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Original Research Article

Plankton Diversity, Abundance and their Variation in BarbilaBeel, Nalbari, Assam, India

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ABSTRACT:
The paper deals with the documentation of plankton diversity Barbilabeel and their seasonal variation in three consecutive years from 2017 to 2020. We recorded 53 forms of phytoplankton belonging to five classes – Cyanophyceae (15 species), Chlorophyceae (14 species), Bacillariophyceae (20 species), Euglenophyceae (3 species) and Dinophyceae (1 species). On the other hand, 38 forms of Zooplankton were identified belonging to four different groups- Rotifer (17 species), Protozoa (06 species), Cladocera (07 species) and Copepods (08 species). Plankton diversity showed statistically significant site wise as well as seasonal variations during the study period. Rich diversity of plankton in Barbilabeel indicates the well physic-chemical behavior of soil and water of the beel. As some of the anthropogenic threats are introduced in last few years, care should be taken for sustainable development of the beel.

Keywords: Beel, Plankton, Diversity, Conservation

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INTRODUCTION

The planktons are microscopic aquatic forms that live as free floating and suspended in open or pelagic waters. Plankton comprises microscopic plants and animals. The planktonic plants are referred to as phytoplankton and planktonic animals are known as 300 plankton.

The phytoplankton bears photosynthetic pigments and with the help of solar energy, the phytoplankton work like a factory of life. Phytoplanktons transform the Sun's radiant energy into chemical energy and store it in the protoplasm and they are called primary producers. The phytoplanktons form the base of ecological pyramids.

Zooplanktons play a vital role in making efficient use of dead and living organic matter. They stand in the second position in the energy flow pyramid. Both the diversity and abundance Phyto and zooplankton influence the productivity of beel ecosystem which are again dependent on the quality of the environment of the water system.

Wetlands are the areas of land which are either temporarily or permanently covered by water. The lentic aqua systems are popularly known as 'Wetlands'. In Assam, the wetlands are locally known as 'beels'. A total of 11,178 wetlands have been identified in Assam which occupies 764372 hacter that is around 9.74% of the geographic area of the state (Sarma and Borah, 2014).

The wetlands along with other biodiversity accommodate diverse group of both phytoplankton and zooplankton species with definite phonological cycle. They show considerable variations in different season as well as different water bodies. Thus, the ecological study of aquatic environment is an integral part to know the ecosystem functioning and aquatic biodiversity conservation. However, information on plankton diversity and their abundance in different seasons from the beels of Assam are very limited. Therefore, the present study has been aimed to know the present status of plankton diversity and its abundance of Barbilabeel, Nalbari, Assam, India.

MATERIALS AND METHODS

Barbilabeel is an important beel of Nalbari district and is located at the South-West corner of the district at the intersection $26^{\circ}15^{/}30^{//}$ East meridian of longitude. The Barbila beel is a seasonally open or livebeels and connected with Narkurajan in eastern side and Alpajan in western side. Although the direct link was lost with Narkurajan and Alpajanbut in rainy season it is again connected to them by flood water. The beel is covered by an area of 65 hectare.

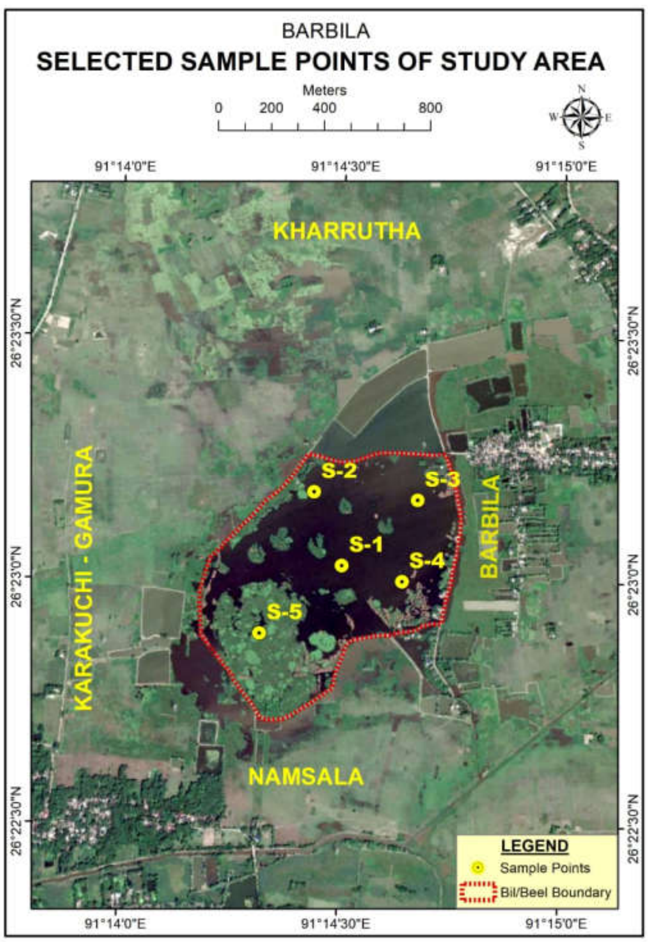

Figure 1: Map and Selected Sample Point of Study Area

Plankton samples were collected with the help of plankton net and samples were preserved in 4% formalin. Following that, 10-20 ml of the collected samples were centrifuged for 10 minutes at 1000 rpm and the supernatant was removed and volume was made 5 ml. Identification of plankton was done following Needham and Needham (1986), Battish (1992), Segers (1995), APHA (2005), Sarma and Sarma (2008) and Datta Munshi *et al.,* (2010).

Calculation:
Total number of plankton present in a liter of water sample were calculated using the following formula:

$N = (n \times v)/V$

Where

$N =$ Total number of plankton cells per liter of water filtered.

$n =$ Average number of plankton cells in/ml of plankton sample.

$v =$ Volume of plankton concentration.

All the statistical analysis and preparation of graphs were carried out in SPSS 16.0 and Excel Sheet 2016. To compare the means of the different parameters (soil, water, phytoplankton and zooplanktoms) of the Barbilalbeel in accordance to year-wise, seasonal-wise and site-wise variations, ANOVA test was performed at 95% ($p \leq 0.01$) for different parameters.

RESULT

Phytoplankton: The present investigation reported 53 forms of phytoplankton from Barbilabeelin 4 different seasons. They belong to 5 classes – Cyanophyceae (15 species), Chlorophyceae (14 species), Bacillariophyceae (20 species), Euglenophyceae (3 species) and Dinophyceae (1 species) (Table 1).

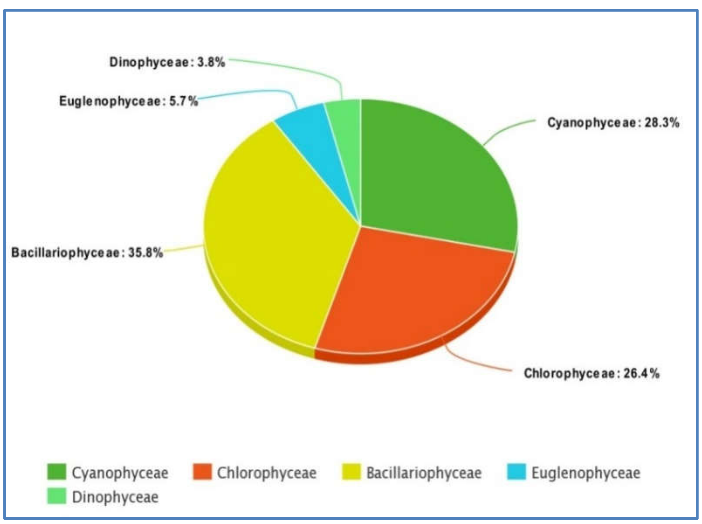

Figure 2: Percentage Composition of Different Groups of Phytoplankton

Table 1: Phytoplankton Species Recorded in Barbila*beel*.

Class	Sl. No.	Genera	Abundance
Cyanophyceae (Blue green algae)	1	*Spirulina*	+++
	2	*Nostoc*	+++
	3	*Anabaena*	+++
	4	*Oscillatoria*	+++
	5	*Synechococeus*	++
	6	*Microcystis*	+++
	7	*Lyngbya*	++
	8	*Amphanothece*	++
	9	*Rivularia*	+++
	10	*Nodularia*	+++
	11	*Peridinium*	++
	12	*Ceratium*	+
	13	*Microchaete*	++
	14	*Gomphosphacria*	+
	15	*Scytonema*	++
Chlorophyceae	16	*Closterium*	+++
	17	*Sprirogyra*	+++
	18	*Docidium*	+++
	19	*Microspora*	+++
	20	*Scendesmus*	++
	21	*Chlorella*	+++
	22	*Eudorina*	++
	23	*Ulothrix*	++
	24	*Zygnema*	++
	25	*Volvox*	+++
	26	*Oedogonium*	++
	27	*Pediastrum*	++
	28	*Cladophora*	+++
	29	*Penium*	++
Bacillariophyceae	30	*Navicula*	++
	31	*Diatoma*	+++
	32	*Achanthes*	+++
	33	*Pinnularia*	+++
	34	*Amphora*	+++
	35	*Cymbella*	++
	36	*Neidium*	+
	37	*Coloneis*	++
	38	*Pleurosigma*	++
	39	*Diploneis*	++
	40	*Fragillaria*	+++
	41	*Mastoglia*	+
	42	*Gyrosigma*	+
	43	*Anomoeneis*	+
	44	*Neidium*	++
	45	*Surirella*	+++
	46	*Eunotia*	++

	47	*Synendra*	++
	48	*Calonies*	+
	49	*Euglena*	++
Euglenophyceae	50	*Phacus*	+++
	51	*Colacoium*	+++
	52	*Ceratium*	++
Dinophyceae (DinoflageUates)	53	*Peridinium*	++

+++ = Most Abundant
++ = Abundant
+ = Less Abundant

Year wise variations of phytoplanktons
During the study period, the highest mean values of Cyanophyceae was observed in 2017; Bacillariophyceae and Dinophyceaein 2018; and Chlorophyceae and Euglenophyceae in 2019 (Table 2; Figure 3). On the hand, lowest mean values of Cyanophyceae and Chlorophyceae in 2018; Euglenophyceae and Dinophyceae in 2017, and Bacillariophyceae in 2019. ANOVA analysis showed that significant difference in the phytoplanktons due to yearly variation was observed only in Bacillariophyceae ($p<0.05$) and Dinophyceae ($p<0.01$) (Table 2)
.

Table 2: Year wise variations of phytoplanktonsin the Barbilabeel during 2017–2019

Year		**Cyanophyceae**	**Chlorophyceae**	**Bacillariophyceae**	**Euglenophyceae**	**Dinophyceae**
2017	Mean	102.90	124.60	46.25	12.85	9.15
	SD	15.79	43.45	11.35	2.35	1.95
	SE	3.53	9.72	2.54	0.53	0.44
2018	Mean	94.70	111.80	52.55	13.15	12.65
	SD	16.80	28.74	12.12	3.44	2.96
	SE	3.76	6.43	2.71	0.77	0.66
2019	Mean	96.10	126.35	41.30	15.60	9.70
	SD	14.82	32.68	12.17	2.44	1.87
	SE	3.31	7.31	2.72	0.55	0.42
Total	Mean	97.90	120.92	46.70	13.87	10.50
	SD	15.97	35.50	12.57	3.01	2.75
	SE	2.06	4.58	1.62	0.39	0.36
One way ANOVA	F	1.54	1	4.50*	5.87	13.23**
	p value	0.22	0.37	<0.05	**0.05**	<0.01

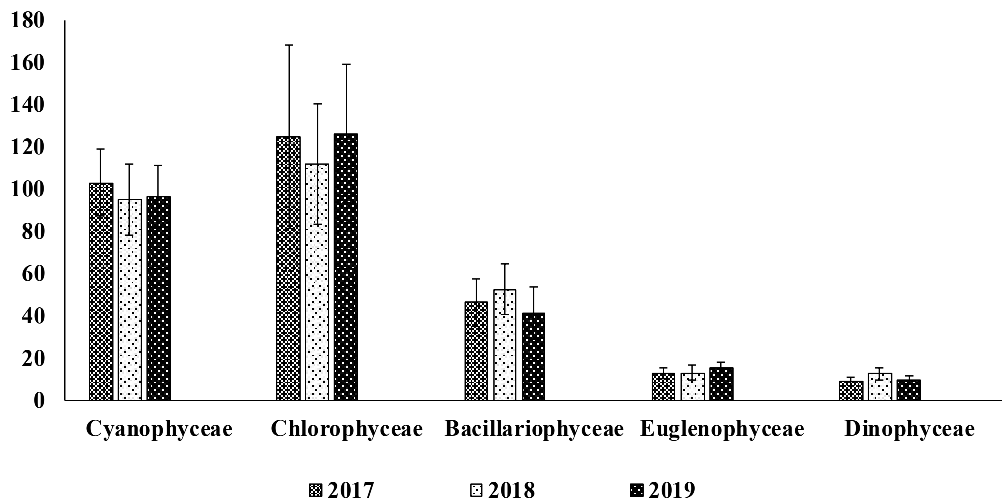

Figure 3: Year-wise average and standard deviation of phytoplankton species in the Barbilabeel during 2017–2019

Seasonal variations of phytoplanktons:
In regard to seasonality, the highest mean values for Chlorophyceae was found in Pre-monsoon season; Cyanophyceae and Dinophyceae during Monsoon; Euglenophyceae in Retreating Monsoon; and Bacillariophyceae in winter respectively (Table 3; Figure 4). On the other hand, lowest values of phytoplanktons in different seasons are as follows: Euglenophyceae in Pre-monsoon, Bacillariophyceae in Monsoon, Cyanophyceae in Retreating monsoon, and Chlorophyceae and Dinophyceae in winter respectively. Statistically, significant difference in the mean values due to seasonality effect was found for all the phytoplanktons except Euglenophyceae (Table 3).

Table 3: Seasonal variations of phytoplanktons in the Barbilabeel during 2017–2019

Season		Cyanophyceae	Chlorophyceae	Bacillariophyceae	Euglenophyceae	Dinophyceae
Pre-monsoon	Mean	106.07	158.33	45.87	13.13	10.73
	SD	8.15	14.31	11.52	2.62	2.82
	SE	2.10	3.69	2.97	0.68	0.73
Monsoon	Mean	106.67	141.47	42.73	13.60	12.13
	SD	10.85	14.78	9.17	2.85	2.10
	SE	2.80	3.82	2.37	0.74	0.54
Retreating monsoon	Mean	89.40	110.33	42.80	14.67	9.93
	SD	7.23	14.98	14.58	3.24	2.94
	SE	1.87	3.87	3.77	0.84	0.76
Winter	Mean	89.47	73.53	55.40	14.07	9.20
	SD	23.03	13.65	11.01	3.35	2.43
	SE	5.95	3.53	2.84	0.86	0.63
One way ANOVA	F	7.48**	100.21**	3.90*	0.70	3.53*
	p value	<0.01	<0.01	<0.05	0.55	<0.05

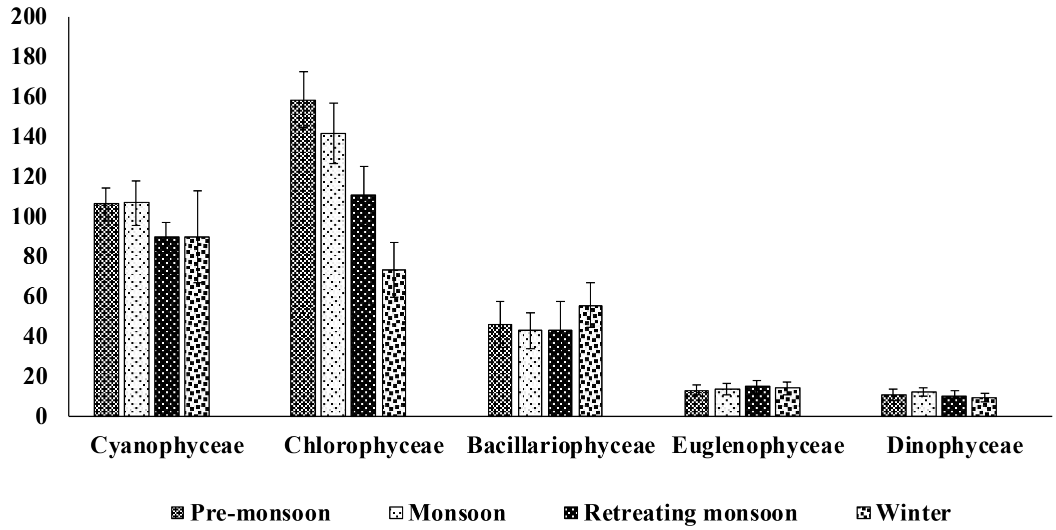

Figure 4: Season-wise average and standard deviation of phytoplankton species in the Barbilabeel during 2017–2019

Site wise variations of phytoplanktons:

In accordance to site-wise analysis, it was found that the phytoplanktons followed a similar pattern, i.e., all the phytoplanktons showed highest values in Site 1, and lowest in Site 5 (Table 4; Figure 5). However, only Cyanophyceae and Euglenophyceae displayed significant difference ($p<0.05$) due to variations in site.

Table 4: Site wise variations of phytoplanktons in the Barbilabeel during 2017–2019

Site		Cyanophyceae	Chlorophyceae	Bacillariophyceae	Euglenophyceae	Dinophyceae
Site 1	Mean	108.42	131.75	51.67	15.67	11.33
	SD	19.09	33.85	13.11	2.19	3.20
	SE	5.51	9.77	3.79	0.63	0.92
Site 2	Mean	99.00	121.17	44.67	14.42	10.17
	SD	12.57	35.37	14.49	2.02	2.44
	SE	3.63	10.21	4.18	0.58	0.71
Site 3	Mean	98.17	117.50	46.92	14.33	10.67
	SD	16.60	37.66	10.44	2.71	3.31
	SE	4.79	10.87	3.01	0.78	0.96
Site 4	Mean	96.17	121.08	47.50	12.92	10.67
	SD	15.56	36.95	10.27	3.85	2.77
	SE	4.49	10.67	2.96	1.11	0.80
Site 5	Mean	87.75	113.08	42.75	12.00	9.67
	SD	9.48	37.05	14.20	2.92	2.02
	SE	2.74	10.70	4.10	0.84	0.58
One way ANOVA	F	2.89*	0.436	0.848	3.09*	0.599
	p value	<0.05	0.782	0.501	<0.05	0.665

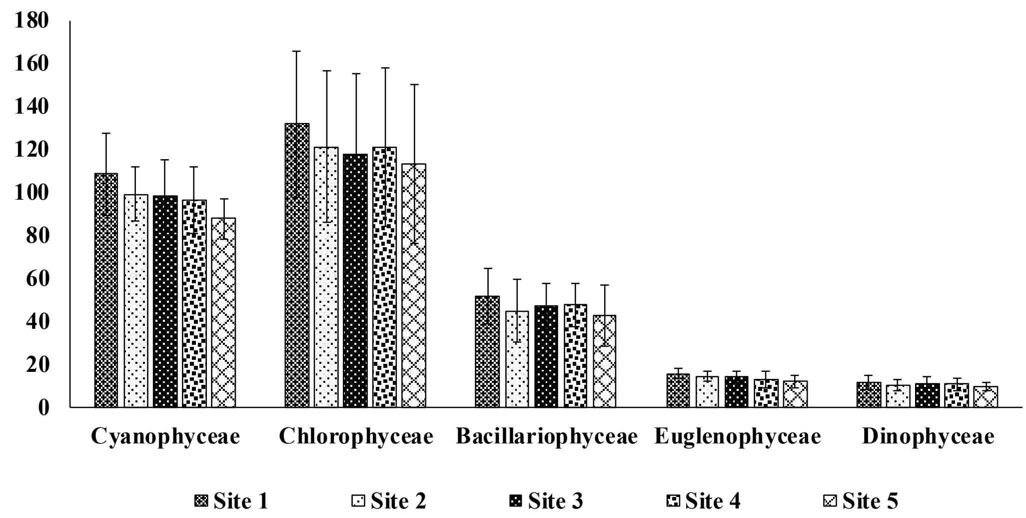

Figure 5: Site-wise average and standard deviation of phytoplankton species in the Barbilabeel during 2017–2019

Zooplankton:
The study recorded 38 forms of Zooplankton were identified in five different sites belonging to four groups-Rotifer (17 species), Protozoa (06 species), Cladocera (07 species), Copepod (08 species) (Table 5).

Table 5: Zooplankton species recorded in Barbila*beel*

Group	Sl. No.	Genera	Abundance
Rotifera	1	*Polyarthraplatiptem*	+++
	2	*Filiniabory*	+++
	3	*Brachionusangularis*	++
	4	*Brachionuscaudatum*	+++
	5	*Keratellatropica*	+++
	6	*Keratellacochlearis*	++
	7	*Keratellaprocurva*	++
	8	*Keratellaquadrata*	+++
	9	*Plationuspatulus*	++
	10	*Epiphanesbrachionus*	+
	11	*Mytilinaventralis*	++
	12	*Lepadellaovalis*	+++
	13	*Lepadella patella*	++
	14	*Brachionusbidentatus*	++
	15	*Testudinella patina*	+++
	16	*Filiniasaltator*	+++
	17	*Conochilusunicornis.*	+
Protozoa	18	*Difugia*	++
	19	*Arcella*	+++
	20	*Centropryxis*	+++
	21	*Euglypha*	+++
	22	*Pandorina*	++
	23	*Nabela*	+++
Cladocera	24	*Daphnia*	+++

	25	*Moina*	+++
	26	*Bosmina*	++
	27	*Ceriodaphnia*	+
	28	*Macrothrix*	+
	29	*Oxyurella*	++
	30	*Acroperus*	+
Copepods	31	*Nauplii*	+++
	32	*Mesocyclops*	+++
	33	*Neodiaptomus*	++
	34	*Cyclops muller*	+++
	35	*Eucyclops*	+++
	36	*Heliodiaptomus*	+
	37	*Tropocyclops*	++
	38	*Microcyclops*	++

+++ = Most Abundance
++ = Abundance
+ = Less Abundance

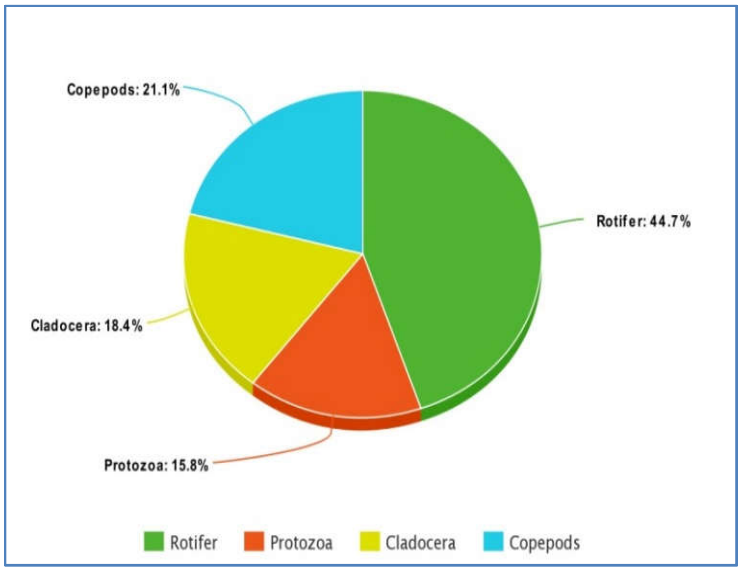

Figure 6: Percentage Composition of Different Groups of Zooplankton

Year wise variations in Zooplanktons:
Analysis of yearly concentration of Zooplanktons showed that the mean values of Rotifera and Cladocera were highest in 2017; Protozoa in 2019; and Copepoda in both 2017 and 2019 respectively (Table 6; Figure 7). On the other hand, lowest concentrations of the Zooplanktons follow: Protozoa in 2017, Copepoda and Cladocera in 2018, and Rotifera in 2019 respectively. ANOVA results displayed that only Cladocera ($p<0.01$) and Protozoa ($p<0.05$) showed statistically significant difference in means due to yearly variations (Table 6).

Table 6: Year wise variations of Zooplanktons in the Barbilabeel during 2017–2019

Year		Copepoda	Rotifera	Cladocera	Protozoa
2017	Mean	77.75	65.30	41.20	10.70
	SD	8.60	4.65	3.16	1.63
	SE	1.92	1.04	0.71	0.36
2018	Mean	74.20	62.60	28.25	11.20
	SD	6.93	8.39	5.22	1.74
	SE	1.55	1.88	1.17	0.39
2019	Mean	77.75	60.40	38.60	13.30
	SD	9.89	8.59	6.11	4.28
	SE	2.21	1.92	1.37	0.96
Total	Mean	76.57	62.77	36.02	11.73
	SD	8.58	7.58	7.47	3.00
	SE	1.11	0.98	0.96	0.39
One way ANOVA	F	1.15	2.18	37.79**	4.76*
	p value	0.33	0.12	<0.01	<0.05

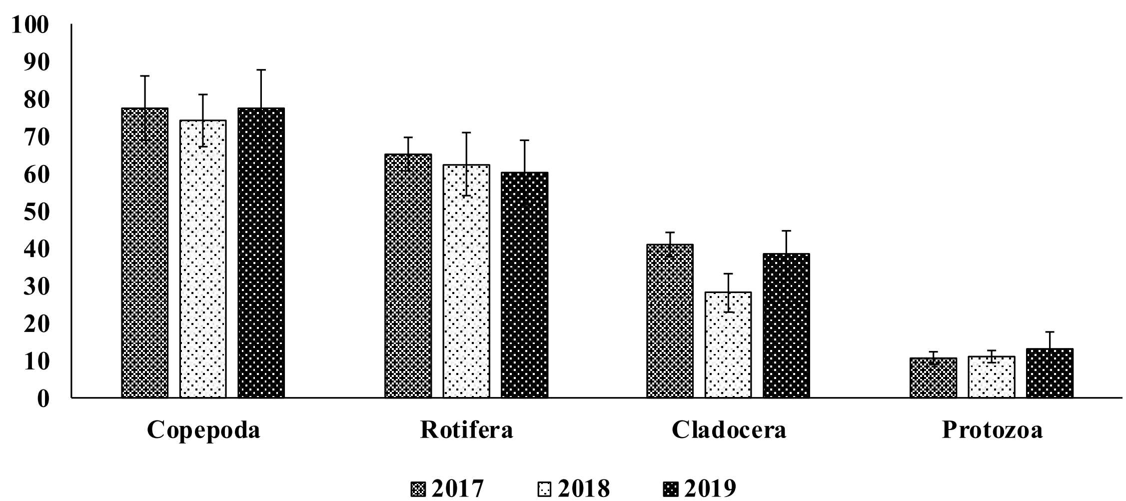

Figure 7: Year-wise average and standard deviation of zooplankton species in the Barbilabeel during 2017–2019

Seasonal variations of Zooplanktons:

Seasonally, the mean concentrations of Cladocera was highest during Pre-monsoon and Winter seasons (Table 7; Figure 8). Copepoda and Rotifera showed highest mean values in Winter, and Protozoa during Retreating monsoon. On the other hand, Copepoda, Rotifera and Cladocera showed lowest mean values in Monsoon season, while Protozoa during Winter. Statistically significant difference in means was observed in Copepoda ($p<0.01$) and Protozoa ($p<0.05$) due to seasonal variation (Table 7).

Table 7: Seasonal variations of zooplanktons in the Barbilabeel during 2017–2019

Season		Copepoda	Rotifera	Cladocera	Protozoa
Pre-monsoon	Mean	72.27	62.13	37.00	11.93
	SD	3.83	4.45	9.34	1.53
	SE	0.99	1.15	2.41	0.40
Monsoon	Mean	67.87	58.20	34.47	10.73
	SD	5.07	4.49	8.99	1.16
	SE	1.31	1.16	2.32	0.30
Retreating monsoon	Mean	81.13	62.20	35.60	13.87
	SD	6.35	11.06	6.05	4.76
	SE	1.64	2.86	1.56	1.23
Winter	Mean	85.00	68.53	37.00	10.40
	SD	5.50	4.58	5.07	1.92
	SE	1.42	1.18	1.31	0.50
One way ANOVA	F	33.58**	5.98	0.39	4.90*
	p value	<0.01	0.01	0.76	<0.05

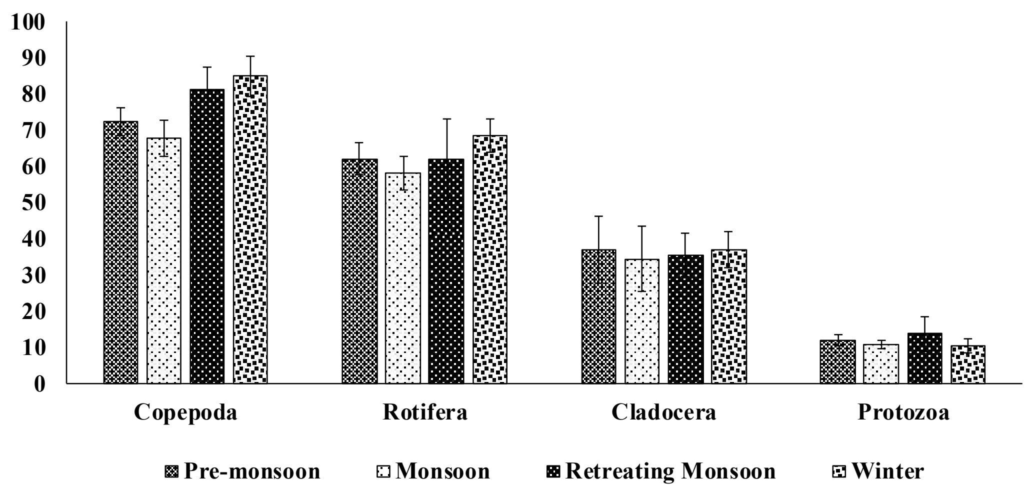

Figure 8: Season-wise average and standard deviation of zooplankton species in the Barbilabeel during 2017–2019

Site wise variations in Zooplanktons:
Site-wise analysis of the zooplanktons revealed that Rotifera and Cladocera were found to be highest in Site 1, while Copepoda and Protozoa were highest in Site 3 and Site 2 respectively (Table 8; Figure 9). On the other hand, Rotifera, Cladocera and Protozoa were found to be lowest in Site 5, whereas Copepoda was lowest in Site 1. However, no statistically significant difference was found in the mean values of zooplanktons due to variations in sites (Table 8).

Table 8: Site wise variations of zooplanktons in the Barbilabeel during 2017–2019

Site		Copepoda	Rotifera	Cladocera	Protozoa
Site 1	Mean	75.25	63.92	36.83	11.33
	SD	9.84	7.57	6.52	2.67
	SE	2.84	2.19	1.88	0.77
Site 2	Mean	76.75	63.58	35.92	12.42
	SD	7.67	6.39	7.12	2.94
	SE	2.21	1.84	2.05	0.85
Site 3	Mean	77.58	63.58	36.67	12.25
	SD	8.85	8.05	6.91	3.67
	SE	2.55	2.32	1.99	1.06
Site 4	Mean	77.08	61.67	35.67	11.42
	SD	8.86	6.54	7.57	2.47
	SE	2.56	1.89	2.19	0.71
Site 5	Mean	76.17	61.08	35.00	11.25
	SD	8.90	9.75	9.94	3.42
	SE	2.57	2.81	2.87	0.99
One way ANOVA	F	0.12	0.33	0.11	0.39
	p value	0.97	0.85	0.98	0.81

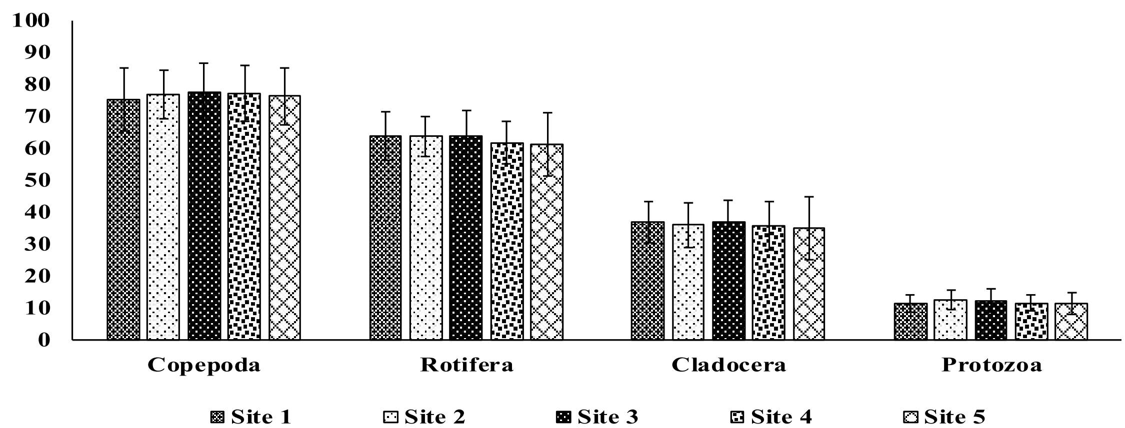

Figure 9: Site-wise average and standard deviation of zooplankton species in the Barbilabeel during 2017–2019

Species Diversity and Species Richness:
Shanan-Weiner index for phytoplankton showed higher value in 2018 than 2017 and 2019. Simpson's index of dominance was found similar during the three years. Simpson's inverse value was measured higher in 2019 and lower in 2017. Simpson's index of diversity was found similar during the three years.

Table 9: Species Richness and Diversity indices of Phytoplankton Diversity of Barbilabeel from 2017-2019

YEAR	H	H Max	E	S	D	1/D	1-D
2017	1.277	1.61	0.79	5	0.003	310.80	0.997
2018	1.311	1.61	0.81	5	0.003	342.13	0.997
2019	1.278	1.61	0.79	5	0.003	392.79	0.997

Shanan-Weiner index value for zooplankton showed higher values in 2019 and lowest value in 2018. Simpson's index of dominance was similar during the three studied years. Evenness value was almost similar during the study period. Simpson's invers was highest in 2019 and lowest in 2018. Simpson's index of diversity was almost similar during the three years.

Table 10: Species Richness and Diversity indices of Zooplankton Diversity of Barbilabeel from 2017-2019

Year	H	H Max	E	S	D	1/D	1-D
2017	1.221	1.39	0.88	4	0.001	727.72	0.999
2018	1.096	1.39	0.79	4	0.002	464.32	0.998
2019	1.240	1.39	0.89	4	0.001	943.69	0.999

DISCUSSION

The present study revealed that Barbilabeel is rich in plankton diversity. The species composition is very much similar to the findings reported from other beels of Assam (Sarma and Sarma, 2008, Bhuyan 2011 and Barthakur, 2014)

Das *et al.*, (2022) reported a number of physico-chemical factors that control the growth and abundance of plankton population. The plankton have developed a complex behavior and characteristics life cycles due to the physico-chemical conditions of their environment. Individuals of the same species may be developed different structures in different seasons to cope with the changed environmental conditions (Goldman and Horne, 1983). According to Sarma and Aruna (2019) grazing and the prevailing environmental conditions greatly influence plankton population. The phytoplanktons are called primary producers as they produce complex food from CO_2 and water with the help of solar energy. Thus, they help in decreasing the amount of carbon dioxide in the atmosphere and leading to area of comparatively lower temperature (Peters, 2004).

Zooplanktons are important component in water body as they works as a primary and secondary linker in the food chain (Hutchinson, 1967). The seasonal variations in plankton population in Barbilabeel suggested that the favourable period for plankton growth was April to October when nutrient accumulation from fresh water runoff due to monsoon rainfall as reported by (Choudhury *et al.*, 2008)

During the study period it was seen that Chlorophyceaeis the dominant group in the water body during premonsoon period. *Closterium, Spirogyra, Ulothrix, Oedogonium and Eudorina* belonging to chlorophyceae were found most dominant to flourish during this season. *Scendesmus, Pediastrum, Zygnema, Penium* showed their dominance during the monsoon season and *Microspora* were observed equally in retreating monsoon as well as monsoon period. *Volvox* showed their abundance in winter period. These findings were inconformity with Bhuyan (2011). Chlorophyceae are restricted to shallow waters and are attached to the submerged plants. Baruah *et al.*, (1998) and Islam *et al.*, (2001) reported about the adaptability of chlorophyceae to different conditions. Cyanophyceae (Blue green algae) of Barbila*beel* were comprised of *Nostoc, Anabaena, Oscillatoria, Synechococeus, Microcystis, Lyngbya, Amphanothece, Rivularia, Nodularia, Peridinium, Ceratium, Microchaete, Gomphosphacria*and

Scytonema. These species were found throughout the years and exhibited seasonal variations which has close similarity with the findings of Rahman (2020). In Barbila*beel*, the Euglenophyceae was represented by only three species: *Euglena, Phacus and Certium*.

In the *beel*, zooplankton abundance indicates the fertility of the specific water body and fishery potential as they play an important role as a source of food for higher organisms including fish (Korstad, 1983). During the study period, Rotifera group was found dominant among all which is a common feature of Indian fresh water (Lahon, 1983; Sharma and Sharma, 2008). Out of seventeen species *Filaniabory, Brachionus angularis, Brachionus caudatum, Keratella tropica, Keratellaprocurva, Keratella quadrata, Lepadella ovalis* and *Lepadella patella* were abundant in winter whereas *Testudinella patina* was dominant during retreating monsoon.

Copepods of Barbilabeel were comprised of *Nauplii, Mesocyclops, Neodiaptomus, Cyclops, Eucyclops, Heliodiaptomus, Tropocyclops* and *Microcyclops. Neodiaptomus*, Out of these, *Mesocyclops*and*Eucyclops* showed their dominance in retreating monsoon and *Cyclops* and *Nauplii* during the winter period as depicted by Sharma and Noroh (2020) in three flood plain lakes of Dibru-Saikhowa Biosphere Reserve, Upper Assam, Northeast India.

In Barbila*beel* seven species of zooplankton belonging to cladocera were recorded- *Daphnia, Moina, Bosmina, Ceriodephnia, Macrothrix, Oxyurella*and *Acroperus* and they were found abundant during winter and in retreating monsoon season.

During the study period, protozoans were reported in all the seasons. *Diflugia* was found during monsoon and retreating monsoon, *Arecella* during latter part of the premonsoon. These findings were in conformity with Barthakur (2014).

CONCLUSION

In the recent period, Barbilabeel has been exposed to various anthropogenic factors which may in turn affect the physic chemical characteristics of soil and water of beel ecosystem. Alternation in physic chemical behavior of soil and water of any aqua system disturb the plankton diversity and abundance leading to decrease in productivity of the beel. Therefore, the village people nearby area needed to make aware for the sustainable growth of the beel.

Conflict of interest:
Authors have declared that no competing interests exist.

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