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Assessment of the Ichthyofaunal Diversity in Relation to Physico-Chemical Attributes of the Chathe River (Nagaland), India

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ABSTRACT

Ichthyofaunal density and diversity of Chumoukedima-seithekima area of the Chathe River in Nagaland (India) was examined for one year in 2016 to create firstever official database and to survey the relationship of fish arrays in connection to some of physicochemical parameters of the stream. Amid this examination around 40 species of 23 genera, 10 families and 4 orders of fishes were encountered in the area of which *Cyprinidae* was found to rule the conduits with nineteen species. Cyprinids like *Barilius bendelisis* and *Puntius conchonius* were recorded as the most predominant and bounteous fishes. *Pseudecheneis*, *Awaous* and *Mystus* were observed to be seasonal visitor in the area. Seasonal variation of physicochemical factors of the stream were observed to be ideal for the survival of aquatic life as prescribed by USEPA with the exception of turbidity, which was observed to be most extreme in July (179-218 NTU) in different survey fragments of the waterway. Diversity of fishes was not critically altered in monsoon season regardless of high turbidity, because of the contribution of other physicochemical factors at their recommended level. Pearson's correlation coefficient between ichthyofaunal diversity indices and various physicochemical parameters of the area were significantly associated. Principal component analysis between ichthyofaunal density (at genus level) and physicochemical variables revealed the degree of association of different fishes towards their environment. Maximum gathering of diverse fishes was recorded in premonsoon followed by postmonsoon season, though lowest diversity was recorded in winter.

Key Words: Physicochemical Characteristics; Ichthyofauna; Diversity; Dominance; Association

INTRODUCTION

Streams are typically variable environments that harbor diverse and unique biota (Malmqvist and Rundle 2002). These are amongst the most threatened ecosystems in the world (Allan and Flecker 1993). All waterways are unique, as they never contain same sort and distribution of substrates, same hydrologic administrations, the indistinguishable sorts and amounts of dissolved solids and gases, nor do they get indistinguishable contributions of allochthonous materials and radiant energy. Due to these natural contrasts, aquatic organisms in waterways differ impressively in their reaction to ecological changes created by human beings. Anthropogenic exercises have strong effects on aquatic ecosystems prompting to far reaching change of the physical habitat and thus of biotic communities and ecological functioning (Poff et al. 1997). The nature and size of the community alteration relies on the nature and severity of the ecological change. Ichthyofaunal density and diversity are unequivocally associated with physical and chemical traits of the waterways. Fishes are a standout amongst the most critical marker of the status of aquatic eco-system and involve a striking position from a financial perspective. Physicochemical parameters like dissolved oxygen, current flow, pH, water temperature, BOD, turbidity were found to be firmly responsible for the distribution of ichthyofaunal community in the waterbody by numerous specialists (Scott et al. 2005, Marshall et al. 1998, Boyd et al. 1998, Blaber et al. 2000, Ali et al. 2003). Reclamation of waterway or stream requires a comprehension of the structure and capacity of stream passage environments and the physical, chemical and biological procedures that shape those (Hu et al. 2007). Any interference in the aquatic ecosystem is at once reflected by the adjustment in the physical and chemical qualities. In this way, the estimation of physicochemical attributes with connection to ichthyofaunal diversity is an advantageous approach to analyze the adjustments in water quality (Singh et al. 1980, Trivedy et al. 1987, APHA 2005) and to create a public awareness, which could help in implementing water quality improvement projects to secure the waterway against any further damage. Major streams flowing through Dimapur district of Nagaland (India) are Dhansiri and Chathe. In spite of the fact that the region has the potential for advancement of fisheries, the aggregate zone of the fish cultivating is just 1170.81 ha. In spite of the fact that few works have been accomplished for the Dhansiri River by Dept. of Fisheries (Govt. of Nagaland), no real commitment was done yet to record the ichthyofaunal diversity of the Chathe River solely for Chumoukedima-Seithekima area of Dimapur district. The river Chathe is a perennial stream portrayed by pools, riffles and keeps running at various segments of its stream bed. It has fragmented water flow amid winter and pre-monsoon season. The waterway indicates blue-line stream flow during monsoon and post-monsoon seasons contingent upon normal precipitation. Numerous little channels from Medziphema territory join to form the Chathe River in Dimapur district having an aggregate extend of around 42.78 km in Nagaland, which lastly meet at the Dhansiri River in Karbi Anglong region (Assam) of North east India as the Bakala River. The river has been partitioned by a dam in Chumoukedima area by the department of irrigation and flood control (Govt. of Nagaland). Damming of stream usually alter normal flow regime of the stream, which lead to develop a spatial niche in downstream region with an adjustment of the physicochemical properties of the downstream locales and ichthyofaunal group (Standford et al. 2001). The present investigation was intended to survey the association of the physical and chemical characteristics with the ichthyofaunal diversity of the Chathe River (Nagaland) and to record the quality status of the river.

STUDY AREA

The present investigation was made for one year from December 2015 to November 2016 in Chumoukedima-Seithekiema area of the Chathe River in Dimapur district (Nagaland, India) (Figure 1). Three stations selected for the study were:

Zone I (ZI): This was the upstream locale considered as reference reach with a total length of 2.17 km (25° 47' 12.4" N and 93° 48' 05.4" E to 25° 47' 46.8" N and 93° 48' 16.1" E). The width in this stretch varid seasonally between 13.7 m and 28.6 m. Vegetation at this site included overhang tree cover, grass, scours around the mountain slopes and macrophytes on the waterbed. The waterway was for the most part made out of composed of hard rock bed and pebbles with the fix of sand and mud. This area was least influenced by human settlements but received a little runoff from horticultural and animal farms.

Zone II (ZII): This area (25° 47' 46.8" N and 93° 48' 16.1" E to 25° 47' 50.7" N and 93° 47' 58.3" E) had an extent of around 446.5 m and a width varying seasonally between 15.7m and 28.0m. Vegetation of this site included overhang tree cover, grass and hedges around the mountain grades and few macrophytes on the waterbed. The waterway of this zone was for the most part made out of rocks, dirt and sand. This zone received water from horticultural watershed, animal farm spillover and traffic contamination.

Zone III (ZIII): This station (25° 47' 51.2" N and 93° 47' 57.2" E to 25° 48' 29.2" N and 93° 47' 42.3" E) was the downstream area isolated from other review stations by dam, having an aggregate extend of around 1.48 km, with a width shifted occasionally between 8.56m to 42.29m depending on average precipitation. The conduit in this station was made out of rock bed, stones and sand. The vegetation of this zone was ruled by rural farmland, grass, shrubs, direct overhang tree cover at the stream bank and a significant measure of macrophytes in the riverbed. This station received some runoff from agricultural fields, municipality discharges and traffic effluents.

METHODOLOGY

Sub-surface and middle-depth water samples were collected thrice every month for a year, from the selected zones of the stream. Water samples were collected in 1000mL bottles for analyzing various physico-chemical parameters. Water samples for estimating dissolved oxygen content were collected in 500mL brown bottles and fixed at site following modified Winkler’s method. All samples were brought to the laboratory in an icebox.

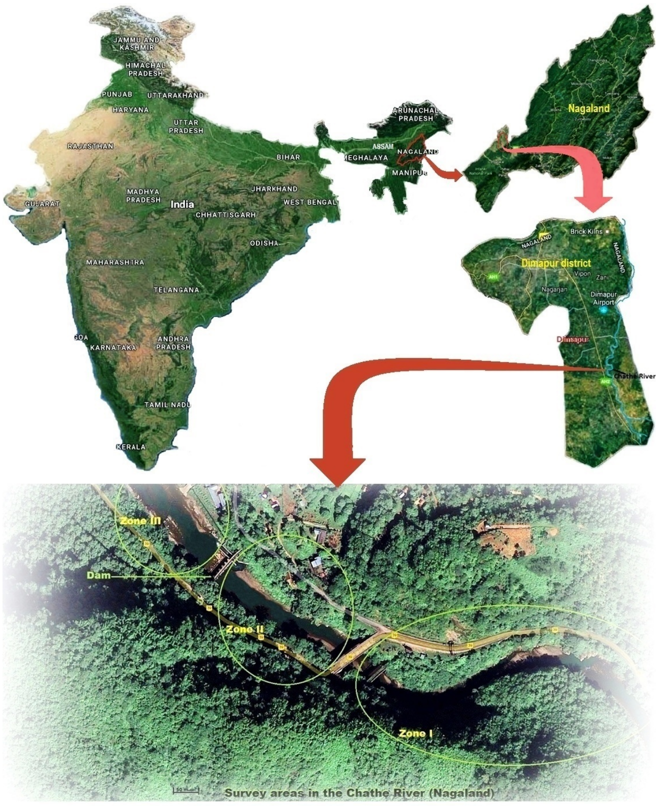


Figure 1. Map of the surveyed area of the Chathe River and location of sampling sites

Through several days of trial-sampling, the Chathe River was ascertained to be the home for just the small fishes; specific sampling strategy was adopted for the collection of fishes during the investigation. Fish were collected from each survey area utilizing a cast net of 4m diameter and "D" net of 600 micron mesh size by kicking and clearing in all microhabitats. The net contents were checked and kept periodically in sample jars to prevent loss of organisms by flood from nets. The samples were raken to the laboratory and major taxa were photographed. Samples were then preserved in plastic jugs containing 70% ethanol. Ten samples were taken for fish study at each of the three stations, where ten batches were considered as one sample. Average of the samples was divided by total sampling area (m^2) of any review station to assess the catch per m^2 per segment. This was done in order to ascertain the quality representatives of a single sample, to assess the taxa richness, density and diversity indices. Most of the ichthyofauna were identied up to species level and a few up to genus level with the help of the published keys (Talwar et al. 1991, Jayaram 1999, Chu et al. 1999, Chatterjee et al. 2012, Das et al. 2008, Nagaland Fishery Directory 2005, Fishbase.org).

Analytical Procedures

Physical Parameters

Physical parameters like current velocity, water temperature, pH, turbidity and depth were measured by digital water velocity meter (Model-FP111, GFP), mercury bulb thermometer, Hanna's pH meter (pHep, Model-HI96107), turbidity meter (Model-EI335) and Secchi disc respectively.. Humidity and air temperature were measured with the Pacer's hygrothermometer (Model-TH406). TDS and conductivity were measured by Hanna's conductivity-TDS meter (DiST, Model-HI96303). Area-average rate of precipitation per month was recorded with the help of TRMM-3B43-7 Precipitation data product (NASA).

Chemical Parameters

Chemical parameters like dissolved oxygen by modified Winkler's method (Trivedy et al. 1987); free CO_2 and bicarbonate alkalinity following Welch (1952); calcium hardness, total hardness and chloride following APHA (2003) were evaluated thrice every month during this investigation. BOD was estimated by incubating the water sample in dark at 20°C± 1°C for 5 days in BOD incubator.

Ichthyofaunal Density

The population density was calculated as percent composition of the families of fishes in the sample as follows:

$$\text{Density}(\%) = \frac{N_i}{N} \times 100$$

where, N_i= Total no. of individuals belonging to i^{th} taxon (or family) and N= Total no. of individuals in the sample.

Total number of fish species gathered per sampling station was counted per month to calculate taxa richness.

Ichthyofaunal Diversity Indices

Four diversity, one dominance and two evenness indices were applied in this study as follows,-

Shannon Diversity Index (H):
It is the widely used index having values in between 0 – 5. Any values above 3 indicate the habitat as stable and balanced. Values under 1 indicate degraded habitat and values in between 1.5-3.5 indicate the normal habitat with slight/moderate pollution. This index is calculated following Shannon (1949):

$$H = \sum(N_i/N) \log_2 (N_i/N)$$

where, n_i= No. of individuals belonging to i^{th} species
N= Total no. of individuals in the sample

Simpson Diversity Index (1-D):
It is designed to measure the probability of any two randomly selected individuals from an infinitely large community belong to the same species. Simpsonn diversity is calculated following Simpson (1949):

$$\text{Simpson dominance (D)} = \left[\sum (n_1(n_i-1)\right]/\left[N(N-1)\right]$$

where, n_i= Total no. of individuals belonging to i^{th} species, and N= Total no. of organisms of all species.

So, Simpson diversity = 1-D

Margalef Diversity Index (Ma):
It was calculated following Margalef (1958):

$$Ma = (S-1)/ \ln N$$

where, N= Total no. of individuals in the sample
S= Total no. of species

McIntosh Diversity Index (Mc):
It measures the homogenous distribution of an organism in the studied community, having values ranging between 0 and 1. Any value closer to 1 indicates homogenous distribution of an organism in the community. McIntosh diversity is calculated following McIntosh (1967):

$$\left(N - \sqrt{\sum n_i^2}\right)/\left(N - \sqrt{N}\right)$$

where, n_i= Total no. of individuals belonging to i^{th} species, and N= Total no. of organisms of all species

Pielou Evenness Index (J):
It measures the equitable distribution of individuals in the community, the value of which range between 0 and 1. It is calculated following Pielou (1966):

$$J = H / H_{max}$$

where, H= Value of Shannon index
H_{max}= ln S; and S= Total no. of species

McIntosh Evenness Index (McE):
It was calculated following McIntosh (1967):

$$\left(N - \sqrt{\sum n_i^2}\right)/\left[N - \left(N/\sqrt{S}\right)\right]$$

where, n_i= Total no. of individuals belonging to i^{th} species; N= Total no. of organisms of all species; and S= Total no. of species.

The collected data on physicochemical variables and ichthyofaunal diversity indices were processed in MS-Excel 2007 for means, standard deviations, and Pearson's correlation coefficient for the association between different physicochemical variables and diversity indices. Principal component analysis between physicochemical variables and ichthyofaunal families was made with the help of XLSTAT (2014) software.

RESULTS

Physico-Chemical Parameters

Data on the physicochemical parameters of the three sites in the Chathe River (Tables 1 and 2) show that the

Table 1. Mean ± SD of physical parameters of the Chathe River

Month	Water temperature (°C)			pH			Current flow (m s^{-1})		
	ZI	ZII	ZIII	ZI	ZII	ZIII	ZI	ZII	ZIII
Dec	**15.97 ± 0.57**	**16.2 ± 0.76**	**16.0 ± 0.87**	8.52 ± 0.20	8.50 ± 0.20	8.50 ± 0.15	0.34 ± 0.03	0.35 ± 0.02	0.34 ± 0.03
Jan	21.2 ± 2.26	21.2 ± 1.76	21.3 ± 2.26	8.53 ± 0.25	8.42 ± 0.14	8.45 ± 0.13	**0.30 ± 0.02**	**0.30 ± 0.02**	**0.29 ± 0.02**
Feb	20.7 ± 0.76	20.3 ± 0.58	20.7 ± 0.76	8.15 ± 0.05	8.13 ± 0.08	8.13 ± 0.06	0.50 ± 0.07	0.52 ± 0.06	0.51 ± 0.06
Mar	17.7 ± 0.58	18.0 ± 0.50	17.7 ± 0.58	8.95 ± 0.30	8.98 ± 0.36	8.97 ± 0.34	0.77 ± 0.10	0.75 ± 0.11	0.74 ± 0.12
Apr	18.8 ± 1.04	19.0 ± 1.32	18.9 ± 0.96	8.87 ± 0.44	8.85 ± 0.44	8.87 ± 0.47	0.77 ± 0.17	0.76 ± 0.18	0.77 ± 0.17
May	27.1 ± 0.70	26.7 ± 0.27	26.5 ± 0.50	8.27 ± 0.06	8.28 ± 0.10	8.28 ± 0.10	0.80 ± 0.33	0.76 ± 0.29	0.83 ± 0.33
Jun	24.95 ± 0.50	24.9 ± 0.71	24.8 ± 0.85	**7.95 ± 0.21**	**7.95 ± 0.21**	**7.95 ± 0.21**	0.65 ± 0.16	0.63 ± 0.11	0.64 ± 0.15
Jul	26.5 ± 0.55	27.4 ± 1.00	27.3 ± 0.76	7.98 ± 0.19	7.97 ± 0.16	7.98 ± 0.20	0.54 ± 0.02	0.55 ± 0.02	0.55 ± 0.02
Aug	27.2 ± 0.76	26.5 ± 0.46	26.9 ± 0.51	8.20 ± 0.27	8.18 ± 0.16	8.18 ± 0.16	0.44 ± 0.07	0.40 ± 0.10	0.41 ± 0.10
Sept	**28.0 ± 0.20**	**27.9 ± 0.74**	**27.9 ± 0.31**	9.05 ± 0.35	9.00 ± 0.39	8.97 ± 0.36	0.57 ± 0.05	0.58 ± 0.09	0.58 ± 0.09
Oct	25.8 ± 0.29	26.07 ± 0.12	26.4 ± 0.69	9.18 ± 0.33	9.23 ± 0.35	9.22 ± 0.38	**0.87 ± 0.21**	**0.92 ± 0.23**	**0.87 ± 0.19**
Nov	23.9 ± 0.90	23.97 ± 0.72	24.1 ± 0.36	**9.38 ± 0.16**	**9.40 ± 0.13**	**9.35 ± 0.10**	0.32 ± 0.03	0.33 ± 0.07	0.33 ± 0.05

Month	Conductivity (mS cm^{-1})			Turbidity (NTU)			Total dissolved solid (mg L^{-1})		
	ZI	ZII	ZIII	ZI	ZII	ZIII	ZI	ZII	ZIII
Dec	0.17 ± 0.01	0.17 ± 0.01	0.17 ± 0.01	**4.31 ± 0.98**	**4.17 ± 1.14**	**4.04 ± 1.11**	109.87 ± 7.39	107.73 ± 6.66	106.67 ± 7.39
Jan	0.11± 0.02	0.11 ± 0.02	0.11 ± 0.01	7.90 ± 2.52	7.37 ± 2.20	7.50 ± 1.48	70.40 ± 11.54	69.33 ± 9.78	67.20 ± 6.40
Feb	0.12 ± 0.02	0.12 ± 0.01	0.12 ± 0.02	17.83 ± 5.03	19.00 ± 6.07	17.10 ± 6.27	74.67 ± 10.29	73.60 ± 8.47	74.67 ± 1.24
Mar	0.14 ± 0.003	0.14 ± 0.01	0.14 ± 0.01	13.87 ± 6.75	13.87 ± 5.16	16.48 ± 7.66	88.53 ± 1.85	87.47 ± 4.89	87.47 ± 4.89
Apr	**0.19 ± 0.02**	**0.19 ± 0.02**	**0.19 ± 0.01**	52.03 ± 13.26	44.10 ± 11.19	41.60 ± 6.76	**119.47±10.29**	**118.13 ± 10.0**	**118.40 ± 8.47**
May	0.10 ± 0.01	0.11 ± 0.003	0.10 ± 0.02	71.2 ± 24.30	66.07 ± 24.98	68.67 ± 26.63	66.13 ± 4.89	68.27 ± 1.85	66.13 ± 12.12
Jun	0.08 ± 0.01	0.08 ± 0.004	0.08 ± 0.004	28.3 ± 7.92	28.40 ± 10.75	27.65 ± 14.64	51.20 ± 4.53	49.60 ± 2.26	49.60 ± 2.26
Jul	0.05 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	**178.8±123.53**	**217.80 ±165.18**	**180.6 ±121.41**	34.13 ± 4.89	36.27 ± 4.89	35.20 ± 5.54
Aug	**0.05 ± 0.003**	**0.05 ± 0.003**	**0.05 ± 0.003**	80.93 ± 8.02	76.67 ± 5.42	80.63 ± 4.52	**33.07 ± 1.85**	**33.07 ± 1.85**	**33.07 ± 1.85**
Sept	0.07 ± 0.01	0.07 ± 0.01	0.07 ± 0.01	75.47 ± 37.24	68.73 ± 35.76	75.53 ± 32.49	43.73 ± 6.66	42.67 ± 4.89	42.67 ± 4.89
Oct	0.07 ± 0.01	0.07 ± 0.003	0.07 ± 0.003	15.21 ± 7.39	16.87 ± 9.50	16.47 ± 8.21	43.73 ± 3.70	43.73 ± 1.85	43.73 ± 1.85
Nov	0.08 ± 0.01	0.08 ± 0.01	0.08 ± 0.01	4.333 ± 1.05	5.03 ± 0.60	4.75 ± 0.51	52.27 ± 6.66	51.20 ± 6.40	51.20 ± 3.20

Maximum and minimum values are shown in bold

highest area-average precipitation (371.2mm) was recorded during pre-monsoon (March-May) and the lowest in winter (3.32mm) season (December-February). The maximum mean depth of the river was during the monsoon (0.78 m) and minimum during winter (0.26 m). Water temperature in the river was recorded to be maximum during the post-monsoon (27.9-28ºC) and minimum during the winter (15.97-16.2ºC). The pH was highest (9.35 - 9.4) during post-monsoon (September-November) and lowest in the monsoon (7.95) season. Highest current flow of the river occurred during post-monsoon (0.87 - 0.92 m s^{-1}) while the lowest in the midst of winter (0.29 - 0.3 m s^{-1}); highest turbidity was seen in the midst of monsoon (178.77 - 217.8NTU) and the lowest during winter (4.04 - 4.31NTU); total dissolved solids of the river were recorded to be maximum in pre-monsoon and minimum during the monsoon season (Table 1). Similarly, minimum (8.69 - 8.83 mg L^{-1}) DO concentration was found during monsoon and the maximum (19.5-20 mg L^{-1}) during the post-monsoon; highest mean biochemical oxygen demand was noticed during the monsoon (2.67-2.77 mg L^{-1}) as the lowest during winter (0.61-0.65 mg L^{-1}); free CO_2 was maximum during monsoon (18.7 - 19 mg L^{-1}) and lowest during the post-monsoon (4.47-4.8 mg L^{-1}). Further, bicarbonate alkalinity ranged between 81.3 mg L^{-1} during winter and 24.7 mg L^{-1} during the monsoon; calcium hardness from 0.28 mg L^{-1} to 0.08 mg L^{-1}) monsoon; and total hardness varied from 113.2 mg L^{-1} during pre-monsoon to a low of 37.33 mg L^{-1} during the monsoon.

Table 2. Mean ± SD of chemical parameters of the Chathe River

Month	Dissolved O_2 (mg L^{-1})			BOD (mg L^{-1})			Free CO_2 (mg L^{-1})			Bicarbonate alkalinity (mg L^{-1})		
	ZI	ZII	ZIII	ZI	ZII	ZIII	ZI	ZII	ZIII	ZI	ZII	ZIII
Dec	14.93± 1.80	15.07± 1.22	14.93± 1.29	**0.61± 0.10**	**0.65± 0.12**	**0.63± 0.06**	5.27± 1.03	5.27± 1.50	5.13± 1.63	**80.00± 4.00**	**81.33± 4.04**	**81.00± 4.00**
Jan	10.13± 0.46	10.00± 0.40	9.87± 0.42	2.60± 0.52	2.52± 0.48	2.60± 0.54	7.00± 1.73	6.80± 1.06	6.87± 1.86	68.80± 4.33	68.80± 4.33	67.47± 6.58
Feb	16.13± 0.61	16.12± 0.46	16.03± 0.55	1.36± 0.29	1.32± 0.26	1.29± 0.27	7.33± 0.83	7.53± 0.50	7.40± 0.35	64.87± 7.60	65.20± 7.75	65.27± 8.06
Mar	16.33± 0.81	16.49± 0.74	16.43± 0.77	1.33± 0.40	1.25± 0.22	1.20± 0.12	9.87± 2.20	10.13± 2.0	9.87± 1.80	78.00± 4.36	77.47± 4.01	78.20± 4.70
Apr	16.40± 0.60	16.57± 0.64	16.40± 0.60	1.51± 0.40	1.48± 0.34	1.49± 0.36	15.67± 2.7	15.67± 3.3	15.60± 3.0	56.67± 12.2	56.93± 12.4	57.13±12.01
May	14.67± 0.83	14.67± 1.62	14.84± 1.30	1.23± 0.15	1.32± 0.41	1.27± 0.44	15.40± 3.6	15.73± 3.4	15.60± 3.5	34.33± 7.7	33.93± 7.9	34.00± 7.94
Jun	8.89± 0.48	8.87± 0.87	8.93± 0.64	2.00± 0.45	1.98± 0.31	1.98± 0.42	**18.70± 1.6**	**19.00± 0.8**	**19.00± 0.8**	**25.00± 1.98**	**25.30± 2.40**	**24.70± 2.40**
Jul	**8.76± 0.54**	**8.83± 0.44**	**8.69± 0.51**	**2.17± 0.44**	2.21± 0.38	2.25± 0.38	16.00± 1.6	16.00± 1.8	16.13± 1.6	34.67± 2.08	35.00± 1.78	35.07± 2.20
Aug	9.14± 0.16	9.14± 0.09	9.04± 0.27	**2.77± 0.32**	**2.68± 0.24**	**2.67± 0.19**	11.20± 2.3	11.20± 2.0	11.00± 2.4	28.93± 3.11	28.93± 2.84	28.93± 2.84
Sept	10.96± 1.57	11.17± 1.80	11.03± 1.67	0.68± 0.17	0.71± 0.22	0.72± 0.17	7.67± 0.70	7.47± 0.81	7.67± 0.70	36.53± 6.82	36.33± 6.51	36.87± 5.75
Oct	**20.00± 2.88**	**19.47± 2.41**	**19.87± 2.41**	**0.77± 0.12**	0.84± 0.12	0.83± 0.12	5.40± 0.35	5.40± 0.35	5.20± 0.35	51.07± 6.43	51.33± 5.86	51.13± 6.09
Nov	18.67± 1.89	18.93± 1.67	17.87± 1.67	0.65± 0.17	0.65± 0.13	0.69± 0.09	**4.47± 0.50**	**4.47± 0.50**	**4.80± 0.69**	69.47± 2.72	69.87± 3.36	70.00± 3.12

Month	Calcium hardness (mg Ca^{++}/L)			Total hardness (mg L^{-1})			Chloride (mg L^{-1})		
	ZI	ZII	ZIII	ZI	ZII	ZIII	ZI	ZII	ZIII
Dec	0.14± 0.01	0.14± 0.01	0.14± 0.01	64.00± 2.01	63.53± 2.5	64.00± 2.0	**6.68± 1.6**	**6.51± 1.3**	**6.58± 1.7**
Jan	0.15± 0.01	0.15± 0.01	0.15± 0.01	64.67± 5.03	64.67± 5.28	65.20± 4.23	6.94± 1.40	6.78± 1.12	6.78± 1.25
Feb	0.23± 0.02	0.22± 0.01	0.22± 0.01	88.67± 8.33	89.20± 9.53	88.67± 10.02	19.19± 1.61	19.69± 1.16	19.35± 1.53
Mar	**0.28± 0.02**	**0.28± 0.02**	**0.28± 0.02**	113.20± 10.10	111.33± 10.07	112.13± 10.11	24.96± 1.10	25.03± 0.87	24.80± 0.75
Apr	0.22± 0.03	0.22± 0.03	0.22± 0.03	84.00± 6.00	84.27± 6.00	84.00± 6.00	22.86± 2.03	23.36± 1.73	23.19± 1.76
May	0.16± 0.01	0.16± 0.01	0.155± 0.01	66.00± 4.00	65.47± 4.01	65.93± 3.93	**25.03± 2.65**	25.13± 2.01	24.93± 2.09
Jun	0.13± 0.01	0.13± 0.01	0.13± 0.004	59.00± 1.41	58.70± 3.25	58.70± 3.25	**25.03± 1.41**	25.28± 1.77	25.28± 1.77
Jul	0.12± 0.01	0.12± 0.01	0.12± 0.01	37.33± 7.02	37.80± 7.30	38.20± 7.30	24.69± 3.52	24.49± 3.41	24.49± 3.61
Aug	**0.08± 0.01**	**0.09± 0.01**	**0.09± 0.01**	40.00± 2.00	41.00± 2.60	41.20± 2.31	**25.03± 2.65**	**25.53± 3.12**	**25.43± 2.76**
Sept	0.09± 0.003	**0.09± 0.01**	**0.09± 0.01**	41.33± 2.08	41.33± 2.08	41.67± 2.31	21.69± 0.58	22.02± 0.50	21.52± 0.50
Oct	0.10± 0.01	0.10± 0.01	0.10± 0.01	52.53± 3.23	52.33± 3.51	52.47± 3.50	19.02± 1.00	18.85± 1.44	18.52± 1.80
Nov	0.11± 0.01	0.11± 0.01	0.11± 0.01	52.13± 5.14	52.47± 5.16	52.60± 5.07	11.68± 1.26	11.51± 1.32	12.01± 1.32

Maximum and minimum values are shown in bold

Maximum chloride content was observed during monsoon (25.03 - 25.43 mg L^{-1}) whereas the lowest chloride cooncentration was recorded during winter (6.5-6.7 mg L^{-1}; Table 2).

Ichthyofaunal Density

During our study, the ichthyofauna of the Chathe River was represented by 40 species belonging to 23 genera, 10 families and 4 orders (Table 3). Various fishes encountered in different sampling stations of the Chathe River are shown in Figures 2 and 3. The monthly variation in the density of various fishes is shown in Figure 4. Among these, Cyprinidae were most common during monsoon and post-monsoon seasons, and were followed by Nemacheilidae in the postmonsoon and Psilorhynchidae during the winter (Table 4). Maximum ichthyofaunal taxa richness was observed during premonsoon and the minimum during winter at all the sites (Table 5). Principal component analysis (PCA) for mean density of fish species and physicochemical attributes showed a significant increase in the density of *Lepidocephalichthys*, *Mastacembelus*, *Amblypharyngodon*, *Olyra, Psilorhynchus*, *Salmostoma*, *Chagunius* and *Esomus* during premonsoon and post-monsoon with an increase in current flow, pH, dissolved oxygen and total hardness in various sampling stations of the Chathe River (Figure 5). The densities of *Devario*, *Puntius*, *Garra*, *Badis* and *Nemacheilus* were directly correlated with current flow, free CO_2 and chloride during the pre-monsoon. The

Table 3. List of the fishes recorded in the Chathe River

Order	Family	Species
Synbranchiformes	Mastacembelidae	*Mastacembelus armatus* Lacepède, 1800
Cypriniformes	Cyprinidae	*Puntius conchonius* Hamilton,1822
		Puntius sophore Hamilton,1822
		Barilius bendelisis Hamilton,1807
		Barilius barila Hamilton,1822
		Barilius barna Hamilton,1822
		Barilius sp
		Chagunius nicholsi Myers.1924
		Crossocheilus burmanicus Hora, 1936
		Aspidoparia sp
		Amblypharyngodon mola Hamilton,1822
		Devario affinis Blyth,1860
		Devario regina Fowler, 1934
		Devario assamensis Barman, 1984
		Devario aequipinnatus McClelland, 1839
		Danio rerio Hamilton,1822
		Salmostoma phulo Hamilton,1822
		Esomus danricus Hamilton,1822
		Garra mcclellandi Jerdon, 1849
		Garra sp
	Cobitidae	*Pangio pangia Hamilton,1822*
		Lepidocephalichthys berdmorei Blyth,1860
	Psilorhynchidae	*Psilorhynchus balitora* Hamilton,1822
		Psilorhynchus nudithoracicus Tilak and Husain, 1980
		Psilorhynchus sp
	Nemacheilidae	*Nemacheilus botia* Hamilton,1822
		Nemacheilus multifasciatus Day, 1878
		Nemacheilus beavani Günther, 1868
		Nemacheilus corica Hamilton,1822
Siluriformes	Sisoridae	*Glyptothorax telchitta* Hamilton,1822
		Glyptothorax siamensis Hora, 1923
		Glyptothorax trilineatus Blyth, 1860
		Glyptothorax dorsalis Vinciguerra, 1890
		Glyptothorax ngapang Vishwanath and Linthoingambi, 2007
		Pseudecheneis sulcata McClelland, 1842
	Bagridae	*Mystus ngasep* Darshan, Vishwanath, Mahanta, and Barat, 2011
		Olyra longicaudata McClelland, 1842
Perciformes	Badidae	*Badis* sp.
	Channidae	*Channa stewartii* Playfair, 1867
	Gobiidae	*Awaous* sp

Figure 3. Fishes of the Chathe River of Nagaland, India

Figure 5. Fishes of the Chathe River of Nagaland, India

density of *Danio* and *Pangio* was directly correlated with bicarbonate alkalinity, total dissolved solid, conductivity, dissolved oxygen and total hardness during most of winter and postmonsoon. Fishes like *Barilius* and *Glyptothorax* were also recorded to increase with an increase in bicarbonate alkalinity, total dissolved solids, conductivity, dissolved oxygen and total hardness during winter and postmonsoon in sampling stations ZI and ZIII. During monsoon, late premonsoon and early postmonsoon, the density of fishes like *Danio*, *Pangio*, *Channa* and *Barilius* declined in most of the sampling stations with an increase in water temperature, BOD, turbidity, free CO_2 and chloride. An increase in water temperature, turbidity, BOD, free CO_2 and chloride was observed to enhance the density of *Crossocheilus* and *Awaous* during the monsoon, late premonsoon and early postmonsoon in the survey area (Figure 5).

Ichthyodiversity Indices

Various diversity indices exhibited a wide range: Shannon's diversity from 1.738 to 3.18, Pielou's evenness from 0.951 to 0.995, Simpson's dominance from 0.031 to 0.123, Simpson's diversity from 0.877 to 0.969, Margalef's diversity from 1.949 to 5.884, McIntosh's diversity from 0.764 to 0.895 and McIntosh's evenness from 0.947 to 0.99 (Table 6). Maximum mean Shannon, Simpson, Margalef and McIntosh diversity indices were

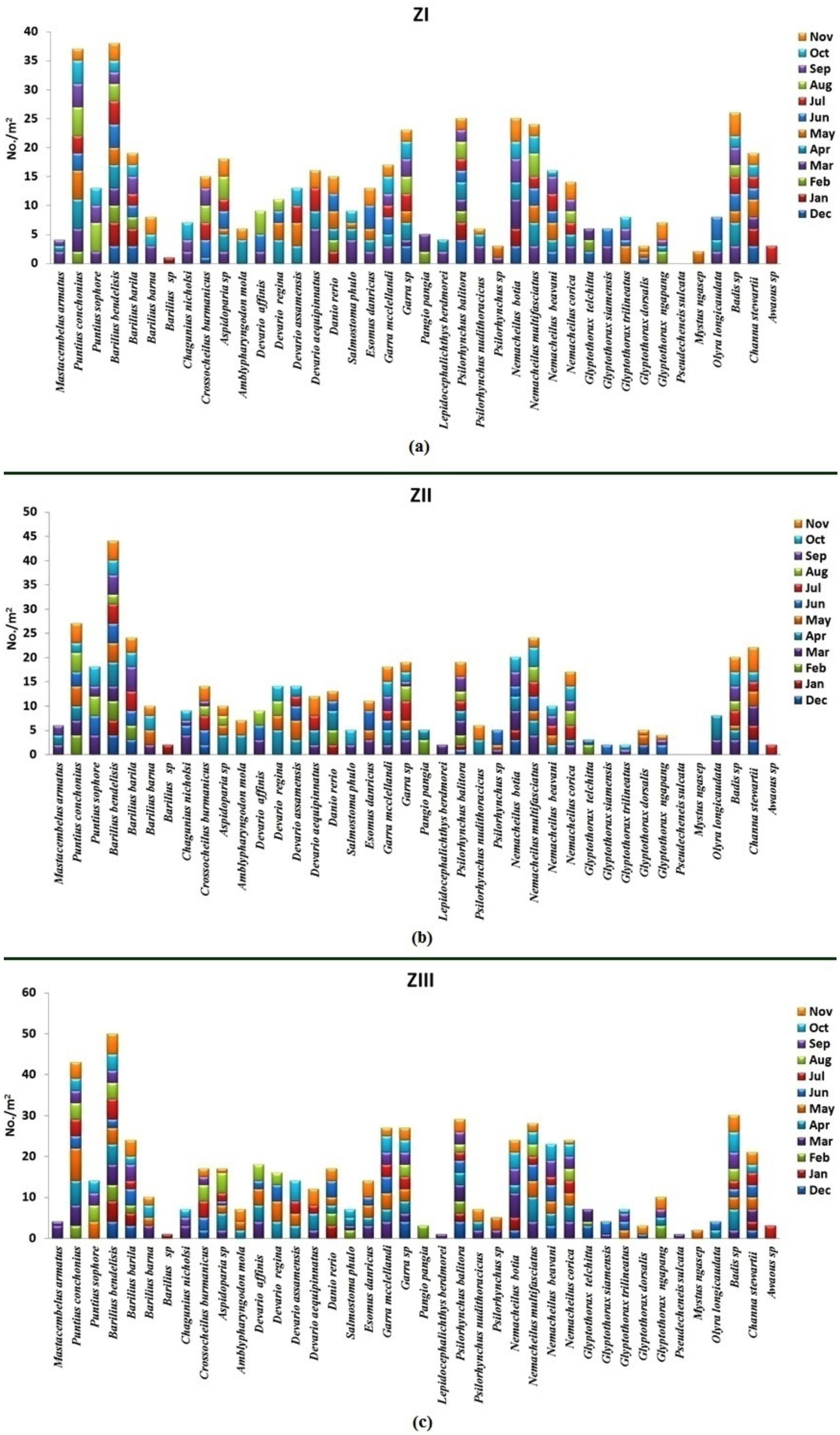
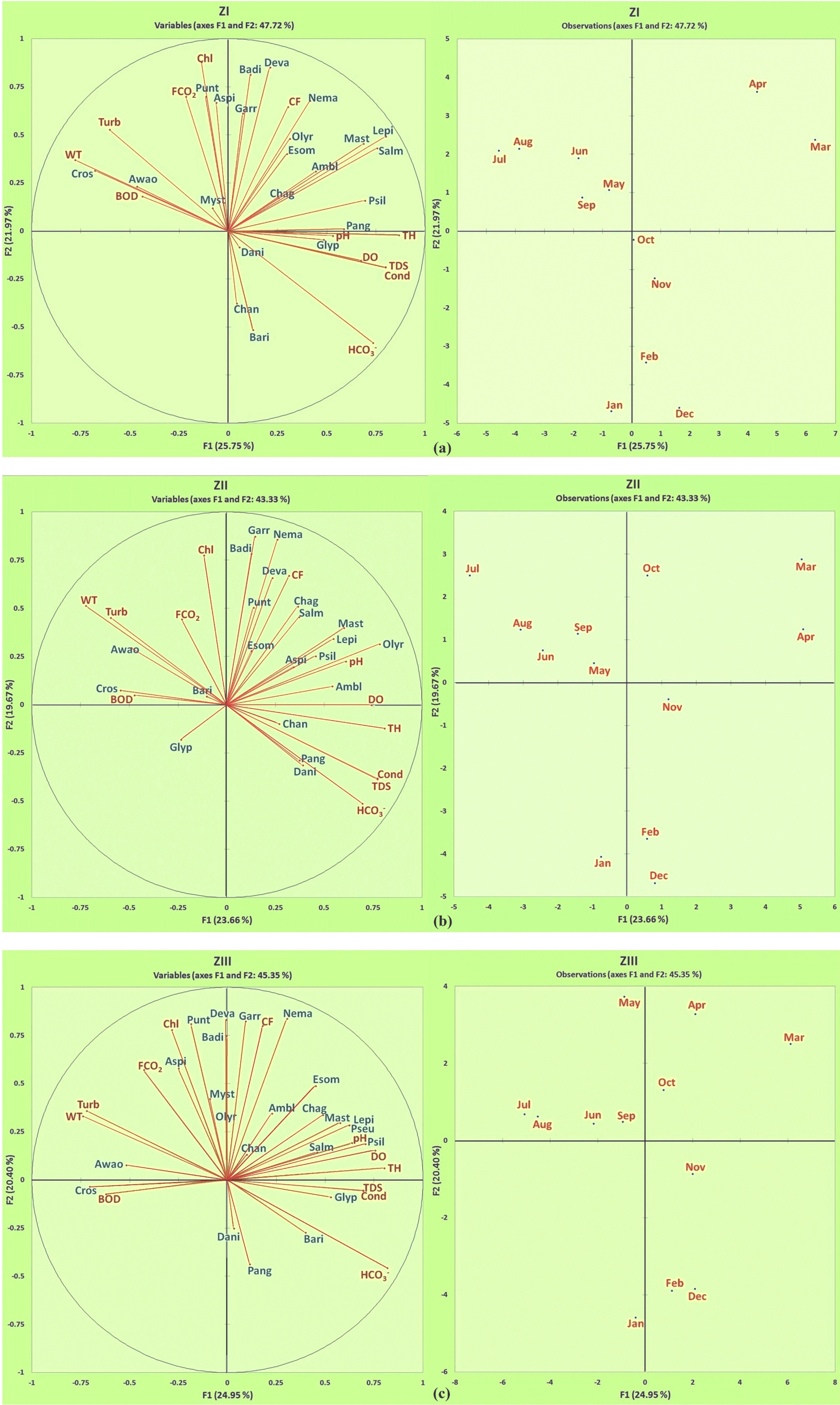


Figure 4. Monthly variation in the density of Ichthyofaunal species of the Chathe River

Table 4. Density (percent composition) of the fishes of the Chathe River

Families &	WINTER			PREMONSOON			MONSOON			POSTMONSOON		
Zone	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Mastacembelidae												
ZI	0	0	0	**2.86**	1.59	0	0	0	0	2.5	0	0
ZII	0	0	0	3.39	3.28	0	0	0	0	**5.88**	0	0
ZIII	0	0	0	**4.29**	0	0	0	0	0	2.17	0	0
Cyprinidae												
ZI	**40.0**	52.63	52.94	48.57	58.73	55.81	60.0	60.47	**72.50**	55.0	67.50	57.69
ZII	**50.0**	53.85	66.67	52.54	59.02	68.57	**71.74**	56.41	69.70	50.0	62.50	61.82
ZIII	**46.43**	63.16	58.33	48.57	60.27	66.67	55.77	62.22	**73.81**	50.0	58.49	60.66
Cobitidae												
ZI	0	0	**11.76**	7.14	3.17	0	0	0	0	0	0	0
ZII	0	0	**14.29**	3.39	3.28	0	0	0	0	0	0	0
ZIII	0	0	**12.50**	1.43	0	0	0	0	0	0	0	0
Psilorhynchidae												
ZI	**16.0**	15.79	11.76	8.57	7.94	4.65	4.0	4.65	7.5	5.0	0	5.77
ZII	5.56	7.69	9.52	6.78	8.20	2.86	6.52	5.13	6.06	8.82	0	**10.91**
ZIII	**14.29**	10.53	12.50	11.43	6.85	4.35	5.77	4.44	4.76	6.52	0	9.84
Nemacheilidae												
ZI	20.0	15.79	0	15.71	17.46	13.95	10.0	16.28	15.0	**22.5**	17.5	17.31
ZII	16.67	15.38	0	16.95	14.75	11.43	10.87	20.51	18.18	20.59	**25.0**	9.09
ZIII	17.86	15.79	0	20.0	20.55	14.49	15.38	15.56	14.29	23.91	**26.42**	9.84
Sisoridae												
ZI	12.0	0	**23.53**	7.14	1.59	9.30	8.0	0	0	7.5	5.0	7.69
ZII	**11.11**	0	9.52	0	0	5.71	10.87	0	0	5.88	2.08	3.64
ZIII	14.29	0	**16.67**	7.14	2.74	2.90	9.62	0	0	8.70	1.89	8.20
Bagridae												
ZI	0	0	0	2.86	3.17	4.65	**8.0**	0	0	0	0	0
ZII	0	0	0	5.08	**8.20**	0	0	0	0	0	0	0
ZIII	0	0	0	0	2.74	2.90	**3.85**	0	0	0	0	0
Badidae												
ZI	0	0	0	4.29	6.35	4.65	6.0	6.98	5.0	7.5	5.0	**7.69**
ZII	0	0	0	5.08	3.28	2.86	0	7.69	6.06	**8.82**	6.25	5.45
ZIII	0	0	0	2.86	6.85	4.35	3.85	4.44	7.14	8.70	**9.43**	6.56
Channidae												
ZI	12.0	**15.79**	0	2.86	0	6.98	4	4.65	0	0	5.0	3.85
ZII	16.67	**23.08**	0	6.78	0	8.57	0	5.13	0	0	4.17	9.09
ZIII	7.14	**10.53**	0	4.29	0	4.35	5.77	6.67	0	0	3.77	4.92
Gobiidae												
ZI	0	0	0	0	0	0	0	**6.98**	0	0	0	0
ZII	0	0	0	0	0	0	0	**5.13**	0	0	0	0
ZIII	0	0	0	0	0	0	0	**6.67**	0	0	0	0

Maximum and minimum (other than 0) values are shown in bold



INDEX	
Mast	*Mastacembelus sp*
Punt	*Puntius sp*
Bari	*Barilius sp*
Chag	*Chagunius sp*
Cros	*Crossocheilus sp*
Aspi	*Aspidoparia sp*
Ambl	*Amblypharyngodon sp*
Deva	*Devario sp*
Dani	*Danio sp*
Salm	*Salmostoma sp*
Esom	*Esomus sp*
Garr	*Garra sp*
Pang	*Pangio sp*
Lepi	*Lepidocephalichthys sp*
Psil	*Psilorhynchus sp*
Nema	*Nemacheilus sp*
Glyp	*Glyptothorax sp*
Pseu	*Pseudecheneis sp*
Myst	*Mystus sp*
Olyr	*Olyra sp*
Badi	*Badis sp*
Chan	*Channa sp*
Awao	*Awaous sp*
WT	Water temperature
pH	H^+ ion potential
CF	Current flow
Cond	Conductivity
TDS	Total dissolved solids
Turb	Turbidity
DO	Dissolved oxygen
BOD	Biochemical oxygen demand
FCO_2	Free carbon-di-oxide
HCO_3^-	Bicarbonate alkalinity
TH	Total hardness
Chl	Chloride

Figure 5. PCA between ichthyofaunal species density and physico-chemical parameters of Chathe River

Table 5. Taxa richness of fishes of the Chathe River (No. of species m^{-2})

Season	Months	ZI	ZII	ZIII
Winter	December	1.0	0.7	1.0
	January	0.7	0.6	0.7
	February	0.8	0.7	0.9
Premonsoon	March	**2.6**	**2.1**	**2.4**
	April	2.3	2.0	22
	May	1.7	1.4	2.1
Monsoon	June	1.8	1.7	1.8
	July	1.6	1.4	1.6
	August	1.2	1.2	1.2
Postmonsoon	September	1.6	1.5	1.6
	October	1.6	1.8	1.7
	November	2.1	2.0	2.0

recorded during premonsoon and minimum during winter whereas Simpson's dominance was maximum during winter and minimum during the pre-monsoon in the sampling areas. Maximum and minimum estimates of Pielou's evenness varied in different seasons in different sampling stations. McIntosh's evenness was recorded to be highest during monsoon and lowest during the winter in most of the sampling stations barring ZII, where both maximum and minimum value was noticed during the postmonsoon (Table 6).

Pearson's correlation analysis between mean values of various diversity indices and physicochemical attributes of the Chathe River, show a direct correlation ($p<0.05$) of Shannon, Simpson, Margalef and McIntosh diversity indices with current flow. Chloride content of the river was also directly correlated ($p<0.05$) with Simpson's diversity in all study areas. Shannon and McIntosh diversity had a direct association with chloride in stations ZII and ZIII. Simpson's dominance was inversely correlated ($p<0.05$) with current flow and chloride in all sampling areas. Pielou's evenness was directly correlated with water temperature and chloride but inversely correlated ($p<0.05$) with bicarbonate alkalinity in station ZIII. Further, McIntosh's evenness was also directly correlated ($p<0.05$) with chloride in ZIII of R. Chathe (Table 7).

DISCUSSION

Fishes are considered to be one of the most efficient biomonitoring agents as they represent various trophic levels and function as an indispensable agent of nutrient cycling, alteration of residual surface and fussy predation, and hence an integral part of freshwater ecosystems (Carpenter et al. 1985). The recommended range of ichthyofaunal tolerance for a couple of the physico-chemical variables viz., pH (6.5-9.0), water temperature (25-30°C), total dissolved solid (<400 mg L^{-1}), dissolved oxygen (>5 mg L^{-1}), BOD (3-20 mg L^{-1}), free CO_2 (<15 mg L^{-1}), bicarbonate alkalinity (20-400 mg L^{-1}) and total hardness (20-300 mg L^{-1}) were reported as the principal components to alter the pattern of ichthyofaunal density and diversity in many rivers (Tarazona et al. 1995, Wotton 1995, Fairfield 2000, Boyd 2003, FAO 2006).

The Chathe River being a hilly perennial stream has a medley habitat with shallow-clean water, fair seasonal fluctuation in physicochemical attributes in conjunction with dynamic geomorphic properties of the waterway that facilitated the occurrence of various fish species with wide preferences of their survival viz., rocky or sandy riverbed with weak current flow (*Mastacembelus*, *Danio*), fast flowing stream bed (*Lepidocephalichthys)*, shallow running waters with sandy bottom (*Psilorhynchus*, *Pangio*), riverbed with stones or pebbles and feeble current flow (*Crossocheilus*, *Nemacheilus*), relatively cool, shallow and clean water with wide riparian zones (*Barilius*, *Olyra*), well-aerated water with high current flow (*Esomus, Devario, Danio*), with bounteous immersed vegetation (*Badis*), waterway with relatively warm water area (*Chagunius*), others with adhesive structure to stick on exposed rock in modest current flow (*Garra*, *Glyptothorax*, *Pseudecheneis*) and additionally diverse phytoplankton and macro-invertebrate assemblage of the river. Fishes usually shield themselves against any sudden change in pH by covering their skin and gills with mucus; however at extreme pH their skin and gill tissues get harmed. Being poikilothermic, physiology of fishes and reproductive activity is firmly associated with water temperature though at >20°C, fishes turn out to be less immune and less dynamic during the summer (Boyd 1990, Lawson 1995). Some fishes with wide range of temperature tolerance like *Barilius*, *Nemacheilus*, *Pseudecheneis*, *Glyptothorax* etc. are reported to flourish even at 8°C to 30°C (Nath 1994). An increase in water temperature enhances metabolic and regenerative capacities of aquatic organisms, and may also lead to oxygen deficit in the river (Wotton 1995). Amount of available oxygen is one of the principal determinants of sound stream as it is vital for respiration of all the aquatic organisms which

Table 6. Fish diversity indices of the Chathe River (ZI – ZIII)

		H	J	D	1-D	Ma	Mc	McE
ZI								
Winter	Dec	2.227	**0.967**	0.077	0.923	2.796	0.829	**0.970**
	Jan	**1.886**	0.969	**0.111**	**0.889**	**2.038**	**0.782**	0.969
	Feb	2.069	**0.995**	0.074	0.926	2.471	0.848	0.993
Pre-monsoon	Mar	**3.180**	0.976	**0.031**	**0.969**	**5.884**	**0.895**	0.980
	Apr	3.063	0.977	0.034	0.966	5.310	0.889	0.982
	May	2.747	0.970	0.047	0.953	4.254	0.871	0.974
Monsoon	Jun	2.847	0.985	0.041	0.959	4.346	0.879	0.988
	Jul	2.741	0.989	0.044	0.956	3.988	0.876	**0.989**
	Aug	2.437	0.981	0.068	0.932	2.982	0.829	0.981
Post-monsoon	Sept	2.709	0.977	0.046	0.954	4.066	0.874	0.981
	Oct	2.731	0.985	0.044	0.956	4.066	0.879	0.987
	Nov	2.991	0.982	0.034	0.966	5.062	**0.895**	0.986
Z II								
Winter	Dec	1.879	0.966	0.111	0.889	2.076	0.784	0.964
	Jan	**1.738**	0.970	**0.115**	**0.885**	**1.949**	0.791	0.966
	Feb	1.914	0.983	0.110	0.890	1.971	**0.781**	0.981
Premonsoon	Mar	**2.996**	0.984	**0.036**	**0.964**	**4.905**	**0.888**	0.987
	Apr	2.928	0.977	0.041	0.959	4.622	0.874	0.981
	May	2.560	0.970	0.055	0.945	3.656	0.858	0.973
Monsoon	Jun	2.785	0.983	0.043	0.957	4.179	0.876	0.985
	Jul	2.601	**0.986**	0.053	0.947	3.548	0.860	0.986
	Aug	2.451	**0.986**	0.061	0.939	3.146	0.849	0.986
Postmonsoon	Sept	2.576	**0.951**	0.057	0.943	3.970	0.856	**0.956**
	Oct	2.849	**0.986**	0.040	0.960	4.391	0.883	**0.988**
	Nov	2.928	0.977	0.039	0.961	4.741	0.881	0.982
Z III								
Winter	Dec	2.236	0.971	0.079	0.921	2.701	0.820	0.973
	Jan	**1.855**	**0.953**	**0.123**	**0.877**	**2.038**	**0.764**	**0.947**
	Feb	2.145	0.976	0.083	0.917	2.517	0.818	0.977
Premonsoon	Mar	**3.068**	0.965	**0.037**	**0.963**	**5.414**	**0.880**	0.974
	Apr	3.018	0.976	0.039	0.961	4.895	0.873	0.980
	May	2.972	0.976	0.042	0.958	4.724	0.869	0.977
Monsoon	Jun	2.835	0.981	0.043	0.957	4.302	0.873	0.984
	Jul	2.726	0.983	0.047	0.953	3.940	0.867	0.984
	Aug	2.461	**0.990**	0.065	0.935	2.943	0.833	**0.990**
Postmonsoon	Sept	2.724	0.983	0.047	0.953	3.918	0.867	0.986
	Oct	2.770	0.978	0.048	0.952	4.030	0.862	0.981
	Nov	2.979	0.978	0.038	0.962	4.865	0.882	0.983

Maximum and minimum values are shown in bold

H- Shannon-Wiener index; J - Pielou evenness index; D - Simpson dominance index 1-D – Simpson diversity index; Ma - Margalef diversity index; Mc - McIntosh diversity index and McE - McIntosh evenness index

Table 7. Pearson's correlation between fish diversity indices and physicochemical parameters of Chathe River

	WT	pH	CF	Cond	Turb	DO	BOD	FCO_2	HCO_{3-}	TH	Chl
ZI											
H	0.121	0.394	**0.602**	0.001	0.165	0.284	-0.300	0.380	-0.172	0.151	0.571
J	0.305	-0.222	0.116	-0.457	0.257	0.023	0.106	0.126	-0.289	-0.105	0.409
D	-0.205	-0.328	**-0.626**	0.079	-0.223	-0.327	0.406	-0.359	0.246	-0.083	**-0.625**
1-D	0.205	0.328	**0.626**	-0.079	0.223	0.327	-0.406	0.359	-0.246	0.083	**0.625**
Ma	-0.019	0.463	**0.588**	0.130	0.052	0.370	-0.346	0.310	-0.014	0.304	0.488
Mc	0.154	0.355	**0.615**	-0.044	0.159	0.414	-0.489	0.289	-0.160	0.150	0.568
McE	0.307	-0.085	0.246	-0.405	0.233	0.123	-0.041	0.182	-0.303	-0.069	0.488
ZII											
H	0.297	0.461	**0.615**	-0.156	0.139	0.292	-0.223	0.349	-0.279	0.034	0.593
J	-0.013	-0.234	0.235	-0.172	0.153	0.091	0.410	0.280	-0.073	0.186	0.348
D	-0.419	-0.390	**-0.608**	0.265	-0.223	-0.187	0.140	-0.401	0.400	0.076	**-0.640**
1-D	0.419	0.390	**0.608**	-0.265	0.223	0.187	-0.140	0.401	-0.400	-0.076	**0.640**
Ma	0.246	0.559	**0.592**	-0.105	0.048	0.333	-0.291	0.270	-0.194	0.072	0.504
Mc	0.415	0.420	**0.599**	-0.278	0.189	0.180	-0.120	0.371	-0.374	-0.074	**0.594**
McE	0.077	-0.074	0.372	-0.198	0.160	0.186	0.278	0.332	-0.143	0.178	0.478
ZIII											
H	0.218	0.386	**0.664**	-0.021	0.189	0.320	-0.344	0.423	-0.247	0.098	**0.615**
J	0.623	-0.162	0.178	-0.502	0.527	-0.171	-0.027	0.312	**-0.684**	-0.558	**0.594**
D	-0.287	-0.311	**-0.631**	0.105	-0.271	-0.280	0.391	-0.406	0.323	0.010	**-0.660**
1-D	0.287	0.311	**0.631**	-0.105	0.271	0.280	-0.391	0.406	-0.323	-0.010	0.660
Ma	0.089	0.436	**0.643**	0.081	0.087	0.371	-0.361	0.381	-0.102	0.244	0.535
Mc	0.280	0.326	**0.607**	-0.114	0.256	0.282	-0.413	0.390	-0.294	-0.001	**0.630**
McE	0.478	0.015	0.304	-0.368	0.419	0.015	-0.213	0.287	-0.534	-0.358	**0.644**

At 5% confidence & Df_{10}, table value of r = 0.576, all the numerals in bold indicate the significant values ($p<0.05$)
H- Shannon-Wiener index; J - Pielou evenness index; D - Simpson dominance index; 1-D – Simpson diversity index
Ma - Margalef diversity index; Mc - McIntosh diversity index; McE - McIntosh evenness index; WT-Water temperature
pH- Hydrogen ion potential; CF - Current flow; Cond - Conductivity; Turb - Turbidity; BOD – Biochemical oxygen demand
DO - Dissolved oxygen; FCO_2 - Free CO_2; HCO_{3-} - Bicarbonate alkalinity; CaH - Calcium hardness; TH - Total hardness; Chl - Chloride

may vary contingent upon the types of fishes and the environmental or habitat parameters. Cyprinids were recorded to flourish even at 6-8 mg L^{-1} of dissolved oxygen while other species may demand higher concentration. Increase in salinity and turbidity also lowers the amount of dissolved oxygen in water. Fishes like Cyprinids can flourish at 8-15 mg L^{-1} BOD (Ghosh et al. 1988). Higher concentration of free CO_2 in a river could be lethal for fishes, though their tolerance of unexpected increase in free CO_2 for brief periods was reported (Lawson 1995). Higher concentration of free CO_2 above the prescribed limit during the monsoon did not have any significant impact on ichthyofaunal taxa richness in R. Chathe, as it was neutralised by bicarbonate alkalinity.

Current flow of river water is also a key component for mixing of various strata of water, egg-transport, hatching and migration of fishes. However, a large rise in current flow due to heavy precipitation may increase turbidity of the stream that may interfere with foraging and turn out to be lethal by clogging their gills. Turbidity may aid ichthyofaunal diversity by providing better assurance to juveniles against predators, acting as marker for abundance of food and aid in orientation mechanism for migration by fishes (Blaber 2000).

Ichthyodiversity of the Chathe River was closely associated with current flow. Alteration in stream flow may have detrimental effect on ichthyofaunal assemblage as it reduces abundance and increase taxa dominance along with immigrants in the waterway (Poff et al. 2010). PCA in our study isolated eleven components of which two initial components alone were with higher eigenvalue of 43.33 to 47.72% of the total difference between sampling stations (Figure 5). First component axis explained 23.7-25.7% of variance with eigenvalues in the range of 7.8-8.7 while second component axis clarified 19.7- 21.9% of total difference with eigenvalues in the range of 6.5-7.5 in all the survey areas (Figure 5). PCA has shown a direct association of current flow with mean density of *Lepidocephalichthys*, *Mastacembelus*, *Esomus*, *Badis*, *Amblypharyngodon*, *Salmostoma*, *Psilorhynchus*, *Chagunius*, *Olyra, Puntius*, *Garra*, *Nemacheilus* and *Devario* besides their differential response towards pH, dissolved oxygen, total hardness, free CO_2 and chloride during premonsoon. Further, an optimum rise in concentration of bicarbonate alkalinity, total dissolved solid, conductivity, dissolved oxygen and total hardness were also found to enhance density of *Barilius, Glyptothorax, Danio* and *Pangio* amid winter and postmonsoon in R. Chathe. It has been reported that, inter- or intraspecific interactions and habitat properties are the principal determinant of ichthyodiversity in a stream (Johnson et al. 2007). Ichthyodiversity indices and taxa abundance were maximum during premonsoon due to the accessibility of extended niche with a large nutrient flux from allochthonous sources, whereas increase in dominance during winter may be ascribed to water deficiency, feeble current flow, reduced riparian zones and steady decrease in the accessibility of supplements which enhanced relative abundance of piscivorous and invertivorous group of fishes in the river (Arunachalam 2000, Kar et al. 2006, Tejerina-Garro et al. 2010). Ichthyodiversity declined also during the monsoon due to strong oscillations in the water level, when ichthyofaunal assemblage was dominated by omnivorous fishes (Tejerina-Garro et al. 2010). An increase in conductivity, BOD and bicarbonate alkalinity but decline in pH was also recorded to expand taxa dominance in the Chathe River.

CONCLUSION

Physicochemical attributes of the Chathe River in Nagaland were found within the permissible limit (BIS 1983) for most of the seasons of the study year, yet modest decline in overall quality was found during the monsoon due to high turbidity and BOD, and in the winter because of low discharge, decreased profundity and feeble current flow in the studied section of the river. The ichthyodiversity of the Chathe River could not be appraised with accuracy because of exploitation of fishes by local people. Blast-fishing and electro-fishing were preferred for convenient gathering of more fish. Overexploitation and capture of mature fishes from the area has posed a consistent threat to the ichthyofaunal community in the sampling stations. Taxa abundance was maximum during premonsoon and minimum in the winter. Cypriniformes in particular *Barilius bendelisis*, *Puntius conchonius*, *Psilorhynchus balitora* and *Nemacheilus multifasciatus* were dominant throughout the year. Maximum ichthyodiversity was recorded in station ZI. Though segregated by dam from rest of the study area, the physicochemical characteristics and diversity of station ZIII were not critically altered due to regular management of flow regime by the Irrigation and Flood Control department of Nagaland. Most of ichthyodiversity indices were significantly improved by greater flow; however water temperature, pH, turbidity, dissolved oxygen, free CO_2 had no significant impact.

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