density during autumn especially at site II.

Chlorophyceae, in general, depicted a long growth period and showed its maximum growth in spring for site II (21881 individuals l^{-1}) and summer for site IV (15834 individuals l^{-1}). The population declined gradually till minimum populations were obtained in winter for sites I (1916 individuals l^{-1}) and IV (1740 individuals l^{-1}).

Bacillariophyceae

This was the second dominant group after Chlorophyceae among phytoplankton, being represented by 43 species. *Cymbella cistula, Diatomella elongatia, Fragilaria capucina, Navicula cincta, N. radiosa, Pinnularia nobilis, Synedra acus* and *S. ulna* occurred regularly throughout the year. *Astronella formosa* was recorded in low to moderate temperature of spring, autumn and winter seasons, while as organisms like *Cymbella turgida, Navicula cuspidata, Nitzschia chaurli* and *Tebellaria floculosa* lived in moderate to high temperature of spring, summer and autumn seasons. *Navicula radiosa* was the most dominant species in Bacillariophyceae and exhibited its maximum development during autumn at site IV (3600 individuals l^{-1}) and minimum during winter at sites I (360 individuals l^{-1}) and III (260 individuals l^{-1}) respectively while as *Nitzschia radicula* had a restricted growth during autumn at site I (340 individuals l^{-1}). During the present investigation diatoms showed their maximum development during spring (site IV-18640 individuals l^{-1}) and fall during summer (site I-3240 individuals l^{-1}) as against the minimum being recorded during winter especially at site I (1020 individuals l^{-1}).

Xanthophyceae

The group had limited species distribution and was represented by taxa like *Botrydiosera arhiza, Ophicytium capitatum* and *Vaucheria* sp. However, none of these existed throughout the year and were sporadiac in nature. The group, in general, disappeared during the winter season as hardly any individual could be encountered in sampling. *Botrydiosera arhiza* showed its appearance during spring and recorded its maximum population at site IV (330 individuals l^{-1}), followed by site III (1800 individuals l^{-1}). *Ophicytium capitatum* was recorded during autumn season only while as *Vaucheria* sp. showed its appearance during summer and existed upto autumn. The species was, however, absent at site II.

Chrysophyceae

It had a limited species distribution, being represented by *Tribonema bombyeinum* and *Dinobryon borgei*. The former was, however, registered during summer at sites II and IV while as later was recorded only during autumn at all the sites excepting site IV.

Dinophyceae

It was represented by only one taxon, Perdinum sp. The genus was recorded during autumn at sites II (20 individuals l^{-1}) and III (60 individuals l^{-1})

Euglenophyceae

The noteworthy feature of the group was the occurrence of species like *Euglena acus, E. deses, E. viridis, Lepocynclis texta* and *Phacus caudatus minor* throughout the year. They showed their maximum development in autumn and minimum in winter. However, the taxa like *Astasia kelebsii, Euglenaris* sp., *Euglenopsis vorax, Eutrepia viridis* and *Phacus oribicularis* were restricted to autumn season only. The present investigation revealed the sporadic occurrence of *Euglena oxyuris* and *Phacus acuminatus* during winter, the former being obtained at sites I and II and the latter at site IV.

In general, Euglenophyceae showed their peak growth during spring (site IV-2680 individuals l^{-1}) and summer seasons (site II-3330 individuals l^{-1}). The population declined gradually in autumn till minimum was obtained at sites I (320 individuals l^{-1}) and III (300 individuals l^{-1}) in that order.

Total phytoplankton

Seasonal varition in the density of phytoplankton showed in general two peaks of phytoplankton growth, one in spring and other in autumn. The populations were moderate in summer and low in winter (Table 2)

Seasonal succession (based on relative density)

During spring the diatoms were the most dominant and comprised 28.72 - 54.96 % of the total phytoplankton. However, Chlorophyceae alone comprised 54.96% at site II during spring. A notable population of cyanophyceans (8.74 —

Table 2. Seasonal fluctuations in the density of phytoplankton

Group	Site	Seasons			
		Spring	Summer	Autumn	Winter
Cyanophyceae	I	2780	1770	1340	500
	II	3480	3460	2892	1180
	III	1192	2390	2220	5760
	IV	3820	2700	2880	700
Cholorphyceae	I	4582	4700	3510	1916
	II	21881	10454	5465	3140
	III	6071	9742	4226	2560
	IV	7711	15834	4012	1740
Bacillariophyceae	I	5895	3418	3240	1020
	II	11435	7468	7380	1800
	III	13720	6067	8910	2120
	IV	18620	10195	6780	1520
Xanthophyceae	I	540	-	120	-
	II	900	01	182	-
	III	1800	02	01	-
	IV	3300	02	-	-
Chrysophyceae	I	-	-	100	-
	II	-	400	80	-
	III	-	-	100	-
	IV	-	200	-	-

Table 2 continued

Dinophyceae	I	-	-	-	-
	II	-	-	20	-
	III	-	-	60	-
	IV	-	-	-	-
Euglenophyceae	I	900	120	1960	320
	II	2120	3330	2640	800
	III	2180	2020	2380	300
	IV	2680	2140	2610	600

18.92 %), xanthopyceans (2.26—9.13%) and eugleniods (5.32—8.73%) were also recorded during spring season (Fig 2).

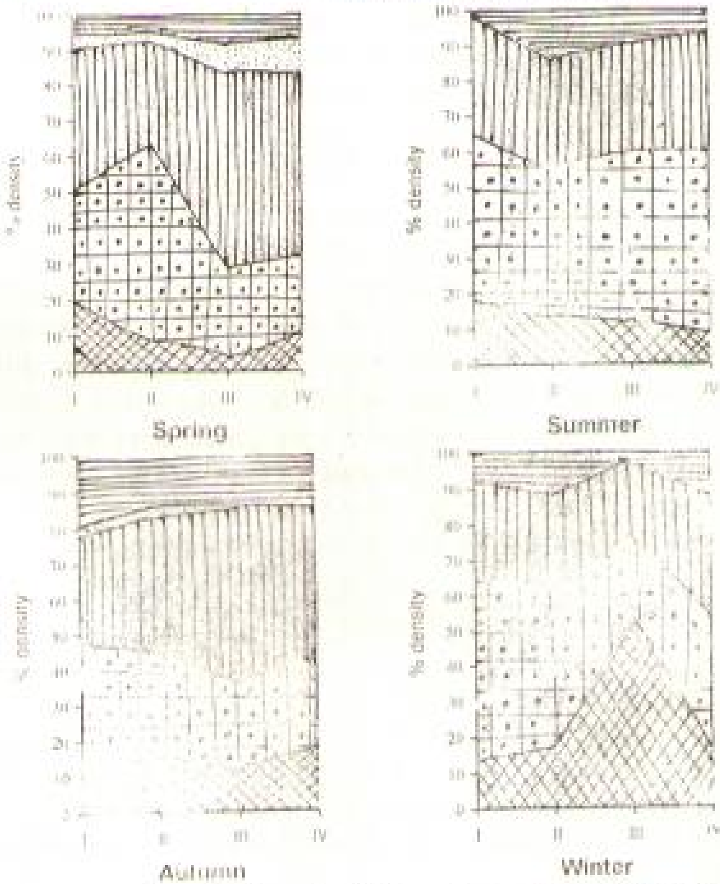

Fig.2. Seasonal succession (% density) of various phytoplankton groups

During summer, the main contributors were green algae (41.63—50.96%) as against diatoms (29.74—34.16%). The xanthophceans and chrysopyceans declined in terms of percentage contribution while as euglenoids contributed 1.20—9.99% for summer phytoplankton.

Features of autumn plankton were the increased population of diatoms and a slight decrease in percentage contribution of green algae (23.61—34.18%) from that of summer. Dinophyceans made their insignificant contribution (0.11—0.34%) during this season only. However, euglenoids showed slight increase in their contribution, from those of spring and summer (13.30—19.08%).

In winter, the phytoplankton was again dominated by green algae (23.84—51.01%) as compared to diatoms and blue-green algae. A noteworthy feature of winter plankton was the exceptionally great prevalence of Cyanophyceae (53.63%) at site III while as xanthophyceans, chrysophyceans and dinophyceans did not contribute to winter plankton.

The seasonal succession of phytoplankton thus showed the dominance of diatoms in spring except for site II, green algae in summer, diatoms in autumn and green algae in winter. The two dominant groups thus had regular seasonal succession.

DISCUSSION

The Hokarsar wetland is a small sized waterbody with a little water depth and the water transparency is greatly reduced in most of the months except during winter months, due to: (i) silt and clay brought into the wetland by Doodganga stream, (ii) rich concentration of nutrients and (iii) development of plankton, besides many exogenous and endogenous materials. The high transparency during winter is attributed to the low biological activity within the system. The surface water of the wetland showed a close relationship with the atmospheric temperature and as such the waters are warmer which is being attributed to the narrow depth and little water volume of the wetland itself (Pandit, 1980). In general, the oxygen level, being inversely related to temperature, is low in this typical wetland. However, the high dissolved oxygen during winter is the result of low biological activity (Vass *et al.*, 1977 and Qadri *et al.*, 1981) and low temperature.

Conductivity, a factor of considerable importance, was found to be always higher. The higher conductivity values, an indication of total salt concentration, place this wetland in β-meso-area type of Olson (1950). The alkalinity of the water is principally due to bicarbonates of calcium and magnesium. Ionic composition of the waterbody reveals the predominance of calcium and bicarbonates over the other ions and, therefore, the usual ionic progression ($HCO_3^- > Ca^{++} > Cl^- > Mg^{++} > Na^+ > K^+$) brings it close to well known sequence for global freshwaters (Rodhe , 1949). The wetland, according to Ohle (1934), is calcium rich which owes its origin to the lacustrine deposits in the valley (Pandit, 1999). The high chloride content of the wetland may be attributed to the presence of large amounts of organic matter of both allocthonous and autocthonous origin (Pandit, 1999). Thresh *et al.* (1944) related it to organic pollution of animal origin.

Nitrogen and phosphorus are important factors in aquatic ecosystems because they play a key role in the productivity of water. The comparatively higher levels of nitrogen and phosphorus as obtained during the present investigation can be attributed to the heavy anthropogenic pressures in the catchment area. Forysth and Mc Coll (1975) attributed the high phosphorus and nitrogen values to the use of fertilizers in the paddy fields bordering the wetland. The values of nitrogen and phosphorus according to Strem (1930) place the Hokarsar wetland in moderate eutrophic category.

The growth and abundance of phytoplankton are closely related to the physico-chemical characteristics of water. Secchi disc transparency seems to be a good index of planktonic populations, as it showed a definite inverse relationship with the later. Maximum transparency was recorded during winter at site II where minimum phytolplanktonic growth proceeded. Similar relationship between transparency and phytoplankton was observed by Timm's (1970). Temperature was found to be very closely related to the planktonic growth. The increase in temperature may affect the net growth of phytoplankton either positively or negatively, depending upon the type of species. In freshwaters the optimum temperature for the great majority of the algae lies between 20-25°C (Prescott, 1984). In the present investigation the high planktonic productivity was recorded under moderate temperature of spring and autumn while moderate planktonic growth was obtained during warm-water period of summer as against the minimum growth being observed in cold winter.

Kaul *et al.* (1978) and Pandit (1980) have found that in most of the freshwaters of Kashmir rich in nutrients, thick population of plankton especially cyanophyceans were observed. High values of total alkalinity (68-352 mg l^{-1}) were recorded for the Hokarsar wetland. However, in the present study no direct relationship between alkalinity and planktonic growth was observed. The present findings are also not in consonance with those of Jana (1978) who generalized that waters with high alkalinity values show a great productivity. However, the planktonic growth and pH showed hardly any significant relationship, a fact also revealed by Jana and Sarkar (1982).

A close but inverse relationship between dissolved oxygen and planktonic productivity was clearly observed during the present study and as such high dissolved oxygen values (12.50 mgl^{-1}) obtained during the winter indicated low planktonic growth and as such low O_2 consumption during respiration of these organisms. In conformity to the above statement, the dissolved oxygen values ranging between 4.20-8.00mgl^{-1} indicated high planktonic production of spring and autumn periods. These findings are in contrast to those of Rao (1955) who pointed out that high concentration of dissolved oxygen favoured the growth of Chlorophyceae but in the present study the phytoplankton population did not show any preference for waters having high dissolved oxygen concentration.

The conductivity values are the indications of the total nutrient level of the waterbodies and, therefore, this parameter is used to indicate the tropic status. The conductivity was found to be highest during spring and lowest during winter. In the present study, a close relationship between conductivity and planktonic growth existed. Thus, the maximum conductivity values were obtained during spring and so was the planktonic growth which boosted up as result of availability of nutrients. Similarly, minimum conductivity values recorded during winter corresponded with the low phytoplankton population for the same season.

The importance of nitrate and phosphate content in plankton ecology has been emphasized by Pearsall (1921) and Fitzgerald (1970). In the present study the phytoplankton showed a close relationship with the nitrates and phosphates. Nitrates indicated a positive correlation with Bacillariophyceae which is in accordance with the view point held by other authors like Lind (1938) and Zutshi *et al.* (1984) suggesting nitrates to be the main factor controlling the periodicity of diatoms; whereas Rao (1955) did not find any correlation between the two. The studies revealed that phosphorus has close relationship with Chlorophyceae and it was among Chlorophyceae, Chlorococcales showed a direct relationship with phosphorus. For both the parameters (phosphorus and Chlorococcales) summer maxima and winter minima have been registered. Abundance of Euglenophycea has been attributed to a number of variables like high level of organic matter (Hutchinson, 1967), high temperature and elevated concentration of CO_2 (Singh, 1955). However, in the present investigation, the euglenoid maxima was found to be associated with high temperature and high phosphate concentration of summer. These findings are in tune with the early findings of Munawar (1974) and Pandit (1980). The overall moderate to high levels of phosphates obtained during the study period are indicative of high population growth of phytoplankton except Chrysophyceae and Dinophyceae. The decline in the population of later groups is attributed to the high phosphorus level as per their requirement and its inhibitory influence on their species as also opined by

Rodhe (1948). A noteworthy feature of the winter phytoplankton was the presence of *Enteromorpha intestina* (Chlorophyceae) with its peak development as against the most of the other chlorophycean species. Another interesting feature of the present study was the complete absence of Xanthophyceae, Chrysophyceae, Dinophyceae among phytoplanktons during winter at most of the sites. This may be attributed to the low availability of nutrients coupled with low temperature.

In general, two peaks of phytoplankton growth were registered, one in spring and other in autumn, being the result of regeneration and availability of minerals which in turn is due to the decomposition of organic matter in sediments during these two peak periods. These findings are in agreement with those of Kaul *et al.* (1978). Further the number of phytoplankton species have declined from that reported earlier by Pandit (1980) which seems to be an outcome of vigorous eutrophciation being faced by the waterbody (Jampanen, 1976).

In conclusion, the heavy anthropogenic pressures resulting in siltation and nutrient enrichment indicate the eutrophic nature of the wetland.

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