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Temporospatial variation in zooplankton abundance and diversity in the Narmada River near Chutka, Madhya Pradesh, India

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Abstract
Various anthropogenic and climatic factors pose a threat to the ecological integrity of the river ecosystem. Temporal and spatial changes in zooplankton abundance and diversity predict the environmental health of the River stretch. The present study reveals that alteration in zooplankton composition occurs seasonally and location wise in the River Narmada around Chutka. Zooplankton community represent twenty-nine genera belong to Cladocera, Copepoda, Rotifera, Protozoa, larvae, and eggs of different species. The dominance of genera was in the order of Copepoda>Rotifera>Larval forms>Cladocera>Protozoa, which is almost similar to the zooplankton dominance reported earlier in the Narmada water at Jabalpur. The seasonal change in the abundance was distinct, and the highest population density was recorded in post-monsoon, while the lowest number of zooplankton was noticed in winter. Zooplankton community and individual genera show high and significant correlation with environmental factors, particularly with pH and hardness. A contrary, negative relationship existed between nitrite-nitrogen and individual zooplankton group. Shannon's diversity index was low, but varied location wise. Overall results indicate spatial and temporal variation in the zooplankton population. Besides, the zooplankton population showed spatial diversity and correlation with chemical parameters of the Narmada water.

Keywords: Zooplankton, diversity, water quality, Narmada, Chutka

Introduction
Zooplanktons are free-living organisms play a crucial role in the nutrient cycle and energy flow in river ecosystem [1]. Physical and chemical characteristics of an ecosystem influence species composition and distribution of zooplankton [2]. Thus, different group of zooplankton adopt various strategies to cope with the fluctuating extreme environmental conditions [3]. Zooplankton community respond fast to various fluctuating water parameters particularly to temperature, conductivity, pH, alkalinity, and nutrient contents.
Exploring and interpreting biodiversity patterns are basic interests in ecology. River basin and floodplains serve as key biodiversity hosts globally, particularly owing to their high spatiotemporal variability and heterogeneity at multiple scales [4]. Diverse nature of river water bodies influence habitats of microorganisms and adapt suitable ecological strategies for acclimation and flourish [5]. Zooplankton diversity serves as crucial ecological indicators of the aquatic ecosystems. Also, zooplankton diversity is essential for maintaining ecosystem healthy because of their significant role in recycling nutrients, structuring food webs for maintaining a healthy ecosystem [6]. Sensitiveness to anthropogenic impacts and environmental fluctuations, the zooplankton diversity pattern may predict the long term changes of any aquatic ecosystem [7, 8]. Dramatic rates of river intervention by constructing dams and artificial levees worldwide [9] have impeded the dynamic effect of the flood pattern in most floodplain areas in rivers. In spite of multiple evidences showed the effects of dynamic water levels on the organism's diversity in flood plains, scanty information is available on the expected consequences of the deterioration of environmental heterogeneity which causes a threat to biological diversity. The River Narmada is the largest west-flowing River and a series of the dam has been constructed across the entire Narmada River. Besides rapid urbanization, agricultural and industrial development has taken place in several parts of the Narmada basin. As a consequence, the basin not only deteriorated the sanctity of the River but affected abiotic and biotic parameters of the ecosystem.

Among thirty large dams, Bargi dam constructed in Madhya Pradesh along the upper zone of the River and impeding the river course with dams altered basin conditions. Moreover, a plenty of hills and hillocks present in the upper valley project areas created uneven depth amid the captive river basin [10]. Recently Nuclear Power Corporation India Ltd. and Department of Atomic Energy, Government of India have proposed the construction of a nuclear power plant at Chuka village of Mandla district of Madhya Pradesh. Chutka is located on the right banks of River Narmada near Bargi Dam reservoir (Rani Avanti Bai Lodhi Sagar Dam). There is plenty and continuous supply of freshwater available for the smooth functioning of a power plant. The present study has been carried out from 2013 to 2015 for assessing zooplankton distribution and diversity with relation to physicochemical parameters of Bargi dam around Chutka on the Narmada River basin.

Material and methods

Study area

Stretch of 39.5 km along the Narmada River around Bargi dam was surveyed using boat. Seven locations (Table 1 and Fig. 1) were selected for the samples collection on the basis of approachability and availability of water throughout the year. Sampling sites were selected in a way, that it covered maximum habitats including shallow with rapid flow, deep with slow flowing water and lentic water (reservoir).

Table 1: Geographical locations and physiography of sampling sites.US, Upstream, DS.

Serial no.	Sampling Points	Latitude (°E)	Longitude (°N)	Physiography
S1	Tewar (DS)	22°97’.071	79°87’.919	*Shallow &rapids*
S2	Zero tanky (DS)	22°92’79	79°90’235	*Reservoir*
S3	Poudimul (DS)	22°84’774	80°01’284	*Deep/ slow flowing*
S4	Tatighat (DS)	22°76’93	80°08’368	*Deep/ slow flowing*
S5	Chutaka	22°78’213	80°09’301	*Reservoir*
S6	Patha (US)	22°84’774	80°01’284	*Reservoir*
S7	Kikara mal (US)	22°77’552	80°18’989	*Deep/ slow flowing*

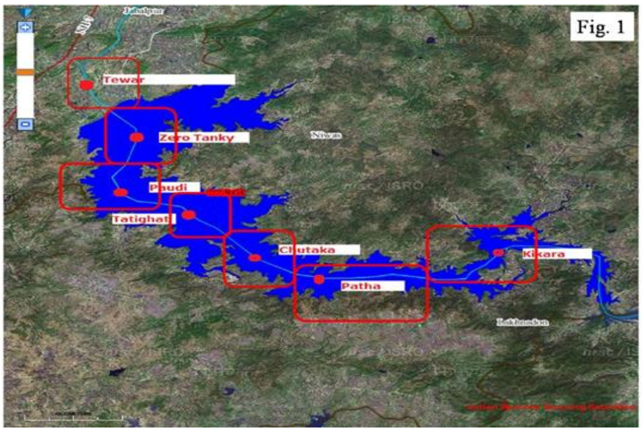

Fig 1: Portal map of sampling locations along the Narmada River around Chutka.

Analysis of Physicochemical parameters of water

Selected physicochemical parameters were analysed in different seasons such as summer (mid-March to mid-June), monsoon (Mid- June to mid-September), post-monsoon (Mid-September to mid- December) and winter (Mid-December to mid- March) during 2013 to 2015. Surface water temperature was measured *in situ* using a mercury thermometer. pH was measured using a portable instrument (HANNA meter model 210). Dissolved oxygen (DO), nitrate-nitrogen, nitrite-Nitrogen (NO3-N; NO2-N) and phosphate-phosphorus (PO4-P) were analyzed following standard guidelines and procedures [11].

Collection and analysis of zooplankton

Zooplankton samples were collected by using plankton net having pore size 45 µ, wide mouth of diameter 30 cm and length 70 cm [12]. The net was trawled on the surface of the water for a distance of 10m at dusk. The zooplankton collected was anesthetized with commercial sparkling water and preserved in 4% formalin [13]. Sucrose was added particularly to prevent female Cladocerans from damaging eggs and to minimize carapace distortion. In the laboratory, three sub-samples were taken from each habitat sample, and all individuals were identified [14] and counted in a Sedgwick Rafter counting cell (1 mL), qualitative and quantitative analysis of zooplankton was done by following [15]. The identification of zooplankton was made following standard protocol [16, 17].

Statistical Analysis

Analysis of Variance (ANOVA) and correlation among the water parameters and microalgae abundance was done using SPSS. Primer 5 (version 5.2.9), and Bio Diversity Pro (version 2) were used to determine the diversity pattern of the zooplankton community at different sampling stations.

Results and Discussion

Physical and chemical characteristics of water

Physical and chemical water parameters showed location variation and in some cases seasonal fluctuations. Characteristics of water bodies influence the abundance, species composition, and diversity of aquatic organisms. Among the different sites of sampling, the average temperature was lowest at Tewar and highest at Tatighat, which did not vary further upstream (Fig. 2). The average water temperature ranged between 32.0 °C and 16.8 °C.

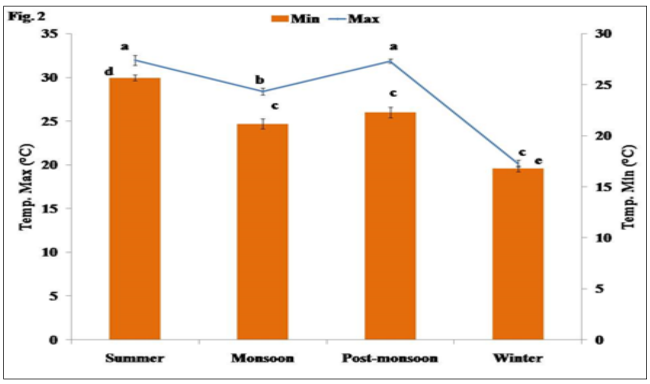

Fig 2: Seasonal variation in temperature. Max, maximum temperature; Min, minimum temperature. Values are mean ± SEM. Different letters depict statistically significant (*p*<0.05).

The average maximum surface water temperature ranged between 20.2 ± 0.39 °C and 32.0± 0.55 °C, while the mean minimum temperature was in the range of 16.8 to 25.7 °C in the Narmada water under study (Fig. 2). The mean maximum temperature in summer did not significantly vary from that of the post-monsoon season, whereas the temperature decreased significantly in monsoon and winter seasons. The average minimum temperature significantly varied among the seasons (Fig. 2). The minimum and maximum temperature of upper stream of the Narmada River at Manot ranged between 17.33 and 27.45 °C [18], whereas, the same of the Narmada basin at Sethanighat has recorded between 20.3 °C and 28 °C in the winter and summer season respectively, with a mean value of 24.1 °C [19].

In the present study, the pH values were circum-neutral, and maximum average pH value of 7.52±0.19 was recorded in Kikramal, whereas the minimum value was noted as 7.1±0.15 in Chutka, which was not significantly different ($p>0.05$) from that of Tatighat (Fig. 3A). The pH of other locations was not significantly varied ($p>0.05$) from the value of Kikramal. Although the pH values varied in different seasons between 7.2 and 7.6, the post-monsoon pH value was significantly different ($p<0.05$) among the seasons (Fig. 3B). The pH of Narmada water was reported in the range of 7.6 to 8.6 in the upstream, midstream, and downstream of Sethanighat in the river Narmada [19]. The pH at Manot located along the upstream of the river Narmada was in the range of 7.7 to 8.33 [18], which was slightly higher than that of the present value.

The DO levels in different sampling locations ranged between 6.5 and 8.1 mg L^{-1} with significant differences among the locations. The DO level in Paudimal and Tatighat (6.5±0.3 mg L^{-1}) located just the up-stream of the Bargi dam (Zero tanky) was significantly lower ($p<0.05$) compared to other locations (Fig. 3A). Seasonal variation of DO was observed in the range of 6.23 to 7.51 mg L^{-1} during the study, and there were significant differences between the values of post-monsoon and the rest of the seasons (Fig. 3B). The DO level of the Narmada River at Manot was reported between 4.75 and 7.23 mg L^{-1} [18]. The DO level in the range of 4 to 6 mg L^{-1} is generally considered suitable for healthy aquatic life [20].

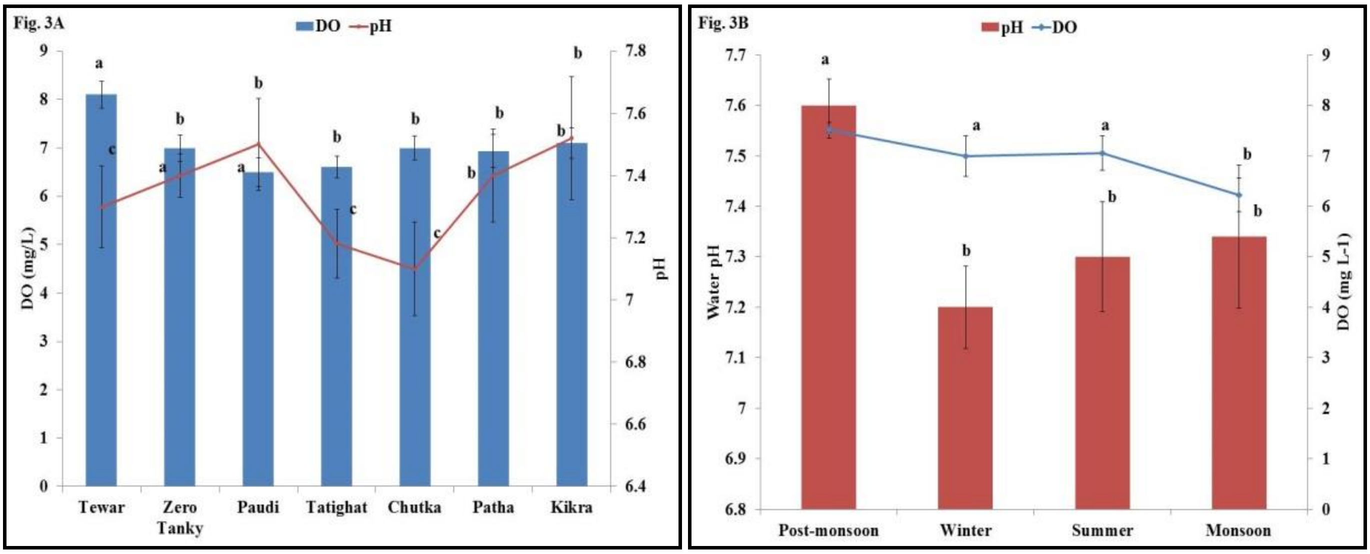

Fig 3: A. Spatial variation in dissolved oxygen (DO) and pH. **B.** Seasonal changes in DO and pH during study period. Values are mean ± SEM. Different letters depict statistically significant ($p<0.05$).

The water alkalinity signifies capacity to neutralize a strong acid and is distinguished by the presence of hydroxyl ions capable of forming complex with hydrogen ions [21]. The alkalinity of different sampling sites ranged from 113.0 to 116.5 mg/L with maximum value in Patha and minimum in Zero Tanky (Fig. 4A).The seasonal alkalinity showed similar values and did not vary significantly (Fig. 4B). An earlier study reported that alkalinity was highest in monsoon and low in winters, but no regular trend was observed with mean values in Narmada River at Hosangabad, Madhya Pradesh [22]. Much higher values were reported between 129 and 234mg/l in the river Narmada near Sethanighat, with highest and lowest values in the winter and monsoon, respectively [19].

Total hardness at different sampling sites varied from 76.65 to 112.5 mg/L with maximum and minimum values at Zero Tanky and Kikra, respectively (Fig. 4A). Total hardness remained between 83.1 and 88.1 mg L^{-1}, did not change seasonally ($p>0.05$) (Fig. 4B). The mean value of total hardness was recorded as 125.75±44.78 with wide fluctuations seasonally in the river Narmada at Hoshangabad, Madhya Pradesh [22].

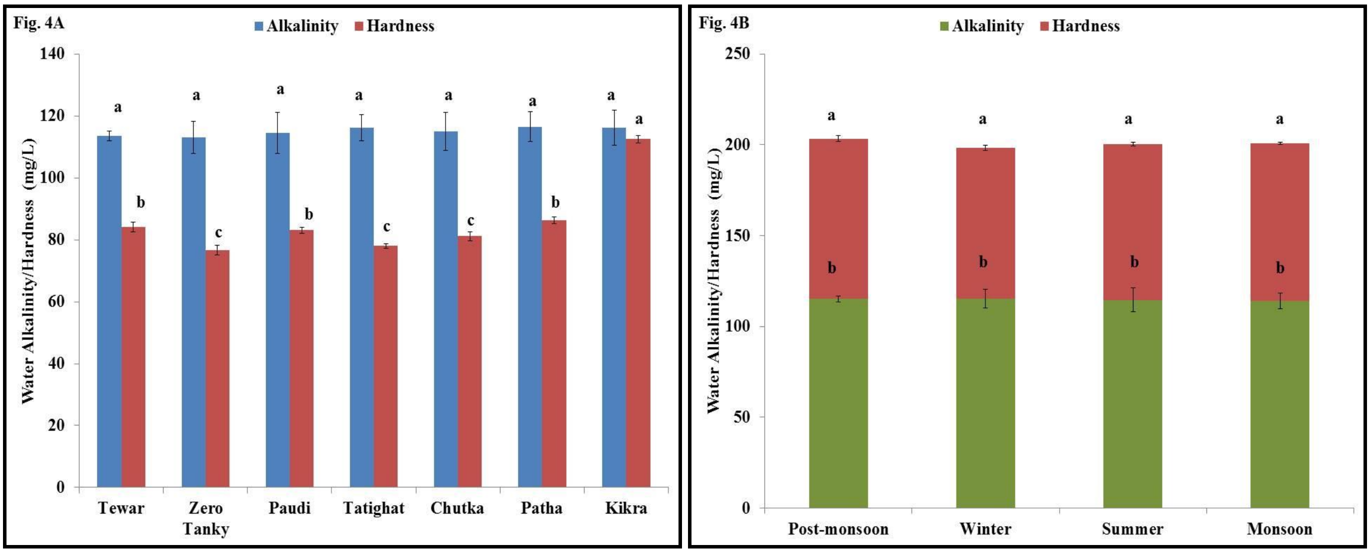

Fig 4: A. Spatial variation in alkalinity and total hardness. B. Seasonal changes in alkalinity and hardness during study period. Values are mean ± SEM. Different letters depict statistically significant (p<0.05).

Total hardness fluctuated from 140 to 198mg/l in the winter and monsoon seasons respectively with a mean value of 169 mg L^{-1}in the Narmada near Sethanighat [19].

Phosphate content in water bodies cause eutrophication in freshwater system if exceeds a critical limit. In the present study, mean phosphate concentrations ranged between 0.28 and 0.83 mg L^{-1}, and the maximum and minimum value were recorded at Patha and Tewar, respectively (Fig. 5A). The phosphate concentrations in monsoon were significantly lower (p<0.05) compared to other seasons (Fig. 5B). The phosphate value was reported between 0.1 to 0.4 mg L^{-1} in the Narmada water near Sethanighat, M.P. [19]. In the present study, the phosphate concentration was more than 0.090 mg/L, represents a freshwater body of meso-eutrophication status[23]. A wide range of phosphate value between 0.02 and 0.7 mg L^{-1} was reported in the upper stretch of the Narmada River at Manot [18]. Discharge of industrial and sewage wastes or inflow of fertilizer creates higher phosphate level in river water [24].

Various agricultural and anthropogenic activities increase nitrate level of surface water, otherwise the level remains below or equal to 1mg L^{-1} [25, 26]. The NO3-N values ranged between 0.15 and 0.52 mg L^{-1}in different sampling sites, and the lowest value was recorded in Tewar followed by Patha compared (p<0.05) to that recorded for other sites (Fig. 5A). Seasonal variation in NO3-N values was not noticed during the study period (Fig. 5B). The nitrate nitrogen value varied widely between 0.03 to 1.9 mg L^{-1}in Manot at upstream of the Narmada [18]. The NO2-N values ranged between 0.2 and 0.56 mg L^{-1}in different sites and spatial changes follow the same pattern as shown by nitrate nitrogen. The values of nitrite nitrogen were not significantly different among seasons (Fig. 5B).

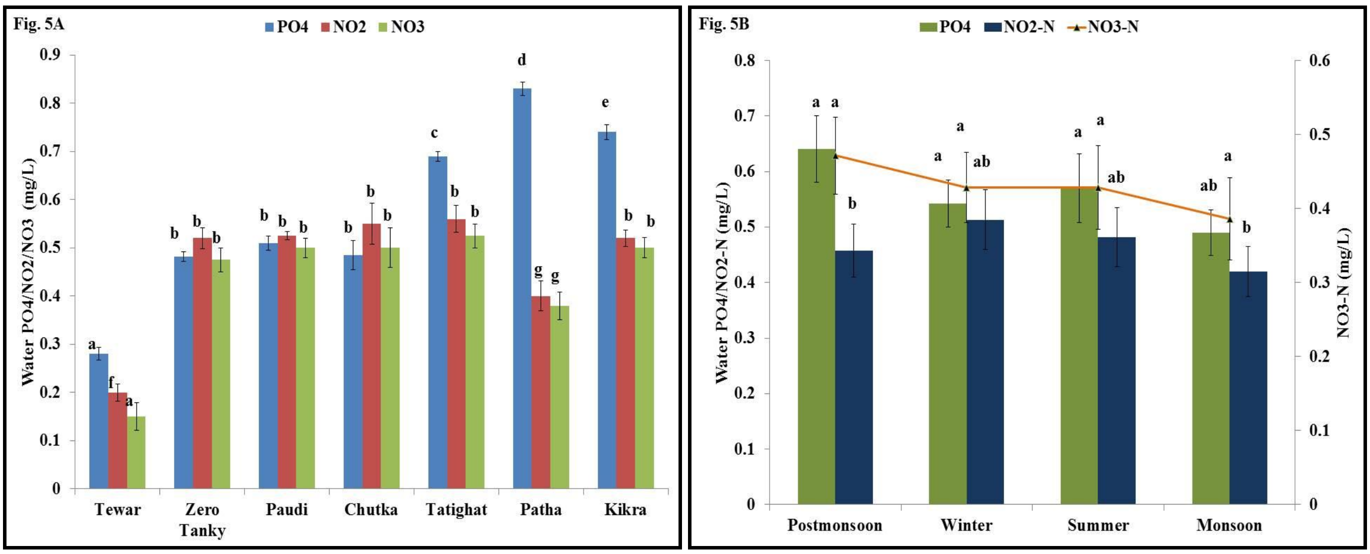

Fig 5: A. Location wise variation in phosphate (PO4), nitrite (NO2-N) and nitrate nitrogen (NO3-N) in water. B. Seasonal changes in PO4, NO2-N and NO3-N during study period. Values are mean ± SEM. Different letters depict statistically significant (p<0.05).

Composition of zooplankton Communities

Zooplankton community of the Narmada River around Chutka comprised of Twenty nine genera belonging to five groups (Table 2), such as Cladocera (10 genera), Copepoda (7 genera), rotifer (6 genera), protozoa (6 genera) and larvae and eggs of different species. Among the groups, Copepoda ranked first in percentage composition with 24%, followed by Rotifera 22.9%, larvae and eggs 22.2%, Cladocera, Cladocera

16.6% and Protozoa 14.3% (Fig. 6B). Similarly twenty eight species were reported from the Narmada River at Jabalpur site (Pandey *et al*., 2015), whereas, Rai *et al*., (2016) reported a total of 23 species belonging to four groups such as, Rotifera (7 species), Cladocera (4 species), Copepoda (5 species) and Protozoa (7 species) from the same area. Among Copepod, *Diaptomus spp.* was most dominant, followed by *Mesocylops spp.*, while among rotifer, *Keratella* was the most dominant genus, followed by *Echlanis*.

Table 2: The most frequent taxa of zooplankton in the Narmada River under study.

Group	Species
Cladocera (10)	*Polyphemus spp., Monia spp., Pediculus spp., Chydorus spp., Alona spp., Pleuroxus spp., Ceriodaphnia sp., Simocephalus spp., Macrothrix sp., Monostyla spp.*
Copepoda (7)	*Cyclops spp., Mesocyclops spp., Macrocyclop ssp., Diaptomus spp., Eucyclopsprionophorus sp., Bosmiacornuta spp., Cypris sp.*
Rotifera (6)	*Branchionus caudatus, Haxarthra sp., Keratella spp., Echlanis sp., Cephalodella auriculata, Chromogaster spp.*
Protozoa (6)	*Arcella sp., Actinophyxis spp., Prorodon spp, Vorticella sp., Lacrymaria sp., Opercularia sp.*
Larvae and eggs	Copepod, Brachiopod, Gastropod *Zoea*, Bivalvia, Decapod, Bivalve eggs

The population density of zooplankton was ranged between 352 and 1180 organisms/m^3 during the study period (Fig. 6A). Zooplankton abundance was higher in the upper reaches (59.0–3132.u.l^1) in compare to the middle sector (8.3–14.4 u.l^1) of the Narmada River [10]. Earlier reports showed a different trend of the dominance of zooplankton at various locations along the Narmada River basin. The Rotifera followed by Cladocera dominated in the zooplankton communities at Jabalpur, Omkareshwar, Mandleshwar, Maheshwar and Barwani region [21, 22]. Zooplankton distribution is often related to the presence of plankton feeder fish and their feeding habits [29]. Minimum abundance of Cladocera indicates presence of planktivorous fish, because they prefer large plankton like Cladocera than the smaller groups like rotifers [30]. The present order of dominance of zooplankton groups is almost similar to the zooplankton dominance in the Narmada water at Jabalpur [27].

Seasonal variation in zooplankton community

Zooplankton community showed significant seasonal variation, the maximum and minimum population density was noticed in the po
st-monsoon and winter season respectively. The summer abundance was significantly (p<0.01) lower than that of post-monsoon, whereas, did not vary (p>0.01) from that of monsoon (Fig. 6A). The individual group showed almost similar pattern like total abundance except protozoa and copepod. The abundance of protozoa and copepod did not vary between post-monsoon and monsoon (Fig. 6C). The protozoa abundances remained same in all the seasons except winter (Fig. 6C). The Copepoda abundance drastically decreased in summer and further in winter. Similarly, the zooplankton abundance in Nanfei River, China was much higher in autumn compared to the other season [34]. The water residence time increases in the dry season (autumn) and the slow water flow in the river accumulate phytoplankton biomass. As a result, the grazing conditions improve and zooplankton increased in number [34].

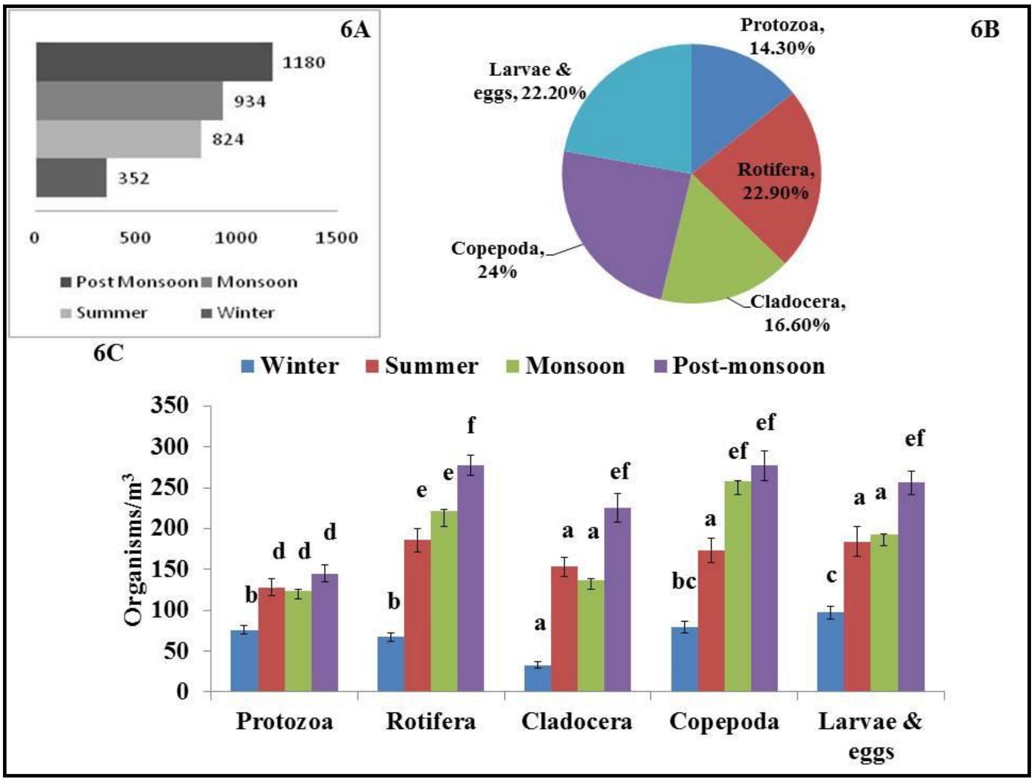

Fig 6A: Spatial variation in zooplankton number in the study area. **B.** Share of individual zooplankton group in the total community. Seasonal changes in various groups of zooplankton during the study. Values are mean ± SEM. Different letters depict statistically significant (p<0.05).

Seasonal zooplankton abundance in the Narmada near Hoshangabad showed a significant peak in the summer season of the first year while in the second year the zooplankton peak shifted to the monsoon season [31]. Similar to the present study, Copepoda and Cladocera were dominant species in post-monsoon and monsoons in Ukkadam lake, Coimbatore [32].

Correlation of chemical parameters of water and zooplankton

Correlations analysis showed a highly significant and positive correlation of zooplankton community and individual genera with pH and hardness (pH, r = 0.76 to 0.88 and hardness, r >0.92) similar to the earlier report in Narmada water [21]. Among zooplanktons, Cladocera showed a positive correlation with all the phytoplankton groups, protozoa, and rotifer indicates Cladocera flourishes at a place abundant with its food [33]. Contrary, negative correlation (r = -0.66 to 0.88) existed between nitrite-nitrogen and individual zooplankton group. The larvae showed moderate correlation (r = 0.62-0.8) with phytoplankton groups, and high correlation (r = 0.93 to 0.99) with all the zooplankton genera. Nitrate-nitrogen showed positive correlation (r = 0.98) with PO4. The present study reveals the significant positive correlation among temperature, pH, chloride, and rotifers density. Earlier studies correlate zooplankton abundance concerning other abiotic factors like pH, total nitrogen, total and soluble phosphorus in Nanfei River [34].

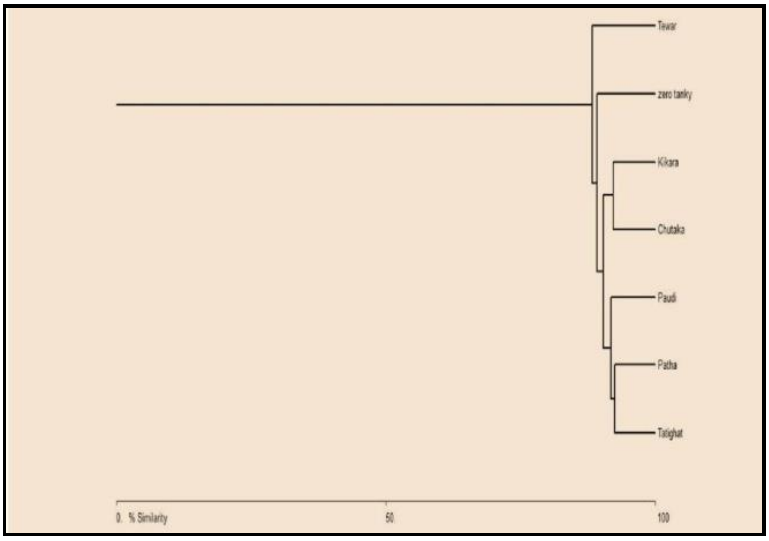

Fig 7: Similarity index among the various locations under study.

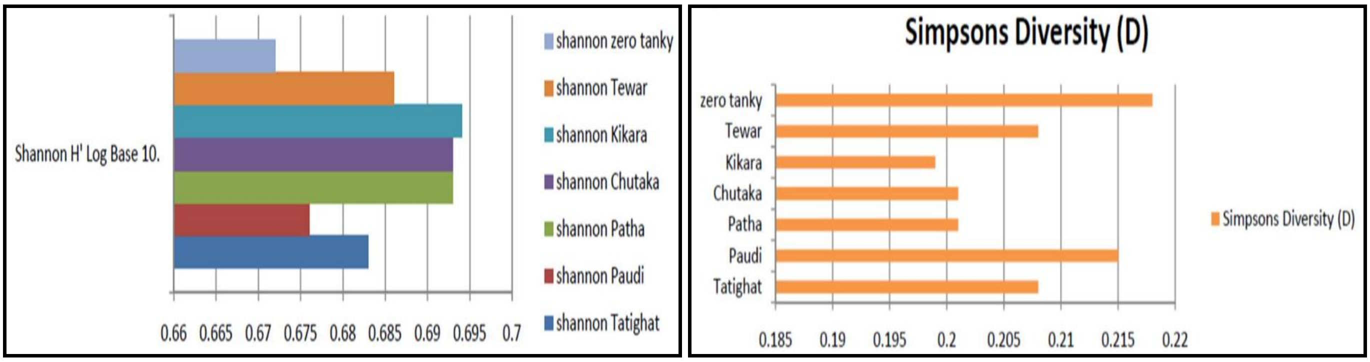

Fig 8&9: Changes in evenness (Fig. 8) and richness (Fig. 9) in zooplankton population in various locations.

Zooplankton diversity

Three different analyses were performed to evaluate the diversity of zooplankton population among the different locations. Bray Curtis cluster analysis showed that there was more than 90% similarity between zooplankton population at Patha and Tatighat as well as between Chutka and Kikramal (Fig. 7). Besides, it revealed that zooplankton composition at Tewar was different than those of other sampling sites (Fig. 7).

Shannon-Weaver index reflects diversity in zooplankton communities. The Index value fluctuated narrowly from 0.672 to 0.694 during the study. The zooplankton diversity was maximum at Kikramal and minimum at Zero Tanky (Bargi) (Fig. 8). However, there was no difference in the diversity in the zooplankton population among three up-stream locations, Chutka, Patha, and Kikramal. Higher Shannon's diversity was reported between 3.46 and 3.18 in the Narmada River near Hoshangabad [31] and in Chambal River [35]. Low Shannon's diversity index in the current study indicates less diversity in the zooplankton population in the Narmada River around Chutka compared to that of Hoshangabad. Simpson's index indicated the even distribution in the population at Zero tanky (Bargi dam) followed Poudimal, Tatighat, and Tewar (Fig. 9). Zooplankton composition was least evenly distributed at Kikramal among all the stations (Fig. 9).

Conclusion

The present study reveals that alteration in zooplankton composition, abundance occurs seasonally and spatially in the River Narmada around the Chutka. Zooplankton community represent twenty-nine genera belong to Cladocera, Copepoda, Rotifera, Protozoa, larvae, and eggs of different species. The dominance of genera was in the order of Copepoda>Rotifera> Larval forms >Cladocera> Protozoa, which is almost similar to the zooplankton dominance in the Narmada water at Jabalpur [27]. The least population density was noticed in the winter season, and the highest population density was noticed in post-monsoon, which varied from summer and monsoon. Zooplankton community and individual genera show high and significant correlation with environmental factors, particularly with pH and hardness. Shannon's diversity index was low, but varied location wise. Overall results indicate temporal and spatial variation in the zooplankton population, which was correlated with environmental parameters of the study area.

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