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An Assessment of Physico-chemical Parameters of Water in Association with the Ichthyofauna Diversity of Dhir Beel in Dhubri District of Assam, India

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ABSTRACT

The present investigation was intended to study the variation between physico-chemical parameters of water quality and ichthyofauna diversity in Dhir beel in Assam, India during June 2016 to May 2019. Dhir beel is an Oxbow lake connecting to the river Brahmaputra through a long channel. The relationship between the physico-chemical parameters of water and the fish diversity of the beels were found to be in association supporting the beel hydrobiology. The study revealed the occurrence of 83 species of fishes belonging to 56 genera, under 29 families and 10 orders. Of these, *Gudusia chapra* was the most abundant (8.71%), followed by *Amblypharyngodon mola* (5.14%), *Botia dario* (4.82%), and *Anguilla bengalensis* was least abundant (0.15%). Five sites were selected at a gap of 1 Km per site to study the seasonal effect of physico-chemical characters of water quality in the beel. These factors found to be as Water temperature ranges from 11.0 to 25.0°C, Air temperature 14.0 to 29.0°C, Transparency 58 to 68 cm, pH 6.6 to 6.9, Humidity 51.0 to 68.0 mmHg, DO 8.0 to 10.0 Mg/L, BOD 3.0 to 4.5 Mg/L, FCO_2 6.5 to 7.5 Mg/L, TA 26.0 to 30.8 Mg/L, TH 26.0 to 29.0 Mg/L, TDS 24.5 to 30.0 ppm, TSS 58.0 to 66.5 ppm, Specific conductivity 0.39 to 0.71 mS, Salinity 0.95 to 1.31 ppt, Ca^{2+} 15.0 to 19.0 Mg/L, Mg^{2+} 12.5 to 17.0 Mg/L, Cl^- 5.5 to 8.5 Mg/L, HCO_3^- 23.0 to 28.0 Mg/L, Na^+ 0.55 to 0.65 Mg/L, K^+ 1.10 to 1.40 Mg/L, SO_4^{2-} 4.0 to 7.5 Mg/L, NO_3^- 0.60 to 1.35 Mg/L, PO_4^{3-} 0.45 to 0.90 Mg/L, N_2 1.40 to 1.70 Mg/L, Zn^{2+} 0.25 to 0.40 Mg/L, and these showed significant impact on Dhir beel ichthyofauna diversity in different seasons specifically during monsoon and post-monsoon period. Thus, this assessment of water quality and ichthyofauna diversity allows understanding the Dhir beel's present ecological status for the fish productivity as well as conservation of fish species.

Keywords: Oxbow lake, Water quality, Species, Abundant, Seasons, Ecological status.

INTRODUCTION

All the water bodies are the lifeline for all living organisms on the earth. Wetland is such a water body exists as a transitional area between terrestrial and aquatic ecosystem, which is either covered by shallow water to deep water. There are 3,513 wetlands in Assam, but only 1197 are listed as floodplain wetlands, out of which 430 are registered and remaining 767 are unregistered. These wetlands are distributed at about 92000 hectares over the Brahmaputra valley and about 8000 hectares in Barak valley (Chandra 2014) including certain oxbow lakes and significant support for a vast aquatic wealth, notably the diverse fish groups. Thus, the Dhir beel having all the characters of a wetland located in the western part of Assam situated at a latitude of 26°16'54.65" N and longitude 90°23'21.52" E has well been appeared as potential water body. The Beel has been rich in its aquatic flora and fauna diversity (Yadav 1987), yet demands further investigations with regards to ichthyofaunal diversity and its association with the water quality. Being flood plain wetland or Oxbow lakes, the beel itself exhibits a high degree of fish productivity and the growth of economy of the locals. The productivity of fish could well be enhanced by sustainable use of fish catch and the regular monitoring of the water quality, may attribute for the sustenance of sustainable growth and development of the beel fishery (Sugunan 1995). A general study on the various limnochemical parameters and assessment of the fisheries potential and monitoring of water quality at regular interval is an essential component for the fish productivity in a given wetland ecosystem (Das et al. 2019). Therefore, the physico-chemical parameters of water of this Oxbow lake with regards to pH, surface water temperature, air temperature, humidity, DO, BOD, FCO_2, hardness, alkalinity, salinity, salt concentrations including other limnological parameters should be recorded regularly for keeping the aquatic habitat favourable to the fish group (Mondal et al. 2010). The variation of the hydrological characters, which are dynamic in nature, extends an enormous impact on the diversity of fish fauna since the beel itself is a dynamic ecosystem.

Therefore, the present investigation has been aimed to assess the physico-chemical parameter of water quality of Dhir beel (Flood Plain Lake) for a period of three years from 2016 to 2019. The river Brahmaputra has been found to be connected with that of a link which might have an extended relationship with that of fish assemblages, seasonal fluctuation of water quality and different biodiversity indices of the beel. It is very pertinent to mention that the water quality parameters might have attributed great influence on fish assemblage in a given lake system (Carol et al. 2006). The flood plain lakes like the Dhir beel of Assam have become the victims of environmental detoriation since last decade. Presently, most of the beel areas are continuously shrinking possibly due to siltation and anthropogenic intervention which includes agricultural runoff and eutrophication (Khan and Ansari 2005).

Thus, the main objective of the present study was to assess the physico-chemical parameter of water quality and its relationship with the biodiversity indices which may allow drawing a logical inference in association with the ichthyofauna diversity in Dhir beel and ultimately would diffract a wide range of spectrum on the ecological health of the beel.

MATERIALS AND METHODS

Sampling of water and fish were carried out during June 2016 to May 2019 from selected sampling sites of the beel an Oxbow lake at weekly interval. Dhir beel is located in the Western Assam, India with coordinates of 26°16’54.65" N, 90°23’21.52" E in Chapar-Salkocha Block, Dhubri District, Assam, India (Fig. 1). Water samples were collected seasonally without disturbing the water column and survey were taken in between 7:00 A.M. to 2:00 P.M in a day. The water samples were collected below one foot of the surface water. The sample for DO and BOD was obtained in a 300 ml capacity glass bottle and the samples for other chemical parameters were collected in a 2000 ml plastic bottle. A Celsius thermometer (scale ranges between 0ºC to 100ºC) was used to measure the surface water temperature. HiMedia Aquachek water test kit was deployed to measure pH, salinity, specific conductivity and total dissolved solids of water. dissolved oxygen (DO), biological oxygen demand (BOD) and free carbon dioxide (FCO_2), total alkalinity (TA), total hardness(TH), chloride (Cl^-), nitrate (NO_3^-), nitrogen (N_2) and phosphate (PO_4^{3-}) following the different procedures of (APHA 2012, Gogoi 2017, Kalita 2017). The period of water sample collection and survey within a year has been divided into four different seasons (Borthakur 1986), the seasons are specified as (i) Pre-monsoon (March to May), (ii) Monsoon (June to September), (iii) Post-Monsoon (October to November) and (iv) Winter (December to February). The samples were collected for a period of 30 days per season to the tune of 120 days per year. Fish Specimens were collected after Walsh and Meador (1998) and deposited in the Fish Museum (USTM-MF). General measurements and counts were followed (Hubbs and Lagler 1946, Kottelat 2001). The identification of fishes were made (Nelson et al. 2016, Darshan et al. 2019) and also used to correct the taxa of fishes. PAST V4.0 was used for statistical analysis of the data and MS Excel 2003 was deployed in this investigation.

RESULTS

The physico-chemical characters of the water quality of Dhir beel has been depicted in the Table 1 and 2. Surface water temperature was noted at the highest level during post-monsoon and the lowest during the winter season of the study period at a range variation of 11.0 to 25.0°C. Lower temperature was recorded

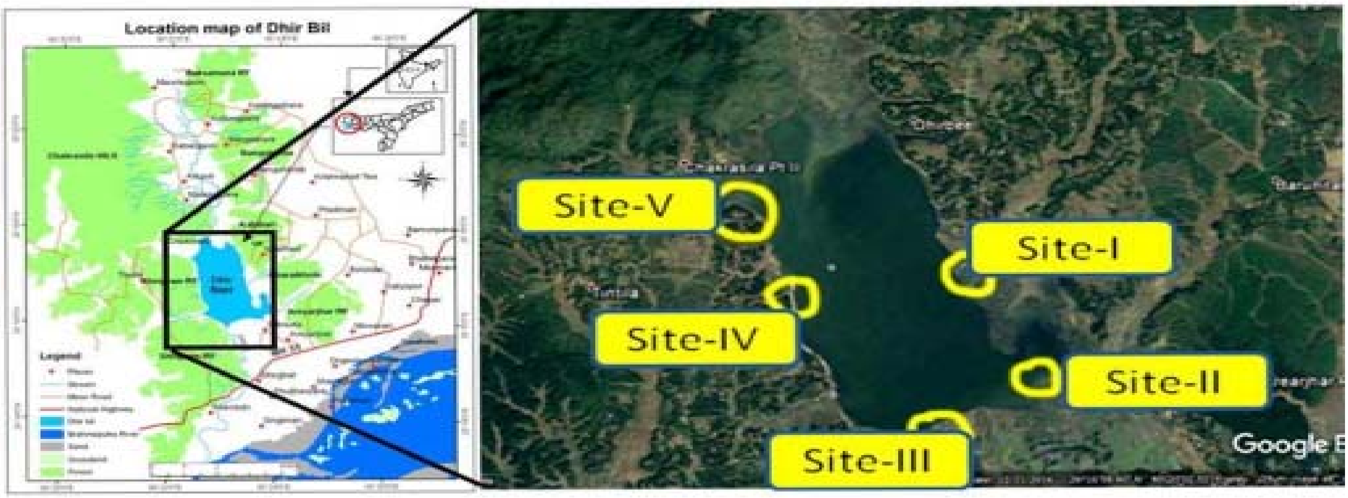

Figure 1. Map and Google satellite imagery showing five collection site(s) at Dhir beel, Chapar, Assam.

Table 1. Physical parameters of Dhir beel during 2016 to 2019

Parameter	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
Water Temperature(°C)	17.29± 1.16	19.42± 4.10	18.97± 3.23	11.06± 1.38
(11.0 - 25.0 °C)	22.28± 1.51	24.17± 2.72	24.71± 2.06	18.69± 1.33^{a}
Air Temperature(°C)	19.34± 1.03	22.32± 4.93	22.89± 2.87	14.74± 1.61
(14.0 - 29.0 °C)	25.57± 0.86	28.91± 2.03	28.56± 0.65	21.68± 0.98^{a}
Transparency (Cm) (58.0 – 68.0)	64.20± 3.52	58.85± 5.48^{a}	67.67± 2.50	66.60± 2.12
pH (6.66 – 6.98)	6.80± 0.07	6.91± 0.10	6.92± 0.07	6.66± 0.09^{a}
Humidity (mmHg) (51.0 – 68.0)	55.41± 1.92	62.04± 5.42	60.65± 3.10	51.52± 1.78^{a}
DO (Mg/L) (8.0 – 10.0)	8.38± 0.24	9.74± 0.14	9.13± 0.85	8.13± 0.77^{a}
BOD(Mg/L) (3.0 – 4.5)	3.89± 0.31	3.52± 0.19	3.44± 0.70	4.24± 0.27^{a}
Free CO_2 (Mg/L) (6.5 – 7.5)	6.75± 0.39	7.00± 0.15	6.81± 0.08	7.46± 0.19^{a}
Total Alkalinity (Mg/L) (26.0 – 30.8)	28.93± 1.17	26.32± 2.52	29.91± 0.62	30.67± 0.91^{a}
Total Hardness (Mg/L) (26.0 – 29.0)	27.08± 0.66	26.32± 1.17	28.98± 1.70	26.04± 1.01^{a}
TDS (ppm) (24.5 – 30.0)	24.84± 0.12	29.75± 3.90^{a}	24.26± 0.78	24.43± 0.79
TSS (ppm) (58.0 – 66.5)	58.89± 1.40^{a}	66.24± 2.35	65.11± 1.97	63.01± 1.36
Specific Conductivity (mS) (0.39 – 0.71)	0.70± 0.03	0.71± 0.08	0.39± 0.04^{a}	0.60± 0.04
Salinity (ppt)(0.95 – 1.31)	0.95± 0.09^{a}	1.08± 0.02	1.31± 0.04	1.07± 0.04

Superscript indicates significant difference within and among the seasons (P<0.05). Figures in parenthesis shows the range variation.

during winter (11.06°C) and higher temperature was at 24.71°C during post-monsoon. The air temperature was noted at its highest during monsoon at 28.91°C and the minimum was at 14.74°C during winter. The range variation took place in between 14.0 to 29.0°C during the study period. The Transparency of water ranged from 58.0 cm to 68.0 cm having lower during monsoon and higher was at winter season. pH was minimum during winter and maximum was during post-monsoon period throughout the study period having a range variation between 6.66 to 6.98. The winter had presented a significantly enhanced pH at 6.66 during the study period. The Humidity ranged between 51.00 mmHg to 68.00 mmHg. The humidity recorded lowest during the winter and highest during the monsoon season. The DO of water ranged between 8.0 to 10.0 Mg/L having minimum during winter and maximum during monsoon. The ranged value of BOD was in between 3.0 to 4.5 Mg/L. Significantly, lower value of BOD was recorded

Table 2. Chemical parameters of Dhir beel during 2016-2019.

Parameters	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
Calcium (Mg/L) (15.0 - 19.0)	18.54± 0.40	17.21± 0.29	17.35± 0.29	15.24± 0.11[a]
Magnesium (Mg/L) (12.5 – 17.0)	16.22± 0.83	15.92± 0.43	12.87± 0.79[a]	15.08± 0.57
Ca^{2+} : Mg^{2+} ratio	1.14	1.08	1.34	1.01
Chloride (Mg/L) (5.5 – 8.5)	5.73± 0.46[a]	7.98± 0.69	7.80± 0.41	8.08± 0.34
Bicarbonate (Mg/L) (23.0 – 28.0)	27.97± 1.12	23.40± 2.02[a]	26.32± 1.14	26.61± 0.86
Sodium (Mg/L) (0.55 – 0.65)	0.58± 0.02[a]	0.61± 0.01	0.64± 0.04	0.61± 0.03
Potassium (Mg/L) (1.10 – 1.40)	1.24± 0.08	1.20± 0.04	1.34± 0.04[a]	1.25± 0.04
Sulphate (Mg/L) (4.0 – 7.5)	5.88± 0.10	6.23± 0.67	5.34± 0.35	4.81± 0.26[a]
Nitrate (Mg/L) (0.60 – 1.35)	1.27± 0.07[a]	0.72± 0.13	0.67± 0.08	0.76± 0.07
Phosphate (Mg/L) (0.45 – 0.90)	0.83± 0.25[a]	0.50± 0.07	0.53± 0.06	0.60± 0.08
Nitrogen (Mg/L) (1.40 – 1.70)	1.42± 0.13	1.49± 0.07	1.51± 0.01	1.66± 0.15[a]
Zinc (Mg/L) (0.25 – 0.40)	0.37± 0.02	0.36± 0.06	0.29± 0.03[a]	0.29± 0.02[a]
Copper (Mg/L)	ND	ND	ND	ND
Chromium (Mg/L)	ND	ND	ND	ND
Cadmium (Mg/L)	ND	ND	ND	ND

ND: Not Defined. Superscript indicates significant difference within and among the seasons (P<0.05). Figures in parenthesis shows the range variation.

during winter. Free Carbon dioxide (FCO_2) of water ranged in between 6.5 to 7.5 Mg/L. It was lower in pre-monsoon and was higher during winter and was found to be significantly increased from monsoon to winter season (7.46 Mg/L). Total Alkalinity (TA) was higher in winter and lower in monsoon season of the study period with a range of 26.0 to 30.8 Mg/L. Alkalinity value showed significant increasing trend from monsoon to winter (P<0.05). Total Hardness (TH) ranged 26.0 to 29.0 Mg/L and the lowest was recorded during winter. An increasing trend was recorded from pre-monsoon to the post-monsoon season of the year. Total Dissolved Solids (TDS) ranged from 24.5 to 30.0 ppm and the minimum was during winter was noted and increases during monsoon. There has been sudden decrease in TDS from winter to supple period of time. It was significant during monsoon period. Total Suspended Solids (TSS) ranged between 58.00 to 66.5 ppm. The pre-monsoon had minimum and the monsoon period had the maximum TDS. Significantly, it was lower during the monsoon period (P<0.05). Specific conductivity ranged from 0.39 to 0.71mS. The minimum was post-monsoon (P<0.05) and the maximum was at monsoon period. The salinity of water ranged from 0.95 to 1.31 ppt having minimum value in pre-monsoon against the highest at post-monsoon season. The lowest in the pre-monsoon period (P<0.05) has been recorded. Calcium (Ca^{2+}) of water ranged between 15.00 to 19.00 Mg/L. The winter showed the lowest quantity against the highest value during pre-monsoon period. Magnesium (Mg^{2+}) ranged from 12.00 to 17.00 Mg/L, the lowest was during post-monsoon (P<0.05) and the highest was at pre-monsoon.

Chloride (Cl^-) content of water varied from 5.5 to 8.5 Mg/L. The lowest quantity was formed during pre-monsoon (P<0.05) and the highest was observed in winter season. Bicarbonate (HCO_3^-) ranged between 23.00 to 28.00 Mg/L carrying the lowest quantity in the monsoon (P<0.05), while the highest was noted at the pre-monsoon season. Sodium (Na^+) was at minimum during pre-monsoon (P<0.05) against the maximal quantity in post-monsoon period having range variation of 0.55 to 0.65 Mg/L. Potassium (K^+) ranged between 1.10 to 1.40 Mg/L with its lowest value at monsoon and the highest during the post-monsoon (P<0.05) period. Sulphate (SO_4^{2-}) was ranged in between 4.0 to 7.5 Mg/L showing the lowest at winter (P<0.05) and the highest at monsoon period. Nitrate (NO_3^-) was highest during pre-monsoon (P<0.05) with a range variation of 0.60 to 1.35 Mg/L. Phosphate (PO_4^{3-}) was highest during the period of pre-monsoon (P<0.05) with range variation of 0.45 to 0.90 Mg/L. Nitrogen (N_2) content varied from 1.40 to 1.70 Mg/L. Significantly, higher values were recorded during winter period ($P<0.05$). Both the post-monsoon and the winter presented a significantly higher values ($P<0.05$) of Zinc (Zn^{2+}) with range of 0.25 to 0.40 Mg/L. Copper (Cu), Chromium (Cr) and Cadmium (Cd) could not be detected throughout the study period.

PCA Analysis

The Physical parameters of water in the beel such as pH, humidity, total hardness, air temperature are positively correlated with monsoon and post-monsoon period. The increase in these parameters is influenced by minimum air temperature, DO, TDS and TSS. The parameter like water temperature, air temperature, has been found to be positively correlated with the monsoon and post-monsoon period. Similarly, the salinity, total alkalinity and transparency are negatively correlated with the pre-monsoon period. The pre-monsoon period has been observed to be decreased in regard to the salinity, TA and transparency while FCO_2 and BOD has been proved to be positively correlated with the winter season (Fig. 2).

The chemical parameters of the beel are influenced by seasonal variations Ca^{2+}, Zn^{2+} and SO_4^{2-} are positively correlated with the monsoon period. NO_3^-, PO_4^{3-} and Mg^{2+} presented positive correlation with the pre-monsoon. Cl^-, HCO_3^-, N_2 and Na^+ exhibited negative correlation with the winter, but found to be positively correlated with the post-monsoon season (Fig. 3).

Seasonal Abundance of Ichthyofauna diversity in Dhir beel

A total of 83 species from 29 families, 56 genera and 10 orders had been sampled from Dhir beel throughout the entire study period (Table 3). The most abundant species was *Gudusia chapra* (Clupidae) comprising 8.71% of the total fish caught, followed by *Amblypharyngodon mola* (Cyprinidae - 5.14%) and *Botia dario* (Botidae - 4.82%). Maximum and minimum abundant family was the Cyprinidae (36.98%) and Anguilidae (0.15%) respectively. Among the 83 species recorded, only 22 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, Eutropiichthys vacha, Notopterus notopterus, N. chitala, Puntius chola, P. sophore, Pangasius pangasius, Chanda nama, Amblypharyngodon mola, Trichogaster fasciata*) constituted the important fish component of the beel. All the 22 species were recorded to be abundant in the beel during the study period. Exotic carps like *Ctenopharyngodon idella, Hypopthalmicthys molitrix* and *Cyprinus carpio* were also recorded in abundance. The order Cypriniformes with the highest abundance with (54%), followed by Siluriformes

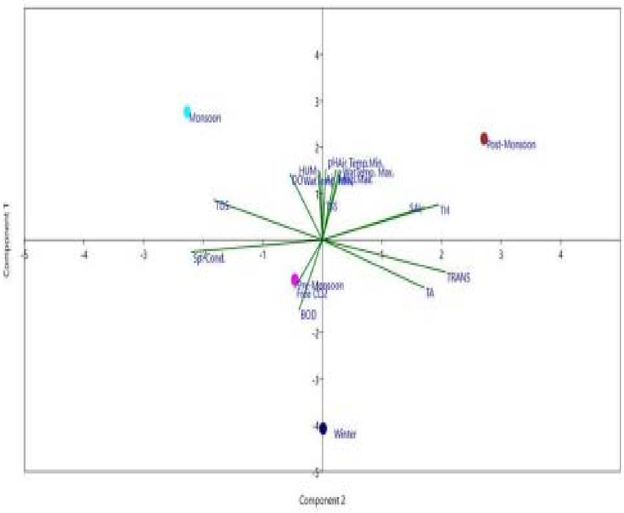

Figure 2. PCA of Physical Parameters of water of Dhir beel with seasons.

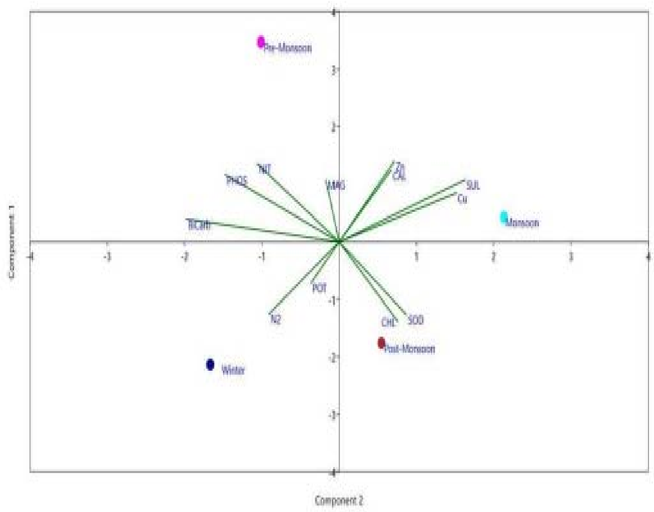

Figure 3. PCA of Chemical Parameters of water with seasons in Dhir beel.

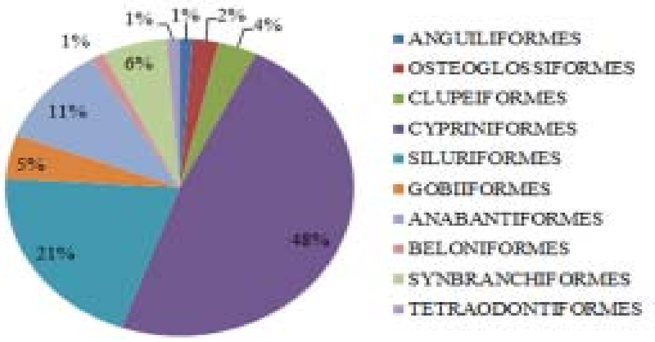

Figure 4. Fish Population diversity of Dhir beel.

(14%), Clupeiformes (10%), Anabantiformes (9%) and Gobiiformes (8%) had been recorded, respectively (Fig. 4). Cyprinidae family presented the abundant fish family followed by Clupeidae, Nemacheilidae, and Chacidae in Dhir beel during the study period (Fig. 5).

The ichthyofauna diversity, in terms of Simpson index has been presented in the Table 4. The Simpson index shows the Site-IV and Site-V presented higher value compared to other three sites. As observed the year 2016-17 showed the highest Simpson diversity (1-D) index value (Table 4).

DISCUSSION

The interactions of the physical and chemical properties of water play an important role in composition, distribution, abundance, movements and diversity of aquatic organisms (Mustapha and Omotosho 2005, Sangpal et al. 2011, Murugan and Prabaharan 2012, Deepak and Singh 2014). To minimize energy expenditure for survival, species typically favour habitat conditions that optimize their physiological process (Matthews 1990). In particular, fish populations are highly dependent upon the variations of physico-chemical characteristics of their aquatic habitat which supports their biological functions (Whitfield 1998, Koloanda and Oladimeji 2004, Ojutiku and Koloanda 2011, Mushahida-Al-Noor and Kamruzzaman 2013). Among the physicochemical factors, temperature, Dissolved Oxygen, pH, turbidity, water transparency and current among others, and their regular or irregular fluctuations were identified as determinants in riverine fish ecology (Boyd 1998, Whitfield 1998, Blaber 2000, Thirumala et al. 2011, Mushahida-Al-Noor and Kamruzzaman 2013).

The Surface water temperature of Dhir beel noted at the highest level during post-monsoon and the

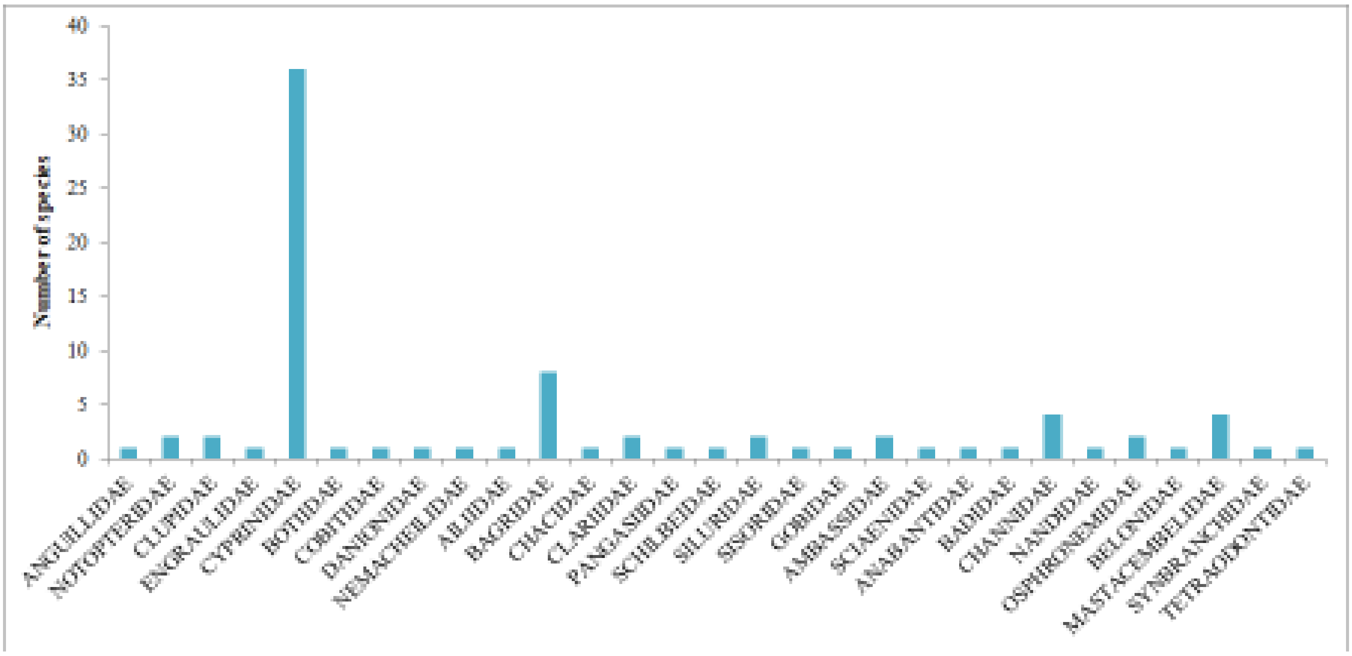

Figure 5: Fish family diversity in Dhir beel.

Table 3. Ichthyofauna diversity of Dhir beel (during 2016-19, Catch/week).

Sl. No.	Order	Family	Genus	Species	Total catch in 3 years from 5 sites	Mean value of the catch per year	%
1	Anguiliformes	Anguillidae	*Anguilla*	*A. bengalensis*	127	42±17	0.15
2	Osteoglossiformes	Notopteridae	*Notopterus*	*N. notopterus*	278	93±17	0.33
3			*Chitala*	*C. chitala*	385	100±37	0.46
4	Clupeiformes	Clupidae	*Gudusia*	*G. chapra*	7288	2429±150	8.71
5			*Tenualosa*	*T. ilisha*	673	181±95	0.80
6		Engraulidae	*Setipinna*	*S. phasa*	740	247±31	0.88
7	Cypriniformes	Cyprinidae	*Amblypharyngodon*	*A. mola*	4300	1433±189	5.14
8			*Barilius*	*B. barila*	1796	599±137	2.15
9			*Chagunius*	*C. chagunio*	616	205±59	0.74
10			*Cirrhinus*	*C. cirrhosus*	650	200±9	0.78
11				*C. reba*	1250	228±31	1.49
12			*Ctenopharyngodon*	*C. idella*	581	127±30	0.69
13			*Cyprinus*	*C. carpio*	696	232±28	0.83
14			*Danio*	*D. devarlo*	733	244±76	0.88
15				*D. rerio*	822	274±25	0.98
16			*Hypopthalmichthys*	*H. molitrix*	293	98±19	0.35
17				*H. nobilis*	461	154±75	0.55
18			*Labeo*	*L. catla*	1126	375±140	1.35
19				*L. bata*	1593	531±77	1.90
20				*L. calbasu*	1358	453±61	1.62
21				*L. gonius*	707	236±10	0.85
22				*L. nandina*	1221	407±103	1.46
23				*L. rohita*	2543	848±209	3.04
24			*Laubuka*	*L. laubuca*	492	164±75	0.59
25			*Pethia*	*P. guganio*	678	226±34	0.81
26				*P. conchonius*	1298	433±104	1.55
27				*P. gelius*	785	200±35	0.94
28				*P. ticto*	955	318±53	1.14
29				*P. phutunio*	631	210±20	0.75
30			*Puntius*	*P. chola*	1067	356±22	1.28
31				*P. sophore*	1290	424±93	1.54
32				*P. terio*	720	240±20	0.86
33			*Rasbora*	*R. daniconius*	817	272±28	0.98
34				*R. elanga*	567	189±15	0.68
35				*R. rasbora*	487	162±14	0.58
36			*Osteobrama*	*O. cotio*	917	222±43	1.10
37			*Cyprinion*	*C. semiplotum*	426	142±53	0.51
38			*Aspidoparia*	*A. jaya*	857	269±24	1.02
39				*A. morar*	710	237±20	0.85
40			*Raiamas*	*R. guttatus*	1409	470±113	1.68
41			*Salmostoma*	*S. bacaila*	1389	463±10	1.66
42			*Tor*	*T. tor*	589	196±53	0.70
43		Danionidae	*Esomus*	*E. danrica*	2075	625±15	2.48
44		Botiidae	*Botia*	*B. dario*	4031	1344±298	4.82

Table 3. contd........

Sl. No.	Order	Family	Genus	Species	Total catch in 3 years from 5 sites	Mean value of the catch per year	%
45		Cobitidae	*Lepidocephalichthys*	*L. guntea*	852	284±62	1.02
46		Nemacheilidae	*Paracanthocobitis*	*P. botia*	1242	414±110	1.48
47	Siluriformes	Ailiidae	*Ailia*	*A. coila*	439	146±18	0.52
48		Bagridae	*Bagarius*	*B. bagarius*	530	177±39	0.63
49			*Batasio*	*B. batasio*	413	138±12	0.49
50			*Mystus*	*M. menoda*	411	137±19	0.49
51				*M. tengara*	1850	617±169	2.21
52				*M. bleekeri*	496	165±12	0.59
53				*M. cavasius*	791	230±9	0.95
54				*M. vittatus*	1492	497±107	1.78
55			*Rita*	*R. rita*	569	190±19	0.68
56		Chacidae	*Chaca*	*C. chaca*	225	75±27	0.27
57		Clariidae	*Clarias*	*C. magur*	539	180±18	0.64
58			*Heteropneustes*	*H. fossilis*	642	214±23	0.77
59		Pangasiidae	*Pangasius*	*P. pangasius*	585	128±37	0.70
60		Schelibeidae	*Eutropiichthys*	*E. vacha*	685	228±15	0.82
61		Siluridae	*Ompok*	*O. bimaculatus*	495	195±38	0.59
62			*Wallago*	*W. attu*	547	182±23	0.65
63		Sisoridae	*Gagata*	*G. cenia*	623	208±36	0.74
64	Gobiiformes	Gobidae	*Glossogobius*	*G. giuris*	619	206±26	0.74
65		Ambassidae	*Chanda*	*C. nama*	3475	1142±14	4.15
66			*Parambassis*	*P. ranga*	2044	681±64	2.44
67		Sciaenidae	*Johnius*	*J. coitor*	605	202±11	0.72
68	Anabantiformes	Anabantidae	*Anabas*	*A. testudineus*	1113	371±105	1.33
69		Badidae	*Badis*	*B. badis*	1676	559±20	2.00
70		Channidae	*Channa*	*C. marulius*	593	198±13	0.71
71				*C. gachua*	483	161±8	0.58
72				*C. punctata*	780	260±34	0.93
73				*C. striata*	864	221±48	1.03
74		Nandidae	*Nandus*	*N. nandus*	1010	337±27	1.21
75		Osphronemidae	*Trichogaster*	*T. fasciata*	653	184±30	0.78
76				*T. lalius*	627	209±24	0.75
77	Beloniformes	Belonidae	*Xenentodon*	*X. cancila*	189	63±7	0.23
78	Synbranchi-formes	Mastacembeli-dae	*Macrognathus*	*M. aculeatus*	751	250±36	0.90
79				*M. aral*	477	159±36	0.57
80				*M. pancalus*	485	162±23	0.58
81			*Mastacembelus*	*M. armatus*	447	116±23	0.53
82		Synbranchidae	*Monopterus*	*M. cuchia*	327	109±9	0.39
83	Tetraodonti-formes	Tetraodontidae	*Leiodon*	*L. cutcutia*	592	197±12	0.71

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

Year	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

lowest during the winter season of the study period. The air temperature was noted at its highest during monsoon and the minimum during winter. This might be because of the solar radiation occurs at a different intensity of sunlight during monsoon to winter seasonal cycle. This change leads to the alteration in the water storage level of the beel. High solar radiation and reduced level of beel water basically the cause of higher temperature at the last part of post-monsoon to winter (FAO 2010, Dey et al. 2015). It is of the fact that high water temperature during the monsoon and post-monsoon period reduces the oxygen holding capacity thereby reduced value of DO, has been obtained in this period in wetland as observed in the Hasadanga beel of West Bengal (Sarkar and Saha 2021) which is in contradiction with the DO level in Dhir beel (9.74 and 9.13 Mg/L), which might be due to moderately high water temperature during this two seasons.

In the present investigation pH values has been affected by environmental factors like temperature, salinity and DO. The pH of this study significantly recorded for lower direction in the winter (6.66) compared to the other seasons, which is within the acidic domain. The pH values were positively correlated with DO, TH, TSS, salinity and humidity. Similarly, DO presents a positive correlation with water temperature with that of pH, TH, TDS and TSS in terms of PCA analysis. Recently, it has well been highlighted that pH presented a positive correlation with those of DO, BOD, TH and TA, while a negative correlation with that NO_3^-, water temperature and FCO_2 (Triparna et al. 2021). Oxygen availability throughout the year has well been influenced by other chemicals present in the water, biological processes, and temperature (Balakrishna et al. 2013). The Free CO_2 values were positively correlated with transparency, TDS, specific conductivity, TA, TSS and BOD in the beel water area. Infact, transparency suggests for effectiveness of the water body. Less transparency and higher TDS (Monsoon) showed an inverse relationship between the reduced transparency and TDS during the monsoon period. Meanwhile, Triparna et al. (2021) categorically suggested turbidity has been able to exhibit positive correlation with that of NO_3, water temperature and CO_2, (Panigrahi and Debnath 2013, Kumar et al. 2019) yet the present study has been failed to address this aspect.

The Alkalinity is the buffering capacity of a water body. During the present investigation of the total alkalinity values has been found to be positively correlated with transparency, Free CO_2, salinity, total hardness and BOD. The total hardness values are caused by dissolved polyvalent metallic ions present in water. The higher alkalinity during the monsoon and post-monsoon period might be due to organic decomposition, which results increase in CO_2 and HCO_3^-. Dilution of beel water due to rainfall during monsoon and post-monsoon period causes the reduction of alkalinity (Dey et al. 2015). High level ($P<0.05$) was obtained during winter possibly due to the reduced level of water, however, contradiction existed with the work of Sarkar and Saha (2021).

Chloride plays very important role in determining the water quality in a water body. During the present investigation chloride values was maximum in winter against the lowest in monsoon because of increase with the degree of eutrophication. Similar results were observed in Urpod beel (Sarma and Dutta 2012). The PCA analysis showed Chloride values are positively correlated with Sodium, Potassium and Nitrogen.

Estimated value for SO_4^{2-} was the lowest during winter against its highest during monsoon throughout the study period. Sulphate is a common compound found in water as a result of the dissolution of minerals from soil and rocks. Low SO_4^{2-} in this beel is suggestive for a healthy ecosystem of the beel, while Reddy et al. (2015) presented higher SO_4^{2-} in Nizam Sagar Dam. Sulphate values are positively correlated with Calcium, Magnesium, Phosphate, Nitrates and Zinc as per the PCA analysis. The high rainfall in the N.E. region of India including Assam might be an attributing factor in lowering the PO_4^{3-} quantity in monsoon period, while the reduced level of the beel water presented an enhanced PO_4^{3-} level, might be an inverse relationship. The presence of phosphate in large quantities in fresh water indicates pollution through sewage and industrial waters (Pejaver and Gurav 2008). PCA analysis presented a positive correlation between PO_4^{3-} and Ca^{2+}, Mg^{2+}, NO_3^-, PO_4^{3-} and Zn^{2+}. The highest BOD values were observed in winter and the lowest in pre-monsoon with all possibilities due to the reduced DO during this period. Therefore, BOD showed a positive correlation with that of Free CO_2, total alkalinity as well as specific conductivity.

The ionic composition of beel water is important for all fishes. The divalent cation Ca^{2+} and Mg^{2+} plays vital role in the ionic regulation of the freshwater fish, since these ions modulate the branchial permeability and growth (Adhikari et al. 2007), while the total hardness of water is dependent upon Ca^{2+} and Mg^{2+} (Wendelaar et al. 1983). Further the inappropriate TH may lead to the retardation of growth and development (Kane et al. 1990, Townscend et al. 2003, Molokwu and Okpokwasili 2004). However, water deficient with either Ca^{2+} and Mg^{2+} had been proved to be toxic to rare minnows larvae (Luo et al. 2016). It is observed that high level of water derived Ca^{2+} and Mg^{2+} could lead to the hypocalcaemia or hypercalcaemia may affect on the fish population (van der Velden et al. 1991). Further, excessively high or low Ca^{2+}:Mg^{2+} ratio in the water might lead to the accumulation of cellular Ca^{2+} and Mg^{2+}, because of competitive relationship between these two cations leading to the production of toxicity.

Moreover, some groups of fishes showed broader adaptability to TH than the other freshwater fishes, including Silver catfishes (*Rhamdia quelen*) (Townscend et al. 2003), Silver carp (*Hypopthalmichthys molitrix*) (Gonzal et al. 1987), Vundu catfish (*Hypopthalmichthys longifilis*) and African catfish (*Clarias gariepinus*) (Ofor and Udeh, 2012) and many other fishes. The present findings on the Dhir beel water parameters has shown neither low nor less Ca^{2+}:Mg^{2+} ratio, suggestive of the fish productivity, could well be safely expressed in favour of its optimal condition to support a wide range of ichthyofauna diversity showing the Simpson index value at below 1.0 (Table 4 and Fig. 6).

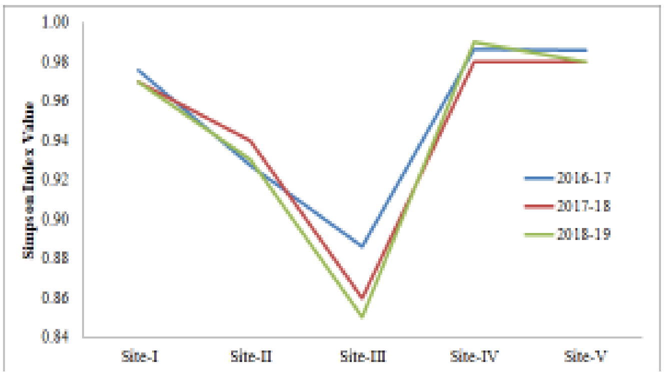

Figure 6: Simpson Index of Dhir beel 2016-19.

The Ichthyofauna diversity and distribution are always governed by both biotic and abiotic factors in a given wetland. Predation was one of the major attributor in affecting fish populations with direct and indirect movements. Increasing and decreasing trends of fish diversity in reservoirs and beels are not constant, but depend both on the autochthonous and allochthonous recruitment levels. The beel has been able to present a higher diversity index (Site-IV-0.99, Site-V-0.98) in number of species and abundance in each category of species in each site (Fig. 6). The moonsoon season with 8 orders presented its abundance where the Cypriniformes (39%) >Siluriformes (24%) > Anabantiformes (10%) > Gobiiformes (10%) > Synbranchiformes (7%), Clupeiformes (5%) > Beloniformes and Tetraodontiformes (2.5%) occupy a significant position, respectively (Fig. 7). It reveals that the breeding season of the fishes in Dhir beel in monsoon and the spawning of these abundant fishes supports the diversity (Fig. 7). The abundance of Ichthyofauna during winter is mainly dominated by Cypriniformes (52%) > Siluriformes (18%) > Anabantiformes (12%) > Gobiiformes (6%) > Synbranchiformes & Osteoglossiformes (4%) > Clupeiformes & Anguiliformes (2%) respectively (Fig. 8), yet notable, presence of Cypriniformes followed by Siluriformes have also been recorded in the Hasadanga beel (Sarkar and Saha 2021). Similarly, in certain selected beels of Nadia district of West Bengal the identical pattern of findings were recorded (Mukherjee et al. 2015). The Simpson dominance index ranged between 0.944 - 0.952 (Table 4) correspond to the findings of Ghosh and Biswas (2017), where site II and III presented lower value against the other three sites probably due to contamination with that of agricultural run off during the monsoon period. Sulphate concentration has a

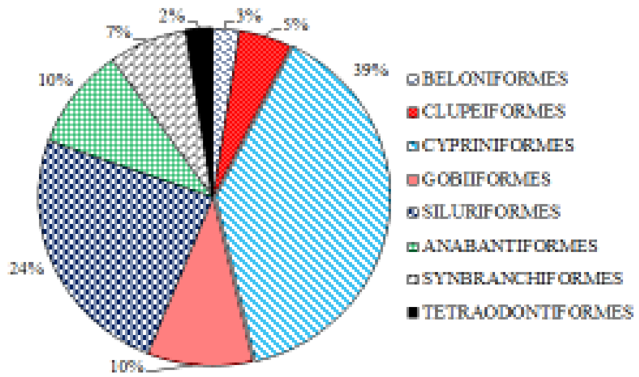

Figure 7. Abundance of fish in Dhir beel during monsoon season

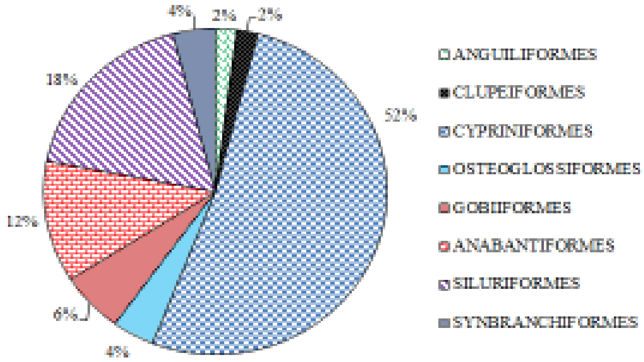

Figure 8. Abundance of fish in Dhir beel during winter season

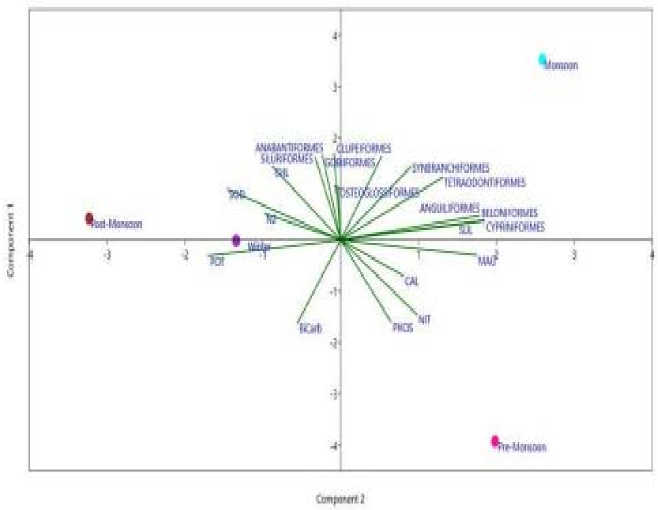

Figure 9. PCA - Chemical parameters of water with major fish group in different seasons in Dhir beel

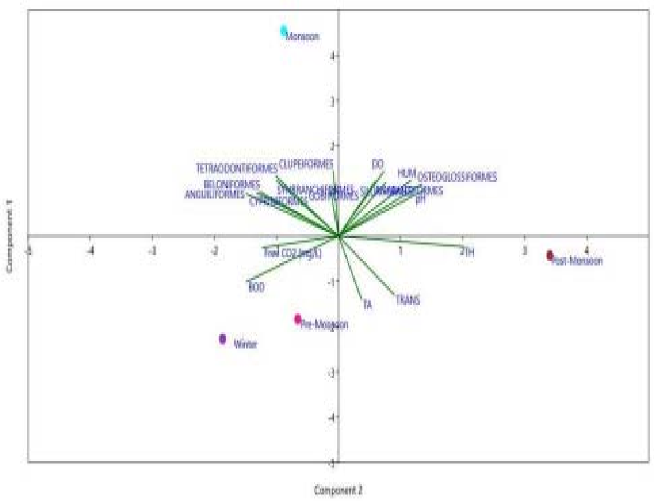

Figure 10. PCA-Physical parameters of water with major fish group in different season in Dhir beel

strong positive correlation to the major fish group in the Dhir beel in monsoon (Fig. 9). The Physical parameters of the water in the beel show great variation during different seasons. Physical parameters like BOD, total alkalinity, humidity plays a great role in pre-monsoon and monsoon season with the diversity of Cypriniformes fish group. DO is very significant in post-monsoon and winter season. Free CO_2, Transparency positively correlated to the post-monsoon and winter season (Fig. 10). It is very interesting to suggest that for turbid hypertrophic environment, where narrow ranges of water transparency are traditionally neglected appears as important factor for the fish groups (Jose Rosso et al. 2010). Increasing water turbidity and subsequent reduced transparency has several effects on fish fauna composition and structure (Henley et al. 2000, Lin and Caramaschi 2005), since the water transparency is a good predictor of fish assemblage and composition (Pouilly and Rodriguez 2004) through an interaction between underwater visibility conditions and species foraging adaptations. Thus, the present status of the beel suggested for a cyclical changes (+ve) in terms turbidity (monsoon and pre-monsoon) to transparency (winter and pre-monsoon). Further work of de Melo et al. (2009) suggests that the relative abundance of cynodontidae and water transparency presented a significant correlation that each group shows species specific habitat affinities for clearer waters.

The monsoon period has been able to project a rich diversity and richness of fish abundance, examplifying the Cyprinidae family (Fig. 5). A relationship could be extended in favour of the fish abundance due to O_2 distribution, which provides a good index of productivity and quality of the environment (Fernandes and Achuthankutty 2010). Higher O_2 concentration was found to vary indicaticating a well oxygenated waterbody like Dhir beel. Variation in pH in the wetland under the study was marginal, though winter presented a pH value at 6.66. However, seasonally higher values had been observed during monsoon and post-monsoon period. In this context De Souza (1983) has categorically advocated that evaporation was high due to solar radiation which in turn may cause the rise of pH of the water bodies.

Salinity and temperatures has been considered as significant factors responsible to make the fresh waterbodies to allow to be good breeding sites. However, many authors (Penn 1981, Achuthankutty et al. 1993) have attained a logical conclusion that factors like low salinity, relatively higher temperature with nutritionally rich food and protection from the predators provide stable environment for the growth of young fishes, which are well evident during the period of post monsoon (Table 1) period of this study. In the present collection very small juvenile stage of fishes were generally absent because of the mesh size of the nets. All the seasons have been able to present all the 10 orders having 56 genera, 29 families and 83 number of species with a percent variation like Cypriniformes at 39% during monsoon, 52% during winter (Figure 7 and 8). Although, there are monthly variations in the catch composition of various species contributed more or less equally to beel catch.

Principal component analysis (PCA) suggested that the ordination of the fish order Cypriniformes towards the seasonality, i.e. of monsoon and the Siluriformes for pre-monsoon period in terms of relative abundance. The amount of variation accounted by new axes were maximised, proceeded by way of an Eigen value analysis in correlation matrix. PCA ordination of the fish order Cypriniformes contributed to the maximum variability in the first PC and considered as the dominant group (Fig. 9). Second component revealed that the order Siluriformes had close association in the fish composition of the wetland and almost identical with that of the Harika wetland (Kaur et al. 2017). However, the least abundant fish groups like Anguiliformes, Beloniformes and Tetraodontiformes has been recorded to be positively associated with, as recorded in the Dhir beel during the monsoon period. Yet, negative correlation has obtained against post-monsoon, winter and pre-monsoon period (Fig. 10). Physical parameters like humidity, DO, pH have found to be positively correlated with the monsoon season with the abundance of Cypriniformes, Siluriformes, Osteoglossiformes, Clupeiformes. Transparency, TH, Total alkalinity, BOD and FCO_2, have been recorded to be negatively correlated against the other water quality parameter and also to the major fish group of Dhir beel.

CONCLUSIONS

The rivers, floodplains, beels are components of a single integrated open water fishery production system. The floodplain wetlands like Dhir beel plays the most important role in maintaining and enhancing fish diversity with physico-chemical parameters supporting the biotic community of an aquatic ecosystem. The assessment of water quality in the five sites of Dhir beel revealed that water quality in the beel is within at optimal level and conclusive to support the diversity of fish specially the Cyprinidae family. The beel has least numbers of fish catch during the study period belongs to the family like Anguillidae, Notopteridae, Chacidae, Belonidae and Synbranchidae compared to other groups might be due to some other anthropogenic factors, needs further evaluation. The study presented that breeding season of the fishes in Dhir beel is in monsoon and its abundance supports the diversity. Among these, Cypriniformes (39%) and Siluriformes (24%) were found to be in highest numbers during monsoon period with respect to other major fish groups. The abundance of ichthyofauna during winter is also dominated by Cypriniformes (52%) and Siluriformes (18%) which are major component of fishery resource in Dhir beel and is supported by observed physico-chemical parameters during the study period. Another important findings of this study showed that the calcium magnesium ratio which was found to be in between the range 1.01 to 1.34 might supports the Dhir beel ichthyofauna diversity and its association with physico-chemical characters. Yet, the variations and associations detected could reach adverse conditions if any measure is not taken to monitor the water quality and the connecting channel of the beel into the river Brahmaputra. This must be taken into account to ensure the conservation and precautionary measures to check degradation of the quality of the rich biodiverse aquatic ecosystems. The data found in this investigation and their analysis and interpretation will improve in understanding and knowledge base about the status of water quality and the ichthyofauna diversity of dynamic Dhir beel. In future, more such core investigations are required with proper scientific monitoring methodologies in Dhir beel to maintain the physico-chemical parameters under control for the benefits of the biotic components of beel.

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Conflict of interest: We declare that there is no conflict of interest.

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