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Abundance and Diversity of Zooplankton and Its Seasonal Variation in the Water of Sahebbandh, Purulia, India: A Quantitative Study

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Abstract:
A quantitative study on the abundance and diversity of zooplankton and its seasonal variation in the water of SahebBandh, Purulia, the only source of drinking water in Purulia town, has been done. Four major groups of zooplanktons, viz. Rotifera, Copepoda, Cladocera and Ostracoda have been identified in the water. Bio-diversity indices have been used to monitor the community composition of the zooplanktons and environmental standards or quality of the environment of SahebBandh. Five indices, viz., Shannon-Wiener diversity index (ψ), Index of species richness (μ), Index of dominance (η), Evenness index (ε) and Sorensen's index of similarity (θ_S) are employed and estimated in the present investigation. Seasonal variation of these indices has been studied.

Keywords: *Zooplankton communities, Seasonal abundance, Bio-diversity indices, Ecology, Purulia*

1. Introduction

In freshwater ecosystem, zooplanktons are identified as important food sources for many aquatic animals, especially for fishes. The zooplankton occupies an intermediate position in the food web in the aquatic ecosystem. Zooplankton communities are highly sensitive to environmental variation [1-8]. Therefore, changes in zooplankton abundance, diversity or community composition can provide important information regarding environmental changes. Zooplankton thus plays an important role in determining the water quality, eutrophication status and productivity of a freshwater body [9].In order to find out the status of a freshwater body, it is necessary to observe seasonal diversity and abundance of zooplanktons in that water body.

The concept of bio-indication of water quality is an emerging field of environmental assessment. Several authors [10-12]have used zooplanktons as an indicator for monitoring water quality, tropic status and pollution levels. Zooplankton community, thus, plays an important role in the tropho-dynamics, ecological cycling of materials and its productivity.

Though a number of workers have focussed on the limnology of Indian lakes and reservoirs [13-16], not much is known regarding the limnological status and planktonic diversity of SahebBandh, Purulia, India.

Purulia town (23.33° N, 86.37°E)is the district headquarters of the district of Purulia, in the state of West Bengal. The town is located at an average altitude of 228 metres (748 feet) [17] from mean sea level. It is a drought prone area having average annual rainfall of 1300 mm [17]. Due to high altitude, steep land slope and rocky nature of the region, the soil cannot retain rain water in it.The town dwellers often suffer from scarcity of water during spring and summer. "SahebBandh" is the only source of drinking water supply for the town dwellers of Purulia other than the river of Kansabati. The British Cornel Tikley took major initiative in digging this lake (1843-1848) to eradicate the serious drinking water crisis of the area. The lake was renamed as NibaranSayer, after the famous freedom fighter of Purulia, Nibaran Chandra Dasgupta [17].

According to our knowledge, the present study is going to be the first quantitative approach to monitor systematically the diversity and seasonal variation of zooplankton abundance in the water of SahebBandh,Purulia. This will provide important information regarding the water quality of this very important water source in this drought prone area.

2. Materials and methods

2.1. Duration of the Study

The study was carried out for a period of five years (September 2007- August 2012) for more elaborate results and greater accuracy.

2.2. Zooplankton Collection and Counting

Around 20-50 L of water was passed through plankton net (mesh size 64 micron) to concentrate zooplankton. The zooplankton thus collected and preserved immediately with an appropriate quantity of buffered formalin (5%) to make a final concentration. The entire water was centrifuged, decanted and concentrated to make 1 ml volume for observation under S-R (Sedgwick-Rafter) counting cell. Before counting, let the S-R cell stand for at least 15 minutes to settle the zooplankton and counted the organisms settled on the bottom. The zooplankton were observed and counted under the microscope using 10 x magnifications. The number per m^3 is expressed by the following formula:

$$\text{Number/ } m^3 = \frac{C \times V_2}{V_1 \times V_3} \quad (1)$$

Where, C = total number of counted individuals ofspecies in a sample
V_1 = volume of concentrated samplethrough plankton net
V_2 = centrifuged, decanted andconcentrated volume of sample in ml
V_3 = volume of grab sample in m^3 i.e., 20 L /1000

2.3. Sampling Sites, Collection and Preservation of Water Samples

Figure 1 shows the position of Sahebbandh in Purulia town. It is situated in the south-west corner of the town. The lake is about 1000 m long along the north-west to south-east direction and its maximum width is about 500 m along east-west direction.There are a number of motor repairing shops, garages, nursing home, private apartments, housing complexes; bathing ghats, amusement park etc. have cropped up surrounding the lake (Figure 2). It is quite obvious that the pollution of the lake water from these sources will affect plankton community who uses the lake as their dwelling place. Regular samplings of water were done weekly during September, 2007 - August, 2012from three selected sites of the bandh as indicated in figure 2:
Site 1: Located at the northern side. Most of the major sewage points are located on this side.
Site 2: Located at the western side of the bandh near a nursing home,
Site 3: Located at the middle of eastern side and is devoid of sewage points,
Water samples were collected fortnightly in clear glass bottles from surface (maximum depth 20 cm) and vegetated zone of three different sites/stations of the bandh. Water samples were collected in three replicates from surface, column and bottom of each station and mean values of all three observations were taken into consideration.

2.4. Analysis of Zooplankton Community

Qualitative and quantitative analysis are done on zooplankton community available in Sahebbandh, Purulia. Number of individuals for a particular species used in all the studies is the mean value of the data collected for five consecutive years (2007-2012). Data collected from different sampling sites has been used separately. Identification of the zooplanktons is done and zooplankton abundance is calculated taking the counts of four major groups only.Bio-diversity indices have been used to monitor the environmental standards or quality of the environment of SahebBandh. Five indices, viz., Shannon-Wiener diversity index (ψ), Index of species richness (μ), Index of dominance (η), Evenness index (ε) and Sorensen's index of similarity (θ_S) are employed and estimated in the present investigation.

2.4.1. Shannon - Wiener index of diversity

Shannon-Wiener index of diversity is calculated using the formula

$$\psi = -\sum_{i=1}^{s} \left(\frac{n_i}{N}\right) \ln \left(\frac{n_i}{N}\right) \quad (2)$$

Where, ψ = Shannon - Wiener index
n_i = individual number in a species in experimental site
N = Total number of individuals

2.4.2. Species richness

Species richness is expressed by simple ratio between total species (S) and total number or importance value (N)

$$\mu = \frac{S-1}{\log_{10} N} \quad (3)$$

Where, μ = Species richness

2.4.3. Index of Dominance

The index of dominance (Simpson 1949) is the sum total of squares of the proportion of the species in the community and is expressed as follows

$$\eta = \sum_{i=1}^{s} \left(\frac{n_i}{N}\right)^2 \quad (4)$$

Where, η = Index of dominance
n_i = individual number of species i
N = Total importance value

2.4.4. Evenness Index

Another major component of diversity is 'evenness' or 'equitability' in the apportionment of individuals among the species. It is expressed as

$$\varepsilon = \frac{\psi}{\log_{10} S} \quad (5)$$

Where, ψ = Shannon-Wiener index
S = Number of species

2.4.5. Sorensen's Index Of Similarity
The index of similarity (θ_s) between two samples as proposed by Sorensen (1948) is calculated as follows

$$\theta_S = \frac{2c}{(a+b)} \quad (6)$$

a = Number of species in sample one
b = Number of species in sample two
c = Number of species common to both

2.4.6. Statistical Analysis
All data are expressed as means ± SE. A two-way analysis of variance (ANOVA) is usedto find out the significance of the differences in density of the zooplankton groups among the different stations, seasons of the lake using Origin 9.1.

3. Results and Discussions

3.1. Seasonal Changes in the Meteorological Conditions of the Lake
SahebBandh has an area of 86 hectares [17], mean depth of 4.8±0.2 meter and the lake has a maximum retention capacity of 50000 m^3 of water [17]. In the centre of the lake there is a small island which is frequently visited by a large variety of migratory birds [17]. The range of seasonal variation of air temperature at the time of sampling in the lake is from 48.6°C to 19.7°C respectively. The climate of this region is found to be more or less dry with a maximum relative humidity of 76%. The climate can be categorized into four distinct seasons, viz, the summer, the monsoon, the post-monsoon and the winter.
The summer starts from the first week of March and continues till the end of May. This season is characterized by high atmospheric temperature, which was unto a maximum of 48.6°C, bright sunshine and longer days.
The monsoon starts from the first week ofJune and usually lasts till September with some irregular spells of bright sunshine in between. The monsoon months are cloudy and the atmosphere is humid with a maximum of relative humidity of 76%. The atmospheric temperature in rainy months is moderately high sometimes with fast winds of a maximum velocity of 80Km/hour.
The post-monsoon/ spring seasons show a wide range of variation so far as the rainfall, humidity, sunshine and wind velocity is concerned. Overall the air is relatively dry with bright sunshine while its duration is reduced due to shorter day length. The post-monsoon season can be differentiated from winter for hardly a couple of months (October and November). From last week of November winter arrives with cold and dry air and frequent fast winds. The winter and the springexperiences some short spells of sharp showers usually brought about by the depressions in Bay of Bengal or by north-east monsoon clouds.
The annual rainfall in the catchment area of the lake is in the order of 12 cm with maximum rain being observed during months of August-September during all the years of investigation. Wind velocity, which is an important parameter for mixing of water column, remained quite high over during the rains. Duration of sunshine recorded in hours also varied with the season. It starts declining from June to October (5.7 to 4.1 hours per day) and thereafter increased steadily to reach the maximum early summer month.

3.2. Qualitative Analysis of Zooplanktons
The zooplanktons are found in relatively lower numbers when compared to the phytoplankton present in the lake. More than 98% of the available zooplanktons can be classified in the four major zooplanktonicgroups of Rotifera, Copepoda, Cladocera and Ostracoda. Less than 2% of population is identified as Protozoa, Polychaetaand larval stages of insects and fresh water molluscs. No marked difference is observed regarding species composition in different sampling station of the lake. The qualitative analysis of zooplanktons in SahebBandh has been presented in Table I.

3.3. Quantitative Analysis of Zooplanktons
Quantitative studies are done on the zooplankton community of SahebBandh to monitor the structure and functioning of the animal communities and the impact of nature or man induced change on them.

3.3.1. Zooplankton Abundance
Figure 3(a-d) shows the abundance of zooplanktons in site 3 for summer, monsoon, post-monsoon and spring respectively. Data used in this study is the mean value of the data collected for five consecutive years (2007-2012). It can be noticed from the figure that the maximum abundance of rotifers (62.24 %) is found in monsoon where minimum abundance (43.87 %) has been recorded in spring. Copepods showed maximum abundance (16.70 %) in monsoon while minimum abundance (15.81 %) has been recorded in spring. Cladocerans showed maximum abundance (34.78 %) in spring and minimum abundance (20.33 %) in monsoon.

Ostracods showed maximum abundance (5.53 %) in spring while minimum abundance (0.73 %) was observed in monsoon. Percentage abundance of zooplanktons from site 1 and site 2 showed almost similar patterns of variation against seasonal changes. Based on four major zooplankton groups and total zooplankton as test variables, analysis of variance was performed to assess the significant difference of zooplankton faunal abundance existing in relation to stations and seasons of sahebbandh. Total zooplankton abundance (Ind/L) showed significant difference ($p < 0.01$) between stations and seasons ($p < 0.01$) i.e., in summer, monsoon, post-monsoon and spring in SahebBandh. Significant differences were also observed with respect to four major groups between stations and seasons ($p < 0.01$) in SahebBandh.

Rotifers and Copepods get favourable atmospheric condition in monsoon to attain adulthood in their life cycle. Also water coming from different water sources contained recognisable Rotifers and Copepods mix with the lake water in monsoon. These reasons are primarily accountable for observed highest abundance for these two groups in monsoon. Variation in percentage abundance in four groups of zooplanktons can also be explained on the basis of the eutrophication of the lake, climax community for a particular group at the sampling site, presence of predators and consumers in food web and several other external factors.

3.3.2. Shannon - Wiener Index of Diversity (ψ)

The value of Shannon - Weiner index can theoretically range from zero to infinity. However, values normally range from 0 to 4. The more unequal is the abundance of the species, the smaller is the value of corresponding Shannon-Wiener index (ψ).The seasonal variation in the ψ value for the four groups of zooplanktons available in the lake under investigation was studied.

For site 3 in Rotifers, ψ value showed maximum ($\psi = 2.1$) in the month of January and then decreases constantly to reach a plateau region during the months from April to September ($\psi = 1.88$-1.91), reaches minimum in October ($\psi = 1.79$) and then again starts increasing.For Cladocerons, ψ value showed minimum ($\psi = 0.96$) in the month of January and then increases constantly to reach its maximum values during November-December ($\psi = 1.36$). For Copepods, ψ value showed maximum ($\psi = 1.12$) in the month of March and reaches minimum in July ($\psi = 0.84$) and then again starts increasing. The ψ value remained confined in between these stationary values throughout the year. For Ostracods, ψ value showed maximum ($\psi = 1.08$) in the month of February and its minimum in September ($\psi = 0.63$).

The seasonal variation in ψ value follows almost same patterns for all the four groups of zooplanktons from sites 1 and 2.

3.3.3. Species Richness (μ)

One of the major components of species diversity is 'Species richness' or Margalef's diversity index (μ). This index commonly varies between 1 and 5, and larger the index indicates a more healthy body of water. When it tends towards 1, pollution is thought to increase and damage should be suspected.In the present work, μ value showed its minimum during summer (month of May) and its maximum during post-monsoon (month of October) for all the four groups of zooplanktons. The seasonal variation pattern is found to be similar for all the three sites under study. In the summer, the water level of the lake goes down below a certain level which degrades the water quality of the lake while in the months of post-monsoon presence of adequate water level improves the water quality.

3.3.4. Index of Dominance (η)

Within a major community there are species or groups which largely control the energy flow and strongly affect the environment of all other species. They are known as ecological dominance. The degree to which dominance is concentrated in one or many species can be expressed by an appropriate index of dominance that sums each species importance in relation to community as a whole. The value of η varies between 0 and 1. Higher diversity values reflect diversified resources in the habitat available for components of the community. Decreased values indicate increase by an average species resulting in the lowering of the number of coexisting species in the community.In the present work, η value showed its minimum during post-monsoon (month of October) and its maximum during summer (month of May) for all the four groups of zooplanktons. The seasonal variation pattern is found to be similar for all the three sites under study.

3.3.5. Evenness Index (***ε***)

In the present study for Rotifers of site 3, ε showed maximum value in the month of January and reaches its minimum value in October and then again starts increasing in November and December. For Cladocerons, ε showed minimum value in the month of January and then increases constantly to reach its maximum values during November-December. For Copepods, ε showed maximum value in the month of March and reaches minimum in July and then again starts increasing. For Ostracods, ε showed maximum value in the month of February and its minimum value in September. The seasonal variation in ε value follows almost same patterns for all the four groups of zooplanktons from sites 1 and 2.

3.3.6. Sorensen's Index of Similarity (Θ_s)

Similarity indexis used particularly as a basis for quantifying similarities between the communities of different sampling sites. It measures the similarity in the species composition in the sample and the value of θ_s ranges in between 0 to 1. Value zero indicates complete dissimilarity, whereas value one (1) denotes maximum similarity in between samples (or communities). This index has been used to compute the species similarity of zooplanktons at different sites of the water body. In the present study, maximum similarity in the species composition ($\theta_s=1$) is observed in between all the three sampling sites throughout the year.

Name of the Species	Sampling site		
	Site 1	Site 2	Site 3
Group: Rotifera			
Family: Brachionidae			
Brachionus plicatillis(Müller, 1786)	+	+	+
Brachionus angularis (Gosse, 1851)	+	+	+
Brachionus quadridentatus (Hermann, 1783)		+	+
Brachionus caudatus (Barrois&Dadai, 1894)	+	+	+
Brachionus calyciflorus (Pallas, 1766)	+	+	+
Keratella cochlearis(Gosse, 1851)	+	+	+
Keratella tropica(Apstein, 1907)	+	+	+
Family: Filinidae			
Filinia longiseta (Ehrenberg, 1834)	+	+	+
Family: Asplanchnidae			
Asplanchna brightwelli(Gosse, 1851)	+	+	+
Pompholyx sp. (Gosse, 1851)	+	+	+
Group: Copepoda			
Family: Cyclopidae			
Cyclops sp. (Müller, 1785)	+	+	+
Mesocyclops leuckarti (Claus, 1857)	+	+	+
Group: Cladocera			
Family: Moinidae			
Moina affinis (Birge, 1893)	+	+	+
Moina brachieta (Jurine, 1820)	+	+	+
Family: Daphniidae			
Daphnia carinata (King, 1852)	+	+	+
Ceriodaphnia cornuta (Sars, 1886)	+	+	+
Family: Sididae			
Sida crystallina ((Müller, 1776)	+	+	+
Group: Ostracoda			
Family: Cyprididae			
Cypria opthalmica (Jurine, 1820)	+	+	+
Cyclocypris ovum (Jurine, 1820)	+	+	+
Family: Candonidae			
Candona candida (Müller, 1776)	+	+	+

Table 1:Qualitative analysis of zooplanktons present in three different sampling sites of SahebBandh

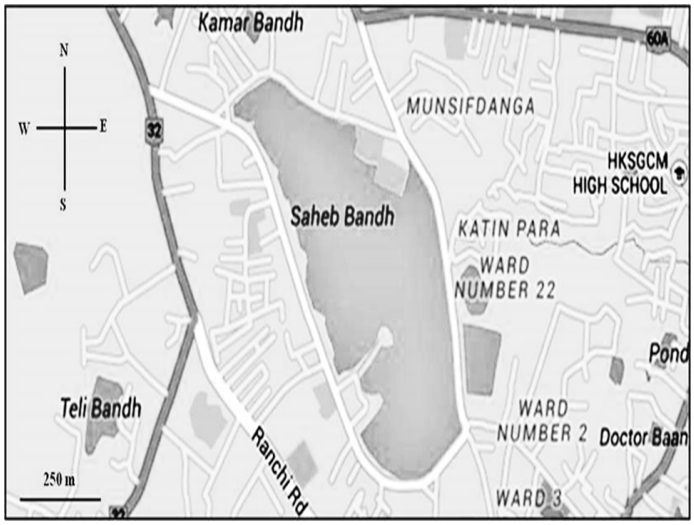

Figure 1: Google map of SahebBandh, Purulia, showing the location of the lake in Purulia town.

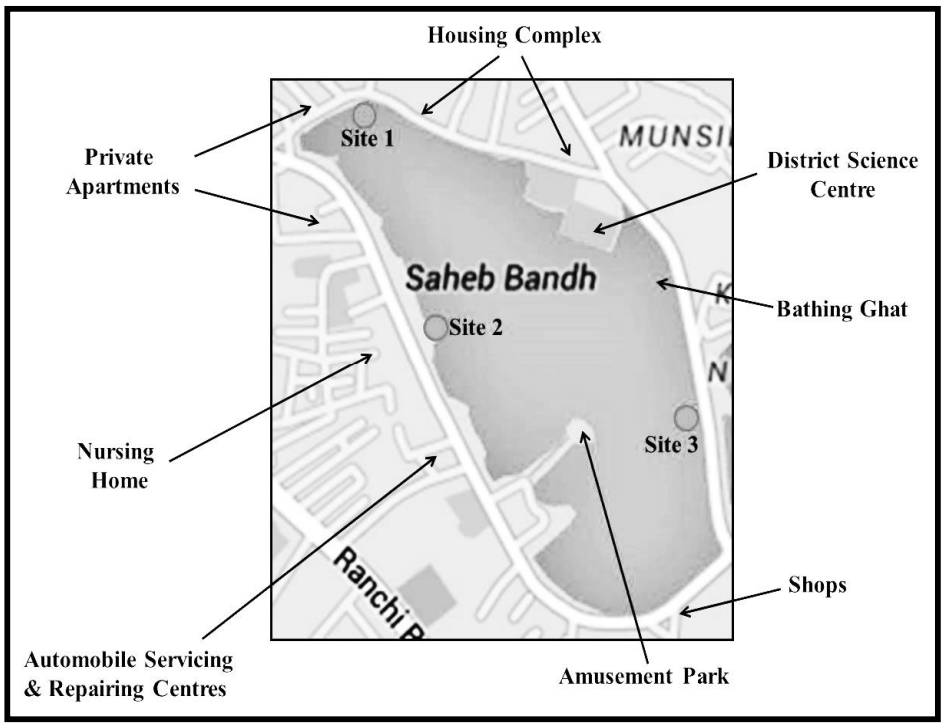

Figure 2: Magnified Google map of SahebBandh, Purulia, indicating surrounding landmarks and the sampling sites of the present study.

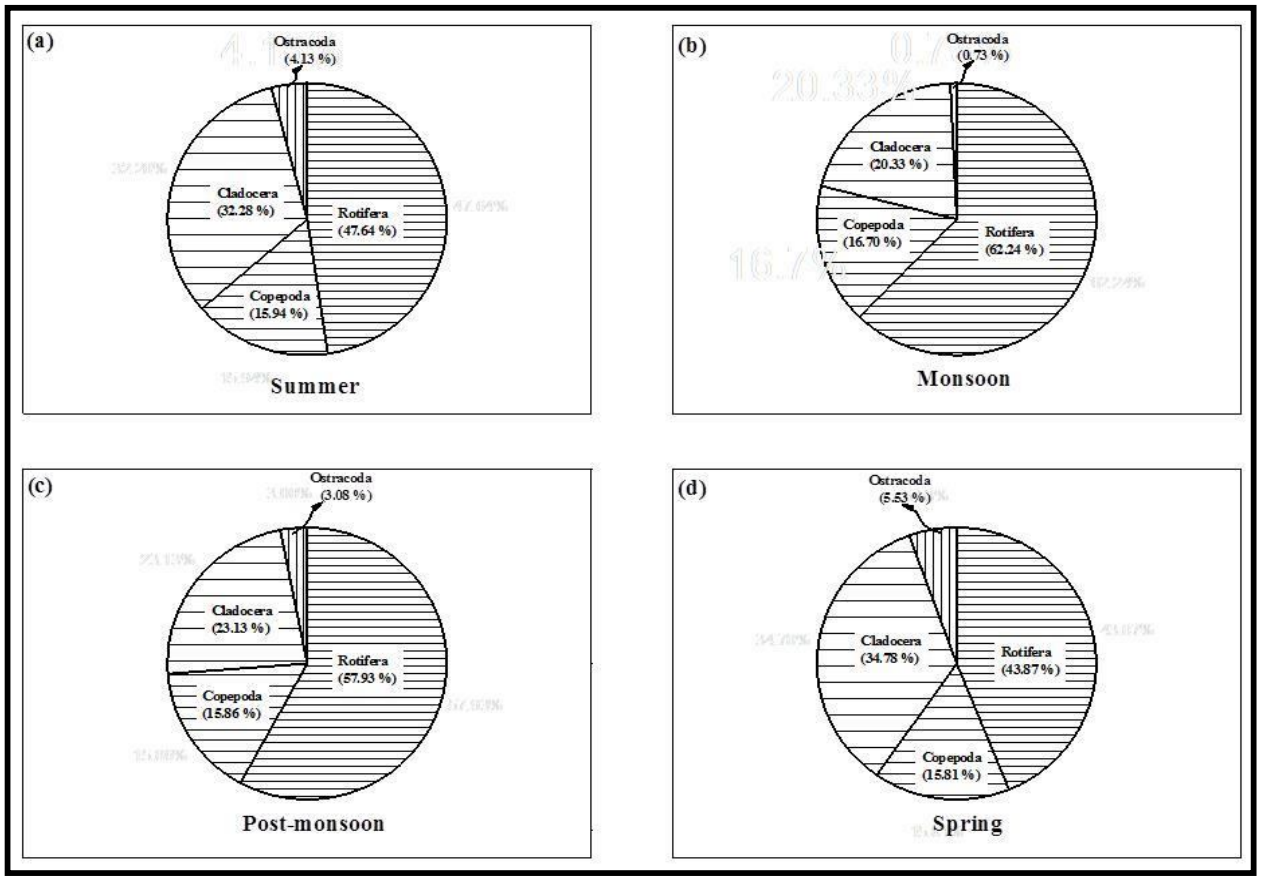

Figure 3: Pie-chart showing seasonal abundance of four major groups of zooplanktons available in SahebBandh, Purulia.

4. Conclusion

A quantitative approach was employed to study the abundance and diversity of zooplankton and its seasonal variation in the water of SahebBundh, Purulia, India. More than 98% of the available zooplanktons were classified in the four major zooplanktonic groups of Rotifera, Copepoda, Cladocera and Ostracoda. Total zooplankton abundance showed significant difference ($p < 0.01$) between stations and seasons ($p < 0.01$) i.e., in summer, monsoon, post-monsoon and spring. Significant differences were also observed with respect to four major groups between stations and seasons ($p < 0.01$). Seasonal variation in community composition of zooplanktons was studied calculating different biodiversity indices.

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