RESEARCH ARTICLE

The study of correlation between physico-chemical parameters and abundance of *Barilius bendelisis* in three rivers at different seasons

Abhisek Saha[1*], Debashis Das[2], Gobinda Chandra De[3]

Saha A, Das D, De CG. The study of correlation between physico-chemical parameters and abundance of *Barilius bendelisis* in three rivers at different seasons. AGBIR. 2022; 38(4):321-331.

The present investigation was carried out on the Torsa, Mansai (Jaldhaka), Raidak-1 river flowing through the Coochbehar district at three spots to access the seasonal variation of physico-chemical parameters with abundance of *Barilius bendelisis* species. The constituents monitored included *viz*. Air temperature, Water temperature, Turbidity, pH, TDS, TSS, Total solid, Depth, Conductivity, DO, Free CO_2, BOD, Nitrate, Phosphate, Chloride, Total hardness, and total alkalinity. The results of the present study are based upon the observations (n=54) carried out through field sampling between March 2018 to November 2019, and expressed as Catch Par Unit Effort (CPUE). To explain observed changes in CPUE for both sampling years, the data were treated to a two-way factorial ANOVA with sampling locations and seasons as predictor variables. Results suggested that the CPUE varied significantly with the variables at the P<0.05 level. Further, both the years' data were also subjected to regression analysis concerning physico-chemical parameters. The degree of interrelation among the Physico-chemical parameters is represented through the Pearson correlation matrix. For the first year, the value of correlation coefficient (r) was found highest between pH and Total suspended solid (r=0.97), followed by that of Total suspended solid and Total solid (r=0.77) and pH and Total solid (r=0.73). However, for the subsequent year, 'r' was found to be highest between pH and Total suspended solid (r=0.98) followed by Air temperature and Water temperature (r=0.89) and Total suspended solid and Total solid (r=0.77) All these values were positively significant at 0.01 level (2 tailed).

Key Words: *Physico-chemical parameters; ANOVA; Pearson correlation matrix; Barilius bendelisis*

INTRODUCTION

Northern part of West Bengal, popularly known as North Bengal is gifted with numerous torrent fresh water rivers; the river "Torsa, Mansai (Jaldhaka)" are popular among them. There are six major river systems longitudinally cut the Cooch behar district flowing in a south-easterly direction. From the west to east these are the Tista, Jaldhaka, Torsa, Kaljani, Raidak and Gangadhar (Sonkosh) system. Some notable tributary rivers are Dharla, Jaldhaka, Raidak–II, Dudua, Kaljani, Sankosh, Gadadhar, Mansai, Ghargharia Jorai etc., [1].

River Torsa situated in the Cooch Behar district covers a stretch of about 61 Km up to the lower reaches of the river. The Torsa River has a total length of about 354.42 km, and runs down through the districts of Jalpaiguri, Alipurduar and Cooch Behar, originating from Chumhi valley in Tibet (China) is a Trans-Himalayan river in true sense. The Torsa River flows into Bangladesh as the Kaljani and meets the Jamuna there. River Raidak-1 situated in Cooch Behar district covers a stretch of about 59.20 Km up to the lower reaches of the river. The Raidak-1 river has a total length of about 90 km and runs down through the districts of Alipurduar and Cooch Behar. The river flows from the ice field of the Jomolhari Peak (7270 m)-Kungphu (6894 m)-Takaphu (6493 m) of Himalaya in Bhutan. Raidak's source is located at an elevation of 6400 meters. Within the Bhutanese territory, the headstream of the Raidak is known as Wong-Chu. It receives two major tributaries the Paro Chu and the Ha Chu. The catchment region has an area of 5505.2 square kilometers, of which 4813 square kilometers are located in Bhutan. 692 sq. km within the sub-Himalayan northern part of West Bengal and only 450 sq. km is situated within the Alipurduar district. The Raidak meets the Brahmaputra at a stretch of 327 kilometers in Bangladesh's Kurigram District, where it is also known as the Dudhkumar River. Raidak-1 joins the united stream of Torsa and Kaljani. Jaldhaka river is known as the Mansai river in the Mathabhanga region of the Cooch Behar district, has a total length of about 192 km., and runs down through the districts of Darjeeling, Jalpaiguri, and Cooch Behar of West Bengal, India originating from Bitang Lake in Sikkim at an altitude of 4250 m to 4550 m which is known as Dichu in Bhutan. River reach at Cooch Behar district from the northwest in Dhulia Baldiahati of Mekhliganj Subdivision of Cooch Behar. It enters Bangladesh at Barabangla in the Dinhata Subdivision and meets the Brahmaputra. The river is also known as Mansai, Singhimari, and Dharala in the different locations of Cooch Behar district. The portion of the river which is called Mansai in the area of Mathabhanga subdivision of Cooch Behar district of West Bengal. The Jaldhaka is known as Mansai at Mathabhanga subdivision of Cooch Behar district and Singimari at Dinhata subdivision in Cooch Behar district of West Bengal of India. The total length of the river is 192 km, among which 98 km is in the District.

Barilius bendelisis is a tropical freshwater species known locally as 'Boroli' and has economic importance because of the ornamental value and prospective food fish [2]. Tropical freshwater fish *Barilius bendelisis* [3] found in the Torsa, Teesta, Mansai (Jaldhaka), Raidak-1, and adjoining rivers of northern-West-Bengal, India. The *Barilius bendelisis* is beautiful silver-colored with bright blue bands having peaceful nature with barbles is considered as indigenous fish. *Barilius bendelisis* has been ranked as least concern IUCN *ver* 3.1 (last assessed 26 May 2021) [4] but in Himalayan drainages, it wants effective conservation actions [5]. According to the CAMP Report on freshwater fish of India, the conservation status of this Barilius species is indicated as 'Lower Risk near Threatened' (LRnt) [6].

The abundance of these hill touts is declining as a result of overfishing using non-scientific fishing practices (poisoning of stream water, electric current, hammering, etc.). However, despite economic and ecological importance, *Barilius bendelisis* is facing a rapid reduction in India, especially in eastern parts due to overfishing, habitat loss, hydrologic modification, and water pollution [7]. For example, in recent years, *Barilius bendelisis* has become infrequent in Torsa, Mansai (Jaldhaka), and Raidak-1 river at Cooch Behar region of West Bengal and adjoining rivers of northern-West Bengal, India [8].

The present status of the *Barilius bendelisis* is mainly because of the deterioration of the environment particularly, water quality which may be due to agricultural run-offs or pesticide effects of tea gardens and various anthropogenic activities in the Terai and Dooars regions of West Bengal,

[1]*Department of Chemistry, Tufanganj College, West Bengal 736160, India;*[2]*Department of Zoology, Tufanganj College, West Bengal 736160, India;*[3]*Department of Chemistry, Cooch Behar Panchanan Barma University, West Bengal 736101, India*

Correspondence: *Saha A, Department of Chemistry, Tufanganj College, West Bengal 736160, India, E-mail: abhisek.nbu@gmail.com*

Received: *15-Jun-2022, Manuscript No. AGBIR-22-67396;* **Editor assigned:** *17-Jun-2022, Pre QC No. AGBIR-22-67396 (PQ);* **Reviewed:** *01-Jul-2022, QC No. AGBIR-22-67396;* **Revised:** *06-Jul-2022, Manuscript No. AGBIR-22-67396 (R);* **Published:** *13-Jul-2022, DOI:10.35248/0970-1907.22.38.321-331*

India. In the northern region of West Bengal, India, Barilius species are regarded as a good choice for eating fish [9]. In the region of the present study occurrence of Barilius species is becoming low throughout the year.

Barilius bendelisis represent a vital part of the protein diet of the countryside human population residing in the neighborhood of the stream banks and the neighboring locality. Immediate rehabilitation of Barilius species is important from its extinction from the environment. *Barilius bendelisis* conservation will provide a permanent protein source for fishing people and other residents. Studying this species and its identification at the molecular level is in an urgent need. Therefore *Barilius bendelisis* were selected for this research study. Live fishes of *Barilius bendelisis* were collected from different sampling sites of Torsa, Raidak-1, and Mansai river of Cooch Behar district of West Bengal and immediately oxygen packed in sterile polythene bags and transported to the laboratory. The basin of these rivers sustains life and livelihoods of farmers, fishermen and slum-dwellers. Farmers consume the water resource for cultivation and drain off the utilized excess water which carries varieties of pesticides and fertilizers to that river [10,11]. The fishermen utilize the downstream of these rivers for fishing [12]. Slum-dwellers exploit the water resource for bathing, washing of cloths etc. Sewage from municipality, garbage from market directly discharges to this river. As a consequence the physical, chemical and biological characteristics of the river water are gradually changing and producing the harmful effect on aquatic biota and thereby human beings due to biomagnification. A quantity of physico-chemical variables of the water along with the abundance of the *Barilius bendelisis* were studied to get an adequate knowledge [13] of their oscillating rhythmic phenomena, and to throw a close insight into the environment of the system. A considerable quantity of research has been carried out on the physicochemical parameters of riverine water and their impact on aquatic biota in India [14-18]. However, this type of study has not been carried out in respect in Raidak-I river of West Bengal. The objectives of this study is to investigate physical and chemical properties of this river water in different seasons of the year and to examine the density and diversity of captured fin-fish resources from the river so as to find the relation in between the fish population with hydrological parameters to get a picture of the effect of pollution if any.

MATERIALS AND METHODS

Sampling site

Barilius bendelisis collected from fishermen landing at the bank of the Torsa, Raidak-1, Jaldhaka (Mansai) river of Cooch Behar district of West Bengal (Figure 1). It is necessary to document a comprehensive nutrient profile with a specific focus on popular Small Indigenous Species (SIS) *Barilius bendelisis* in Cooch Behar for pre-monsoon, monsoon and the post-monsoon period during the period of March 2018 to November 2019 in different spots of each river (Table 1). The collected fish samples were transported in an insulated icebox with a proper identification mark to the laboratory.

Figure 1) *Landscape visualization of the Torsa, Raidak-1, and Mansai (Jaldhaka) river systems' origins and networks, together with sampling locations*

TABLE 1

GPS location of sampling spots of *Barilius bendelisis*

River	Spot of fish and water sample collection	GPS Readings with height from sea level
Torsa river	ST1	26°21'27"N, 89°22'42"E, 158 ft
	ST2	26°17'13"N , 89°27'33"E, 122 ft
	ST3	26°15'5"N , 89°36'37"E, 109 ft
Raidak-1 river	SR1	26°21'07"N, 89°40'29"E, 122 ft
	SR2	26°18'39"N , 89°40'14"E,118 ft
	SR3	26°13'09"N , 89°41'37"E,104 ft
Jaldhaka (Mansai river)	SJ1	26°21'35"N, 89°13'31"E, 146 ft
	SJ2	26°19'10"N , 89°14'23"E, 157 ft
	SJ3	26°15'34"N, 89°15'59"E, 137 ft

Fishing techniques used for fishing in Torsa, Raidak-1, and Mansai (Jaldhaka) river

The fish were caught in the Torsa, Raidak-1, and Mansai (Jaldhaka) rivers at three different locations using a cast net (mesh size 6 mm × 6 mm) or a vessel net or Khara Jal (mesh size 6 mm × 6 mm.) and a gillnet (variable mesh sizes) and other conventional techniques with the support of trained local fishermen, as recommended [19,20].

Collection procedure of river water

Water samples were taken at three seasons of the year for physicochemical parameter analysis, which was done following [21], *viz*. pre-monsoon (March to May), monsoon (June to September), retreating monsoon (October to November). Random samples of water were collected from all sampling sites (Figure 1) used in the morning of the first week of every month between the periods of 6.30 am to 8.30 am. Nineteen Physico-chemical parameters were undertaken for a detailed investigation. The monthly average was calculated by combining all fifteen-day samples. All water samples were collected in duplicate form by two glass Dissolved Oxygen (DO) bottles with the capacity of 300 ml each and one large PVC (1 litter capacity) bottle. Immediately the water samples were transferred to the departmental laboratory for all physicochemical studies except the air, water temperature, pH, conductivity and Total Dissolved Solids (TDS). A simple mercury thermometer was used to measure the air temperature at 1 ft. above surface water and the water temperature was measured with the same thermometer by placing it inside the water at the depth of 1 ft. on the three sampling stations (Table 1). The depth of the water body was measured by a marked (in ft.) wooden stick at the time of sampling. Other physicochemical parameters were examined in the Chemistry laboratories of Tufanganj Mahavidyalaya in Cooch Behar and Cooch Behar Panchanan Barma University in Cooch Behar, India, except for BOD; all tests were performed on the same day as early as possible (within 2-3 hours).

Experimental procedures

Water quality: Water samples for Physico-chemical analysis of water were collected from the experimental areas at monthly intervals during the study period. All the Physico-chemical parameters have been analyzed using the standard method [22-24].

Statistical analysis: The statistical investigation was done utilizing SPSS 21, PAST 4.03, MS Excel 2007 software.

Ethical issues: The examination was as per the Declaration of Helsinki and guidelines on good clinical practice locally accessible. It was likewise endorsed by the institutional ethics board and morals committee [25].

RESULTS

Physico-chemical parameters of River Torsa at ST1, ST2, and ST3 were observed during 2018-2019, and the mean value of each parameter is calculated which is summarized in the following table (Tables 2-4).

Monthwise comparative study of average CPUE at different spots

Monthwise average CPUE of *Barilius bendilisis* at different sites of three rivers during the period of 2018-2019 was recorded. From the graphical representation, it is found that the average CPUE is maximum (Average CPUE=23) at ST1 of Torsa river in October and November and minimum (Average CPUE=4) at SR1 of Raidak-1 river in September (Figure 2).

From the graphical representation, it is found that the average CPUE is maximum (Average CPUE=4) at SJ2 in April, October, and November. At ST2, CPUE is also maximum in October and minimum (Average CPUE=1) at SR2 of Raidak-1 river in March and May. At ST2 also showed a minimum count in April and May and at SJ2 in August (Figure 3).

TABLE 2

Physico-chemical parameters of Torsa River at ST1, ST2, and ST3 during the period 2018-19

Water quality parameters(Average values of 2018 and 2019)	Pre-monsoon	Monsoon	Post-monsoon	Mean
AT(0C)_ST1	27	27	16	23.3
AT(0C)_ST2	26	26	14	22.0
AT(0C)_ST3	27.5	26	5.5	19.7
WT(0C)_ST1	28.2	29	19	25.4
WT(0C)_ST2	28	28	18	24.7
WT(0C)_ST3	27.9	27	18.2	24.4
Turbidity(NTU)_ST1	20	38	10	22.67
Turbidity(NTU)_ST2	29	63.3	13	35.10
Turbidity(NTU)_ST3	38	55	12	35.00
PH (Unit)_ST1	6.8	7.5	6.8	7.03
PH (Unit)_ST2	6.8	7.2	6.7	6.90
PH (Unit)_ST3	6.7	7	6.3	6.67
TDS(ppt)_ST1	0.03	0.03	0.03	0.03
TDS(ppt)_ST2	0.07	0.06	0.07	0.07
TDS(ppt)_ST3	0.06	0.04	0.03	0.04
TSS(ppt)_ST1	0.05	0.07	0.06	0.06
TSS(ppt)_ST2	0.06	0.4	0.07	0.18
TSS(ppt)_ST3	0.12	0.68	0.15	0.32
TS(ppt)_ST1	0.048	0.057	0.09	0.07
TS(ppt)_ST2	0.16	0.23	0.12	0.17
TS(ppt)_ST3	0.46	0.84	0.17	0.49
Depth(ft)_ST1	1.7	19	1.3	7.33
Depth(ft)_ST2	16	25	16	19.00
Depth(ft)_ST3	14.5	23	15.3	17.60
Conductivity(µs/cm)_ST1	40.6	73.6	36	50.07
Conductivity(µs/cm)_ST2	88	67	7.1	54.03
Conductivity(µs/cm)_ST3	54	44	47	48.33
DO(ppm)_ST1	6.4	7.2	4.2	5.93
DO(ppm)_ST2	5.6	6.1	3.65	5.12
DO(ppm)_ST3	5.18	5.02	3.4	4.53
F-CO2 (ppm)_ST1	5.85	5.92	6.47	6.08
F-CO2 (ppm)_ST2	7	5.2	5.8	6.00
F-CO2 (ppm)_ST3	9.15	5.6	6.7	7.15
BOD(ppm)_ST1	2	1.8	1.06	1.62
BOD(ppm)_ST2	3.2	1.02	1.3	1.84
BOD(ppm)_ST3	1.73	0.85	2.26	1.61
Nitrate(ppm)_ST1	0.39	0.25	0.18	0.27
Nitrate(ppm)_ST2	0.57	0.28	0.3	0.38
Nitrate(ppm)_ST3	0.52	0.33	0.26	0.37
Phosphate(ppm)_ST1	0.18	0.1	0.06	0.11
Phosphate(ppm)_ST2	0.28	0.1	0.11	0.16
Phosphate(ppm)_ST3	0.23	0.05	0.07	0.12
Chloride(ppm)_ST1	2.3	7.2	6.2	5.23
Chloride(ppm)_ST2	12.33	7.5	8.5	9.44
Chloride(ppm)_ST3	13	6.2	6.6	8.60
TH (ppm)_ST1	42.5	26.8	30.9	33.40
TH(ppm)_ST2	33	33	31.2	32.40
TH(ppm)_ST3	28.5	27.7	29.1	28.43
TA(ppm)_ST1	57.58	67	51	58.53
TA(ppm)_ST2	100	84	95	93.00
TA(ppm)_ST3	90	86	105	93.67

TABLE 3

Physico-chemical parameters of Mansai (Jaldhaka) River at SJ1, SJ2, and SJ3 where observed during 2018-2019

Water quality parameters (Average values of 2018 and 2019)	Pre-Monsoon	Monsoon	Post-Monsoon	Mean
AT(0C)_SJ1	26.5	27	26.4	26.6
AT(0C)_SJ2	26.4	27.3	16.3	23.3
AT(0C)_SJ3	27.5	26.8	15.6	23.3
WT(0C)_SJ1	27.5	24.9	28.5	26.9
WT(0C)_SJ2	28.5	23.6	19.7	23.9
WT(0C)_SJ3	26.7	28.1	18	24.2
Turbidity(NTU)_SJ1	23	34	33	30.00
Turbidity(NTU)_SJ2	33	54	12.5	33.17
Turbidity(NTU)_SJ3	34	57	12	34.33
PH (Unit)_SJ1	6.9	67	6.7	26.87
PH (Unit)_SJ2	6.7	6.9	6.5	6.70
PH (Unit)_SJ3	6.4	6.8	6.6	6.60
Total dissolved solid(ppt)_SJ1	0.02	0.03	0.07	0.04
Total dissolved solid(ppt)_SJ2	0.07	0.06	0.05	0.06
Total dissolved solid(ppt)_SJ3	0.12	0.02	0.04	0.06
Total suspended solid(ppt)_SJ1	0.02	0.04	0.05	0.04
Total suspended solid(ppt)_SJ2	0.05	0.6	0.04	0.23
Total suspended solid(ppt)_SJ3	0.38	0.53	0.06	0.32
Total solid(ppt)_SJ1	0.02	0.047	0.17	0.08
Total solid(ppt)_SJ2	0.17	0.27	0.14	0.19
Total solid(ppt)_SJ3	0.55	0.59	0.19	0.44
Depth(ft)_SJ1	1.7	19	17	12.57
Depth(ft)_SJ2	17	26	16.5	19.83
Depth(ft)_SJ3	14.4	22	17	17.80
Conductivity(µs/cm)_SJ1	35	85.1	84	68.03
Conductivity(µs/cm)_SJ2	84	68	36	62.67
Conductivity(µs/cm)_SJ3	53	43	52	49.33
DO(ppm)_SJ1	5.8	6.2	5.7	5.90
DO(ppm)_SJ2	5.7	5.03	3.3	4.68
DO(ppm)_SJ3	5.4	5.05	3.42	4.62
Free Carbon dioxide (ppm)_SJ1	5.29	5.99	7.6	6.29
Free Carbon dioxide (ppm)_SJ2	7.6	5.2	5.9	6.23
Free Carbon dioxide (ppm)_SJ3	8.8	5.4	6.75	6.98
BOD(ppm)_SJ1	2.2	2.1	3	2.43
BOD(ppm)_SJ2	3	1.01	1.8	1.94
BOD(ppm)_SJ3	2	0.83	2.08	1.64
Nitrate(ppm)_SJ1	0.39	0.22	0.65	0.42
Nitrate(ppm)_SJ2	0.65	0.32	0.31	0.43
Nitrate(ppm)_SJ3	0.46	0.31	0.2	0.32
Phosphate(ppm)_SJ1	0.047	0.11	0.27	0.14
Phosphate(ppm)_SJ2	0.27	0.09	0.15	0.17
Phosphate(ppm)_SJ3	0.2	0.09	0.06	0.12
Chloride(ppm)_SJ1	1.8	7	11.8	6.87
Chloride(ppm)_SJ2	11.8	7.1	8.5	9.13
Chloride(ppm)_SJ3	14	6	6.9	8.97
Total Hardness(ppm)_SJ1	41	25	35	33.67
Total Hardness(ppm)_SJ2	35	32	30.6	32.53
Total Hardness(ppm)_SJ3	28.9	27.1	26.5	27.50
Total alkalinity(ppm)_SJ1	47	68	100	71.67
Total alkalinity(ppm)_SJ2	100	87	96	94.33
Total alkalinity(ppm)_SJ3	97	88	94	93.00

TABLE 4

Physico-chemical parameters of Raidak-1 river at SR1, SR2, and SR3 were observed during 2018-2019

Water quality parameters (Average values of 2018 and 2019)	Pre-Monsoon	Monsoon	Post-Monsoon	Mean
AT(0C)_SR1	26.5	28	13	22.5
AT(0C)_SR2	26	26	15	22.3
AT(0C)_SR3	27	26	16	23.0
WT(0C)_SR1	28.1	28	15.6	23.9
WT(0C)_SR2	28	27	19	24.7
WT(0C)_SR3	27.9	28	18.5	24.8
Turbidity(NTU)_SR1	26.25	31	15	24.08
Turbidity(NTU)_SR2	29	63	14	35.33
Turbidity(NTU)_SR3	39	60	13	37.33
PH (Unit)_SR1	7.11	7.2	6.7	7.00
PH (Unit)_SR2	6.9	7.2	6.7	6.93
PH (Unit)_SR3	6.8	7.2	6.6	6.87
TDS(ppt)_SR1	0.03	0.03	0.065	0.04
TDS(ppt)_SR2	0.07	0.06	0.07	0.07
TDS(ppt)_SR3	0.05	0.03	0.04	0.04
TSS(ppt)_SR1	0.03	0.08	0.07	0.06
TSS(ppt)_SR2	0.06	0.4	0.07	0.18
TSS(ppt)_SR3	0.38	0.62	0.13	0.38
Total solid(ppt)_SR1	0.037	0.064	0.12	0.07
Total solid(ppt)_SR2	0.16	0.23	0.13	0.17
Total solid(ppt)_SR3	0.6	0.92	0.27	0.60
Depth(ft)_SR1	1.4	18	1.5	6.97
Depth(ft)_SR2	17	25	16	19.33
Depth(ft)_SR3	13	23	16	17.33
Conductivity(µs/cm)_SR1	41	92	36	56.33
Conductivity(µs/cm)_SR2	88	67	71	75.33
Conductivity(µs/cm)_SR3	53	44	53	50.00
DO(ppm)_SR1	5.79	7	4.21	5.67
DO(ppm)_SR2	5.6	5.96	3.65	5.07
DO(ppm)_SR3	4.88	5.3	3.39	4.52
F-CO2 (ppm)_SR1	5.63	6.06	6.54	6.08
F-CO2 (ppm)_SR2	7.1	5.2	5.9	6.07
F-CO2 (ppm)_SR3	8.9	5.4	6.86	7.05
BOD(ppm)_SR1	1.9	2.7	0.98	1.86
BOD(ppm)_SR2	3.2	1.02	1.1	1.77
BOD(ppm)_SR3	1.6	0.81	1.79	1.40
Nitrate(ppm)_SR1	0.38	0.22	0.17	0.26
Nitrate(ppm)_SR2	0.57	0.29	0.33	0.40
Nitrate(ppm)_SR3	0.47	0.36	0.21	0.35
Phosphate(ppm)_SR1	0.062	0.12	0.06	0.08
Phosphate(ppm)_SR2	0.28	0.1	0.13	0.17
Phosphate(ppm)_SR3	0.2	0.04	0.05	0.10
Chloride(ppm)_SR1	2.2	7	5.7	4.97
Chloride(ppm)_SR2	12	7.5	8.5	9.33
Chloride(ppm)_SR3	12	5.6	7	8.20
TH(ppm)_SR1	37	27.4	30.2	31.53
TH(ppm)_SR2	32	33	31.3	32.10
TH(ppm)_SR3	29	26.9	28.4	28.10
TA(ppm)_SR1	54	72	70	65.33
TA(ppm)_SR2	101	85	96	94.00
TA(ppm)_SR3	99.9	76	92	89.30

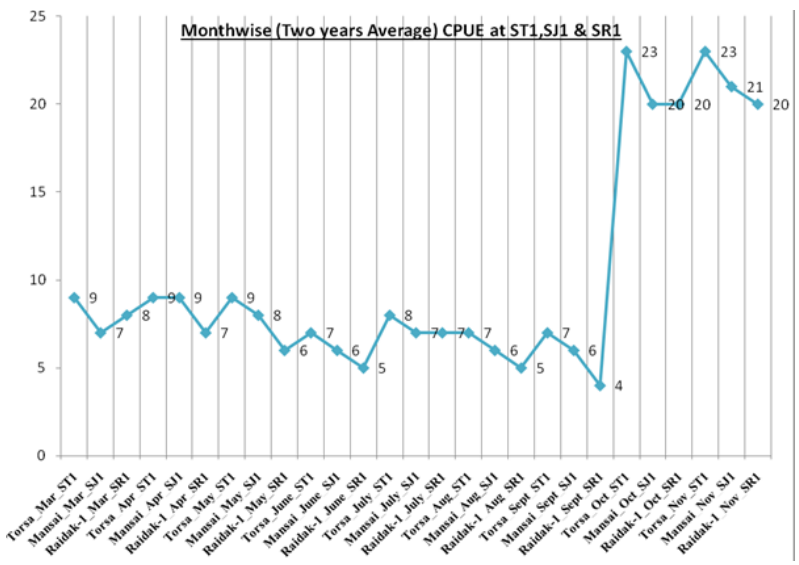

Figure 2) *Graphical representation of months' average CPUE of Barilius bendelisis at ST1, SJ1, and SR1*

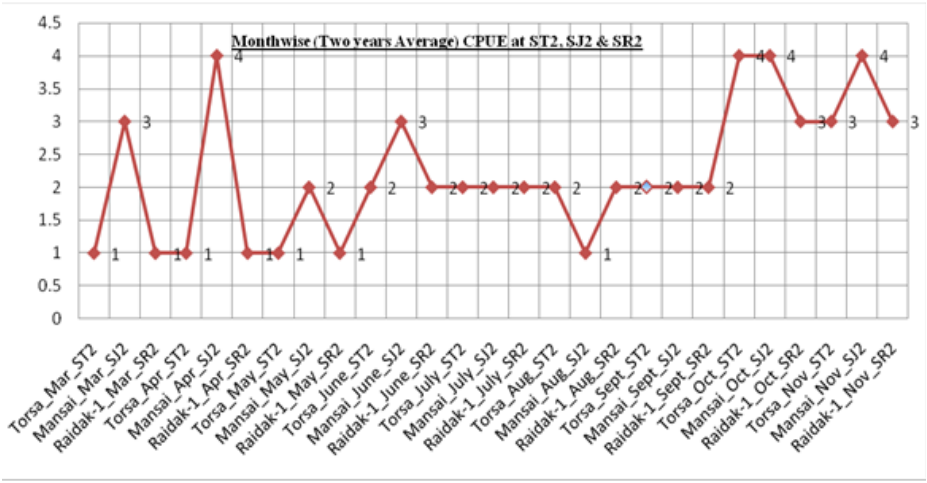

Figure 3) *Graphical representation of months' average CPUE of Barilius bendelisis at ST2, SJ2, and SR2*

From the graphical representation, it is found that the average CPUE is maximum (Average CPUE=21) at ST3 of Torsa river in November and minimum (Average CPUE=3) at SR3 of Raidak-1 river in July and September (Figure 4).

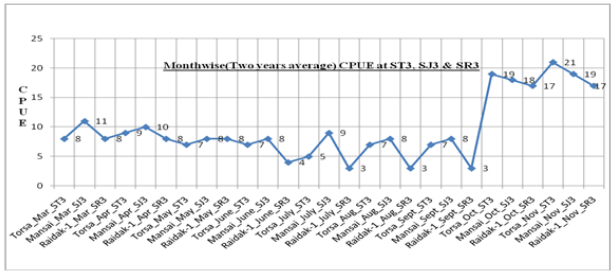

Figure 4) *Graphical representation of months' average CPUE of Barilius bendelisis at ST3, SJ3, and SR3*

Among the three rivers average CPUE (23) is maximum at ST1 of Torsa River in October and CPUE (1) is minimum at ST2 of Torsa River in March, April, and May whereas the same value was obtained for the Raidak-1 River at SR2 in March and May and SJ2 of Mansai river in August.

Statistical analysis on physico-chemical parameters of Torsa, Raidak-1, and Mansai (Jaldhaka) river with CPUE of *Barilius bendelisis.*

Two way factorial ANOVA: To explain observed s in CPUE for both sampling years (2018 and 2019), the data were treated to a two-way factorial ANOVA with sampling sites and seasons (Pre-monsoon, monsoon, and post-monsoon) as predictor variables. Results suggested that the CPUE of *Barilius bendelisis* varied significantly with the variables at the $P<0.05$ level. All F values are significant at the $P<0.05$ level.

Limnology correlation (2018 and 2019): Limnology Correlation was calculated for two consecutive years and represented below (Tables 5 and 6). Correlation is significant at the 0.01 level (2-tailed). And Correlation is also significant at the 0.05 level (2-tailed) in both years.

Regression analysis on limnology: Further, both the year's data (2018 and 2019) were also subjected to regression analysis concerning Physico-chemical parameters *viz.* Air temperature, Water temperature, Turbidity, pH, TDS, TSS, Total solid, Depth, Conductivity, DO, Free CO_2, BOD, Nitrate, Phosphate, Chloride, Total hardness, and Total alkalinity and abundance CPUE of *Barilius bendelisis* (Figures 5 and 6).

TABLE 5

The correlation matrix for Physico-chemical parameters based on limnology data collected in 2018

	AT	WT	TURB	pH	TDS	TSS	TS	DEPTH	CON	DO	Free CO_2	BOD	NITRATE	PHOSPHATE	CHLORIDE	TH
WT	.495**															
TURB	.362**	.479**														
pH	-0.02	0.04	-0.03													
TDS	-0.1	-0.07	.162*	.346**												
TSS	-0.01	0.01	0.06	.970**	.517**											
TS	0.08	0.1	.193*	.727**	.243**	.765**										
DEPTH	.305**	.223**	.591**	-0.1	-0.06	-0.04	.159*									
CON	.337**	.365**	.223**	0	-0.01	-0.02	-0.13	.403**								
DO	.501**	.613**	.327**	0.03	-0.05	-0.01	-0.14	0.11	.442**							
Free CO_2	-0.04	0.03	-.225**	-0.05	-0.03	-0.06	0	-0.169*	0.12	-0.05						
BOD	0.09	.236**	-.244**	0.08	0.09	0.03	-0.15	-0.171*	.428**	.206**	.315**					
NITRATE	.240**	.410**	0.11	-0.02	-0.03	-0.02	0.05	0.02	.225**	.271**	.478**	.360**				
PHOSPHATE	.195*	.379**	0.03	0.08	0.11	0.07	-0.03	0.05	.384**	.228**	.444**	.534**	.604**			
CHLORIDE	0.06	0.12	0.09	0.08	0.14	0.11	0.12	.281**	.346**	-0.01	.620**	.297**	.383**	.634**		
TH	0.01	.176*	0	0.01	-0.03	-0.02	-0.158*	-0.308**	-0.03	.204**	0.02	.227**	.404**	.184*	-.167*	
TA	-0.06	-0.03	0.1	-0.03	0.13	0.04	.171*	.461**	.174*	-.320**	.331**	.191*	.270**	.406**	.587**	-0.09

Note: **. Correlation is significant at the 0.01level (2-tailed).

TABLE 6

The correlation matrix for Physico-chemical parameters based on limnology data collected in 2019

	AT	WT	TURB	pH	TDS	TSS	TS	DEPTH	CON	DO	Free CO_2	BOD	NITRATE	PHOSPHATE	CHLORIDE	TH
WT	0.896**															
TURB	0.542**	.524**														
pH	-0.09	-0.01	-0.04													
TDS	-0.02	0.04	0.09	.483**												
TSS	-0.07	0.01	0.04	.980**	.519**											
TS	0.04	0.1	.186*	.726**	.337*	.769**										
DEPTH	-.334**	.243**	0.576**	-0.09	0.04	-0.01	0.15									
CON	.398**	.300**	0.12	-0.07	-0.01	-0.1	-0.214**	.428**								
DO	.641**	.586**	.361**	-0.07	0.02	-0.08	-0.204**	0.15	.421**							
Free CO_2	0.01	0	-0.204**	0.01	-0.03	-0.01	0.07	-0.156*	0.1	-0.06						
BOD	0.196*	.207**	-0.234**	0.11	0	0.03	-0.13	-0.14	.495**	.250**	.324**					
NITRATE	.312**	.364**	0.09	-0.01	-0.01	0	0.07	-0.02	.158*	.238**	.463**	.360**				
PHOSPHATE	.283**	.303**	-0.05	-0.1	-0.03	-0.13	-0.15	0.02	.408**	.241**	.462**	.529**	.553**			
CHLORIDE	0.14	0.13	0.08	-0.12	-0.05	-0.11	0.01	.258**	.346**	-0.01	.603**	.307**	.375**	.639**		
TH	0.07	0.14	0.01	0.11	0.12	0.09	-0.12	-0.381**	-0.13	.181*	-0.04	.196*	.351**	0.09	-0.232**	
TA	-0.05	-0.01	0.09	0.01	0.06	0.05	.194*	.456**	.196*	-0.320**	.342**	.176*	.256**	.398**	.611**	-0.179*

Note:** . Correlation is significant at the 0.01level (2-tailed), *. Correlation is significant at the 0.05level (2-tailed).

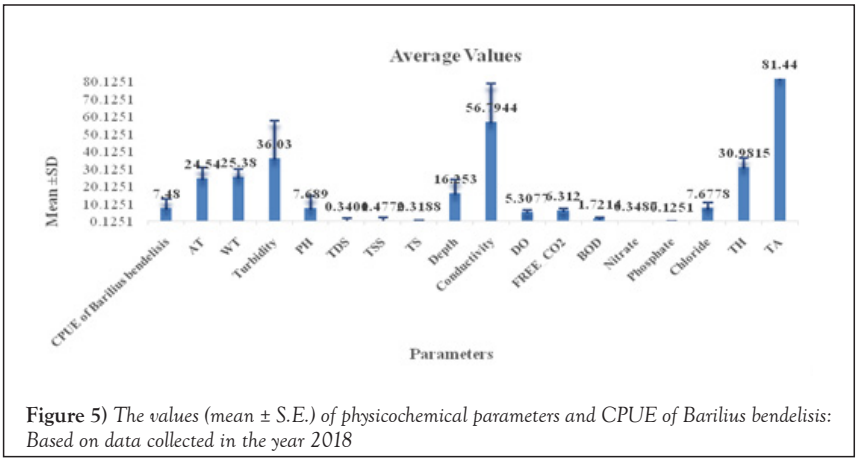

Figure 5) *The values (mean ± S.E.) of physicochemical parameters and CPUE of Barilius bendelisis: Based on data collected in the year 2018*

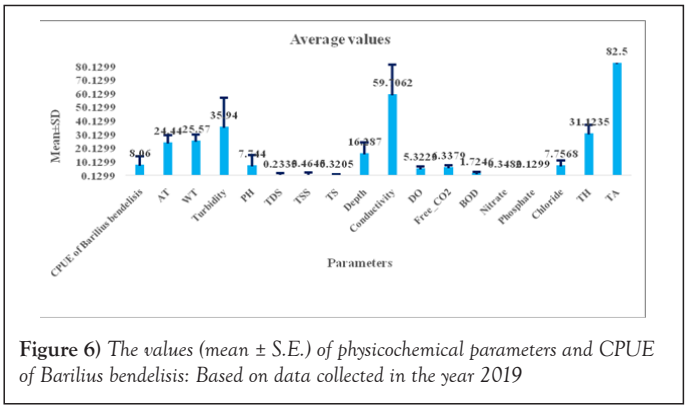

Figure 6) *The values (mean ± S.E.) of physicochemical parameters and CPUE of Barilius bendelisis: Based on data collected in the year 2019*

The model suggests for the year 2018, R-value, R Square, Adjusted R Square is, Std. Error of the Estimate and the value of Durbin-Watson was 0.821, 0.673, 0.635, 3.476, 1.132 respectively. The model suggests for the year 2019, R-value, R Square, Adjusted R Square, Std. Error of the Estimate and the value of Durbin-Watson was 0.818, 0.670, 0.631, 3.714 and 1.239 respectively. R square values for both the years considered a moderate effect size. The value of Durbin-Watson is below 2, it generally indicates a positive autocorrelation.

Coefficients calculation: Unstandardized Coefficients and Standardized Coefficients were calculated in two consecutive years. From Collinearity Statistics, Tolerance and VIF were also calculated for AT, WT, Turbidity, pH, TDS, TSS, TS, Depth, Conductivity, DO, Free CO_2, BOD, Nitrate, Phosphate, Chloride, TH, TA. The degree of interrelation among the Physico-chemical parameters with abundance CPUE of *Barilius bendelisis* is represented through, the Pearson correlation matrix (Tables 7 and 8).

TABLE 7

The degree of interrelation (Pearson correlation matrix) among the Physico-chemical parameters and abundance (CPUE) of *Barilius bendelisis*: Based on the year 2018

CPUE of *Barilius bendelisis*	AT	WT	TURB	pH	TDS	TSS	TS	DEPTH	CON	DO	Free CO_2	BOD	NITRATE	PHOSPHATE	CHLORIDE	TH
- 0.05																
-0.53	0.50															
-0.43	0.36	0.48														
0.09	-0.02	0.04	-0.03													
0.08	-0.10	-0.07	0.16	0.35												
0.08	-0.10	0.01	0.06	0.97	0.52											
0.01	0.08	0.10	0.19	0.73	0.24	0.77										
-0.57	0.31	0.22	0.59	-0.10	-0.06	-0.04	0.16									
-0.38	0.34	0.37	0.22	0.00	-0.01	-0.02	-0.13	0.40								
-0.36	0.50	0.61	0.33	0.03	-0.05	-0.01	-0.14	0.11	0.44							
0.15	-0.04	0.03	-0.22	-0.05	-0.03	-0.06	0.00	-0.17	0.12	-0.05						
-0.14	0.09	0.24	-0.24	0.08	0.09	0.03	-0.15	-0.17	0.43	0.21	0.31					
-0.36	0.24	0.41	0.11	-0.02	-0.03	-0.02	0.05	0.02	0.23	0.27	0.48	0.36				
-0.33	0.19	0.38	0.03	0.08	0.11	0.07	-0.03	0.05	0.38	0.23	0.44	0.53	0.60			
-0.22	0.06	0.12	0.09	0.08	0.14	0.11	0.12	0.28	0.35	-0.01	0.62	0.30	0.38	0.63		
-0.11	0.01	0.18	0.00	0.01	-0.03	-0.02	-0.16	-0.31	-0.03	0.20	0.02	0.23	0.40	0.18	-0.17	
-0.24	-0.06	-0.03	0.10	-0.03	0.13	0.04	0.17	0.46	0.17	-0.32	0.33	0.19	0.27	0.41	0.59	-0.09

TABLE 8

The degree of interrelation (Pearson correlation matrix) among the Physico-chemical parameters and abundance (CPUE) of *Barilius bendelisis*: Based on the year 2019

	CPUE of *Barilius bendelisis*	AT	WT	TURB	pH	TDS	TSS	TS	DEPTH	CON	DO	Free CO_2	BOD	NITRATE	PHOSPHATE	CHLORIDE	TH
AT	-.600																
WT	-.563	.896															
TURB	-.460	.542	.524														
pH	.096	-0.89	-.010	-.036													
TDS	-.003	-.024	.037	.088	.483												
TSS	.071	-.066	.010	.039	.980	.591											
TS	.026	.036	.097	.186	.726	.337	.769										
DEPTH	-.539	.334	.243	.576	-.088	.042	-.014	.148									
CON	-.433	.398	.300	.124	-.072	-.088	-.099	-.214	.428								
DO	-.385	.641	.586	.361	-.068	.018	-.085	-.204	.145	.421							
Free CO_2	.185	.010	-.003	-.204	.013	-.026	-.008	.068	-.156	.104	-.063						
BOD	-.112	.196	.207	-.234	.108	-.004	.067	-.016	.158	.238	.463	.360					
NITRATE	-.345	.312	.364	.089	-.005	-.010	-.004	.067	-.016	.158	.238	.463	.360				
PHOSPHATE	-.294	.283	.303	-.050	-.100	-.026	-.127	-.149	.019	.408	.241	.462	.529	.553			
CHLORIDE	-.194	.137	.127	.079	-.117	-.045	-.115	.011	.258	.346	-.012	.603	.307	.375	.639		
TH	-.102	.072	.141	0.09	.105	.121	.089	-.116	-.381	.126	.181	.038	.196	.351	.091	-.232	
TA	-.180	-.051	-.008	.090	.014	.058	.051	.194	.456	.196	-.320	.342	.176	.256	.398	.611	-.179

Collinearity diagnostics: Collinearity Diagnostics were done in two consecutive years. For the two consecutive years, several eigenvalues are near zero, suggesting that the predictor variables are highly correlated. The following equation revealed the relationship: y=1/(1+exp (–(a+b1 × 1–b2 × 2 – b3 × 3 – b4 × 4 – b5 × 5 – b6 × 6 – b7 × 7 – b8 × 8 – b9 × 9 – b10 × 10 – b11 × 11 – b12 × 12 – b13 × 13 – b14 × 14 – b15 × 15 – b16 × 16 – b17 × 17))); where y represents the CPUE of *Barilius bendelisis*,×1 to ×17 denotes all the above mentioned physico-chemical parameters.

DISCUSSION

The abundance of *Barilius bendelisis* in the Torsa river at three spots in three seasons was observed in two consecutive years in terms of CPUE of the fishes and at ST1, CPUE in the pre-monsoon, monsoon, and post-monsoon period was in the range (7-12), (4-10) and (20-25) respectively. At ST2, CPUE in the pre-monsoon, monsoon, and post-monsoon period was in the range (1-4), (2-4), and (3-5) respectively. At ST3, CPUE in the pre-monsoon, monsoon, and post-monsoon period was in the range (6-10), (5-8), and (18-22) respectively. The abundance of *Barilius bendelisis* in Mansai (Jaldhaka) river at three spots in three seasons was observed in two consecutive years in terms of CPUE of the fish and at SJ1, CPUE in the pre-monsoon, monsoon, and post-monsoon period was in the range (6-10), (5-9) and (20-22) respectively. At SJ2, CPUE in the pre-monsoon, monsoon, and post-monsoon period was in the range (2-6), (1-5), and (3-6) respectively. At SJ3, CPUE in the pre-monsoon, monsoon, and post-monsoon period was in the range (6-12), (6-11), and (15-25) respectively. The abundance of *Barilius bendelisis* in Raidak-1 river at three spots in three seasons was observed in two consecutive years in terms of CPUE of the fish and at SR1, CPUE in the pre-monsoon, monsoon, and post-monsoon period was in the range (6-9), (4-8) and (19-22) respectively. At SR2, CPUE in the pre-monsoon, monsoon, and post-monsoon period was in the range (1-2), (2-4), and (2-4) respectively. At SR3, CPUE in the pre-monsoon, monsoon, and post-monsoon period was in the range (7-10), (2-5), and (16-19) respectively. For the first year (2018), the value of the correlation coefficient (r) was found highest between pH and Total suspended solid (r=0.97), followed by that of Total suspended solid and Total solid (r=0.77) and pH and Total solid (r=0.73). However, for the subsequent year (2019), r was found to be highest between pH and Total suspended solid (r=0.98) followed by Air temperature and Water temperature (r=0.89) and Total suspended solid and Total solid (r=0.77) All these values were positively significant at 0.01 level (2 tailed).

CONCLUSION

The water quality parameters that were considered in the present observation were found within the range of standard limit for the survival of fishes and also within the range of drinking water standard with some limitations. Among the study sites, ST2, SR2, SJ2 were identified as the polluted sites out of the nine observation sites during the period of study. Anthropogenic activities might be responsible for the deterioration of the above-mentioned polluted sites. The results of the present study are based upon the observations (n=54) carried out through field sampling between March 2018 to November 2019, and expressed as Catch Par Unit Effort (CPUE). To explain observed changes in CPUE for both sampling years, the data were treated to a two-way factorial ANOVA with sampling locations and seasons as predictor variables. Results suggested that the CPUE varied significantly with the variables at the $P<0.05$ level. In cases where the variables did not vary significantly, it may be attributed to the independent/interdepend variation of the variables. Further, both the years' data were also subjected to regression analysis concerning Physico-chemical parameters *viz*. Air temperature, Water temperature, Turbidity, pH, TDS, TSS, Total solid, Depth, Conductivity, DO, Free CO_2, BOD, Nitrate, Phosphate, Chloride, Total hardness, and total alkalinity

ACKNOWLEDGEMENTS

The authors acknowledge the Head, Department of Chemistry, Cooch Behar Panchanan University, Cooch Behar-736101 and Principal, Tufanganj College, Cooch Behar-736160 for providing necessary laboratory facilities for carrying out the research work. We are also thankful to Dr.Soumyajit Banerjee from the Department of Zoology, Serampore College, Hooghly, West Bengal for helping in statistical work. It is our great pleasure to express sincere thanks to Prof. Goutam Kumar Saha, Department of Zoology, University of Calcutta. We are also thankful to Prof. Ashis Kumar Saha, Remote Sensing-GIS from the Universty of Delhi for his help to create the location map of sampling.

CONFLICT OF INTEREST

The authors declare that they have no actual and potential conflict of interest.

REFERENCES

1. Majumdar, S.C (1942): Rivers of the Bengal Delta, University of Calcutta. Kolkata, India.
2. Mishra AK, Lakra WS, Bhatt JP, et al. Genetic characterization of two hill stream fish species *Barilius bendelisis* (Ham. 1807) and Barilius barna (Ham. 1822) using RAPD markers. Molecular biology reports. 2012; 39(12):10167-10172.
3. Hamilton F. An account of the fishes found in the river Ganges and its branches. Archibald Constable; 1822.
4. Vishwanath W. (Manipur University (Eastern Himalayas). (2010, January 22). The IUCN Red List of Threatened Species.
5. Kurup, B. M., Radhakrishnan, K. V., & Manojkumar, T. G. (2004). Biodiversity status of fishes inhabiting rivers of Kerala (S. India) with special reference to endemism, threats and conservation measures. In R. L. Welcomme, & T. Peter (Eds.), Proceedings of the second internationalsymposium on the management of large rivers for fisheries (Vol. 2, pp. 11-14) February, 2003, Phnom Penh, Kingdom of Cambodia: RAP Publication.
6. Molur S, Walker S. Report of the Workshop on Conservation assessment and management plan for freshwater fishes of India.
7. Paul A, Mukhopadhyay T, Bhattacharjee S. Genetic characterization of Barilius barna (Hamilton, 1822) in the Teesta river of sub-Himalayan West Bengal, India, through RAPD and ISSR fingerprinting. Proc Zool Soc. 2018: 203-212.
8. Saha A, De GC, Das D. Biochemical study of indigenous *Berilius Sp.* in relation to physico-chemical properties of water of international transboundary river at downstream. Ann Romanian Soc. Cell Biol. 2021:3849-3858.
9. Sarkar T. Coldwater fish diversity and their conservation status in the Teesta, Jaldhak, Torsa, Kaljani and Sankosh Rivers of the Dooars region, West Bengal, India. Asian J Conserv Biol. 2021; 10(1):146-152.
10. Ray PC. Life and experience of a Bengali chemist, II. Reprinted by Asiatic Society (1996), Kolkata. 1932:159-160.
11. Rudra K. Rivers of West Bengal/Dying, Living. Ramaswamy R. Iyer. Oxford, New Delhi. 2015:188-204.
12. Willcocks W. Lectures on the ancient system of irrigation in Bengal.
13. Barat S, Jha P. Changes in the water quality and total coliform bacterial load in a streach of River Mahananda at Siliguri city, West Bengal, India. Asian J Microbiol Biotech Env. Science. 2002; 4(4):571-575.
14. Adebisi A. A. (1980): The physico-chemical hydrology of a season and tropical upper Oyun River. Hydrobiologia. 79:157-165.
15. Barat S, Jha P. Changes in the water quality and total coliform bacterial load in a streach of River Mahananda at Siliguri city, West Bengal, India. Asian J Microbiol Biotech Env Science. 2002; 4(4):571-575.
16. Dhanapakiam P, Sampoorani V, Kavitha R. Assessment of water quality of the river Cauvery. Journal of Environmental Biology. 1999; 20(4):374-452.
17. Pande RK, Rawat DS, Pant A. Seasonal rhythm in the physico-chemical properties of Nana Kasi river (Kumaun Himalaya) In: RK Trivedy (ed.) Ecology and pollution in Indian rivers. Ashish Pub. House, New Delhi, India. 1988:209-218.
18. Dey A, Sarkar K, Barat S. Evaluation of fish biodiversity in rivers of three districts of eastern Himalayan region for conservation and sustainability. Int J Appl Res. 2015; 1(9):424-435.
19. Das D. Ichthyofaunal diversity of River Torsa and its tributaries at Terai region of West Bengal, India. Int J Sci Nature. 2015; 6(2):256-263.
20. Paul A, Das D. Ornamental Fishes of Coochbehar District of West Bengal, India. International Journal of Science and Research. 2016; 5(11):1827-1832.

21. Borthakur M. Weather and climate of north east India. The Northeast Geographer. 1986; 18(1):20-27.

22. Federation WE, Aph Association. Standard methods for the examination of water and wastewater. American Public Health Association (APHA): Washington, DC, USA. 2005; 21.

23. APHA, (2012). Standard methods for the examination of water and waste water. 22nd Edition, American Public Health Association, American Water Works Association, Water Environment Federation.

24. Trivedy RK, Goel PK. Chemical and biological methods for water pollution studies. Environmental publications; 1984.

25. Declaration of Helsinki. Amended by World Medical Assembly, Venice, Italy, 1964 and 1983. BMJ.