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Seasonal Variations in Ichthyofaunal Assemblage in Relation to Physico-chemical Parameters, Phytoplankton Assemblage and Habscore of the Chathe River

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ABSTRACT
Density and diversity of Ichthyofaunal assemblage in some selected areas of the Chathe River in Nagaland (India) was investigated for a year in 2014 to survey its seasonal distribution in association with a few selected Physico-chemical parameters, Phytoplankton assemblage and Habscore of the stream. Various physicochemical parameters were found to be at recommended ranges of tolerance for Ichthyofauna to flourish in the Chathe River. Phytoplankton assemblage was recorded to be comprised of 56 species under 44 genera of 7 classes in the sampling areas of which Bacillariophyceae and Chlorophyceae were witnessed to be the most abundant classes of phytoplankton in the river. Further, amidst this investigation, 40 species of fishes under 23 genera of 10 families and 4 orders were encountered in the river of which Cyprinidae was found to be the most abundant family followed by Nemacheilidae and Psilorhynchidae throughout the year. Seasonal distribution of Ichthyofaunal assemblage and their diversity or dominance in the river was noticed to be directly influenced by abundance of phytoplankton, since herbivore fishes mostly rely on phytoplankton for their nourishment. Habitat quality was recorded in the range of 'fair' to 'good' during most of the seasons except monsoon when, Ichthyofaunal assemblage was witnessed to be relatively declined in the river. Further canonical correlation analysis and canonical correspondence analysis has revealed the degree of association of Ichthyodiversity indices and Ichthyofamily abundance with physicochemical attributes, phytoplankton diversity and habscore of the surveyed areas of the Chathe River.

Key words: Ichthyofauna, Phytoplankton, Physicochemical, Habscore, Density, Diversity, Association, Chathe

INTRODUCTION

Northeast India forms two of 34 biodiversity hotspot in the world i.e. the Indo-Burma and the Himalayas region (Ramanujam et al. 2010). Nagaland is belonged to Indo-Burma region and consists of 17 rivers flowing through the state. The Chathe River of Dimapur district in Nagaland is a perennial river characterised by pools, riffles and runs at different segments of its river bed. It has fragmented water flow during winter and torrential amidst premonsoon; while a blue-line river flows during monsoon and postmonsoon season depending on normal area-average rainfall. The river is originated as a few small channels in Medziphema area which are united together near New Chumukedima area (25º46'07.4" N, 93º48'31.1" E) which then moved through the Dimapur district having a total stretch of around 42.78 km in Nagaland and finally meet at River Dhansiri as the Bakala river (25º58'21.9" N, 93º46' 35.6" E) in Karbi Anglong district, Assam. Being a hilly-mountainous stream, the Chathe is having diverged habitat with shallow-clean water, sandy or rocky bed with pools and riffled territories in places, wide spread canopy cover with riparian zones, veered phytoplankton and macro-invertebrate array as well as fair seasonal alternation in physicochemical variables, which facilitate in harbouring wide variety of fishes in the riverbed. In spite of the fact that several works on fish diversity of various rivers of Nagaland has been published in various literatures (Nzano et al. 2009, Acharjee et al. 2012); however this examination has been first ever identification of seasonal dynamics of density and decent variety of fishes in the Chathe River.

During the past 40 years, trophical importance of fishes in a lotic ecosystem has been well documented in many literatures. Fishes play a key role in converting nutrient of wastewater into consumable product for human (Parmar et al. 2016). All living organisms have a precise limit of tolerance to meticulous range physicochemical parameters in which they perform optimally. A sharp ascend or descend within this limit drastically effect their reproduction and metabolism (Kiran 2010). Physicochemical parameters like water temperature, depth, turbidity and dissolved oxygen play a significant role for endurance, growth, composition and allocation of fishes (Akbulut 2009, Obiyor et al. 2017). As various species of ichthyofaunal assemblage have a place with different trophic levels even including predators and moderately long life cycle, they might be considered as splendid marker of any magnified effects of anthropogenic stresses on health of the river (Carlisle et al. 2008). On the contrary, sedentary fishes like loaches were accounted for to be more affected by site-explicit water quality than the portable species and their abundance or nonattendance may uncover exact status of stream health (Mainstone et al. 1992). So, the present investigation was done to survey the impact of occasional ascent or fall of physicochemical attributes, phytoplankton assemblage and habitat quality on Ichthyofaunal assemblage of the Chathe River.

MATERIALS AND METHODS

Study area

The present investigation was carried out in three sampling stations i.e. ZI, ZII and ZIII of the Chathe River in Chemukedima-Seithekima area of Dimapur district in Nagaland (Fig.1). The study was conducted for a year (December 2013 – November 2014) on monthly as well as seasonal basis viz., winter (December-February), pre-monsoon (March-May), Monsoon (June-August) and post-monsoon (September-November).

ZI: The station was considered as the reference area located upstream with a stretch of 2.17 km (25°47'12.4" N and 93°48'05.4" E - 25°47'46.8"N and 93°48'16.1"E) at an altitude of 232.04 - 236.93 m amsl. This area is covered with significant vegetation and riverbed is mostly dominated by cobbles and pebbles. The stream flow structure of this area dominated by riffles, runs and pools. Watershed property of ZI is mostly contributed by agricultural and animal farm runoff.

ZII: It's the midstream study area with a stretch of 446.52 km (25°47'46.8" N and 93°48'16.1" E - 25°47'50.7" N and 93°47'58.3" E) located at an altitude of 237.05 - 223.04 m amsl. Vegetation of this area is mostly trees, grass and bushes in the stream bank along with macrophytes in riverbed. This stream flow structure is dominated by runs and flats which are mostly covered by pebbles and sand. Watershed property of this area is recorded to be agricultural and domestic run off.

ZIII: This is the downstream region located after a dam, with a stretch of 1.48 km (25°47'51.2" N and 93°47'57.2" E - 25°48'29.2" N and 93°47'42.3" E) at an altitude of 220.37 - 200.26 m amsl. Vegetation of this area is portrayed almost like station ZII. Stream flow structure of this area is composed of riffles, runs, pools and flats which are covered by boulder, pebble, cobble and silt. Watershed property of this area is recorded to be agricultural, traffic effluents and municipality spill-over.

Sample collection

Water sample was collected from sub-surface and middle-depth of selected sampling stations of the Chathe River thrice every month for a year for analysing physicochemical attributes of the waterway. Water was collected in 500 ml BOD bottles for analysing dissolved oxygen (DO), phytoplankton productivity and biochemical oxygen demand (BOD); while bottles of 1000ml capacity were used to collect water sample to analyse other physicochemical parameters.

Fishes were collected from survey area thrice every month for a year by a cast net of 4 m^2 diameters and "D" net of 600 micron mesh size by kicking and cleaning in all microhabitats present at the site. The net contents were checked and kept periodically in sample jars which were then preserved in plastic bottles containing 10% formalin. A most extreme of 10 samples were taken at each of the three stations where ten batches were considered as one sample and an average of the samples was divided by total sampling area (m^2) of any review station to assess the average catch per m^2 per segment. Moreover, individual species per day (overnight, approx.8 hrs) trapped in the gill net were considered for estimating ichthyofaunal density. Most of the ichthyofaunal identification was done up to species level and a few up to genus level with the help of the keys published by Talwar et al. (1991), Chatterjee et al. (2012),

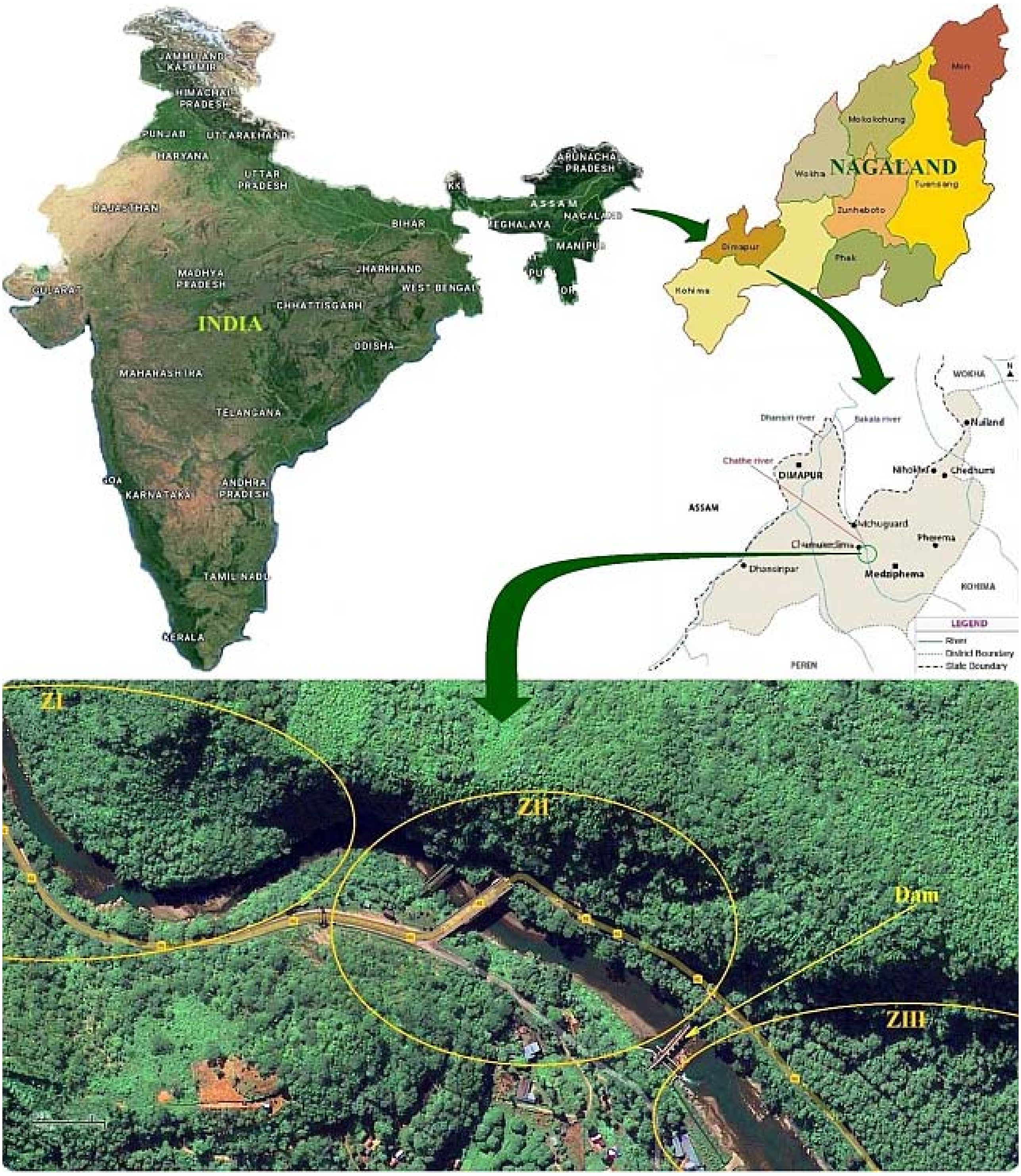


Figure 1. Map of the surveyed areas of Chalthe River in Nagaland

Nagaland fishery directory (2005) and Fishbase.org (Web link). The sample was collected and counted for thrice every month for the study year to deduce monthly mean density of fishes.

Phytoplankon was collected thrice per month as 100 ml samples by plankton net separately from different sampling stations and then poured into 250 ml cylinders, which was then added with Lugol's solution (@1 ml/100 ml sample). The cylinders were then kept undisturbed for 24 hours, after which 1ml subsample from 10X concentration was added in a Sedgewick-Rafter cell and counted under compound microscope. Phytoplankton was identified following Palmer (1962), Prescott (1964) and Vuuren et al. (2006).

Analytical procedure

Area-average rate of precipitation per month was recorded with the help of TRMM-3B43-7 Precipitation data product (NASA). Physical parameters like depth, water temperature, pH, current flow, conductivity and Turbidity at each survey stations of the Chathe River was measured by Secchi disc, mercury bulb thermometer, Hanna's pH meter, digital water velocity meter, Hanna's conductivity-TDS meter and turbidity meter respectively. 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 (2005) were evaluated thrice every month during this investigation. BOD was estimated by incubation of the water sample in dark at 20±1°C for 5 days in BOD incubator. Phytoplankton productivity of the river water was estimated by light and dark bottle method following APHA (1995).

The population density of fishes were calculated as number of individuals per square meter of sampling site and percent composition of the ichthyofamily in the sample were calculated by expression:

$$\text{Density } (\%) = \frac{N_1}{N} \text{ X } 100$$

Where, N_i is the total no. of individuals belonging to i^{th} taxon and N is the total no. of individuals in the sample. Ichthyodiversity indices like Shannon's diversity (H'), Pielou's evenness (J), Simpson's dominance (D), Simpson's diversity (1-D) and Margalef's diversity (Ma) were estimated following Shannon (1949), Pielou (1966), Simpson (1949) and Margalef (1958), respectively. Further, population density of phytoplankton was measured as number of units/ml of the sample following Hötzel et al. (1999). Number of units (or, cells) of specific class of phytoplankton were counted in the grids of Sedgwick-Rafter cell. Phytoplankton diversity was calculated following Shannon (1949). Diversity indices for fishes and phytoplankton were calculated by diversity add-in software in MS-excel 2007.

Habitat quality or Habscore was measured with the help of stream visual assessment protocol (USDA 1998). This protocol provides an assessment based primarily on physical conditions within the study areas like channel condition, hydrology alteration, riparian zone, riverbank stability, water appearance, nutrient enrichment, barriers of fish movement, instream fish cover, pools, invertebrate habitat, canopy cover, manure presence, salinity, riffle embeddedness and macro-invertebrates observed. Habscore was calculated as the ratio of total score to the number of assessed characters in any surveyed station. Habitat quality of any stream could be interpreted as excellent (> 9), good (7.5-8.9), fair (6.1-7.4) and poor (< 6).

Statistical analysis

During this investigation, arithmetic mean and standard deviation of physicochemical parameters, ichthyofamily density, phytoplankton density, various diversity indices and Habscore were calculated in MS-excel (2007). Pearson's correlation coefficient among various physicochemical attributes and with various diversity indices were calculated in XLSTAT (2014). Further, Canonical correlation analysis (CCorA) and Canonical correspondence analysis (CCA) was executed for ichthyodiversity indices and ichthyofamily density with physicochemical parameters, phytoplankton diversity and habscore with the help of XLSTAT (2014).

RESULTS

Physicochemical parameters

Area average monthly rainfall for the study period (December 2013-November 2014) was witnessed to be highest during early monsoon (358.82 mm) and lowest amid winter (0.043 mm). Monthly mean depth was found to be extreme during pre-monsoon as 0.906 m ± 0.145 in ZI, during late monsoon as 1.182 m ± 0.274 in ZII and during early post-monsoon as 2.176 m ± 0.712 in ZIII, whereas lowest amid winter as 0.281 m ± 0.017, 0.286 m ± 0.035 and 0.256 m ± 0.026 in ZI, ZII and ZIII, respectively. Maximum monthly mean water temperature in various surveyed areas were recorded in the range of 28.3-28.8 ºC during late monsoon, whereas minimum in the range of 16.2-16.8 ºC during late post-monsoon and also amid early winter just in ZI. Monthly mean utmost pH was recorded in ZI as 8.38 ± 0.104 during late winter and 8.38 ± 0.144 during early pre-monsoon. Moreover utmost mean pH was also recorded as 8.53 ± 0.236 in ZII during pre-monsoon and 8.48 ± 0.035 in ZIII during early monsoon. Lowest monthly mean pH was recorded during monsoon in the range of 7.8-7.82 in all surveyed stations. Extreme mean current flow was witnessed amidst pre-monsoon in the range of 0.792-0.801m/s in different sampling stations, whereas monthly mean least current flow was observed in ZI as 0.204m/s ±0.002 during early monsoon, in ZII as 0.192 m/s ± 0.069 during winter and 0.167 m/s ± 0.024 amid pre-monsoon. Maximum monthly mean conductivity was recorded in the range of 0.195-0.2 mS/cm during pre-monsoon whereas, minimum in the range of 0.06-0.67mS/cm during late monsoon in various surveyed stations. Monthly mean turbidity was found to be extreme in the range of 251.4-306.23 NTU during late monsoon but, lowest in the range of 3.94-4.37 NTU amid early winter in sampling areas. Monthly mean dissolved oxygen (DO) was recorded to be highest in the range of 16.27-17.07 mg/L during early pre-monsoon, whereas lowest amid late monsoon as 8.73 mg/L ± 0.306 in ZI and 6.76 mg/L ± 1.189 in ZIII, except 8.8 mg/L ± 0.693 amid late pre-monsoon in ZII. Monthly mean Free CO_2 was recorded to be maximum in the range of 10.27-11.47 mg/L during late monsoon but minimum in the range of 2-2.3 mg/L during early monsoon in surveyed areas. Maximum mean BOD was witnessed in the range of 3.81-4.08 mg/L during late monsoon whereas minimum in the range of 0.33-0.35 mg/L amid winter in the Chathe River. Utmost bicarbonate alkalinity in the surveyed stations were recorded in the range of 154.33-159 mg/L during pre-monsoon but, lowest was found amid late monsoon in the range of 53-57.67 mg/L. Monthly mean calcium hardness was witnessed to be utmost during pre-monsoon in the range of 0.167-0.182 mg/L whereas, lowest amid late monsoon in the range of 0.062-0.071 mg/L. Assessment of monthly mean total hardness in the Chathe River has shown a maximum value in ZI as 86.67 mg/L ±8.083 and ZII as 85 mg/L ±6.557 amid pre-monsoon except in ZIII during winter as 83.2 mg/L ± 10.253. During this investigation, monthly mean total hardness was recorded to be the least during late monsoon in the range of 29.67-34.33 mg/L. Maximum monthly mean chloride content in surveyed stations of the Chathe River was observed in the range of 22.69-23.36mg/L during pre-monsoon and minimum was observed during post-monsoon in the range of 8.34-9.18mg/L. Assessment of phytoplankton productivity in the selected stations of the Chathe River has shown a monthly mean maximum net primary productivity (NPP) in the range of 0.79-0.8 mg C/m^3/hr during late post-monsoon and gross primary productivity (GPP) in the range of 0.82-0.83 mg C/m^3/hr during late post-monsoon; whereas minimum NPP in the range of 0.02-0.04 mg C/m^3/hr and GPP as 0.12-0.19 mg C/m^3/hr during monsoon. Community respiration in the Chathe River was found to be extreme in the range of 0.51-0.58 mg C/m^3/hr during late pre-monsoon whereas, least was recorded as 0.02 mg C/m^3/hr ± 0.006 amidst late post-monsoon in ZI and ZII, as well as during winter in ZI and ZIII.

Phytoplankton assemblage

During this study, 56 species of phytoplankton under 44 genera of 7 classes (Cyanophyta, Chrysophyta, Bacillariophyta, Cryptophyta, Dinophyta, Euglenophyta and Chlorophyta) were encountered in different survey stations of the Chathe River (Table 1). Amidst this investigation, monthly mean density of phytoplankton was recorded maximum during early post-monsoon in ZI and ZIII while amid late monsoon in ZII. On the contrary, minimum phytoplankton density was observed during most part of monsoon in all surveyed areas (Fig. 2). Bacillariophyceae was recorded to be the most abundant class of phytoplankton followed by Chlorophyceae, Euglenophyceae and Chrysophyceae throughout various seasons of the study year in various sampling stations of the Chathe River (Table 2). Mean density of Bacillariophyceae was found to be extreme in the range of 335 - 387 units/ml during late winter in ZI and ZIII, while during pre-monsoon in ZII. Mean density of Bacillariophyceae was recorded to be least in the range of 219 - 284 units/ml during late post-monsoon in ZI and ZII, while during monsoon in ZIII (Table 2). Seasonal mean density of Chlorophyceae was found maximum in the range of 339 - 347 units/ml during early post-monsoon in ZI and ZIII while, during late monsoon in ZII. Least seasonal mean density of Chlorophyceae was witnessed in the range of 220 - 282 units/ml

Table 1. List of phytoplankton of the Chathe River

Class	Genera	No. of species	Class	Genera	No. of species
Cyanophycee	*Cylindrospermopsis* sp	**2**	**Euglenophyceae**	*Euglena* sp	**4**
	Spirulina sp	**1**		*Phacus* sp	**1**
	Anabaena sp	**2**	**Chlorophyceae**	*Ankistrodesmus* sp	**1**
	Oscillatoria sp	**1**		*Chlamydomonas* sp	**1**
Chrysophyceae	*Mallomonas* sp	**1**		*Closterium* sp	**1**
Bacillariophyceae	*Aulacoseira* sp	**1**		*Coelastrum* sp	**1**
	Craticula sp	**1**		*Cosmarium* sp	**1**
	Cymbella sp	**1**		*Crucigenia* sp	**1**
	Cymbopleura sp	**1**		*Dictyosphaerium* sp	**1**
	Diadesmis sp	**1**		*Lagerheimia* sp	**1**
	Diatoma sp	**2**		*Microcystis* sp	**1**
	Gomphonema sp	**1**		*Microspora* sp	**1**
	Gyrosigma sp	**1**		*Monoraphidium* sp	**2**
	Navicula sp	**3**		*Netrium* sp	**1**
	Pinnularia sp	**2**		*Oocystis* sp	**1**
	Synedra sp	**1**		*Pandorina* sp	**1**
	Nitzschia sp	**1**		*Pediastrum* sp	**1**
Cryptophyceae	*Cryptomonas* sp	**1**		*Radiosphaera* sp	**1**
Dinophyceae	*Ceratium* sp	**1**		*Scenedesmus* sp	**1**
	Prorocentrum sp	**1**		*Spirogyra* sp	**1**
Euglenophyceae	*Strombomonas* sp	**1**		*Staurastrum* sp	**1**
	Trachelomonas sp	**3**		*Volvox* sp	**1**

during early winter in ZI while, during pre-monsoon in ZII and ZIII. Mean density of Euglenophyceae was recorded to be extreme in the range of 78 - 102 units/ml during early post-monsoon whereas, least in the range of 43 - 58 units/ml during early monsoon in ZI and ZIII while amidst late winter in ZII. Maximum seasonal mean density of Chrysophyceae was found in the range of 59 - 68 units/ml during early post-monsoon in ZI, during early pre-monsoon in ZII and during late winter in ZIII. Minimum mean density of Chrysophyceae was recorded to be in the range of 12 - 22 units/ml amidst late pre-monsoon in ZI and ZII, while during monsoon in ZIII. Seasonal mean density of Cyanophyceae was found to be mostly in the range of 15 - 35 units/ml during late post-monsoon in ZI and ZIII, while during late monsoon in ZII (Table 2). Least mean density of Cyanophyceae was witnessed in the range of 5-8 units/ml during early pre-monsoon in ZI, while amid late winter in ZII and ZIII. Maximum mean density of Cryptophyceae was found in the range of 20 - 28 units/ml during post-monsoon, but was witnessed to be absent amid most of winter and monsoon in different sampling stations of the Chathe River. Though Dinophyceae was absent during most of winter, pre-monsoon and monsoon in the sampling stations, yet maximum mean density was recorded during post-monsoon in the range of 8 - 9 units/ml (Table 2). A few genera like *Nitzschia*, *Synedra*, *Pinnularia*, *Navicula*, *Cymbella, Ankistrodesmus*, *Chlamydomonas*, *Closterium*, *Scenedesmus* and *Crucigenia* were noticed to be the regular inhabitants of the river throughout the study period.

When diversity of phytoplankton was assessed, maximum mean diversity was witnessed in the range of 1.38 - 1.43 during pre-monsoon whereas minimum in the range of 1.11 - 1.19 amidst monsoon (Table 2). Analysis of Pearson's correlation coefficient has shown a direct association of monthly mean phytoplankton diversity with pH, current flow,

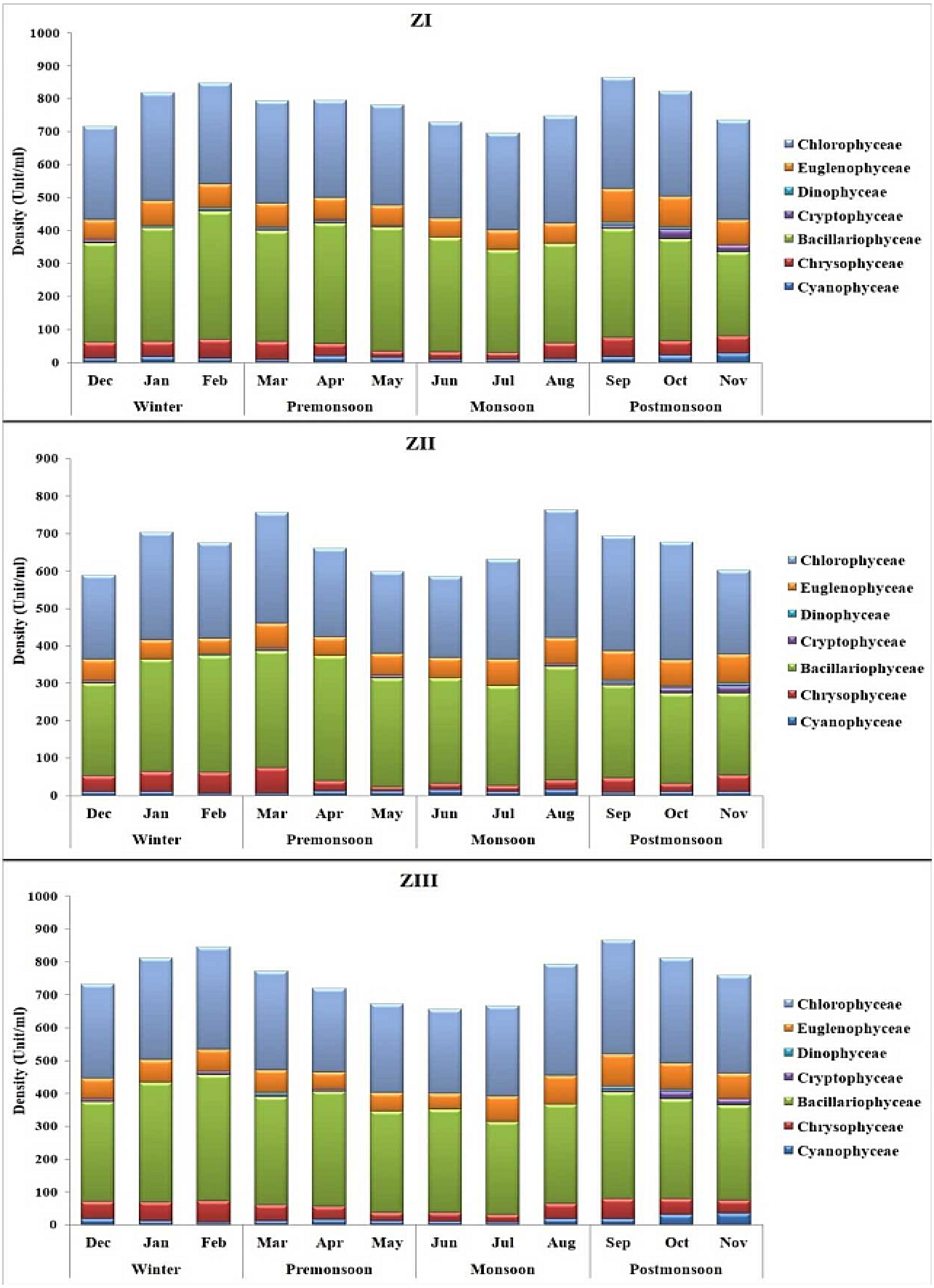


Figure 2. Monthly mean density of various classes of phytoplankton

Table 2. Monthly mean density (Unit/ml) and diversity of phytoplankton

CLASSES	Site	Winter			Pre-monsoon			Monsoon			Post-monsoon		
		Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Cyano-phyceae	ZI	12±2.32	16±3.1	12±1.11	**8**±0.47	18±2.18	14±0.56	9±2.11	9±3.18	10±1.55	17±0.22	21±2.88	**28**±5.01
	ZII	9±2.1	10±2.17	**5**±3.17	6±0.63	11±0.65	11±0.87	14±1.11	10±2.64	**15**±0.75	8±3.22	10±6.21	10±3.61
	ZIII	18±1.22	12±1.11	**7**±2.11	11±0.38	15±0.78	11±0.62	10±1.17	8±2.67	18±0.58	17±0.11	31±8.22	**35**±3.11
Chryso-phyceae	ZI	48±3.21	46±2.16	58±2.14	55±1.02	38±1.11	**20**±1.65	22±0.54	21±2.34	48±0.65	**59**±5.55	43±6.12	52±4.11
	ZII	42±2.28	52±3.02	56±2.05	**68**±2.05	28±1.09	**12**±2.11	18±0.87	15±5.61	25±1.75	38±4.87	22±5.48	43±3.18
	ZIII	52±3.12	57±3.11	**65**±1.21	50±2.05	40±1.09	25±2.18	26±0.78	**22**±2.76	47±0.87	62±2.67	48±4.87	39±4.11
Bacillario-phyceae	ZI	302±8.2	346±8.22	**387**±6.42	335±8.82	365±2.19	376±5.67	347±7.22	310±3.78	302±5.35	328±3.53	310±9.98	**253**±11.6
	ZII	248±8.5	302±7.31	312±5.48	313±8.25	**335**±3.11	289±6.72	280±8.34	268±2.75	304±5.87	248±3.67	240±11.2	**219**±9.87
	ZIII	305±6.33	365±6.52	**384**±5.01	328±8.01	350±3.15	310±6.78	316±7.25	**284**±2.35	302±4.98	324±2.88	304±10.5	291±7.85
Crypto-phyceae	ZI	10±3.02	**0**	4±5.27	6±0.68	8±3.41	4±0.76	**0**	**0**	**0**	11±0.87	**28**±2.11	22±3.87
	ZII	7±5.11	**0**	**0**	6±0.86	**0**	8±0.32	**0**	**0**	8±4.87	8±0.47	14±3.87	**20**±5.11
	ZIII	9±2.24	**0**	10±2.11	5±0.59	8±3.11	**0**	**0**	**0**	**0**	9±0.77	**23**±0.73	18±7.32
Dino-phyceae	ZI	**0**	5±3.26	7±3.42	6±3.57	3±3.08	**0**	**0**	**0**	**0**	**8**±0.51	**8**±0.76	**0**
	ZII	**0**	**0**	4±5.32	0	**0**	**0**	**0**	**0**	**0**	6±0.67	4±0.98	**8**±0.55
	ZIII	**0**	**0**	**0**	8±3.52	**0**	**0**	**0**	**0**	**0**	**9**±0.47	6±0.97	**0**
Eugleno-phyceae	ZI	61±1.15	77±3.11	73±2.65	72±1.65	66±2.76	62±3.14	**58**±4.33	60±2.76	62±0.76	**102**±4.87	92±5.43	78±6.66
	ZII	58±2.13	52±2.86	**43**±2.04	66±2.01	49±3.22	58±4.26	55±2.54	72±4.73	70±0.87	**78**±5.38	72±5.63	77±8.11
	ZIII	61±2.15	68±3.04	68±3.11	70±2.11	52±3.32	55±5.64	**47**±1.86	78±4.26	87±0.55	**98**±3.76	81±7.46	78±9.32
Chloro-phyceae	ZI	**282**±6.11	328±8.11	307±5.69	312±5.55	298±7.06	305±7.22	292±5.22	295±2.11	326±3.18	**339**±2.22	321±9.87	301±9.87
	ZII	225±4.58	286±7.12	254±6.11	297±5.38	237±9.54	**220**±8.42	218±4.74	266±2.17	**342**±4.12	308±2.98	315±8.98	225±9.78
	ZIII	287±5.55	308±6.18	310±6.11	298±6.21	**253**±8.76	272±8.03	257±4.87	275±1.76	337±4.13	**347**±2.67	318±8.97	298±9.99
Phyto-plankton diversity	ZI	1.33±0.03	1.31±0.06	1.28±0.04	1.37±0.05	**1.38**±0.03	1.25±0.04	**1.19**±0.07	1.21±0.06	1.22±0.04	1.37±0.04	1.30±0.04	1.28±0.03
	ZII	1.22±0.05	1.24±0.03	1.21±0.02	**1.38**±0.04	1.23±0.03	1.32±0.04	1.15±0.04	**1.11**±0.07	1.20±0.06	1.30±0.02	1.31±0.01	1.30±0.02
	ZIII	1.29±0.06	1.26±0.02	1.22±0.04	**1.43**±0.03	1.35±0.02	1.25±0.02	1.20±0.02	**1.17**±0.01	1.23±0.03	1.38±0.01	1.34±0.03	1.31±0.05

Maximum values are shown in bold Red and minimum in bold Black

conductivity, dissolved oxygen, free CO_2, bicarbonate alkalinity, calcium hardness, total hardness, net primary productivity, gross primary productivity and habscore ($p>0.05$); whereas indirect association with water temperature, turbidity, biochemical oxygen demand, chloride and community respiration which was insignificant in 5% confidence level (Table 3).

Habscore

Habscore of the sampling stations of the Chathe River was calculated with the help of monthly or seasonal scoring for different geomorphological and biological parameters of habitat following stream visual assessment protocol as proposed by USDA (1998). In this study, seasonal mean habscore was witnessed to be maximum in the range of 7 - 9.14

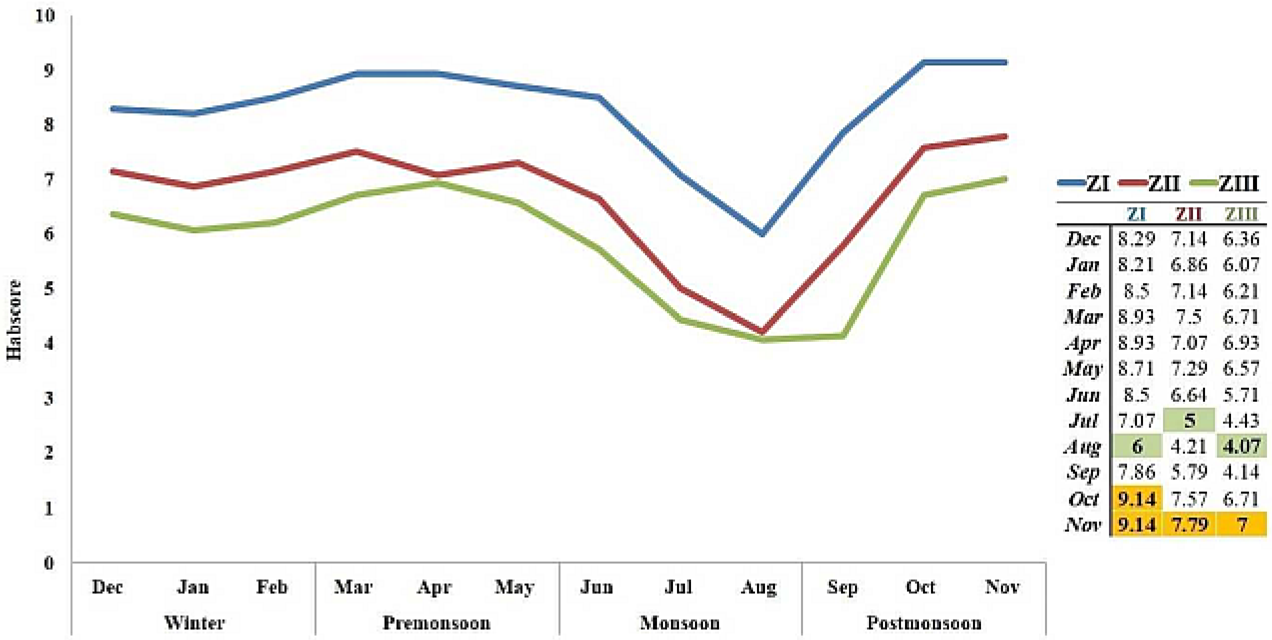


Figure 3. Monthly variation in Habscore of Chathe River in Nagaland

Table 3. Pearson's correlation coefficient of Phytoplankton diversity

Phytoplankton	Zone	pH	WT	CF	Cond	Turb	DO	BOD	FCO_2
Diversity	ZI	0.3291	-0.3909	0.0892	0.6413	-0.4606	0.7473	-0.4118	0.1955
	ZII	0.1988	-0.2877	0.1585	0.2246	-0.2261	0.5716	-0.2619	0.2579
	ZIII	0.3686	-0.2118	0.3007	0.3235	-0.2492	0.7784	-0.1683	0.2826
Phytoplankton	**Zone**	**HCO_3^-**	**CaH**	**TH**	**Chl**	**NPP**	**GPP**	**CR**	**HabS**
Diversity	ZI	0.5323	0.4714	0.5164	-0.0063	0.3525	0.1650	-0.2678	0.4543
	ZII	0.2917	0.2639	0.2253	-0.4811	0.4773	0.3841	-0.2286	0.5727
	ZIII	0.3701	0.2681	0.2125	-0.0749	0.3999	0.1995	-0.3125	0.3312

At 5% confidence & df_{10}, table value of **r = 0.576**

Index: **pH**: Hydrogen ion potential; **WT**: Water temperature; **CF**: Current flow; **Cond**: Conductivity; **Turb**: Turbidity; **DO**: Dissolved oxygen; **BOD**: Biochemical oxygen demand; **FCO_2**: Free Carbon dioxide; **Chl**: Chloride; **HCO_3^-**: Bicarbonate alkalinity; **CaH**: Calcium hardness; **TH**: Total hardness; **NPP**: Net primary productivity; **GPP**: Gross primary productivity; **CR**: Community respiration; **HabS**: Habscore amidst late post-monsoon whereas, minimum in the range of 4.07 - 6 during late monsoon in various sampling stations of the Chathe River (Fig. 3). Habitat quality of the Chathe River was interpreted as 'fair' to 'good' amid most of the seasons except monsoon, when the river was severely influenced by disintegrated stream bank, maximum wastewater deluge, huge turbidity, alteration of riparian vegetation and huge oxygen deficit due to huge tidal surge caused by monsoonal precipitation.

Ichthyofaunal assemblage

During this study, 40 species of fishes under 23 genera of 10 families (Mastacembelidae, Cyprinidae, Cobitidae, Psilorhynchidae, Nemacheilidae, Sisoridae, Bagridae, Badidae, Channidae, Gobiidae) and 4 orders (Synbranchiformes, Cypriniformes, Siluriformes and Perciformes) were encountered in the sampling stations of River Chathe (Table 4). Maximum monthly mean density of Ichthyofauna was witnessed amidst early pre-monsoon whereas minimum was noticed during winter in all surveyed areas (Fig. 4). Mastacembelidae was witnessed to show maximum per cent presence amid early post-monsoon in ZI (4.76%) while, amid pre-monsoon in ZII (5%) and ZIII (3.85%). In contrast, Mastacembelidae was found absent during most of other seasons (Table 5). Maximum mean per cent presence of Cyprinidae was recorded during winter in ZI (66.67%), while, during early monsoon in ZII (70.45%) and late monsoon in ZIII (76.67%). Seasonal mean per cent presence for Cyprinidae was found to be least amid early post-monsoon in ZI (47.62%); while, during winter in ZII (33.33%) and ZIII (42.31%). Though Cobitidae was found absent amid most of the seasons of the study year, yet maximum mean per cent presence was recorded during late winter in ZI (12.5%) and ZIII (14.29%), but during early pre-monsoon in ZII (Table 5). Psilorhynchidae was recorded to have highest mean presence during winter (15.79 - 22.22%) in surveyed areas; whereas least presence amid monsoon in ZI (2.33%) and ZII (3.13%); while, in ZIII (4.35%) amid late premonsoon (Table 5). Seasonal mean presence of Nemacheilidae was noticed to be extreme during early post-monsoon in ZI (23.81%), early winter in ZII (27.78%) and pre-monsoon in ZIII (25.76%). Maximum mean presence of Sisoridae was recorded amid winter in ZI (16.67%) and ZIII (15.38%); while in ZII (13.64%) during early monsoon (Table 5).

Table 4. List of fishes of the Chathe River

Family	Genus and species
Mastacembelidae	*Mastacembelus armatus*
Cyprinidae	*Puntius conchonius*
	Puntius sophore
	Barilius bendelisis
	Barilius barila
	Barilius (Opsarius) barna
	Barilius sp
	Chagunius sp
	Crossocheilus burmanicus
	Aspidoparia sp
	Amblypharyngodon mola
	Devario affinis
	Devario regina
	Devario assamensis
	Devario aequipinnatus
	Danio rerio
	Salmostoma phulo
	Esomus danrica
	Garra mcclellandi
	Garra sp
Cobitidae	*Pangio pangia*
	Lepidocephalichthys berdmorei
Psilorhynchidae	*Psilorhynchus balitora*
	Psilorhynchus nudithoracicus
	Psilorhynchus sp
Nemacheilidae	*Nemachilus botia*
	Nemachilus multifasciatus
	Nemachilus beavani
	Nemachilus corica
Sisoridae	*Glyptothorax telchitta*
	Glyptothorax siamensis
	Glyptothorax trilineatus
	Glyptothorax dorsalis
	Glyptothorax ngapang
	Pseudecheneis sulcata
Bagridae	*Mystus ngasep*
	Olyra longicaudata
Badidae	*Badis* sp
Channidae	*Channa stewartii*
Gobiidae	*Awaous* sp

Though Bagridae was also found to be absent most of the year, yet recorded to have highest mean presence during pre-monsoon in ZI (5.08%) and ZII (6.45%), but amid early monsoon in ZIII (7.84%).

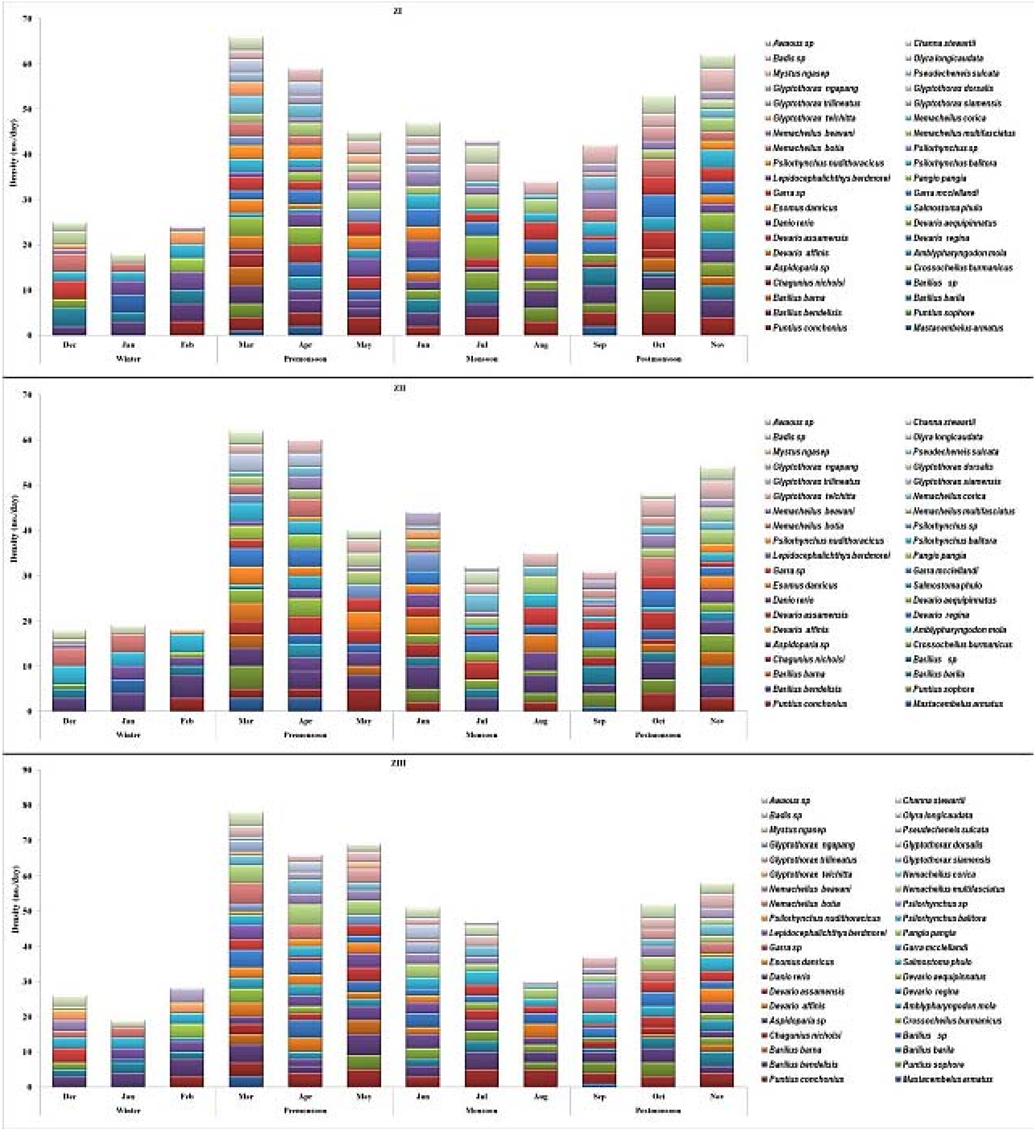


Figure 4. Monthly mean density of various fishes in Chathe River in Nagaland

Maximum seasonal mean presence of Badidae was witnessed during post-monsoon in ZI (9.52%) and ZIII (8.11%) whereas during late monsoon in ZII (8.57%). Though least presence of Badidae was recorded during premonsoon (3.03 - 3.23%) yet, found to be totally missing amid winter in the Chathe River (Table 5). Maximum seasonal mean presence of Channidae was recorded during winter (11.11 - 11.54%). But, least presence of Channidae was witnessed amid late pre-monsoon in ZI (4.44%) and ZIII (2.9%) while in ZII (2.08%) during post-monsoon (Table 5). Gobiidae was only recorded amid monsoon (2.13 - 3.13%) in the Chathe River. The fishes like *Barilius bendelisis*, *Puntius conchonius*, *Channa stewartii* and *Psilorhynchus balitora* were found to be the most common inhabitant of the river

Table 5. Monthly density (Per cent composition) of the fishes of the Chathe River

Families		WINTER			PRE-MONSOON			MONSOON			POST-MONSOON		
		Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Mastacembelidae	**ZI**	0	0	0	1.52	3.39	0	0	0	0	**4.76**	0	0
	ZII	0	0	0	4.84	**5**	0	0	0	0	1	0	0
	ZIII	0	0	0	**3.85**	0	0	0	0	0	1	0	0
Cyprinidae	**ZI**	48	**66.67**	58.33	51.52	54.24	55.56	59.57	62.79	73.53	**47.62**	66.04	59.68
	ZII	**33.33**	52.63	66.67	56.45	55	62.50	**70.45**	56.25	65.71	61.29	62.50	61.11
	ZIII	**42.31**	57.89	50	50	56.06	66.67	54.9	61.70	**76.67**	45.95	57.69	56.90
Cobitidae	**ZI**	0	0	**12.5**	1.52	5.08	0	0	0	0	0	0	0
	ZII	0	0	5.56	**6.45**	5	0	0	0	0	0	0	0
	ZIII	0	0	**14.29**	5.13	0	0	0	0	0	0	0	0
Psilorhynchidae	**ZI**	8	11.11	**12.5**	12.12	8.47	6.67	6.38	**2.33**	5.88	7.14	0	9.68
	ZII	**22.22**	15.79	**22.22**	9.68	6.67	7.50	9.09	**3.13**	8.57	3.23	0	7.41
	ZIII	11.54	**15.79**	10.71	7.69	7.58	**4.35**	5.88	8.51	6.67	8.11	0	8.62
Nemacheilidae	**ZI**	20	11.11	0	13.64	15.25	13.33	**10.64**	13.95	11.76	**23.81**	15.09	11.29
	ZII	**27.78**	21.05	0	8.06	18.33	10	**6.82**	21.88	17.14	12.90	22.92	9.26
	ZIII	19.23	15.79	0	17.95	**25.76**	**13.04**	13.73	14.89	13.33	24.32	23.08	13.79
Sisoridae	**ZI**	16	0	**16.67**	7.58	**3.39**	8.89	8.51	0	0	7.14	5.66	6.45
	ZII	5.56	0	5.56	0	0	7.5	**13.64**	0	0	12.90	**4.17**	9.26
	ZIII	**15.38**	0	25	6.41	**3.03**	5.8	7.84	0	0	10.81	5.77	8.62
Bagridae	**ZI**	0	0	0	4.55	**5.08**	4.44	4.26	0	0	0	0	0
	ZII	0	0	0	**6.45**	5	0	0	0	0	0	0	0
	ZIII	0	0	0	0	4.55	2.9	**7.84**	0	0	0	0	0
Badidae	**ZI**	0	0	0	**3.03**	5.08	6.67	4.26	9.3	8.82	**9.52**	5.66	8.06
	ZII	0	0	0	**3.23**	5	7.5	0	6.25	**8.57**	6.45	8.33	7.41
	ZIII	0	0	0	3.85	**3.03**	4.35	3.92	6.38	3.33	**8.11**	5.77	6.90
Channidae	**ZI**	8	**11.11**	0	4.55	0	**4.44**	6.38	9.3	0	0	7.55	4.84
	ZII	**11.11**	10.53	0	4.84	0	5	0	9.38	0	0	**2.08**	5.56
	ZIII	**11.54**	10.53	0	5.13	0	**2.9**	5.88	6.38	0	0	7.69	5.17
Gobiidae	**ZI**	0	0	0	0	0	0	0	**2.33**	0	0	0	0
	ZII	0	0	0	0	0	0	0	**3.13**	0	0	0	0
	ZIII	0	0	0	0	0	0	0	**2.13**	0	0	0	0

Maximum values are shown in bold **Red** and minimum in bold **Black** throughout the year (Fig. 4). Moreover, *Nemacheilus multifaciatus, Aspidoparia* sp., *Garra mcclellandi, Garra sp* and *Badis sp* were noticed to be flourished amid most of the seasons except winter. On the contrary, fishes like *Mastacembelus armatus*, *Devario affinis*, *Devario regina*, *Devario aequipinatus*, *Salmostoma phulo*, *Pangio pangia*, *Leidocephalichthys berdmorei*, *Psilorhynchus nudithoracicus*, *Glyptothorax telchitta*, *Glyptothorax siamensis*, *Glyptothorax trilineatus*, *Glyptothorax dorsalis*, *Glyptothorax ngapang*, *Pseudocheneis sulcata*, *Mystus ngasep*, *Olyra longicaudata* and *Awaous* sp. were recorded to be present occasionally in the river (Fig. 4).

For ichthyodiversity indices of the Chathe River, seasonal mean Shannon diversity (H) was noticed to be highest (3.008 - 3.149) during early pre-monsoon and lowest (1.767 - 1.908) during winter

Table 6. Monthly mean Ichthyodiversity indices of the Chathe River

Season	Months	Sites	**H**	**J**	**D**	**1-D**	**Ma**
Winter	**December**	**ZI**	2.200 ±0.125	**0.955** ±0.018	0.083 ±0.008	0.917 ±0.008	2.796 ±1.251
		ZII	1.937 ±0.233	0.932 ±0.015	0.111 ±0.007	0.889 ±0.007	2.422 ±1.243
		ZIII	2.251 ±0.201	0.978 ±0.018	0.074 ±0.007	0.926 ±0.007	2.762 ±1.115
	January	**ZI**	**1.908** ±0.065	0.981 ±0.017	**0.105** ±0.012	**0.895** ±0.014	**2.076** ±1.012
		ZII	**1.767** ±0.087	**0.986** ±0.009	0.129 ±0.010	0.871 ±0.015	**1.698** ±1.015
		ZIII	**1.886** ±0.076	0.969 ±0.008	**0.111** ±0.012	**0.889** ±0.015	**2.038** ±0.098
	February	**ZI**	2.029 ±0.09	0.976 ±0.019	0.098 ±0.002	0.902 ±0.002	2.203 ±0.785
		ZII	1.798 ±0.11	**0.924** ± 0.021	**0.137** ±0.003	**0.863** ±0.002	2.076 ±0.864
		ZIII	2.128 ±0.097	0.969 ±0.021	0.093 ±0.003	0.907 ±0.002	2.401 ±0.865
Pre-Monsoon	**March**	**ZI**	**3.149** ±0.214	0.978 ±0.017	**0.030** ±0.008	**0.970** ±0.016	**5.728** ±0.664
		ZII	**3.008** ±0.207	0.973 ±0.012	0.037 ±0.012	0.963 ±0.018	**5.088** ±0.607
		ZIII	**3.096** ±0.201	0.974 ±0.015	**0.036** ±0.014	**0.964** ±0.012	**5.279** ±0.650
	April	**ZI**	3.111 ±0.111	0.979 ±0.018	**0.030** ±0.006	**0.970** ±0.005	5.641 ±0.482
		ZII	2.999 ±0.154	0.985 ±0.016	**0.036** ±0.007	**0.964** ±0.007	4.885 ±0.549
		ZIII	3.017 ±0.132	0.976 ±0.018	0.038 ±0.006	0.962 ±0.07	5.012 ±0.537
	May	**ZI**	2.794 ±0.130	0.986 ±0.007	0.042 ±0.008	0.958 ±0.009	4.203 ±1.177
		ZII	2.586 ±0.125	0.980 ±0.009	0.055 ±0.007	0.945 ±0.008	3.524 ±1.231
		ZIII	2.992 ±0.132	0.983 ±0.009	0.039 ±0.007	0.961 ±0.009	4.724 ±0.986
Monsoon	**June**	**ZI**	2.858 ±0.176	**0.989** ±0.005	0.039 ±0.011	0.961 ±0.015	4.415 ±0.987
		ZII	2.754 ±0.154	0.972 ±0.006	0.047 ±0.009	0.953 ±0.014	4.228 ±0.956
		ZIII	2.844 ±0.174	0.984 ±0.011	0.042 ±0.008	0.958 ±0.015	4.324 ±0.897
	July	**ZI**	2.655 ±0.107	0.958 ±0.015	0.054 ±0.010	0.946 ±0.006	3.988 ±0.564
		ZII	2.523 ±0.097	0.956 ±0.018	0.058 ±0.011	0.942 ±0.008	3.751 ±0.666
		ZIII	2.711 ±0.089	0.978 ±0.014	0.050 ±0.008	0.950 ±0.005	3.896 ±0.346
	August	**ZI**	2.440 ±0.095	0.982 ±0.023	0.062 ±0.019	0.938 ±0.019	3.119 ±0.321
		ZII	2.416 ±0.111	0.972 ±0.018	0.067 ±0.017	0.933 ±0.017	3.094 ±0.333
		ZIII	2.387 ±0.102	**0.961** ±0.020	0.069 ±0.016	0.931 ±0.019	3.234 ±0.341
Post-Monsoon	**September**	**ZI**	2.685 ±0.097	0.968 ±0.018	0.050 ±0.006	0.950 ±0.005	4.013 ±0.451
		ZII	2.612 ±0.069	0.965 ±0.016	0.049 ±0.007	0.951 ±0.006	4.077 ±0.324
		ZIII	2.664 ±0.088	**0.961** ±0.015	0.050 ±0.006	0.950 ±0.006	4.154 ±0.281
	October	**ZI**	2.707 ±0.098	0.976 ±0.014	0.052 ±0.007	0.948 ±0.004	3.778 ±0.618
		ZII	2.799 ±0.069	0.968 ±0.017	0.045 ±0.007	0.955 ±0.004	4.391 ±0.576
		ZIII	2.794 ±0.066	**0.986** ±0.017	0.044 ±0.004	0.956 ±0.003	4.049 ±0.555
	November	**ZI**	2.999 ±0.119	0.985 ±0.008	0.036 ±0.004	0.964 ±0.007	4.846 ±1.087
		ZII	2.952 ±0.127	0.985 ±0.009	**0.036** ±0.006	**0.964** ±0.005	4.763 ±1.112
		ZIII	2.993 ±0.115	0.983 ±0.007	**0.036** ±0.004	**0.964** ±0.005	4.926 ±1.023

Maximum value is shown in bold **Red** and minimum in bold **Black** in various survey stations (Table 6). Highest mean Pielou's evenness (J) was found amid early monsoon in ZI (0.989±0.005), during winter in ZII (0.986 ±0.009) and during post-monsoon in ZIII (0.986±0.017). Seasonal mean Pielou's evenness (J) was found to be the least during early winter in ZI (0.955±0.018) and ZII (0.924 ±0.021); while amid late monsoon (0.961±0.020) and early post-monsoon (0.961±0.015) in ZIII (Table 6). Seasonal mean Simpson's dominance (D) was recorded to be maximum (0.105-0.137) during winter; whereas minimum (0.030-0.036) during pre-monsoon and post-monsoon in most of the surveyed stations. Seasonal mean Simpson's diversity (1-D) was recorded to be maximum (0.964-0.970) during pre-monsoon and post-monsoon in all survey areas (Table 6). On the contrary, lowest mean Simpson's diversity (1-D) was witnessed amidst winter (0.863-0.895) in the most of the sampling stations of River Chathe (Table 6). Seasonal mean Margalef's diversity (Ma) was found to be extreme during early pre-monsoon (5.088-5.728); whereas lowest during winter (1.698-2.076).

When Pearson's correlation was analysed between ichthyodiversity indices and physicochemical parameters of the Chathe River, a direct association of the diversity indices like Shannon (H), Simpson (1-D) and Margalef (Ma) were witnessed with water temperature (WT), pH, current flow (CF), biochemical oxygen demand (BOD), bicarbonate alkalinity (HCO_3^-), chloride, gross primary productivity (GPP) and community respiration (CR) in most of the sampling stations of the Chathe river, where current flow was found to have a direct association ($p<0.05$) with Shannon's diversity in ZII (Table 7). Moreover, Simpson's diversity (1-D) was witnessed to have direct association ($p>0.05$) with turbidity in all sampling stations (Table 7). Pielou's evenness (J) was recorded to have direct association with WT, pH, CF, Free CO_2, conductivity, turbidity, HCO_3^-, chloride, net primary productivity (NPP), GPP and CR in most of sampling stations; where association with Free CO_2 and GPP were witnessed to be significant just in ZIII ($p<0.05$). During this investigation, a direct association ($p>0.05$) of Simpson's dominance (D) was observed with conductivity, dissolved oxygen (DO), free CO_2, HCO_3^-, calcium hardness (CaH), total hardness (TH), NPP and GPP in most of the sampling stations (Table 7).

Canonical correlation analysis of ichthyodiversity indices

When canonical correlation analysis (CCorA) was executed for ichthyodiversity indices with physicochemical parameters, habscore and phytoplankton diversity of three sampling stations of the Chathe River, it has isolated four components of which two initial components i.e., F1 and F2 in all sampling stations were recordrd to have higher eigenvalues of 50% of total difference between sampling stations. Each of initial component axes F1 and F2 has explained 25% of total variance with eigenvalue 1. CCorA has shown a significant direct association of ichthyodiversity indices like Shannon, Simpson and Margalef diversity with Pielou's evenness and indirect association with Simpson's dominance in stations ZI and ZII (Fig. 5). On the other hand, Pielou's evenness and Simpson's dominance were recorded to have an insignificant direct association with Shannon and Margalef diversity while indirect association with Simpson diversity in station ZIII (Fig. 5). A significant direct association of Shannon, Simpson and Margalef diversity with habscore, phytoplankton diversity, conductivity, bicarbonate alkalinity, dissolved oxygen, calcium hardness, NPP and GPP; while indirect association with current flow, water temperature, turbidity, BOD, chloride and community respiration was witnessed in ZI (Fig. 5). Further, an insignificant indirect association of ichthyodiversity with turbidity and direct association with other parameters were recorded in ZII. Trifling association of ichthyodiversity with physicochemical parameters, habscore and phytoplankton diversity were noticed in ZIII (Fig. 5). In ZI, pielou's evenness was found to be restricted due to a significant decline in pH, dissolved oxygen, calcium hardness, total hardness GPP, NPP and habscore while by insignificant decline in free CO_2, conductivity and phytoplankton diversity (Fig. 5). Further, Pielou's evenness was found to be enhanced by an increment in bicarbonate alkalinity, pH, dissolved oxygen, GPP, NPP, calcium hardness and phytoplankton diversity, which was recorded to be insignificant in ZII but significant in ZIII (Fig. 5). On the contrary, evenness

Table 7. Pearson's correlation coefficient of Ichthyodiversity indices

Indices	Sites	WT	pH	CF	Cond	Turb	DO	BOD	FCO_2	HCO_3^-	CaH	TH	Chl	NPP	GPP	CR
H	ZI	0.24	0.21	0.48	-0.03	-0.07	0.14	0.24	-0.10	0.27	0.04	-0.25	0.32	-0.14	0.13	0.29
	ZII	0.31	0.23	**0.58**	-0.14	-0.03	-0.08	0.37	-0.09	0.10	-0.08	-0.29	0.13	-0.06	0.13	0.21
	ZIII	0.43	0.22	0.20	0.73	0.72	0.54	0.41	0.66	0.45	0.82	0.32	0.24	0.80	0.53	0.29
J	ZI	0.09	0.39	0.19	0.07	0.22	0.11	-0.04	0.04	0.13	0.15	-0.08	0.14	-0.06	0.26	0.32
	ZII	0.12	0.15	0.33	-0.04	0.10	-0.08	0.17	-0.20	0.13	-0.09	-0.21	0.04	0.00	0.05	0.05
	ZIII	0.55	0.62	0.86	0.83	0.10	0.75	0.48	**0.05**	0.46	0.57	0.78	0.53	0.27	**0.03**	0.45
D	ZI	-0.33	-0.12	-0.49	0.15	-0.03	-0.02	-0.35	0.12	-0.19	0.07	0.34	-0.29	0.22	-0.04	-0.31
	ZII	-0.40	-0.10	-0.56	0.31	-0.06	0.16	-0.51	0.10	0.02	0.25	0.44	-0.08	0.15	0.02	-0.18
	ZIII	0.34	0.37	0.25	0.41	0.87	0.76	0.24	0.68	0.71	0.77	0.20	0.37	0.72	0.77	0.42
1-D	ZI	0.33	0.12	0.49	-0.15	0.03	0.02	0.35	-0.12	0.19	-0.07	-0.34	0.29	-0.22	0.04	0.31
	ZII	0.40	0.10	0.56	-0.31	0.06	-0.16	0.51	-0.10	-0.02	-0.25	-0.44	0.08	-0.15	-0.02	0.18
	ZIII	0.34	0.37	0.25	0.41	0.87	0.76	0.24	0.68	0.71	0.77	0.20	0.37	0.72	0.77	0.42
Ma	ZI	0.16	0.30	0.49	0.13	-0.15	0.27	0.13	-0.10	0.39	0.18	-0.12	0.40	-0.12	0.17	0.30
	ZII	0.25	0.25	0.57	-0.08	-0.12	0.00	0.31	-0.09	0.12	-0.02	-0.23	0.12	0.00	0.17	0.17
	ZIII	0.51	0.17	0.17	0.86	0.73	0.42	0.46	0.75	0.37	0.75	0.37	0.24	0.85	0.55	0.36

At 5% confidence & df_{10}, table value of **r = 0.576**, all the numerals in bold indicate the significant values ($p<0.05$)

Index: WT: Water temperature; **pH**: Hydrogen ion potential; **CF**: Current flow; **Cond**: Conductivity; **Turb**: Turbidity; **DO**: Dissolved oxygen; **BOD**: Biochemical oxygen demand; **FCO_2**: Free Carbon dioxide; **HCO_3^-**: Bicarbonate alkalinity; **CaH**: Calcium hardness; **TH**: Total hardness; **Chl**: Chloride; **NPP**: Net primary productivity; **GPP**: Gross primary productivity; **CR**: Community respiration; **H**: Shannon's diversity; **J**: Pielou's evenness; **D**: Simpson's dominance; **1-D**: Simpson's diversity; **Ma**: Margalef's diversity.

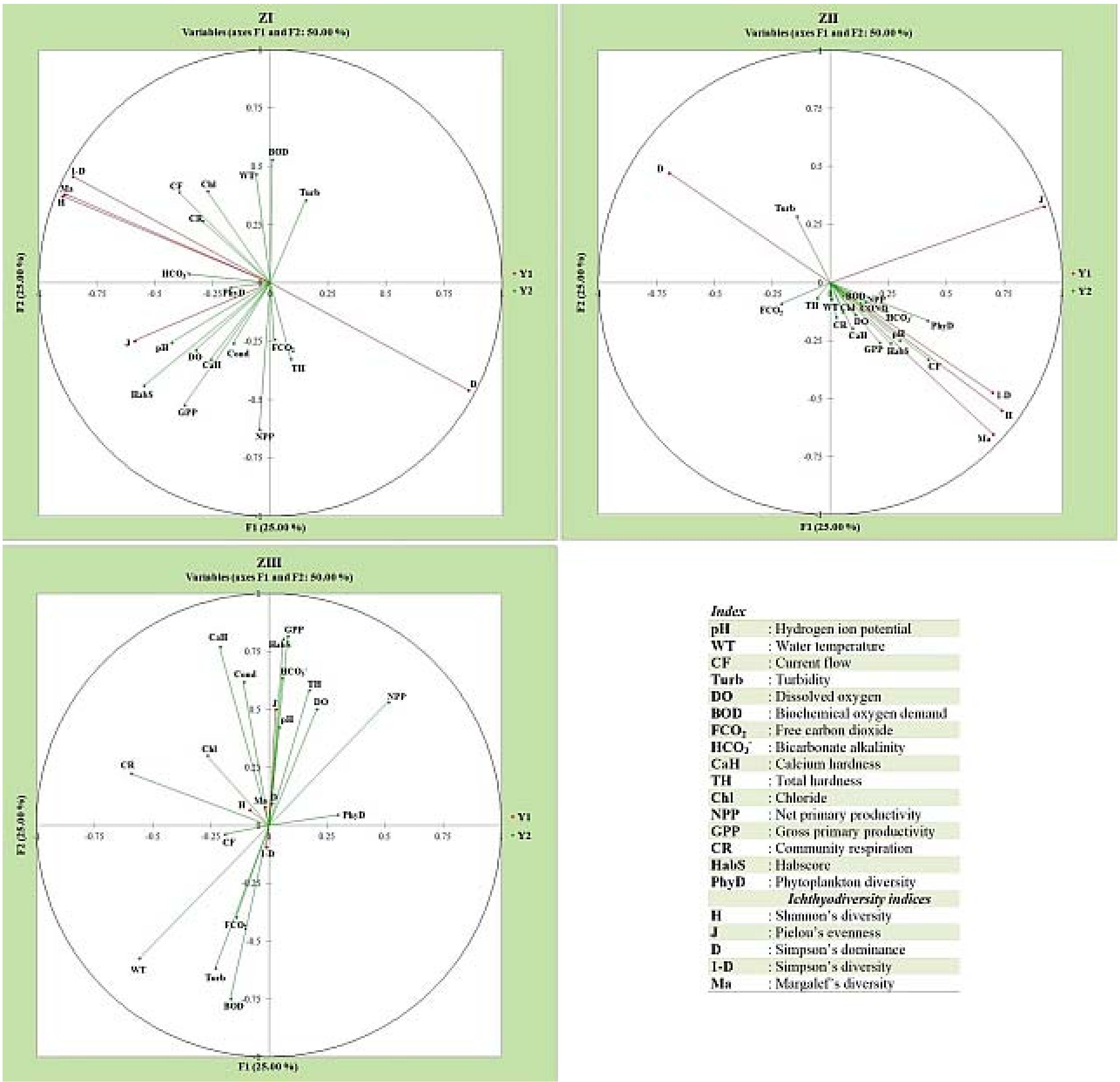
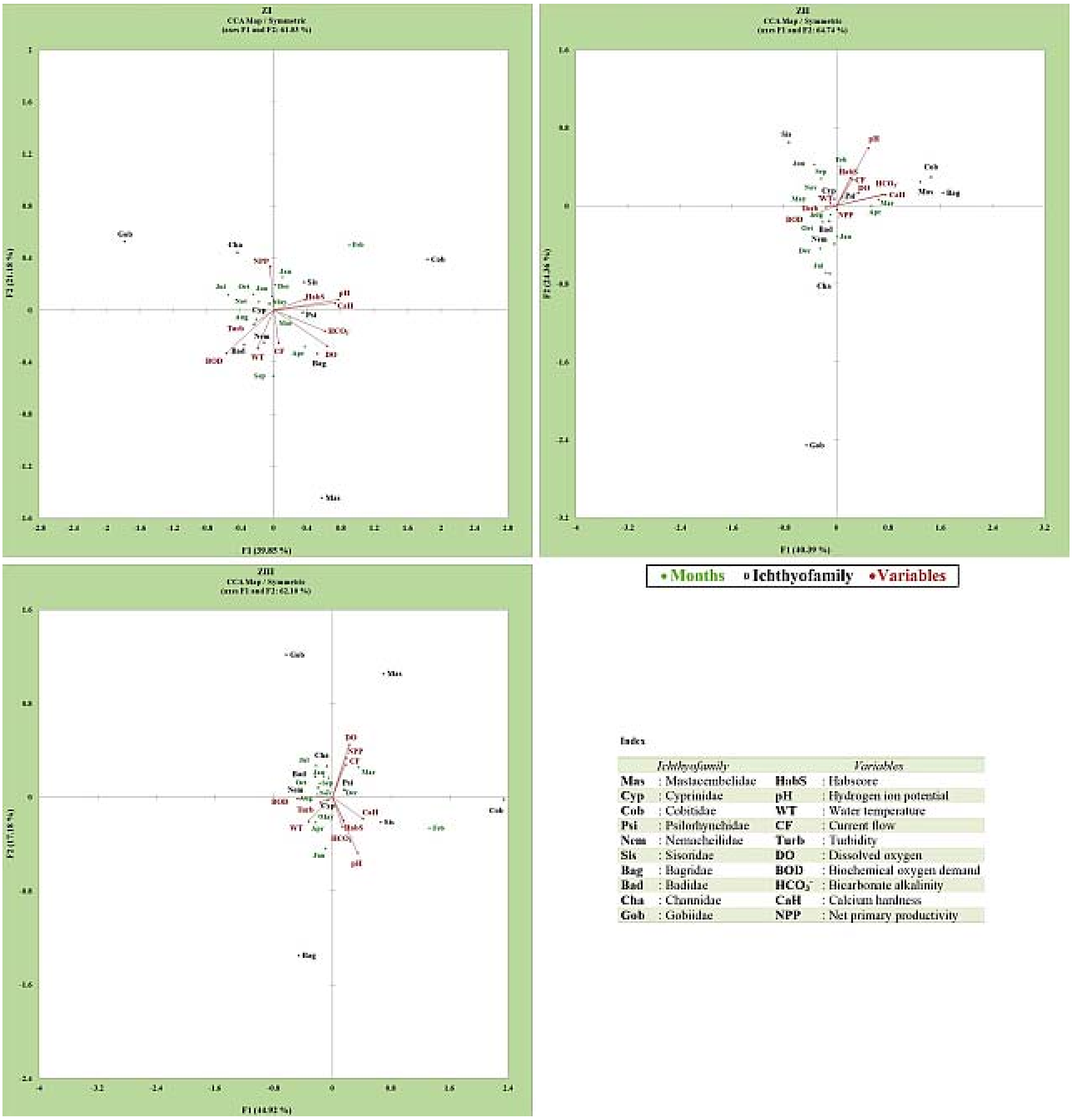


Figure 5. Canonical correlation (CCorA) of Ichthyodiversity indices of Chathe River in Nagaland

was found to be indirectly associated with free CO_2 and total hardness in ZII while with water temperature, BOD and turbidity in ZIII. Simpson's dominance was found to be augmented in ZI by an increase in turbidity and BOD while in ZII by turbidity. In contrast, a decrement in water temperature, turbidity, BOD and free CO_2 was rather found to increase dominance in ZIII (Fig. 5).

Canonical correspondence analysis of Ichthyofamily density

When canonical correspondence analysis (CCA) was encouraged between Ichthyofamily density (no/day) and some selected physicochemical parameters along with habscore, nine components were extracted of which two initial components (F1 and F2) have explained 61.03 - 64.74% of total variance among sampling stations. F1 component axis alone explained 39.85 - 44.92% of variance with eigenvalues in the range of 0.1 - 0.13; while F2 component axis explained 17.18 - 24.36% of variance with eigenvalues in the range of 0.05 - 0.08 in all sampling stations. The months of the study year in relation to the position of ichthyofamilies on CCA biplot was noticed to provide a direct reflection of the influence of physicochemical parameters and



Index

Ichthyofamily		*Variables*	
Mas	: Mastacembelidae	**HabS**	: Habscore
Cyp	: Cyprinidae	**pH**	: Hydrogen ion potential
Cob	: Cobitidae	**WT**	: Water temperature
Psi	: Psilorhynchidae	**CF**	: Current flow
Nem	: Nemacheilidae	**Turb**	: Turbidity
Sis	: Sisoridae	**DO**	: Dissolved oxygen
Bag	: Bagridae	**BOD**	: Biochemical oxygen demand
Bad	: Badidae	**HCO_3^-**	: Bicarbonate alkalinity
Cha	: Channidae	**CaH**	: Calcium hardness
Gob	: Gobiidae	**NPP**	: Net primary productivity

Figure 6. Cannonical corrospondence analysis (CCA) of Ichthyofamilies in Chathe River in Nagaland

habscore. First axis of CCA was significantly correlated with physicochemical parameters and habscore, while the positive terminal of CCA first axis was moderately associated with ichthyofamily, whereas negative terminal of the axis was associated with ichthyofamily which were intolerant to impairment of water quality at any given month of the study year. In CCA, the most of the inertia is carried by the first axis (F1), which means that the two-dimensional CCA will be enough to analyze the relationship between the ichthyofamily and the variables during any given month of the study year.

During this investigation, CCA of Icthyofamily density has shown a direct association of Mastacembelidae with dissolved oxygen, bicarbonate alkalinity, calcium hardness, pH, current flow amid early premonsoon and most of winter; whereas indirect association with water temperature, turbidity and biochemical oxygen demand (BOD) during most of monsoon and postmonsoon in all sampling stations (Fig. 6). Cyprinidae was noticed to have a direct association with net primary productivity during most of monsoon and postmonsoon in ZI, while with habscore, pH, calcium hardness, dissolved oxygen and bicarbonate alkalinity in all surveyed stations during most of winter and early premonsoon. Further, density of Cyprinidae was noticed to be relatively declined by higher water temperature, turbidity and BOD amid most of monsoon, late premonsoon and most of postmonsoon (Fig. 6). Cobitidae was noticed to have direct association with habscore, pH, calcium hardness, dissolved oxygen and bicarbonate alkalinity amid winter and early pemonsoon; while an indirect association with water temperature, turbidity and BOD in most of the sampling stations amid monsoon and most of postmonsoon (Fig. 6). Psilorhynchidae was found to be flourished during most of premonsoon by elevated level of either or all of the variables like pH, dissolved oxygen, bicarbonate alkalinity, current flow, calcium hardness and decent quality of habscore whereas, a decline in density was observed during monsoon and early postmonsoon by elevated level of water temperature, turbidity and BOD in most of the surveyed areas. A direct association of Nemacheilidae with current flow, dissolved oxygen, bicarbonate alkalinity and net primary productivity amid most of premonsoon and postmonsoon; while indirect association with water temperature, turbidity and BOD during late premonsoon and most of monsoon (Fig. 6). Density of Sisoridae was recorded to be enhanced amid early premonsoon, late postmonsoon and winter due to an elevated level of either or all of the variables like calcium hardness, pH, bicarbonate alkalinity, dissolved oxygen, current flow and habscore in surveyed stations. Family Bagridae was witnessed to be flourished amid most of premonsoon in ZI and ZII due to higher current flow, dissolved oxygen, bicarbonate alkalinity and decent habscore (Fig.6). An increment in turbidity and BOD was witnessed to reduce the presence of Bagridae during late monsoon and early postmonsoon in ZI, amid most of monsoon, postmonsoon and early winter in ZII while during most of premonsoon and late monsoon in ZIII. Elevated level of turbidity and BOD was found to reduce the density of Badidae during late monsoon, early postmonsoon and winter in ZI and ZII; while their presence during most of postmonsoon was recorded to be directly associated with the elevated level of dissolved oxygen and current flow in ZI and ZIII (Fig.6). Channidae was found to show a preference towards net primary productivity along with all or none of variables like pH, bicarbonate alkalinity, calcium hardness and decent habscore amid most of premonsoon, postmonsoon and winter in the sampling stations (Fig.6). Further their density was witnessed to be restricted during most of monsoon by an elevation of water temperature, turbidity and BOD. Any influence of either of the selected variables on occurrence of Gobiidae was obscure in this investigation.

DISCUSSION

Distinctive seasonal variations in terms of phytoplankton assemblage, physicochemical parameters and habscore facilitate in harbouring different fish species with differential preferences in the Chathe River. Diverged habitat of the Chathe River ranging from rocky or sandy riverbed with weak current flow to the area with fast flowing stream as well as feeble stream or area with well-aerated water accompanied by high current flow or relatively cool, shallow and clean water zones of the waterway with wide riparian zones or with copious inundated vegetation or shallow running waters with sandy bottom or the zone with relatively warm water or the area with feeble momentum stream among the pebbles and stream areas with exposed rock surfaces portray the river to harbour a wide selection of ichthyofauna with varieties of choices to build their guilds. Since, harbivore fishes mostly feed on phytoplankton, so seasonal variation in phytoplankton assemblage become one of the most indispensable factors to direct the distribution of fishes in any stream. During this investigation, superior phytoplankton density was noticed during late winter, early pre-monsoon and post-monsoon due to moderate water temperature with adequate thermal stratification, higher DO, low turbidity, ideal prey-predator interaction and maximum nutrient mixing through moderate wind velocity. On the contrary, a sharp reduction of phytoplankton density and diversity amid most part of monsoon was witnessed because of extreme water temperature, shady sky, higher turbidity, strong stream-flow, differential light intensity and elevated grazing pressure (Giripunje et al. 2013, Dey Baidya 2019). Analyses of monthly ichthyofaunal assemblage have indicated the maximum mean density of family Cyprinidae followed by Nemacheilidae and Psilorhynchidae throughout the year in the river, which was also supported by several investigators (Singh et al. 2006, Basavaraja et al. 2014). Small sized fishes like *Barilius* sp., *Puntius* sp., *Devario* sp., *Danio* sp. and *Esomus* sp. are progressively proficient in discovering shelter and nourishment in shallow zones as are increasingly shielded from predators of incredible territories of the water body (Jepsen 1997). The recommended range of Ichthyofaunal tolerance for physicochemical variables viz., pH (6.5-9), water temperature (25-30ºC), dissolved oxygen (>5 mg/L), free CO_2 (<15 mg/L), BOD (3-20 mg/L), bicarbonate alkalinity (20-400 mg/L) and total hardness (20-300 mg/L) were reported as the principal components to alter the pattern of ichthyofaunal assemblage in several rivers (Fairfield 2000, Boyd 2003). An optimum pH in the range of 7.8- 8.53 was also noticed to enhance Icthyofaunal assemblage in River Chathe. pH at its extreme over 11 or underneath 4 could be equally lethal for most types of fishes (Lawson,1995; Tarazona et al. 1995). It has also been reported that, at extremely low pH conceptive capacity of fishes is halted (Boyd 1990). Water temperature in the range of 16.2 - 28.8ºC in River Chathe was found optimum for the growth of fishes as also reported in Dahikhura reservoir (Yogesh 2001) and Narmada River (Sharma et al. 2012). Higher water temperature amid late pre-monsoon and monsoon accelerates metabolical demands of the organism, thus recorded to reduce the concentration of dissolved oxygen in the waterway. Cyprinids were recorded to flourish in River Chathe throughout the year due to their maximum species diversity with diverged level of tolerance for dissolved oxygen in the range of 6 - 8 mg/L and BOD in the range of 8 - 15 mg/L (Ghosh et al. 1988). Though some fishes viz., *Barilius*, *Nemacheilus*, *Pseudecheneis*, *Glyptothorax* were reported to have wide range of temperature tolerance at 8- 30ºC (Nath 1994); yet ichthyofaunal density was found to be reduced amid monsoon, late pre-monsoon and early post-monsoon due to a colossal increase in water temperature in the sampling stations of the Chathe River (Fig.4). Augmentation in density and diversity of fishes amid most part of pre-monsoon and late post-monsoon was noticed to be directly associated with elevated habscore, which may be ascribed to an increased accessibility of extended niche with higher nutrient flux from allochthonous sources in River Chathe. Maximum density and diversity of fishes amid most part of pre-monsoon and late post-monsoon was found to be significantly associated with an increment in alkalinity, dissolved oxygen, pH and total hardness. Further, current flow is also considered to be a vital component for enhancing ichthyofaunal assemblage, since it acts for nutrient mixing between various strata of water body, transport of eggs, hatching and migration of fishes. On the other hand, a huge rise in current flow caused by heavy precipitation also may lead to raise turbidity and BOD of the river. Though huge turbidity may prove to be fatal for ichthyofaunal assemblage by clogging their gills and interfering in foraging; but turbidity also may act as an aid in superior endurance of juveniles against predators, as marker for plenitude of nourishment as well as orientation mechanism for migration by fishes (Blaber 2000). Indeed, even the floods brought about by expanded water level may change the structure of ichthyofaunal assemblage, since it dislodges or butcher life forms and alter their typical territories (Franssen et al. 2006). Trivial reduction in ichthyofaunal assemblage noticed during monsoon was due to an increase in oscillations in water level, BOD, turbidity and water temperature when ichthyofaunal asssemblage was found to be mostly dominated by omnivorous fishes (Tejerina-Garro et al. 2010). Omnivores like *Awaous* sp. belonged to the family Gobiidae was noticed to be sporadic visitor in the river only during part of monsoon season, which was probably carried to the surveyed stations from upstream areas by huge tidal surges. Herbivore fishes are more sensitive than carnivore fishes to any pollution stress, which in turn lead to seasonal variations in distribution of fishes (Ganasan and Hughes 1998). Density of herbivorous fishes decline in downstream region amid late pre-monsoon and monsoon due to huge increase in pollution loads when they shift themselves towards upstream regions. A steady decrease in phytoplankton assemblage, current flow, profundity, riparian zones and accessibility of nutrients amidst winter were witnessed to enhance dominance of piscivorous and invertivorous fishes in surveyed stations of the river (Kar et al. 2006, Tejerina-Garro et al. 2010). *Mastacembelus armatus*, the only species traced in River Chathe belonged to the family mastacembelidae was found to flourish amidst early pre-monsoon and post-monsoon due to an enhanced phytoplankton assemblage.

CONCLUSION

Amid this investigation, it has been revealed that physicochemical parameter, phytoplankton assemblage, ichthyofaunal assemblage and habitat quality of the Chathe River was commendable for most part of the year, yet moderate decline in overall quality was seen during monsoon due to an immense raise in water temperature, turbidity and BOD. Huge decline in ichthyofaunal density was witnessed amid winter due to a reduction in stream flow, profundity, riparian zones and accessibility of nutrients in surveyed areas of the Chathe River. Physicochemical parameters like current flow, bicarbonate alkalinity, water temperature and dissolved oxygen were revealed to be the principal determinant of distribution and abundance of a variety of fishes in all sampling stations of the Chathe River. Besides alteration in channel morphology and hydrological regime due to huge monsoonal rain, augment in turbidity above prescribed limit associated with oxygen deficit may have acted as the principal stressors during most part of monsoon. Cyprinidae was witnessed to be least influenced by water temperature and dissolved oxygen and so was recognized as the most dominant family throughout the year in all the sampling stations.

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