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Analysis of planktonic abundance and its correlation to fish diversity in Dhir beel (Oxbow Lake), Assam, India

Arup Nama Das*and Dhirendra Kumar Sharma

Department of Zoology, University of Science and Technology, Meghalaya, 9th Mile, Baridua, Ri-Bhoi-793101, Meghalaya, INDIA

***Corresponding Author: arupn8@gmail.com**

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ABSTRACT

Wetland is also known as beels in Assam, India enriched with various types of Zooplanktons, Phytoplanktons and Ichthyofauna. These wetlands are the transitional zones between the terrestrial and aquatic environments. The north-Eastern part of India is blessed with biological reservoirs, especially the Oxbow lakes. An Oxbow lake (named Dhir beel in Assam, India) was investigated from June 2016 to May 2019. Results revealed the presence of the group Chlorophyceae (48%) among the Phytoplanktons and Cladocera (33%), showing the highest among the Zooplanktons and 83 species of fishes belonging to 56 genera, under 29 families. Of these, *Gudusia chapra* was the most abundant (8.71%) and *Anguilla bengalensis* was the least abundant (0.15%) in this wetland. The diversity index of Site-IV and Site-V were higher in comparison among the five sites selected in terms of fish diversity. The present study showed a correlation between the increase in species richness and the decline in species abundance. This might be due to the decrease in the planktonic population, possibly resulting from anthropogenic interference and natural siltation.

INTRODUCTION

The diet of fish determines the abundance of zooplankton, which in turn regulates the level of phytoplankton **(Carpenter *et al.*, 1985)**. A recent study **(Sarvala *et al.*, 1998)** revealed that changes in the abundance of Planktivorous fish do affect both the phytoplankton and zooplankton. However, most of the available information comes from experimental enclosures, and much less is known about the trophic interactions in large ponds **(Brett & Goldman, 1996)**. The exploitation of fisheries resources in Assam, as well as elsewhere in India, has been carried out in the absence of adequate ecological information of the fish food organisms **(Yadav, 1987)**. The high percentage of the global fish species found in fresh water, and the ability of some species to produce very high fish yields indicate that natural feeding strategies used by freshwater fishes are highly successful **(Fernando, 1994)**. Understanding these strategies will assist in fish culture and the management of freshwater fisheries. In India from the last three decades, attention has been turned toward fish farming for increasing fish production. The blue revolution in India has brought a tremendous change in the aquaculture following the adoption of new techniques. The Cyprinids occupied more than 53% in terms of fish landings **(Das *et***

***al*., 2019a)**. Planktivorous fish have a major influence on the structure of the whole plankton where they modify the density and size structure of communities **(Carpenter *et al.*, 1985)**.

Phytoplankton and zooplankton are considered the main natural food for fish culture, especially during the early stages. **Seymour (1980)** stated that the carrying capacity and the production of fishponds could be increased by fertilization that encourages growth of phytoplankton and in turn zooplankton, required as natural food for fish. **Touliabah (1992)** evaluated the impacts of fish production and fertilization on managing phytoplankton in Serw Fish Farm. The zooplankton population for fish culture in addition to the artificial food are helpful for the breeding of fishes.

The relationship between phytoplankton, zooplankton and fish culture is of paramount importance in determining the primary productivity and the fish production. This point hasn't been studied in the recent times in Dhir beel since long **Yadav (1987)**. The aim of the present study is to re-evaluate this relationship between the plankton abundance and fish diversity in the oxbow lake has been framed with the following objectives to find out the zooplankton diversity, phytoplankton diversity and ichthyofauna diversity in different seasons.

MATERIALS AND METHOD

1. Study Area

An Oxbow lake, Dhir beel is located in the Western Assam of India with coordinates (26°16'21" N, 90°22'46" E), Chapar-Salkocha Block, Dhubri District, Assam, India **(Fig. 1)**.

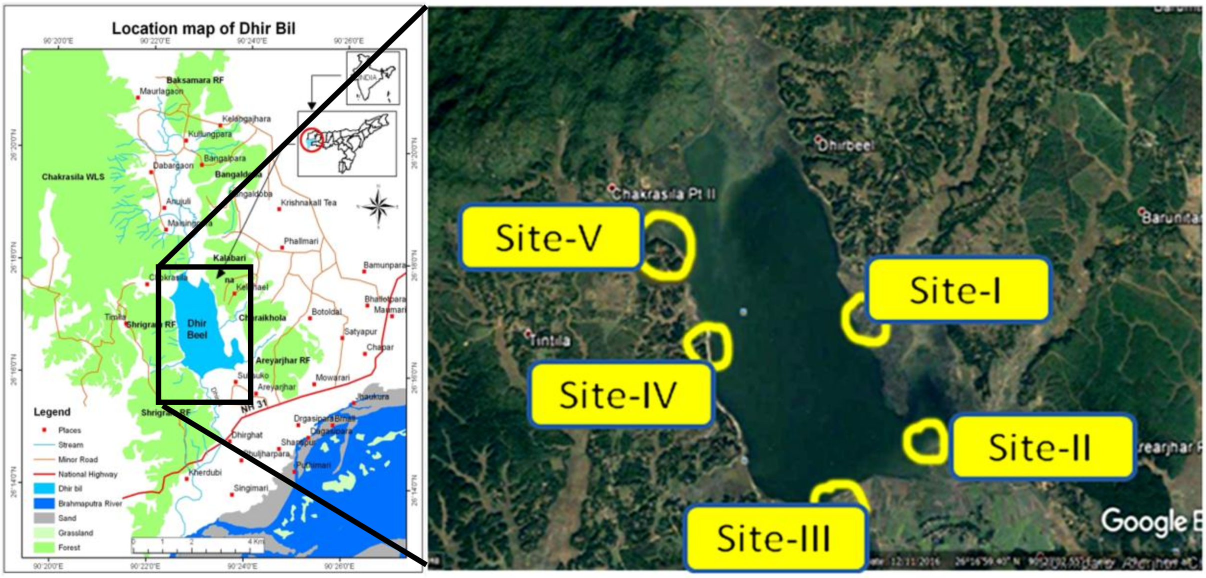

Fig. 1. Map and Google satellite imagery showing collection sites of specimens at Dhir beel, Chapar, Assam Along with its five sites (Scale 1”= 2Km.)

The collection period was divided into four different seasons as follows **(Borthakur, 1986)** (a) Monsoon (June-September), (b) Post-monsoon (October-November), (c) Winter (December-February) and (d) Pre-monsoon (March-May).

2. Phytoplankton collection

Protocols of **FDEP (2006)** were followed for collection and identification. Plankton samples were collected, preserved at 5% formalin and identified in the laboratory of Botany Department, University of Science and Technology, Meghalaya. Phytoplankton identification was mainly based on the study of **Bellinger and Sigee (2010)**.

3. Zooplankton collection and identification

Samples were seasonally collected **(Borthakur, 1986)** and preserved at 10% formalin from five different sites of the beels. Samples were collected using plankton net (Nylobolt no. 25) and analysed according to the studies of **Edmondson (1959)**, **Needham and Needham (1966)** and **Saikia *et al.* (2017)**.

4. Collection and identification of fish specimens

Fish specimens were collected according to the method of **Walsh and Meador (1998)** and deposited in the Museum of Fish, University of Science and Technology, Meghalaya. General measurements and counts followed the methods of **Hubbs and Lagler (1946)** and **Kottelat (2001).** Identification of fishes was made following **Nelson *et al.* (2016)** and **Darshan *et al.* (2019)**.

5. Species status: Followed the IUCN Red List web portal.

6. Survey Time: Day duration of the survey was taken between 7:00 A.M. to 2:00 P.M.

7. Statistics: PAST4 & XLSTAT V3 were used for analysis.

RESULTS

1. Phytoplankton

1.1. Phytoplankton diversity

The total population structure of different phytoplankton classes **(Fig. 2)** was recorded as follows: Cyanophyceae (15 species), Chlorophyceae (29 species), Bacillariophyceae (10 species), Xanthophyceae (2 species) and Euglenophyceae (4 species). A total of 60 species were found (Chlorophyceae> Cyanophyceae> Bacillariophyceae> Euglenophyceae> Xanthophyceae).

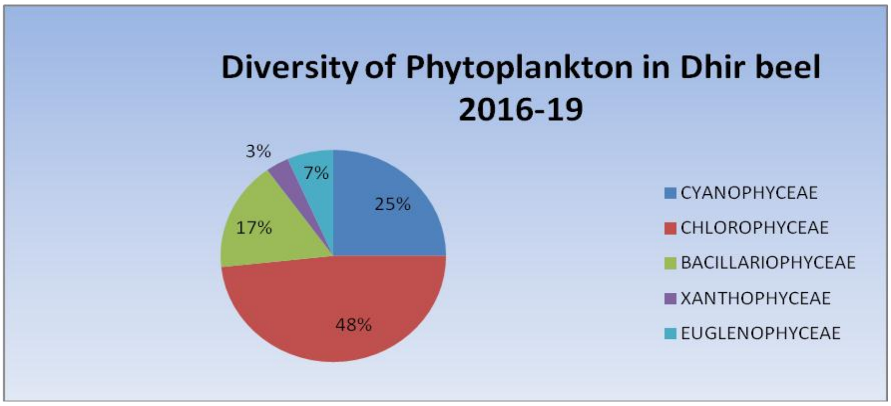

Fig. 2. Abundance of Phytoplanktons in Dhir beel 2016-2019

1.2. Seasonal abundance of phytoplankton

1.2.1. Cyanophyceae

The abundance of Cyanophyceae was at 456±9 in monsoon to 552 ±21 uL^{-1} in winter, while it was 411 ±12 in winter to 382 ±13 uL^{-1} in pre-monsoon **(Table 1)**. The seasonal trend of Cyanophyceae was recorded as winter > monsoon > post-monsoon > pre-monsoon in the last three years. In the three years of investigation, the highest growth of Cyanophyceae was contributed to *Anabaena orientalis*, *A. fertilissima*, and *Nostoc mascorum* during the study period.

1.2.2 Chlorophyceae

The abundance of Chlorophyceae abundance was at 1345 ± 43 uL^{-1} in winter to 847 ± 12 uL^{-1} during pre-monsoon as observed, while it was 1093 ± 20 uL^{-1} in monsoon and 880 ±17 uL^{-1} in post-monsoon season **(Table 1)**. The seasonal trend of Chlorophyceae was as follows: winter> monsoon > post-monsoon > pre-monsoon in the three years of observation. The highest number of Chlorophyceae was contributed to *Desmidium* sp., *Hormidium* sp., *Pandorina* sp., *Volvox aureus* and *Micrasterias foliacea*.

1.2.3. Bacillariophyceae

The abundance of Bacillariophyceae was recorded at 295±13 uL^{-1} in monsoon to 241 ± 14 uL^{-1} during post-monsoon during three years of observation **(Table 1)**, against 292 ± 9 uL^{-1} in winter to 346 ± 15 uL^{-1} in pre-monsoon. The seasonal trend of Bacillariophyceae had been assessed as pre-monsoon > monsoon > winter > post-monsoon. The highest number of Bacillariophyceae was contributed to *Navicula rhynchocephala, Nitzschia* sp. and *Gomphonema* sp..

1.2.4. Xanthophyceae

The abundance of Xanthophyceae was recorded at 53±11 uL^{-1} in monsoon to 76 ± 30 uL^{-1} in post-monsoon **(Table 1)** and 62±20 uL^{-1} in winter to 66± 8 uL^{-1} in pre-monsoon period (Table 1). The seasonal trend for Xanthophyceae was as follows: post-monsoon > pre-monsoon > winter > monsoon in the three years of observation. The species *Botryococcus* was the highest in numbers.

1.2.5. Euglenophyceae

The abundance of Euglenophyceae was found in the range of 99 ±11 uL^{-1} in monsoon to 145± 15 uL^{-1} in post-monsoon **(Table 1)** and the range of 100± 17 uL^{-1} in winter to 130±4 uL^{-1} in pre-monsoon season **(Table 1)**. The seasonal trend for Euglenophyceae was arranged as post-monsoon> pre-monsoon> winter> monsoon in the three years of observation. *Euglena gracilis* and *Phacus acuminatus* were abundant among all the species.

Table 1. Abundance of Phytoplankton in Dhir beel during the period 2016-2019

Phytoplankton groups (uL^{-1})	**Seasons (2016-2019)**			
	Monsoon	**Post-Monsoon**	**Winter**	**Pre-monsoon**
1. Cyanophyceae	456±9	411±12	552±21	382±13
2. Chlorophyceae	1093±20	880±17	1345±43	847±12
3. Bacillariophyceae	295±13	241±14	292±9	346±15
4. Xanthophyceae	53±11	76±30	62±20	66±8
5. Euglenophyceae	99±11	145±15	100±17	130±4

2. Zooplankton

2.1. Zooplankton diversity

The total population structure of different zooplankton classes **(Fig. 3)** was as follows: Protozoa (8 species), Rotifera (13 species), Copepoda (7 species), Cladocera (14 species) and Ostracoda (2 species). A total of 44 species were found (Cladocera > Rotifera > Protozoa > Copepoda > Ostracoda).

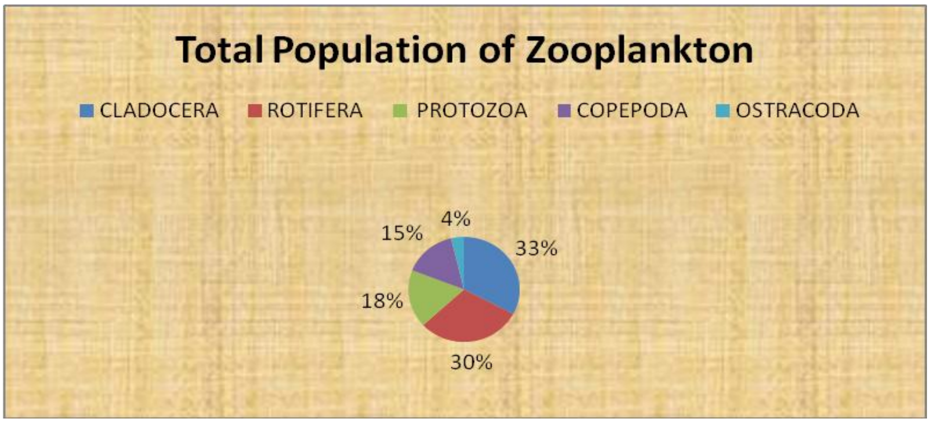

Fig. 3. Pie chart showing abundance of zooplantons in the oxbow lake, Dhir beel during 2016-19

2.2. Seasonal variation of zooplankton abundance

2.2.1. Protozoa

The abundance of Protozoa was found in the range value of 201±6 uL^{-1} in monsoon to 344±22 uL^{-1} in winter of the study period. While, the abundance of Protozoa in pre-monsoon was 179±14 and in post-monsoon was at 224±14 uL^{-1}. The seasonal trend of Protozoa was observed as follows: pre-monsoon< monsoon< post-monsoon< winter in the last three years of observation. *Arcella discoides, A. vulgaris, Difflugia corona* and *Centropyxis minuta* were the abundant Protozoans **(Table 2)**.

2.2.2. Rotifera

The abundance of Rotifera was valued at a 387±7 in monsoon to 478±18 uL^{-1} in winter season, while it was 290±8 in pre-monsoon to 460±10 uL^{-1} in post-monsoon season during 2016-2019 in Dhir beel. The seasonal trend of Rotifera observed was pre-monsoon < monsoon < post-monsoon < winter. *Horaella brehmi, Testudinella patina* and *Trichocera procellus* were the abundant Rotifers **(Table 2)**.

2.2.3. Copepoda

The abundance of Copepoda was at 236±11 in monsoon to 174±5 uL^{-1} in winter of 2016-19, while it was 154±5 in pre-monsoon to 252±18 uL^{-1} in post-monsoon season. The seasonal trend of Copepoda was pre-monsoon< winter< monsoon< post-monsoon. The two major species were *Mesocyclops leuckarti* (male and female) and *Cyclopoid copepoidite* **(Table 2)**.

2.2.4. Cladocera

The abundance of Cladocera was at 428±11 uL^{-1} in monsoon to 583±21 uL^{-1} in winter, while it was 446±19 to 284±8 uL^{-1} in pre-monsoon during the three years of observation. The seasonal trend of Cladocera was pre-monsoon< monsoon < post-monsoon< winter. *Daphnia* sp., *Macrothrix spinosa*, *M. triseralis* and *Alona rectangular* were the abundant Cladocera species **(Table 2)**.

2.2.5. Ostracoda

The abundance of Ostracoda was at 66±17 in monsoon to 49±1 uL^{-1} in winter during the three year of observation, while it was 43±8 in pre-monsoon and 40±1 uL^{-1} in post-monsoon. The seasonal trend of Ostracoda was observed as follows: post-monsoon< pre-monsoon< winter< monsoon in the three years of observation. The species *Centrocypris* and *Heterocypris* were observed in all the three years of investigation **(Table 2)**.

Table 2. Abundance of different zooplankton classes (Total ± SD individuals/L) in Dhir beel

Zooplankton groups (uL^{-1})	Seasons (2016-2019)			
	Monsoon	Post-Monsoon	Winter	Pre-monsoon
1. Protozoa	201±6	224±14	344±22	179±14
2. Rotifera	387±7	460±10	478±18	290±8
3. Copepoda	236±11	252±18	174±5	154±5
4. Cladocera	428±11	446±19	583±21	284±8
5. Ostracoda	66±17	40±1	49±1	43±8

3. Ichthyofauna

3.1. Diversity of Ichthyofauna

A total of 83 fish species were found in the beel during the present study. The total population structure of different orders in Ichthyofauna **(Fig. 4)** is as follows: Cypriniformes (40 species), Siluriformes (17 species), Anabantiformes (9 species), Synbranchiformes (5 species) and Gobiiformes (4 species).

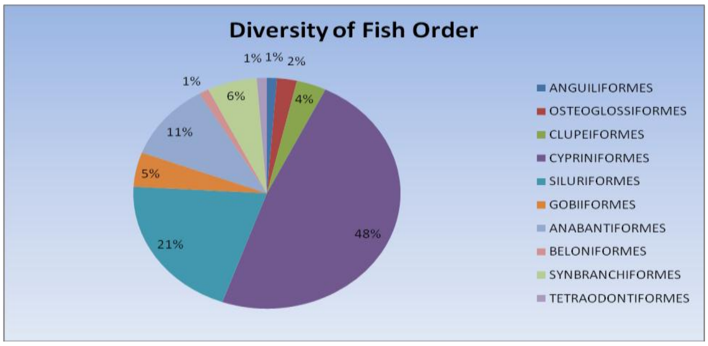

Fig. 4. Fish groups diversity of Dhir beel

3.2. Abundance of Ichthyofauna

A total of 83663 fish individuals comprising 83 species were sampled from Dhir beel throughout the entire study period **(Table 3)**. The highly abundant species was *Gudusia chapra* (8.71% of the total fish caught), followed by *Amblypharyngodon mola* (5.14%) and *Botia dario* (4.82%). In terms of family, the highest abundant was the Cyprinidae (36.98%), and the lowest was Anguilidae (0.15%). Only twenty-two species (*Labeo rohita*, *L. gonius*, *L. Calbasu*, *L. bata*, *L. catla*, *Cirrhinus cirrhosus*, *C. reba*, *Wallago attu*, *Mystus cavasius*, *M. menoda*, *Setipinna phasa*, *Tenualosa ilisha*, *Gudusia chapra*, *Eutropiichthvs vacha*, *Notopterus notopterus*, *N. chitala*, *Puntius chola*, *P. sophore*, *Pangasius pangasius*, *Chanda nama*, *Amblypharyngodon mola* and *Trichogaster fasciata*) constituted the important fish groups of the beel. It is significant to note that, these 22 species were the abundant fish species in this Oxbow lake, Dhir beel as earlier reported in **Das *et al*. (2021**). Cypriniformes showed abundance during the study period.

The seasonal incidence of the catch recorded from 2016 to 2019 including all fish groups are mentioned in **Table (3)**, showing the weekly records on the total fish catch in Dhir beel from 2016 to 2019. However, an account of the fisheries of important species along with the different order of fishes were observed under the majority of them, entering the fishable stock in their first year of life, with an average of only six months old. Although the fish species are exposed to regular capture, the stock is supplemented through fresh recruitment from year to year. The studied oxbow lake receives most of these ichthyodenizens (both breeders and juveniles) from the river Brahmaputra which incidentally serves as the primary source of fish input. Increasing and decreasing trends of fish yield in reservoirs and beels are not constant since they depend on the movement of fishes.

Table 3. Ichthyofaunal structure and abundance in Dhir Beel during 2016-19

Sl. No.	Order	Family	Genus	Species	Composition %
1	Anguiliformes	Anguillidae	*Anguilla*	*A. bengalensis*	0.15**
2	Osteoglossiformes	Notopteridae	*Notopterus*	*N. notopterus*	0.33**
3			*Chitala*	*C. chitala*	0.46**
4	Clupeiformes	Clupidae	*Gudusia*	*G. chapra*	8.71*
5			*Tenualosa*	*T. ilisha*	0.80
6		Engraulidae	*Setipinna*	*S. phasa*	0.88
7	Cypriniformes	Cyprinidae	*Amblypharyngodon*	*A. mola*	5.14*
8			*Barilius*	*B. barila*	2.15*
9			*Chagunius*	*C. chagunio*	0.74
10			*Cirrhinus*	*C. cirrhosus*	0.78
11				*C. reba*	1.49
12			*Ctenopharyngodon*	*C. idella*	0.69
13			*Cyprinus*	*C. carpio*	0.83
14			*Danio*	*D. devario*	0.88
15				*D. rerio*	0.98
16			*Hypopthalmichthys*	*H. molitrix*	0.35**
17				*H. nobilis*	0.55
18			*Labeo*	*L. catla*	1.35
19				*L. bata*	1.90
20				*L. calbasu*	1.62
21				*L. gonius*	0.85
22				*L. nandina*	1.46
23				*L. rohita*	3.04*
24			*Laubuka*	*L. laubuca*	0.59
25			*Pethia*	*P. guganio*	0.81
26				*P. conchonius*	1.55
27				*P. gelius*	0.94
28				*P. ticto*	1.14
29				*P. phutunio*	0.75
30			*Puntius*	*P. chola*	1.28
31				*P. sophore*	1.54
32				*P. terio*	0.86
33			*Rasbora*	*R. daniconius*	0.98
34				*R. elanga*	0.68
35				*R. rasbora*	0.58
36			*Osteobrama*	*O. cotio*	1.10
37			*Cyprinion*	*C. semiplotum*	0.51
38			*Aspidoparia*	*A. jaya*	1.02
39				*A. morar*	0.85
40			*Raiamas*	*R. guttatus*	1.68
41			*Salmostoma*	*S. bacaila*	1.66
42			*Tor*	*T. tor*	0.70
43		Danionidae	*Esomus*	*E. danrica*	2.48*
44		Botiidae	*Botia*	*B. Dario*	4.82*
45		Cobitidae	*Lepidocephalichthys*	*L. guntea*	1.02
46		Nemacheilidae	*Paracanthocobitis*	*P. botia*	1.48
47	Siluriformes	Ailiidae	*Ailia*	*A. coila*	0.52

48		Bagridae	*Bagarius*	*B. bagarius*	0.63
49			*Batasio*	*B. batasio*	0.49**
50			*Mystus*	*M. menoda*	0.49**
51				*M. tengara*	2.21*
52				*M. bleekeri*	0.59
53				*M. cavasius*	0.95
54				*M. vittatus*	1.78
55			*Rita*	*R. rita*	0.68
56		Chacidae	*Chaca*	*C. chaca*	0.27**
57		Clariidae	*Clarias*	*C. magur*	0.64
58			*Heteropneustes*	*H. fossilis*	0.77
59		Pangasiidae	*Pangasius*	*P. pangasius*	0.70
60		Schelibeidae	*Eutropiichthys*	*E. vacha*	0.82
61		Siluridae	*Ompok*	*O. bimaculatus*	0.59
62			*Wallago*	*W. attu*	0.65
63		Sisoridae	*Gagata*	*G. cenia*	0.74
64	**Gobiiformes**	Gobidae	*Glossogobius*	*G. giuris*	0.74
65		Ambassidae	*Chanda*	*C. nama*	4.15*
66			*Parambassis*	*P. ranga*	2.44*
67		Sciaenidae	*Johnius*	*J. coitor*	0.72
68	**Anabantiformes**	Anabantidae	*Anabas*	*A. testudineus*	1.33
69		Badidae	*Badis*	*B. badis*	2.00*
70		Channidae	*Channa*	*C. marulius*	0.71
71				*C. gachua*	0.58
72				*C. punctata*	0.93
73				*C. striata*	1.03
74		Nandidae	*Nandus*	*N. nandus*	1.21
75		Osphronemidae	*Trichogaster*	*T. fasciata*	0.78
76				*T. lalius*	0.75
77	**Beloniformes**	Belonidae	*Xenentodon*	*X. cancila*	0.23**
78	**Synbranchiformes**	Mastacembelidae	*Macrognathus*	*M. aculeatus*	0.90
79				*M. aral*	0.57
80				*M. pancalus*	0.58
81			*Mastacembelus*	*M. armatus*	0.53
82		Synbranchidae	*Monopterus*	*M. cuchia*	0.39**
83	**Tetraodontiformes**	Tetraodontidae	*Leiodon*	*L. cutcutia*	0.71

***: abundant; **: Least abundant**

3.3. Simpson index of fish diversity in different sites in Dhir beel

The Simpson index showed that Site-IV and Site-V were higher with respect to other three sites in all the three years of observations. Moreover, 2016-17 showed the highest Simpson diversity among the last three years **(Table 4)**. The Simpson index presented a higher diversity in Site-IV (0.99); Site-V (0.98) revealed the higher diversity of fish species and the higher abundance of fish species among all five sites **(Fig. 5)**.

Table 4. Simpson Index of three years fish diversity Site wise in Dhir beel

Simpson Index	Site-I	Site-II	Site-III	Site-IV	Site-V	Mean
2016-17	0.98	0.93	0.89	0.99	0.99	**0.952**
2017-18	0.97	0.94	0.86	0.98	0.98	**0.946**
2018-19	0.97	0.93	0.85	0.99	0.98	**0.944**

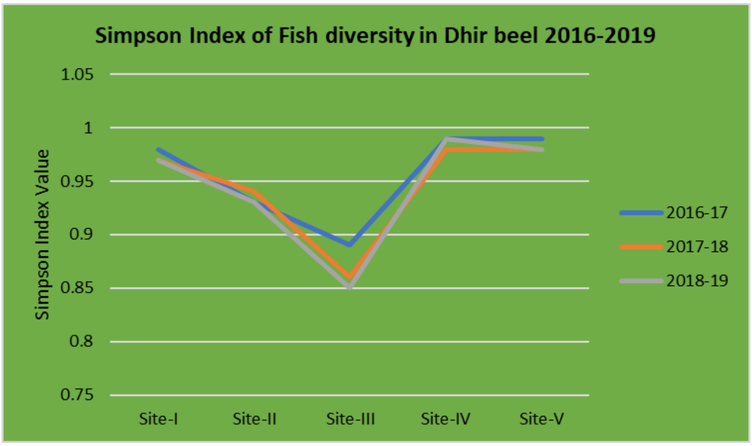

Fig. 5. Simpson Index of fishes of Dhir beel 2016-19

3.4. Seasonal variation of fish abundance

During moonsoon season, 8 orders showed its abundance as follows: Cypriniformes (46%) >Siluriformes (21%) > Anabantiformes (8%) > Synbranchiformes (6%) > Clupeiformes (6%) > Gobiiformes (9%), Beloniformes & Tetraodontiformes (2%) respectively **(Fig. 6)**. The results revealed the breeding seasons of the fishes in Dhir beel in monsoon and the spawning of these abundant fishes.

The abundance of ichthyofauna during winter is mainly dominated by Cypriniformes (61%) > Siluriformes (15%) > Gobiiformes (8%) > Clupeiformes (6%) > Osteoglossiformes (4%) > Synbranchiformes (4%) > Anguiliformes (2%) **(Fig. 7)**.

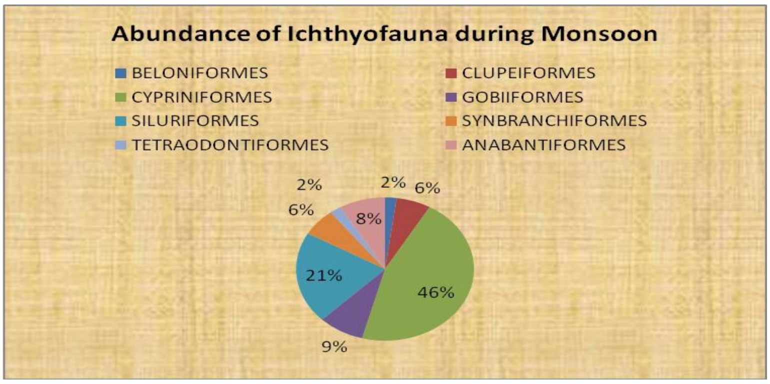

Fig. 6. Abundance of fish in dhir beel during monsoon season

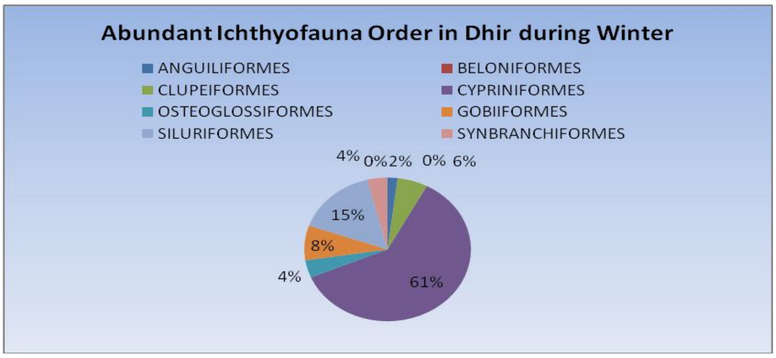

Fig. 7. Abundance of fish in Dhir beel during winter

DISCUSSION

Wetlands are changing at a very fast rate, and being the kidney of a landscape they have a great role in terms of the maintenance of ecosystem energetics. Beels are the source of income playing a great role in ecosystem energetics. The present study selected five different sites in an oxbow lake, the Dhir beel, and recorded the plankton diversity and their relationship with the fish diversity in a study period of three years from June 2016 to May 2019.

1. Phytoplankton

The present study revealed that there were 60 genera of phytoplankton under 5 families with the representation of Chlorophyceae at 1345 uL^{-1} during the winter season **(Table 1)**. The reflection of the occupation of various groups of phytoplankton is presented in the **Fig. (2)**. The 48% representation of Chlorophyceae suggests a favourable ecological condition of the oxbow lake, Dhir beel. Other phytoplanktons such as Cyanophyceae (25%), Bacillariophyceae (17%), Euglenophyceae (7%) and Xanthophyceae (3%) were recorded during the study period. The study detected the highest abundance of phytoplankton diversity during winter season.

The ecological conditions, viz. stable water, availability of nutrients, low water volume, less turbidity, and the availability of sunlight helped the growth of phytoplanktons in freshwater ecosystem **(Shrivastava, 2005)**. The lowest phytoplankton abundance during pre-monsoon and monsoon seasons of the study period were attributed to heavy rains, runoff water from the catchment areas, turbulence of water and flood. These were unfavourable ecological conditions that increased the depth of the beel, the suspended solid as well as the turbidity and water dynamics in the beel. All these ecological adversities influenced the phytoplankton growth. This observation agrees with the study of certain workers **(Datta & Banik, 1987; Bhaumik *et al.*, 2003a, b)**. Dhir beel has a wide range of abiotic physical parameters which supports a wide range of beels biotic components **(Das *et al.*, 2019b)**. The distribution of chlorophyceae depends on some physical parameters of water such as temperature and pH **(Singh, 1965)**. The temperature and pH range recorded in the present study supported the favourable conditions for growth of Chlorophyceae (48%). The second dominant phytoplankton family was Cyanophyceae contributing 25% to the total phytoplankton population. The occurrence of Cyanophyceae was noticed in all seasons. Additionally, **Shrivastava (2005)** stated that, Cyanophyceae occurred in all types of water. Bacillariophyceae with 17% occurrence could be supported by the findings of **Kumar and Hosmani (2006)**, while working in freshwater lake of Mysore. The Euglenophyceae contributed 7% to the total phytoplankton abundance. The Euglenophyceae was absent in winter and pre-monsoon season of the study period. High temperature, water dynamics possibly affected the growth and developments of Chlorophyceae during pre and post monsoon period. According to **Dumont (1994)**, the water body considered as rich if the system possesses 30-50 phytoplankton species. The Dhir beel may be considered as rich water body in terms of occurrences of phytoplankton species richness.

2. Zooplankton

Zooplankton occupies the position of primary consumers in the food chain of aquatic ecosystem. The present study revealed that zooplankton comprised of 44 genera under 5 taxa. Among the zooplankton eight species of Protozoa, thirteen species of Rotifera, seven species of Copepoda, fourteen species of Cladocera, and two species of Ostracoda were detected (**Table 2** & **Fig. 3**). The analysis of zooplankton during the study period clearly showed the presence of diverse zooplankton species in different seasons of the beel. It was observed that the abundance of zooplankton in the beel was in close proximity with the seasonal change. The peak abundance of zooplankton individual was recorded with 1628 uL^{-1} in winter season; sum total of zooplankton was recorded at its minimum at 950 uL^{-1} during pre-monsoon. Earlier, the maximum number of zooplankton individual was observed in monsoon and winter season in the study of **Khatri (1992)** in freshwater lake. Similarly, maximum zooplankton in winter was reported in the wok of **Sinha and Islam (2003)** in lentic water bodies of Assam. In the present study, the water temperature ranging between 11.06 - 24.71°C **(Das *et al.*, 2021)** appeared favourable for the growth of zooplankton individuals. Zooplankton abundance could also be linked to the availability of phytoplankton. During the study period, certain zooplankton species such as *Bosmina* sp., *Daphnia* sp., *Mesocyclops* sp. and *Articella* sp. showed high growth.

These findings coincide with the findings of **Kalita (2017)** but contrary to the report of **Rajagopal *et al.* (2006)**. Zooplankton fauna of Dhir beel is composed of 44 species under 5 groups. Among these groups, quantitatively the first dominant groups were Cladocera and Rotifera, with a contribution of 33% and 30%, respectively, to the total zooplankton **(Table 2)**. **Baruah and Das (1997)** suggested that, the particular plankton dominance was dependent on some ecological conditions including temperature of the wetland ecosystem.

The third dominant zooplankton group was Protozoa, contributing 18% of total zooplankton. The Protozoa exhibited uniform abundance in all seasons throughout the investigation period. The physico-chemical parameters of water favored the uniform growth of Protozoa. **Fasihuddin and Kumar (1990)** made similar observation while working on freshwater pond. The abundance of Rotifera was more in monsoon and perhaps influenced by the high water temperature. Similar observation was made in **Rajagopal *et.al.* (2006)** and **Mukherjee (2011)**. A higher density of zooplankton in the Dhir beel was due to favorable physico-chemical characteristics of water and organic rich environment. Similar observation was reported in the study of **Rajagopal *et al.* (2006)** in freshwater pond.

The Copepoda constituted the 15% of the zooplankton community found throughout the study period. The domination of Copepoda in freshwater ecosystem was reported in several works **(Fasihuddin & Kumar, 1990; Khatri, 1992; Isainarasu *et.al.*, 1995; Kumar and Tripathi, 2004**; **Shrivastava, 2005)**. According to **Ma *et al.* (2019)**, copepods were linked with rich trophic status of wetland. Similarly, the present study recorded a good trophic status of the Dhir beel as indicated by the dominance of copepods.

3. Ichthyofauna diversity

Total 83 species of fishes belonging to 29 families and 10 orders are mentioned in **Table (3)** and 56 genera were collected from the landing sites. Order Cypriniformes recorded highest 40 nos. of species and order Anguilliformes, Beloniformes and Tetraodontiformes were recorded with least number (1 nos.) of species, respectively.

4. Statistical analysis

Shannon index for zooplankton ranged between 2.28 and 2.33. This index clearly demonstrated the presence of diverse zooplankton in different seasons of the study period. The diversity index value was almost similar in all seasons; however, the high diversity was found in pre- winter season and winter **(Table 5)**. The diversity found was the indication of longer food chain and good trophic status of the beel. Additionally, the diversity of the zooplanktons showed the presence of good diet for the smaller group of fishes in Dhir beel.

The Shannon index measures the species diversity in a community. It provides the information about the rarity and commonness of species in a community. It measures the zooplanktons community structure during pre-monsoon, monsoon and the post-monsoon, winter; a similar community structure was recorded in Dhir beel during the entire study period.

Table 5. Shannon Index of Zooplanktons in Dhir Beel

Seasons	No. of Individuals	H'
Monsoon	1318	2.28
Post-monsoon	1422	2.33
Winter	1628	2.33
Pre-monsoon	950	2.29

The correlation between the zooplankton and phytoplankton diversity can be studied by canonical correspondence analysis **(CCA)** that Bacillariophyceae and Ostracoda diversity are positively related to pre-monsoon and monsoon, the abundance of both the planktons showed they are favorable to rainy season which is known as a breeding season for many fish groups. Rotifera, Cladocera and Copepoda are closely related to almost all the seasons but mostly favored by post-monsoon and winter season. Euglenophyceae and Xanthophyceae are positively related to post-monsoon. Protozoa, Chlorophyceae and Cyanophyceae are positively related to winter season, which agrees with the finding of **Kamble and Sarwade (2014)**. It showed the increase in the biomass of phytoplanktons during winter which makes the growth season for the fishes in this Oxbow lake, Dhir beel **(Fig. 8)**.

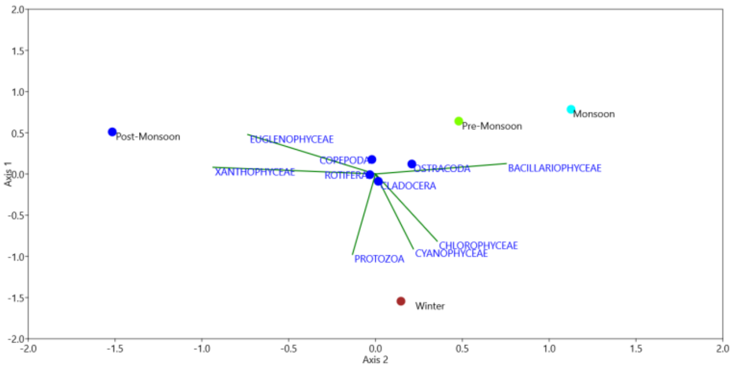

Fig. 8. Canonical correspondence analysis (CCA) of zooplankton diversity and phytoplankton diversity in Dhir beel at different seasons showing diversity of planktons correlated to the variations during changes of seasons

The CCA of zooplankton and fish diversity of Dhir beel showed that the Cypriniformes, Siluriformes, Osteoglossiformes, Clupeiformes and Tetraodontiformes were directly correlated to the Cladocera, Protozoa and Rotifera in winter. It showed that the abundance of fish species mostly depended upon the Cladocera, Protozoa and Rotifera, which act as fish diet during winter and favored in winter season. Perciformes and Synbranchiformes presented direct relation with Copepoda which were dominant in post-monsoon. Hence, they were present in breeding season of fish. Significantly, almost all the fish groups and zooplankton showed negative correlations to the pre-monsoon in Dhir beel **(Fig. 9)**.

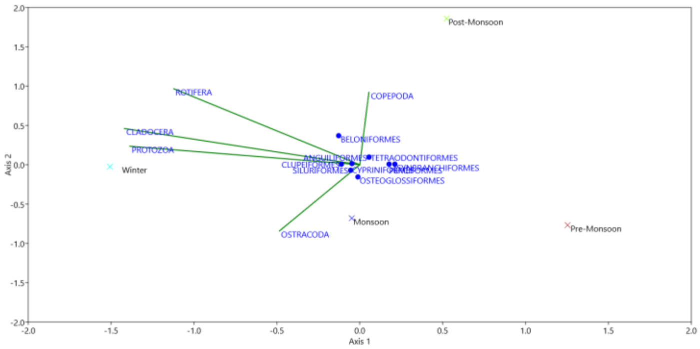

Fig. 9. Canonical correspondence analysis (CCA) of zooplankton diversity and fish diversity in Dhir beel at different
seasons showing diversity of planktons correlated to the variations during changes of seasons

The present findings showed that the growth of zooplanktons, such as Cladocera, Protozoa and Rotifera was significantly correlated to the Chlorophyceae. The plankton community is dominant in winter. The abundance of Cladocera showed good trophic status of lentic ecosystem. Moreover, the plankton showed positive growth from pre-monsoon, monsoon, post-monsoon to winter. It revealed that the quality of limnoplanktons were still in good conditions. The phytoplankton densities in Dhir beel were correlated with the densities of zooplankton as shown in **Fig. (10)**; this may be due to two main factors: 1) the regeneration of the nutrients by zooplankton leading to an increase in the abundance of phytoplankton **(Janik, 1989)**; 2) predation of fishes on large zooplankton leading to the development of phytoplankton **(Elhigzi *et al*., 1995)**.

The Simpson index showed a higher fish diversity in Site-IV-0.99, Site-V-0.98 **(Table 4)** that reflected the rich diversity of the sites in terms of species richness and the abundance including both the zooplankton and phytoplankton groups **(Fig. 11)**. The Simpson index of Protozoa and Cladocera showed the highest diversity among zooplanktons, whereas the Chlorophyceae and Euglenophyceae showed the highest among the phytoplanktons **(Fig. 11)**. Therefore, it was a clear indication of the positive correlation between zooplanktons and the phytoplanktons.

The Shannon index measures the species diversity in a community. It provides the information about the similarity of species in a community. The diversity index showed that the diversity of Bacillariophyceae and Xanthophyceae was almost the same, and Chlorophyceae, Cyanophyceae and Euglenophyceae are almost similar in their community structure. Furthermore, in case of zooplanktons - Protozoa, Cladocera was similar in community structure and Rotifera, Copepoda, Ostracoda had similar sharings in Dhir beel. The Shannon diversity measure was 1.38, and the analysis revealed rich diversity and evenly distributed plankton individual in Dhir beel **(Fig. 12)**.

Dominance index measures the relative importance of a species related to the degree of influence it has on ecosystem components or other organisms whom it influences. As shown in the graph **(Fig. 13)**, the group Protozoa followed by Cladocera showed its influence over all phytoplanktons as well as over its co-zooplankton groups in Dhir beel **(Fig. 13)**. The dominance index of the Protozoa describes the environmental complexity of all the sites, showing its abundance over other species. According to **McNaughton and Wolf (1970)**, dominance is the potential niche space of the certain subordinate species by other dominant species and thus can be manifested more clearly only within a trophic level.

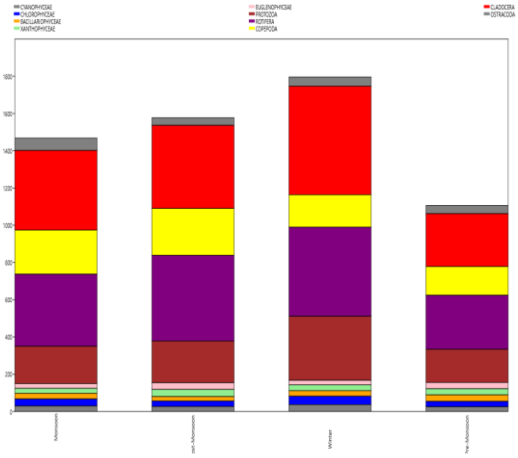

Fig. 10. Stacked Bar Chart showing zooplankton and phytoplankton diversity in Dhir beel

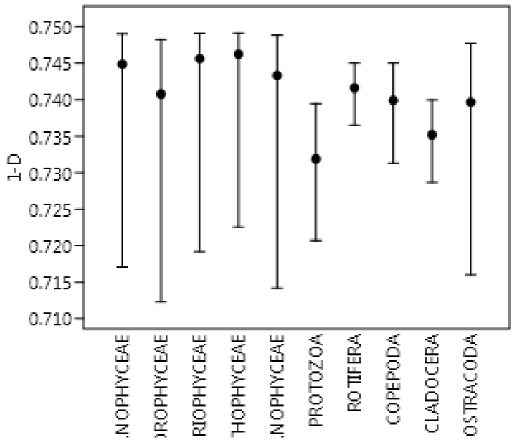

Fig. 11. Simpson Diversity showing zooplankton and phytoplankton diversity in Dhir beel

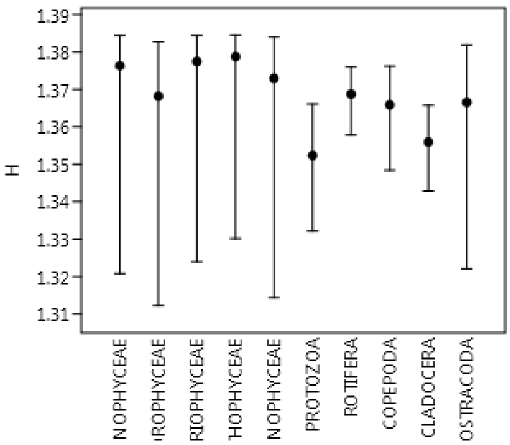

Fig. 12. Shannon Diversity showing zooplankton and phytoplankton diversity in Dhir beel

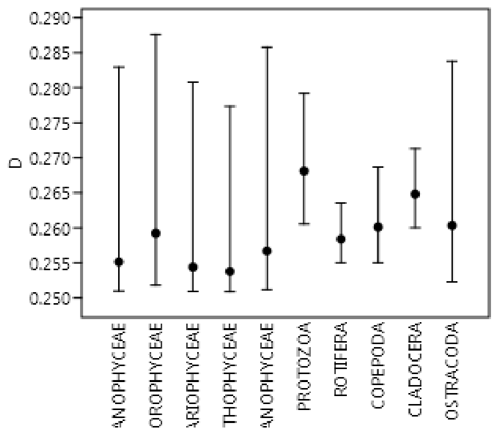

Fig. 13. Dominance Index showing zooplankton and phytoplankton diversity in Dhir beel

All freshwater fishes feed on plankton in a broad sense at some stages of their life. It is generally accepted that the first food of the post - larval fish (after disappearance of the yolk sac) consists at least partially of plankton **(Fernando, 1994)**. **Mavuti (1990)** studied the feeding habits of fish and found that they feed mainly on zooplankton (60%), chironomid larvae (30%), and algae (10%). Phytoplankton and zooplankton communities in fishponds were subjected to wide variations in environmental conditions in addition to the fish predation **(Mageed & Konsowa, 2002)**. The present study in Dhir beel reveals that fish orders like Cypriniformes, Clupeiformes, Anguiliformes, Beloniformes and Siluriformes were directly proportional to the phytoplankton's Chlorophyceae and Cyanophyceae in winter season. The fish orders like Perciformes and Tetraodontiformes are directly correlated to Euglenophyceae and Xanthophyceae in post-monsoon season. Osteoglossiformes and Synbranchiformes are directly correlated to the Bacillariophyceae in pre-monsoon and monsoon season in Dhir beel **(Fig. 14)**.

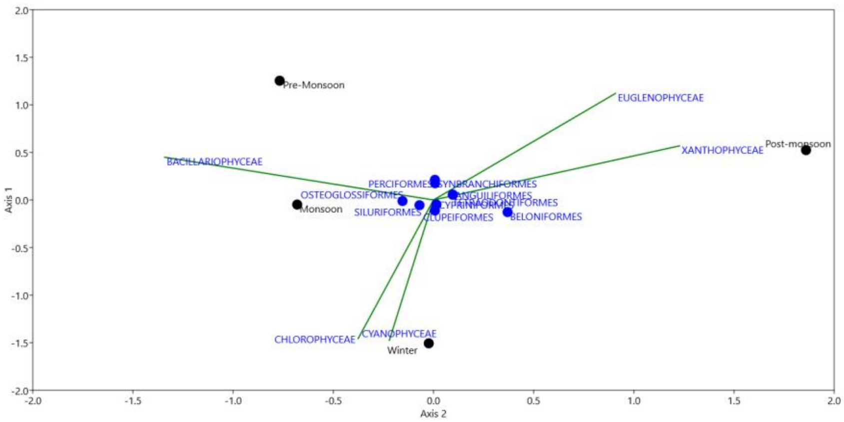

Fig. 14. Canonical correspondence analysis (CCA) of phytoplankton diversity and fish diversity in Dhir beel at different seasons showing diversity of planktons correlated to the variations during changes of seasons

Fish has been a significant link of material circulation and energy transfer as an important ecological group in a freshwater ecosystem. The law of fishery biological communities is closely related to the variation of plankton community carrying a strong correlation between the living environment and periodic movement habits of dominant species. Therefore, variation in the fish community distribution affects the plankton community structure to regulate the ecological health of the wetland ecosystem **(Chai & Cao, 2022)**.

CONCLUSION

The greater production of fish yield is not only the result of the utilization of food as yet unused components, but is also the result of processes leading to greater productivity of the water body. The rivers, floodplains, beels and ponds are components of a single integrated open water fishery production system. During the monsoon months, all the components become connected with each other and remained under a single sheet of water, thus becoming a single integrated fishery production system. Within this system, the floodplains play the most important role in maintaining and enhancing fishery productivity. In Dhir beel; an Oxbow lake, due to human settlement and active brick industries around the beel (Lake) wastes are added in its connected channel making the water saturated and at times oversaturated with organic and inorganic pollutants. These wetlands became the dumping grounds for these sediments and pollutants. The result is serious deterioration of the aquatic resources and as a result native fish species are declining and exotic carp fish diversity found to be increasing in Dhir beel. The highest fish diversity was found in Site-IV, Site-V and Site-I compared to low fish diversity at Site-II and Site-III. This might be due to change in planktonic abundance within the last 30 years in Dhir beel (Oxbow lake).

Fish habit has been influenced the intraplanktonic dynamics; Chlorophyceae occupied the first predominant position in Dhir beel and constituted about 48% of the total population followed by Cyanophyceae (25%), Bacillariophyceae (17%), Euglenophyceae (7%) and Xanthophyceae (3%). The small rotifers and larvae of Cladocera (33%) were the most dominant in the beel in spite of the large forms in the main feeder. The food for fish cultures especially during the early stages are based upon the carrying capacity and production of beel fishery could be increased by fertilization that encourages growth of phytoplankton and in turn zooplankton that is required as natural food for fish. Thus, the zooplanktons and the phytoplankton abundance are very much found to be correlated with the fish production and the fish diversity in Dhir beel.

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