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Research Article

Seasonal Assessment of Phytoplankton Diversity in Morvan Dam (Neemuch District), M.P., India

¹Resham Rajput and ²Nageshwar Wast

¹Department of Zoology, Government Girls PG College, Khandwa, Madhya Pradesh, India

²Department of Zoology, Jai Prakash University, Chapra, Bihar, India

Abstract

Background and Objective: Since phytoplankton act as primary producers in most of the aquatic bodies and fish production are associated with phytoplankton primary productivity. Therefore, the objective of the current study was aimed to investigate phytoplankton diversity at the three selected stations (the station I, II and III) of Morvan Dam (Neemuch District, M.P.), India through seasonal surveys (Winter, Summer and Monsoon) concerning different physico-chemical profile during two annual cycles 2016-17 and 2017-2018. **Materials and Methods:** The plankton samples were collected seasonally from three sampling stations of Morvan Dam and counted through the counting chamber under a C.Z., inverted microscope as cells mL⁻¹ and was preserved in 70% alcohol. The qualitative analysis and diversity of phytoplankton were done as per standard formulae. **Results:** The *Chlorophyceae* exhibited the highest phytoplanktonic density among all the selected three-station, followed by *Bacillariophyceae*, *Myxophyceae*, *Dinophyceae*, *Desmidiaceae* and *Xanthophyceae*. The seasonal variation in density of *Chlorophyceae*, *Xanthophyceae*, *Bacillariophyceae*, *Desmidiaceae*, *Myxophyceae* and *Dinophyceae* were documented in the range from 250-810, 00-35, 210-520, 10-75, 130-400 and 0-200 mL⁻¹, respectively among all the three selected station of Morvan Dam during 2016-18. However, the total density of recorded phytoplanktonic species was found to vary from 1140-1525, 1035-1430 and 940-1405 mL⁻¹ at the stations I, II and III, respectively during 2016-18. Eventually, phytoplanktonic density, based upon Menhinick's, index at station I, II and III were noticed as 0.462458306, 0.345262562 and 0.431870654, respectively, whereas the overall phytoplanktonic diversity of Morvan Dam was estimated at 0.717249045 during 2016-18. **Conclusion:** Morvan Dam consists of large and diverse kinds of phytoplankton species which has been documented as *Chlorophyceae*>*Bacillariophyceae*>*Myxophyceae*>*Dinophyceae*>*Desmidiaceae*>*Xanthophyceae* (in order of abundance). The species richness of phytoplankton indicates the low pollution status and good health of other aquatic organisms in the dam during the specified period.

Key words: Morvan dam, phytoplankton diversity, *Chlorophyceae*, Menhinick's index

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Corresponding Author: Nageshwar Wast, Department of Zoology, Jai Prakash University Chapra, Bihar, India

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The productivity of aquatic bodies depends mainly on the density of plankton diversity and it was found that the plankton density is regulated by aquatic profile and other biotic communities in aquatic bodies. The evaluation of plankton's productivity provides the knowledge in the context of conservation ratio on different trophic levels and resources which are needed for better management of water bodies. Phytoplankton acts as primary producers and becomes an important tool for the biomonitoring of aquatic ecosystems concerning pollution status. It has been reported that the species diversity of the phytoplanktonic group is an efficient bio-indicator to assess the quality of water bodies¹. The previous study illustrates that biotic interactions and physical and chemical forces are the factors that control seasonal phytoplankton dynamics². It has been known that phytoplankton is the foundation of the food web in any aquatic body which provides nutrients to zooplankton and also to other invertebrates, shells and finfish³ and the freshwater fishes depend mostly on zooplankton for their food source during its critical developmental stages. A lot of literature on phytoplankton diversity from freshwater bodies was observed⁴⁻¹³.

Since phytoplankton is the base of most of the aquatic food webs and fish production is linked to phytoplankton's primary productivity. Therefore, to establish the relationship between water quality, trophic status and fisheries, planktonic studies becomes an integral part of aquatic biology. Because of this, the attention has been focused to assess the seasonal variation (Winter, Summer and Monsoon) of phytoplankton diversity in Morvan Dam (Neemuch District), M.P., India during two annual cycles 2016-17 and 2017-18.

MATERIALS AND METHODS

Study area: The Morvan Dam is located in Morvan Village belonging to Tehsil Jawad (Neemuch District) of Madhya Pradesh. It is a stone masonry dam is constructed on Gambhiri sub-river basin of Chambal in 1960 with latitude: 27°-37'-06"N and longitude: 75°-03'-30"E. The length and width of the dam were measured as 990 and 12 m, respectively and, its total water holding capacity is 16.46 M m³. The maximum depth and average depth of the dam were recorded as 27.42 and 13 m, respectively. The average rainfall of the dam was measured as 760 mm whereas, the water spread area and catchment area of the dam were observed as 3.21 and 62.16 km², respectively. It covers approximately 267100 ha of

total irrigation area. This dam is important to the villagers since it provides drinking water and facilitates irrigation as well as fish production.

Sampling stations: The map of the dam was taken from Google tool and Digital camera. There are three sampling stations were selected in the Morvan Dam (Neemuch District), M.P., for seasonal assessment of Phytoplankton.

Plankton analysis: The plankton samples were collected from all three sampling stations by utilizing Hansen's Standard Plankton net composed of bolting silk no. 25.

For quantitative estimations: There are 50 L of surface water was filtered through a small plankton net and Subsample of 10 mL was taken. Plankton counting was done in a counting chamber under a C.Z., inverted microscope. Phytoplankton numbers were expressed as cells mL⁻¹ and the collected plankton was preserved in 70% alcohol. The number of phytoplankton were estimated by using the following formula:

$$\text{Phytoplankton (cells mL}^{-1}\text{)} = A \times \left(\frac{B}{C} \times \frac{1}{d} \right) \times 10^3$$

Where:

- A = Total number of individuals in observed strips
- B = Volume of sample in the cell
- C = Volume of observed strips
- d = Concentration factor

Qualitative analysis of phytoplankton samples was done as per the standard method cited by Shah *et al.*¹⁴ Ananthan *et al.*¹⁵ and Hossain *et al.*¹⁶.

Biodiversity: The biodiversity of Phytoplankton was studied as per Menhinick's method documented by Rombouts *et al.*¹⁷:

$$\text{Menhinick's index (d)} = d = \frac{s}{\sqrt{n}}$$

Where:

- s = Total number of species
- n = Total number of organisms

RESULTS AND DISCUSSION

The diverse kinds of phytoplanktonic community at the station I, II and III of Morvan Dam (Neemuch District), M.P., in different seasons (Winter, Summer and Monsoon) during two

annual cycles (2016-17 and 2017-18) has been noticed. Phytoplankton species identified were common in all the selected three-station of Morvan Dam and it has been represented by six groups viz., *Chlorophyceae*, *Xanthophyceae*, *Bacillariophyceae*, *Desmidiaceae*, *Myxophyceae* and *Dinophyceae* but their percentage composition were found to be different in all three stations.

Station I: There are a total of 41 forms were identified and out of these 15 belonged to *Chlorophyceae*, 2 to *Xanthophyceae*, 2 to *Desmidiaceae*, 8 to *Myxophyceae*, 3 to *Dinophyceae* and 11 to *Bacillariophyceae*. The *Chlorophyceae* was illustrated by *Volvox* sp., *Eudorina* sp., *Pandorina* sp., *Scenedesmus* sp., *Ankistrodesmus* sp., *Coelastrum* sp., *Spirogyra* sp., *Oedogonium* sp., *Ulothrix* sp., *Cladophora* sp., *Chlamydomonas* sp., *Mougeotia* sp., *Pediastrum* sp., *Oocystis* sp. and *Microspora* sp. *Desmidiaceae* was noticed as *Cosmarium* sp. and *Desmidium* sp., whereas, *Xanthophyceae* included *Chlorobutyryl* sp. and *Botryococcus* sp. The *Microcystis* sp., *Agmenellum* sp., *Anabaena* sp., *Oscillatoria* sp., *Nostoc* sp., *Spirulina* sp., *Cochlearis* sp. and *Gomphosphaeria* sp., represent *Myxophyceae* at station I of Morvan Dam. Further, *Dinophyceae* included *Glenodinium* sp., *Peridinium* sp. and *Sphaerodinium* sp. and *Bacillariophyceae* consists of *Cyclotella* sp., *Synedra* sp., *Fragilaria* sp., *Navicula* sp., *Pinnularia* sp., *Nitzschia* sp., *Asterionella* sp., *Amphora* sp., *Gomphonema* sp., *Cymbella* sp. and *Bacillaria* sp., in Table 1.

The percentage composition of phytoplankton (based upon density) indicated the following ranking in Fig. 1. *Chlorophyceae* (43%) > *Bacillariophyceae* (31%) > *Myxophyceae* (16%) > *Dinophyceae* (6%) > *Desmidiaceae* (3%) > *Xanthophyceae* (1%).

The *Chlorophyceae* were analyzed in the ranges from 250-810 cells mL⁻¹ whereas the range of *Desmidiaceae*, *Xanthophyceae* and *Myxophyceae* were noticed from 20-60, 10-20 and 135-270 cells mL⁻¹, respectively. Moreover, *Dinophyceae* and *Bacillariophyceae* were observed in the range of 00-200 and 300-455 cells mL⁻¹, respectively. The overall density of phytoplanktonic groups was noticed in the ranges from 1140 (Monsoon, 2016-17) to 1525 (Winter, 2016-17) cells mL⁻¹ during two years, 2016-18 in Table 2. In season-wise observations, *Chlorophyceae* exhibited peak during Monsoon, 2017-18. Whereas, *Bacillariophyceae* showed a peak during the summer of both years. Desmids and *Myxophyceae* illustrate the highest density during Winter, 2017-18. *Xanthophyceae* exhibited peak during Winter, 2017-18. However, the highest density of *Dinophyceae* was noticed during Summer, 2016-17.

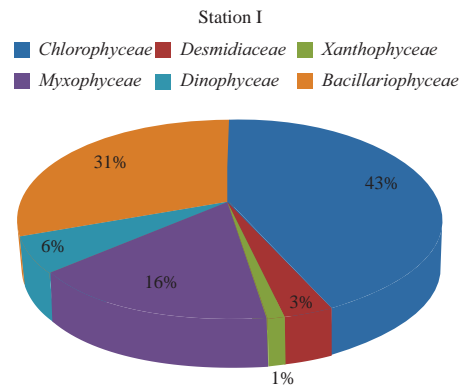


Fig. 1: Group-wise composition of phytoplankton at station I of Morvan Dam during 2016-18

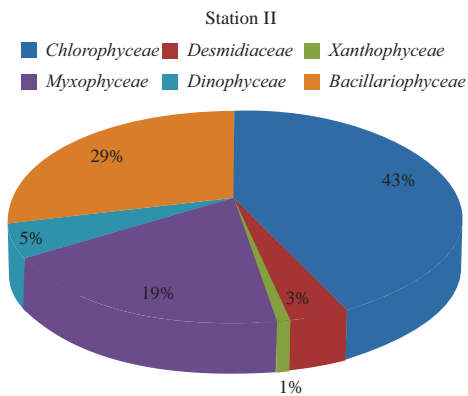


Fig. 2: Group-wise composition of phytoplankton at station II of Morvan Dam during 2016-18

Station II: In station II of Morvan Dam, there are a total of 38 forms were reported and out of these 14 belonged to *Chlorophyceae*, 9 to *Bacillariophyceae*, 8 to *Myxophyceae*, 3 to *Dinophyceae*, 2 to *Desmidiaceae* and 2 to *Xanthophyceae*. The *Chlorophyceae* was dominated by *Volvox* sp., *Spirogyrasp.*, *Oedogoniumsp.*, *Ulothrixsp.*, *Chlamydomonas* sp., *Pediastrum* sp., *Oocystis* sp. and *Microspora* sp. Whereas, *Desmidiaceae* includes *Cosmarium* sp., *Desmidium* sp. and *Xanthophyceae* was consists of *Chlorobutyryl* sp. and *Botryococcus* sp. but *Microcystis* sp., *Agmenellum* sp., *Anabaena* sp., *Oscillatoria* sp., *Spirulina* sp., *Cochlearis* sp., and *Gomphosphaeria* sp., belonged to *Myxophyceae* at station II. *Dinophyceae* consists of *Glenodinium* sp., *Peridinium* sp. and *Sphaerodium* sp., whereas, *Bacillariophyceae* included *Cyclotella* sp., *Synedra* sp., *Fragilaria* sp., *Navicula* sp., *Pinnularia* sp., *Nitzschia* sp., *Amphora* sp., *Cymbella* sp. and *Bacillaria* sp. (Table 1).

Based on density, the percentage composition of phytoplankton indicated the following ranking in Fig. 2.

Table 1: Phytoplankters occurred at three stations of Morvan Dam during 2016-1

Name of phytoplankton	Station I						Station II						Station III					
	2016-17			2017-18			2016-17			2017-18			2016-17			2017-18		
	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M	W	S	M
Chlorophyceae																		
<i>Volvox</i> sp.*	130	55	75	140	80	75	200	-	-	220	-	-	310	-	75	405	-	100
<i>Eudorina</i> sp.	-	-	65	-	-	40	55	-	-	30	-	-	-	55	-	-	90	-
<i>Pandorina</i> sp.	-	-	-	45	40	-	-	-	10	-	-	-	-	-	-	65	50	90
<i>Scenedesmus</i> sp.	60	10	-	-	40	65	40	-	-	25	-	50	80	-	-	-	-	45
<i>Ankistrodesmus</i> ssp.	-	-	70	-	-	-	-	40	-	-	-	-	-	-	-	55	-	-
<i>Coelastrum</i> sp.	70	-	-	30	-	-	-	45	30	-	-	-	-	-	45	-	75	40
<i>Spirogyra</i> sp.	110	-	-	130	-	110	-	65	110	70	-	135	65	60	-	140	130	170
<i>Oedogonium</i> sp.	115	60	150	125	-	145	105	125	90	-	140	100	20	-	145	55	-	65
<i>Ulothrix</i> sp.	80	-	-	95	70	130	-	-	125	-	-	-	-	-	-	-	-	-
<i>Cladophora</i> sp.	-	-	60	30	40	65	-	-	-	-	-	-	-	-	-	-	40	-
<i>Chlamydomonas</i> sp.	-	25	-	-	-	35	45	-	80	95	-	15	-	-	35	-	-	-
<i>Mougeotia</i> sp.	30	-	-	40	-	30	20	-	-	-	-	-	-	-	-	-	-	-
<i>Pediastrum</i> sp.	35	40	70	50	35	80	55	25	135	20	150	70	-	75	130	45	175	35
<i>Oocystis</i> sp.	25	30	-	35	60	-	40	-	-	-	75	95	10	-	120	-	-	-
<i>Microspora</i> sp.	45	30	35	50	30	30	20	80	155	35	-	-	-	70	90	-	60	105
Desmidiaceae																		
<i>Cosmarium</i> sp.	30	-	20	25	20	40	10	40	30	10	50	30	20	20	20	10	40	35
<i>Desmidium</i> sp.	15	20	25	35	10	10	-	-	20	20	-	45	-	10	-	-	20	10
Xanthophyceae																		
<i>Chlorobutyril</i> sp.	5	-	15	10	-	10	10	10	-	20	-	-	25	-	-	25	15	-
<i>Botryococcus</i> sp.	10	10	-	10	10	5	10	5	10	-	-	-	5	10	-	10	10	10
Myxophyceae																		
<i>Microcystis</i> sp.	60	55	-	-	100	-	70	-	150	110	90	-	-	80	85	95	-	95
<i>Agmenellum</i> sp.	-	-	-	-	75	55	-	70	-	70	-	95	-	25	-	-	35	-
<i>Anabaena</i> sp.	-	-	-	80	30	25	-	40	-	50	70	-	-	85	-	65	45	-
<i>Oscillatoria</i> sp.	-	25	40	-	25	25	-	-	45	-	20	35	-	50	-	25	55	35
<i>Nostoc</i> sp.	35	20	-	60	-	-	-	30	-	-	-	-	80	20	15	40	-	-
<i>Spirulina</i> sp.	60	25	-	50	-	35	25	-	-	-	-	-	35	-	75	65	45	-
<i>Cochlearia</i> sp.	85	95	95	80	-	-	105	-	-	130	-	-	45	40	-	40	-	70
<i>Gomphosphaeria</i> sp.	-	10	-	-	-	20	-	-	-	40	70	-	-	-	-	-	-	-
Dinophyceae																		
<i>Glennodinium</i> sp.	50	75	-	-	60	-	40	-	-	30	-	60	-	-	80	-	-	-
<i>Peridinium</i> sp.	40	70	-	70	30	-	30	60	-	-	40	50	20	85	50	-	-	-
<i>Sphaerodinium</i> sp.	-	55	-	-	-	-	-	-	-	-	50	-	-	65	-	-	-	-
Bacillariophyceae																		
<i>Cyclotella</i> sp.	90	40	-	100	-	60	65	-	-	80	-	55	-	45	-	-	-	65
<i>Synedra</i> sp.	-	-	-	-	80	20	-	-	60	35	-	55	45	-	-	-	90	70
<i>Fragilaria</i> sp.	-	20	85	-	-	45	-	-	-	60	-	-	-	75	140	-	-	-
<i>Navicula</i> sp.	145	120	-	35	-	50	75	-	80	-	30	-	-	-	95	105	-	-
<i>Pinnularia</i> sp.	-	-	30	-	35	30	-	-	-	70	65	30	-	45	-	-	-	-
<i>Nitzschia</i> sp.	-	45	80	-	85	35	50	95	65	-	45	-	-	-	85	-	100	80
<i>Asterionella</i> sp.	-	-	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Amphora</i> sp.	-	100	-	-	70	-	-	-	50	-	75	65	-	80	-	-	80	-
<i>Gomphonema</i> sp.	-	-	65	90	-	20	-	-	-	-	-	-	-	-	-	-	100	55
<i>Cymbella</i> sp.	40	60	100	-	85	40	-	85	60	-	-	65	70	-	110	50	40	-
<i>Bacillaria</i> sp.	160	70	-	110	100	-	100	170	85	100	75	85	95	-	-	55	110	80

Chlorophyceae (43%)>*Bacillariophyceae* (29%)>*Myxophyceae*(19%)>*Dinophyceae* (5%)>*Desmidiaceae* (3%)>*Xanthophyceae* (1%).

The *Chlorophyceae* were estimated in the ranges from 380-660 cells mL⁻¹ but the range of *Desmidiaceae*, *Xanthophyceae* and *Myxophyceae* were noticed from 10-75, 00-30 and 130-400 cells mL⁻¹, respectively. However,

Dinophyceae and *Bacillariophyceae* were analyzed in the range of 00-110 and 280-420 cells mL⁻¹, respectively. The overall density of Phytoplanktonic groups was ranged from 1035 (Summer, 2016-17) to 1430 (Winter, 2017-18) cells mL⁻¹ during the study period, 2016-18 in Table 3. Phytoplankton analysis at station II of Morvan Dam exhibited that *Chlorophyceae* was at its peak during Monsoon, 2016-17.

Table 2: Seasonal variation in density of Phytoplanktonic groups (cells mL⁻¹) at station I of Morvan Dam during 2016-18

Years	Seasons	<i>Chlorophyceae</i>	<i>Desmidiaceae</i>	<i>Xanthophyceae</i>	<i>Myxophyceae</i>	<i>Dinophyceae</i>	<i>Bacillariophyceae</i>	Total density
2016-17	Winter	700	45	15	240	90	435	1525
	Summer	250	20	10	230	200	455	1165
	Monsoon	525	45	15	135	00	420	1140
2017-18	Winter	725	60	20	270	70	335	1480
	Summer	400	30	10	230	90	455	1215
	Monsoon	810	50	15	160	00	300	1335

Table 3: Seasonal variation in density of Phytoplanktonic groups (cells mL⁻¹) at station II of Morvan Dam during 2016-18

Years	Seasons	<i>Chlorophyceae</i>	<i>Desmidiaceae</i>	<i>Xanthophyceae</i>	<i>Myxophyceae</i>	<i>Dinophyceae</i>	<i>Bacillariophyceae</i>	Total density
2016-17	Winter	570	10	10	200	70	290	1150
	Summer	380	40	15	140	60	400	1035
	Monsoon	660	50	00	195	00	350	1255
2017-18	Winter	520	30	30	400	30	420	1430
	Summer	460	50	00	250	90	280	1130
	Monsoon	450	75		130	110	290	1055

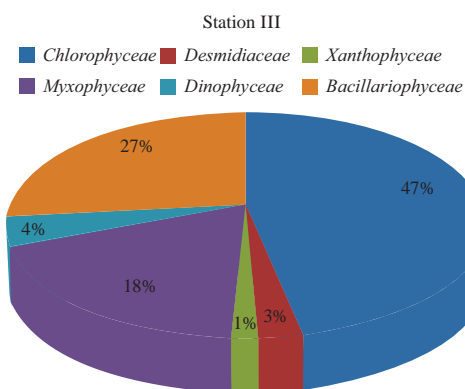


Fig. 3: Group-wise composition of phytoplankton at station III of Morvan Dam during 2016-18

Xanthophyceae and *Myxophyceae* showed a peak during Winter, 2017-18. Whereas, *Desmidiaceae* and *Dinophyceae* illustrate the highest density during Monsoon, 2017-18 and *Bacillariophyceae* were observed highest during Winter, 2017-18 (Table 3).

Station III: In the present investigation, there are a total of 37 forms were identified and out of these 13 belonged to *Chlorophyceae*, 7 to *Myxophyceae*, 10 to *Bacillariophyceae*, 3 to *Dinophyceae*, 2 to *Desmidiaceae* and 2 to *Xanthophyceae* at sampling station III of Morvan Dam during 2016-18. The *Chlorophyceae* was mostly represented as *Volvox* sp., *Spirogyra* sp., *Pandorina* sp., *Eudorina* sp., *Pediastrum* sp., *Microspora* sp., *Oedogonium* sp. and *Oocystis* sp., whereas, *Desmidiaceae* illustrates *Cosmarium* sp. and *Desmidium* sp. The group *Xanthophyceae* included *Chlorobutyryl* sp. and *Botryococcus* sp., however, the *Myxophyceae* was illustrated by *Microcystis* sp., *Spirulina* sp., *Cochlearis* sp., *Anabaena* sp., *Oscillatoria* sp., *Nostoc* sp. and *Agmenellum* sp. The *Dinophyceae* included

Peridinium sp., *Glenodinium* sp. and *Sphaerodinium* sp., whereas, *Bacillariophyceae* was noticed as *Bacillaria* sp., *Fragilaria* sp., *Cymbella* sp., *Nitzschia* sp., *Gomphonema* sp., *Amphora* sp., *Navicula* sp., *Synedra* sp. and *Cyclotella* sp. (Table 1).

The percentage composition of phytoplankton indicated the following ranking in Fig. 3. *Chlorophyceae* (47%) > *Bacillariophyceae* (27%) > *Myxophyceae* (18%) > *Dinophyceae* (4%) > *Desmidiaceae* (3%) > *Xanthophyceae* (1%).

The ranges of *Chlorophyceae* were observed from 260-800 cells mL⁻¹ however, the range of *Desmidiaceae*, *Xanthophyceae* and *Myxophyceae* were analyzed from 10-60, 00-35 and 160-330 cells mL⁻¹, respectively. Further, the *Dinophyceae* and *Bacillariophyceae* were noticed from 00-150 and 210-520 cells mL⁻¹, respectively. Eventually, the overall density of Phytoplanktonic groups was estimated in the range from 940 (Winter, 2016-17) to 1405 (Summer, 2017-18) cells mL⁻¹ during the two annual cycles, 2016-18 in Table 4. Phytoplankton analysis showed that *Chlorophyceae* was at its peak during Winter, 2017-18. Whereas, *Bacillariophyceae* illustrate the highest density during Summer 2017-18 and *Dinophyceae* exhibited a peak during Summer, 2016-17. *Myxophyceae* showed the highest density during Winter, 2017-18 and *Desmidiaceae* illustrates the highest density during Summer, 2017-18, *Xanthophyceae* was observed highest during Winter 2017-18 (Table 4).

In the current study, the biological diversity of Phytoplanktonic groups based on Menhinick's index at the station I, II and III of Morvan Dam has been summarized in Table 5-7. The range of biological diversity (based on Menhinick's index) for *Chlorophyceae*, *Desmidiaceae* and *Xanthophyceae* were noticed from 0.305505046 (Monsoon, 2016-17) to 0.442718872 (Summer, 2016-17), 0.223606798 (Summer, 2016-17) to 0.365148372 (Summer, 2017-18) and

Table 4: Seasonal variation in density of Phytoplanktonic groups (cells mL⁻¹) at station III of Morvan Dam during 2016-18

Years	Seasons	<i>Chlorophyceae</i>	<i>Desmidiaceae</i>	<i>Xanthophyceae</i>	<i>Myxophyceae</i>	<i>Dinophyceae</i>	<i>Bacillariophyceae</i>	Total density
2016-17	Winter	500	20	00	160	20	210	940
	Summer	260	30	30	300	150	245	995
	Monsoon	605	20	10	175	130	430	1360
2017-18	Winter	800	10	35	330	00	210	1385
	Summer	620	60	25	180	00	520	1405
	Monsoon	650	45	10	200	00	350	1255

Table 5: Biological diversity of Phytoplanktonic groups based on Menhinick's index at station I of Morvan Dam

Years	Seasons	<i>Chlorophyceae</i>	<i>Desmidiaceae</i>	<i>Xanthophyceae</i>	<i>Myxophyceae</i>	<i>Dinophyceae</i>	<i>Bacillariophyceae</i>
2016-17	Winter	0.377964473	0.298142397	0.516397779	0.25819889	0.210818511	0.1940285
	Summer	0.442718872	0.223606798	0.316227766	0.395628284	0.212132034	0.328165062
	Monsoon	0.305505046	0.298142397	0.25819889	0.172132593	00	0.292770022
2017-18	Winter	0.371390676	0.25819889	0.447213595	0.243432248	0.119522861	0.218543346
	Summer	0.4	0.365148372	0.316227766	0.263752189	0.210818511	0.281284339
	Monsoon	0.386500603	0.282842712	0.516397779	0.395284708	00	0.461880215

Table 6: Biological diversity of Phytoplanktonic groups based on Menhinick's index at station II of Morvan Dam

Years	Seasons	<i>Chlorophyceae</i>	<i>Desmidiaceae</i>	<i>Xanthophyceae</i>	<i>Myxophyceae</i>	<i>Dinophyceae</i>	<i>Bacillariophyceae</i>
2016-17	Winter	0.376968517	0.316227766	0.316227766	0.212132034	0.239045722	0.234888088
	Summer	0.307793506	0.158113883	0.516397779	0.253546276	0.129099445	0.2
	Monsoon	0.233549683	0.282842712	00	0.143222975	00	0.267261242
2017-18	Winter	0.394676109	0.365148372	0.365148372	0.25	0.182574186	0.292770022
	Summer	0.186500962	0.141421356	00	0.252982213	0.210818511	0.298807152
	Monsoon	0.23570226	0.230940108	00	0.175411604	0.190692518	0.29361011

Table 7: Biological diversity of Phytoplanktonic groups based on Menhinick's index at station III of Morvan Dam

Years	Seasons	<i>Chlorophyceae</i>	<i>Desmidiaceae</i>	<i>Xanthophyceae</i>	<i>Myxophyceae</i>	<i>Dinophyceae</i>	<i>Bacillariophyceae</i>
2016-17	Winter	0.268328157	0.223606798	0.365148372	0.237170825	0.223606798	0.207019668
	Summer	0.248069469	0.365148372	0.316227766	0.346410162	0.163299316	0.255550626
	Monsoon	0.243934688	0.223606798	00	0.226778684	0.175411604	0.192897129
2017-18	Winter	0.247487373	0.316227766	0.338061702	0.33028913	00	0.207019668
	Summer	0.281126765	0.25819889	0.4	0.298142397	00	0.263117406
	Monsoon	0.313785816	0.298142397	0.316227766	0.212132034	00	0.267261242

0.25819889 (Monsoon, 2016-17) to 0.516397779 (Winter, 2016-17 and Monsoon, 2017-18) respectively. However, the biological diversity for *Myxophyceae*, *Dinophyceae* and *Bacillariophyceae* were analyzed in the ranges from 0.172132593 (Monsoon, 2016-17) to 0.395628284 (Summer, 2016-17), 00 (Monsoon, 2016-18) to 0.212132034 (Summer, 2016-17) and 0.1940285 (Winter, 2016-17) to 0.461880215 (Monsoon, 2017-18) respectively at the station I of Morvan Dam in Table 5. The biological diversity (based on Menhinick's index) range for *Chlorophyceae*, *Desmidiaceae* and *Xanthophyceae* were recorded from 0.186500962 (Summer, 2017-18) to 0.394676109 (Winter, 2017-18), 0.141421356 (Summer, 2017-18) to 0.365148372 (Winter, 2017-18) and 00 (Monsoon, 2016-17, 2017-18) to 0.516397779 (Summer, 2016-17) respectively, however, the value of biological diversity for *Myxophyceae*, *Dinophyceae* and *Bacillariophyceae* were documented in the ranges from 0.143222975 (Monsoon, 2016-17) to 0.253546276 (Summer, 2016-17), 00 (Monsoon, 2016-17) to 0.239045722 (Winter, 2016-17) and 0.200 (Summer, 2016-17) to 0.298807152

(Summer, 2017-18) respectively at station II of Morvan Dam in Table 6. Similarly, the biological diversity (based on Menhinick's index) for *Chlorophyceae*, *Desmidiaceae* and *Xanthophyceae* were analyzed in the ranges from 0.243934688 (Monsoon, 2016-17) to 0.313785816 (Monsoon, 2017-18), 0.223606798 (Winter and Monsoon, 2016-17) to 0.365148372 (Summer, 2016-17) and 00 (Monsoon, 2016-17) to 0.400 (Summer, 2017-18). Furthermore, the biological diversity for *Myxophyceae*, *Dinophyceae* and *Bacillariophyceae* were ranged from 0.212132034 (Monsoon, 2017-18) to 0.346410162 (Summer, 2016-17), 00 (all seasons, 2017-18) to 0.223606798 (Winter, 2016-17) and 0.192897129 (Monsoon, 2016-17) to 0.267261242 (Monsoon, 2017-18) respectively at station III of Morvan Dam in Table 7. There are a total diversity of phytoplanktonic groups based on Menhinick's index at station I, II and III of Morvan Dam were ranges from 0.53311399 (Monsoon, 2016-17) to 0.766332772 (Monsoon, 2017-18), 0.423418078 (Monsoon, 2016-17) to 0.661107357 (Winter, 2017-18) and 0.433860916 (Monsoon, 2016-17) to 0.602340494 (Summer, 2016-17) respectively

Table 8: Total diversity of phytoplanktonic groups based on Menhinick's index at stations I, II and III of Morvan Dam during 2016-18

Plankters	Station	2016-17			2017-18			Total	Overall diversity of Morvan Dam
		Winter	Summer	Monsoon	Winter	Summer	Monsoon		
Phytoplankton	I	0.614577024	0.732448419	0.53311399	0.597856532	0.659841607	0.766332772	0.462458306	0.717249045
	II	0.589767825	0.528419391	0.423418078	0.661107357	0.475971294	0.492599257	0.345262562	
	III	0.521862458	0.602340494	0.433860916	0.510538754	0.560249055	0.536329565	0.431870654	

however, the total Menhinick's index of diversity for the station I, II and III of Morvan Dam was calculated as 0.462458306, 0.345262562 and 0.431870654, respectively. The overall diversity of Morvan Dam based on Menhinick's index was estimated as 0.717249045 in two annual cycles, 2016-18 in Table 8.

There are high and diverse kinds of phytoplankton species identified in the current investigation were represented by six groups viz., *Chlorophyceae*, *Xanthophyceae*, *Bacillariophyceae*, *Desmidiaceae*, *Myxophyceae* and *Dinophyceae* in various seasons (Summer, Winter and monsoon) during two annual cycles i.e., 2016-17 and 2017-18 (Table 1). During the current study, the total density of phytoplankton species was fluctuated seasonally from 1185 mL⁻¹ (Summer, 2016-17) to 1535 mL⁻¹ (Winter, 2016-17) at station I (Table 2) whereas, the seasonal variation in phytoplankton density at station II and III of the Morvan Dam were found to be ranges from 1045 mL⁻¹ (Summer, 2016-17) to 1460 mL⁻¹ (Winter, 2017-18) and 980 mL⁻¹ (Winter, 2016-17) to 1425 mL⁻¹ (Summer, 2017-18), respectively during two annual cycles, 2016-17 and 2017-18 (Table 3 and 4).

There are a total of 27 taxa of phytoplankton were recorded, belonging to 4 families as *Chlorophyceae* (47%), *Cyanophyceae* (27%), *Bacillariophyceae* (23%) and *Euglenophyceae* (3%) in River Narmada¹⁸. However, the maximum number of species was noticed during pre-monsoon (29) and minimum during winter (23) and the *Chlorophyceae* group were found to be most abundant in pre-monsoon and monsoon season¹⁹. There are 10 species of *Chlorophyceae*, 5 species of diatoms, 3 species of *Cyanophyceae* and 1 *Euglenophyceae* were analyzed whereas, *Bacillariophyceae* were dominated in River Oluwa, Ondo State, Nigeria²⁰. *Chlorophyceae* was found to be the most dominant group with 34.48 and 35.08% of the total phytoplankton in both perennial and non-perennial ponds followed by *Cyanophyceae* (34.16 and 30.79%: Perennial and non-perennial ponds), *Bacillariophyceae* (13.87 and 13.27%: Perennial and non-perennial ponds), *Euglenophyceae* (10.68 and 13.40%: Perennial and non-perennial ponds) and *Dinophyceae* with 6.50 and 7.27% in perennial and non-perennial ponds, respectively²¹. Furthermore, out of a total of 93 species of phytoplankton, 52 species were found at the Estuarine station. In estuarine station, diatoms exhibited 45.5%

of the total phytoplankton populations followed by *Chlorophyceae* (31.0%), *Cyanophyceae* (13.4%), Euglenoids (9.3%), chrysophytes (0.6%) and dinoflagellates (0.2%). However, the highest total means the density of phytoplankton in the estuarine station was analyzed as 128.8 ± 14.0 cells m⁻¹²².

Whereas, 66 phytoplankton species were reported belonging to 44 genera, 34 families and six phyla and, notice the phytoplankton abundance in the order of *Bacillariophyta* > *Charophyta* > *Chlorophyta* > *Cyanobacteria* > *Miozo* > *Euglenophyta* in water bodies within the Buea Municipality, Cameroon²³. The highest number phytoplankton was illustrated by *Chlorophyceae* (48.37%) whereas, the *Cyanophyceae*, *Bacillariophyceae* and *Euglenophyceae* were noticed as 26.80, 18.90 and 5.93%, respectively at one sampling station but at another sampling station, the percent ranking was noticed for *Bacillariophyceae*, *Chlorophyceae*, *Cyanophyceae* and *Euglenophyceae* as 46.46, 27.70, 17.84 and 8%, respectively in River Sutlej, Punjab²⁴. It has been noticed that the dominance of *Chlorophyceae* might be due to moderate values of pH, DO content, turbidity, nitrates as well as high temperatures. Consequently, phytoplankton diversity exhibits the percent composition of *Chlorophyceae*, *Bacillariophyceae*, *Cyanophyceae* and *Desmidiaceae* as 22, 11, 10 and 1%, respectively in Krishna River, Sangli, Maharashtra²⁵. It has been noticed the highest number of the *Chlorophyceae* flowed by *Bacillariophyceae*, *Cyanophyceae* and *Euglenophyceae* among the group of phytoplankton are during seasonal surveys of Godavari River water²⁶. However, Phytoplankton diversity represents *Chlorophyceae*, *Cyanophyceae*, *Bacillariophyceae*, *Dinophyceae* and *Euglenophyceae* but the *Chlorophyceae* group was found to be the most significant and dominant group consisting of 37% whereas, *Euglenophyceae* and *Dinophyceae* were includes 3% of the total phytoplankton species recorded in Khedi Kalan station of Dholawad Dam (Saroj Sarovar Dam) of Ratlam District, M.P.²⁷. There are a total of 96% of the total phytoplankton species constitute *Cyanophyta*, *Chlorophyta* and *Bacillariophyta* during the seasonal analysis of phytoplankton diversity and dynamics in Chamo Lake (Ethiopia) and observed the most predominant species were *Chlorophyta* (*Pediastrum*, *Closterium* and *Scenedesmus*)

during the rainy seasons. Different phytoplankton species were observed during four seasons across different sampling sites. However, among all sampling sites, the maximum diversity was high during winter²⁸. There is complete dominance of *Chlorophyta* has been recorded with 18 genera followed by *Cyanophyta* with 14 genus, *Chrysophyta* with 5 genera and *Rhodophyta* with 1 genus. These authors observed total numbers of phytoplankton, ranging from a minimum of 43 counts/L (February) to a maximum of 5508 counts/L (May) whereas, the highest number of Phytoplankton were recorded during summer and monsoon as compared to winter²⁹. However, Sabita *et al.*³⁰ observed the phytoplankton diversity of Nirmalagiri Lake and Kengeri Lake in Bangalore and reported that *Chlorophyceae* was the most dominant group in both lakes. These authors noticed the percentage of *Chlorophyceae*, *Euglenophyceae*, *Bacillariophyceae* and *Cyanophyceae* as 86.12, 0.90, 5.85 and 7.11%, respectively in Nirmalagiri Lake but in Kengeri Lake the percentage of *Chlorophyceae*, *Euglenophyceae*, *Bacillariophyceae*, *Cyanophyceae*, *Charophyceae* and *Dinophyceae* were found to be 76.55, 1.24, 7.14, 12.57, 2.32 and 0.15%, respectively. There are 15 genera from 3 classes were reported as *Cyanophyceae* (57.9%)> *Chlorophyceae* (33.3%)>*Bacillariophyceae* (8.8%) during the study of abundance and distribution of phytoplankton across Ivo River Basin south-eastern Nigeria³¹. Similarly, the *Chlorophyceae* (55.88%) was found to dominant group followed by *Bacillariophyceae* (17.64%), *Cyanophyceae* (11.76%), *Dinophyceae* (5.88%) and *Euglenophyceae* (8.82%) during the study of seasonal distribution and diversity of phytoplankton of Gomti River, Lucknow¹². Eventually, the results of the current investigation are also conformities to the literature cited by several researchers³²⁻⁴⁰.

Previous literature illustrates that hydrology, trophic status, morphometry, light availability and discharge have affected the seasonal diversity in abundance and composition of phytoplankton in Dam⁴¹⁻⁴³. However, different physicochemical profiles viz., air and water temperature, pH, total dissolved solids (TDS), transparency, dissolved oxygen, total hardness, total alkalinity, nitrate and phosphate have also been analyzed and correlated together during the years of 2010-12 in Morvan Dam⁴⁴. It has been noticed that the diversity and distribution of Phytoplankton exhibit a positive correlation with various physico-chemical parameters of water bodies in Dongarwada Ghat of River Narmada, Madhya Pradesh¹⁸. Further, a more or less similar pattern of results was obtained in the current investigation as suggested by previous authors⁴⁵⁻⁴⁸. This study has a great significant value from an

aquaculture point of view as it may help to establish the relationship between water quality, trophic status and fisheries potential of the Morvan Dam.

CONCLUSION

From the current investigation, it is clear that the Morvan Dam harbour high and diverse kinds of phytoplankton species which have been represented in the order of abundance as *Chlorophyceae*>*Bacillariophyceae*>*Myxophyceae*>*Dinophyceae*>*Desmidiaceae*>*Xanthophyceae*, however, their percentage composition were found to be different in all the three selected station during the specified period.

SIGNIFICANCE STATEMENT

The species richness of phytoplankton illustrates the low pollution status and good health of Ichthyofaunal species during the specified period in Morvan Dam. This investigation also provides baseline data to obtain the recommended quality of water for better management and improved quality of aquatic species particularly, fishes for forthcoming research in Morvan Dam.

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