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Plankton diversity in Dhaura and Baigul reservoirs of Uttarakhand

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ABSTRACT

Studies conducted for one year from June 2006 to May 2007 in two reservoirs of Uttarakhand *viz.*, Dhaura and Baigul, revealed moderate plankton biodiversity. There were 30 species of phytoplankton and 15 species of zooplankton. The average plankton population was 28,201- 2,18,229 units l^{-1} in terms of phytoplankton and 952-11581 units l^{-1} in terms of zooplankton throughout the study. *Microcystis* spp. belonging to the group cyanophyceae was the most dominant among phytoplankton. The range of Shannon and Simpson diversity indices (2.006-2.947 and 0.8019- 0.9215 respectively) indicate moderate diversity of plankton in these water bodies. The values of diversity indices indicate less disturbance level and medium productivity. Study of various physico-chemical and biological parameters revealed that these reservoirs have medium productivity and if managed properly, production at all the trophic levels can be enhanced.

Keywords: Biodiversity, Diversity indices, Phytoplankton, Trophic levels, Zooplankton

Introduction

The scientific management of fisheries in a water body requires a thorough understanding of its trophic structure, their population characteristics and the nature of nutrient cycling with a view to achieving optimum fish productivity (Deorari, 1993). The reservoirs are a great source of aquatic biodiversity and their inter-relationship plays an important role in making the system viable. Phytoplankton, the major primary producer in an aquatic ecosystem which are grazed by zooplankton, constitute an important link in energy flow (Sharma, 1980). Plankton is the most important component of trophic structure which helps in transfer of energy to higher trophic levels. Consequently, the fish yield of almost all natural aquatic systems is directly or indirectly dependent on plankton abundance.

Several researchers have studied various aspects of plankton population in different reservoirs. Sugunan (1980) has documented the temporal variations in plankton population of Nagarjun Sagar Reservoir. Information on community structure of plankton of two manmade lakes of Rajasthan has been provided by Jhingran (1987). Some of the notable contributions on various aspects of phytoplankton and zooplankton ecology in the Indian reservoirs have been made by Sharma and Pant (1984), Salim and Ahmed (1985), Rao and Choubey (1990), Deorari (1993) and Ariyadej *et al.* (2004). However, sufficient investigations have not been done on the ecology and production of reservoirs of Tarai region of Himalayas. The present study is an effort to bridge the gaps in our knowledge on reservoirs of Dhaura and Baigul, located in the Tarai region of Udham Singh Nagar in Uttarakhand. Dhaura Reservoir was constructed in 1961 across the River Dhaura which receives a number of rivulets in the course of their flow. Similarly, Baigul Reservoir was constructed in 1967 on Baigul River, a small tributary of the Ganges, originating from the Siwalik Hills of Kumaon Himalayas (Table 1).

Materials and methods

For the qualitative and quantitative analyses, the plankton samples were collected every month from three zones of water surface (lentic, transition and lotic zones) during morning hours (8-10 am) horizontally using conical plankton net of 50 cm diameter (40 µ aperture) from selected sites following standard methods (APHA, 1995). Zooplankton samples were preserved in 5% formalin and phytoplankton in 0.3% Lugol's solution for analysis (Philipose, 1959; Pennak, 1978). Phytoplankton was counted using haemocytometer. Five counts were made for

each sample and results calculated in terms of cells per litre following APHA (1995):

$$\text{Phytoplankton (per litre)} = \frac{\text{Counts in the central chamber}}{\text{Concentration factor}} \times 10^7$$

where, Concentration factor = $\frac{\text{Volume of water concentrated}}{\text{Volume of water after concentration}}$

All species were counted as a single unit whether colonial, single-celled or filamentous.

For the quantitative study of zooplankton, a counting cell was used adopting the procedure outlined by Welch (1948). A minimum of five sub-samples were counted. Density of zooplankton per litre was estimated as:

$$\text{Number of plankton (per litre)} = \frac{a \times c \times 1000}{L}$$

where, a = average number of plankton in one small counting cell

c = volume of concentrate in ml

L = volume of water filtered in litres

Diversity indices *viz.,* Shannon and Simpson diversity index (1949), Menhinik and Margalef index (1964) and richness index (1959) were computed following basic programme PAST.

Margalef's richness index $R1 = \frac{S-1}{\ln(n)}$ where, S is the number of species and n is the total number of individuals observed in the sample.

Menhinik index $R_2 = \frac{S}{\sqrt{n}}$ where, S is the number of species and n is the total number of individuals observed in sample.

Simpson's diversity index $\lambda = \sum_{i=1}^{S} \frac{ni\,(ni-1)}{n\,(n-1)}$ where, ni is the total number of individuals in the i^{th} species and, n is the total number of individuals in the sample

Shannon's diversity index $H' = -\sum_{i=1}^{S} (pi \ln pi)$

where, S is the number of species in the sample and *pi* is the proportion of i^{th} species in the total sample.

Sheldon evenness index $E_2 = \frac{e^{H'}}{S}$

where, H' is diversity index and S is the total number of species in the sample.

Dominance index D = 1 – J where, J is evenness index.

Table 1. Geomorphological and hydrological features of Dhaura and Baigul reservoirs of Uttarakhand

Parameters	Dhaura	Baigul
Latitude	28^0 53' N	28^0 56' N
Longitude	79^0 34' E	79^0 40' E
Altitude (m)	200	211
District	Udham Singh Nagar	Udham Singh Nagar
State	Uttarakhand	Uttarakhand
Feeder rivers	Dhaura	Baigul or Sukhi
Construction year	1961	1967
Area of FRL (ha)	1280	2995
Type of foundation	Earthen	Earthen
Total length of bundh (km)	9.05	15.3
Top width of the dam (m)	4.0	4.8
Maximum height of reservoirs (m)	14.0	13.7
Mean depth (m)	2.2	2.6
Spill way	manual	manual
Number of gates	3	5
Top bundh level (ft)	715.0	696.39
Total catchment area (km^2)	134.68	305

Results and discussion

Composition and distribution of phytoplankton

A total of 30 species of phytoplankton belonging to Chlorophyceae (10 species), Bacillariophyceae (11 species), Cyanophyceae (6 species) and Dinophyceae (3 species) were recorded from Dhaura and Baigul reservoirs, while Salim and Ahmed (1985) recorded 35 species of phytoplankton in Baigul and Deorari (1993) reported 33 species from Dhaura Reservoir (Table 2 and 3).

The commonly occurring green algae were *Pediastrum* spp., *Scenedesmus quadricauda*, *Spirogyra* sp., *Zygnema* sp., *Volvox* sp. and *Mougeotia* sp. Among these, *Pediastrum* spp. were dominant and observed in all the seasons in both the reservoirs. *Spirogyra* sp. and *Zygnema* sp. were dominant during winter. *Chlorella vulgaris, Eudorina elegans*, *Cosmarium* sp. and *Ankistrodesmus falcatus* were observed occasionally. The density of *Pediastrum* spp. was found to be the maximum in Dhaura Reservoir (40,000 cells l^{-1}) and in Baigul (38,250 cells l^{-1}) during June, 2006. In Dhaura Reservoir, *S. quadricauda* was in the highest density (10,000 cells l^{-1}) in lentic sector in June, 2006 while in Baigul, it was the highest (10,825 cells l^{-1}) in the same sector in August, 2006. Generally, the members of Chlorophyceae were in high numbers from the onset of summer to the beginning of autumn seasons. A number of studies in India have reported a similar behaviour of Chlorophyceae and attributed it to the input of allochthonous organic matter with increased nitrate concentration in July favouring the growth of phytoplankton from August onwards (Sharma, 1980; Deorari, 1993).

Table 2. Monthly distribution of phytoplankton community in Dhaura Reservoir

Plankton	Jun 06	Jul 06	Aug 06	Sept 06	Oct 06	Nov 06	Dec 06	Jan 07	Feb 07	Mar 07	Apr 07	May 07
Chlorophyceae												
Pediastrum spp.	**	**	*	-	*	*	-	**	**	**	-	-
Scenedesmus quadricauda	*	*	*	-	*	*	-	*	*	*	-	-
Chlorella vulgaris	*	-	*	-	-	-	-	-	-	-	-	-
Spirogyra sp.	*	*	*	-	*	*	-	*	*	*	-	-
Zygnema sp.	*	*	*	-	*	*	-	*	*	*	-	-
Volvox sp.	*	*	*	-	*	*	-	*	*	*	-	-
Eudorina elegans	*	-	*	-	-	-	-	-	-	-	-	-
Cosmarium sp.	*	-	*	-	-	-	-	-	-	-	-	-
Mougeotia sp.	*	*	*	-	*	*	-	*	*	*	-	-
Ankistrodesmus falcatus	*	-	-	-	-	-	-	-	-	-	-	-
Bacillariophyceae												
Cymbella sp.	-	*	-	-	-	*	-	-	-	-	-	-
Synedra acus	*	*	*	*	*	*	-	*	*	*	*	*
Navicula viridula	*	*	*	*	*	*	-	*	*	*	*	*
Melosira granulata	*	*	*	*	*	**	-	*	*	*	*	*
Nitzschia palea	-	*	-	-	-	*	-	-	-	-	-	-
Amphora ovalis	*	*	*	*	*	*	-	*	*	*	*	*
Pinnularia sp.	*	*	*	*	*	*	-	*	*	*	*	*
Fragillaria crotonensis	*	*	*	*	*	*	-	*	*	*	*	*
Gomphonema sp.	-	*	-	-	-	*	-	-	-	-	-	-
Cyanophyceae												
Microcystis aeruginosa	**	**	**	*	**	***	*	***	**	**	**	**
Anabaena spiroides	*	*	*	*	*	*	*	*	*	*	*	*
Oscillatoria sp.	*	*	*	*	*	*	*	*	*	*	*	*
Nostoc sp.	-	-	-	-	-	*	-	*	-	-	-	-
Spirulina sp.	-	-	-	-	-	*	-	*	-	-	-	-
Aphanocaspa sp.	-	-	-	-	-	*	-	*	-	-	-	-
Dinophyceae												
Gymnodinium sp.	-	-	-	-	-	-	-	-	*	-	*	-
Ceratium sp.	-	-	-	-	*	-	*	-	*	*	*	*
Peridinium sp.	-	-	-	-	*	-	*	-	*	*	*	*

* < 25000 units l^{-1}
** 25000 - 50000 units l^{-1}
*** 50000 - 75000 units l^{-1}
- Absent

Diatoms were represented by *Synedra acus*, *Navicula viridula*, *Nitzschia palea*, *Melosira granulata*, *Fragillaria crotonensis*, *Gomphonema* sp., *Neidium* sp., *Cymbella* sp. and *Diatoma* sp. *S. acus* exhibited the highest density (10,150 cells l^{-1}) in the lentic sector in July, 2006 while it was absent in December, 2006 in Dhaura and in Biagul in August, 2006. The abundance of diatoms observed during winter is similar to the reports of the earlier workers (Kumar and Bhagat, 1978; Rishi and Kachroo, 1981; Raina *et al.,* 1984; Deorari, 1993) as the diatoms require diminished light and moderate water temperature for their growth. However, Rao (1955) pointed out that in general, peak of diatom occurred following a period of high concentration of silicates, nitrates and phosphates.

Among blue green algae, *Microcystis aeruginosa*, *Anabaena spiroides*, *Oscillatoria* sp., *Spirulina* sp., *Nostoc* sp. and *Aphanocapsa* sp. were recorded. *M. aeruginosa*, *A. spiroide* and *Oscillatoria* sp. were observed throughout the study period in all the sectors with the maximum quantity in winter season. *M. aeruginosa* ranged from 37,750 to 74,780 cells l^{-1} in Dhaura during November, 2006 and January, 2007 respectively. In Baigul, variation in the population density of this alga ranged from 19,975 cells l^{-1} in the transition zone during July, 2006 to 85,700 cells l^{-1} in lentic sector during January, 2007. Sugunan (1980; 1995) also reported that blooming of *Microcystis* spp. was common in many of the Indian reservoirs and some of them have permanent algal blooms. Deorari (1993) also recorded *Microcystis* spp. as dominant member of phytoplankton in Dhaura during his study. According to Deorari (1993), Cyanophyceae seemed to thrive well within a temperature range of 15.5 to 25.0 ^{0}C

Table 3. Monthly distribution of phytoplankton community in Baigul Reservoir

Plankton	Jun 06	Jul 06	Aug 06	Sept 06	Oct 06	Nov 06	Dec 06	Jan 07	Feb 07	Mar 07	Apr 07	May 07
Chlorophyceae												
Pediastrum spp.	**	*	*	*	*	*	*	*	*	-	*	*
Scenedesmus quadricauda	*	*	*	*	*	*	*	*	*	-	*	*
Chlorella vulgaris	*	-	-	-	-	-	-	-	-	-	-	-
Spirogyra sp.	*	*	*	*	*	*	*	*	*	-	*	*
Zygnema sp.	*	*	*	*	*	*	*	*	*	-	*	*
Volvox sp.	*	*	*	*	*	*	*	*	*	-	*	*
Eudorina elegans	*	-	-	-	-	-	-	-	-	-	-	-
Cosmarium sp.	*	-	-	-	-	-	-	-	-	-	-	-
Mougeotia sp.	*	*	*	*	*	*	*	*	*	-	*	*
Ankistrodesmus falcatus	*	-	-	-	-	-	-	-	-	-	-	-
Bacillariophyceae												
Cymbella sp.	-	-	-	*	*	-	-	-	-	-	-	-
Synedra acus	*	-	*	*	*	*	-	*	-	*	*	*
Navicula viridula	*	-	*	*	*	*	-	*	-	*	*	*
Melosira granulata	*	-	*	*	*	*	-	*	-	*	*	*
Nitzschia palea	-	-	-	*	*	-	-	-	-	-	-	-
Amphora ovalis	*	-	*	*	*	*	-	*	-	*	*	*
Pinnularia sp.	*	-	*	*	*	*	-	*	-	*	*	*
Fragillaria crotonensis	*	-	*	*	*	*	-	*	-	*	*	*
Gomphonema sp.	-	-	-	*	*	-	-	-	-	-	-	-
Cyanophyceae	-	-	-	*	*	-	-	-	-	-	-	-
Microcystis aeruginosa	-	-	-	*	*	-	-	-	-	-	-	-
Anabaena spiroides												
Oscillatoria sp.	*	*	**	***	**	**	***	B	**	**	**	*
Nostoc sp.	*	*	*	*	-	*	*	*	*	*	*	*
Spirulina sp.	*	*	*	*	*	*	*	*	*	*	*	*
Aphanocaspa sp.	-	-	-	*	*	-	-	*	-	-	-	-
Dinophyceae	-	-	-	*	*	-	-	*	-	-	-	-
Gymnodinium sp.	-	-	-	*	*	-	-	*	-	-	-	-
Ceratium sp.												
Peridinium sp.	-	-	-	-	-	-	-	-	*	-	-	-
Chlorophyceae	-	-	-	-	*	*	-	-	*	*	*	-
Pediastrum spp.	-	-	-	-	*	*	-	-	*	*	*	-

* <25000 units l^{-1}
** 25000 - 50000 units l^{-1}
*** 50000 - 75000 units l^{-1}
B >75000 units l^{-1}
- Absent

during winter season. However, Sharma and Pant (1979), recorded the maximum abundance of blue-green algae during summer months in Kumaon lakes. This obviously may be due to the availability of sufficient sunlight and high water temperature.

Dinoflagellates represented by *Ceratium* sp., *Peridinium* sp. and *Gymnodinium* sp. were observed during summer and winter seasons. Lewis (1987) has emphasised that species richness is lower in tropical water bodies than in temperate ones. The density of *Ceratium* sp. varied from nil to 16,730 cells l^{-1} in Dhaura (highest in transition zone during February, 2007) and from nil to 15,825 cells l^{-1} in Baigul (highest in lentic transition zone during February, 2007) reservoirs, respectively. This group did not exhibit any characteristic seasonal pattern and occurred sporadically during the study period. Deorari (1993) also described a similar pattern in the seasonal behaviour of Dinophyceae in certain freshwater ecosystems in India.

Chlorophyceae was the dominant group in most of the months in both the reservoirs contributing to a maximum of 52.24% in Dhaura during August, 2006 and 52.12% in Baigul in July, 2006 (Table 2 and 3). The population density ranged from 40,533 (November, 2006) to 86,133 cells l^{-1} (June, 2006) in Dhaura and from 52,940 (July, 2006) to 94,085 cells l^{-1} (June 2006) in Baigul. In September and December, 2006 and April – May, 2007, Chlorophyceae

was not observed in both the reservoirs. Also this was not recorded during March, 2007 in Baigul Reservoir. The population density of diatoms was between 30,508 (March, 2007) and 53,266 cells l^{-1} (November, 2006) in Dhaura and varied from 34,220 (March, 2007) to 59,645 cells l^{-1} (September and October, 2006) in Baigul Reservoir. They contributed 54.82% in Dhaura (September, 2006) and 32.46% in Baigul (March, 2007). The blue-green algae constituted a good proportion in both the reservoirs with 26. 51% (February, 2007) to 71.02% (December, 2006) in Dhaura and from 21.60% (June 2006) to 55.29 % (December, 2006) in Baigul. The density of this group varied from 27,816 (September, 2006) to 91,966 cells l^{-1} (November, 2006) in Dhaura and from 32,753 (July, 2006) to 97,738 cells l^{-1} (June, 2007) in Baigul. On the other hand, Dinophyceae was poorly represented. It was recorded maximum (28.97%) in December, 2006 in Dhaura and was 16.16% in February, 2007 in Baigul. The members of this group were not observed in June–September, 2006 and January-March, 2007 in Dhaura and the same condition was also observed in Baigul except that it was recorded during September, 2006. The range of population density of Dinophyceae was between 7,833 (March, 2007) and 19,435 cells l^{-1} (February, 2007) in Dhaura and from 9,808 (November, 2006) to 21,325 cells l^{-1} (February, 2007) in Baigul Reservoir.

It could therefore be inferred that the phytoplankton community in Dhaura and Baigul reservoirs changes frequently during different seasons owing to the changing environmental factors observed in such shallow water bodies (mean depth 2.2 and 2.6 m, respectively). Similar pattern of changes in phytoplankton community in different freshwater bodies were recorded by Sharma (1980), Sharma *et al.* (1982) and Deorari (1993).

Composition and abundance of zooplankton

A total of 15 species of zooplankton including 5 species each of Rotifera, Cladocera and Copepoda were collected during the period of study (Table 4 and 5). Deorari (1993) recorded 8 species of rotifers, 8 species of cladocerans and 6 species of copepods. According to Dumount and Tundisi (1984) and Vijverberg *et al.* (1987), the species diversity of limnetic copepods and cladocerans seems to decrease progressively towards the equator. This is corroborated by Fernando (1980), who showed that number of species occurring in the temperate regions of Britain and Canada were approximately 50% higher than that in tropical Sri Lanka. In a warm sub-temperate monomictic lake of Kumaon, Sharma (1980) identified 48, 5 and 7 species of rotifers, cladocerans and copepods, respectively while Singh *et al.* (1990) reported 15 species of rotifers, 3 species of cladocerans and 2 species of copepods in Nanaksagar, a reservoir located in Tarai area. Rawat (1991) recorded 9, 8 and 4 species of rotifers, cladocerans and copepods, respectively from Tumaria Reservoir, located at the foot hills of Uttarakhand.

Table 4. Monthly distribution of zooplankton community in Dhaura Reservoir

Plankton	Jun 06	Jul 06	Aug 06	Sept 06	Oct 06	Nov 06	Dec 06	Jan 07	Feb 07	Mar 07	Apr 07	May 07
Rotifera												
Keratella spp.	*	**	*	-	**	**	**	*	*	*	*	-
Filinia sp.	-	*	-	-	-	-	-	-	-	-	-	-
Lecane sp.	*	**	*	-	*	*	*	*	*	*	*	-
Brachionus spp.	*	**	*	-	*	*	*	*	*	*	*	-
Notholca sp.	*	*	*	-	*	*	*	*	*	*	*	-
Cladocera												
Daphnia spp.	-	-	*	-	**	*	-	-	*	*	*	-
Moina micrura	-	-	*	-	**	*	-	-	*	*	*	-
Chydorus sp.	-	-	*	-	**	*	-	-	*	*	*	-
Bosmina longirostris	-	-	*	-	*	*	-	-	*	*	*	-
Bosminopsis sp.	-	-	-	-	*	-	-	-	-	-	-	-
Copepoda												
Cyclops sp.	*	*	-	**	**	*	*	*	*	*	*	*
Diaptomus sp.	*	*	-	**	**	*	*	*	*	*	*	*
Mesocyclops leuckarti	*	*	-	*	**	**	**	*	*	*	*	*
Eucyclops sp.	*	*	-	-	*	*	*	*	*	*	*	*
Thermocyclops sp.	-	-	-	-	*	-	-	-	-	-	-	-
Nauplius larvae	-	-	-	-	*	-	-	-	-	-	-	-

* <2500 units l^{-1}
** 2500 - 5000 units l^{-1}
*** 5000 - 7500 units l^{-1}
\- Absent

Table 5. Monthly distribution of zooplankton community in Baigul Reservoir

Plankton	Jun 06	Jul 06	Aug 06	Sept 06	Oct 06	Nov 06	Dec 06	Jan 07	Feb 07	Mar 07	Apr 07	May 07
Rotifera												
Keratella spp.	**	*	**	***	**	**	*	-	-	-	-	-
Filinia sp.	-	-	-	*	*	-	-	-	-	-	-	-
Lecane sp.	*	*	**	*	*	*	*	-	-	-	-	-
Brachionus spp.	*	**	**	***	**	**	*	-	**	-	*	*
Notholca sp.	**	*	*	*	*	*	*	-	-	-	-	-
Cladocera												
Daphnia spp.	-	*	*	-	**	**	-	*	**	**	-	*
Moina micrura	-	*	**	-	**	**	-	*	**	**	-	*
Chydorus sp.	-	*	**	-	*	*	-	*	*	*	-	*
Bosmina longirostris	-	*	*	-	*	*	-	*	*	*	-	*
Bosminopsis sp.	-	-	-	*	-	-	-	-	-	-	-	-
Copepoda												
Cyclops sp.	*	*	-	***	*	*	*	*	*	*	-	*
Diaptomus sp.	*	**	-	***	**	**	*	*	**	*	-	*
Mesocyclops leuckarti	**	**	-	***	***	***	**	**	**	**	-	***
Eucyclops sp.	*	*	-	**	**	**	*	*	**	**	-	**
Thermocyclops sp.	-	-	-	*	*	-	-	-	-	-	-	-
Nauplius larvae	-	-	-	*	*	-	-	-	-	-	-	-

* <2500 units l^{-1}
** 2500 - 5000 units l^{-1}
*** 5000 - 7500 units l^{-1}
- Absent

The members of rotifera recorded were *Keratella* spp., *Filinia longiseta, Lecane* sp., *Brachionus* spp. and *Notholca* sp. *Brachionus* spp. was observed in good numbers in both the reservoirs with density varying from 0 to 870 units l^{-1} in Dhaura, the highest in lentic sector during July, 2006 and from 0 to 1726 units l^{-1} in Baigul Reservoir (1726 units l^{-1} in lentic sector during September, 2006). The highest density of *Keratella* spp. was 1041 units l^{-1} in transition zone of Dhaura during January, 2007 and 1200 units l^{-1} in lentic sector of Baigul during September, 2006. The members of this group were not observed in September and December, 2006 from Dhaura and March, 2007 from Baigul. These species have also been reported by several workers as common components of plankton community of Indian freshwater bodies (Moitra and Bhowmic, 1988; Deorari, 1993; Mishra *et al.,* 2003). Most of the rotifer species occurring in these reservoirs were abundant in lentic and shallower areas having thick vegetation as reported by Sharma (1980), Rawat (1991) and Deorari (1993).

The group cladocera was represented by *Daphnia* spp., *Moina micrura*, *Chydorus* sp., *Bosmina longirostris* and *Bosminopsis* sp. *Daphnia* spp. was more abundant than the other cladocerans. *Bosminopsis* sp. was sparse in these reservoirs. The population of *Daphnia* spp. varied from 0 to 700 units l^{-1} in Dhaura (the highest in lentic sector during October, 2006) and 0 to 605 units l^{-1} in Baigul (the highest in lentic sector during February, 2007). These species have also been reported from a wide variety of freshwater bodies. This probably indicates a relative cosmopolitan nature of most of these species (Davis, 1972). The decline in cladoceran population during monsoon coincided with the inflow of allochthonus nutrients, along with surface run off. Besides, cladocerans produce resting eggs in autumn/ winter months of the year which hatch from February onwards (Dokulil *et al.*, 1990) culminating in peak population during summer. Sweetman and Smol (2006), reported similar cladoceran assemblages. Copepods were represented by four dominant species *viz., Cyclops* sp., *Diaptomus* sp., *Mesocyclops leuckarti* and *Eucyclops* sp. while *Thermocyclops* sp. and nauplius larvae were rare. Peak abundance of *Cyclops* sp. was observed during October, 2006 in lentic sector of Dhaura (880 units l^{-1}) and in September, 2006 in the lotic sector of Baigul (1250 units l^{-1}). The population of *Diaptomus* sp. was the highest during July, 2007 in the lentic sector of Dhaura (1070 units l^{-1}) and during September, 2006 in the lentic sector of Baigul (1185 units l^{-1}). Copepods were not observed in August, 2006 in Dhaura and during August, 2006 and April, 2007 in Baigul.

The population density of rotifera ranged from nil (January and March, 2007) to 3764 units l^{-1} (September and October, 2006) in Baigul and from nil (September, 2006 and May, 2007) to 2046 units l^{-1} (July, 2006) in Dhaura Reservoir (Fig. 1 and 2). The contribution of rotifers varied

from nil to 56.58% (January, 2007) in Dhaura and from nil to 100% (April, 2007) in Baigul Reservoir. Cladocera constituted a significant component of zooplankton community for most part of the study period. They however, fluctuated from nil to 53.26% (August, 2006) in Dhaura and from nil to 48.47% (August, 2006) in Baigul Reservoir. Population density ranged from 0 (June, July, September and December 2006; January and May, 2007) to 2,700 units l^{-1} (October, 2006) in Dhaura and from nil (June- July, October and December, 2006 and April, 2007) to 3,652 units l^{-1} (September, 2006) in Baigul Reservoir. The population density of copepoda ranged from nil (August, 2006) to 3,493 units l^{-1} (October 2006) in Dhaura and from nil (August, 2006 and April, 2007) to 4,165 units l^{-1} (September and October, 2006) in Baigul. Copepods also contributed to the total zooplankton with percentage ranging from nil to 57.84% (July, 2006) in Dhaura and from nil to 70.84% (May, 2007) in Baigul Reservoir.

The percentage distribution of phytoplankton and zooplankton in these reservoirs (Fig. 1 and 2) shows that the maximum contribution was by phytoplankton. The stocking of phytoplankton feeding fish may help to control the phytoplankton and make the system viable.

Diversity indices

During different months, the taxa of plankton varied from 12 to 29 in Dhaura and Baigul reservoirs (Tables 6 and 7). The Margalef and Menhinik richness indices were maximum in March, 2007 in Dhaura and November, 2006 in Baigul. The maximum values (2.947 in Baigul and 2.801 in Dhaura) of Shannon's diversity index were in November and October, 2006, respectively. In Shannon Wiener legislation, the aquatic environment (soil/water) is classified as – very good when H´ is > 4, good quality 4- 3, moderate quality 3-2, poor quality 2-1 and very poor quality <1. A community becomes more dissimilar as the stress increases and accordingly species diversity decreases with poor water quality. A community dominated by relatively few species indicates environmental stress (Plafkin *et al.*, 1989). The Shannon's index value

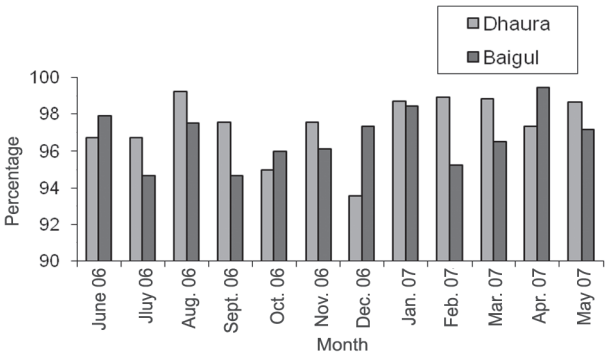

Fig. 1. Monthly variation in percentage population of phytoplankton in Dhaura and Baigul reservoirs

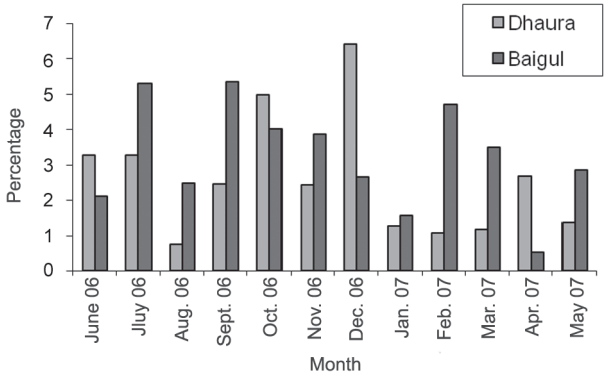

Fig. 2. Monthly variation in percentage population of zooplankton in Dhaura and Baigul reservoirs

(2.005- 2.947) obtained during this study indicates less pollution in these water bodies. The Simpson index (low value) indicates an increase in dominance of fewer species in May, 2007 due to high variation in water quality. September, 2006 was the month of maximum when even distribution of the plankton shows favourable condition. In Baigul, plankton taxa varied from 17 to 29 (Table 7). A scale of pollution in terms of species diversity (3.0 - 4.5 slight, 2.0 - 3.0 light, 1.0 - 2.0 moderate and 0.0 - 1.0 heavy pollution) has been described by Staub *et al.* (1970).

Table 6. Plankton diversity indices of Dhaura Reservoir

Diversity index	Jun 06	Jul 06	Aug 06	Sep 06	Oct 06	Nov 06	Dec 06	Jan 07	Feb 07	Mar 07	Apr 07	May 07
Taxa	23	23	23	12	29	27	13	23	29	29	23	13
Individuals	1706992	1678992	1706495	692995	1771140	1832908	378596	1588659	1866239	1741275	1125658	932937
Dominance	0.127	0.1115	0.1257	0.167	0.09088	0.1453	0.1748	0.166	0.1015	0.1093	0.1653	0.1909
Shannon	2.414	2.624	2.426	2.031	2.801	2.372	2.005	2.375	2.662	2.633	2.353	2.006
Simpson	0.873	0.8885	0.8743	0.833	0.9091	0.8547	0.8252	0.834	0.8985	0.8907	0.8347	0.8091
Evenness	0.4859	0.5998	0.4921	0.6354	0.5675	0.3971	0.571	0.4672	0.4941	0.4798	0.4572	0.5719
Menhinick	0.0176	0.01775	0.01761	0.01442	0.02179	0.01994	0.02113	0.01825	0.02123	0.02198	0.02168	0.01346
Margalef	1.533	1.535	1.533	0.8179	1.946	1.803	0.9343	1.541	1.939	1.948	1.579	0.873

Table 7. Plankton diversity indices of Baigul Reservoir

Diversity index	Jun 06	Jul 06	Aug 06	Sep 06	Oct 06	Nov 06	Dec 06	Jan 07	Feb 07	Mar 07	Apr 07	May 07
Taxa	23	21	23	23	28	29	17	23	23	19	21	27
Individuals	2075758	1081576	2008942	2301959	1965989	2084972	1373211	2352244	1646127	1303511	1878543	1775425
Dominance	0.08409	0.1006	0.08312	0.08913	0.08666	0.07851	0.1981	0.1465	0.1072	0.1418	0.1077	0.09139
Shannon	2.747	2.596	2.787	2.791	2.871	2.947	2.123	2.488	2.654	2.449	2.579	2.695
Simpson	0.9159	0.8994	0.9169	0.9109	0.9133	0.9215	0.8019	0.8535	0.8928	0.8582	0.8923	0.9086
Evenness	0.6777	0.6386	0.7058	0.7085	0.6308	0.657	0.4917	0.5233	0.6178	0.6091	0.628	0.5483
Menhinick	0.01596	0.02019	0.01623	0.01516	0.01997	0.02008	0.01451	0.015	0.01793	0.01664	0.01532	0.02026
Margalef	1.512	1.439	1.516	1.502	1.863	1.924	1.132	1.5	1.537	1.278	1.384	1.807

According to this range, these reservoirs are below pollution level (the values ranged from 2.005 to 2.947). The Margalef and Menhinick richness indices ranged from 1.132 to 1.924 and from 0.0145 to 0.0203, respectively which indicate moderate richness of the organisms.

The study indicates that the plankton diversity and density in these reservoirs are in moderate range. *Microcystis* spp. was the most dominant group recorded. Variation observed in the plankton density was related to variations in environmental conditions. Since the plankton is the base of trophic level in any aquatic system, a thoughtful utilisation of the plankton community from these water bodies along with adaptation of proper management practices and stock enhancement may increase the fish production from these water bodies.

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