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DIVERSITY OF PLANKTON POPULATION OF MANAS RIVER, ASSAM, INDIA

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ABSTRACT: The present study was carried out to investigate the plankton diversity of Manas River, Assam from January 2015 to November 2017. A total of 57 genera of plankton were recorded from the river. Population of phytoplankton was represented by 42 genera belongs to the family Bacillariophyceae (14 genera), Chlorophyceae (21 genera), Cyanophyceae (5 genera) and Xanthophyceae (1 genera) and Phaeophyceae (1 genera). Zooplankton population was represented by 15 genera belong to Copepoda (4 genera), Cladocera (6 genera) and Rotifera (5 genera). The population density of plankton varied from season to season and found maximum (88800 u/l) in retreating monsoon and minimum in pre monsoon (54800 u/l). The Shannon-Weiner diversity index of plankton population of the river was recorded 2.957 which indicates moderate to high diversity. Present study revealed that pH, water temperature, water velocity, total hardness and chloride were the most driving force for annual variation in both phytoplankton and zooplankton structure.

Key words: Plankton, Diversity, Manas River, Assam.

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INTRODUCTION

Plankton forms the most sensitive component of the aquatic ecosystem as they signal environmental disturbances (Carle, 1979). Apart from primary production, phytoplankton plays an important role as food for herbivorous animals and act as biological indicator of water quality in pollution studies. Zooplankton is heterotrophic planktonic animals which constitute an important food source for many species of aquatic organisms (Guy, 1992). Zooplankton provides fish with nutrients since fish require proteins, fats, carbohydrates, mineral salts and water in the right proportion. They are globally recognized as pollution indicator organisms in the aquatic environment (Yakubu *et al*., 2000). Phytoplankton converts light energy to chemical energy through primary production which makes them very important in the food web. On the other hand, Zooplankton plays an important role at consumer level and overall fish production in water bodies. Several workers have studied limnology and plankton diversity of freshwater bodies in different regions (Goswami, 1997; Bairagi & Goswami, 1994; Battish 1992; Goswami & Kalita, 1989; Jakher *et al*., 1989; Goswami, 1985; Jakher & Misra, 1985; Jakher 1984; Kar, 1984; Jakher *et al*., 1981). But very few works has been reported on the limnobiolgical status of lentic and lotic systems of Assam and north east India (Dey, 1981; Lahon, 1983; Kar, 1984; Goswami, 1985; Dutta *et al*., 1990).

The River Manas along with its tributaries like Beki, Sankosh, Saralbangha, Hel, Aai, Tanali, etc. constitute the largest river system with a total length of 3200 km flowing through Bhutan and India. The River Manas serves as an important source of livelihood to the communities residing in the vicinity of the River who are totally depended on its fish and fisheries.

Plankton form a vital link in the food chain of every organism of any lotic or lentic water body and fish growth is directly or indirectly dependent on the abundance of plankton, thus making it an important biological parameter in determining the status of the water body as well as various aquatic organisms including fishes. Therefore, present study on diversity of plankton community of Manas River has been undertaken as no systematic work on plankton diversity has been reported from the River.

MATERIALS AND METHODS

Five study sites along the entire stretch of Manas River were selected for the collection of plankton. Sites were chosen on the basis of accessibility and similarity in physical habitat. The locations of sampling sites were documented by using global positioning system. The five study sites were: Mothanguri (B_1) (26°46′90.2″N, 90°57′41.9″E, 87.5m MSL), Narayanguri (B_2) (26°39′63.0″N, 90°59′43.2″E, 56.7m MSL), Bekipar (B_3) (26°29′71.1″N, 90°55′16.7″E, 40.8m MSL), Kolgachia (B_4) (26°23′31.0″N, 90°45′17.3″E, 29.9m MSL) and Jogighopa (B_5) (26°11′57.4″N, 90°34′18.0″E, 13.4m MSL). Figure-1 shows the map of study area along with sampling sites.

The present investigation was conducted from January 2015 to November 2017. For physico- chemical parameter analysis, water samples were collected seasonally followed after Barthakur (1986). Certain physico chemical attributes like Dissolved Oxygen [DO (mg l^{-1}), Total Hardness (mg l^{-1}), Total Alkalinity (mg l^{-1}) and Chloride (mg l^{-1}) were estimated titrimetrically following the method of APHA (2005). Water Temperature (°C) was measured by Mercury Thermometer. pH, was estimated by portable digital water analyzing kit (Systronics make), water velocity was measured following Saha (2010).

The plankton samples were collected by filtering 100 litres of water through standard plankton net made up of bolting silk of 70 micron mesh size. The concentrated plankton biomass of 100 litres sample water is transferred to a 30 ml plastic bottle and fixed in 5% formalin (Koste, 1978). For qualitative and quantitative analysis, 1 ml well mixed sub sample from this preserved stock is drawn with a wide mouthed graduated pipette and poured into a Sedge wick Rafter Plankton Counter (SRPC) having 1 ml capacity. All the thousand cells of SRPC are examined critically under the microscope (100x).

The collected plankton species were identified following Battish (1992), Edmondson (1992), Needham and Needham (1997) and APHA (2005) up to the generic level. The diversity indices of the plankton population of the study area were calculated following Shannon-Weiner (1963).

The relative abundance (RA) of each plankton genera across five different sampling sites was calculated using the following formula.

Number of samples of particular plankton genera × 100/Total number of samples

Canonical Correspondence Analysis (CCA) and Bray Curtis Similarity index were estimated using the software program PAST ver. 2.17c.

RESULTS

Physico-chemical parameters analysis

The variations in physico-chemical parameters of the studied sites in all four seasons are presented in Table 1. The water temperature was found to fluctuate moderately among all the study sites and ranged from 11.9°C to 20.45°C. The value of pH was observed between the range of 5.73 and 8.3 and estimated to be slightly acidic in sites- B_2, B_4 and B_5 in retreating monsoon season, however, it was estimated alkaline in nature in sites-B_1 and B_3 in all the seasons. The concentration of DO varied from 14.73 mgl^{-1} to 6.33 mgl^{-1} and almost uniform throughout all sampling sites. The annual range of total hardness in the entire sampling site varied from 42 mg l^{-1} to 210 mg l^{-1} with lowest value recorded in retreating monsoon in site-B_3 and highest value recorded in pre monsoon from site B_5. The calculated alkalinity values in all sampling sites ranged from 75 mgl^{-1} to 180 mgl^{-1} throughout the annual cycle. The annual mean concentration of chloride was observed to fluctuate slightly within the five sampling sites during four seasons within the range of 9.57 mg l^{-1} and 15.01 mg l^{-1} with highest value recorded in winter in site-B_1 and lowest value observed in pre monsoon from site- B_3. Water velocity recorded were between the range of 0.2 ms^{-1} in pre monsoon in site- B_5 and 1.15 ms^{-1} in retreating monsoon in site-B_1.

Table 1. Site-wise physico- chemical parameters in four seasons in Manas River.

Sites	Seasons	Physico chemical parameters						
		P^H (mg/l)	DO(mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Chloride (mg/l)	Water temp. (^{0}C)	Water Velocity (m/s)
Site-B1	**Pre monsoon**	7.7	12.57	115	52	11.01	14	0.8
	Monsoon	7.9	9.59	145	44	10.11	15.3	1.2
	Retreating Monsoon	6.9	11.22	135	48	11.51	9.8	1.15
	Winter	6.55	14.73	160	65	15.01	8.5	0.9
Site B2	**Pre monsoon**	7.18	8.95	115	55	10.01	15	0.7
	Monsoon	7.31	9.2	85	42.7	11.01	16.5	1.1
	Retreating Monsoon	5.73	10.57	130	64	10.51	13.4	1
	Winter	7.55	12.04	155	63	12.51	10	0.8
Site B3	**Pre monsoon**	8	11.02	125	44	9.57	17.9	0.3
	Monsoon	7.05	8.95	112	49	10.51	19.5	0.6
	Retreating Monsoon	6.19	10.1	145	42	10.11	15.2	0.5
	Winter	7.33	12.53	150	60	11.51	11.3	0.5
Site-B4	**Pre monsoon**	8.3	8.97	134	61	12.51	20.5	0.35
	Monsoon	7.8	6.94	162	65	13.01	26	0.5
	Retreating Monsoon	6.65	6.33	170	71	11.012	18.2	0.48
	Winter	6.92	10.28	180	66	13.04	14.3	0.3
Site- B5	**Pre monsoon**	8.2	8.8	75	210	12.51	23.6	0.2
	Monsoon	7.96	8.36	133	60	13.04	25.3	0.4
	Retreating Monsoon	6.53	9.59	171	69	10.51	17.4	0.35
	Winter	6.96	10.9	175	64	11.012	15.5	0.25

Plankton abundance, diversity and distribution

A total of 57 genera of plankton were recorded from the River Manas. Population of phytoplankton was represented by 42 genera belonging to Bacillariophyceae (14 genera), Chlorophyceae (21 genera), Cyaenophyceae (5 genera) and Xanthophyceae and Phaeophyceae (1 genera each). Zooplankton population was represented by 15 genera belonging to Copepoda (4 genera), Cladocera (6 genera) and Rotifera (5 genera).

The phytoplankton community of the study area constituted 95.98 % out of the total plankton collected throughout the studied period. Out of the 42 genera of phytoplankton recorded, 14 belong to the group Bacillariophyceae. Chlorophyceae forms the most dominant group consisting of 21 genera followed by the group Cyaenophyceae with 5 genera. The groups Xanthophyceae and Phaeophyceae comprised of one genera each. The highest percentage (relative abundance) of phytoplankton was found during retreating monsoon season (34.99%) and was dominated by *Navicula* sp. (21.13%).

Zooplankton community constituted only 4.02% of the total plankton hauled. A total 15 genera of zooplankton were recorded. The most dominant group was Cladocera with 6 genera followed by Rotifera (5 genera). Copepoda was the third dominant group consisting of 4 genera (Table 2). The relative abundance of zooplankton population was found highest during the winter season (40.12%) and was dominated by *Cyclops* (0.92%).

The population density of plankton varied from season to season (Figure 2) and found maximum (88800 u/l) in retreating monsoon and minimum in pre monsoon (54800 u/l). It was observed that the population density of phytoplankton was maximum in retreating monsoon (86490 u/l) and minimum in pre monsoon (52760 u/l) whereas the population density of zooplankton was recorded maximum in winter (4180 u/l) and minimum in the retreating monsoon (1860 u/l).

Table 2. Seasonal Diversity and Relative Abundance of Plankton in Manas River

S. No.	Type of Plankton	Seasons				Relative Abundance
		Premonsoon	Monsoon	Retreating Monsoon	Winter	
	PHYTOPLANKTON					
A.	**Bacillariophyceae**					
1	*Frustulia sp.*	*	*	*	*	2.24
2	*Stauroneis sp.*	*		*	*	0.65
3	*Gyrosigma sp.*	*	*	*	*	3.46
4	*Navicula sp.*	*	*	*	*	**21.13**
5	*Pinnularia sp.*		*	*	*	2.03
6	*Surirella sp.*	*		*	*	1.04
7	*Tabellaria sp.*	*	*	*	*	0.3
8	*Achnanthes sp.*	*			*	0.09
9	*Nitzschia sp.*			*		0.15
10	*Diatoma sp.*	*			*	0.26
11	*Cymbella sp.*		*	*	*	1.92
12	*Gomphonema sp.*	*	*	*	*	11.71
13	*Fragilaria sp.*	*	*	*	*	4.51
14	*Synedra sp.*	*	*	*	*	7.91
B.	**Chlorophyceae**					
15	*Hydrodictyon sp.*	*		*	*	0.27
16	*Eudorina sp.*	*	*	*		0.15
17	*Microspora sp.*	*	*	*	*	1.94
18	*Chlamydomonas sp.*	*	*	*	*	4.23
19	*Draparnaldiopsis sp.*	*	*	*	*	9.48
20	*Closterium sp.*	*	*	*	*	1.82
21	*Chaetophora sp.*			*	*	0.28
22	*Oedogonium sp.*		*			0.03
23	*Closteriopsis sp.*		*	*		1.05
24	*Microthamnion sp.*	*		*	*	0.71
25	*Chaetomorpha sp.*				*	0.06
26	*Rhizoclonium sp.*	*		*	*	7.27
27	*Cladophora sp.*	*		*	*	1.03
28	*Pandorina sp.*		*			0.19
29	*Desmidium sp.*	*	*	*	*	0.7
30	*Volvox sp.*	*	*	*		0.37
31	*Hyalotheca sp.*	*	*	*	*	1.76
32	*Spirogyra sp.*	*	*	*	*	1.77
33	*Gonatozygon sp.*	*	*	*	*	3.34
34	*Staurastrum sp.*	*			*	0.12
35	*Docidium sp.*				*	0.12
C.	**Cyaenophyceae**					
36	*Anabaena sp.*	*	*	*	*	0.53
37	*Oscillatoria sp.*	*		*		0.59
38	*Aphanizomenon sp.*	*		*	*	0.19
39	*Rivularia sp.*	*				0.12
40	*Spirulina sp.*		*	*	*	0.19
D.	**Xanthophyceae**					
41	*Tribonema sp.*	*			*	0.12
E.	**Phaeophyceae**					
42	*Ectocarpus sp.*	*				0.12

Table-1 cont…

	ZOOPLANKTON					
A.	**Copepoda**					
1	*Nauplii sp.*	*		*	*	0.37
2	*Cyclops*	*	*	*	*	**0.92**
3	*Diaptomus sp.*	*	*		*	0.18
4	*Mesocyclops sp.*	*	*		*	0.20
B.	**Cladocera**					
5	*Alona sp.*	*	*			0.12
6	*Moina sp.*	*		*	*	0.26
7	*Bosmina sp.*	*	*	*	*	0.28
8	*Ceriodaphnia sp.*	*		*	*	0.32
9	*Daphnia sp.*	*	*	*	*	0.42
10	*Leydigia sp.*	*			*	0.09
C.	**Rotifera**					
11	*Monostyla sp.*			*	*	0.12
12	*Filina sp.*	*			*	0.09
13	*Brachionus sp.*		*	*	*	0.17
14	*Keratella sp.*	*	*	*	*	0.43
15	*Lepadella sp.*	*				0.03

Note: "*" indicates the presence of plankton.

Species diversity of the plankton population varied slightly among the four seasons across all the studied sites. The species richness for phytoplankton was observed maximum in winter (33 genera) and minimum in monsoon (24 genera). Similarly, for zooplankton, the species richness was observed maximum both in pre-monsoon and winter season with 13 genera and minimum in monsoon season (8 genera). The Shannon-Weiner diversity index (H´) was observed maximum in pre-monsoon season for both the phytoplankton and zooplankton (2.82 and 2.44) and minimum in the monsoon season (2.16 and 1.79) respectively. However, the overall Shannon-Weiner diversity index of plankton population in all the four seasons was calculated to be 2.96 which indicated moderate to high species diversity. The Evenness (E) estimation of the collected plankton genera showed slightly altered variation (Table 3). Evenness (E) of phytoplankton was observed to be highest in pre monsoon season (0.522) and lowest in winter season (0.351). However, in case of zooplankton community, evenness values were observed to be highest in pre monsoon season (0.883) and lowest (0.748).

Bray-Curtis Cluster Analysis shows the formation of three clads for both phytoplankton and zooplankton genera where a comparable picture of similarities and association-ship among the collected genera from the studied sites was revealed. It has been observed that there was close similarity and association-ship in phytoplankton genera composition between the sampling sites B_1 and B_2 and between sampling sites B_4 and B_5. However, phytoplankton genera composition of site B_3 was somewhat similar to site B_1 and B_2 but slightly dissimilar with that of sites B_4 and B_5. Highest similarity and association ship between zooplankton genera composition was observed between sampling sites B_1 and B_3 and between B_4 and B_5. Site B_2 was observed to bear some resemblance in their zooplankton genera composition with that of sites B_1 and B_3. However, it was observed to be dissimilar with that of sites B_4 and B_5. The similarity in genera composition across sites is shown in dendogram (Figure 3 and 4), obtained from Bray- Curtis Cluster Analysis.

The Canonical Correspondence Analysis (CCA) revealed that diversity and evenness of phytoplankton was positively correlated with pH, water temperature and Total Hardness, whereas negatively correlated with all other hydrological variables. Except DO, alkalinity and water velocity, richness of phytoplankton was negatively correlated with all other hydrological variables (Figure 5). Similarly, except water velocity, the richness of zooplankton was positively correlated with all the hydrological variables. The diversity of zooplankton was positively correlated with pH, DO, Total Hardness and Total Chloride and negatively correlated with water temperature and water velocity. The evenness of zooplankton was positively correlated with DO, Total Alkalinity and water velocity and negatively correlated with all other variables (Figure 6).

Table 3. Seasonal species richness, Shannon Weiner diversity index and evenness of planktons from Manas River, India.

S. No.	Seasons	Species richness		Diversity Index (H')		Evenness (E)	
		Phyto-plankton	Zoo-plankton	Phyto-plankton	Zoo-plankton	Phyto-plankton	Zoo-plankton
1	Pre-Monsoon	32	13	2.82	2.44	0.522	0.883
2	Monsoon	24	8	2.16	1.79	0.361	0.748
3	Retreating Monsoon	32	9	2.60	2.08	0.422	0.886
4	Winter	33	13	2.45	2.38	0.351	0.833

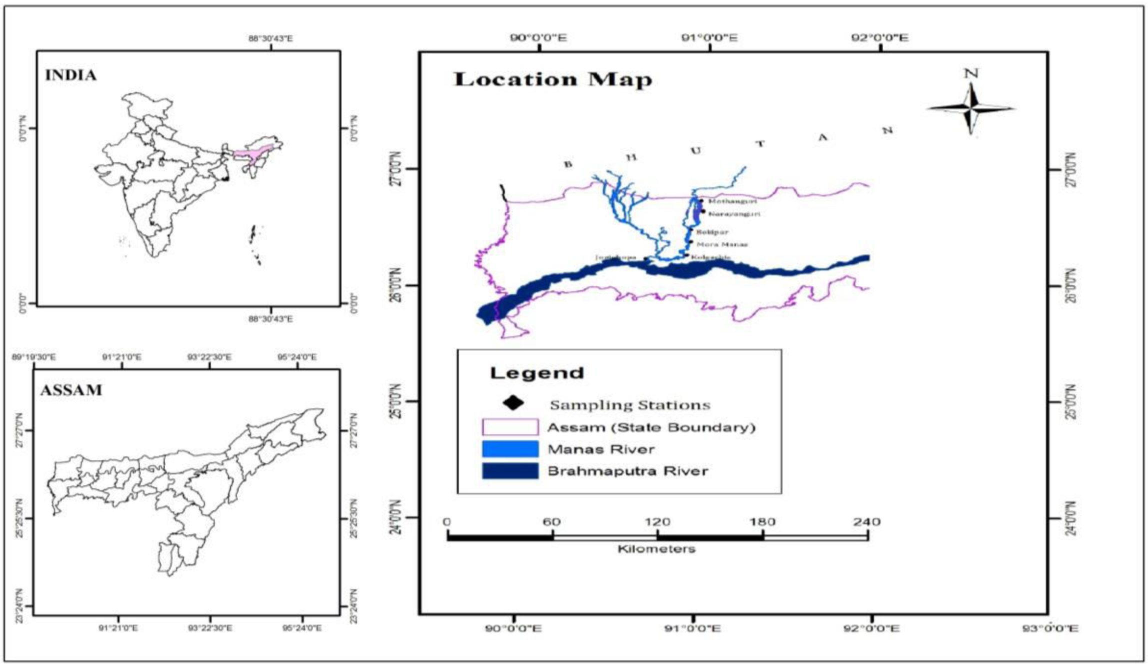

Fig. 1. Map showing study area with sampling sites

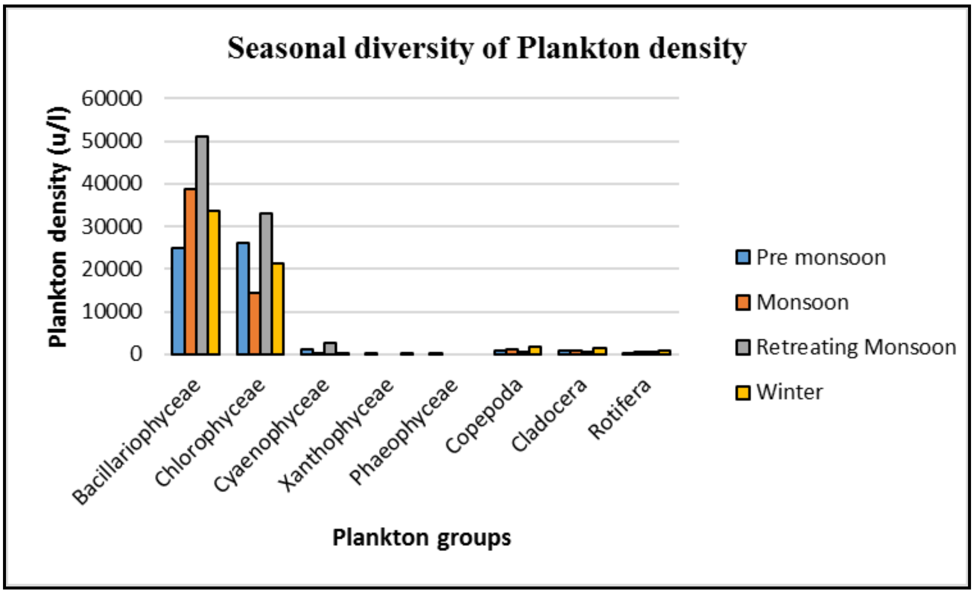

Fig. 2. Seasonal diversity of plankton density of Manas River

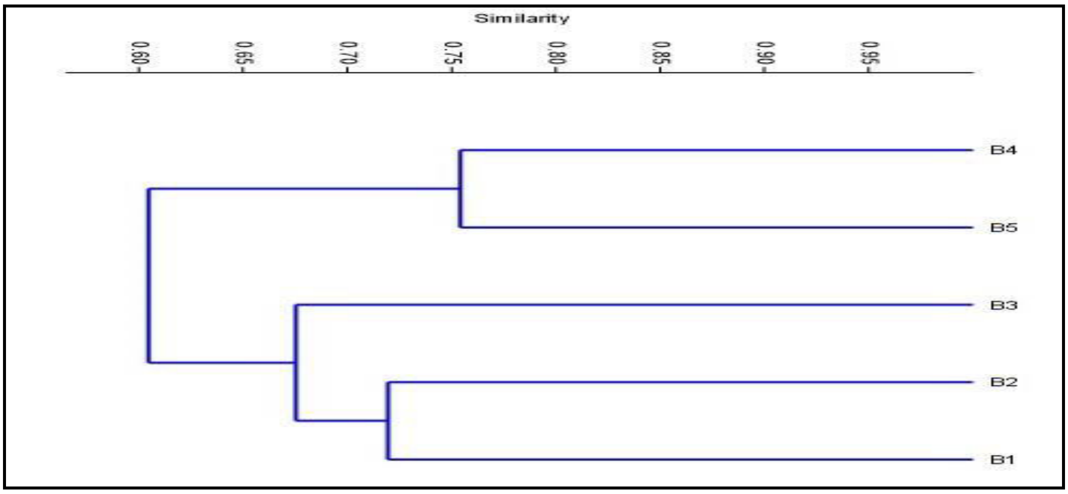

Fig. 3. Bray-Curtis Similarity Index showing similarity in Phytoplankton genera composition across five sampling sites of Manas River.

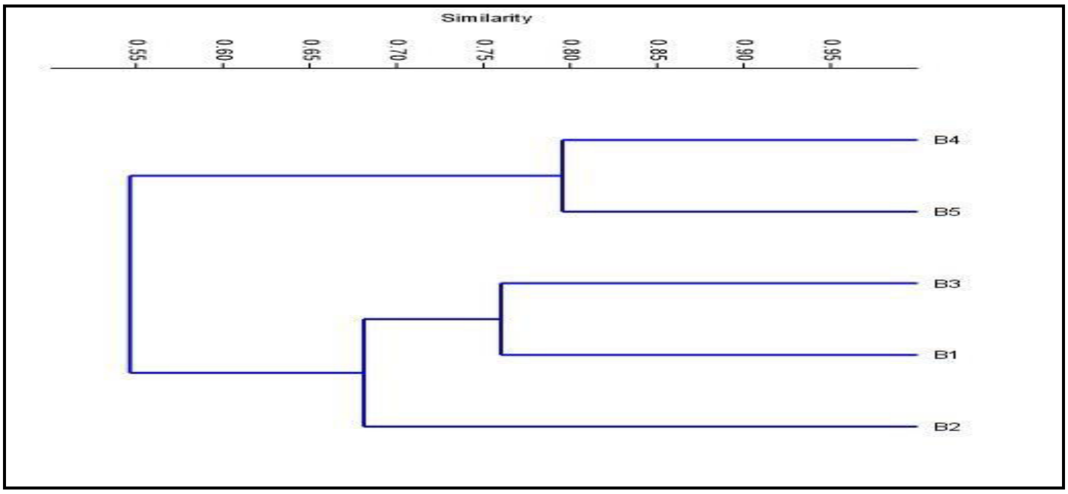

Fig. 4. Bray-Curtis Similarity Index showing similarity in Zooplankton genera composition across five sampling sites of Manas River

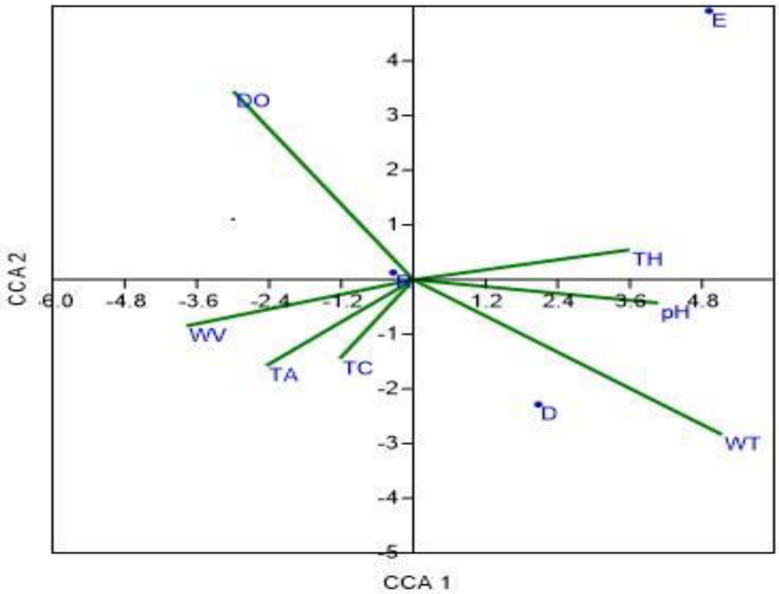

Fig. 5. CCA ordination of phytoplankton assemblages and hydrological variables of Manas River, India (Note: R-Richness; D-Diversity; E-Evenness; DO-Dissolved Oxygen; TA-Total Alkalinity; TH-Total Hardness; TC-Total Chloride; WT-Water Temperature; WV-Water Velocity)

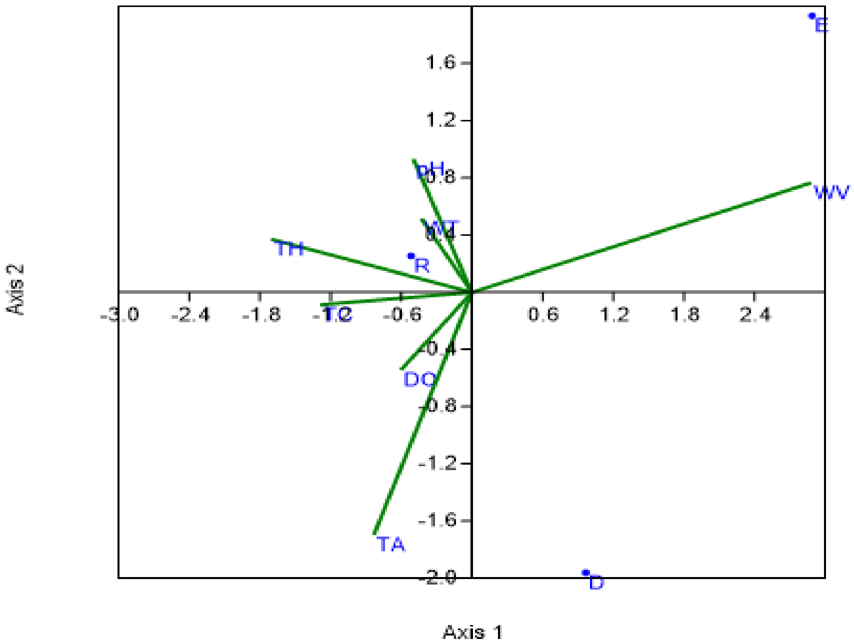

Fig. 6. CCA ordination of zooplankton assemblages and hydrological variables of Manas River, India (Note: R-Richness; D-Diversity; E-Evenness; DO-Dissolved Oxygen; TA-Total Alkalinity; TH-Total Hardness; TC-Total Chloride; WT-Water Temperature; WV-Water Velocity).

DISCUSSION

Monitoring and assessment of the freshwater environment are often based on water temperature, pH, DO and Turbidity. Seasonal occurrence of plankton is directly or indirectly influenced by the hydrological attributes (Crossetti *et al*., 2007; Schagerl *et al*., 2009). The fact is in agreement with the present study where few of the physico-chemical variables were observed to be the key habitat features which determined the plankton genera distribution in the Manas River.

Water Temperature which has key role in biochemical interactions is considered as an immensely important factor (Gangwar *et al.,* 2012, Senthilkumar & Sivakumar, 2008). The present study records lowest water temperature 8.5°C in winter and highest 15.3°C in summer which are considered as moderate for the growth of plankton species in hill stream and is found to be comparable with the findings of Sharma *et al.* (2016). The favourable conditions in pre-monsoon was attributed mainly by influx of nutrients which was also supported by the pH value 7.88 and might be one of the factors for growth of plankton biomass where pH is a regulating factor affecting the nutrients uptake processes and on the equilibrium of nutrients (Peterson *et al*., 1984). pH above permissible limit can influence the chemical reaction in aquatic bodies and thus regarded as a vital factor in river ecosystem (Wang et *al.,* 2002).

DO concentrations above 5.0 mg l^{-1} are considered suitable for most aquatic organisms (Stickney, 2000). Lower values of DO during monsoon season might be due to reduced rate of photosynthesis which could be a reason for low phytoplankton production recorded during the present study in monsoon season (Moulood *et al*., 1978).

Total Hardness levels of the Manas River were observed within the permissible limit. Hard and alkaline water may be considered suitable to high planktonic growth to some extent (Sujitha *et al*., 2011). Total Hardness of water may not be a pollution parameter, but may indicate water quality mainly in terms of Ca^{2+} and Mg^{2+} (Baruah *et al*., 1993). Similarly, the Total Alkalinity of water is due to the presence of mineral salts and is primarily caused by the carbonate and bicarbonate ions. Alkalinity (20-200 mgL^{-1}) is common in most of the fresh water ecosystems (Ishaq and Khan, 2013). In our present study, Total Alkalinity was found within this range. The observation of comparatively high values of alkalinity during winter season can be attributed to high plankton growth during the studied season (Sujitha *et al*., 2011) which also coincides with the concentration of nutrients and bicarbonates in particular.

Peres-Neto (2004) also reported that species occurrence can be directly related to the abiotic factors than that of their interactions. Variation in the value of pH may cause some of the solutes to precipitate or may affect the solubility of the suspended matters (Bellingham, 2012).

The present study revealed high biological productivity in terms of better population density of plankton. The presence of *Monostyla sp.* in the retreating monsoon as well as winter season, *Keratella sp.,* and *Anabaena sp.* in all the four seasons, and *Lepadella sp*. in pre monsoon indicate clean and fresh condition of water of the river (Ambujam *et al*., 2011). According to Cander-Lund & Lund (1995) *Anabaena* sp. can be found in non-polluted water. The study also revealed presence of high density of *Navicula sp*., *Gomphonema sp., Synedra sp.* in all the four seasons and *Oscillatoria sp*. in pre-monsoon and retreating monsoon which are most prominent indicators of organic pollution (Hosmani, 2013). These might be possibility of organic pollution in the sampling sites B_2, B_3 and B_4, since the villagers in the nearby area are completely dependent on the river and also uses the water for various purposes like washing clothes, bathing, etc. Moreover, site-B_2 has been designated as a picnic spot which might serve as another reason for deterioration of the water quality of the river. However, species of *Pandorina* and *Chlamydomonas* are highly sensitive to environmental conditions (Hosmani, 2013) and thus their presence indicates that the water quality of Manas River is favourable for planktonic growth.

Zooplanktons can be used widely as indicators for monitoring and assessment of various forms of pollution viz; acidification, pesticide pollution and algal toxins. Zooplankton community of Manas River is dominated by *Cyclops sp.* and their larval forms (*Nauplii).* The dominance of *Cyclops* sp. might have resulted due to high nutrient concentration of the river. Adholia and Vyas (1991) reported *Cyclops sp.* and *Nauplius* larvae as dominant genera of Copepods as pollution form since they are sensitive to pollution and decrease in number as and when pollution increases. The dominance of *Cyclops sp.* and the presence of the above mentioned pollution indicator species in Manas River thus indicate that the river is not under the sign of any acute alarming condition and rich in nutrients and the water body is unpolluted.

Phytoplankton community is generally dominated by the members of Bacillariophyceae perhaps because of their capability in utilizing the nutrients (Oritz & Cambra, 2007). In the present study, however, Chlorophyceae > Bacillariophyceae were observed to be the most dominant group; followed by Chlorophyceae and Cyanophyceae. Similarly, the zooplankton genera; Cladocera > Rotifera were observed as most dominant group followed by Copepoda (Sharma & Sharma, 2012).

High value of Shannon-Weiner index (H´) indicates greater planktonic diversity (Dash, 1996). The value of Shannon-Weiner diversity index (H´) varies from 0 where the community is composed of single species to 4.5 or 5 bits/ individual for the most diversified communities (Faurie *et al*., 2001). The values of Shannon- Weiner diversity index (H´) computed for both phytoplankton and zooplankton population in the present investigation indicated a moderate to highly diversified community.

The maximum similarity in plankton genera composition as inferred from Bray-Curtis Cluster Analysis between B_1 and B_2 and between B_4 and B_5 may be attributed to the similarity in physical habitat since sites B_1 and B_2 are both located in the upstream consisting of riffles, pools and runs with a dominant pebbly and rocky bottom. On the other hand, sites B_4 and B_5 are both located in the lower stretches of the River Manas.

Canonical Correspondence Analysis (CCA) of abundance data for recorded plankton genera during the present investigation revealed that pH, water temperature, water velocity, total hardness and chloride were responsible for more of the annual variation in both phytoplankton and zooplankton structure compared to DO and total alkalinity. Gosselain *et al.*, (1994) concluded that increase in water temperature promote development of chlorophytes in large, eutrophic rivers (Europe) and the progressive dominance (in cell density) of this group over diatoms.

CONCLUSION

The present study revealed that Manas River carried high biological productivity in terms of better population density of plankton. The present study provides a framework for future studies examining phytoplankton and zooplankton abundance, composition, and distribution in the studied area. The results have shown the requirement of plankton as an index of water quality. Thus, this hill stream should be developed under protected area network by conserving its biodiversity in protecting aquatic natural habitats.

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REFERENCES

Abujam, S.K.S., Dakua, S, Bakalial, B., Saikia, A.K., Biswas, S.P., Choudhury, P. (2011). Diversity of Plankton in Maijan Beel, Upper Assam. *Asian J. Exp. Biol. Sci*: Vol. 2, 4, 526-568.

Acharjee, B., Dutta. A., Choudhury, M. (1999). Role of physicochemical parameters in the evaluation of productivity of Dighali beel, Assam, Environ. & Ecology: Vol. 17, 2, 274-279.

Adholia, N.U., Vyas, A. (1992). Correlation between Copepods and Limnochemistry of Mansarover Reservoir, *Bhopal. J. Environ. Biol*: Vol.13, 4, 281-290.

APHA (2005). Standard Methods for the Examination of Water and Wastewater. 25th Edn. Washington, D.C.

Bairagi, S. P., Goswami, M. M. (1994). Ecology of water blooms in some ponds of North East India. *Environ. & Ecology*: Vol. 12, 3, 568-571.

Barthakur, M. (1986). Weather and climate in N.E. India. Northeastern Geographer: Vol. 18, 1&2, 20-27.

Baruah, A.K., Sharma, R.N., Borah, G.C. (1993). Impact of Sugar Mill and Distillery Effluents on Water Quality of River Gelabil, Assam. *Ind. J.Env. Hlth*: Vol. 35, 288-293.

Battish, S. K. (1992). Freshwater Zooplankton of India, Oxford an IBH Pub. Co., New Delhi, pp:233.

Bellingham, K. (2012). Stevens Water Monitoring Systems Inc. pp:205-209.

Boruah, S., Biswas, S.P. (2002). Ecohydrology and fisheries of the upper Brahmputra basin. *Environmentalist*: Vol. 22, 119–131.

Cander-Lund, H., Lund, J.W.G. (1995). Freshwater algae. Their microscopic world explored Biopress Ltd. England. UK. pp:360.

Carle, F.L. (1979). Environmental monitoring potential of the odonata with a list of rare and endangered anisoptera of Virginia, United States, *Odontologia*: Vol. 8, 319-323.

Crossetti, L.O., Cardoso, D.L., Callegaro, S., Alves-Da-Silva, V.L.M., Werner, S.M., Rosa, V.R., ZM, Motta-Marques, D.D. (2007). Influence of the hydrological changes on the phytoplankton structure and dynamics in a subtropical wetland-lake system. *Acta Limnologica Brasiliensia*: Vol. 19, 315-329.

Dash, M.C. (1996). Fundamentals of Ecology, Tata. McGraw Hill Publishing Company limited. New Delhi.

Dey, S.C. (1981). Studies on the hydrobiological conditions of some commercially important Lakes (Beels) of Kamrup district of Assam and their bearing on fish production. Tech. Proj. Rep., NEC, Govt. India, New Delhi, India.

Dutta, A., Chutia, P, Das, D. (1990). Seasonal fluctuation in plankton population of two freshwater ponds at Guwahati (Assam). *J. Assam Sci. Soc.*: Vol. 32, 12-19.

Edmonson, W.T. (1992). Freshwater Biology. 2nd ed. International books and periodicals supply service. New Delhi. pp:1248.

Faurie, C., Ferra, C., Medori, P., Devaux, J. (2001). Ecology Science and Practices. Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi.

Gangwar, R.K., Khare, P., Singh, J., Singh, A.P. (2012). Assessment of physicochemical properties of water: River Ramganga at Bareilly, U.P. *J. Chem. Phar. Res*: Vol. 4, 4231-4234.

Gosselain, V., Descy, J.P., Everbecq, E. (1994). The phytoplankton community of the River Meuse, Belgium: seasonal dynamics (year 1992) and the possible incidence of zooplankton grazing. Hydrobiol: Vol. 289, 179–191.

Goswami. M. M. (1985). Limnological investigations of a tectonic lake of Assam, India and their bearing on fish production, PhD Thesis, Gauhati University, Assam, India.

Goswami, M. M., Kalita, G. (1989). Record of occurrence of colonial rotifer fauna in Assam, India. *J. Assam Sci. Soc*: Vol. 31, 4, 41-49.

Goswami, N. (1997). Studies on the productivity indicators in three different types of wetlands of Assam, India, PhD Thesis, Gauhati University, Assam, iv+217.

Guy D (1992) The ecology of the fish pond ecosystem with special reference to Africa, Pergamon press, pp:220–230.

Hamaidi-Chergui, F., Errahmani, M.B., Hamaidi, M.S. (2013). Preliminary Study on Physico-chemical Parameters and Phytoplankton of Chiffa River (Blida, Algeria), *J. Ecol*: Vol. 155, 1-9.

Ishaq, F., Khan, A. (2013). Aquatic biodiversity as an ecological indicator for water quality criteria of river Yamuna in Doon Valley, Uttarakhand, India. *World J. Fish Mar. Sci*: Vol. 5, 322-334.

Jakher, G. R., Dey, T., Misra, S. D. & Bhargava, S.C. (1981). Diurnal variations in physico-chemical factors and zooplankton population in Balsamand lake, Jodhpur. Geobios: Vol. 8, 119-122.

Jakher, G. R. (1984). Diurnal rhythm of zooplankton and certain abiotic factors in Lake Balsamand, Jodhpur. *Oikoassay*: Vol. 1, 1&2, 32-36.

Jakher, G.R. & Misra, S.D. (1985). Quantitative distribution of Macrobenthic fauna of Lal Sagar Reservoir, Jodhpur, *Geobios*: Vol. 8, 119-122.

Jakher, G.R.,Bhargava, S.C. & Singha, R.K. (1989). Comparative Limnology of Sambhar and Didwana lakes (Rajasthan, NW India). *Hydrobiologia*: Vol. 197, 245-256.

Kar, D. (1984). Limnology and fisheries of Lake Sone in the Cachar district of Assam, India, Ph.D Thesis, Gauhati University, Assam, India.

Koste, W. (1978). Rotatoria. Die Radertiere Mittelleuropas. Gebruder Borntraeger. Berlin. Stuttgart. Bd. I & II.

Lahon, B. (1983). Limnology and fisheries of some commercial beels of Assam (India). Doctoral thesis, Gauhati Univ., India.

Malhotra, P., Bhatnagar, A. & Chopra, G. (2014). Phytoplankton Diversity of Western Yamuna Canal and River Yamuna in Yamunanagar, Haryana, India. *Int. Res. J. Envir. Sci*: Vol. 3, 1-7.

Needham, J.G. & Needham, P.R. (1997). A Guide to the Study of Fresh water Biology. 4th Edn. Comstock Publishing Company, Inc. New York.

Negi, R.K. & Rajput, A. (2011). Diversity of phytoplankton in the fresh water streams of Kumaon Himalaya of Uttarakhand State. *The Ecoscan*: Vol. 5, 15-19.

Oritz R. & Cambra J. (2007). Distribution and taxonomic notes of Eunotia Ehrenberg 1837 (Bacillariophyceae) in rivers and streams of northern Spain, *Limnetica*: Vol. 26, 2, 415-434.

Peres-Neto, P.R. (2004). Patterns in the co-occurrence of stream fish meta communities: the role of site suitability, morphology and phylogeny versus species interactions. *Oecologia*: Vol. 140, 352-360.

Peterson, H.G., Healey, F.P. & Wagemann R. (1984). Metal toxicity to algae: a highly pH dependent phenomenon. *Can. J. Fish. Aquat. Sci*: Vol. 41, 974-979.

Saha, R. K. (2010). A work book on limnology. Narendra Publishing House, New Delhi.
pp:258

Schagerl, M., Drozdowski, I., Angeler, D.G., Hein, T. & Preiner, S. (2009). Water age–a major factor controlling phytoplankton community structure in a reconnected dynamic floodplain (Danube, Regelsbrunn, Austria). *Limnology*: Vol. 68, 274-287.

Senthilkumar, R. & Sivakumar, K. (2008). Studies on phytoplankton diversity in response to abiotic factors in Veeranam Lake in the Cuddalore district of Tamil Nadu. *J. Envir. Biol*: Vol. 29, 747-752.

Shannon, C.E. & Wiener, W. (1963). The Mathematical theory of communication. University of Juionis Press, Urbana. pp:117.

Sharma, B.K. & Sharma, S. (2012). Diversity of zooplankton in a tropical floodplain lake of the Brahmaputra river basin, Assam (Northeast India). *Opuscula Zoologica* (Budapest): Vol. 43, 187–195.

Sharma R.C., Singh, N & Chauhan, A. (2016). The influence of physico chemical parameters on phytoplankton distribution in a headwater stream of Garhwal Himalayas: A case study. *The Egyptian Journal of Aquatic Research*: Vol. 42, 1, 11-21.

Stickney, R.R. (2000). Encyclopedia of Aquaculture. John Wiley and Sons, New York.

Sujitha, P.C., Mitra, D.D., Sowmya, P.K. & Mini, P.R. (2011). Physicochemical parameters of Karamand River water in Trivandrum District, Kerala. India. *International J. Envir. Sci*: Vol. 2, 472 - 490.

Wang, W., Wang, A., Chen, L., Liu, Y. & Sun, R. (2002). Effects of pH on survival, Phosphorous Concentration, Adenylate Energy Charge and Na+, K+ ATPase Activities of Penaeus chinensis Osbeck Juveniles. *Aquat. Toxicol*: Vol. 60, 75-83.

Yakubu, A.F., Sikoki F.D., Abowei J.F.N. & Hart S.A. (2000). A comparative study of phytoplankton communities of some rivers creeks and borrow pits in the Niger Delta Area, *Journal of Applied Science, Environment and Management*: Vol. 4, 2, 41-46.

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