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Ecology and Diversity of Zooplankton of the River Ganga at Bihar, India in Relation to Water Quality

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Abstract

A study was carried out to evaluate the ecology and diversity of the zooplankton of the Ganga River at Arrah from Bihar, India from January 2018 to December 2019. Varied physical and chemical parameters supporting the zooplankton and corresponding biodiversity indices were studied. The water temperature showed inverse correlation with pH, dissolved oxygen, whereas direct relationship with total alkalinity, hardness, chloride, nitrate and sulfate. A total of 23 genera of zooplankton belonging to 6 genera of Rotifera, 5 of Protozoa, 5 of Cladocera, 4 of Copepoda and 3 of Ostracoda were identified with a density from 2 to 213 ind./L. The analysis showed that density of zooplankton declined in post-monsoon and remained maximum in summer because of the various environmental and inflow characteristics of the water body. The density of zooplankton showed direct correlation with total alkalinity, hardness and chloride of water but inverse correlation with water temperature, pH and dissolved oxygen. Shannon-Weiner index, Margalef richness index, Pielou's evenness index, Menhninick's index and Simpson index were won't to assess relation of water quality with zooplankton and limnological profile of the river. The diversity indices indicated moderate to high diversity of zooplankton and moderately polluted conditions of the river.

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Introduction

The biota of aquatic systems affects directly or indirectly human beings. Among all the freshwater aquatic biota, zooplankton is able to reflect the physical and chemical parameters as well as secondary productivity potential of aquatic systems.[1] Zooplankton provides several advantages as indicators of environmental quality in lotic and lentic water bodies.[2] Zooplankton distribution shows wide spatio-temporal variations because of the various

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limnological factors on individual species. They additionally act as sensible indicators of water quality as the previous studies made on zooplankton from the River Ganga and River Tons in Utarakhand.[3,4] Zooplankton is employed in the conversion of plant protein into animal protein in the aquatic bodies.[5]

Freshwater zooplankton is generally dominated by Protozoa, Rotifera, Cladocera, Copepoda and Ostracoda. The Protozoan plankton has least developed or no locomotion however others could move in quiescent water. Zooplankton diversity refers to variety within community and their diversity is one of the most important ecological parameters as they are a link between phytoplankton and fish. Generally, species/genera richness indices are considered best indicator of biodiversity.[6,7,8]

The physical and chemical parameters like temperature, pH, dissolved oxygen etc. are affected by seasonal variations along water body that influence distribution, abundance and species diversity of zooplankton.[9] The species diversity and abundance of the community structure of the zooplankton is necessary to assess the potential fishery resource of an aquatic body.[10,11]

The plankton diversity seems one of the important ecological parameters in water bodies because of its participation in food chain. But information is lacking on quantitative aspects of zooplankton in relation to physical and chemical parameters and biodiversity studies at Arrah.[1,3] Hence, an attempt has been made to study certain aspects of zooplankton of the Ganga River, Arrah. The study will provide the basic information of ecology and the present condition of this water body.

Materials and Methods

Water samples were collected fortnightly between January 2018 and December 2019 from three stations at the Ganga River. The surface runoff water and sewage from the surrounding catchments area enter to degrade water quality. The climate of Arrah (25^{0}33'21.7584"N and 84^{0}39'37.1952"E) district is healthy, the district fall in drier part of India with annual rainfall 1025.2 to 1106.2 mm.

Water temperature and pH were assessed at the time of sampling using refractometer. pH, dissolved oxygen, total alkalinity, hardness, chloride, nitrate and sulfate were determined following standard methods.[12] Seasonal variations were observed during summer (March, April and May), monsoon (June, July, August and September) post-monsoon (October and November) and winter (December, January and February).

Zooplankton was collected by horizontal hauls at a depth of about 1.00 m for 5-10 minutes using bolting silk net with a mouth area of 0.0855 m^2 and mesh size 0.02 mm. Collected samples of zooplankton were transferred to 100 ml plastic bottles and fixed with 10% formalin. Stereoscopic microscope and Olympus FX 100 microscope were used to observe plankton and standard keys were used for identification.[13] Sedgwick rafter was used for cell counting. The zooplankton density was quantified by Drop Count Methodology.[14]

The values of Shannon-Weiner index (H') <1.0 indicate heavy pollution, from 1.0 to 3.0 moderate pollution and >3.0 non-polluted water.[15] Similarly, the value of Margalef's richness index (d') <1 indicates heavy pollution, from 1 to 3 moderately polluted conditions and >3 no pollution.[16] Pielou evenness index (J') is a function of some diversity measure and number of individuals in a sample of collection.[17] Simpson diversity index (D') ranges from 0 to 1. 0 represents numerous genera/species and infinite diversity and 1 for no diversity.[7] With the decrease of D' the percent of the genus becomes more equitable. Simpson dominance index (1-D') also ranges from 0 to 1. The Simpson reciprocal index (1/D') begins from 1 for only one genus/ species. Its value increases with diversity and is influenced the equitability of percent of each genus present and richness. If there are five genera/species in a sample, then its maximum value will be 5.

Analyses of collected data were done using Microsoft Excel, 2007 software, while Diversity indices analyzed were calculated using Graph Pad Prism 5 software.

Results and Discussion

The Indian freshwater rivers usually carry contaminated water because of heavy pollution and industrial poisons that currently threaten the life once nurtured by these rivers. Hydrological parameters

analyzed from the Ganga River, Arrah showed spatial and temporal variations. The observed values of 262.4±10.7mg/L of total alkalinity and 318.8±11.52 mg/L of hardness were exceeding the standards.[18]

The water temperature was more in summer and less in winter due to depth of the river body (Table 1). Observed range of water temperature of 18.72-34.89^{0}C is suitable for culture of major carps. The lowest temperature is due to strong breeze and the highest value could be attributed to high solar radiation.[19] Increase in water temperature decreases the dissolved oxygen in water.[20] pH of water remained alkaline throughout the study period due to presence of carbonate and bicarbonate originating from the alkaline earth metals. pH of water was lowest during summer and highest was on winter (Table 1). pH ranged from 7.85 to 8.20 is good for fish life. Our results on pH of water is in close conformity with earlier finding.[21] Aquatic organisms are affected by pH of water because most of their metabolic activities are pH dependent.[22] Dissolved oxygen of water ≥ 5.0mg/L is desirable for good for growth of fauna and flora. The low dissolved oxygen of water in summer months were possibly due to the lower oxygen holding capacity of water at high temperature and increase in its assimilation for biodegradable organic matter by microorganism. These results on dissolved oxygen of water supported the earlier finding. It has been explained that at low level of dissolved oxygen of water, decomposition of organic matters started.[23] Water temperature had a negative significant relationship with pH, dissolved oxygen however positive significant relationship with total alkalinity, hardness, chloride, nitrate and sulfate. pH and dissolve oxygen of water showed significant negative relationship with total alkalinity, hardness and chloride (Table 2).

Table 1: Physicochemical parameters of water of Ganga River, Ara during 2018-2019

	WT (^{0}C)	pH	DO (mg/L)	TA (mg/L)	TH (mg/L)	Cl^- (mg/L)	NO_3^-(mg/L)	SO_4^{-2}(mg/L)
Summer Season	34.89±3.50	7.02±0.75	5.92±0.54	275.5±23.7	333.5±23.29	223.83±12.18	21.23±1.16	140.4±7.51
Monsoon Season	25.94±5.55	7.28±0.44	7.02±0.58	264.8±29.8	322.8±25.53	211.13±13.31	23.07±1.78	148.8±3.75
Post-Monsoon Season	18.72±4.74	7.21±1.03	7.53±0.43	259.4±31.0	317.1±27.57	208.57±11.82	21.10±1.19	134.9±5.65
Winter Season	9.39±4.80	7.41±0.70	8.30±0.58	249.8±43.0	301.6±22.87	197.73±12.66	20.03±1.33	124.2±2.20
Average	**22.23±9.37**	**7.23±0.14**	**7.19±0.86**	**262.4±10.7**	**318.8±11.52**	**210.32±9.28**	**21.36±1.09**	**137.08±8.93**

Table 2: Correlation-coefficient of physicochemical parameters of water of Ganga River, Ara during 2018-2019

	WT (^{0}C)	pH	DO (mg/L)	TA (mg/L)	TH (mg/L)	Cl^- (mg/L)	NO_3^-(mg/L)	SO_4^{-2} (mg/L)
WT (^{0}C))	1.0	-0.893*	-0.992***	0.997***	0.991***	0.982***	0.554NS	0.772NS
pH		1.0	0.926**	-0.924**	-0.916*	-0.961**	-0.197NS	-0.481NS
DO (mg/L)			1.0	-0.998***	-0.979***	-0.992***	-0.447NS	-0.690NS
TA (mg/L)				1.0	0.991***	0.994***	0.491NS	0.727NS
TH (mg/L)					1.0	0.985***	0.561 NS	0.784 NS
Chloride (mg/L)						1.0	0.414NS	0.668NS
Nitrate (mg/L)							1.0	0.953* *
Sulfate (mg/L)							1.0	

(NS= Not Significant, *=Significant, **=Moderately Significant and ***=Highly Significant)

Maximum values of total alkalinity of water in summer might be due to increased photosynthesis leading to greater use of carbon dioxide, disposal of dead bodies of animals and urban discharge through open drains in the river. The highest total alkalinity of water during summer and the lowest during winter has also been reported earlier.[21] Total alkalinity of water was related with the fluctuations in the photosynthesis of phytoplankton. Water with alkalinity greater than 100 mg/L is productive and ideal for fish culture.[24] In this work, total alkalinity of water was found in the range of 249.8-275.5mg/L. Total alkalinity and hardness of water also showed significant positive relationships to chloride (Table 2). Chloride of water showed decline from summer to winter has also recorded earlier.[25] But, chloride level of water more than 100mg/L (192.34 to 228.65mg/L in this work) can burn the edges of the gills of fishes. Nitrate and sulfate of water was highest during the monsoon season. High value of nitrate during monsoon is due to the excessive entry of water from agricultural fields, decayed vegetable, animal matter etc. The high nitrate detected in the river can be attributed to the use of fertilizers, which leached and eroded in river bodies. Such findings on nitrate and sulfate of water were also reported.[26]

Table 3: Seasonal variation of zooplankton density (ind/m^3) of Ganga River, Ara during 2018-2019

Group	No. of genera	Representatives and annual density	Summer	Monsoon	Post-Monsoon	Winter	Total
Protozoa	5 (21.74%)	*Amoeba (37), Arcella (51), Diffulgia (50), Vorticella (45) and Paramaecium (42)*	77 34.22%	55 24.44%	43 19.11%	50 22.22%	225 18.10%
Rotifera	6 (26.09%)	*Asplanchna (51), Brachionus 213 (223), Cephlodella (52) , Keratella(92) Lecane (68) and Testudinella (56),*	85 39.30%	74 15.68%	170 13.65%	542 31.37%	43.60%
Cladocera	5 (21.74%)	*Bosmina (84), Chydorus (83), Daphnia (44), Daphniosoma (38) and Monia (36)*	101 35.44%	67 23.51%	53 18.60%	64 22.46%	285 31.11%
Copepoda	4 (17.39%)	*Heliodiaptomous (44), Mesocyclops (35), Nauplius (42) and Thermocyclops (46)*	52 31.14%	37 22.16%	32 19.16%	46 27.54%	167 22.93%
Ostracoda	3 (13.04%)	*Cypris (8), Stenocypris (10) and Lothonura (6)*	10 41.67%	4 16.67%	2 8.33%	8 33.33%	24 1.93%
			453 36.44%	248 19.95%	204 16.41%	338 30.01%	1243

Zooplankton is one of the most important biotic components influencing food chains, energy flow and cycling of matter of aquatic ecosystems because of its role of secondary consumer. An aggregate of 23 genera of zooplankton comprising 6 Rotifera followed by 5 of Protozoa, 5 of Cladocera, 4 of Copepods and 3 genera of Ostracods were identified from the Ganga River (Table 3). These results were similar to earlier observation.[27] A total of 21 genera of zooplankton belonging to 5 major groups *viz.* Protozoa (7), Cladocera (5), Copepod (1), Rotifera (7) and Ostracod (1) have been reported from Tons river in Dehradun.[28] Earlier, out of 46 genera of zooplankton, 19 rotifera, 6 protozoa, 9 cladocera, 9 copepoda and only 3 Ostracoda was identified at Shershah Suri pond, Bihar, India.1 Besides, 38 genera of zooplankton having Copepoda with 17, Protozoa and larval forms of animals consisted of 5 genera and Ostracoda with 3 species at River Kali at Karwar, has been reported.[29]

Dominancy of rotifers is the indicators of eutrophication and measures taken to minimize the aquatic pollution.[30] In this study also, maximum

share in zooplankton composition was shown by Rotifers (43.60%) followed by Cladoceran (31.11%), Copepods (22.93), Protozoan (18.10) and least by Ostracods (1.93%). Among these groups of zooplankton, Cladoceran and Copepods can be used as indicator of freshwater aquatic environments.[31] Abundance and dominance of rotifera isreported in several water bodies.[32,33] This pattern is common in many fresh water bodies like lakes, ponds, reservoirs, rivers or streams.[34]

Table 4: Correlation-coefficient of physicochemical parameters of water and zooplankton of Ganga River, Ara during 2018-2019

	WT (^{0}C)	pH	DO (mg/L)	TA (mg/L)	TH (mg/L)	Cl^- (mg/L)	NO_3(mg/L)	SO_4^{-2} (mg/L)
Protozoa	-0.817*	-0.837*	-0.854*	0.819*	0.834*	0.817*	0.124^{NS}	0.356^{NS}
Rotifera	-0.260^{NS}	-0.347^{NS}	-0.360^{NS}	0.298^{NS}	0.167^{NS}	0.314^{NS}	-0.497^{NS}	-0.316^{NS}
Cladocera	-0.870*	-0.831*	-0.827*	0.888*	0.896*	0.883*	0.041^{NS}	0.280^{NS}
Copepoda	-0.316^{NS}	-0.327^{NS}	-0.423^{NS}	0.342^{NS}	0.210^{NS}	0.341^{NS}	-0.371^{NS}	-0.207^{NS}
Ostracoda	-0.266^{NS}	-0.280^{NS}	-0.355^{NS}	0.293^{NS}	0.159^{NS}	0.291^{NS}	-0.402^{NS}	-0.294^{NS}

On quantitative share basis, species of *Arcella* (20%), *Diffulgia* (19.6%) and *Vorticella* (17.65%) were the most abundant among Protozoa. Among Rotifera, species of *Brachionus* (41.14%), *Keratella* (16.97%), *Lecane* (12.55%) and *Testudinella* (10.33%) were abundant. Abundance of *Brachionus* in freshwater water bodies is perhaps depend on physical and chemical nature of water.[35] Species of *Bosmina* (29.47%), *Monia* (29.12%), *Daphnia* (15.44%), *Diaphanosoma* (13.33%) were abundant among Cladocera. It has been reported that the density of Cladocera is determined by food supply as they are abundant when food supply to the water body is adequate.[36] *Thermocyclops* sp. (27.54%) among Copepoda and only one genus of Ostracod namely *Stenocypris* sp. (41.67%) was found throughout the study period (Table 5). Abundance of species of *Vorticella, Brachionus, Keratella, Bosmina, Daphnia, Diapanosoma* and *Moina* were also reported also in Tons river at Dehradun.[28] *Bosmina sp* with 46.15 % in Chhariganga Oxbow Lake derived from the River Ganga in Nadia, WB has been reported.[37] These observations also resembles the earlier reports.[1,28,37]

In this study, the density of zooplankton showed temporal variation. The abundance of zooplankton is used to determine the conditions of aquatic environment. The numerical density of zooplankton fluctuated from 2 to 213 ind./L (Table 3). In a study, it was reported that numerical density of 12 taxa of zooplankton at Vasishti estuary was 10845/100m^3 to 23308/100m^3.[38] The maximum density of zooplankton was recorded during summer and minimum during post-monsoon. While analyzing seasonal dynamics of Rotifers in relation to physic-chemical conditions of River Yamuna made similar observations in increased densities of zooplanktons in summers and reduced densities in winters.[39] The highest count of Rotifers was recorded in the north-east monsoon season followed by winter and summer season at Yadigir, Karnataka.[40] According to an earlier report Ostracods and Protozoan was of maximum in summer months and minimum in monsoon months.[41] More numerical density of zooplankton more during summer and lowest during winter months was also reported.[42] Regular flash out of water, rain fall and perhaps cloudy sky during the monsoon seems a major cause of less plankton diversity because zooplankton prefer either the steady or the low water current.[30,43] The present study seems to resemble with these observations.

The distribution of zooplankton community depends on a complex of factors such as change of climatic conditions, physical and chemical parameters such as water temperature, pH, dissolved oxygen and nitrate.[44] In the present study, abundance and distribution of zooplankton was found to dependent on physical and chemical parameters of water at given point of time. Increase in water temperature can impact aquatic biodiversity, biological productivity, and the cycling of contaminants through the ecosystem. The density of zooplankton was found negatively correlated with water temperature, pH, dissolved oxygen, nitrate and

sulfate. But, density of zooplankton was positively correlated with total alkalinity, hardness and chloride (Table 4).[45] However, a positive correlation between water temperature and zooplankton has also been reported.[46] The high zooplankton density of this river might be due to relatively stable environmental conditions like temperature and good standing crop of phytoplankton prevailing in that region.[3]

Table 5: Biodiversity indices of Zooplankton of Ganga River, Ara during 2018-2019

Phylum/ Group	Shannon-Weinner Index	Pielou Evenness Index	Simpson Dominance Index	Simpson Diversity	Simpson Reciprocal	Menhninick's Index	Margalef Richness Index
Protozoa	1.063	0.996	0.203	0.797	4.935	2.236	2.486
Rotifera	1.767	0.908	0.231	0.769	2.769	2.645	3.083
Cladocera	1.538	0.956	0.229	0.771	4.362	2.236	2.484
Copepoda	1.381	0.996	0.253	0.747	3.961	2.000	2.165
Ostracoda	1.078	0.981	0.347	0.653	2.880	1.732	1.818
Average	1.473	0.967	0.253	0.747	3.953	2.170	2.407

The value of Shannon Weinner index in the present observation (x of H' =1.473, range=1.063 to 1.767) showed heavy to moderately polluted water of the Ganga River. This means that H' of a maximum value of exp(2.4) has an equivalent diversity as a community with maximum of 4 equally-common species. Further, Margalef's richness index (x of d'= 2.407, range=1.818 to 3.083) also showed high diversity of this river. The value of d' is strongly dependent on sampling and highlighted genera/species richness of 2 to 3 genera/species. The values of H' from 0.44 to 3.4 and d' from 0.35 to 2.09 at Mumbai harbour.[3] The maximum values of H' and d' were also calculated at Dhaula and Baigul.[47] Pielou evenness index (J') permits considerable refinement in diversity studies. The value of 0.908 to 0.996 of this index observed in this work showed similarities with earlier reports. The observation indicated moderate diversity and very even abundance of genera. Simpson indices take into account the representativeness of the species with the highest value of importance. Therefore, present observation (D'=0.653 to 0.797) showed moderate diversity with mature communities. Simpson dominance index (1-D') Its value of 0.203 to 0.347 observed in this work showed similarities and indicates moderate diversity. The value of The Simpson reciprocal index (1/D') of 2.769 to 4.935 shows conformity with the number of genera (3 to 5) observed in this study. An average of Margalef's Richness of 5, Pielou Evenness of 0.90, Shannon-Weiner Index of 1.42, Simpson diversity Index of 0.72 and Simpson dominance Index of 0.28 of different zooplankton species were observed in a River Ganga derived Chhariganga Oxbow Lake at West Bengal.[37] Thus, the present work corroborates the earlier findings. Margalef (d') and Menhninick's (M_d) Index richness provide an understandable and instantaneous expression of diversity. The Menhninick's Index is used for comparison of samples of different sizes. Earlier, it has been reported this index from 0.870 to 0.942 at Ramesar. A range of 1.732 to 2.645 of this work featured high diversity.[48] The mean values of H' > 2 and D' > 0.9 indicates the healthy diversity of the ecosystem.[49] Therefore, present work indicates some unhealthy diversity of zooplankton in this water body.

Conclusions

Depending on the limnological parameters, it may be concluded that the Ganga River, Arrah seem to be suitable for fish culture because of physical and chemical parameters and type of zooplankton. The composition and biomass of zooplankton were evenly distributed and the physical and chemical parameters are of suitable range. The number of zooplankton was highest during summer and lowest during post-monsoon. The study indicates that temperature has an important role in the distribution of zooplankton in a freshwater habitat. The biodiversity indices indicated a moderate diversity of zooplankton, productive and moderately

polluted condition of the Ganga River at Arrah. The results depict that more monitoring of all the parameters is necessary.

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Conflict of Interest
The authors have do not have any conflict of interest.

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