



## Assessment of abiotic factors and planktonic structure of Baur and Haripura reservoirs, Uttarakhand, India

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### ABSTRACT

The study investigated the variation in physico-chemical parameters and planktonic community structure (biotic) of two reservoirs *viz.* Baur and Haripura located in Tarai region of Uttarakhand from September 2018 to April 2019. The reservoirs hold tremendous potential for inland fisheries development and offer ample scope for fish yield optimisation through adoption of suitable management norms. Variations have been recorded in different water quality parameters *viz.* temperature (20.00-32.65°C), pH (7.25-8.4), dissolved oxygen (4.35-6.35 mg l<sup>-1</sup>) and total dissolved solids (159.5-254.0 mg l<sup>-1</sup>) which shows a positive correlation (except temperature) with phytoplankton and zooplankton production in the selected reservoirs. A total of 29 and 23 phytoplankton genera were observed in Baur and Haripura reservoirs, respectively belonging to Bacillariophyceae (49% in Haripura, 46% in Baur), Chlorophyceae (44% in Baur, 31% in Haripura), Cyanophyceae (9% in Haripura, 4% in Baur), Euglenophyceae (10% in Haripura, 5% in Baur) and Dinophyceae (1% in each) groups. The density of phytoplankton population was found highest in the month of April and lowest during September. A total of 14 zooplankton genera belonging to 3 classes were recorded from both the reservoirs with class Cladocera occupying the major proportion of total zooplankton recorded. A surge in the zooplanktonic community was witnessed in November with minimum density in the month of September. The reservoir Baur observed a higher phytoplankton and zooplankton density as compared to Haripura, pointing towards a more productive ecosystem.

Keywords: Phytoplankton, Seasonal abundance, Water quality, Zooplankton

### Introduction

Aquatic water bodies are influenced by basin morphometry as well as physical, chemical and biological interactions. Indian reservoirs are endowed by extensive fishery resources with untapped potential for economic activity (Jayasankar *et al.*, 2018). The experimental reservoirs constructed during post-independence period for irrigation purpose are an important source of fish production in Uttarakhand State (Desai, 2006; Mishra, 2007). The management of aquatic resources for enhancing fish production, depends greatly on its limnological characteristics (Mishra *et al.*, 2010). The abiotic and biotic factors are important and fundamental components to know the trophic dynamics of an aquatic ecosystem (Sharma, 2000). The important abiotic characteristics (water temperature, transparency, conductivity, TDS, dissolved oxygen, total alkalinity, pH and nutrients), dynamics of biotic communities, primary and secondary production and energy flow constitute the major components of hydrology (Ahmad and Sarkar, 1997). Also, the size and shape of reservoirs influence their productivity (Sugunan, 1995).

Presently, reservoirs are contributing 2.44 lakh t fish production which is 3.81% to the total inland fish production of India and is the single largest inland fishery

resource in terms of resource size and production potential (DoF, 2020). The physico-chemical parameters especially water temperature, pH, dissolved oxygen, transparency and total dissolved solids have direct relation to the primary and secondary production (Mishra *et al.*, 2003). Assessment of water quality includes analysis of physico-chemical and biological parameters that in turn reflects its abiotic and biotic status (Smitha and Shivashankar, 2013). Deshmukh and Ambore (2006) from their study revealed that an intricate relationship exists between the metabolism of aquatic biota and hydro-biological characteristics of an aquatic ecosystem. Thus, the water quality analysis of a water body not only determines how well an aquatic organism grows but also whether the environment is conducive for its survival or not. Biotic communities on the other hand, hold a key position in the aquatic environment with the planktonic communities providing an elaborate knowledge of the ecological characteristics of the system (Ingole *et al.*, 2010). They are also used as a reliable indicator to determine the ecosystem's water quality, health and productivity potential (Agandi *et al.*, 2005; Saha and Bandyopadhyay, 2009).

The Uttarakhand State has enormous aquatic resources in the form of reservoirs (20,000 ha) (Sharma and Mishra,

2009). In the present study, The physico-chemical and biological parameters of Baur and Haripura reservoirs located in the Tarai region of Uttarakhand and having different topographic features, was monitored for the period from September 2018 to April 2019 in order to understand their contribution towards sustainable fish production.

### Materials and methods

The reservoirs Baur and Haripura situated in the Tarai belt of the Shivalik range at coordinates 29°8'N and 79°18'E of Himalayan foothills and having an area of 1,271 and 1,158 ha respectively were selected for the present study. The Baur Reservoir is fed by rivers Baur and Kakarala while rivers Bhakhara and Khajia supply water to Haripura Reservoir. Two sampling sites, one in the peripheral zone and another in the barrage area (S1 and S2 in Haripura and S1' and S2' in Baur), located at a distance of 2.5 km, were selected in each reservoir. Monthly assessment of water quality parameters and plankton distribution were carried out from September 2018 to April 2019 to assess the variability in parameters and productivity.

For the study of limnological parameters, water samples were collected in the morning hours between 09:00 and 11:00 hrs and analysed following standard methods (APHA, 2012). The entire analysis was carried out at two levels *viz.* on-site analysis that included the estimation of water temperature (by simple mercury thermometer), TDS (by HANNA digital TDS meter), pH (by digital pH meter) and dissolved oxygen (following iodometric titration method), while the second step constituted the observation, identification and quantitative estimation of plankton (Sharma, 2000), which was carried out in the laboratory of College of Fisheries, G. B. Pant University of Agriculture and Technology (GBPUAT), Pantnagar, India.

The plankton samples were collected from all the sampling stations of each habitat (stagnant and fluvatile) selected under the study by filtering 50 l of water using a plankton net of bolting silk no. 25; transferred the concentrate to small specimen tubes and preserved in 4% Lugol's iodine solution for phytoplankton) and in 5% formalin for zooplankton and observed in the laboratory. The readings were taken in triplicate for each sample (APHA, 2012). All the identified species of phytoplankton were counted as one, whether it was single-celled, filamentous or a colony and calculated using the formula:

$$\text{Phytoplankton density (cells l}^{-1}\text{)} = \frac{\text{Count in the centre chamber} \times 10^7}{\text{Concentration factor}}$$

$$\text{where, Concentration factor} = \frac{\text{Initial volume of water concentrated}}{\text{Volume of concentrated water}}$$

For estimation of zooplankton, Sedgewick Rafter counting cell was used and number of individuals were counted adopting standard methods (Sharma, 2000; APHA, 2012) and calculated using the given formula. The samples of plankton were observed under high power digital microscope (Motic, China).

$$\text{Number of individuals per ml} = \frac{\text{No. of organisms counted}}{\text{No. of replicates taken}}$$

The effect of limnological parameters on variability of plankton population between selected reservoirs was analysed statistically using Pearson correlation analysis and One Way ANOVA using MS EXCEL and SPSS softwares (16.0).

### Results and discussion

The variation in water quality parameters are depicted in Fig. 1 to 6. The atmospheric and water temperature are interrelated and go hand in hand. During the study period, the average atmospheric temperature in Baur and Haripura was found to be 27.56±4.4 and 27.25±4.66°C, respectively. The mean water temperature varied from 20.40 to 32.65°C and 20.00 to 32.50°C in Baur and Haripura reservoirs, respectively. In the Baur Reservoir, the average temperature at sampling sites S<sub>1</sub>' and S<sub>2</sub>' was noted to be 27.31±4.53 and 26.23±4.83°C, respectively (Fig. 1a). In case of Haripura Reservoir, the average temperature at sampling sites S<sub>1</sub> and S<sub>2</sub> were 26.95±4.60 and 25.81±4.54°C, respectively (Fig. 1b). A slightly higher average water temperature in the peripheral part was observed in comparison to the barrage part in both the reservoirs which may be attributed to the shallow characteristic of that site. Similar result has been recorded by Mishra (2007) in the littoral zone of Baigul and Dhaura reservoirs of Uttarakhand. The water temperature revealed a positive correlation with the atmospheric temperature and pH while a negative correlation with DO, phytoplankton and zooplankton for all the three habitats. The results of the present study are in consonance to the findings of Jawale and Patil (2009) and Garg *et al.* (2010) showing an elevated temperature in the summer months which reduced in the winter months. Low temperature during the winter months may be due to low air temperature, increased water level and lesser solar radiation while a steady increase of temperature witnessed in the summer months could be attributed to clear atmosphere, low water level, intense solar radiation and prolonged photoperiod. Verma (2013) found that the average water temperature of reservoirs located in Tarai region of Uttarakhand State remains above 20°C, providing a favourable environment for growth and survival of tropical fishes.

The mean pH of Baur Reservoir ranged between 7.3 and 8.4. The highest pH (8.3 in S1' and 8.5 in S2') was recorded in the month of April while minimum pH was recorded in the month of January (7.2 in S1' and 7.4 in S2') in both the sampling sites (Fig. 2a). On the other hand, in the Haripura Reservoir, the mean pH value oscillated between 7.25 and 7.95. The maximum (8.1 in S1 and 7.8 in S2) and minimum (7.4 in S1 and 7.1 in S2) pH was recorded in the month of April and January respectively (Fig. 2b). The pH values were found to be positively correlated with atmospheric temperature, water temperature, total dissolved solids (TDS), phytoplankton and zooplankton and negatively with dissolved oxygen. ANOVA showed a significant difference in pH among the selected sites ( $p < 0.05$ ). The results are in consonance with those of Lokhande (2013), where the pH of Dhanegaon Reservoir in Maharashtra was alkaline with minimum and maximum values in winter and summer season respectively.

In the Baur Reservoir, the mean TDS was recorded in the range of 159.50 (September) - 234.00 (April)  $\text{mg l}^{-1}$

(Fig. 3a). On the other hand, in the Haripura Reservoir the range of average TDS was observed between 182.00 (September) and 254.00  $\text{mg l}^{-1}$  (April) (Fig. 3b). The TDS showed positive correlation with pH, phytoplankton and zooplankton in all habitats. Elevated TDS value during summers may be due to high water temperature, low water level, increased evaporation rate and less water flow into the reservoir as reported by Karne and Kulkarni (2009). The summer months witnessed a peak in the TDS values (Narayana *et al.*, 2005; Jemi and Balasingh, 2011). A drop in the TDS values during monsoon may be due to low evaporation rate, elevated water level and excessive rate of dilution. Similar trend has been noticed in the Madduvalasa Reservoir of Andhra Pradesh where the TDS value was maximum in the summer months (232  $\text{mg l}^{-1}$ ) and minimum in the monsoon months (216.66  $\text{mg l}^{-1}$ ) (Tejaswi and Prasad, 2017).

The average monthly values of DO in the two selected sites of Baur Reservoir *i.e.* S<sub>1</sub>' and S<sub>2</sub>' were  $5.48 \pm 0.47 \text{ mg l}^{-1}$  and  $5.84 \pm 0.47 \text{ mg l}^{-1}$ , respectively (Fig. 4a) while in Haripura Reservoir, it was  $5.13 \pm 0.54 \text{ mg l}^{-1}$  (S<sub>1</sub>) and

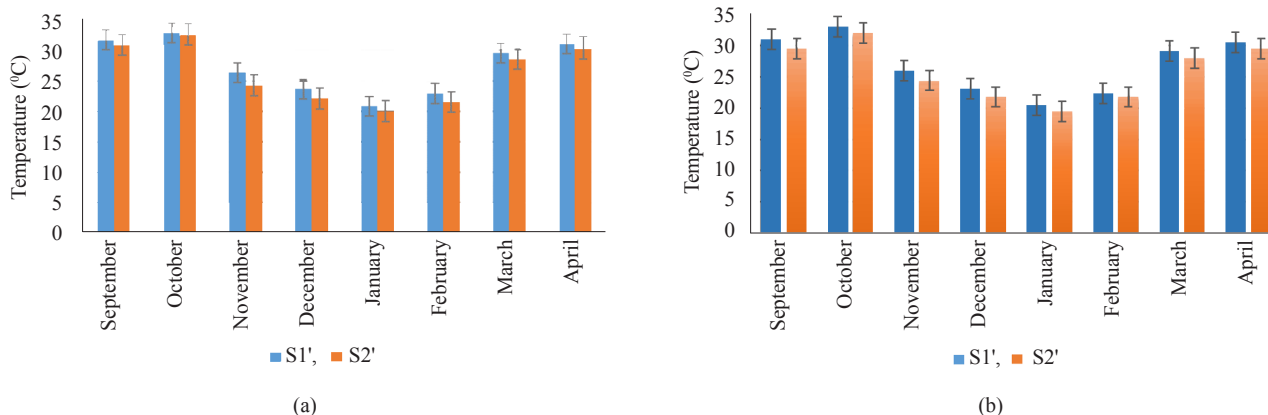


Fig. 1. Monthly variations in water temperature (°C) of (a) Baur and (b) Haripura reservoirs

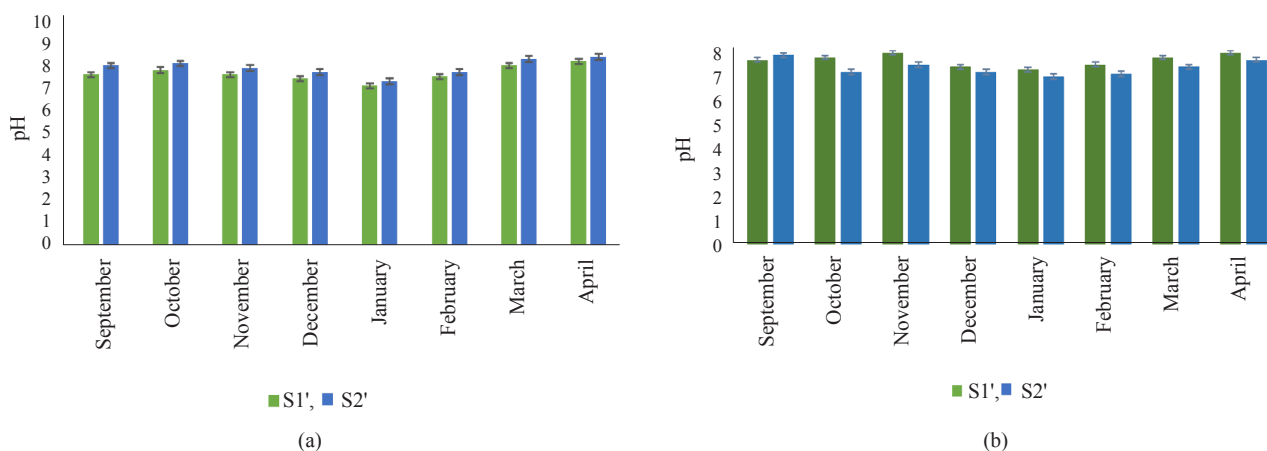


Fig. 2. Monthly variations in pH of (a) Baur and (b) Haripura reservoirs

$5.48 \pm 0.54 \text{ mg l}^{-1}$  ( $S_2$ ) (Fig. 4b). The mean maximum value of DO in Baur ( $6.35 \text{ mg l}^{-1}$ ) and Haripura ( $5.95 \text{ mg l}^{-1}$ ) reservoirs were recorded in the month of January while minimum mean value in Baur ( $4.90 \text{ mg l}^{-1}$ ) and Haripura ( $4.35 \text{ mg l}^{-1}$ ) reservoirs were recorded in September. The DO values were negatively correlated with atmospheric temperature, water temperature and pH while positively correlated with phytoplankton and zooplankton in both the habitats. A significant variation in DO was found among the selected sites ( $p < 0.05$ ). Maximum DO value in the winter season and minimum in the summer season was delineated by Srinivas *et al.* (2017) in the Lower Manair Dam, Telangana. A drop in the DO level during dry summer months may be due to high water temperature, less solubility and limited water influx from rivers (Rani *et al.*, 2004). Elevation in the DO concentration during the winter months may be due to low temperature and high photosynthesis. Tyagi and Malik (2018) also recorded highest DO value ( $9.66 \text{ mg l}^{-1}$ ) during winters and lowest DO value ( $8.42 \text{ mg l}^{-1}$ ) during monsoon in the Ram-Ganga Reservoir situated in Garhwal, Uttarakhand.

#### Phytoplankton population

The composition of phytoplanktonic community in Baur and Haripura reservoirs recorded during the study period is illustrated in Table 1. In the Baur Reservoir, a total of 29 phytoplankton genera were observed belonging to 5 classes with Bacillariophyceae (15) being the dominant class followed by Chlorophyceae (10), Cyanophyceae (2), Euglenophyceae and Dinophyceae (1 each). The class-wise representation of the recorded phytoplankton were manifested in the following order of dominance in terms of phytoplankton diversity: Bacillariophyceae (46%) > Chlorophyceae (44%) > Euglenophyceae (5%) > Cyanophyceae (4%) > Dinophyceae (1%). On the other hand in Haripura Reservoir, a total of 23 genera belonging to 5 classes of phytoplankton were observed encompassing 11 genera of Bacillariophyceae, 8 genera of Chlorophyceae, 2 genera of Cyanophyceae and 1 genera each of Euglenophyceae and Dinophyceae, with Bacillariophyceae and Chlorophyceae being the major contributors. The class-wise portrayal of the observed phytoplankton

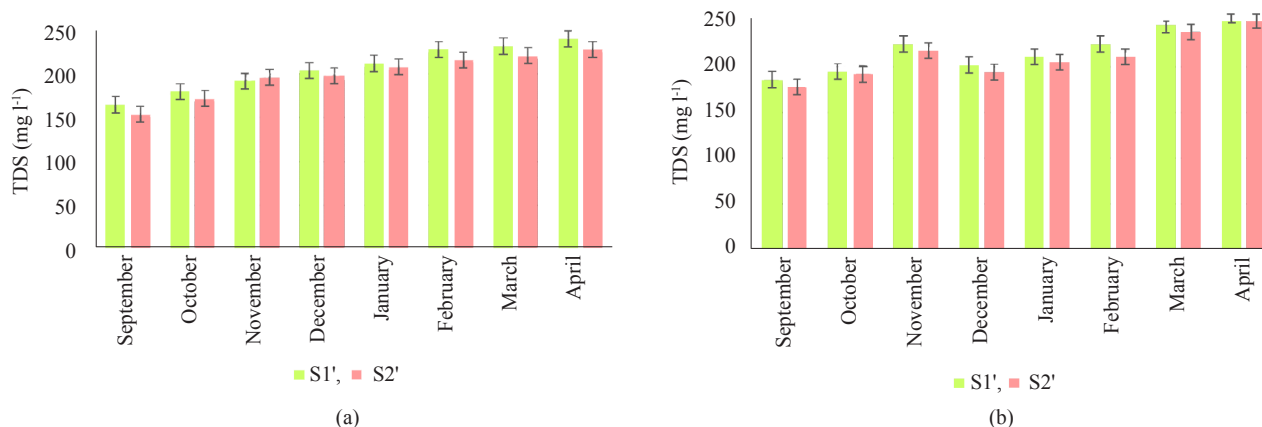


Fig. 3. Monthly variations in TDS ( $\text{mg l}^{-1}$ ) of (a) Baur and (b) Haripura reservoirs

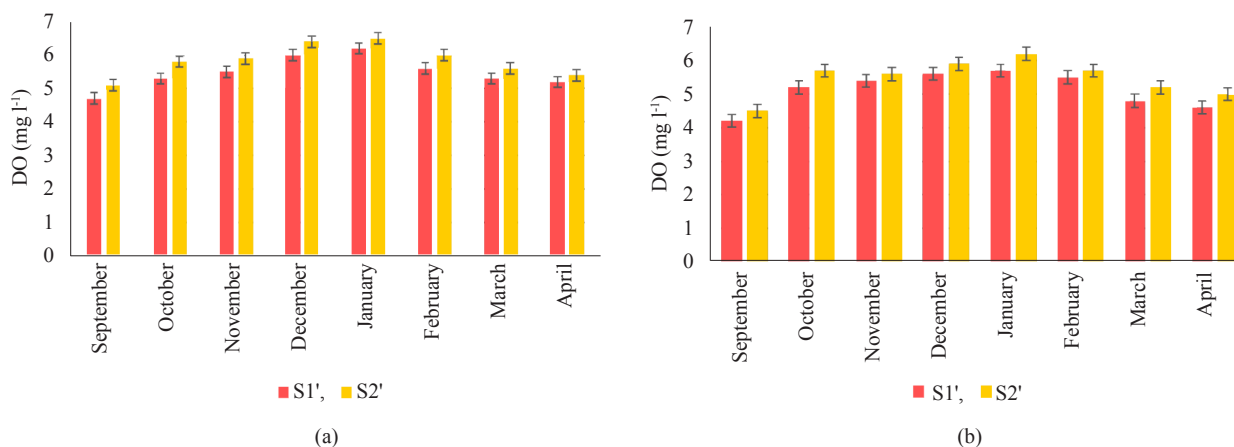


Fig. 4. Monthly variations in DO ( $\text{mg l}^{-1}$ ) of (a) Baur and (b) Haripura reservoirs

Table 1. List of phytoplankton recorded from Baur and Haripura reservoirs

Group	Species	Baur	Haripura
Bacillariophyceae	<i>Nitzschia</i> sp.	+	+
	<i>Achnanthes</i> sp.	+	-
	<i>Navicula</i> sp.	+	+
	<i>Amphora</i> sp.	+	-
	<i>Gomphonema</i> sp.	+	-
	<i>Synedra</i> sp.	+	+
	<i>Gyrosigma</i> sp.	+	+
	<i>Fragillaria</i> sp.	+	-
	<i>Caloneis</i> sp.	+	-
	<i>Epithemia</i> sp.	+	+
	<i>Pinnularia</i> sp.	+	+
	<i>Rhopalodia</i> sp.	+	+
	<i>Denticula</i> sp.	+	+
	<i>Cymbella</i> sp.	+	+
	<i>Amphipleura</i> sp.	+	-
<i>Bacillaria</i> sp.	-	+	
<i>Tabellaria</i> sp.	-	+	
Chlorophyceae	<i>Chlorococcus</i> sp.	+	-
	<i>Cosmarium</i> sp.	+	+
	<i>Spirogyra</i> sp.	+	+
	<i>Hyalotheca</i> sp.	+	+
	<i>Mougeotia</i> sp.	+	+
	<i>Zygnema</i> sp.	+	+
	<i>Scenedesmus</i> sp.	+	-
	<i>Rhizoclonium</i> sp.	+	+
	<i>Ulothrix</i> sp.	+	+
	<i>Ankistrodesmus</i> sp.	+	+
Cyanophyceae	<i>Oscillatoria</i> sp.	+	+
	<i>Microcystis</i> sp.	+	+
Euglenophyceae	<i>Euglena</i> sp.	+	+
Dinophyceae	<i>Ceratium</i> sp.	+	+

+ Present; - Absent

in terms of phytoplankton diversity evinced the following order of dominance: Bacillariophyceae (49%)>Chlorophyceae (31%)>Euglenophyceae (10%)>Cyanophyceae (9%)>Dinophyceae (1%). In the present study, occurrence of several pollution indicators *viz.*, *Nitzschia* sp., *Navicula* sp., *Euglena* sp., *Cymbella* sp., *Gomphonema* sp., *Scenedesmus* sp. and *Oscillatoria* sp. were reported from both the reservoirs pointing towards eutrophic condition of the ecosystem (Nandan and Aher, 2005; Shekhar *et al.*, 2008; Mishra *et al.*, 2010). In both Haripura and Baur reservoirs, class Bacillariophyceae was abundant among all algal classes. The relative abundance of diatoms was observed to be higher in Haripura (49%) as compared to Baur (46%) which may be due to lesser temperature. The next major group was Chlorophyceae which manages to flourish under high temperature, pH and DO (Kadam *et al.*, 2014). The presence of green algae was found to

be higher in the Baur Reservoir which could be due to elevated temperature and DO concentration. Karthi *et al.* (2013) recorded 32 phytoplankton species belonging to classes Bacillariophyceae (15 species), Chlorophyceae (10 species) and Cyanophyceae (7 species) from Lake Vaduvar. In the findings of Sharma (2013), the diatoms represented 39.81% of the total phytoplankton from Tighra Reservoir, Gwalior. According to Gadag *et al.* (2005) presence of *Oscillatoria* sp. shows biological pollutants and indicates nutrient enrichment in water bodies (Zargar and Ghosh, 2006). Diatoms are known to grow well under low temperature (Ganai *et al.*, 2010; Gurung *et al.*, 2013). The diversity of blue-green algae on the other hand is found to be more during elevated temperature and reduced DO, which indicates the presence of organic load in any aquatic system (Sedamkar and Angadi, 2003).

In the Baur Reservoir, the trend of monthly variability of phytoplankton population was maximum during April (46,500 cells l<sup>-1</sup>) while it was minimum during September (13,000 cells l<sup>-1</sup>). The mean value of phytoplankton density was found to be highest at site S<sub>2</sub>' (35,500±12,612.35 cells l<sup>-1</sup>) followed by site S<sub>1</sub>' (31,250±12,421.18 cells l<sup>-1</sup>). The Haripura Reservoir also followed the same trend with phytoplankton peak during April (30,000 cells l<sup>-1</sup>) and minimum density during September (11,000 cells l<sup>-1</sup>). The average density of phytoplankton was highest at site S<sub>2</sub> (23,775±7,982.436 cells l<sup>-1</sup>) followed by site S<sub>1</sub> (20,125±7,019.107 cells l<sup>-1</sup>). Reduced phytoplankton count was observed at site S<sub>1</sub>. The phytoplankton density revealed a positive correlation with pH, TDS, DO and zooplankton and a negative correlation with atmospheric and water temperature. The graphical representation of monthly variation in the phytoplankton density of Baur and Haripura reservoirs is illustrated in Fig. 5a and b. A significant variation in phytoplankton density among the selected sites was found (p<0.05). The results are in accordance with the investigation of Sebastian and Thomas (2016) who studied the phytoplankton of the Idukki Reservoir, Kerala and reported maximum phytoplankton abundance during the pre-monsoon season (February-May) *i.e.* 747.30 cells l<sup>-1</sup> and minimum during the monsoon season (June-September) *i.e.* 217.51 cells l<sup>-1</sup>. A decreasing trend of phytoplankton density in the months of September and October can be attributed to dilution of water and mixing of silt due to heavy downpour which reduces the availability of nutrients for planktonic growth. With the advent of summer months, a surge in the phytoplankton count observed may be due to a rise in temperature and increased decomposition rate leading to an increase in the nutrient concentration (Santhanam and Perumal, 2003).

#### Zooplankton population

The zooplankton composition of Baur and Haripura reservoirs recorded during the study period is illustrated

in Table 2. A total of 14 zooplankton genera belonging to 3 classes *viz.* Cladocera (7 genera), Copepoda (5 genera) and Rotifera (2 genera) were reported from the Baur Reservoir. The class Cladocera occupied the major proportion of total zooplankton recorded. The class-wise representation of the observed zooplankton were in the following order in terms of zooplankton diversity: Cladocera (55%)>Copepoda (40%)>Rotifera (5%). In the Haripura Reservoir too, a total of 14 genera of zooplankton belonging to 3 classes *viz.* Cladocera (7 genera), Copepoda (5 genera) and Rotifera (2 genera) were observed. The class-wise portrayal of percent composition of observed zooplankton evinced the following order of dominance in terms of diversity: Cladocera (52%) > Copepoda (34%) > Rotifera (14%) with Cladocera and Copepoda being the major contributors. Commonly found zooplankton genera in both the reservoirs were *Mesocyclops sp.*, *Moina sp.*, *Ceriodaphnia sp.*, *Brachionus sp.* and *Chydorus sp.* A moderate density of zooplankton comprising of

Table 2. List of zooplankton recorded from Baur and Haripura reservoirs

Group	Species	Baur	Haripura
Copepoda	<i>Cyclops sp.</i>	+	+
	<i>Eucyclops sp.</i>	+	+
	<i>Mesocyclops sp.</i>	+	+
	<i>Diaptomus sp.</i>	+	+
	<i>Nauplius larva</i>	+	+
Cladocera	<i>Daphnia sp.</i>	+	+
	<i>Moina sp.</i>	+	+
	<i>Ceriodaphnia sp.</i>	+	+
	<i>Chydorus sp.</i>	+	+
	<i>Alona sp.</i>	+	+
	<i>Bosmina sp.</i>	+	+
	<i>Diaphanosoma sp.</i>	+	-
Rotifer	<i>Brachionus sp.</i>	+	+
	<i>Notholca sp.</i>	+	+
	<i>Asplanchna sp.</i>	-	+

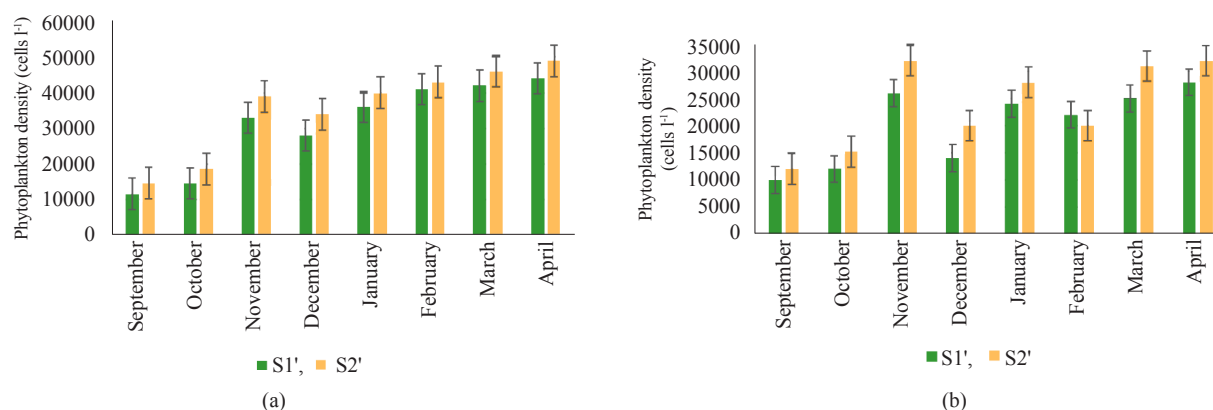


Fig. 5. Monthly variations in phytoplankton density (cells l<sup>-1</sup>) of (a) Baur and (b) Haripura reservoirs

29 species was recorded by Sharma and Tiwari (2011) in the Lony dam of Madhya Pradesh. Dubey *et al.* (2014) reported the percent composition of cladocerans in the Kaliasote Reservoir as 36%. Presence of *Mesocyclops* sp. and *Diaptomus* sp. indicates organic pollution in the waters (Rajagopal *et al.*, 2010). Rotifers prefer alkaline conditions and their richness indicates eutrophication (Ana *et al.*, 2012).

In the Baur Reservoir, monthly variability in zooplankton population was observed to be maximum in the month of November (3,800 individuals l<sup>-1</sup>) and minimum in the month of September (1,800 individuals l<sup>-1</sup>). The mean average values of zooplankton density were highest at site S<sub>2</sub>' (3,150±763.450 individuals l<sup>-1</sup>) followed by site S<sub>1</sub>' (2,750±659.003 individuals l<sup>-1</sup>). The Haripura Reservoir also followed the same trend; a surge in the zooplankton community was witnessed in the month of November (3,400 individuals l<sup>-1</sup>) while minimum during September (1,500 individuals l<sup>-1</sup>). The average mean value of zooplankton density was 2,575±677.706 and 2,325±575.077 individuals l<sup>-1</sup> at sites S<sub>1</sub> and S<sub>2</sub>, respectively. Zooplankton were found to be positively correlated with phytoplankton, pH, DO and TDS and negatively with temperature. The graphs indicating monthly variation in the zooplankton density of Baur and Haripura are presented in Fig. 6a and b. The ANOVA values showed a significant difference in the zooplankton density among the selected sites (p<0.05). Manickam *et al.* (2017) reported the zooplankton population to be higher in the summer season and lower during the monsoons. The findings of Patel *et al.* (2013) and Dede and Deshmukh (2015) revealed that factors like low light intensity, cloudy skies and high turbidity are responsible for reducing the zooplankton diversity. An elevation in the overall zooplankton density during the summer months may be due to stable limnological conditions and high standing crop of primary producers leading to greater availability of food (Manickam *et al.*, 2017).

The findings of the present study revealed that the limnological characteristics of these water bodies are favourable for proper phytoplankton and zooplankton growth. The limnological parameters were found to have an impact on the phytoplankton and zooplankton structure. Due to differences in limnological characteristics of the selected habitats, a fair difference has been recorded in population structure of phytoplankton and zooplankton. The highest density of phytoplankton in both reservoirs was recorded during April month at the site situated in Barrage area while zooplankton density was highest during November month at the same site. The higher density of plankton population indicates that the productivity of Baur Reservoir is better than Haripura Reservoir. The presence of many pollution indicator species of phytoplankton and zooplankton shows that these water bodies are subjected to organic pollution which may be controlled by adopting suitable management practices *viz.*, balancing food chain spectrum through stocking ecofriendly fishes and by conservation of habitats.

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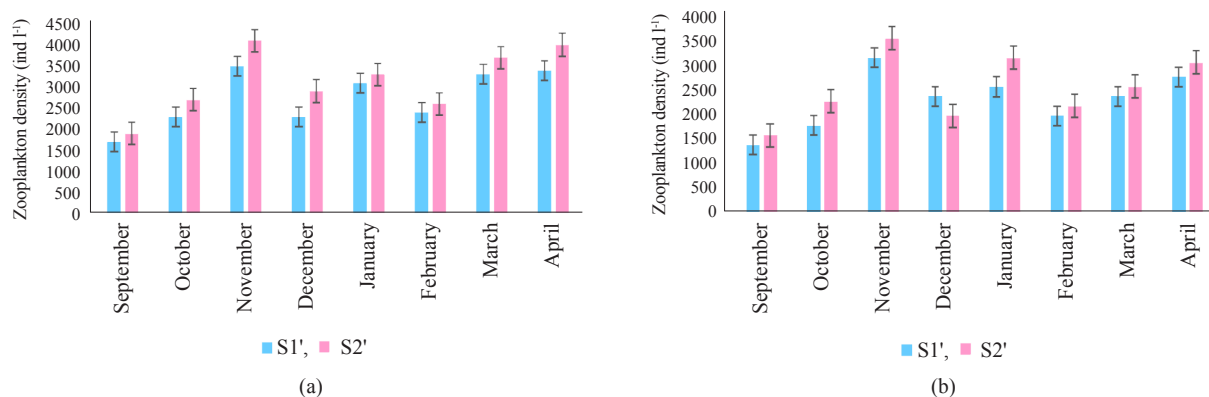


Fig. 6. Monthly variations in zooplankton density (individuals l<sup>-1</sup>) of (a) Baur and (b) Haripura reservoirs

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