Research Article

Seasonal Dynamic in Primary Productivity and Phytoplankton Diversity in Berach River System of Udaipur District, Rajasthan

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ABSTRACT

The Berach river basin was studied for phytoplankton diversity and primary production in water from Madar tank to Sarjana tank. This study also included a few isolated ponds of the Berach river such as Up-stream, Daroli and Gadwa ponds. The phytoplankton community in fresh water bodies is primarily responsible for organic production at the primary level. During the study we observed 47 forms of Phytoplankton; they belong to Chlorophyceae, Bacillariophyceae, Desmidiaceae, Dinophyceae and Myxophyceae classes. In the Berach river 47 forms were identified; out of these 17 belonging to Chlorophyceae, 14 to Bacillariophyceae, 10 to Myxophyceae, 3 to Desmidiceae, 2 to Chrysophyceae and 1 to Dinophyceae. The lowest phytoplankton density (4cells/ml) was observed in the winter of 2019 in Downstream Pond and the highest density of 6113 cells/ml was recorded in the summer of 2018 in Udaisagar Lake. The mean density of plankton in the Berach river system ranged from 39.61 to 4222.66 cells/ml during study. The lake Udaisagar, which is characterised by algal blooms, had the highest gross primary production (1.87 gc/m^2/day) during the summer of 2018. Primary production was at a minimum (0.12 gc/m^2/day) during summer 2019 in Downstream Pond. The highest average phytoplankton density was found in Udaisagar lake (4222.6667 number/litre) followed by Chota Madar tank (3590.1667 number/litre), Fatehsagar lake (3569.6667 number/litre), Bada Madar tank (3442.1667 number/litre), Sarjana tank (2094.6667 number/litre), Daroli pond (1987.6667 number/litre), Gadwa pond (1467), Upstream pond (1045.8333 number/lit) and minimum density was found in Downstream pond (39.1667 number/ litter).

Key words: Phytoplankton, Primary productivity, Biomass, Density, Season, Berach river.

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INTRODUCTION

Phytoplankton are one of the first biological components from which energy is transferred up the food chain to higher organisms.[1-3] Phytoplankton are main producer of aquatic ecosystem, which regulate biological productivity of ecosystem. Phytoplankton is the pioneer of the aquatic food chain and represents the microscopic algal communities of water bodies. They are the main component of an aquatic food chain, accounting for nearly half of all photosynthetic production on the planet.[4,5] Phytoplankton is an autotrophic organism that belongs to the first trophic level.[6] Phytoplankton was used to estimate potential fish yield,[6,7] productivity,[8] energy flow,[9] water quality,[10] tropic status[11] and management in water body ecosystems.[12,13] Phytoplankton communities are highly sensitive to changes in their aquatic habitat.[14] They play a significant role in reducing global CO_2 levels, mitigating climate change and global warming.[15] Phytoplankton and algal blooms contribute to wetlands increased productivity by exposing their large surface areas to sunlight for photosynthetic activity.[16] Wetland productivity is enhanced by phytoplankton production

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and the growth of useful phytoplankton can be considered an important factor for fish production in these bodies of water.[17,18] These ubiquitous microscopic life forms also serve as biological indicator for water quality and essential for health monitoring and evaluation of aquatic ecosystem.[3] Phytoplankton diversity and abundance is ecological indicator of an aquatic ecosystem's trophic status and aid in determining the degree of eutrophication.[19] The diversity of phytoplankton has a direct relationship with the productivity of an aquatic system. Its presence, absence, diversity, density and abundance are influenced by abiotic and biotic factors.[20,21-23] Plankton distribution, occurrence and species diversity are also influenced by various physico-chemical factors.[24] High nutrient availability such as high phosphate and nitrate, high water temperature, low dissolved oxygen and carbon dioxide favor growth of euglenoids, nitrate and phosphate are also important for growth of diatoms.[25-28] Several studies also conclude direct relationship with blue green algae and concentration of nitrate, phosphate, COD and BOD in water.[29,30] Several studies also have been conducted on the hydro-biological profiling of lentic ecosystem for the past two to three decades in order to measure the water quality.[31] These studies represent quality of water day by day declined and also affect aquatic life forms. Phytoplankton acts as primary producers as well as direct food source for aquatic animals. They also regulate the level of dissolved oxygen in aquatic life forms.[32,33] Several physiochemical parameters influence presence and absence of phytoplankton community in aquatic ecosystem.[34,35] In order to Phytoplankton presence and abundance also influence by water temperature. High P^H values of water also enhance algae and result in blooms.[35] Several studies have been conducted on the plankton of pond ecosystem.[36,37] The study of phytoplankton provides a useful and relevant focal point for research into the mechanism of eutrophication and its negative effects on the aquatic ecosystem. Several studies on phytoplankton diversity in ponds, lakes and reservoirs have been carried out in India[38-40] and abroad.[41-43] Algae have short life cycles and reproduce quickly;[44] as a result, they respond quickly to a wide range of pollutants and could be useful as early warning indicators of deteriorating conditions and possible causes.[45] Algae blooms are a sign of nutrient pollution[46] and commonly used to assess river quality.[47] Phytoplankton assemblages have also been used as indicators of water quality, pollution and human interference in the marine and fresh water environment.[48,49] Water quality is affected by differences in anthropogenic activities, seasonal variations and pollutants, which influence the phytoplankton community dynamics of estuaries.[50,51] Changes in phytoplankton composition, abundance and diversity over different spatial and temporal scales are influenced by changes in physical, chemical and biological conditions.[10,52] Several studies on limnology of Udaipur water have been made covering physico-chemical features, phytoplankton and primary production by Sharma MS and Dhurve VS, Rao MG, Sharma *et al*., Kumar *et al*., Shivani *et al*.[53-57]

During the present study we analyzed primary production and phytoplankton diversity in Berach river system (Madar tank to Sarjana Tank) from January, 2018 to December, 2019. We also assessed primary production and phytoplankton diversity in various isolated pond in the river bed including Udaisagar lake, Upstream pond, Downstream pond, Daroli pond, Gadwa Pond were also undertaken in addition to Bada Madar tank, Chhota Madar tank, Fateh Sagar lake and Sarjana tank.

MATERIALS AND METHODS

Studies on phytoplankton and primary production were undertaken for the period of January, 2018 to December, 2019. Season vise (summer, winter and monsoon) water samples were collected from January, 2018 to December 2019 at all selected nine water bodies of Berach river system namely Bada Madar (73°36'0"E and 24°38'0"N), Chota Madar (73°37°0" E and 24°35'0"N), Fatesh Sagar (73°47'0" E and 24°33'0"N), Udaisagar (74°39'5"E and 24°39'5" N), Upstream pond(74°39'5" E and 24°39'5"N), Downstream Pond(74°39'5"E and 24°39'5"N), Gadwa Pond(74°39'5"E and 24°39'5"N), Daroli pond (74°39'6"E and 25°40'7"N) and Sarjana tank(73°57'10"E and 24°14'30"N). Season wise surface water samples were collected for analysis of gross primary productivity and phytoplankton diversity in all selected nine water bodies of Berach river system. Phytoplankton samples were collected using a planktonic net with a mesh size of 20 microns (μ) and phytoplankton were fixed in 4% neutralized formalin and occasionally in 70% ethyl alcohol. Under a light microscope, the samples were analyzed qualitatively for the identification of different types of phytoplankton. Systematic identification of phytoplankton was done with the help of previously available literature.[58-61]

RESULTS

Phytoplankton forms the basic tier of ecological pyramid in aquatic ecosystem. Organic production at primary level is mainly due to the phytoplankton community in most of the fresh water bodies. As depicted in Table 1 (A and B), the phytoplankton community of water

Table 1 (A): List of Phytoplankton inhabiting in the different water bodies along with their occurrence during different seasons of 2018-2019.

S.No.	Phytoplankton	Bada Madar						Chota Madar						Fateh Sagar						Udaisagar						Up-Stream		
		2018			2019			2018			2019			2018			2019			2018			2019			2018		
		W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M
A	**Chlorophyceae (Greens)**																											
1	**Volvox**	–	–	+	–	–	–	–	–	+	–	–	–	–	–	+	–	–	–	–	–	+	+	–	+	–	–	–
2	**Pandorina**	+	–	–	+	+	–	+	–	–	+	+	–	–	–	–	+	+	–	+	–	–	–	–	–	+	+	–
3	**Eudorina**	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–	–	–	–	–	–	+	–
4	**Scenedesmus**	–	+	+	+	–	–	+	+	+	+	–	+	–	+	+	+	–	+	–	+	+	+	+	+	+	–	+
5	**Chlorella**	–	+	+	–	+	–	–	+	+	–	+	+	+	+	+	–	+	+	+	–	+	+	–	–	–	+	+
6	**Ankistrodesmus**	–	+	+	–	+	+	+	+	+	–	+	+	–	+	+	–	+	+	+	–	–	–	–	–	+	+	–
7	**Selenestrum**	–	+	+	+	–	–	+	+	+	+	–	–	–	+	+	+	–	–	+	–	–	+	–	–	+	–	–
8	**Coelastrum**	–	–	–	+	–	+	–	–	–	+	–	+	+	–	–	+	–	+	+	–	–	–	–	–	+	–	+
9	**Stegeoclonium**	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
10	**Spirogyra**	+	–	–	+	+	+	+	–	–	+	+	+	+	–	–	+	+	+	+	–	–	+	+	+	+	+	–
11	**Oedogonium**	–	–	+	+	+	+	+	–	+	+	+	+	+	–	+	+	+	+	+	–	+	+	+	+	–	+	+
12	**Ulothrix**	+	–	–	+	+	+	+	–	–	+	+	+	+	–	–	+	+	+	+	–	–	+	+	+	+	+	+
13	**Cladophora**	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
14	**Chlamydomonas**	+	–	+	+	–	–	+	–	+	+	–	–	+	–	+	+	–	–	+	–	+	+	–	–	–	–	–
15	**Stichococcus**	+	–	–	+	–	–	–	–	–	+	–	–	+	–	–	+	–	–	+	–	–	+	–	–	+	–	–
16	**Mougeotia**	+	–	–	+	–	–	+	–	–	+	–	–	+	–	–	+	–	–	+	–	–	+	–	–	–	–	–
17	**Zygnema**	–	–	–	–	+	+	–	–	–	–	+	+	–	–	–	–	+	+	–	–	–	–	+	+	–	+	+
B	**Desmidiaceae**																											
18	**Cosmarium**	–	+	–	–	+	–	+	–	+	–	+	–	+	–	+	+	+	–	–	+	+	–	–	+	–	+	–
19	**Closterium**	–	–	–	+	+	–	+	–	–	+	–	–	–	–	–	+	–	–	+	+	–	+	+	–	+	–	–
20	**Pediastrum**	–	–	–	–	+	+	+	–	–	–	–	–	–	–	–	+	+	+	–	+	+	–	+	+	+	+	+
C	**Chrysophyceae**																											
21	**Chromulina**	–	+	+	–	–	+	+	+	+	–	+	+	+	–	–	+	+	+	+	–	+	+	–	+	–	+	+
22	**Lyngbya**	–	–	+	+	–	+	+	–	+	+	–	+	+	+	–	+	+	–	+	–	+	+	–	+	+	+	–

continued...

Table 1 (A): Cont'd.

S.No.	Phytoplankton	Bada Madar						Chota Madar						Fateh Sagar						Udaisagar						Up-Stream		
		2018			2019			2018			2019			2018			2019			2018			2019			2018		
		W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M
D	**Bacillariphyceae(Diatoms)**																											
23	**Cyclotella**	−	+	+	−	−	+	+	+	+	+	+	+	+	+	−	−	+	−	+	+	+	+	+	+	−	+	−
24	**Synedra**	+	+	+	+	−	+	−	−	−	−	+	+	+	+	+	−	+	+	−	−	−	−	+	+	−	+	+
25	**Fragillaria**	+	+	+	+	−	+	−	+	+	−	+	+	+	+	+	−	+	−	−	+	+	−	+	+	−	+	−
26	**Stauroneis**	−	−	−	+	−	−	+	−	+	+	−	+	−	−	+	−	−	−	+	−	+	+	−	+	−	−	−
27	**Navicula**	+	+	−	+	+	+	+	+	+	+	+	−	+	−	+	+	+	+	+	+	+	+	+	−	−	+	+
28	**Pinnularia**	+	+	−	−	+	−	+	−	+	+	+	−	+	−		+	−	+	+	−	+	+	+	−	+	−	−
29	**Nitzschia**	−	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
30	**Asterionella**	−	+	+	−	−	−	−	+	+	−	−	−	−	+	+	−	−	−	−	+	+	−	−	−	−	−	−
31	**Amphora**	+	−	+	−	−	−	+	−	+	−	−	−	+	−	+	−	−	−	+	−	+	−	−	−	−	−	−
32	**Enotia**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−
33	**Gomphonema**	+	−	+	+	−	+	+	−	+	+	−	+	+	−	+	+	−	+	+	−	+	+	−	+	+	−	+
34	**Cymbella**	−	−	+	−	−	+	−	−	+	−	−	+	−	−	+	−	−	+	−	−	+	−	−	+	−	−	+
35	**Cymatopleura**	−	−	−	−	−	−	+	−	−	−	−	−	+	−	−	−	−	−	+	−	−	−	−	−	−	−	−
36	**Denticula**	−	−	+	−	−	−	−	−	+	−	−	−	−	−	+	−	−	−	−	−	+	−	−	−	−	−	−
E	**Dinophyceae**																											
37	**Thecadium**	−	−	−	+	−	−	+	−	−	+	−	−	+	−	−	+	−	−	+	−	−	+	−	−	+	−	−
F	**Myxophyceae(Blue-greens)**																											
38	**Microcystis**	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
39	**Merasmopedia**	+	+	+	−	+	+	−	+	+	+	+	+	+	−	+	−	−	−	−	+	+	−	+	+	−	−	−
40	**Synechococcus**	−	+	−	−	+	−	−	+	−	−	+	−	−	−	−	−	+	−	−	+	−	−	+	−	−	+	−
41	**Oocystis**	−	+	−	−	+	+	−	+	−	−	+	−	−	−	−	−	−	−	−	+	−	−	+	+	−	−	−
42	**Anabaena**	+	+	−	+	+	−	+	+	−	+	+	−	−	+	+	−	−	−	+	+	−	+	+	−	−	−	−
43	**Oscillatoria**	−	+	−	−	+	−	−	+	−	−	+	−	−	−	−	+	−	+	−	+	−	−	+	−	+	−	+
44	**Phormidium**	−	−	+	+	−	+	+	−	+	−	−	+	+	−	+	−	+	+	+	−	+	+	−	+	−	+	−
45	**Chroococcus**	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−
46	**Nostoc**	−	+	+	−	+	−	−	+	+	−	+	+	−	−	−	−	−	+	−	+	+	−	+	−	−	−	−
47	**Spirulina**	+	−	−	+	+	+	−	−	−	+	−	−	+	−	+	−	−	+	−	−	−	+	+	+	−	−	+

Table 1 (B): List of Phytolankters inhabiting in the different water bodies along with their occurrence during different seasons of 2018-2019.

S.No.	Phytoplankton	Up- Stream						Down-Stream						Gadwa						Daroli						Vallabh Nagar (Sarjana)					
		2019			2018			2019			2018			2019			2018			2019			2018			2019					
		W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M
A		Chlorophyceae (Greens)																													
1	**Volvox**	+	−	+	−	−	−	−	−	−	−	−	−	+	−	+	−	−	−	−	−	−	−	−	+	+	−	+
2	**Pandorina**	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−
3	**Eudorina**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−
4	**Scenedesmus**	+	+	+	−	−	−	−	−	−	−	−	−	−	−	+	+	−	+	−	−	+	−	+	+	+	+	+
5	**Chlorella**	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	+	−	+	+	−	−
6	**Ankistrodesmus**	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	+	+	−	+	+	−	−	−	−	−
7	**Selenestrum**	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	+	−	−	+	+	−	−	+	−	−
8	**Coelastrum**	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	+	+	−	+	+	−	−	−	−	−
9	**Stegeoclonium**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−
10	**Spirogyra**	−	−	+	−	−	−	−	−	−	−	+	−	−	−	+	+	−	+	−	−	+	+	−	−	+	+	+
11	**Oedogonium**	−	+	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	+	+	+	+
12	**Ulothrix**	+	−	+	−	−	−	−	−	−	−	−	+	+	−	−	+	−	+	+	−	+	+	−	−	+	+	+
13	**Cladophora**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−
14	**Chlamydomonas**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	+	+	−	−
15	**Stichococcus**	+	−	−	−	−	−	−	−	−	−	−	−	+	−	+	−	−	+	−	−	+	−	−	−	+	−	−
16	**Mougeotia**	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	+	−	−
17	**Zygnema**	−	+	+	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	+
B		**Desmidiaceae**																													
18	**Cosmarium**	−	−	+	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	+	+	−	−	+
19	**Closterium**	+	+	−	−	−	−	−	−	+	−	−	−	+	−	−	+	−	+	−	−	+	+	+	−	+	+	−
20	**Pediastrum**	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	+	+	−	+	+
C		**Chrysophyceae**																													
21	**Chromulina**	−	−	+	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	+	+	−	+
22	**Lyngbya**	+	−	+	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	+	+	−	+

continued...

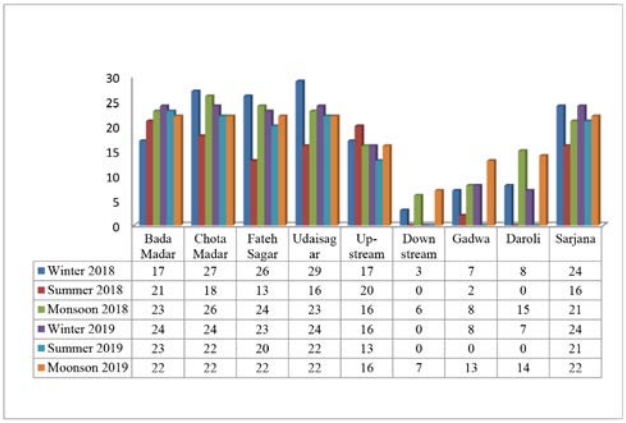
Table 1 (B): Cont'd.

S.No.	Phytoplankton	Up- Stream						Down-Stream						Gadwa						Daroli						Vallabh Nagar (Sarjana)					
		2019			2018			2019			2018			2019			2018			2019			2018			2019					
		W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M
D		Bacillariphyceae(Diatoms)																													
23	Cyclotella	+	+	+	+	−	−	−	−	+	−	−	+	−	−	−	−	−	−	−	−	−	−	+	+	+	+	+	+		
24	Synedra	−	−	−	−	−	+	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	+		
25	Fragillaria	−	−	+	+	−	−	−	−	−	−	−	−	−	−	+	+	−	+	+	−	+	−	+	+	−	+	+			
26	Stauroneis	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	+	−	−	+	−	+			
27	Navicula	−	−	−	−	−	+	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	+	+	+	+	+	−			
28	Pinnularia	−	+	−	−	−	−	−	−	−	+	−	−	−	−	+	+	−	+	+	−	+	−	−	+	+	+	−			
29	Nitzschia	+	+	+	+	−	+	−	−	+	+	−	−	−	−	−	−	−	+	+	−	+	+	+	−	+	+	+			
30	Asterionella	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−			
31	Amphora	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	+	−	−	−			
32	Enotia	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−			
33	Gomphonema	+	−	+	−	−	+	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	+	−	+	+	−	+			
34	Cymbella	−	−	−	−	−	+	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	+	−	−	+			
35	Cymatopleura	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−			
36	Denticula	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−			
E		Dinophyceae																													
37	Thecadium	+	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	+	−	−	+	−	−			
F		Myxophyceae(Blue-greens)																													
38	Microcystis	+	+	+	−	−	−	−	−	+	−	−	+	+	−	+	+	−	+	−	−	+	+	+	+	+	+	+			
39	Merasmopedia	−	+	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	+	+	−	+	+			
40	Synechococcus	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−			
41	Oocystis	−	+	+	−	−	−	−	−	−	−	−	+	+	−	+	−	−	−	−	−	−	−	+	−	−	+	+			
42	Anabaena	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	+	−	+	+	−			
43	Oscillatoria	−	+	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	+	+	−	+	−	+	−	−	+	−			
44	Phormidium	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	+	+	−	+			
45	Chroococcus	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−			
46	Nostoc	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	+	−	+	+	−	+	−			
47	Spirulina	+	−	+	−	−	−	−	−	−	−	−	+	+	−	+	−	−	−	−	−	−	−	−	−	−	+	+			

bodies covered during present study was represented by all five groups *i.e.* Chlorophyceae, Bacillariophyceae, Desmidiaceae, Dinophyceae and Myxophyceae. The group Chlorophyceae was represented by *Eudorina*, *Pandorina, Volvox, Scendesmus, Chlorella, Ankistrodesmus, Selenestrum, Coelastrum, Stegoclonium, Spirogyra, Oedogonium, Ulothrix, Cladophora, Chlamydomonas, Stichococcus, Mougeotia, Zygnema* and *Hydrodictyon*. Although some of these forms are filamentous but at times some filamentous join planktonic biomass. These green forms were dominant over other groups in Bada and Chhota Madar tanks, Fatehsagar and up to some extent in Udaisagar. Bacillarriophyceae was represented by *Synedra, Cyclotella, Fragillaria, Stauroneis, Navicula, Pinnularia, Nitzschia, Asterionella, Amphora, Enotia, Gomphonema, Cymbella, Cyrnatopleura, Denticula, Desmids* were represented by *cosmarium, Closterium and Pediastrum*. Chrysophyceae was represented by *Chromulina* and *Lyngbya*. Blue green forms *viz Microcystis, Merasmopedia, Synechococcus, Oocystis, Anabaena, Oscillatoria, Phormidium, Chroococcus, Nostoc and Spirulina* represented Myxophyceae. Some of above-mentioned forms were abundant and were in the form of blooms in the lake Udaisagar and Sarjana tank. As depicted in Table 1 (A and B) total 47 forms were identified and out of these 17 belonged to Chlorophyceae, 14 to Bacillariophyceae, 10 to Myxophyceae, 3 to Desmidiceae, 2 to Chrysophyceae and 1 to Dinophyceae in water bodies of Berach river system. The dynamics of phytoplankton communities with respect to their interaction with water quality have been studied by Rao MG, *et al*., Kumar S *et al*., Sumitra M *et al*., Ranu *et al*., Mishra SR, *et al*.[53,55,62-64] During study mean density of phytoplankton's varied between 39.61 to 4222.66 cells/ml in the Berach river system. Although lowest density of phytoplankton was 4 cell/ml observed during winter of 2019 in Downstream pond and maximum density of 6113 cell/ml occurred during summer 2018 in Udaisagar lake (Table 2).

Seasonal variation in phytoplankton diversity: During study period (winter, 2018), we observed maximum phytoplankton diversity in Udaisagar (29) species followed by Chota Madar (27), Fateh sagar (26), Sarjana dam (Vallabh nagar) (24), Bada Madar and Upstream (17), Daroli (8), Gadwa (7) and the minimum was observed in Downstream pond (3) (Figure 1). In summer, 2018; maximum phytoplankton diversity was observed in Bada Madar (21) species followed by Upstream Pond (20), Chota Madar (18), Udaisagar and Sarjana (16), Fateh sagar (13), Gadwa (2) and phytoplankton occurrences were absent in Down-stream and Daroli ponds. Chota Madar (26) had the highest phytoplankton diversity in monsoon 2018, followed by Fateh Sagar (24), Udaisagar and Bada Madar (23), Sarjana (21), Upstream Pond (16), Daroli (15), Gadwa (8), and Down-stream Pond (8) (Figure 1). Phytoplankton diversity was highest in Bada Madar, Chota Madar, and Sarjana dams (24) in winter 2019, followed by Fateh Sagar (23), Upstream Pond (16), Gadwa (8), and Daroli (7), and phytoplankton occurrence was absent in the downstream pond during the study period (Figure 1). In summer, 2019; maximum phytoplankton diversity were observed in Bada Madar (23) followed by Chota Madar and Udaisagar (22), Sarjana dam (21), Fateh sagar (20) and Up-stream pond (13). Phytoplankton was absent in Downstream, Gadwa and Daroli ponds during the summer season of 2019. During Monsoon 2019, the highest phytoplankton diversity was found in Bada Madar, Chota Madar, Fateh Sagar, Udaisagar, and Sarjana dams, Vallabhnagr (22), followed by Upstream (16), Daroli (14), and Gadwa (13), and the lowest diversity was found in Down-stream pond (7) (Figure 1).

Gross primary production- Primary production is rate of photosynthesis which is energy binding reduction process of carbon dioxide resulting in to production of carbohydrate and oxygen. Gross primary production is total production which includes chemical energy used in respiration. Estimation of primary production gives a clear picture of trophic status of a lake or pond. The lakes are classified on the basis of their productivity. The deep-water lakes with clear and oxygenated water having less organic production are termed as oligotrophic. The shallow weed infested lakes with poor dissolved oxygen and high turbidity are termed as eutrophicatic lakes and thus have high organic production. Moderately productive lakes are known as mesotrophic lakes. The brown water humus containing lakes are known as dystrophic lakes. Primary



	Bada Madar	Chota Madar	Fateh Sagar	Udaisagar	Up-stream	Down stream	Gadwa	Daroli	Sarjana
Winter 2018	17	27	26	29	17	3	7	8	24
Summer 2018	21	18	13	16	20	0	2	0	16
Monsoon 2018	23	26	24	23	16	6	8	15	21
Winter 2019	24	24	23	24	16	0	8	7	24
Summer 2019	23	22	20	22	13	0	0	0	21
Moonson 2019	22	22	22	22	16	7	13	14	22

Figure 1: Seasonal occurrence of Phytoplankton in different water bodies of Berach river system.

production depends upon turnover rate of nutrients like nitrates and phosphates. Primary production studies not only important for conservation of lakes but from fisheries point of view also this gives an idea of living and non-living food available for fishes. During present study Gross primary production was assessed by dark and light bottle method. Table 2 depicts seasonal values of Gross primary production in nine water bodies studied. Maximum Gross primary production (1.87 gc/m^2/day) was observed during summer 2018 in the lake Udaisagar which is characterized by algal blooms. Primary production was minimum (0.12 gc/m^2/day) during summer 2019 in Downstream pond. Maximum Gross primary production (0.8817 gc/m^2/day) was in the comparatively unpolluted lake Fatehsagar (Table 2). Although Bada and Chhota Madar tanks are also unpolluted water bodies but perhaps high nutrient level of Fatehsagar attributed to high production in this lake. Minimum primary production (0.1417 gc/m^2/day) was observed in Gadwa pond. Primary production was nil during monsoon period in almost all water bodies (Table 2).

Average total phytoplankton density and Primary production in different water bodies- During the study, we observed maximum average phytoplankton density in Udaisagar lake (4222.6667 number/litre) followed by Chota Madar tank (3590.1667 number/litre), Fatehsagar lake (3569.6667 number/litre), Bada Madar tank (3442.1667 number/litre), Sarjana tank (2094.6667 number/litre), Daroli pond (1987.6667 number/litre), Gadwa pond (1467), Upstream pond (1045.8333 number/lit) and minimum density was found in Downstream pond (39.1667 number/ litter). Fatehsagar lake had the highest average primary productivity (.8817 mgc/m^2/hr.), followed by Udaisagar lake (0.8403 mgc/m^2/hr.), Sarjana tank (0.7667 mgc/m^2/hr.), Bada Madar tank (0.615 mgc/m^2/hr.), Upstream pond (0.5133 mgc/m^2/hr.), Chota Madar tank (0.495 mgc/m^2/ hr) (Table 2).

DISCUSSION

The lowest phytoplankton density was observed in the winter of 2019 in Downstream Pond and the highest density was recorded in the summer of 2018 in Udaisagar Lake. The nutrient enrichment of Udaisagar through domestic and industrial pollution was responsible for harbouring a rich density of phytoplankton. During study (winter, 2018), maximum phytoplankton diversity was observed in Udaisagar and a minimum was found in Downstream pond. In summer 2018, maximum phytoplankton diversity was observed in Bada Madar pond and minimum was found in Gadwa pond, while phytoplankton occurrence was absent in Down-stream and Daroli ponds. In monsoon 2018; maximum phytoplankton diversity was observed in Fateh sagar lake and minimum was found in Gadwa and Down-stream Pond. In winter 2019, the Bada Madar, Chota Madar and Sarjana dams had the highest phytoplankton diversity, while Daroli pond had the lowest and downstream pond had no phytoplankton occurrence. In summer 2019, maximum phytoplankton diversity was observed in Bada Madar and a minimum was observed in the upstream pond. During the summer season, 2019 phytoplankton was absent in Downstream, Gadwa and Daroli Ponds. During 2019 monsoon season, the highest phytoplankton diversity was observed in the Bada Madar, Chota Madar, Fateh Sagar, Udaisagar and Sarjana dam (Vallabhnagar), while the lowest diversity was observed in the down-stream pond. Maximum average phytoplankton density was observed in Udaisagar lake and minimum average density was observed in Downstream pond. Chota Madar tank had lowest average primary productivity and Fatehsagar lake had the highest average primary productivity. Udaisagar was most rich in phytoplankton and downstream pond remained most poor in terms of phytoplankton density. Nutrient enrichment of Udaisagar through domestic and industrial pollution was responsible to harbour rich density of phytoplankton. Although downstream pond was severely polluted pond thus it seems those phytoplanktons reported in this pond were of allochthonous nature and might have come from Upstream pond. Season wise variation in density (Table 2) revealed that in most of the water bodies, phytoplankton density was high during monsoon and summer periods as compared to winter. Similar pattern of abundance was also reported by Sumitra M, *et al*., Sharma M, *et al*.[62,65] Although Udaisagar was most rich in phytoplankton density but this community was dominated by bloom forming blue green forms. But form diversity point of view Bada and Chhota Madar tanks harboured rich diversity of phytoplankton with representation of almost all groups. Phytoplanktonic density as well as diversity was poor in ponds of Berach river due to pollutants as well as presence of macrophytes. As in the case of Udaisagar, in other water bodies also, prominence of myxophyceae was considered as sign of eutrophication by Sankhla SK, Sharma MS.[66,67] Udaisagar was most rich in phytoplankton and downstream pond remained most poor in terms of phytoplankton density. Nutrient enrichment of Udaisagar through domestic and industrial pollution was responsible to harbour rich density of phytoplankton.

Although downstream pond was severely polluted pond thus it seems those phytoplanktons reported in this pond were of allochthonous nature and might have come from Upstream pond. Season wise variation in density (Table 2) revealed that in most of the water bodies, phytoplankton density was high during monsoon and summer periods as compared to winter. Similar pattern of abundance was also reported by Sumitra M, *et al*., Sharma M, *et al*.[62,65] Phytoplanktonic density as well as diversity was poor in ponds of Berach river due to pollutants as well as presence of macrophytes. As in the case of Udaisagar, in other water bodies also, prominence of myxophyceae was considered as sign of eutrophication by Sharma (1980)[66] and Sankhla (1981).[67]

CONCLUSION

Physico-chemical factors influence plankton distribution, occurrence and species diversity. Various anthropogenic activities, seasonal variations and pollutants all have an impact on water quality. Despite the fact that Downstream pond was severely polluted, it appears that the phytoplankton found in this pond was allochthonous in nature and may have come from Upstream pond. Estimating primary production provides a clear picture of a lake's or ponds trophic status. The rate of nutrient turnover, such as nitrates and phosphates, affects primary production. Primary production studies are important not only for lake conservation, but also for fisheries because they provide information about status and quality of waters.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

W: Winter season; **M:** Monsoon season; **S:** Summer season; **GPP:** Gross Primary Proudctivity.

Table 2: Seasonal variation in total phytoplankton density and primary production in the different water bodies of Berach river system in 2018-2019.

Location	Duration	Total Phytoplankton	GPP
Bada madar tank	Winter-18	3446	0.59
	Summer-18	2210	1.15
	Monsoon-18	5110	NIL
	Winter-19	3234	0.84
	Summer-19	1943	1.11
	Monsoon-19	4710	0
Chhota Madar tank	Winter-18	2934	0.34
	Summer-18	2270	1.01
	Monsoon-18	6112	NIL
	Winter-19	3115	0.64
	Summer-19	1880	0.98
	Monsoon-19	5230	NIL
Fatehsagar lake	Winter-18	2698	1.81
	Summer-18	4240	0.81
	Monsoon-18	3020	NIL
	Winter-19	2490	1.12
	Summer-19	4650	1.09
	Monsoon-19	4320	0.46
Udaisagar lake	Winter-18	2536	1.12
	Summer-18	6113	1.87
	Monsoon-18	4995	0.58
	Winter-19	3287	1.16
	Summer-19	3290	0.312
	Monsoon-19	5115	NIL
Upstream pond	Winter-18	1380	0.52
	Summer-18	810	1.03
	Monsoon-18	1925	NIL
	Winter-19	790	0.47
	Summer-19	320	1.06
	Monsoon-19	1050	NIL
Down stream pond	Winter-18	12	0.41
	Summer-18	-	NIL
	Monsoon-18	170	NIL
	Winter-19	4	0.61
	Summer-19	-	0.12
	Monsoon-19	49	NIL
Gadwa	Winter-18	623	0.34
	Summer-18	216	NIL
	Monsoon-18	820	NIL
	Winter-19	512	0.51
	Summer-19	340	NIL
	Monsoon-19	760	NIL
Daroli pond	Winter-18	2210	0.42
	Summer-18	-	
	Monsoon-18	986	NIL
	Winter-19	1840	0.56
	Summer-19	-	
	Monsoon-19	1110	NIL
Sarjana tank	Winter-18	2114	0.91
	Summer-18	1980	1.08
	Monsoon-18	1070	NIL
	Winter-19	1983	1.57
	Summer-19	4005	1.04
	Monsoon-19	1416	NIL

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