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Plankton Diversity of the River Kulik at Uttar Dinajpur District of West Bengal, India

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ABSTRACT
Plankton Diversity of the river Kulik at Uttar Dinajpur District of West Bengal, India was studied from November 2019 to October 2021. A total of 43 phytoplankton species were recorded during the present study. Out of which, Chlorophyceae was the most dominant group with 17 species followed by, Bacillariophyceae with 12 species, Cyanophyceae with 7 species and 2 species belonged to Chrysophyceae, Dinophyceae and Euglenophyceae, 1 species belonged to Charraphyceae. Highest phytoplankton density was recorded during monsoon season of the first year from Site 4 (14640/mL) and the lowest density was found during winter season of first year from Site 1 (3440/mL). The species like *Amphora* sp., *Cymbella* sp., *Diatoma* sp., *Fragillaria* sp., *Nitzchia* sp., *Rhizosolenia* sp., *Chara* sp., *Ankistrodesmus* sp., *Dinobryan* sp., *Anabaena* sp., *Merismopedia* sp., *Microcysctis* sp., *Nostoc* sp., *Phormidium* sp., *Spirulina* sp., *Ceratium* sp. and *Phacus* sp. were found throughout the study period. The presence of species like *Melosira* sp., *Closterium* sp., *Pandorina* sp., *Ankistrodesmus* sp., *Navicula* sp., *Nitzchia* sp., *Chlorella* sp., *Oscillatoria* sp. and *Euglena* sp. supports the higher organic pollution of the river Kulik. The highest organic pollution on the basis of Palmer's Pollution Index was recorded in case Site 3 (17) in the summer season of the first year and Site 4 in the summer season of the second year and the lowest was recorded in case of Site 5 (3) in the summer season of the first year and at Site 1 and Site 3 in monsoon season of the first year. A total of 53 species of zooplankton of five major groups were identified from the surface water samples of Kulik river during the whole study period. Among them Cladocera was the most dominant group with 24 species followed by, Rotifera with 17 species, Copepoda with 6 species, Rhizopoda with 4 species and Ostracoda with 2 species. Rotifera group was the most dominant group of zooplankton. Species like *Chydorus barrosi*, *Chydorus sphaericus*, *Moina* sp., *Diaphanosoma excium*, *Mesocyclops* sp., *Brachionus* sp., *Lecane* sp., *Testudinella* sp. were found throughout the study period. The zooplankton density varied from 9600/m^3 to 17260/m^3 during the whole study period. The lowest density recorded from Site 1 (690/m^3) during monsoon of the first year and the highest density was recorded from Site 4 (4490/m^3) during winter of the first-year study period. The presence of species like *Bosmina longirostris*, *Daphnia* sp., *Moina* sp., *Sida* sp., *Cypris* sp., *Keratella* sp. and *Lecane* sp. supports the higher organic pollution of the river Kulik.

Key words: Phytoplankton, Zooplankton, River Kulik, Pollution, Conservation

INTRODUCTION

All forms of life, on the Earth depend upon water for their mere existence. All the aquatic system and their biota affect human beings directly or indirectly. Among all the aquatic biota, plankton population is able to reflect the nature and potential of any aquatic systems. Plankton are microscopic organisms that drift in the water with the action of waves, current and other forms of water motion. Productivity in aquatic ecosystem is directly depends on the density of plankton which is controlled by the water quality and other biotic communities of the water bodies. Plankton are basically two types: tiny plants - called phytoplankton, and weak-swimming animals - called zooplankton. Phytoplankton communities are the first response assemblage of organisms directly affected by environmental changes in aquatic lotic and lentic systems (Halsey and Jones 2015). In any aquatic environment, phytoplankton considered as the main primary producers, which entrap solar energy by the biological process of photosynthesis and produce carbohydrates in the form of food by assimilating carbon dioxide, thus establish coordination between the abiotic and the biotic factors in the aquatic ecosystem (Saha and Choudhary 2000). They form a bulk of food for zooplankton, fishes and other aquatic organisms. Phytoplankton are one of the initial biological components from which the energy is transferred to higher organisms through food chain (Ananthan et al. 2004). The zooplankton community is an important element of the aquatic food chain. These organisms serve as an intermediary species in the food chain, transferring energy from planktonic algae (primary producers) to the larger invertebrate predators and fish who in turn feed on them. Zooplankton offer several advantages as indicators of environmental quality in both lakes and rivers. As a group, they have worldwide distribution, species composition and community structure which are sensitive to changes in environmental conditions, nutrient enrichment and different levels of pollution (Holz and Hoagland 1996; Jha and Barat 2003). As rivers are dynamic and have expansive watersheds, the natural environment and socioeconomic conditions of the areas intersected by river flows are diverse (Acreman et al. 2014). Although the community structure of phytoplankton in rivers (lotic systems) is less stable than that of the phytoplankton in lakes and reservoirs (lentic systems), and both their seasonal changes are apparent (Tang et al. 2018, Minaudo et al. 2021). Systematic enumeration of plankton is of great biological significance to understand the limnobiotic dynamics of aquatic ecosystem (Shrivastava 2005, Pandey et al. 2011). Sampaio et al. (2002) studied the species composition and abundance of zooplankton community of Paranapanema river, Brazil.

In India, Chakrabarty et al. (1959) studied the plankton of river Jumna at Allahabad. The zooplankton community was represented by rotifera, protozoa, copepoda, cladocerans and ostracoda. The rotifers were found to be dominant group followed by protozoa and crustaceans. Rao and Pragada (2010) studied the seasonal abundance of micro algae in Pandi Backwaters of Godavari Estuary, Andhra Pradesh and found that diatoms were the dominant group followed by the Chlorophyceae and others. Several works have been done on the seasonal variations of plankton from different lakes and small water bodies of West Bengal (Patra et al. 2010, Hassan et al. 2011, Singh et al. 2017). Roy et al. (2013) from the river Ichamati of West Bengal enlisted 19 species of zooplankton. Das et al. (2013) recorded 22 genera of zooplankton from 'Rasikbeel' at Cooch Behar District of West Bengal. Gupta (2019) studied the occurrence of genus *Microcystis* from water bodies of Maldah district of West Bengal.

The river Kulik is a Bangladesh-India inter-border river that flows through Uttar Dinajpur, West Bengal, India. The water of the river is used for a variety of reasons. On the banks of the river up to Abdulghata, Patharmonighat, Elangia, Bisahar and Gorahar near the Kulik Bridge in Raiganj, different crops like paddy, mustard, jute and wheat are cultivated throughout the year. If the irrigation water of the river Kulik will be withdrawn then the cultivation may be destroyed. Local people use the water of the river for bathing, washing linens, utensils and other domestic chores. Even the water of the river Kulik is consumed by the tribal inhabitants of Sherpur.

Till date no work has been carried out to understand the status of plankton diversity of the river Kulik in Uttar Dinajpur district. Therefore, the present study was undertaken to know the plankton diversity of the river Kulik in Uttar Dinajpur district of West Bengal.

MATERIALS AND METHODS

Sites for study

For the present investigation five sampling sites were chosen based on the length of the river and the point and non-point sources of pollution to study the plankton diversity of the river Kulik of Uttar Dinajpur district, West Bengal. Brief descriptions of the sites:

Site 1 – MAKARHAT 2 (Lat 25.810152, Long 88.240520)

This site is located in Makarhat, which is the border of Bangladesh and India. At this site the river Kulik of Bangladesh enters into the India (Fig. 1). One military camp is present near the site to control the mobility of people of both the countries. Human population is lesser at this site. Only some agricultural fields and different plants are present near the site. Fishing is done at this site.

Site 2 – KASIMPUR (Lat 25.690178, Long 88.202701)

This site is situated below the Kasimpur Bridge of Bindole Thakurbari Road, which is the connector of Raiganj and Hemtabad block. This road extends up to the Bangldesh Border (Fig. 1). Some tribal people reside near the site. Local people used to capture fish at this site. They use the water of the Kulik for different purposes like cleaning utensils, clothes, washing of pet-animals, bathing, etc.

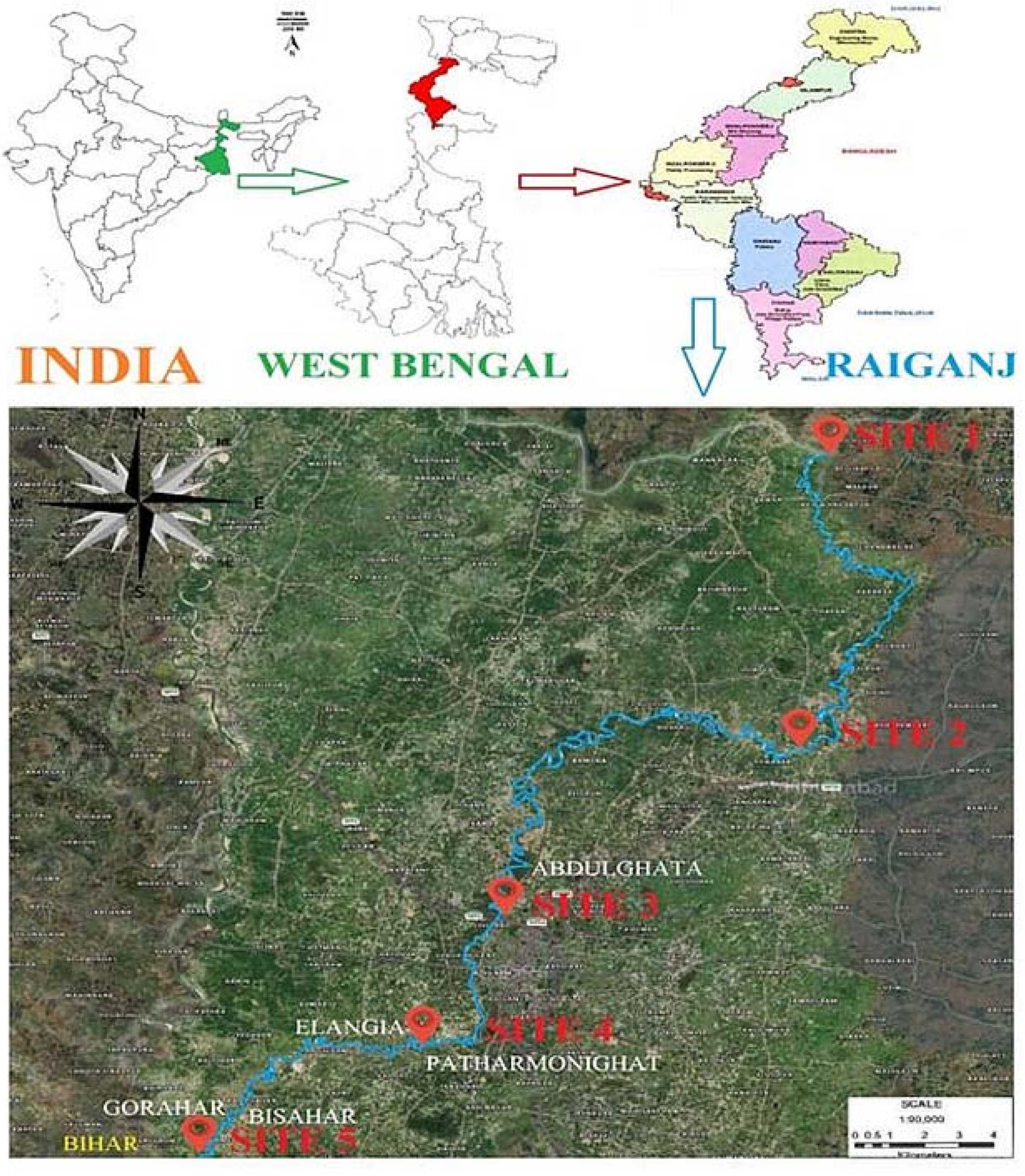

Figure 1. Satellite view of the river Kulik with five selected water sampling Sites at Raiganj and Hemtabad Block. Site 1= Makarhat, Site 2= Kasimpur, Site 3= Kulik Bridge NH34, Site 4= Patharmoni Ghat, Site 5= Nichitpur

Site 3 – KULIK BRIDGE NH34 (Lat 25.620319, Long 88.115684)

This site is located under the Kulik Bridge, which is a part of National Highway (NH34). It is very near to Kulik Wildlife Sanctuary. The sanctuary has a network of artificial canals connected with the river Kulik. During monsoon the river water enters into the sanctuary, which supports a wide variety of food for the birds, particularly for the Asian Openbill Stork, whose main diet is apple snail of the river Kulik (Fig. 1). Under the bridge, many festivals and village fairs are celebrated by the villagers. Agricultural fields are also present, where seasonal crops are cultivated. Boating is one of the main attractions of this site. During winter this site is used for picnic purpose. Fishing and bathing are also done at this site.

Site 4 – PATHARMONI GHAT (Lat 25.595078, Long 88.114579)

This site is situated about 250 m away from the bypass of NH 34. Through this road Bihar is connected with Raiganj. Most of the fishes of the river Kulik are collected from this site. Plenty of fish available at this site and fishing is done here regularly due to the presence of the river buck. The water of this site is used mainly for domestic purposes, specially for bathing pet animals.

Site 5 – NICHITPUR (Lat 25.558380, Long 88.041977)

This site is located at Nichitpur, which is also a link between Bengal and Bihar. This is the outlet of the river Kulik where it meets with the river Nagar (Fig. 1). This site is very important for the villagers of border area of Raiganj and Bihar. Fishing is the main profession of the villagers.

The water sample containing phytoplankton were collected without filtering the surface water. To preserve the sample, 0.3 ml Lugol's Iodine solution was added to 100 ml of water. Water sample were centrifuged at 1500 r.p.m. for 15 minutes and then the studied under microscope. Identification of phytoplankton was done using Standard books (Desikachary 1959, Ward and Whipple 1959, Prescott 1978, Anonymous 2017).

Zooplankton samples were collected by filtering the surface water through plankton net (conical tow net made of bolting silk) and preserved in 4% formalin solution immediately after collection of samples. In laboratory, the samples were concentrated by centrifugation at 1500 r.p.m. for 15 minutes. Sedgwick- Rafter (S-R) cell was used as a device for enumeration of zooplankton under microscope. Then the zooplankton were identified up to genera level or wherever possible upto species level, and were reported as number per cubic meter. The identification was done by referring the keys (Ward and Whipple 1959, Pennak 1978, Battish 1992, Anonymous 2017).

RESULTS

Seasonal variation of phytoplankton present in the surface water of the river Kulik were observed for two years, from November 2019 to October 2021. The phytoplankton diversity and density of water collected from the five sampling sites of the river Kulik of Uttar Dinajpur during winter, summer and monsoon season of two years study period are presented in Table 1.

Phytoplankton diversity

A total of 43 phytoplankton species were recorded during the present study (Table 1). Chlorophyceae was the most dominant group with 17 species followed by, Bacillariophyceae with 12 species, Cyanophyceae with 7 species and 2 species benlonged to Chrysophyceae, Dinophyceae and Euglenophyceae, 1 species belonged to Charraphyceae. *Amphora* sp., *Cymbella* sp., *Diatoma* sp., *Fragillaria* sp., *Nitzchia* sp., *Rhizosolenia* sp., *Stephanodiscus* sp., *Surirella* sp., *Chara* sp., *Ankistrodesmus* sp., *Pandorina* sp., *Pediastrum* sp., *Pleodorina* sp., *Protococcus* sp., *Rhizoclonium* sp., *Scendesmus* sp., *Spirogyra* sp., *Ulothrix* sp., *Volvox* sp., *Zygnema* sp., *Dinobryan* sp., *Synura* sp., *Anabaena* sp., *Merismopedia* sp., *Microcysctis* sp., *Nostoc* sp., *Phormidium* sp., *Spirulina* sp., *Ceratium* sp., *Phacus* sp. were found in all the seasons (Table 1).

Cyclotella sp. and *Oscillatoria* sp. were found in monsoon season of both the years. *Melosira* sp., *Navicula* sp., *Synedra* sp., *Closterium* sp., *Desmidum* sp. and *Pridinium* sp. were observed in winter season of both the years. *Nitzchia* sp., *Chlorella* sp. and *Scendesmus* sp. were found in the summer and monsoon season of both the years. *Cosmarium* sp. and *Microspora* sp. were found only in the summer season of the both years. *Eudorina* sp. and *Pediastrum* sp. were found in the winter and monsoon season of both years. *Phacus* sp. was found in winter and summer season of the both years.

The highest Phytoplankton density was observed at Site 5 (8960/mL), followed by Site 3 and Site 4 (6720/mL), Site 2 (5320/mL) and Site 1 (3440/mL) during the winter season of the year 2019. During the year 2020 the highest Phytoplankton density was observed at Site 3 (9600/mL), followed by Site 4 (7560/mL), Site 5 (7520/mL), Site 1 (6720/mL) and Site 2 (4240/mL) during the winter season of the year 2020.

In the Summer season of the year 2020 the highest phytoplankton density was observed at Site 5 (9440/mL), followed by Site 2 (7240/mL), Site 1 (6320/mL), Site 4 (4520/mL) and Site 3 (4440/mL) and during the year 2021 the highest phytoplankton

Table 1. Seasonal density and diversity of phytoplankton (No./ml) at five selected sampling sites of river Kulik, Uttar Dinajpur

Class/Species	WINTER										SUMMER										MONSOON										Total
	2019					2020					2020					2021					2020					2021					
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	
Bacillariophyceae																															
Amphora sp.	0	320	0	160	600	520	200	480	440	360	120	320	480	480	400	360	320	440	480	480	680	360	680	640	0	600	0	440	520	560	11440
Cyclotella sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	360	0	480	440	0	0	0	320	120	0	1720
Cymbella sp.	280	0	360	0	600	360	0	360	360	560	160	0	320	240	320	160	320	320	120	400	360	440	0	560	760	640	600	480	360	560	10000
Diatoma sp.	0	0	440	240	0	0	0	520	0	0	240	320	0	0	400	320	360	160	0	400	0	0	320	520	0	0	0	400	0	0	4640
Fragillaria sp.	240	320	520	320	600	320	440	480	240	400	200	120	200	280	320	160	400	240	320	320	440	520	600	240	440	600	520	320	0	760	10880
Melosira sp.	280	400	400	0	0	360	0	240	280	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2440
Navicula sp.	0	0	440	520	0	0	0	440	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1400
Nitzchia sp.	0	0	0	0	0	0	0	0	0	0	120	320	240	160	0	0	320	320	280	320	0	0	0	480	0	0	0	0	480	0	3040
Rhizosolenia sp.	0	0	400	360	0	0	0	400	0	0	200	240	0	0	440	240	480	240	0	400	0	0	360	400	0	0	0	480	0	0	4640
Stephanodiscus sp.	0	0	320	240	0	0	0	320	0	0	160	200	0	0	320	240	240	360	0	320	0	0	280	240	0	0	0	400	0	0	3640
Surirella sp.	0	0	240	240	0	0	0	240	0	0	160	240	0	0	320	360	720	320	0	360	0	0	600	360	0	0	0	600	0	0	4760
Synedra sp.	0	400	280	400	520	0	0	520	400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2520
Charraphyceae																															
Chara sp.	0	0	240	400	0	0	0	400	0	0	80	200	0	0	480	240	160	120	0	320	0	0	760	520	0	0	0	480	0	0	4400
Chlorophyceae																															
Ankistrodesmus sp.	280	480	280	0	440	440	320	320	480	280	280	160	200	360	200	320	160	200	480	200	0	560	0	720	520	520	360	360	680	560	10160
Chlorella sp.	0	0	0	0	0	440	0	0	0	360	280	0	320	320	0	320	200	320	320	0	0	0	0	0	0	0	0	0	0	0	2880
Closterium sp.	160	0	240	0	600	560	0	280	560	520	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2920
Cosmariun sp.	0	0	0	0	480	280	0	0	280	0	120	240	160	160	160	160	240	120	160	160	0	0	0	0	0	0	0	0	0	0	2720
Desmidum sp.	120	0	120	400	480	480	360	160	520	400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3040
Eudorina sp.	200	0	120	200	520	360	360	160	360	360	0	0	0	0	0	0	0	0	0	0	640	0	600	400	400	400	360	400	400	800	7040
Microspora sp.	0	0	0	0	0	0	0	0	0	0	240	0	320	320	320	240	320	200	640	480	0	0	0	0	0	0	0	0	0	0	3080
Pandorina sp.	280	520	0	80	320	520	440	160	400	280	160	240	280	160	0	280	240	160	400	240	480	520	480	400	600	600	320	360	560	600	10080
Pediastrum sp.	0	0	360	400	560	320	320	480	360	520	0	0	0	0	0	0	80	0	0	0	320	480	0	400	520	360	600	480	320	640	7520
Pleodorina sp.	0	0	80	160	0	0	0	80	0	0	200	280	0	0	400	360	160	400	0	160	0	0	400	360	0	0	0	400	0	0	3440
Protococcus sp.	0	0	40	80	0	0	0	80	0	0	240	200	0	0	320	360	200	200	0	320	0	0	320	240	0	0	0	400	0	0	3000
Rhizoclonium sp.	0	0	80	80	0	0	0	80	0	0	280	240	0	0	280	320	240	240	0	160	0	0	240	320	0	0	0	360	0	0	2920
Scendesmus sp.	0	0	0	0	0	0	0	0	0	0	200	120	200	240	440	160	160	280	120	440	520	480	760	1120	720	880	840	1000	720	680	10080
Spirogyra sp.	0	0	0	80	0	0	0	80	0	0	360	360	0	0	360	240	280	240	0	360	0	0	320	400	0	0	0	400	0	0	3480
Ulothrix sp.	0	0	0	120	0	0	0	80	0	0	160	240	0	0	240	200	320	360	0	400	0	0	360	400	0	0	0	320	0	0	3200
Volvox sp.	320	560	240	160	480	0	360	200	0	520	0	240	200	80	400	120	320	280	240	360	200	360	240	360	560	240	600	400	480	480	9000
Zygnema sp.	320	600	240	160	400	240	240	0	240	440	0	200	0	640	360	440	280	120	320	400	240	360	320	440	560	320	360	280	600	440	9560
Chrysophyceae																															
Dinobryan sp.	0	0	0	120	0	0	0	80	0	0	360	320	0	0	320	200	320	240	0	200	0	0	360	360	0	0	0	360	0	0	3240
Synura sp.	0	0	0	80	0	0	0	80	0	0	320	360	0	0	280	240	360	280	0	240	0	0	400	320	0	0	0	400	0	0	3360
Cyanophyceae																															
Anabaena sp.	280	360	440	560	600	440	240	520	520	440	280	200	320	280	520	280	280	360	200	640	520	560	800	800	840	800	920	760	520	760	15040
Merismopedia sp.	0	0	0	120	0	0	0	0	0	0	240	320	0	0	320	240	400	320	0	400	0	0	400	400	0	0	0	360	0	0	3520
Microcysctis sp.	0	600	400	400	560	360	0	0	400	440	120	160	200	240	360	80	120	360	280	480	600	0	600	400	560	480	360	720	400	720	10400
Nostoc sp.	0	0	0	120	0	0	0	400	0	0	160	280	0	0	320	240	400	240	0	400	0	0	400	400	0	0	0	320	0	0	3680
Oscillatoria sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	520	0	600	600	0	520	0	0	760	3000
Phormidium sp.	320	480	0	120	0	280	640	320	480	640	200	320	320	400	240	280	240	240	320	400	520	640	360	640	840	0	720	360	0	400	10720
Spirulina sp.	0	0	0	0	0	0	0	360	0	0	320	320	0	0	240	320	320	160	0	360	0	0	320	400	0	0	0	400	0	0	3520
Dinophyceae																															
Ceratium sp.	0	0	0	0	0	0	0	240	0	0	360	280	0	0	360	360	240	360	0	320	0	0	360	360	0	0	0	360	0	0	3600
Peridinium sp.	360	0	0	0	520	440	320	400	240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2280
Euglenophyceae																															
Euglena sp.	0	0	0	0	0	0	0	0	600	0	0	0	320	0	0	0	0	0	240	0	0	0	0	0	0	0	0	0	0	0	1160
Phacus sp.	0	280	440	400	680	0	0	640	400	520	0	200	360	160	0	160	0	440	320	280	0	0	0	0	0	0	0	0	0	0	5280
Total	**3440**	**5320**	**6720**	**6720**	**8960**	**6720**	**4240**	**9600**	**7560**	**7520**	**6320**	**7240**	**4440**	**4520**	**9440**	**8000**	**9200**	**8640**	**5240**	**10720**	**5880**	**5800**	**12120**	**14640**	**7920**	**6440**	**7080**	**13120**	**6160**	**8720**	
Year wise total	**31160**					**35640**					**31960**					**41800**					**46360**					**41520**					

Table 2. Composition (%) of phytoplankton in different season from five selected sampling stations of river Kulik, Uttar Dinajpur

Class	WINTER										SUMMER										MONSOON									
	2019					2020					2020					2021					2020					2021				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
Bacillariophyceae	23.26	27.07	50.60	36.90	25.89	23.21	15.09	41.67	22.75	23.94	21.52	24.31	27.93	25.66	26.69	23.00	34.35	27.78	22.90	27.99	31.29	22.76	27.39	26.50	15.15	28.57	15.82	26.22	24.03	21.56
Charraphyceae	0.00	0.00	3.57	5.95	0.00	0.00	0.00	4.17	0.00	0.00	1.27	2.76	0.00	0.00	5.08	3.00	1.74	1.39	0.00	2.99	0.00	0.00	6.27	3.55	0.00	0.00	0.00	3.66	0.00	0.00
Chlorophyceae	48.84	40.60	26.79	28.57	47.77	54.17	56.60	22.50	42.33	48.94	39.87	34.81	37.84	50.44	36.86	44.00	34.78	36.11	51.15	34.33	40.82	47.59	33.33	37.98	48.99	51.55	48.59	39.33	61.04	48.17
Chrysophyceae	0.00	0.00	0.00	2.98	0.00	0.00	0.00	1.67	0.00	0.00	10.76	9.39	0.00	0.00	6.36	5.50	7.39	6.02	0.00	4.10	0.00	0.00	6.27	4.64	0.00	0.00	0.00	5.79	0.00	0.00
Cyanophyceae	17.44	27.07	12.50	19.64	12.95	16.07	20.75	16.67	18.52	20.21	20.89	22.10	18.92	20.35	21.19	18.00	19.13	19.44	15.27	25.00	27.89	29.66	23.76	24.86	35.86	19.88	35.59	22.26	14.94	30.28
Dinophyceae	10.47	0.00	0.00	0.00	5.80	6.55	7.55	6.67	3.17	0.00	5.70	3.87	0.00	0.00	3.81	4.50	2.61	4.17	0.00	2.99	0.00	0.00	2.97	2.46	0.00	0.00	0.00	2.74	0.00	0.00
Euglenophyceae	0.00	5.26	6.55	5.95	7.59	0.00	0.00	6.67	13.23	6.91	0.00	2.76	15.32	3.54	0.00	2.00	0.00	5.09	10.69	2.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3. Seasonal variation of Shannon Weiner Index (SWI) of phytoplankton (no./ml.) from five selected sampling stations of river Kulik, Uttar Dinajpur

	Sampling Sites										
Season	Site 1	Site 2	Site 3	Site 4	Site 5	Season	Site 1	Site 2	Site 3	Site 4	Site 5
Year - I						**Year - II**					
Winter 2019	0.24	0.30	0.33	0.33	0.36	**Winter 2020**	0.31	0.25	0.35	0.33	0.33
Summer 2020	0.32	0.34	0.27	0.28	0.36	**Summer 2021**	0.32	0.33	0.33	0.26	0.35
Monsoon 2020	0.26	0.26	0.35	0.36	0.30	**Monsoon 2021**	0.29	0.30	0.36	0.28	0.33

density was observed at Site 5 (10720/mL), followed by Site 2 (9200/mL), Site 3 (8640/mL), Site 1 (8000/mL) and Site 4 (5240/mL).

During the year 2020 of the monsoon season the highest phytoplankton density was observed at Site 4 (14640/mL), followed by Site 3 (12120/mL), Site 5 (7920/mL), Site 1 (5880/mL) and Site 2 (5800/mL) and during the year 2021 of the monsoon season the highest phytoplankton density was observed at Site 3 (13120/mL), followed by Site 5 (8720/mL), Site 2 (7080/mL), Site 1 (6440/mL) and the lowest density of the phytoplankton were observed in case of the Site 4 (6160/mL).

During the whole study period Chlorophyceae was the most dominant group with highest percentage at all the sites except Site 3 during winter season of the year 2019 and at Site 4 during winter of the years 2019 and 2020, where Bacillariophyceae percentage were highest (Table 2).

The Shannon Wiener diversity value was highest in case of Site 5 (0.36) during winter season of year 2019 and summer season of year 2020, in case of Site 4 during monsoon month of the year 2020 and in case of Site 3 during monsoon season of the year 2021 and the lowest value was recorded in case of Site 1 (0.24) during winter season of the year 2019 (Table 3).

During winter season of the year 2019 the highest similarity index 0.75 was recorded in between Site 3 and Site 4 and the lowest was found in between Site 1 and Site 4 (0.39) (Table 4). In the winter season of the year 2020 the highest similarity index 0.89 was recorded in between Site 1 and Site 4 and the lowest was found in between Site 2 and Site 3 (0.5) (Table 4).

In the summer season of the year 2020 the highest similarity index 0.91 was recorded in between Site 1 with Site 5 and Site 2 with Site 5. The lowest index value was found in between Site 3 and Site 5 (0.5) (Table 4). During the summer season of the year 2021 the highest similarity index 0.98 was recorded between Site 1 with Site 3 and Site 3 with Site 5. Lowest index value was found between Site 2 and Site 4 (0.61) (Table 4).

Table 4. Similarity Index of phytoplankton in different season from five selected sampling stations of river Kulik, Uttar Dinajpur

	Winter - Year 2019					Summer - Year 2020					Monsoon - Year 2020				
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 1	Site 2	Site 3	Site 4	Site 5	Site 1	Site 2	Site 3	Site 4	Site 5
Site 1	1	0.64	0.56	0.39	0.73	1	0.9	0.58	0.58	0.91	1	0.8	0.55	0.58	0.85
Site 2		1	0.51	0.5	0.69		1	0.53	0.58	0.91		1	0.41	0.55	0.88
Site 3			1	0.75	0.65			1	0.68	0.5			1	0.92	0.45
Site 4				1	0.53				1	0.55				1	0.58
Site 5					1					1					1
	Winter - Year 2020					**Summer - Year 2021**					**Monsoon - Year 2021**				
Site 1	1	0.76	0.53	0.89	0.88	1	0.95	0.98	0.63	0.97	1	0.88	0.57	0.88	0.92
Site 2		1	0.5	0.71	0.76		1	0.97	0.61	0.95		1	0.56	0.77	0.96
Site 3			1	0.59	0.57			1	0.65	0.98			1	0.56	0.59
Site 4				1	0.83				1	0.63				1	0.81
Site 5					1					1					1

In the monsoon season of the year 2020, the highest similarity index 0.92 was recorded in between Site 3 and Site 4 and the lowest index value was found in between Site 2 and Site 3 (0.41) (Table 4). In the monsoon season of the year 2021, the highest similarity index 0.96 was recorded in between Site 2 and Site 5 and the lowest index value was found in between Site 2 with Site 3 and Site 3 with Site 4 (0.56) (Table 4).

The habitat index of each phytoplankton present during the whole study period was presented in Table 5. The highest index values were observed in case of *Anabaena* sp. (4.49) in winter season of the year 2019, *Pediastrum* sp. (4.80) in winter season of the year 2020, *Cosmarium* sp. (4.76) in summer season of first year, *Amphora* sp. (4.89) in summer season of second year, *Pandorina* sp. (4.92) in monsoon season of year 2019 and *Scendesmus* sp. (4.91) in monsoon season of the year 2021.

The seasonal variation of Palmer's algal pollution index values was represented in Table 6. Out of 43 phytoplankton only 13 species show the index value (Table 6). According to Palmer's algal pollution index, *Cyclotella* sp., *Melosira* sp., *Closterium* sp., *Pandorina* sp. and *Phormidium* sp. shows index value of 1. *Synedra* sp., *Ankistrodesmus* sp. and *Phacus* sp. shows index value of 2. While, *Navicula* sp., *Nitzchia* sp. and *Chlorella* sp. shows index value of 3, *Oscillatoria* sp. and *Euglena* sp. shows index value of 5. In the summer season Site1, Site 2 and Site 5 shows moderate pollution during both years and Site 3 (17) during the year 2020 and Site 4 (17) during the year 2021 shows probable high organic pollution (Table 6).

Zooplankton diversity

Zooplankton provide the main food for fishes and can be used as indicators of the trophic status of water body (Rao and Muley 1981, Verma and Munshi 1987). The present study was undertaken to investigate the seasonal variations in zooplankton diversity of the river Kulik. A total of 53 zooplankton species were recorded during the present study (Table 7), out of which, 24 species belonged to Cladocera, 17 species to Rotifera, 6 species to Copepoda, 4 species to Rhizopoda and 2 species belonged to Ostracoda. During the present investigation class Rotifera was dominant among all the zooplankton

Table 5. Seasonal Habitat Index (HI) of phytoplankton diversity at five selected sampling sites of river Kulik, Uttar Dinajpur

Class/Species	Winter				Summer				Monsoon			
	2019		2020		2020		2021		2020		2021	
	HI	Ranking	HI	Ranking	HI	Ranking	HI	Ranking	HI	Ranking	HI	Ranking
Bacillariophyceae												
Amphora sp.	2.39	16	4.64	6	4.40	6	4.89	1	3.81	11	3.96	11
Cyclotella sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	2.96	14	1.66	15
Cymbella sp.	2.71	14	3.84	10	3.77	11	4.32	8	3.71	12	4.84	3
Diatoma sp.	1.84	25	1.00	21	2.89	24	3.69	27	1.89	30	1.00	16
Fragillaria sp.	4.49	2	4.76	3	4.57	4	4.64	4	4.67	4	3.70	12
Melosira sp.	2.93	12	3.74	13	Absent	NA	Absent	NA	Absent	NA	Absent	NA
Navicula sp.	1.99	21	1.00	22	Absent	NA	Absent	NA	Absent	NA	Absent	NA
Nitzchia sp.	Absent	NA	Absent	NA	3.54	12	4.00	12	1.00	32	1.00	17
Rhizosolenia sp.	2.00	20	1.00	23	2.66	29	3.67	28	2.00	20	1.00	18
Stephanodiscus sp.	1.96	22	1.00	24	2.76	28	3.89	17	1.99	23	1.00	19
Surirella sp.	2.00	19	1.00	25	2.80	26	3.53	31	1.88	31	1.00	20
Synedra sp.	3.83	6	1.97	20	Absent	NA	Absent	NA	Absent	NA	Absent	NA
Charraphyceae												
Chara sp.	1.88	24	1.00	26	2.09	32	3.54	30	1.93	29	1.00	21
Chlorophyceae												
Ankistrodesmus sp.	3.78	7	4.80	2	4.61	3	4.23	9	2.94	15	4.72	4
Chlorella sp.	Absent	NA	1.98	19	3.00	16	3.89	18	Absent	NA	Absent	NA
Closterium sp.	2.26	17	3.78	12	Absent	NA	Absent	NA	Absent	NA	Absent	NA
Cosmariun sp.	1.00	28	2.00	18	4.76	1	4.76	3	Absent	NA	Absent	NA
Desmidum sp.	3.00	10	4.53	8	Absent	NA	Absent	NA	Absent	NA	Absent	NA
Eudorina sp.	2.97	11	4.72	5	Absent	NA	Absent	NA	3.82	10	4.46	10
Microspora sp.	Absent	NA	Absent	NA	3.96	9	4.21	11	Absent	NA	Absent	NA
Pandorina sp.	3.15	9	4.46	9	3.78	10	4.61	5	4.92	1	4.71	5
Pediastrum sp.	2.89	13	4.80	1	Absent	NA	1.00	33	3.88	9	4.68	6
Pleodorina sp.	1.81	27	1.00	27	2.79	27	3.43	32	2.00	21	1.00	22
Protococcus sp.	1.81	26	1.00	28	2.90	23	3.75	25	1.96	27	1.00	23
Rhizoclonium sp.	2.01	18	1.00	29	2.99	17	3.80	23	1.96	28	1.00	24
Scendesmus sp.	Absent	NA	Absent	NA	4.18	8	4.00	13	4.55	6	4.91	1
Spirogyra sp.	1.00	29	1.00	30	3.01	14	3.89	15	1.98	24	1.00	25
Ulothrix sp.	1.00	30	1.00	31	2.92	22	3.80	22	2.00	22	1.00	26
Volvox sp.	4.25	3	2.65	17	3.21	13	4.57	6	4.42	7	4.67	7
Zygnema sp.	4.20	4	3.68	14	2.49	31	4.44	7	4.64	5	4.64	8
Chrysophyceae												
Dinobryan sp.	1.00	31	1.00	32	3.00	15	3.85	20	2.00	16	1.00	27
Synura sp.	1.00	32	1.00	33	2.98	18	3.89	16	1.98	25	1.00	28
Cyanophyceae												
Anabaena sp.	4.67	1	4.74	4	4.50	5	4.22	10	4.83	2	4.86	2
Merismopedia sp.	1.00	33	Absent	NA	2.96	20	3.86	19	2.00	18	1.00	29
*Microcysctis*sp.	3.87	5	2.99	15	4.38	7	3.80	21	3.91	8	4.62	9
Nostoc sp.	1.00	34	1.00	34	2.81	25	3.77	24	2.00	19	1.00	30
Oscillatoria sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	2.99	13	1.93	14
Phormidium sp.	2.44	15	4.53	7	4.75	2	4.82	2	4.68	3	2.71	13
Spirulina sp.	Absent	NA	1.00	35	2.96	21	3.75	26	1.98	26	1.00	31
Dinophyceae												
Ceratium sp.	Absent	NA	1.00	36	2.97	19	3.92	14	2.00	17	1.00	32
Peridinium sp.	1.94	23	3.82	11	Absent	NA	Absent	NA	Absent	NA	Absent	NA
Euglenophyceae												
Euglena sp.	Absent	NA	1.00	37	1.00	33	1.00	34	Absent	NA	Absent	NA
Phacus sp.	3.63	8	2.90	16	2.66	30	3.61	29	Absent	NA	Absent	NA

Table 6. Seasonal variation of the Palmer's algal pollution index values at five selected sampling sites of river Kulik, Uttar Dinajpur, West Bengal during November, 2019 to October, 2021

Class/Species	**WINTER**										**SUMMER**										**MONSOON**									
	2019					**2020**					**2020**					**2021**					**2020**					**2021**				
	S1	**S2**	**S3**	**S4**	**S5**	**S1**	**S2**	**S3**	**S4**	**S5**	**S1**	**S2**	**S3**	**S4**	**S5**	**S1**	**S2**	**S3**	**S4**	**S5**	**S1**	**S2**	**S3**	**S4**	**S5**	**S1**	**S2**	**S3**	**S4**	**S5**
Bacillariophyceae																														
Cyclotella sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	-	-	-	1	1	-
Melosira sp.	1	1	1	-	1	1	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Navicula sp.	-	-	3	3	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitzchia sp.	-	-	-	-	-	-	-	-	-	-	3	3	3	3	-	-	3	3	3	3	-	-	-	-	-	-	-	-	-	-
Synedra sp.	-	2	2	2	2	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorophyceae																														
Ankistrodesmus sp.	2	2	2	-	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-	2	-	2	2	2	2	2	2	2
Chlorella sp.	-	-	-	-	-	-	-	-	-	-	3	-	3	3	-	3	3	3	3	-	-	-	-	-	-	-	-	-	-	-
Closterium sp.	1	-	1	-	1	1	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Pandorina sp.	1	1	-	1	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cyanophyceae																														
Oscillatoria sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	5	5	5	5	-	5	5
Phormidium sp.	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Euglenophyceae																														
Euglena sp.	-	-	-	-	-	-	5	-	5	-	-	-	5	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-
Phacus sp.	-	2	2	2	2	-	-	2	2	2	-	2	2	2	-	2	-	2	2	2	-	-	-	-	-	-	-	-	-	-
Total	**6**	**9**	**12**	**9**	**9**	**6**	**9**	**13**	**15**	**8**	**10**	**9**	**17**	**12**	**3**	**9**	**10**	**12**	**17**	**9**	**3**	**9**	**3**	**10**	**9**	**9**	**9**	**6**	**10**	**9**

According to Palmer's Algal Pollution Index values between 0-10 indicate lack of organic pollution, 10-15 moderate pollution, 15-20 probable high organic pollution and 20 and above as confirmed high organic pollution.

groups in all the seasons. However, the diversity of zooplankton varied from season to season and the maximum diversity was recorded in winter season and minimum in monsoon season (Table 7).

During the present study *Chydorus barrosi*, *Chydorus sphaericus*, *Moina* sp., *Diaphanosoma excium*, *Mesocyclops* sp., *Brachionus* sp., *Lecane* sp., *Testudinella* sp. were found throughout the whole study period. On the other hand, species like *Alona davidi*, *Alona quadrangularis*, *Alona rectangular*, *Mesoccyclops hyalinus*, *Polyarthra vulgaris* were found only in the summer seasons of both the years. 23 species of zooplankton *Biapertura affinis*, *Biapertura karua*, *Kurzia* sp., *Natoalona* sp., *Oxyurella* sp., *Bosmina longirostris*, *Ceriodaphnia* sp., *Scapholeberis* sp., *Simocephalus exspinosus*, *Simocephalus vetulus*, *Macrothrix* sp., *Sida* sp., *Mesoccyclops hyalinus*, *Microcyclops* sp., *Arctodiaptomus* sp., *Strandesia* sp., *Arcella* sp., *Centropyxix aculeata*, *Centropyxix ecornis*, *Difflugia* sp., *Ascomorpha* sp., *Monommata* sp., *Synchaetia* sp., were recorded only in the monsoon season of both the years. *Euchalnus* sp., *Cephalodella* sp., *Trichocerca* sp. were recorded only in the winter season of both the years. *Dunhevedia* sp. and *Diaphano somasarsi* were found in the winter as well as monsoon season of both the years. Eleven species *Dunhevedia* sp., *Pleuroxus* sp., *Daphnia carinata*, *Daphnia lumholtzi*, *Trophocyclops* sp., *Heliodiaptomus* sp., *Cypris* sp., *Asplanchna* sp., *Keratella procurva*, *Keratella tropica*, *Filinia* sp. and *Mytilina* sp. were found in the winter and summer season of both the years. *Anuraeopsis* sp. and *Lepadella* sp. were recorded in the summer as well as monsoon season of both the years.

Percentage contribution of all zooplankton population is presented in Table 8. Cladocera contributed maximum species diversity throughout the study period. Cladocera contributed maximum zooplankton population followed by Rotifera (32.08%), Copepoda (11.32%), Rhizopoda (7.55%) and Ostracoda (3.77%), respectively.

The highest zooplankton density was observed at Site 4 (4490/mL), followed by Site 5 (3980/mL), Site 3 (3720/mL), Site 2 (2350/mL) and Site 1 (730/mL) during the winter season of the year 2019. Other hand highest zooplankton density was observed at Site 4 (3460/mL), followed by Site 2 (3150/mL), Site 5 (3020/mL), Site 3 (2440/mL) and Site 1 (2160/mL) (Table 7) during the winter season of the year 2020.

In the Summer season of the year 2020 the highest zooplankton density was observed at Site 2 (2880/mL), followed by Site 4 (2700/mL), Site 1 (2310/

Table 7. Seasonal density and diversity of zooplankton (unit/m^3) at five selected sampling sites of river Kulik, Uttar Dinajpur

Order/Family/Species	WINTER										SUMMER										MONSOON										Total
	2019					2020					2020					2021					2020					2021					
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	
Cladocera																															
Aloninae																															
Alona davidi	0	0	0	0	0	0	0	0	0	0	130	0	160	0	150	80	100	120	140	80	0	0	0	0	0	0	0	0	0	0	960
Alona quadrangularis	0	0	0	0	0	0	0	0	0	0	160	150	0	140	0	80	0	80	120	100	0	0	0	0	0	0	0	0	0	0	830
Alona rectangula	0	0	0	0	0	0	0	0	0	0	0	140	140	0	100	120	80	0	80	120	0	0	0	0	0	0	0	0	0	0	780
Biaperturaaffinis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	130	0	120	150	100	150	80	100	830
Biapertur akarua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	100	0	130	120	150	600
Kurzia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	190	0	100	190	0	200	210	990
Natoalona sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	180	140	0	150	190	200	190	210	1260
Oxyurella sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	0	0	80	100	100	120	150	180	850
Bosminidae																															
Bosmina longirostris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	110	90	100	110	90	90	110	110	110	1000
Chydoridae																															
Chydorus barrosi	200	0	200	280	0	0	150	0	160	130	140	100	0	130	0	100	80	0	100	0	110	0	100	120	0	140	150	0	0	0	2390
Chydorus sphaericus	150	0	240	210	190	0	100	90	0	0	0	120	150	0	100	0	100	80	0	80	130	0	180	110	0	190	140	200	0	210	2770
Dunhevedia sp.	0	150	0	230	250	130	0	0	100	160	0	0	0	0	0	0	0	0	0	0	0	100	0	0	100	0	0	0	210	0	1430
Pleuroxus sp.	0	0	170	0	260	120	0	140	110	0	0	100	150	0	120	0	120	80	0	100	0	0	0	0	0	0	0	0	0	0	1470
Daphniidae																															
Ceriodaphnia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	90	0	0	0	190	100	0	0	150	530
Daphnia carinata	0	280	0	220	240	0	150	170	0	0	130	140	0	130	0	0	80	80	80	0	0	0	0	0	0	0	0	0	0	0	1700
Daphnia lumholtzi	0	0	290	0	290	110	100	0	160	180	140	0	150	130	0	120	0	0	100	120	0	0	0	0	0	0	0	0	0	0	1890
Scapholeberis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	110	0	140	0	130	0	170	0	550
Simocephalusexspinosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	110	0	0	0	150	0	0	0	120	380
Simocephalus vetulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	0	100	0	180	0	170	0	150	750
Macrothricidae																															
Macrothrix sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	0	0	130	80	130	0	90	110	740
Monidae																															
Moina sp.	0	0	160	190	0	140	150	0	140	140	140	130	0	140	0	80	80	0	80	80	0	0	70	100	0	50	40	0	110	110	2130
Sididae																															
Diaphanosoma excium	0	0	290	260	0	150	180	110	170	180	0	100	0	150	100	80	100	100	100	80	0	100	0	150	0	80	110	100	150	130	2970
Diaphanosoma sarsi	0	0	210	0	230	140	0	160	150	140	0	0	0	0	0	0	0	0	0	0	0	0	110	0	150	130	0	100	120	140	1780
Sida sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	140	0	110	100	130	0	140	130	750
Copepoda																															
Cyclopidae																															
Mesoccyclops hyalinus	0	0	0	0	0	0	0	0	0	0	140	120	0	150	120	100	110	0	150	200	0	0	0	0	0	0	0	0	0	0	1090
Mesocyclops sp.	0	0	210	270	240	140	160	0	130	120	0	100	0	120	0	150	140	0	100	100	0	0	90	0	130	110	150	0	90	120	2670
Microcyclops sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	180	0	0	90	90	130	0	110	100	700
Trophocyclops sp.	0	180	0	260	270	120	100	0	110	140	140	100	0	140	0	130	160	0	120	180	0	0	0	0	0	0	0	0	0	0	2150
Diptomidae																															
Arctodiaptomus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	180	0	110	0	110	130	90	100	720
Heliodiaptomus sp.	0	0	280	250	0	120	100	0	120	150	0	100	0	120	150	0	0	110	180	0	0	0	0	0	0	0	0	0	0	0	1680
Ostracoda																															
Cyprididae																															
Cypris sp.	0	200	0	290	210	150	180	140	100	170	150	120	0	100	0	120	180	150	100	150	0	0	0	0	0	0	0	0	0	0	2510
Strandesia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	0	0	110	0	140	180	130	90	800
Rhizopoda																															
Arcellinidae																															
Arcella sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	0	0	180	170	110	180	190	950
Centropyxix aculeata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	190	210	150	0	190	120	100	960

Order/Family/Species	WINTER										SUMMER										MONSOON										Total
	2019					2020					2020					2021					2020					2021					
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	
Centropyxix ecornis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	140	90	0	110	90	100	0	150	130	810
Difflugia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	110	120	0	130	90	110	140	180	880
Rotifera																															
Asplanchnidae																															
Asplanchna sp.	0	270	0	240	250	170	160	170	160	140	0	140	170	0	170	80	80	160	80	160	0	0	0	0	0	0	0	0	0	0	2600
Brachionidae																															
Anuraeopsis fissa	0	0	0	0	0	0	0	0	0	0	160	170	0	150	180	160	0	120	0	160	20	80	0	100	110	110	0	110	0	180	1810
Brachionus sp.	0	220	270	0	260	0	160	160	160	150	140	160	0	150	140	0	80	160	80	80	0	130	0	130	100	0	60	130	150	160	3230
Keratella procurva	0	0	290	210	200	170	190	170	200	160	0	100	0	100	150	80	160	150	100	160	0	0	0	0	0	0	0	0	0	0	2590
Keratella tropica	200	170	220	220	230	150	90	150	130	110	150	160	140	130	160	80	120	120	80	120	0	0	0	0	0	0	0	0	0	0	2930
Colurellidae																															
Lepadella sp.	0	0	0	0	0	0	0	0	0	0	150	140	0	140	140	0	80	80	80	80	80	100	70	0	100	0	70	80	150	110	1650
Euchlanidae																															
Euchalnus sp.	0	0	270	230	0	0	100	150	190	170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1110
Filinidae																															
Filinia sp.	0	200	0	230	220	0	140	100	160	140	150	130	0	140	0	0	80	120	80	80	0	0	0	0	0	0	0	0	0	0	1970
Gastropodidae																															
Ascomorpha sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	130	100	0	0	120	0	110	120	680
Lecanidae																															
Lecane sp.	0	230	220	0	190	0	200	150	180	120	150	0	160	0	140	0	120	100	110	120	0	120	0	110	100	100	110	130	140	120	3120
Mytilinidae																															
Mytilina sp.	0	0	190	190	170	120	100	130	170	110	140	100	0	180	120	140	110	120	190	140	0	0	0	0	0	0	0	0	0	0	2420
Notommatidae																															
Cephalodella sp.	0	0	210	170	0	0	190	140	200	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1010
Monommata sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	90	150	0	100	120	120	150	100	150	100	1080
Synchaetidae																															
Polyarthra vulgaris	0	0	0	0	0	130	160	0	150	0	0	120	80	120	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	840
Synchaetia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	90	100	90	150	120	90	110	90	840
Testudinellidae																															
Testudinella sp.	0	240	0	250	280	0	170	150	160	170	0	140	190	140	180	0	80	160	80	160	80	130	80	100	100	0	110	130	130	160	3570
Trichocercidae																															
Trichocerca sp.	180	210	0	290	0	100	120	160	150	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1350
Total	**730**	**2350**	**3720**	**4490**	**3980**	**2160**	**3150**	**2440**	**3460**	**3020**	**2310**	**2880**	**1490**	**2700**	**2300**	**1700**	**2240**	**2090**	**2330**	**2650**	**690**	**2260**	**2170**	**2060**	**2420**	**3210**	**3230**	**2770**	**3790**	**4260**	
Year wise total	**15270**					**14230**					**11680**					**11010**					**9600**					**17260**					

Table 8. Composition (%) of zooplankton population in various season from different sampling sites of river Kulik, Uttar Dinajpur

Class	WINTER										SUMMER										MONSOON									
	2019					2020					2020					2021					2020					2021				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
Cladocera	47.95	18.30	41.94	30.96	36.68	36.57	26.35	27.46	28.61	30.79	36.36	34.03	50.34	30.37	24.78	38.82	33.04	25.84	34.33	28.68	60.87	43.36	55.76	49.03	38.84	61.68	49.54	46.21	48.55	51.88
Copepoda	0.00	7.66	13.17	17.37	12.81	17.59	11.43	0.00	10.40	13.58	12.12	14.58	0.00	19.63	11.74	22.35	18.30	5.26	23.61	18.11	0.00	7.96	12.44	0.00	13.64	6.23	12.07	4.69	7.65	7.51
Ostracoda	0.00	8.51	0.00	6.46	5.28	6.94	5.71	5.74	2.89	5.63	6.49	4.17	0.00	3.70	0.00	7.06	8.04	7.18	4.29	5.66	0.00	6.64	0.00	0.00	4.55	0.00	4.33	6.50	3.43	2.11
Rhizopoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.19	14.75	15.05	13.22	17.13	11.15	14.80	15.57	14.08
Rotifera	52.05	65.53	44.89	45.21	45.23	38.89	56.51	66.80	58.09	50.00	45.02	47.22	49.66	46.30	63.48	31.76	40.63	61.72	37.77	47.55	39.13	35.84	17.05	35.92	29.75	14.95	22.91	27.80	24.80	24.41

Table 9. Seasonal variation of Shannon Weiner Index (SWI) of zooplankton (no./ml.) from five selected sampling stations of river Kulik, Uttar Dinajpur

	Sampling Sites										
Season	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**		**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**
Year - I						**Year - II**					
Winter 2019	0.15	0.29	0.34	0.36	0.35	**Winter 2020**	0.29	0.33	0.30	0.34	0.33
Summer 2020	0.32	0.35	0.26	0.34	0.32	**Summer 2021**	0.29	0.32	0.32	0.33	0.34
Monsoon 2020	0.19	0.34	0.34	0.33	0.35	**Monsoon 2021**	0.30	0.30	0.33	0.32	0.34

Table 10. Similarity Index of zooplankton in different season from five selected sampling stations of river Kulik, Uttar Dinajpur

	Winter - Year 2019					**Summer - Year 2020**					**Monsoon - Year 2020**				
	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**
Site 1	1	0.27	0.3	0.35	0.19	1	0.61	0.31	0.78	0.48	1	0.17	0.26	0.29	0.16
Site 2		1	0.22	0.6	0.71		1	0.42	0.88	0.75		1	0.26	0.5	0.65
Site 3			1	0.63	0.61			1	0.27	0.67			1	0.56	0.55
Site 4				1	0.67				1	0.59				1	0.42
Site 5					1					1					1
	Winter - Year 2020					**Summer - Year 2021**					**Monsoon - Year 2021**				
Site 1	1	0.68	0.42	0.82	0.76	1	0.75	0.41	0.79	0.79	1	0.75	0.68	0.74	0.88
Site 2		1	0.77	0.89	0.88		1	0.77	0.88	0.88		1	0.67	0.87	0.86
Site 3			1	0.75	0.74			1	0.75	0.8			1	0.73	0.81
Site 4				1	0.48				1	0.86				1	0.88
Site 5					1					1					1

mL), Site 5 (2300/mL) and Site 3 (1490/mL) and in the year 2021 the maximum zooplankton density was observed at Site 5 (2650/mL), followed by Site 4 (2330/mL), Site 2 (2240/mL), Site 3 (2090/mL) and Site 1 (1700/mL) (Table 7).

During the year 2020 of monsoon season the highest zooplankton density was observed at Site 5 (2420/mL), followed by Site 2 (2260/mL), Site 3 (2170/mL), Site 4 (2060/mL) and Site 1 (690/mL) and in the year 2021 of monsoon season the highest zooplankton density was observed at Site 5 (4260/mL), followed by Site 4 (3790/mL), Site 2 (3230/mL), Site 1 (3210/mL) and Site 3 (2770/mL) (Table 7).

During the winter season of the years 2019 and 2020 Rotifera was the most dominant group with highest percentage in winter (66.80) and Ostracoda was the lowest (2.89). In the summer of the years 2020 and 2021 Rotifera was the highest (63.48) at Site 5 and Ostracoda was the lowest (3.70) at Site 4. In the monsoon season of years 2020 and 2021 composition of Cladocera was highest (60.87) at Site 1 and that of Ostracoda was lowest (2.11) at Site 5 (Table 8).

The Shannon Wiener diversity value was highest at Site 4 (0.36) during winter of the year 2019 and lowest at Site 1 (0.15). During the summer of year 2020 the highest Shannon Wiener diversity value was seen at Site 2 (0.35) and the lowest at Site 3 (0.26) during summer of the year 2020. In the monsoon season of year 2020 the highest value was seen at Site 5 (0.35) and the lowest at Site 1 (0.19) (Table 9).

During winter season of year 2019 the highest similarity index 0.71 was recorded between Site 2 and Site 5 and lowest between Site 1 and Site 5 (0.19). In the winter season of year 2020 highest similarity index 0.89 was recorded between Site 2 and Site 4 and the lowest was found between Site 1 and Site 3 (0.42) (Table 10).

In the summer season of the first-year study period the highest similarity index 0.88 was recorded in between Site 2 and Site 4. The lowest index value was found in between Site 3 and Site 4 (0.27). During summer season of second year of the study period the highest similarity index 0.88 was recorded in between Site 2 with Site 4 and Site 2 with Site 5. Lowest index value was found in between Site 1 and Site 3 (0.41) (Table 10).

The highest similarity index (0.65) was recorded between Site 2 and Site 5 and the lowest between Site 1 and Site 5 (0.16) during monsoon of the year 2020. The highest similarity index (0.88) was recorded between Site 1 with Site 5 and Site 4 with Site 5 during the monsoon of year 2021 and the lowest between Site 2 and Site 3 (0.67) (Table 10).

The habitat index of each zooplankton present during the whole study period was presented in Table 11. The highest index values were observed in case of *Keratella tropica* in winter season (4.97) of year 2019 and in summer season (5.00) of year 2020, *Asplancha* sp. (5.00) in winter season of year 2020, *Diphanoso maexcium* (4.99) in summer season of year 2021, *Bosmina longirostris* (4.97) in monsoon season of year 2020 and (4.99) in monsoon season of year 2021.

DISCUSSION

The river Kulik is dominated by Chlorophyceae group, followed by Bacillariophyceae group. Similar pattern of phytoplankton was recorded in Narmada river of Madhya Pradesh (Sharma et al. 2011). The highest and lowest phytoplankton densities in the first year were recorded during the monsoon and winter, respectively, and may have been influenced by water temperature and photoperiod. Temperature was suggested as a key element influencing the development of algae by Ramkrishnaiah and Sarkar (1982). According to Wishard and Mehrotra (1988), the gradually rising water temperature and photoperiod were the greater multiplication of phytoplankton from winter to summer. During the monsoon, a high density and diversity of phytoplankton were also seen (Table 1).

Palmer (1969) compiled a list of the 60 most pollution tolerant algal genera. In the present study, a total of 13 taxa of pollution-tolerant algae were identified from the various sampling sites of the river Kulik (Table 6). Palmer (1969) defined an alga as present when there are 50 or more of them present in one millilitre of water. Because of this, only thirteen algal genera were taken into account to prepare the pollution index, including *Cyclotella* sp., *Melosira* sp., *Closterium* sp., *Pandorina* sp., *Phormidium* sp., *Synedra* sp., *Ankistrodesmus* sp.,

Table 11. Seasonal Habitat Index (HI) of zooplankton diversity at five selected sampling sites of river Kulik, Uttar Dinajpur

Order/Family/Species	Winter				Summer				Monsoon			
	2019		2020		2020		2021		2020		2021	
	HI	Ranking	HI	Ranking	HI	Ranking	HI	Ranking	HI	Ranking	HI	Ranking
Cladocera												
Aloninae												
Alona davidi	Absent	NA	Absent	NA	2.99	15	4.80	5	Absent	NA	Absent	NA
Alona quadrangularis	Absent	NA	Absent	NA	3.00	11	3.91	12	Absent	NA	Absent	NA
Alona rectangula	Absent	NA	Absent	NA	2.95	18	3.87	15	Absent	NA	Absent	NA
Biapertura affinis	Absent	NA	Absent	NA	Absent	NA	Absent	NA	2.00	16	4.74	10
Biapertura karua	Absent	NA	Absent	NA	Absent	NA	Absent	NA	1.00	31	3.94	16
Kurzia sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	1.83	29	3.78	23
Natoalona sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	1.98	20	4.96	3
Oxyurella sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	1.93	25	4.76	9
Bosminidae												
Bosmina longirostris	Absent	NA	Absent	NA	Absent	NA	Absent	NA	4.97	1	4.99	1
Chydoridae												
Chydorusbarrosi	2.93	11	2.99	20	2.96	17	2.99	21	3.00	4	2.00	31
Chydorus sphaericus	3.91	2	2.01	24	2.93	20	2.99	22	2.89	13	3.93	17
Dunhevedia sp.	2.89	16	2.91	23	Absent	NA	Absent	NA	2.01	14	1.00	34
Pleuroxus sp.	1.92	24	2.99	22	2.93	21	2.94	24	Absent	NA	Absent	NA
Daphniidae												
Ceriodaphnia sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	1.00	32	2.83	30
Daphnia carinata	2.98	9	2.00	25	3.01	9	3.03	19	Absent	NA	Absent	NA
Daphnia lumholtzi	2.00	17	3.80	18	3.00	13	3.00	20	Absent	NA	Absent	NA
Scapholeberis sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	1.98	18	1.97	33
Simocephalus exspinosus	Absent	NA	Absent	NA	Absent	NA	Absent	NA	1.00	33	1.98	32
Simocephalus vetulus	Absent	NA	Absent	NA	Absent	NA	Absent	NA	1.93	26	3.00	28
Macrothricidae												
Macrothrix sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	2.97	8	3.89	19
Monidae												
Moina sp.	1.99	22	4.02	8	3.01	10	4.04	8	1.95	23	3.42	26
Sididae												
Diaphanosoma excium	2.00	19	4.89	4	2.90	24	4.99	1	1.93	27	4.82	7
Diaphanosoma sarsi	2.00	18	4.01	11	Absent	NA	Absent	NA	1.96	21	3.97	12
Sida sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	1.98	19	3.97	11
Copepoda												
Cyclopidae												
Mesoccyclops hyalinus	Absent	NA	Absent	NA	3.98	5	3.72	16	Absent	NA	Absent	NA
Mesocyclops sp.	2.98	10	3.98	12	1.99	26	3.89	13	1.94	24	3.89	18
Microcyclops sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	1.81	30	3.95	13
Trophocyclops sp.	2.92	12	3.96	13	2.95	19	3.92	11	Absent	NA	Absent	NA
Diptomidae												
Arctodiaptomus sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	1.90	28	3.95	14
Heliodiaptomus sp.	2.00	20	3.94	14	2.93	22	1.90	25	Absent	NA	Absent	NA
Ostracoda												
Cyprididae												
Cypris sp.	2.92	13	4.85	6	2.93	23	4.84	3	Absent	NA	Absent	NA
Strandesia sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	1.96	22	3.81	21
Rhizopoda												
Arcellinidae												
Arcella sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	1.00	34	4.88	4

Order/Family/Species	Winter				Summer				Monsoon			
	2019		2020		2020		2021		2020		2021	
	HI	Ranking	HI	Ranking	HI	Ranking	HI	Ranking	HI	Ranking	HI	Ranking
Centropyxix aculeata	Absent	NA	Absent	NA	Absent	NA	Absent	NA	2.00	17	3.80	22
Centropyxix ecornis	Absent	NA	Absent	NA	Absent	NA	Absent	NA	2.92	12	3.87	20
Difflugia sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	2.00	15	4.77	8
Rotifera												
Asplanchnidae												
Asplanchna sp.	3.00	4	5.00	1	2.99	16	4.48	7	Absent	NA	Absent	NA
Brachionidae												
Anuraeopsisfissa	Absent	NA	Absent	NA	4.00	4	2.96	23	2.97	7	2.84	29
*Brachionus*sp.	2.99	8	4.02	9	4.01	3	3.59	18	2.98	6	3.66	25
Keratellaprocurva	2.92	14	4.99	2	2.90	25	4.72	6	Absent	NA	Absent	NA
Keratellatropica	4.97	1	4.86	5	5.00	1	4.86	2	Absent	NA	Absent	NA
Colurellidae												
Lepadella sp.	Absent	NA	Absent	NA	4.02	2	4.04	9	2.95	10	3.69	24
Euchlanidae												
Euchalnus sp.	1.99	21	3.83	17	Absent	NA	Absent	NA	Absent	NA	Absent	NA
Filinidae												
Filinia sp.	3.00	5	3.92	15	3.00	14	3.89	14	Absent	NA	Absent	NA
Gastropodidae												
Ascomorpha sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	2.97	9	3.01	27
Lecanidae												
Lecane sp.	2.99	7	3.88	16	3.00	12	4.00	10	3.00	5	4.96	2
Mytilinidae												
Mytilina sp.	3.00	3	4.85	7	3.84	8	4.84	4	Absent	NA	Absent	NA
Notommatidae												
Cephalodella sp.	1.98	23	3.77	19	Absent	NA	Absent	NA	Absent	NA	Absent	NA
Monommata sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	2.93	11	4.87	5
Synchaetidae												
Polyarthra vulgaris	Absent	NA	2.99	21	3.87	7	Absent	NA	Absent	NA	Absent	NA
Synchaetia sp.	Absent	NA	Absent	NA	Absent	NA	Absent	NA	3.01	3	4.84	6
Testudinellidae												
Testudinella sp.	2.99	6	4.01	10	3.94	6	3.62	17	3.91	2	3.95	15
Trichocercidae												
Trichocerca sp.	2.89	15	4.90	3	Absent	NA	Absent	NA	Absent	NA	Absent	NA

Phacus sp., *Navicula* sp., *Nitzchia* sp., *Chlorella* sp. To calculate the value of the algal genus index, the numbers scored by each algal genus were added up. Organic pollution was identified by a score of 20 or above for a sample, a score of 15 to 19 was considered likely proof of substantial organic pollution, and lower values showed that the level of organic pollution was not as high (Palmer 1969).

During the winter season of 2019 to monsoon season of 2020 Site 3 had the highest score of 17, followed by Site 4 (12) and Site 1 (10), while Site 5 had the lowest score of 3. Table 6 displayed the overall results from each of the five sampling sites had total scores that are between 3 and 17, which indicate likely proof of significant organic contamination. Higher scores (17) were obtained from Site 3 and Site 4 during the summer season of the years 2020 and 2021, respectively. The mixing of sewage from a neighbouring municipal disposal site may have caused the contamination at Sites 3 and 4. The garbage dumped into the river Kulik from the Raiganj municipality region might be the cause of pollution at Site 3.

Zooplankton are crucial in determining the productivity of a river. Zooplankton serve as the primary source of nutrition for a variety of aquatic organisms, including fish, which in turn provide food for waterfowl. The trophic status of a waterbody may be determined by the presence or absence of a particular species of zooplankton, which also serves as a conduit for the flow of energy across trophic levels and reveals information about the numerous connections in food chains and the food web (Eramma et al. 2023).

Fifty three species of zooplankton belonging to 5 groups - Cladocera, Copepoda, Ostracoda, Rhizopoda, and Rotifera - were recorded, of which 24 species were from Cladocera, 17 from Rotifera, 6 from Copepoda, 4 from Rhizopoda, and 2 from Ostracoda. The highest zooplankton diversity index (0.36) was recorded during the first-year of the winter season (Table 7). Al-Hashmi et al. (2019) also observed the highest zooplankton diversity during winter and monsoon season at coastal wetlands of Oman.Less zooplankton population during summer season (Table 7) in on account of high turbidity which restricts growth of the planktonic population.

The dominance of rotifers is characteristic of tropical water bodies (Bidwell and Clarke 1977, Egborge 1981, Mwebaza-Nadwula 2005). On the basis of qualitative study, species of *Brachionus angularis, Brachionus falcatus, Keratella tropica, Lecane lunaris* and *Testudinella patina* were the dominant and the most common species which occurred throughout the study period among the class Rotifera. Winter was the season with the highest rotifer population density and variety during the first year of the research (Table 7). Fathibi et al. (2020) found a higher population density and variety of rotifers in the winter in Thrissur Kole wetland, Kerala, India. The water temperature, in particular, has a considerable influence on the relative abundance of rotifers (Diovisalvi et al. 2015). Rotifera makes up the majority of the zooplankton population overall. This group displayed more peaks and a higher level of qualitative variation than other groups. Many scholars have already noted the uneven periodicity in the abundance of the rotifer population (Kar and Kar 2016, Rinaldo et al. 2018). In varied conditions, rotifers can survive, according to Singh (2000); typically, they are prolific in the summer, showing a close link with high temperatures. Similar findings were obtained in the current investigation as well. According to Toth et al. (2020) the rotifers from the Hungarian lowland Oxbow Lake showed dominance in summer season.

In freshwaters, cladocerans are crucial elements of the food web and a crucial link in the aquatic food chain (Battish and Kumari 1986). Cladocera had a significant role in the aquatic food chain as a source of nutrition for both juvenile and adult fish (Pennak 1978). In the river Kulik, cladocerans made up the second-largest zooplankton group. *Bosmina* sp., *Chydorus phaericus, Daphnia carinata, Diaphanosoma excisum* were dominant among Cladocera. In comparison to summer, cladocerans were more numerous in the winter and monsoon. The low density during the summer may be caused by rotifers growing more densely and avoiding competition. This finding is in agreement with Choi and Kim (2020) in a Shallow reservoir of South Korea.

Free living Copepods are an important component of the food chain, occupying the trophic level that is between tiny and large plankton predators and bacteria, algae, and protozoa. These are widely recognised as critical intermediate hosts for helminth infections, while not being as significant in fish diets as Cladocerans. Copepods form the third-largest category in the present study (Table 8). This group was noted throughout the research period, which supports the finding of Sakhare and Jetithor (2021) in the wetland of Ambajogai of Beed District, Maharashtra, India. Copepods were represented in the present study by *Mesocyclops* sp., *Microyclops* sp., and *Trophoclops* sp. *Mesocyclops leuckarti* and *Thermocyclops* sp. were recorded during all the seasons among Copepoda and only one species of class Ostracoda namely *Cypris* sp. was found throughout the study period.

The presumed presence of *Arcella* sp., *Difflugia* sp., *Brachionus* sp., *Cephlodella* sp., *Keratella procurva, Keratella tropica, Lecane* sp., *Bosmina* sp.,*Chydorus sphaericus, Daphnia* sp., *Diaphanosoma excisum, Mesocyclops leuckarti* and *Thermocyclops* sp. in all the seasons indicates the higher trophic status of the river as these species are indicator of eutrophication (David and Roy 1966, Raina 1981, Sharma 1983, Chourasia and Adoni 1985 Agarkar et al. 1994, Wanganeo and Wanganeo 2006, Kumar et al. 2010, Mondal et al. 2013). Two species, *Brachionus* sp. and *Mesocyclops* sp. that have been proposed as pollution indicator species by several researchers (Goyal 2018) were recorded during the present investigation.

CONCLUSION

The river Kulik supports quite a large number of phytoplankton and zooplankton species. The presence of pollution indicator phytoplankton and zooplankton population supports the fact of eutrophication at different sites of the river. Public awareness is very much important to decrease the pollution level and rejuvenate the river. The present study will help formulating the future policy for conservation as well as the management of the river Kulik.

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REFERENCE

Acreman, M., Arthington, A.H., Colloff, M.J., Couch, C., Crossman, N.D., Dyer, F.2014. Environmental flows for natural, hybrid, and novel riverine ecosystems in a changing world. Frontiers in Ecology and the Environment, 12(8), 466-473. http://dx.doi.org/10.1890/130134

Agarkar, M.S., Goswami, H.K. Kaushik, S., Mishra, S.N., Bajpai, A.K. and Sharma, U.S. 1994. Biology, conservation and management of Bhoj wetland. Upper lake Ecosystem in Bhopal. Bionature, 14(2), 1-119. https://globalpresshub.com/index.php/BN/article/view/517

Al-Hashmi, K.A., Piontkovski, S.A., Bruss, G., Hamza, W., Al-Junaibi, M., Bryantseva, Yu. and Popova, E. 2019. Seasonal variations of plankton communities in coastal waters of Oman. International Journal of Oceans and Oceanography, 13(2), 395-426. https://ripublication.com/ijoo19/ijoov13n2_13.pdf

Ananthan, G., Sampathkumar, P., Soundarapandian, P. and Kannan, L. 2004. Observation on environmental characteristics of Ariyankuppam estuary and Verampattinam coast of Pondicherry. International Journal of Aquatic Biology, 19, 67-72.

Anonyous. 2017. Standard Methods for the Examination of Water and Wastewater. 23rd ed, American Public Health Association (APHA), American Water Works Association and Water Environmental Federation, Washington, USA.

Battish, S.K. and Kumari, P. 1986. Effect of physico-chemical factors on the seasonal abundance of cladocera in typical pond at village of Raqba, Ludhiana. Indian Journal of Ecology, 13(1), 146-151.

Battish, S.K. 1992. Fresh Water Zooplankton of India. Oxford and IBH Publishing Company. New Delhi, India. 233pages

Bidwell, A. and Clarke, N.V. 1977. The invertebrate fauna of Lake Kainji. Nigerian Field, 42 (3), 104-110.

Chakrabarty, R.D., Roy, P and Singh, S.B. 1959. A Quantitative study of the plankton and the physicochemical conditions of the river Jumna at Allahabad in 1954 -55. Indian Journal of Fisheries, 6(1), 186-203.

Chourasia, S.K. and A.D. Adoni. 1985. Zooplankton dynamics in a shallow Eutrophic Lake,

Proceedings of National Symposium on Pure and Applied Limnology, Botanical Society, Sagar (MP), India, 32: 30-39.

Choi, J.Y. and Kim, S.K. 2020. Responses of Rotifer community to microhabitat changes caused by summer-concentrated rainfall in a shallow reservoir, South Korea. Diversity, 12, 113. http://doi.org/10.3390/d12030113

Das, D., Sen, A. and Mitra, P. 2013. Major fauna of Rasik Beel Wetland Complex (WB). Records of Zoological

Survey of India, 343, 1-76.

David, A. and Roy, P. 1966. Studies on the pollution of the river Daha (N. Bihar) by sugar and distillery wastes. Environment Health, 8(1), 6-35.

Desikachary, T.V. 1959. Cyanophyta. ICAR. Monograph, ICAR, New Delhi.

Devi, S.B. 1997. Present status, potentialities, management and economics of fisheries of two minor reservoirs of Hyderabad. Ph.D. Thesis, Osmania University, Hyderabad.

Diovisalvi, N., Bohn, V.Y., Piccolo, M.C., Perillo, G.M.E., Baigun, C. and Zagarese, H.E. 2015. Shallow lakes from the Central Plains of Argentina: an overview and worldwide comparative analysis of their basic limnological features. Hydrobiologia, 752, 5-20. https://doi.org/10.1007/s10750-014-1946-x

Egborge, B.M. 1981. The composition, seasonal variation and distribution of zooplankton in Lake Asejire, Nigeria. Revue Zoology Africa, 95, 136-180.

El-Sherbiny, M.M., Al-Aidaroos, A.M. and Gab-Alla, A. 2011. Seasonal composition and population density of zooplankton in Lake Timsah, Suez Canal, Egypt. Oceanologia, 53(3), 837-859. http://doi.org/10.5697/oc.53-3.837

Eramma, N., Lalita, H.M., Satishgouda, S., Renuka Jyothi, S., Venkatesh, C.N. and Patil, S.J. 2023. Zooplankton productivity evaluation of lentic and lotic ecosystem. In: Massarelli, C. and Campanale, C. (Eds.) Limnology, Intechopen, http://doi.org/10.5772/intechopen.107020

Fathibi, K., Sudhikumar; A.V. and Aneesh, E.M. 2020. Species composition and abundance of rotifers (Rotifera: Eurotatoria) in Thrissur Kole wetland, Kerala, India. Egyptian Journal of Aquatic Biology and Fisheries, 24(6), 439-451. http://doi.org/10.21608/ejabf.2020.117375

Goyal, S. 2018. Pollution and trophic indicator species of Bicherli pond, Beawar (Rajasthan). Suresh Gyan Vihar University International Journal of Environment, Science and Technology, 4(2), 35-47.

Gupta, P. 2019. Occurrence of Genus *Microcystis lemmerm* from water bodies of Maldah district, West Bengal, India. The Journal of the Society for Tropical Plant Research, 6(2), 233-240. http://doi.org/10.22271/tpr.2019.v6.i2.033

Hafiz, B.Z., Pandit, A.K. and Shah, J.A. 2014. Phytoplankton community of River Jehlum in Kashmir Himalaya. Journal of Environmental Science and Technology, 7(6), 326-336. http://doi.org/10.3923/jest.2014.326.336

Halsey, K.H. and Jones, B.M. 2015. Phytoplankton strategies for photosynthetic energy allocation. Annual Review of Marine Science, 7, 265-297. http://doi.org/10.1146/annurev-marine-010814-015813

Hassan, M.A., Bhandhopadhyay, M.K., Jha, B.C., Sharma, A.P. and Biswas, B.K. 2011. Plankton and fish productivity pattern in two environmentally different oxbow lakes in West Bengal. Journal of Inland Fisheries Sciences, 43(1), 70-76. https://doi.org/10.47780/jifsi.43.1.2011.121290

Holz, J.C. and Hoagland, K.D. 1996. Experimental microcosm study of the effects of phosphorus reduction on plankton community structure. Canadian Journal of Fisheries and Aquatic Sciences, 53(8), 1754-1764. https://doi.org/10.1139/f96-10

Jain, A., Pal, J., Sharma, E. and Rai, S.C. 2005. Plankton community dynamics of a sacred lake in the Sikkim Himalaya. Ecology, Environment and Conservation Paper, 11(3-4), 555-561.

Jha, P. and Barat, S. 2003. Hydrobiological study of Lake Mirik in Darjeeling, Himalaya. Journal of Environmental Biology, 24(3), 339-344.

Kar, S. and Kar, D. 2016. Zooplankton diversity in a freshwater wetland of Cachar, Assam. International Journal of Advanced Biotechnology and Research, 7(2), 614-620.

Kumar, P., Sonaullah, F. and Wanganeo, A. 2010. A preliminary limnological study on Shershah Suri Pond, Sasaram, Bihar. Asian Journal of Experimental Sciences, 24(2), 219- 226.

Lund, J.W.G. 1965. The ecology of freshwater phytoplankton. Biological Reviews, 40, 281-293. https://doi.org/10.1111/j.1469-185X.1965.tb00803.x

Minaudo, C., Abonyi, A., Leitao, M., Lancon, A.M., Floury, M. and Descy, J.P. 2021. Long-term impacts of nutrient control, climate change, and invasive clams on phytoplankton and cyanobacteria biomass in a large temperate river. Science of The Total Environment, 756, 144074. https://doi.org/10.1016/j.scitotenv.2020.144074

Mondal, D., Pal, J., Ghosh, T.K. and Biswas A.K. 2013. Diversity of Cladocerans and Copepods of Mirik Lake in Darjeeling Himalaya. Journal of Today's Biological Sciences: Research & Review, 2(1), 36-46.

Mwebaza-Nadwula, L., Sekiranda, S.B.K and Kiggundu, V. 2005. Variability in zooplankton community along a section of the Upper Victoria Nile, Uganda. African Journal of Ecology, 43, 251-257. https://doi.org/10.1111/j.1365-2028.2005.00583.x

Palmer, C.M. 1969. A composite rating of algae tolerating organic pollution. Journal of Phycology, 5, 78-82. https://doi.org/10.1111/j.1529-8817.1969.tb02581.x

Pandey, K.K., Chandra, W. and Singh, P.S. 2011. Phytoplankton diversity in relation to physicochemical factors in some selected ponds at Patna (Bihar) India. Environment and Ecology, 29(2), 502-505.

Patra, A., Santra, K.B. and Manna, C.K. 2010. Limnological studies related to physico-chemical characteristics of water of Santragachi and Joypur Jheel, W.B, India. Our Nature, 8, 185-203. https://doi.org/10.3126/on.v8i1.4328

Pennak, R.W. 1978. Freshwater Invertebrates of the United States, 2nd Edition. John Wiley and Sons, New York. 648 pages

Prescott, G.W. 1978. How to Know the Freshwater Algae, 3rd Edition. WMC Brown Company Publishers, Dubuque, Iowa. 224 pages

Raina, R. 1981, Plankton dynamics and Hydrobiology of Bod-Sar Lake, Kashmir. Ph.D. thesis. Kashmir University, Kashmir.

Ramkrishnaiah, M. and Sarkar, S.R. 1982. Plankton productivity in relation to certain hydrobiological factors in Konar reservoir (Bihar). Journal of the Inland Fisheries Society of India, 14, 58-68.

Rao, G.M.N. and Pragada, P.M. 2010. Seasonal Abundance of Micro Algae in Pandi Backwaters of Godavari Estuary, Andhra Pradesh, India. Notulae Scientia Biologicae, 2(3), 26-29. https://doi.org/10.15835/nsb234685

Rao, M.B. and Muley, E.V. 1981. Seasonal and species of zooplankton organisms and their succession in two freshwater ponds at Waghuli Poona. Proceedings of Symposium on Ecology Animal Pool. Zoological Survey of India, 2, 63-64.

Rinaldo, A., Gatto, M. and Rodriguez-Iturbe, I. 2018. River networks as ecological corridors: A coherent ecohydrological perspective. Advances in Water Resources, 112, 27-58. https://doi.org/10.1016/j.advwatres.2017.10.005

Singh, R., Das, N., Kumar, S.K., Bhakta, D., Behera, S., Nagesh, T.S. and Mondal, A. 2017. Limnology and productivity status in wetlands (Beels) of 24- South Parganasdistrict, West Bengal. Journal of Entomology and Zoology Studies, 5(2), 664-668.

Roy, S., Basu, A., Mondal, D., Roy, D., Choudhury, S. and Datta, S. 2013. The composition, diversity and population dynamics of zooplankton in river Ichamati, West-Bengal (India). International Journal of Advanced Life Sciences, 6(4), 380-389.

Saha, B.B. and Choudhary, A.B. 2000. Photosynthetic activity in relation to hydrological characteristics of a brakish water tidal ecosystem of Sundarbans in West Bengal India. Journal of Environmental Biology, 21, 9-14.

Sakhare, V.B. and Jetithor, S.G. 2021. Copepod diversity from seasonal wetland in Ambajogai of Beed District, Maharashtra, India. Acta Scientific Veterinary Sciences, 3(11), 58-61. https://actascientific.com/ASVS/pdf/ASVS-03-0224.pdf

Sampaio, E.V., Rocha, O., Matsumura-Tundisi, T. and Tundisi, J.G. 2002. Composition and abundance of zooplankton in the limnetic zone of seven reservoirs of the Paranapanema River, Brazil. Brazilian Journal of Biology, 62, 525-545. https://doi.org/10.1590/S1519-69842002000300018

Sharma, B.K. 1983. The Indian species of the genus *Brachionus* (Eurotatoria: Monogononta: Brachionidae). Hydrobilogia, 104, 31-39. https://doi.org/10.1007/BF00045949

Sharma, S., Singh, K., Prajapati, R., Solnki, C.M., Sharma, D., Sengupta, T., Gandhi, T., Chouhan, M. and Vyas, A. 2011. Diversity and seasonal abundance of phytoplankton of river Narmada Madhya Pradesh (India). World Rural Observations, 3(2), 14-28.

Shrivastava, N.P. 2005. Plankton status of Ravishankar Sagar Reservoir. Journal of the Inland Fisheries Society of India, 37, 43-47.

Singh, D.N. 2000. Evaluation of physico-chemical parameters in Oxbow Lake. Geobios, 21, 120-124.

Tang, D., Liu, X., Wang, X. and Yin, K. 2018. Relationship between the main communities and environments of an urban river and reservoir: Considering integrated structural and functional assessments of ecosystems. International Journal of Environmental Research and Public Health, 15, 2302. http://doi.org/10.3390/ijerph15102302

Toth, F., Zsuga, K., Kerepeczki, E., Berzi-Nagi, L., Kormoczi, L. and Lovei, G.L. 2020. Seasonal differences in taxonomic diversity of Rotifer communities in a Hungarian lowland oxbow lake exposed to aquaculture effluent. Water, 12, 1300. http://doi.org/10.3390/w12051300

Verma, P.K. and Munshi, J.S.D. 1987. Plankton community structure of Badua reservoir, Bhagalpur (India). Tropical Ecology, 28, 200-207.

Wanganeo, A. and Wanganeo, R. 2006. Variation in zooplankton population in two morphologically dissimilar rural lakes in Kashmir Himalaya. Proceedings of National Academy of Sciences, Section B: Biological Sciences, 76(3), 222–239

Ward, H.B. and Whipple, G.C. 1959. Fresh Water Biology. 2nd edition (Edmondson, W.T. (Ed.) Wiley and sons, New York. 1248 pages

Wishard, S.K. and Mehrotra, S.N. 1988. Periodicity and abundance of plankton in Gulariya reservoir in relation to certain physico-chemical conditions. Journal of the Inland Fisheries Society of India, 20, 42-47.

Zafar, A.R. 1967. On the ecology of algae in certain fish ponds of Hyderabad, India III. The periodicity. Hydrobiologia, 30, 96-112. https://doi.org/10.1007/BF00043729

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