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Population dynamics of zooplankton species in Ganga river and its tributaries at Uttarakhand, India

Amit Kumar Sharma, Vishal Kamboj, Neeraj Pandey, Arvind Kumar Sharma*
Department of Zoology and Environmental Science**,** Gurukula Kangri (Deemed to be University), Haridwar, Uttarakhand, India

Abstract
The Ganga river originates from the ice cave of Gaumukh (33^0 55'N, $79^0$07E) at Gangotri glacier of Western Himalaya, about an elevation of 4100 meters. The population dynamics of zooplankton diversity in Ganga River and its tributaries at Rishikesh was subjected to check the population dynamics of zooplankton diversity from September 2017 to August 2018. The sample was analysed qualitatively as well as quantitatively for distribution of zooplankton. During the present experimental study 15 species of zooplankton of which 5 species of Cladocerans, 4 species of Copepods, 3 species of Protozoa and 3 species of Rotifers were recorded. Shannon Weiner Diversity (H') was ranged from 2.59 to 2.682, evenness (J') was 0.8888 to 0.9746 and Simpson diversity was ranged from 0.9184 to 0.9299.

Keywords: zooplankton, diversity, abundance, shannon weiner index, simpson index, ganga river

Introduction

Riverine ecosystem has been proved the birthplace of civilization all over the world and is more evident in India where the Ganga, Yamuna, Indus and all other river possess cultured identity transmitted down the ages through scared literature i.e. through Vedas and Puranas. Biodiversity is basic for adjustment of a biological system ensuring of general condition quality and for understanding the natural worth of all species on earth. Gaston, (2000) [5] reported that the distribution of biodiversity across the earth can be described in terms of the relatively small number of spatial patterns such as latitude, altitude, or habitat size and also helpful for understanding how these extrinsic drivers influence diversity which remains most significant as well as intellectual challenges to ecologist and bio-geographers. Cladocerans Copepods, and Rotifers groups are the main components of zooplankton diversity in any aquatic ecosystem because of short lifespan, lasting from just a few weeks to a few months, marked oscillations in the population densities are evident in short periods of time Hutchinson, (1967) [7]. Aquatic ecosystem, mainly in the form of rivers are one of the most threatened natural ecosystems worldwide, due to the various anthropogenic and natural calamities factors like damming as per Nilsson *et al.,* (2005) [21]; Dudgeon *et al.,* (2006) [3], Malik *et al.,* (2018) [12, 19, 25, 26]; Sharma *et al.,* (2018) [12, 19, 25, 26, 27]; Sharma *et al.,* (2019) [11]; Malik *et al.,* (2020) [16, 17 18]. explained that when a lotic ecosystem transforms into a lentic ecosystem, all the ecological and habitat processes will be disturbed i.e. change in organic matter production and nutrient cycling. Natural and anthropogenic factors can modify the structure of communities and ecosystem functioning by Sharma *et al.,* (2018) [12, 19, 25, 26, 27]; Tundisi, (1999) [31]; Malik *et al.,* (2020) [16, 17, 18]. The experimental study of freshwater fauna mainly zooplankton, is very broad and complicated due to several factors like physical, geographical, environmental, chemical variations, extrinsic and intrinsic factors. Zooplankton plays a main role in preservation and continuation of ecological balance in any aquatic ecosystem. Monthly fluctuations of the zooplankton diversity and its abundance are well known trend. Wetzel, (2001) [32] observed that zooplankton exhibits a seasonal bimodal oscillation varies from monsoon and post monsoon season in the lakes, rivers and reservoirs. This fluctuation in abundance of zooplankton communities is greatly influenced by the variations in the water temperature along with many other ecological factors. Among these ecological factors, water temperature and water velocity seem to reveal the maximum influence on the periodicity of zooplankton by Prasad and Singh, (2002). Zooplankton population show a crucial role in interlinking the aquatic food chain. Any aquatic ecosystem is primarily shaped by the physical and chemical environment and modified by the biological interaction. Ferdous and Muktadir, (2009) [4] observed that zooplankton can be best indicator which help to understand the shifts in the trophic status. Zooplankton population plays an important ecological role, including the transport of matter as well as energy between producers and consumers at higher trophic levels by Lampert & Sommer, (1997) [13]. Zooplankton rapidly responds to any physical, chemical as well as biological changes in aquatic ecosystem, and can also indicate environmental disturbances as per Simoes *et al.,* (2012) [29]. So, these types of the commune provide a direct link between primary producers and higher tropic levels such as fish. All carnivorous fish species mainly depends upon the zooplankton for food and feeding from their larval phases to their entire life cycle (in some fish species) by Madin and Steinberg, (2001) [15]; Kumar *et al.,* (2019) [11]; Malik *et al.,* (2020) [16, 17, 18]. The distribution, diversity and abundance of zooplankton in an aquatic ecosystem depend mainly on the water quality by Harikrishnan and Azis, (1989) [6]. The physicochemical parameters of any water body play an important role in prevailing the assemblage of plankton which is the main as well as natural food source of many fish species. Zooplanktons are important food source for omnivorous as well as carnivorous fish species and also help to sustain the basic amount of protein for the rapid growth of larval carps

by Rahman and Hussain, (2008) [23]. The qualitative and quantitative abundance of zooplankton in any aquatic ecosystem is of huge importance for successful aquaculture management Boyd, (1982) [2]. The main aim of the present research was to establish the relation between the diversity, abundance and biotic indices of zooplankton with water quality in Ganga River and its tributaries.

Materials and Methods

Study area

The study was focused in the Ganga river system along with its two tributaries (Figure 1) from the period of 2017-2018. An extensive field survey was conducted for collecting the primary data. The study area was divided into four sampling zones and every zone has further three stations for the collection of hydrological parameters and zooplankton species. Sampling zone Z1 was selected at upstream, of the Ganga river at Kaudiyala (30° 6'14.05"N Latitude and 78°23'3.10"E Longitude), Sampling zone Z2 was selected at Nayar River ($30^{0}08^{'}12.69^{"}$ N longitude, $78^{0}23^{'}17.^{"}$ E latitude), Sampling zone Z3 was selected at Henval River (30° 7'19.66"N longitude, 78°23'2.76"E latitude), Sampling zone Z4 was selected at Downstream Ganga river near Shivpuri ($30^{0}07^{'}38.47^{"}$ N longitude, $78^{0}23^{'}29.51^{"}$ E latitude).

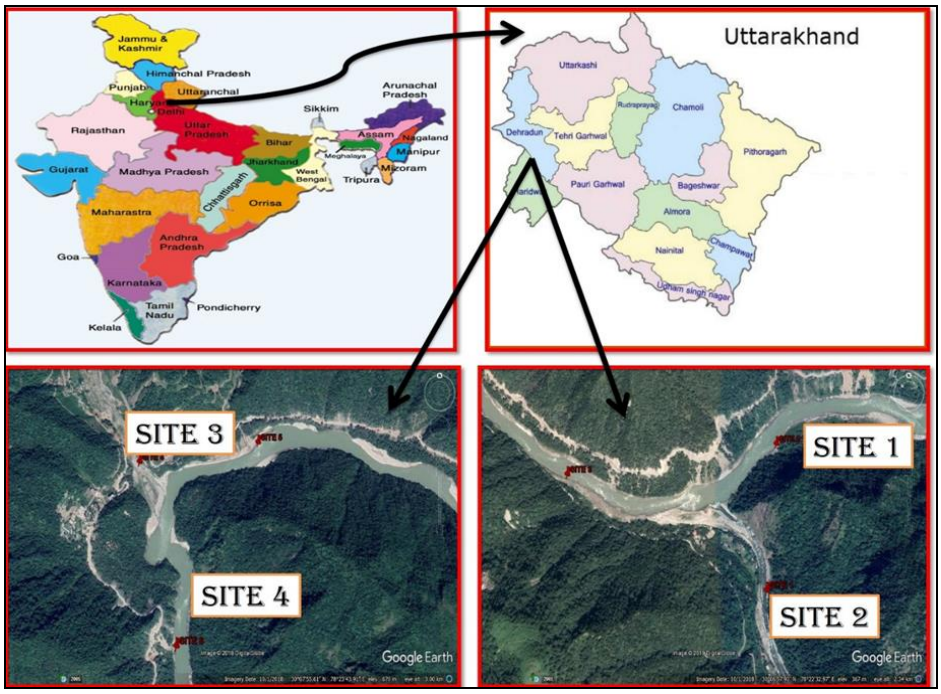

Fig 1: Google map showing selected sampling zones

Collection and preservation of samples: Monthly samples were collected from four sampling zones during September 2017 to August 2018 with the aim to collect the zooplankton species that possibly show a seasonal dynamic. Zooplankton collections were made from the surface of the water as well as column of the river at selected sampling zones. Qualitative collections were done by towing surface water column and quantitative samples were collected by filtering 100 litres of water through a plankton net made bolting silk (No. 25), 62 µm mesh sizes. The collected samples were transferred to a clean polyethylene container which is about 250 ml capacity and preserved in 4% neutralized formaldehyde solution and containers were labelled.

Sedgwick–Rafter Cell method

The quantitative collection was estimated following the Sedgwick-Rafter cell method and the results were expressed in Ind./L (Welch, 1948). The Sedgwick Rafter Cell is a special kind of slide similar to the Haemocytometer. The cell has a 50 mm x 20 mm x 10 mm rectangular cavity that holds 1 ml sample. The cell is moved in horizontal directions on the stage of an inverted microscope and planktonic species encountered in the field are enumerated. A number of replicate samples are enumerated to calculate plankton/ litre.

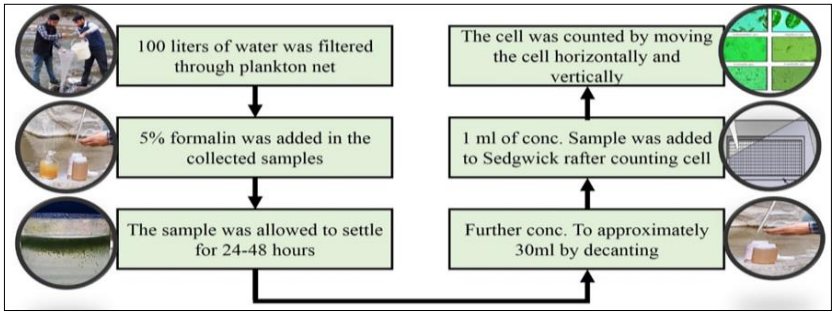

Fig 2

Calculation

$$\text{No. of plankton / ml} = \frac{\text{No. of organism counted}}{\text{No. of replicates taken}}$$

$$(\text{Plankton/l}) = \frac{(a \times 1000)c}{L}$$

Where,
n= no. of plankton/ litre of water
a= Average number of plankton in one small counting chamber of S-R cell
c= ml of plankton concentrates
I=volume of original water filtered in litre

Identification
From the concentrated sample, the slides for the zooplankton were prepared. Then these slides were placed under a microscope, and the zooplankton was observed in 100 X in the binocular microscope. The images of the zooplanktons were captured by using a digital camera. Later on, the zooplankton was identified by using the Needham and Needham, (1962) [20].

Statistical and diversity indices
Species diversity (Shannon- Wiener index, H'), Evenness (e^H/S') and Simpson index (1-D) were analysed.
Shannon Weaver diversity index (H') was calculated using the following formula:

$$(H) = \sum_{i=1} \left(\frac{n_i}{N}\right) \text{Log } 2 \left(\frac{n_i}{N}\right)$$

Where,
H'= Shannon Diversity Index,
n_i= Total no of individuals of the species
N= Total no of individuals of all species

Species Evenness

$$(J') = H'/H'_{max}$$

Where
H' = number of derived from the Shannon diversity index
H'_{max} = maximum possible value of H'. (If every species was equally likely, equal to:

$$H'_{max} = \sum_{i=1}^{S} \frac{1}{S} \ln 1/s = \ln S.$$

Simpson's Diversity index

$$(D) = \Sigma\, n(n-1)/N(N-1)$$

Where,
n = total number of organisms of a particular species
N = total number of organisms of all species

Result and Discussion
Zooplankton is important column tropic component in any aquatic ecosystems. Herbivorous zooplankton is dependent on phytoplankton or algae for food and help to maintain the food chain in water body. Four groups of zooplankton included Cladocera, Copepoda, Protozoa and Rotifera, were recorded in all the sampling zones from Ganga river basin and its tributaries. Five genera of Cladocera represent as *Bosmina sp.*, *Ceriodaphnia sp.*, *Chydorus sp.*, *Daphnia sp.*, and *Monia sp*. were present. Four genera of Copepoda as *Pleuroxus sp.*, *Cyclops sp.*, *Mesocyclops sp.*, and *Diaptomus sp.*, were found. Three species of Protozoa as *Arcella sp.*, *Vorticella sp.*, and *Zoothamnium sp.* were found. Three species of Rotifera as *Asplanchana sp.*, *Keretella sp.*, *Filinia sp.*, were present in selected sampling zones. The dominant genera were recorded as *Bosmina sp.*, *Ceriodaphnia sp.*, *Pleuroxus sp.*, *Cyclops sp.*, *Mesocyclops sp.*, and *Diaptomus sp.*, observed at selected sampling zone. Cladocera reach their maximum during winter (January) when the water temperature ranges from 10-13 ºC. The population decreased during monsoon when the temperature found Higher and water velocity also reaches higher. Various studies showed that the groups of zooplankton consisted of *Daphnia*, *Ceriodaphnia*, *Simocephalus*, *Scapholeberis*, *Bosmina*, *Graptoleberis*, *Alona*, *Alonella*, and *Chydorus* among the Cladocera mentioned by Pandit and Ashok, (1999). Interestingly, *Ceriodaphnia* and *Daphnia* were recorded the most frequently species in selected sampling zones. *Bosmina sp.*, were observed as dominant species from all four zones of Ganga river. Cladocera was observed maximum 210unit/l in zone 2 and minimum 112unit/l at zone 4. Copepoda was observed maximum 219unit/l in zone 3 and minimum 114unit/l at zone 4. Protozoa was observed maximum 86unit/l in zone 2 and minimum 38unit/l was observed at zone 4 and Rotifera was observed maximum 112unit/l in zone 2 and minimum 170unit/l at zone 4 during 2017-2018. Little evidence suggests that the Rotifers population density depends up on the availability of food and temperature described by Lougheed and Chow-fraser, (1998) [14]. In the present study, high values of water velocity are positive correlated with *Keretella sp.*, *Amphora sp.* High values of DO are associated with *Asplanchana sp.* High values of water temperature are positive correlated with *Keretella sp.* High values of BOD are positive correlated with *Bosmina sp.*, *Ceriodaphnia sp.*, *Mesocyclpos sp.* and *Keretella sp.* Some studies have indicated that the main abiotic factor i.e. temperature mainly affects the population of Cladoceran species Hutchinson, (1967) [7]; Bhowmic, (1968) [1]; Kamboj and Kamboj, (2020) [8, 9, 18]; Kamboj *et al.*, (2020) [8, 9, 18] reported that in summer, zooplankton population increases due to higher concentration of nutrients and increased photosynthetic activity of phytoplankton were dominant. Cladocera were dominant among zooplankton during summer might be due to optimal thermal and nutritional conditions and lower concentration of oxygen in river reported by Ojha *et al.*, (2007) [22]; Sharma *et al.*, (2018) [12, 9, 25, 26, 27]; Kamboj and Kamboj, (2019) [10]. Few ecological studies also suggested that increase in zooplankton diversity was found to be highest in summer and lowest in winter in flow riverine system described by Tripathi *et al.*, (2007); Kumar *et al.*, (2018) [12]. The values of diversity indices were calculated according to month and stations (Table 3). Highest Dominance index (D) (0.0816) was found at Zone 3 and lowest (0.0700 was found at zone 1. Higher Dominance index (D) values were found in May (0.0864) where low during January (0.0725). Highest Simpson index (1-D) (0.9261) was found at Zone 2 and lowest (0.9184) was

found at zone 3. Higher Simpson index (1-D) values were found in January (0.9275) where low during June (0.916). Highest Shannon index (H) (2.682) was found at Zone 1 and lowest (2.59) was found at zone 3. Higher Shannon index (H) values were found in January (2.666) where low during May (2.546). Highest evenness value (0.9746) was found at Zone 1 and lowest (0.888) was found at zone 3. Highest evenness value was found (0.9587) in January and lowest value observed (0.8501) in May. Highest Menhinick index (0.8171) was found at Zone 4 and lowest (0.6098) was found at zone 2. Higher Menhinick index values were found in August (1.590) where low during January (0.8996). Highest Margalef index (2.405) was found at Zone 4 and lowest (2.186) was found at zone 2. Higher Margalef index values were found in August (3.119) where low during January (2.488). Highest Equitability index (J) (0.9905) was found at Zone 1 and lowest (0.9565) was found at zone 3. Higher Equitability index (J) values were found in January (0.9844) where low during May (0.9400). Highest Fisher-_alpha index (3.218) was found at Zone 4 and lowest (2.785) was found at zone 2. Higher Fisher_alpha index values were found in August (5.168) where low during February (3.598). Highest Berger-Parker index (0.1147) was found at Zone 3 and lowest (0.09896) was found at zone 1. Higher Berger-Parker index values were found in June (0.1327) where low during March (0.1011). No significant difference was found in the mean value of diversity indices value among the months and zone.

Table 2: Temporal and spatial species abundance of zooplankton in Ganga River and its tributaries during 2017-2018

Species	No.	%	Z1	Z 2	Z3	Z4	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug
Cladocera																		
Bosmina sp.	176	9.342	28	62	51	35	8	11	12	14	31	26	17	13	10	15	10	9
Ceriodaphnia sp.	160	8.493	32	50	49	29	12	14	21	13	24	12	14	13	15	10	5	7
Chydorus sp.	124	6.582	26	48	30	20	5	6	13	13	17	13	10	11	12	7	10	7
Daphnia sp.	75	3.981	27	14	19	15	8	6	7	10	13	5	6	6	3	6	3	2
Moina sp.	87	4.618	22	36	16	13	5	2	3	6	17	14	12	7	5	6	5	5
Total	622	33.016	135	210	165	112	38	39	56	56	102	70	59	50	45	44	33	30
Copepoda																		
Pleuroxus sp.	162	8.599	32	49	57	24	11	12	18	18	21	23	15	12	11	7	5	9
Cyclops sp.	183	9.713	38	52	61	32	9	15	18	16	25	22	16	18	12	9	13	10
Mesocylops sp.	162	8.599	25	51	54	32	5	12	16	21	18	19	18	16	10	10	9	8
Diaptomus sp.	132	7.006	24	35	47	26	10	9	13	15	14	16	13	12	8	6	8	8
Total	639	33.917	119	187	219	114	35	48	65	70	78	80	62	58	41	32	35	35
Protozoa																		
Arcella sp.	86	4.565	16	26	28	16	7	6	8	9	14	8	6	7	3	7	5	6
Vorticella sp.	80	4.246	25	29	16	10	6	7	5	2	12	14	9	7	4	4	7	3
Zoothamnium sp.	77	4.087	19	31	15	12	4	7	9	6	12	14	8	6	4	3	2	2
Total	243	12.898	60	86	59	38	17	20	22	17	38	36	23	20	11	14	14	11
Rotifera																		
Asplanchana sp.	71	3.769	16	25	17	13	12	10	7	6	15	6	5	3	1	2	1	3
Keretella sp.	122	6.476	25	39	34	24	16	8	10	11	20	16	12	8	5	8	5	3
Filinia sp.	187	9.926	29	58	64	36	14	12	20	21	25	21	17	14	12	13	11	7
Total	380	20.171	70	122	115	73	42	30	37	38	60	43	34	25	18	23	17	13
Grand total	1884	100.00	384	605	558	337	132	137	180	181	278	229	178	153	115	113	99	89

Table 3: Temporal and spatial variation in diversity indices of zooplankton in Ganga River and its tributaries during 2017-2018

	Z1	Z 2	Z3	Z4	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug
Individuals	384	605	558	337	132	137	180	181	278	229	178	153	115	113	99	89
Dominance	0.0700	0.0739	0.0816	0.0766	0.0772	0.0761	0.0803	0.0804	0.0725	0.0768	0.0750	0.0775	0.0864	0.0801	0.0839	0.0799
Simpson_	0.9299	0.9261	0.9184	0.9234	0.9228	0.9239	0.9196	0.9196	0.9275	0.9232	0.9249	0.9225	0.9136	0.9199	0.916	0.9201
Shannon	2.682	2.65	2.59	2.631	2.629	2.63	2.6	2.594	2.666	2.626	2.641	2.623	2.546	2.606	2.568	2.599
Evenness	0.9746	0.9434	0.8888	0.9262	0.9243	0.925	0.8973	0.8926	0.9587	0.9216	0.9352	0.9185	0.8501	0.9026	0.869	0.8968
Brillouin	2.594	2.589	2.526	2.534	2.43	2.437	2.444	2.44	2.552	2.496	2.482	2.445	2.333	2.384	2.328	2.337
Menhinick	0.7655	0.6098	0.635	0.8171	1.306	1.282	1.118	1.115	0.8996	0.9912	1.124	1.213	1.399	1.411	1.508	1.59
Margalef	2.353	2.186	2.214	2.405	2.867	2.846	2.696	2.693	2.488	2.577	2.702	2.783	2.951	2.961	3.047	3.119
Equitability	0.9905	0.9785	0.9565	0.9717	0.9709	0.9712	0.96	0.9581	0.9844	0.9699	0.9753	0.9686	0.94	0.9621	0.9481	0.9598
Fisher_alpha	3.109	2.785	2.837	3.218	4.356	4.293	3.89	3.883	3.396	3.598	3.905	4.119	4.606	4.64	4.916	5.168
Berger-Parker	0.098	0.102	0.114	0.106	0.121	0.109	0.116	0.116	0.111	0.113	0.101	0.117	0.130	0.132	0.131	0.112

Conclusion

The present study revealed that the population dynamics of zooplankton species showed seasonal variations. The result also specifies that the maximum and minimum number of genera occurred in Ganga River depends on various environmental factors (i.e. higher during winter season followed by the summer and monsoon season). The rotifers and particle feeder Cladocerans were higher in winter season due to favourable air and water temperature and also the availability of abundant food in the form of bacteria, nanoplankton and suspended detritus. The Copepods had more diversity, species richness, evenness, and diversity indices than Cladocerans, Rotifer and Protozoan's. The copepods were numerically abundant than Rotifers and Cladocerans in Ganga river and its tributaries during the study period.

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