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ORIGINAL ARTICLE **OPEN ACCESS**

Diversity, Abundance and Seasonal Variation of Benthic Macroinvertebrates in Kolar Reservoir, Central India

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ABSTRACT
In the present study, qualitative and quantitative estimation of benthic macroinvertebrate fauna was carried at different stations of Kolar reservoir from pre-monsoon season to post-monsoon season confirmed benthic macroinvertebrate diversity of 43 species belonging to 3 different phyla, viz. Arthropoda, Mollusca, and Annelida. The most abundant species are observed in order Diptera, Phylum Arthropoda. The presence of species belonging to Phylum Mollusca is also more in number with the occurrence of Gastropoda and Bivalvia. The occurrence of Phylum Annelida is prominent with order Rhynchobdellida, Arhynchobdellida, Lumbriculida and Haplotaxida. The species belonging to order Opisthopora of phylum Annelida and order Littorinimorpha of phylum Mollusca are least in the study. Analysis of the various diversity indices showed that the diversity of benthic fauna was higher in monsoon season followed by post-monsoon and pre-monsoon season. Monsoon seems to be a favourable season for benthic organisms in Kolar Reservoir.
KEYWORDS: Benthic macroinvertebrate, Kolar Reservoir, Margalef's index, Pielou evenness index, Seasonal variation, Shannon-Weiner index, Simpson's index.

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INTRODUCTION

A major life-giving factor on earth is water and it supports a wide range of activities [1]. Benthic fauna lives on and in the bottom sediments of the water body or roam freely over rocks, organic debris, and submerged plant parts during their life cycle. For the aim of food, shelter, and reproduction they inhabit this niche of the ecosystem. Benthic fauna includes a heterogeneous assemblage of organisms representing various invertebrate phyla and others. The benthic community forms an important component of the food chain for the higher animal taxa transferring energy and matter from phytoplankton, macrophytes, and zooplankton to fishes, amphibians, reptiles, birds, and mammals [2]. These organisms inhibiting within the lentic or lotic water bodies, encounter the influence of human civilization and urbanization ultimately resulting in considerable variation in their community structure [3].

Benthic macroinvertebrates are attractive targets of biological monitoring efforts because they are various groups of long-lived, sedentary species that react strongly and sometimes, predictably to human influence on aquatic ecosystems [4]. Benthic macroinvertebrates and water quality are interrelated to each other, as they are a possible indicator of water quality [5]. Benthic communities are widely utilized in the monitoring of the effects of pollution because the organisms are mostly sessile and integrate the effects of pollutants over time. Further, the qualitative and quantitative changes in the benthic communities have also been used for developing pollution indices [6, 7, 8]. The copiousness of benthic invertebrates comprehensively depends on the physical and chemical characteristics of the substratum.

Benthic invertebrates show an irregular distribution in Indian reservoirs. The main factors that hold back the benthic community are the fast deposition of silt, frequent water level fluctuation, and mostly rocky bottom and other suspended particles. High shoreline development, variable slopes, and vegetation act as favourable factors for the development of a rich assemblage of benthic organisms [9]. The benthic fauna has a crucial position within the reservoir ecosystem, functions as a link between primary producers, consumers, decomposers, and better trophic levels [10]. They play an important role in key phenomena within reservoir ecosystems such as productivity, food chain dynamics, nutrient cycling, and decomposition [11]. Benthic invertebrates act as a link between primary producers, detrital deposits, and higher trophic levels in aquatic food webs. Therefore, any changes in the reservoir environment, like in mineral concentrations, would be reflected by changes within the structure of the benthic invertebrate community [12]. It means that benthic invertebrates may indicate eutrophication but several other modes of reservoir degradation may also occur.

A study on benthic fauna in Indian reservoirs especially in Madhya Pradesh exposes sparse information. This study has been done to find out the diversity of benthic fauna of Kolar reservoir, Sehore, Madhya Pradesh. The study was undertaken to investigate the diversity of the benthic fauna community and this provides information regarding the water quality of the reservoir as these organisms are inert and integrate the effect of pollution. The present study aimed to investigate the species composition, distribution, abundance and seasonal variation of diversified benthos assemblages in the Kolar reservoir.

MATERIAL AND METHODS

Study Area

The present investigation is based on a field study of the Kolar reservoir, Bhopal, Madhya Pradesh. Kolar reservoir is found about 32 km from Bhopal and at an equivalent level as Bhopal around 1600 ft. near Lawa khedi village in Sehore District. Kolar dam constructed across the Kolar River near Birpur, a tributary of Narmada on the proper bank, the dam is about 45 m high. The area around the reservoir is roofed with thick forest. The submerged area was also a neighbourhood of the forest before the development of the reservoir and thus numbers of trees are submerged within the reservoir. This reservoir (latitude 22°57'03" and longitude 77°18'13") features a catchment basin of 508 km^2. Kolar reservoir is employed for supplying drinking water to Bhopal city. Additionally, the reservoir serves the irrigation purpose of the encompassing areas and also an upscale source for the fishery industries.

Sampling stations

In order to study the benthic fauna of Kolar reservoir from, four stations were selected throughout the water body on the basis of habitat, nutrient type and supply which are as 1. Masonry Dam side, 2. Near Jhal pipli village, 3. Near Sali kheda Village and 4. Lawa khedi village (Table 1 and Fig. 1)

Table 1: Longitude and latitude of sampling stations

S. No.	Stations	Name of stations	Latitude	Longitude
1.	Station- I	Masonry Dam side	22°57'44.77"N	77°20'22.15"E
2.	Station- II	Near Jhal pipli village	22°57'03.62"N	77°20'40.69"E
3.	Station- III	Near Sali kheda Village	22°57'42.86"N	77°18'13.93"E
4.	Station- IV	Lawa khedi village	22°58'03.92"N	77°19'51.06"E

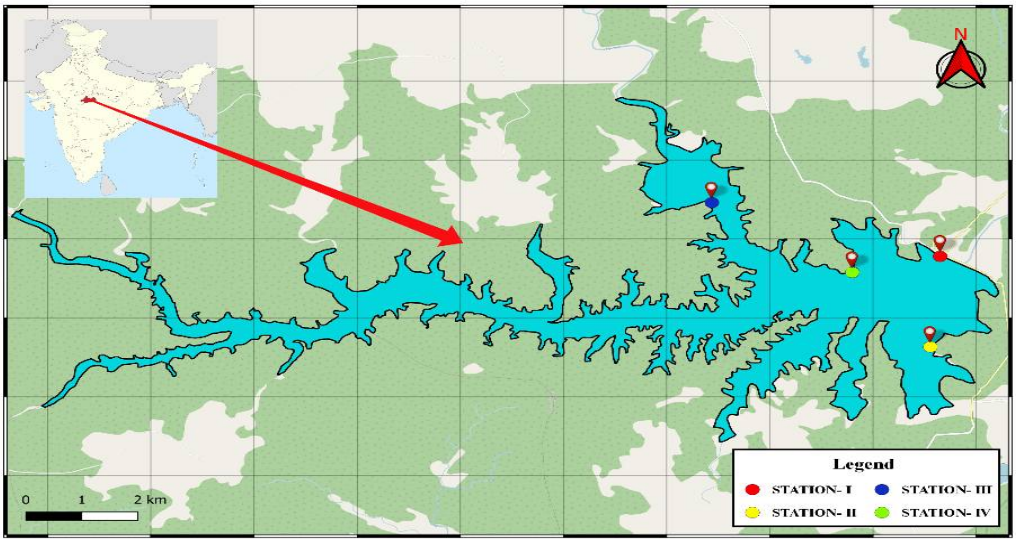

Fig. 1: Map of Kolar Reservoir indicating the study stations

Methodology

For the qualitative and quantitative study of benthic fauna, mud samples were collected in polyethylene bags during pre-monsoon, monsoon and post-monsoon seasons in the year 2017, using Ekman grab mud sampler. The dredged samples along with benthic fauna were screened through U. S. standard sieve no. 18 and 35 of 1 mm and 0.5 mm pore size respectively in order to remove fine sediments and any other extraneous material [13, 14]. The organisms, thus collected on the sieves were transferred to a white enamel tray and sorted out manually for macro benthic organisms and preserving the samples with 4% formaldehyde solution [15]. The results have been expressed in individuals/m^2. The identification of macro benthic fauna collected from the Kolar reservoir was carried up to the species level for their taxonomic and various morphometric characters with the help the standard literatures [16, 17, 18, 19, 20, 21].

The population density of benthic fauna was estimated by the following equation:

$$\textbf{Calculation}: \textbf{Individuals}/\mathbf{m^2} = \frac{\mathbf{Nx10,000}}{\mathbf{A}}$$

Where,

N = Average number of organisms per sample

A = Area of the sampler (232 cm^2)

Statistical analysis

The seasonal benthic macroinvertebrate diversity was computed using diversity indices. The Simpson's index, Shannon-Wiener diversity index, Evenness index, Margalef's richness index and Equitability index were calculated for estimating benthic diversity. The data has been subjected to diversity indices using PAST Software.

Simpson's index

$$\mathbf{1 - D = \left[\sum n_i\,(n_i - 1)\right] / N\,(N - 1)}$$

Where,

D: Simpson Diversity Index

n_i: Number of individuals belonging to i species

N: Total number of individuals

Shannon-Wiener diversity index

$$\boldsymbol{H' = -\sum[(n_i/N)\times(In\ n_i/N)]}$$

Where,

H′: Shannon Diversity Index

n_i: Number of individuals belonging to i species

N: Total number of individuals

Margalef's richness index

$$\boldsymbol{d = (S - 1)/In\,N}$$

Where,

d: Margalef Diversity Index

S: Total number of species

N: Total number of individuals

Pielou Evenness Index

$$\boldsymbol{J' = H'/H'_{max}}$$

Where,

J′: Pielou Evenness Index

H′: The observed value of Shannon index

H'_{max}: In S

S: Total number of species

RESULTS AND DISCUSSION

During the present study, a total of 43 species of benthic macroinvertebrates were sampled and identified from different stations of the Kolar reservoir. Out of 43 species, 24 belonged to phylum Mollusca, 10 to phylum Arthropoda, and 9 to phylum Annelida. The quantitative analysis showed that during the pre-monsoon season, the contribution of Arthropoda 51.5%, Mollusca was 39.0%, and Annelida 9.5% while during monsoon season, the contribution of Arthropoda 57.5%, Mollusca was 32.2% and Annelida 10.3% and in post-monsoon season, the contribution of Arthropoda 47.0%, Mollusca was 33.7% and Annelida 19.3% to the total benthic species at different stations of Kolar reservoir. Benthic macroinvertebrates have an important influence on the nutrient cycle, primary productivity, decomposition, and translocation of material [22, 23]. They are important to mankind due to their nutritive, pathological, and commercial importance [24]. Invertebrates are abundant and diverse in most of the aquatic habitats and are relatively easy to sample and analyse [25]. They are most commonly used for bio-monitoring in aquatic habitats worldwide [26].

In the pre-monsoon season, the average number of benthic macroinvertebrates was lower than that of monsoon and post-monsoon season. The number of species reported from the Kolar reservoir was higher (43 species) in the monsoon season as compared to pre-monsoon season (38 species) and post-monsoon season (42 species). Species composition was the same in pre-monsoon, monsoon, and post-monsoon season except for five species *i.e. Ranatra sp*., *Baetis sp., Anax junius, Melanoides sp. and Gabbia sp.* in pre-monsoon season and one species *i.e. Hydroptila sp.* in post-monsoon season at different stations of Kolar reservoir. The maximum benthic population was recorded in the monsoon season (12,427 individuals/m^2) and the minimum population was recorded in the pre-monsoon season (8,686 individuals/m^2).

The present study revealed that the Molluscs formed the bulk of benthic biomass but the Dipteran was more in number. Phylum Mollusca was reported with 24 species at different stations of Kolar Reservoir in pre-monsoon, monsoon, and post-monsoon season**.** The highest molluscan population density was recorded in the monsoon season (3,999 individuals/m^2). Molluscs act as intermediate foodstuffs between cereals and high protein sources such as fishes and birds. The fluctuations in dissolved oxygen content did not have any effect on the molluscan populations as they can survive in very low oxygen conditions [27, 28]. Molluscs are indicative of non-polluted water and O_2 rich habitat [2]. They play an important role in the mineralization and recycling of organic matter and are an important tool for improving and preserving water quality [29, 30].

In the Kolar reservoir phylum, Arthropoda was found mostly associated with aquatic macrophytes. It was observed that the appreciable seasonal changes of their population may be correlated with the appearance and disappearance of macro vegetation [31]. The number of individuals per unit area was found to increase in monsoon season (7,138 individuals/m^2), then started decreasing in post-monsoon season (4,902 individuals/m^2) and was lowest in pre-monsoon season (4,472 individuals/m^2). This seasonal variation in the abundance of individuals indicates that temperature has a pronounced influence on their life cycle. In the reservoir ecosystem, the significance of benthic fauna as a link in the energy flow from primary productivity to fish yield is well known. In the Kolar reservoir, the most dominant species among phylum Arthropoda were *Chironomus sp*., *Chironomus plumosus, and Hydrellia sp.*

During the study period, the maximum contribution of phylum Annelida was made by order Rhynchobdellida (1,591 individuals/m^2). Whereas Arhynchobdellida (1,118 individuals/m^2) was dominant order followed by Haplotaxida (731 individuals/m^2), Lumbriculida (387 individuals/m^2), and Opisthopora (301 individuals/m^2) in pre-monsoon, monsoon, and post-monsoon season.

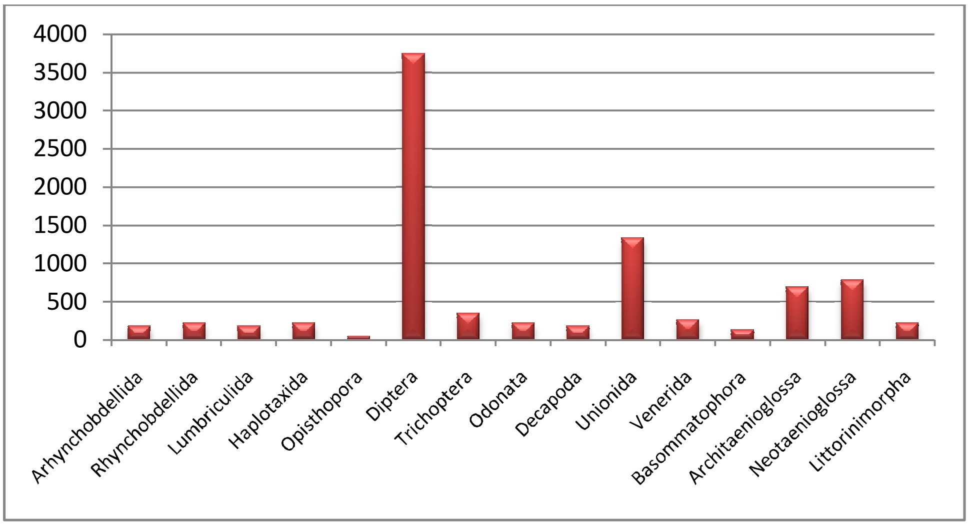

Fig. 2: Order wise individuals at different stations of Kolar reservoir in pre-monsoon season during 2017

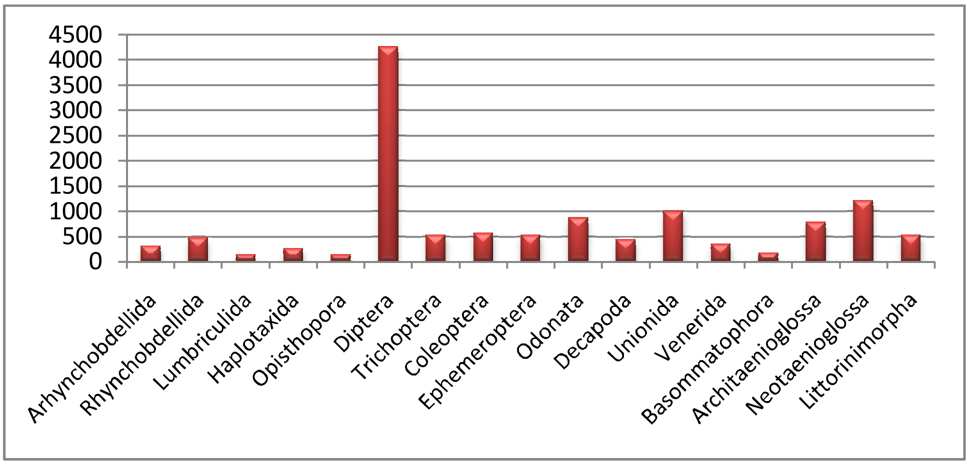

Fig. 3: Order wise individuals at different stations of Kolar reservoir in monsoon season during 2017

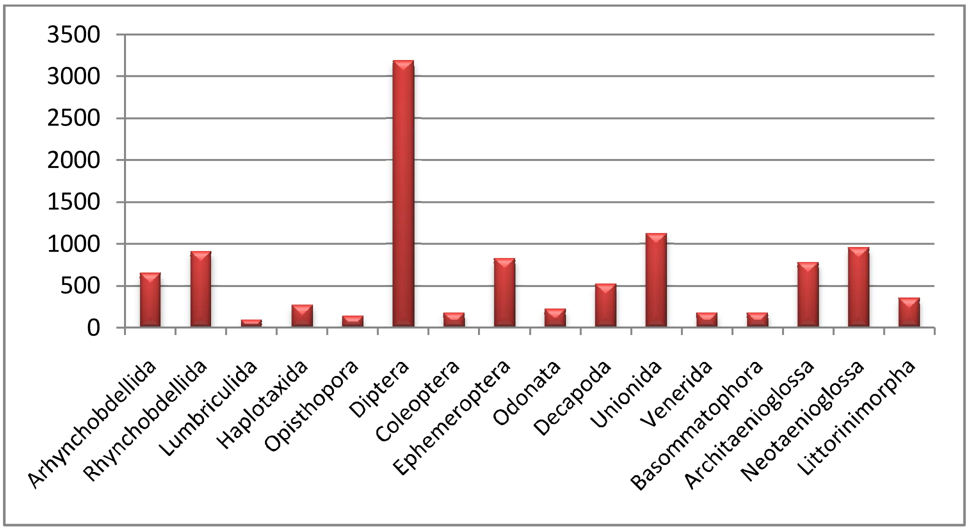

Fig. 4: Order wise individuals at different stations of Kolar reservoir in post-monsoon season during 2017

The abundance, population density, and diversity of benthic fauna mainly depend on the physical and chemical properties of their habitat as they respond more quickly if any change in water quality occurs [5, 32]. Extended residency period of various macrobenthic communities in specific habitats and presence or absence of particular benthic species in a particular environment can be used to group them as bio-indicators of specific environmental & habitat conditions [33]. These can be used as a barometer of the overall biodiversity of an aquatic ecosystem [34]. Benthic fauna is especially of great significance for fisheries as they act as the food of fishes [35].

Diversity indices provide important information about the rarity and commonness of species in a community [36]. A comparison of different diversity indices for pre-monsoon, monsoon, and the post-monsoon season is given in Fig. 4, 5 and 6. The maximum number of species and individuals were recorded in the monsoon season followed by post-monsoon and pre-monsoon season.

Table 2: Variation in various diversity indices at different stations of Kolar reservoir in pre-monsoon season during 2017

Diversity indices	Station-I	Station-II	Station-III	Station-IV
Taxa_S	25	31	22	17
Individuals	2279	2451	2408	1548
Simpson_1-D	0.9377	0.9566	0.9031	0.8904
Shannon_H	2.994	3.281	2.657	2.49
Margalef	3.104	3.844	2.697	2.178
Pielou_J	0.9301	0.9556	0.8597	0.879

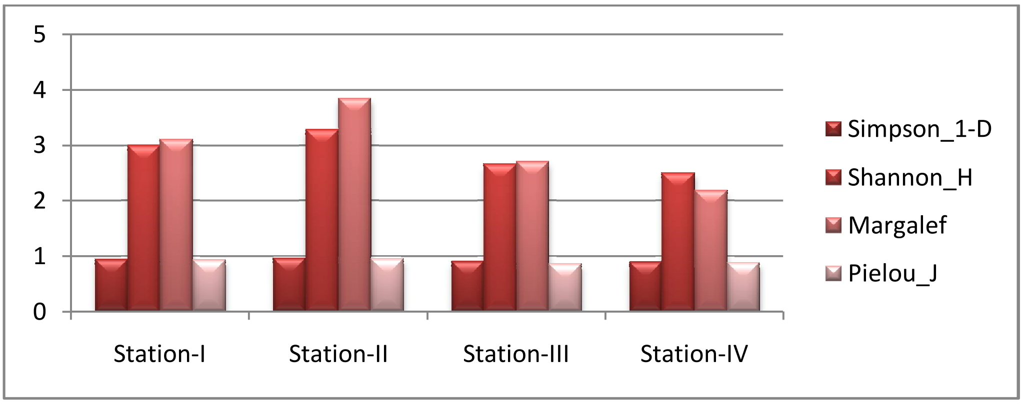

Fig. 5: Variation in various diversity indices at different stations of Kolar reservoir in pre-monsoon season during 2017

Table 3: Variation in various diversity indices at different stations of Kolar reservoir in monsoon season during 2017

Diversity indices	Station-I	Station-II	Station-III	Station-IV
Taxa_S	35	34	24	30
Individuals	3612	3139	2623	3053
Simpson_1-D	0.9589	0.9589	0.9153	0.9454
Shannon_H	3.37	3.352	2.783	3.14
Margalef	4.15	4.099	2.922	3.614
Pielou_J	0.948	0.9507	0.8758	0.9231

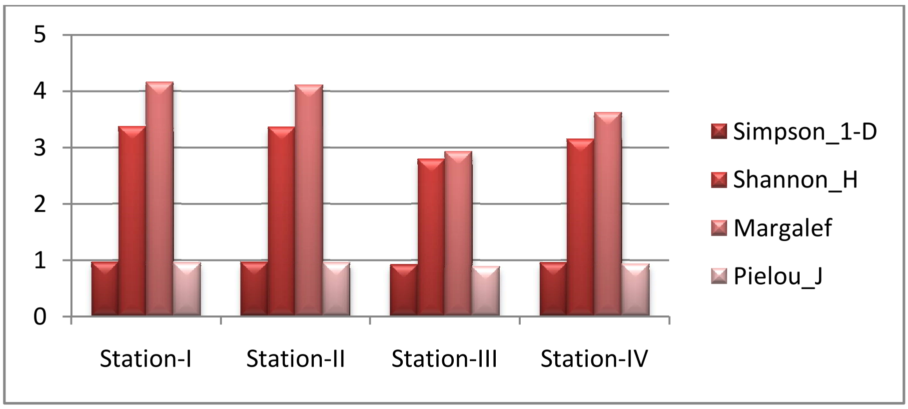

Fig. 6: Variation in various diversity indices at different stations of Kolar reservoir in monsoon season during 2017

Table 4: Variation in various diversity indices at different stations of Kolar reservoir in post-monsoon season during 2017

Diversity indices	Station-I	Station-II	Station-III	Station-IV
Taxa_S	31	32	24	24
Individuals	2924	2967	2322	2236
Simpson_1-D	0.9546	0.9599	0.9252	0.9371
Shannon_H	3.251	3.329	2.852	2.952
Margalef	3.759	3.877	2.968	2.982
Pielou_J	0.9468	0.9604	0.8975	0.9287

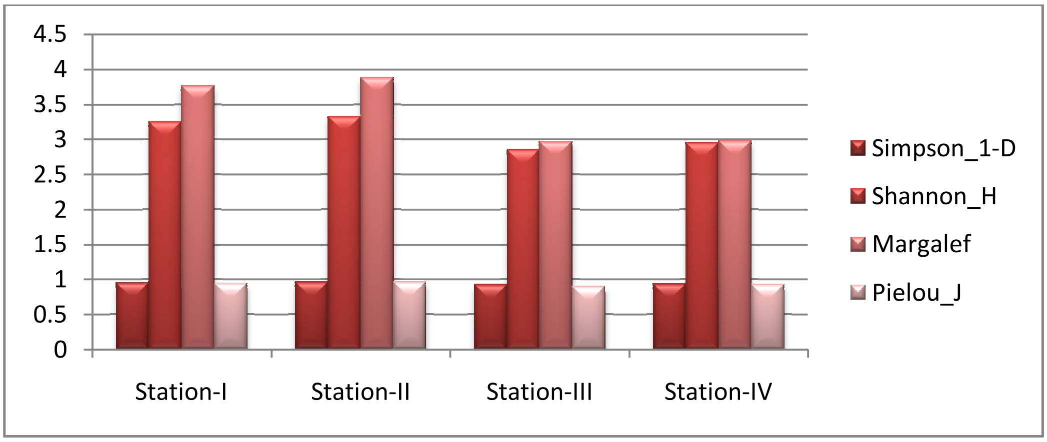

Fig. 7: Variation in various diversity indices at different stations of Kolar reservoir in post-monsoon season during 2017

Analysis of the Shannon and Simpson index of diversity showed that diversity of benthic fauna was higher in monsoon season followed by post-monsoon and pre-monsoon season.

As the species diversity index and species richness index depend upon the number of species as well as the number of individuals in each species and contributes equally to these index values [37], hence decreases or increases in any one of these two variables will influence the overall values of these indices. The high values of indices showed high taxa richness and high relative abundance of benthos which was due to favourable physico-chemical and trophic factors [38].

In the present study overall maximum species, richness in terms of Margalef's index was seen in monsoon season at station-I. In pre-monsoon season maximum species richness in term of Margalef's index was seen at station-II and minimum at station-IV while in post-monsoon season maximum species richness was seen at station-II and minimum at station-III.

Evenness reflects the abundance of the population within a habitat. Evenness was highest in the case of the post-monsoon season and lowest in pre-monsoon season. This means that species evenness decreased with the decrease in the size of the population. It was observed that resource partitioning and niche specialization are the most common ecological features of the species.

CONCLUSION

The diversity, abundance and dominance of benthos indicate well established balanced ecosystem for supporting a complex food web existing in the Kolar reservoir. As discussed above a total of 43 taxa were recorded during the study with different compositions at various stations. The most dominating phylum was arthropods followed by molluscs and then annelids, as also observed by Shrivastava *et al.,* in the year 2003 [39]. It can be concluded that arthropods dominate where organic matter is abundant while molluscs and annelids predominate at stations where macrophytes, sand, and mud found in the reservoirs. The present study revealed that the Kolar reservoir exhibits its uniqueness in benthic diversity.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest

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