

Original Research

DOI : <http://doi.org/10.22438/jeb/44/4/MRN-5036>

Seasonal variation of Ichthyofaunal diversity and it's relation with substratum in the River Changa, West Bengal, India

T. Sarkar^{*}, B.K. Das, M. Das and P.K. Roy

Department of Zoology, Raiganj University, Raiganj-733 134, India

^{*}Corresponding Author Email : tapan.ruzoo@gmail.com^{*}ORCID: <https://orcid.org/0000-0001-9581-9374>

Received: 25.03.2022

Revised: 16.06.2022

Accepted: 17.01.2023

Abstract

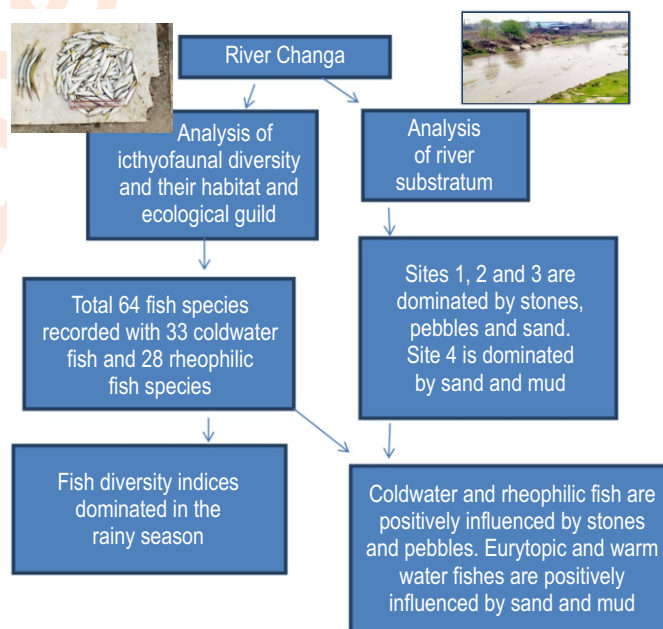
Aim: A survey was conducted at four sampling sites of the River Changa to study the fish diversity in relation to river substratum. The aim of the study was to prepare a check list of ichthyofaunal diversity and their habitat preference guild in relation to sediment type.

Methodology: Ichthyofauna was collected from four selected stations at monthly interval with the help of fishermen using gill net and cast net. For the analysis of the riverine substratum, sediment samples were collected from six square inches area at the sampling sites of the river by grab sampling method. The composition of stones, pebbles, sand and mud were evaluated from the sample.

Results: A total of 64 fish species belonging to 6 families and 18 orders were recorded. Among which 33 were cold water fishes, 31 were warm water fishes, 28 were rheophilic and 24 were eurytopic fishes. Site 1 and 2 were dominated by rheophilic and cold water fishes and Site 4 was rich in eurytopic and warm water fishes. Cypriniformes was the most dominant order with 42 fish species. River sediment of Site 1, 2 and 3 were dominated by stones, pebbles and sand, while sediments collected from Site 4 was dominated by sand and mud. Cold water and rheophilic fishes were positively influenced by stones and pebbles. Eurytopic and warm water fishes were positively influenced by sand and mud.

Interpretation: Cold water and rheophilic fishes were abundant at upstream of the river and eurytopic and warm water fishes were abundant at downstream of the river. Abundance and distribution of fish species depends on the river substratum.

Key words: Ichthyofaunal diversity, Rheophilic, River Changa, River substratum



How to cite : Sarkar, T., B.K. Das, M. Das and P.K. Roy: Seasonal variation of Ichthyofaunal diversity and it's relation with substratum in the River Changa, West Bengal, India. *J. Environ. Biol.*, **44**, 602-611 (2023).

Introduction

The Terai region of West Bengal is adjacent to the Eastern Himalayan biodiversity hotspot and is rich in biodiversity, particularly fish diversity. River Mahananda and its tributaries are home to many indigenous and cold water fishes. Barman (2007) described North Bengal as a 'Hot spot' for freshwater fish species because of its rich endemic fish species. Freshwater fish are the most threatened group of vertebrates on the earth after amphibians (Barton, 1995). India contributed about 11% of total world fish germplasm (Sinha, 1998). The fish diversity in the Terai region is highly distinctive because this region is crisscrossed by many small torrential streams and rivers that originate from the Himalayas. Fish are important sources of food and serve as indicators of the ecological health of river water. River Changa is a charming river in the Terai region and originates from the Himalayas. It is a tributary of the River Mahananda, and all the rivers in the Terai region are part of the Ganga drainage system. It has a continuous flow of water throughout the year. The riparian vegetation of this river includes forest, tea garden, agricultural field, and human settlement. Study of the ecological guilds of fish species is an important method to assess the functioning of river systems (Aarts and Nienhuis, 2003).

The rate of biodiversity loss is gradually increasing day by day, and demands biodiversity survey at a grass-root level (Smith et al., 2003). Small rivers and hill streams of this area harbour great fish diversity with meagre documentation. Freshwater fish diversity all over the world is decreasing at a greater pace because fish are highly sensitive to change in the aquatic habitats (Laffaille et al., 2005). Many ichthyologists have worked on fish diversity of the Terai region such as Shaw and Shebbeare (1937), Hora and Gupta (1941), Paul (2009), Acherjee and Barat (2013), and Sarkar and Pal (2008). Acherjee and Barat (2011) recorded 25 rheophilic cold water fish species from the hill stream Relli, Darjeeling district. Patra et al. (2011) recorded a total of fifty five fish species from the River Karala, a tributary of the River Teesta. Seven species of cat fish belonging to six genera and six families were reported from the River Karala (Patra et al., 2011).

Bandyopadhyaya and Mondal (2014) found a total of 78 fish species that belonged to 21 families in the River Teesta, Torsa, Kaljani, Radak-I, Radak-II, Sankosh in the Dooars region. Das (2015) recorded 105 fish species belonged to nine orders and 29 families in the River Torsa and its tributaries. Dey et al. (2015) observed a total of 113, however, fish species belonged to 28 families in the River Jaldhaka, no such study on fish diversity and its relation with river substratum were done in this river. In light of the above, this study was conducted to prepare a check list of ichthyofaunal diversity and their seasonal variation. Further, the sediment composition and their percentage and relationship to fish diversity was also determined.

Materials and Methods

Sampling sites: An ichthyofaunal survey was conducted from

March 2017 to February 2019 in the River Changa. Four sampling sites: Belgachhi (site 1), Atal (site 2), Ghoshpukur (site 3) and Thakurganj (site 4) were selected for the study and sampling was done at monthly interval with the help of fishermen. Gill net and cast net were used during survey. The gill net was 10 ft. long and 3 ft. high with a mesh size of 2 cm. The area covered by caste 78 sq. ft. with a mesh size of 1cm. Ten hauls were taken from each sampling site during each sampling time with a cast net. The collected fishes were photographed by a digital camera (Canon SX160) and then preserved in 8% formalin.

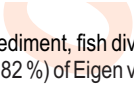
Fish species were identified up to the species level following the keys of Shaw and Shebbeare (1937), Day (1873), Sen (1992), Jayaram (2010). Water temperature was measured with a mercury thermometer. Sediment samples were analysed by the method proposed by Burton and Landrum (1993), using an Eckman grab sampler. A six square inch area of river bottom was selected for collecting sediments from the sampling sites with a sediment grab sampler. From each site, three samples were collected at a time, packed in a plastic bags and brought to the laboratory. The collected sediment samples were then air dried, stones were separated by hand and pebbles, mud and sand were separated through sieving. Later, the percentage of different components of the substratum were estimated by weighing pebbles, mud and sand. For seasonal analysis, March to June is considered as summer, July to October as rainy season and November to February as winter. ANOVA, Shannon diversity index, evenness index, Margalef's richness index, Dominance index and Principal component analysis (PCA) were carried out with the PAST 3.0 software (Hammer et al., 2001).

Results and Discussion

In total 64 fish species under 6 families and 18 orders were reported during the study period. 50, 51, 47 and 35 fish species were found from sites 1, 2, 3 and 4 respectively during the study period. The most dominant order was Cypriniformes with 42 species, followed by Siluriformes with 10 species, Perciformes with 8 species, Synbranchiformes with 2 species and Cyprinodontiformes and Beloniformes with one species each (Fig. 1). The most dominant family was Cyprinidae with 32 species, followed by Balitoridae, Cobitidae and Sisoriidae with 4 species, Channidae with 3 species, Mastacembelidae, Psilorhynchidae, Nandidae and Olyridae with 2 species, Belonidae, Aplocheilidae, Gobiidae, Chacidae, Anabantidae, Heteropneustidae, Clariidae, Bagridae and Amblycipitidae 1 species each (Table 1).

The most dominant fish species were *Barilus* spp., *Psilorhynchus balitora*, *Schistura* spp. *Garra* spp., etc., at Sites 1 and 2, however, at Sites 3 and 4 the most dominant fish species were *Channa* spp., *Esomus danricus*, *Danio rerio* and *Danio dangila*. Two exotic fish species, *Puntius javanicus* and *Cyprinus carpio* were encountered at Site 4 during the rainy season and have become a great warning of fish diversity for the future. These exotic fish species compete with the indigenous fish species for their food and habitat (Barman, 2007). Exotic fish runoff from the

Fig. 1: Percent coposition of fish order reported in River Changa.



species that belonged to 11 orders, and 31 families from the river Teesta. Patra *et al.* (2011) reported a total of 65 fishes from the river Karola. Lalramilana *et al.* (2020) recorded 50 fish species from the Dampa Tiger Reserve, which were fewer than those reported in the present study. Fish species found in this river showed some modification like *Barilius* spp. that inhabit transparent and cold waters at the study Sites lack modifications

species that belonged to 11 orders, and 31 families from the river Teesta. Patra *et al.* (2011) reported a total of 65 fishes from the river Karola. Lalramilana *et al.* (2020) recorded 50 fish species from the Dampa Tiger Reserve, which were fewer than those reported in the present study. Fish species found in this river showed some modification like *Barilius* spp. that inhabit transparent and cold waters at the study Sites lack modifications



Fig. 3: A-*Psilorhynchus sucatio*, B-*Schistura savona*, C-*Garra maclellanei*, D-*Chagnious chagunio*, E-*Amblyceps mangois*, F-*Garagotyla*, G-*Crossocheilus latia*, H-*Barilus barna*, I-*Badis badis*, J-*Acanthocobitis botia*, K-*Labeoboga*, L-*Garra lamta*, M-*Barilus bendelisis*, N-*Barilus bola*, O-*Pseudolaguvia shawi* and P-*Labeo dyocheilus*.

Table 1: Check list of ichthyofaunal diversity along with its habitat preference guild at four sampling sites of River Changa.

Order	Family	Fish species found	FPG	WTP	Site-1	Site-2	Site-3	Site-4
Cypriniformes	Balitoridae	<i>Aborichthys elongates</i> (Hora) Fd, Or	RH	CW	+	+	+	-
		<i>Acanthocobitis botia</i> (Hamilton) Fd, Or	RH	CW	+	+	+	-
		<i>Schistura rupecula</i> (McClelland) Fd, Or	RH	CW	+	+	+	+
		<i>Schistura savona</i> (Hamilton) Fd, Or	RH	CW	+	+	+	-
	Cobitidae	<i>Botia dayi</i> (Hamilton) Fd, Or	RH	CW	+	+	+	-
		<i>Lepidocephalichthys guntea</i> (Hamilton) Fd	EU	WW	+	+	+	+
		<i>Somileptesgongota</i> (Hamilton) Fd, Or	RH	CW	+	+	+	-
		<i>Botia lohachata</i> (Chaudhri) Fd, Or	RH	WW	-	-	-	+
	Cyprinidae	<i>Aspidoparia morar</i> (Hamilton) Fd	EU	CW	+	+	+	-
		<i>Aspidoparia jaya</i> (Hamilton) Fd	EU	CW	+	+	+	-
		<i>Barilius barila</i> (Hamilton) Fd	RH	CW	+	+	+	+
		<i>Barilius barna</i> (Hamilton) Fd	RH	CW	+	+	+	-
		<i>Barilius bola</i> (Hamilton) Fd	EU	WR	+	+	+	+
		<i>Barilius shacra</i> (Hamilton) Fd	RH	CW	+	+	+	-
		<i>Barilius vagra</i> (Hamilton) Fd	RH	CW	+	+	+	+
		<i>Barilius bendelisis</i> (Hamilton) Fd	RH	CW	+	+	+	+
		<i>Barilius tileo</i> (Hamilton) Fd	RH	CW	+	+	+	+
		<i>Bengalaelanga</i> (Hamilton) Fd, Or	LH	WR	-	-	+	+
		<i>Chagunius chagunio</i> (Hamilton) Fd	RH	CW	+	+	+	-
		<i>Crossocheiluslatia</i> (Hamilton) Fd	RH	CW	+	+	+	-
		<i>Devario devario</i> (Hamilton) Fd, Or	RH	WR	+	+	+	+
		<i>Esomus danricus</i> (Hamilton) Fd, Or	EU	WR	-	-	-	+
		<i>Danio rerio</i> (Hamilton) Fd, Or	RH	WR	-	-	-	+
		<i>Danio dangila</i> (Hamilton) Fd, Or	RH	WR	-	-	-	+
		<i>Garra gotyla</i> (Gray) Fd	RH	CW	+	+	+	+
		<i>Garra kempfi</i> (Hora) Fd	RH	CW	+	+	-	+
		<i>Garra lamta</i> (Hamilton) Fd	RH	CW	+	+	+	-
		<i>Garra maclellanei</i> (Jerdon) Fd	RH	CW	+	+	+	-
		<i>Labeo boga</i> (Hamilton) Fd	RH	WR	+	+	-	-
		<i>Labeo dero</i> (Hamilton) Fd	RH	WR	+	+	+	-
		<i>Labeo dyocheilus</i> (McClelland) Fd, Sp	RH	WR	+	+	+	-
		<i>Osteobrama cotio</i> (Hamilton) Fd, Or	EU	WR	-	+	+	+
		<i>Puntius stigma</i> (Hamilton) Fd, Or	EU	WW	+	+	+	-
		<i>Puntius sophore</i> (Hamilton) Fd, Or	EU	WW	+	+	+	+
		<i>Puntius sarana</i> (Hamilton) Fd	EU	WR	+	+	+	-
		<i>Puntius ticto</i> (Hamilton) Fd,	EU	WW	+	+	+	+
		<i>Puntius conchonis</i> (Hamilton) Fd, Or	EU	WW	-	-	-	+
		<i>Puntius gelius</i> (Hamilton) Fd, Or	EU	WW	-	-	-	+
		<i>Puntius javanicus</i> (Bleeker) EX	EU	WW	-	-	-	+
		<i>Cyprinus carpio</i> (Linnaeus) EX	EU	WW	-	-	-	+
	Psilorhynchidae	<i>Psilorhynchus balitora</i> (Hamilton) Fd	RH	CW	+	+	-	-
		<i>Psilorhynchus sucatio</i> (Hamilton) Fd	RH	CW	+	+	+	-
Siluriformes	Amblycipitidae	<i>Amblyceps mangois</i> (Hamilton) Fd, Or	EU	WW	+	+	+	+
	Bagridae	<i>Mystus tengra</i> (Day) Fd, Or	EU	WW	-	-	-	+
	Clariidae	<i>Clarias batrachus</i> (Linnaeus) Fd	EU	WW	+	+	+	+
	Heteropneustidae	<i>Heteropneustes fossilis</i> (Bloach) Fd	EU	WW	+	+	-	+
	Olyridae	<i>Olyra kempfi</i> (Chaudhuri) Fd, Or	RH	CW	+	+	+	-
		<i>Olyra longicaudata</i> (McClelland) Fd, Or	RH	CW	+	+	+	-
	Sisoridae	<i>Gagata cenia</i> (Hamilton) Fd, Or	RH	CW	+	+	+	-
		<i>Nangra punctate</i> (Day) Fd, Or	RH	CW	+	+	+	-
		<i>Pseudolaguvia ribeiroi</i> (Hora) Or	RH	CW	+	+	+	-
		<i>Pseudolaguvia shawi</i> (Hora) Or	RH	CW	+	+	-	-
Perciformes	Anabantidae	<i>Anabas testudineus</i> (Bloch) Fd	EU	WW	-	-	-	+
	Chacidae	<i>Chaca chaca</i> (Hamilton) Or	EU	WW	+	+	+	+
	Channidae	<i>Channa punctate</i> (Bloch) Fd	EU	WW	+	+	+	+

Table continue

		<i>Channa gachua</i> (Hamilton) Fd, Or	EU	WW	+	+	+	-
		<i>Channa striata</i> (Bloach) Fd	EU	WW	-	-	-	+
	Gobiidae	<i>Glossogobius giuris</i> (Hamilton) Fd	EU	WW	+	+	+	+
	Nandidae	<i>Badis badis</i> (Hamilton) Fd, Or	EU	WW	+	+	+	+
		<i>Badiskanabos Kullander & Britz</i> Fd, Or	EU	WW	+	+	+	-
Cyprinodontiformes	Aplocheilidae	<i>Aplocheilus panchax</i> (Hamilton) Or	EU	WW	-	-	-	+
Beloniformes	Belonidae	<i>Xenentodon cancila</i> (Hamilton) Fd, Or	EU	WW	+	+	+	+
Synbranchiformes	Mastacembelidae	<i>Mastacembelus armatus</i> (Lacepede) Fd, Or	EU	WW	+	+	+	+
		<i>Macrognathus spancalus</i> (Hamilton) Fd, Or	EU	WW	+	+	+	+

Fd=food value, Or= ornamental, Sp= sport, FPG=food preference guild, WTP –water temperature preference, Rh= Rheophilic, EU= Eurytopic, WW=warm water, CW= cold water, '+'=indicates present, '-'=indicates absent

to high current. Fish species like *Crossocheilus latius* and *Psilorhynchus balitora* with fine stream lined body adhere to pebbles and stones to counteract high currents the loaches, *Nemacheilus* spp., *Schistura* spp., *Aborichthys elongatus* and *Acanthocobitis botia* resides on pebbles and stone with distinct attachment devices below the lower jaw and fish like *Garra* spp. hold on to the exposed surface of uncovered rocks with adhesive apparatus on their lower surface of lower jaw. Fish species such as *Nemacheilus* spp., *Schistura* spp., *Aborichthys elongatus*, *Acanthocobitis botia* and *Garra* spp., were dominant at Site 1 and 2, and could sustain high water currents by attaching onto the stones by different attachment devices. Site 1 and 2 were rich in stone and boulders, that helped in the attachment of fish species.

The habitat preference guild, based on the flow preference and water temperature preferences of adult fishes is discussed here. Rheophilic fish are confined to lotic water and adopted to torrential water currents and eurytopic fish are confined to both lotic and lentic waters but not adopted to torrential water currents. Cold-water fish can withstand water temperatures of 20 degrees Celsius or higher (Jhingran, 1978). Out of 64 fish species, 33 were rheophilic, 31 eurytopic, 28 cold-water and 24 warm-water fish (Table 2). Sites 1, 2, and 3 recorded the highest number of rheophilic and cold-water fish, while Site 4 the highest number of eurytopic and warm-water or tropical fish were reported. At Site 1, the maximum number of rheophilic (30 species) fish were found, followed by cold-water fish (28 species), eurytopic (20 species), warm-water or tropical fish (15 species), and 7 species of temperature-tolerant fishes. Site 2 recorded the highest number of rheophilic (30 species) fish, followed by cold water fish (28 species), eurytopic (21 species), warm water or tropical fish (15 species) and 8 fish species with a wide range of temperature tolerance. At Site 3, the maximum number of rheophilic (26 species) fish were recorded, followed by cold-water fish (25 species), eurytopic (21 species), fish warm-water or tropical fish (14 species), and eight fish species with a wide range of temperature tolerance. At Site 4, the maximum number of eurytopic fish species (25 species) were recorded, followed by warm-water or tropical fishes (21 species) rheophilic (10 species) and cold-water fishes with a wide range of temperature tolerant species, each with 7 species. Rheophilic fishes were dominant in the upper stretch of the river and gradually decreased in the lower stretch, while the eurytopic fishes showed the reverse trend.

Similar findings were suggested by Chakraborty and Homechaudhry (2013) in the river Teesta. The rivers of the Himalayan region are blessed with cold water and torrential fish (Singh and Akhtar, 2015; Singh and Sarma, 2017). Sarkar (2021) recorded 71 coldwater fish species from different rivers of the Dooars region. Out of 64 fishes, 33 possessed both food and ornamental values, 28 had only food value and 3 had only ornamental value. A few important ornamental fishes reported in this study were *Chacachaca*, *Pseudolaguvia ribeiroi* and *Pseudolaguvia shawi* (Table 1). Swain (2008) reported that 85% of the ornamental fish are exported by the North-eastern states. The maximum average number of taxa was recorded at Site 2 (44.33) and minimum at Site 3 (34.67). The maximum number of individuals (900) were reported at Site 2 and minimum (662) at Site 4. The highest Shannon-Weiner diversity index (3.78) was reported at Site 3, while the lowest Shannon diversity index (3.41) was reported noted at Site 4, respectively. According to Shannon-Weiner index, the River Changa is regarded as good quality and suitable for aquatic organism (Shannon diversity index ranged from 3-4). The highest Margalef's richness index was documented (6.49) at Site 2 and least (5.14) at Site 3 (Table 2). Lalramliana et al. (2020) recorded the diversity index of 3.78 from the rivers following through Dampa Tiger Reserve. Sarkar and Paul (2021) in the River Teesta and Acherjee and Barat (2013) in the hill stream Relli and the river Teesta reported Shannon diversity index and Margalef's richness index which were greater than in the present study. Because the river Teesta and hill stream Relli are large rivers in comparison to river Changa and so, number of fish species is also greater than the river Changa.

The percentage of stone, pebbles, sand, and mud are given in Table 3. The highest percentage of stone (59.0) was recorded at site 1 and nilat site 4 (0.0%). Chakraborty and Homechaudhry (2013) recorded 38% stones in the river Teesta which corroborates with the present findings. The highest percentage of pebbles (42.0) was recorded at Site 3 and the lowest at Site 4 (3.66%). Chakraborty and Homechaudhry (2013) reported 10% pebbles in the Teesta River, which was within the range of the current findings. The maximum percentage of sand (32.0) was recorded at Site 4 and minimum at Site 1 (6.33%). Chakraborty and Homechaudhry (2013) recorded 25.3% sand in the River Teesta, which corroborates with the present findings. The highest percentage of mud (64.0%) was

Table 2: Seasonal variation of number of taxa, individuals and diversity indices along with ANOVA among sites and seasons at four sampling sites of river Changa

Taxa_S	Individuals				Dominance_D				Shannon_H				Evenness_e^H/S				Margalef's R index							
Sum.	Rainy	Wint.	Average	Sum.	Rainy	Wint.	Average	Sum.	Rainy	Wint.	Average	Sum.	Rainy	Wint.	Average	Sum.	Rainy	Wint.	Average					
Site 1	39 ± 3.3	47 ± 3.8	33 ± 2.75	39.67 ± 3.28	859 ± 10.3	1341 ± 12	435 ± 9	878.33 ± 10.3	0.0	0.0	0.0	0.0	3.5 ± 0.8	3.73 ± 0.74	3.44 ± 0.25	3.574 ± 0.6	0.886 ± 0.1	0.887 ± 0.02	0.952 ± 0.01	0.908 ± 0.4	5.62 ± 1.1	6.38 ± 1.28	5.26 ± 1.57	5.76 ± 1.32
Site 2	46 ± 2.5	50 ± 3.4	37 ± 2.7	44.33 ± 2.86	806 ± 12	1518 ± 14	376 ± 10	900 ± 12	0.0	0.0	0.0	0.0	3.6 ± 0.44	3.79 ± 0.5	3.48 ± 0.23	3.63 ± 0.39	0.815 ± 0.02	0.893 ± 0.01	0.879 ± 0.01	0.862 ± 0.01	6.72 ± 1.55	6.68 ± 1.88	6.07 ± 1.4	6.49 ± 1.61
Site 3	35 ± 3.4	44 ± 2.5	25 ± 3.46	34.67 ± 3.36	639 ± 7	1313 ± 8	318 ± 11	756.67 ± 8.66	0.0	0.0	0.0	0.0	3.3 ± 0.23	3.64 ± 0.25	3.10 ± 0.35	3.78 ± 0.28	0.839 ± 0.02	0.870 ± 0.01	0.893 ± 0.01	0.867 ± 0.02	5.26 ± 1.77	5.98 ± 2.10	4.16 ± 1.88	5.14 ± 1.89
Site 4	38 ± 2.4	41 ± 2.7	28 ± 2.0	35.67 ± 2.36	454 ± 7.5	1264 ± 12	269 ± 7.8	662.3 ± 9.1	0.0	0.0	0.0	0.0	3.4 ± 0.32	3.59 ± 0.27	3.20 ± 0.41	3.41 ± 0.33	0.825 ± 0.03	0.883 ± 0.02	0.882 ± 0.02	0.863 ± 0.02	6.04 ± 2.66	5.60 ± 2.40	4.82 ± 1.88	5.49 ± 2.31
F value	Among sites	17			5.325				35	31	43	363	12.29				0.079				7.442			
	Among seas	64.41**			152*			13.79	38.54**			0.0131	9.673											

Table 3: Seasonal variations of sediment with ANOVA among sites and seasons at four sampling sites of river Changa

	Stone %				Pebble%				Sand%				Mud%				Watertemp. in °c			
	Sum.	Rainy	Wint.	Average	Sum.	Rainy	Wint.	Average	Sum.	Rainy	Wint.	Average	Sum.	Rainy	Wint.	Average	Sum.	Rainy	Wint.	Average
Site 1	58 ±5	57 ±4	62 ±3	59.00 ±4.0	36 ±4.6	38 ±3.6	30 ±2.9	34.67 ±3.7	6 ±0.5	5 ±0.5	8 ±0.5	6.33 ±0.5	0 ±0.5	0 ±0.5	0 ±0.5	0 ±0.5	23.4 ±2.10	20.1 ±1.2	6.4 ±0.20	17.83 ±1.16
Site 2	57 ±4	54 ±4.5	62 ±4	57.67 ±4.16	33 ±3.8	34 ±3.7	31 ±3.2	32.66 ±3.56	10 ±0.8	12 ±1.2	7 ±0.85	9.66 ±0.95	0 ±0.85	0 ±0.85	0 ±0.85	0 ±0.85	24.5 ±2.10	23.0 ±1.45	6.0 ±0.2	16.63 ±1.25
Site 3	45 ±2.6	43 ±3.6	48 ±2.8	45.33 ±2.8	40 ±3.5	44 ±4.8	42 ±3.6	42.0 ±3.96	11 ±1.0	10 ±0.99	7 ±0.75	9.33 ±0.91	4 ±0.12	3 ±0.25	3 ±0.35	3 ±0.35	25.7 ±2.2	23.3 ±1.85	7.5 ±1.24	18.83 ±1.76
Site 4	0	0	0	0	4 ±0.8	1 ±0.2	6 ±1.0	3.66 ±0.66	32 ±2.5	34 ±1.8	31 ±2.66	32.3 ±2.32	64 ±5.8	65 ±3.64	63 ±4.21	64.0 ±4.55	26.45 ±2.56	25.1 ±1.88	8.47 ±1.1	20.07 ±1.84
Among sites			796.3*		98.55**				118.6*				8921*				10.87			
F value	Among seas.		7.269		0.4615			1.182					1				673*			

recorded at Site 4, while no mud was found at Site 1 (Table 3). Table 3 shows seasonal variations in sediment composition. The stone, pebbles, sand, and mud percent differed significantly ($p < 0.01$) among sites, while they were not significant among seasons. The temperature of water exhibited significant difference ($p < 0.01$) among seasons. The maximum number of ichthyofaunal taxa, individuals, Shannon diversity index, and Margalef's richness index were recorded during rainy season and minimum during winters at all sites, due to high volume of water during rainy season. The higher fish diversity during rainy season was due to increased water depth with huge nutrients and the river banks covered with vegetation, which helps to retain precipitation in the river basin for longer time (Samal and Majumder, 2005). The number of ichthyofaunal taxa, individuals, and Shannon-Weiner diversity index showed seasonal variation at 5% significance level. The number of ichthyofaunal individuals also showed seasonal variation at 1% significance level (Table 2). The distribution pattern of ichthyofaunal species in the Himalayan streams or rivers depends on the flow rate of water, nature of substratum and water temperature. Sarkar and Paul (2021) and Acherjee and Barat (2013) recorded the maximum number of genera (S), species diversity index (H') and Margalef's species richness index (R) during rainy season and minimum in winter, this is in line with the present findings. The maximum Margalef's richness index was reported in rainy season by Sengupta and Homechaudhuri (2015) and Rahaman et al. (2015). Shahnawaz et al. (2010) and Samal and Majumder (2005) reported that the maximum ichthyofaunal Shannon-Weiner diversity index was found in rainy season due

to the increased volume of water rich in nutrients.

The entire variables were explained by three principal components (PC1, PC2 and PC3). PC1 and PC2 expressed most of the variables. PC1 and PC2 expressed 94.657 and 4.4508% of total variance, respectively (Table 5). Tropical fish diversity was positively influenced by sand and mud. The number of ichthyofaunal individuals was the most influential factor (because of the longest line in PCA) among fish diversity indices. The Shannon-Weiner diversity index and Margalef's richness index were positively influenced by the number of ichthyofaunal individuals (Fig. 2). Cold water and rheophilic fish species were positively influenced by stone and pebbles. Sediment compositions at Site 4 were dominated by sand and mud, so support the warm water or tropical and eurytopic fish. Site 1 and site 2 contained mainly stone and pebbles, so support the rheophilic and cold water fish.

Indiscriminate and overfishing are major threats to ichthyofaunal diversity in River Changa as are sand and stone mining, deforestation along the river, water lifting for tea gardens, and pesticide run-off from tea gardens and crop fields (Patra et al., 2011; Goswami et al., 2012). Establishment of stone embankments inadvertently on rivers side causes loss of breeding ground and habitat for adult fishes. Dudgeon et al. (2006) found that many anthropogenic activities, like over fishing, introduction of exotic fish species, habitat loss and climate change were important factors for the decline in fish species diversity. Baillie et al. (2004) reported that the primary threat to most terrestrial and freshwater species is their habitat destruction. Paul et al. (2009) reported that excessive harvesting of *Barilius* spp. has caused a significant decrease of this fish species. Treeck et al. (2020) revealed that rheophilic fish species showed moderate to high sensitivity and eurytops showed moderate to low sensitivity to environmental changes. Hence, the cold water and rheophilic fish species of this river are highly sensitive to environmental changes. Eurytops showed low sensitivity to environmental changes, which helped them to survive in degraded environmental conditions (Scharf et al., 2011; Treeck et al., 2020) which corroborates with the findings of this study. *Barilius* spp., *Botiadayi*, *Schistura* spp. and *Gara* spp. are highly sensitive to minor environmental changes.

In conclusion, moderate fish diversity in the River Changa acts as 'genetic resources' to the area. Due to high volume of water during rainy season, the maximum number of ichthyofaunal taxa, individuals, Shannon diversity index, and Margalef's richness index were observed in the wet season and the smallest in the dry season at all sites. River substratum has an impact on fish distribution and abundance. Stone and pebbles have a good impact on cold water and rheophilic fish species and are positively correlated, but sand and mud have a positive correlation with tropical and eurytopic fish. Over excavation of sand, pebbles and boulders and many anthropogenic activities have destroyed the habitat for fish. Over excavation of sand, pebbles and boulders for construction work actually changes the river substratum composition, which is a threat to many indigenous fish species. If

Table 4: Results of Principal Components Analysis (PCA) based on sediment, flow preference guild, water temperature preference and fish diversity indices at four study sites.

	PC 1	PC 2	PC 3
Eigenvalue	14048.6	660.571	132.367
% variance	94.657	4.4508	0.89187
Cumulative	94.657	99.1078	99.99967
%Variation			
Eigen vectors			
Stone %	0.22123	0.30239	-0.35
Pebble %	0.040569	0.67391	0.72302
Sand %	-0.088341	-0.19456	0.27384
Mud %	-0.23421	-0.54366	0.41813
Water temp. in °C	-0.011882	-0.00049036	-0.034262
Rheophilic	0.075715	0.11402	-0.10792
Eurytopic	-0.016465	-0.030096	0.062074
Cold water fish	0.078534	0.14226	-0.12253
Warm water fish	-0.020941	-0.075528	0.049266
Wide range of temp.	0.001658	0.017191	0.027416
Taxa_S	0.030013	-0.063508	0.17419
Individuals	0.93439	-0.2769	0.19723
Dominance_D	-2.9043E-05	8.4067E-05	-7.666E-05
Shannon_H	0.00056631	0.0053313	-0.00075303
Evenness_e^H/S	8.2805E-05	-0.00027129	-0.0016114
Margalef	0.0032775	-0.010255	0.028506

we should not take immediate conservation steps we will soon lose our valuable fish resources in near future.

Acknowledgment

Authors are greatfull to the fishermen for their hepl during the study.

Authors' contribution: T. Sarkar: Designing the research and writing the paper; B.K. Das and M. Das: Done the survey work.

Funding: Not applicable.

Research content: The research content of manuscript is original and has not been published elsewhere.

Ethical approval: Not applicable.

Conflict of interest: The authors declare that there is no conflict of interest.

Data availability: Not applicable.

Consent to publish: All authors agree to publish the paper in *Journal of Environmental Biology*.

References

- Aarts, B.G.W. and P.H. Nienhuis: Fish zonations and guilds as the basis for assessment of ecological integrity of large rivers. *Hydrobiologia*, **500**, 157-178 (2003).
- Acharjee, M.L. and S. Barat: Impact of fishing methods on conservation of ichthyofauna of River Relli in Darjeeling Himalaya of West Bengal. *J. Environ. Biol.*, **31**, 431-434 (2011).
- Acharjee, M.L. and S. Barat: Ichthyofaunal diversity of Teesta River in Darjeeling Himalaya of West Bengal, India. *Asian J. Experim. Biol. Sci.*, **4**, 112-122 (2013).
- Baillie, J.E.M., C. Hilton-Taylor and S. Stuart: IUCN Red List of Threatened Species: A global species assessment, IUCN, Gland, Switzerland and Cambridge, UK. 217 pages (2004).
- Bandyopadhyay, N. and K. Mondal: Present status of ichthyofaunal diversity of different rivers of duars of North Bengal, India. *J. Today's Biol. Sci. Res. Rev.*, **3**, 1-8 (2014).
- Barman, R.P.: A review of the fresh water fish fauna of West Bengal, India with suggestions for conservation of the threatened and endemic species. Records of the Zoological Survey of India, Occasional Paper, **263**, 1-48 (2007).
- Bruton, M.N. Have fishes had their chps? The dilemma of threatened fishes. *Environ. Biol. Fishes*, **43**, 1-27 (1995).
- Burton, G.A Jr. and P. F Landrum: ASTM Standard Guide For Collection, Storage, Characterization, and Manipulation of Sediments for Toxicological Testing (1993).
- Chakrabarty, M. and S. Homechaudhuri: Fish guild structure along a longitudinally-determined ecological zonation of Teesta, an Eastern Himalayan river in West Bengal, India. *Arxius de Miscell. Zool.*, **11**, 196-213 (2013).
- Das, D.: Ichthyofaunal diversity of River Torsa and it's tributaries at Terai region of West Bengal, India. *Int. J. Sci. Nat.*, **6**, 256-263 (2015).
- Day, F.: On some new fishes of India. The Journal of the Linnean Society of London. *Zoology*, **11**, 524-530 (1873).
- Dey, A., R. Nur, D. Sarkar and S. Barat: Evaluation of fish biodiversity in rivers of three districts of Eastern Himalayan region for conservation and sustainability. *Int. J. Appl. Res.*, **1**, 424-435 (2015).
- Dudgeon, D., A.H. Arthington, M.O. Gessner, Z.I. Kawabata, D.J. Knowler, C. Lévêque, R.J. Naiman, A.H. Prieur-Richard, D. Soto and M.L. Stiassny: Freshwater biodiversity: Importance, threats, status and conservation challenges. *Biol. Rev. Camb. Philos. Soc.*, **81**, 163-182 (2006).
- Goswami, U., C. Basistha, S.K. Bora, D. Shyamkumar, K. Saikia and B. Changsan: Fish diversity of North-East India, inclusive of the Himalayan and Indo- Burma biodiversity hotspots zones: A checklist on their taxonomic status, economic importance, geographical distribution, present status and prevailing threats. *Int. J. Biodive. Conserv.*, **4**, 592-613. (2012).
- Hammer, Ø., D.A.T. Harper and P.D. Ryan: PAST Paleontological statistics software package for education and data analysis, **4**, 9pp. (2001). http://palaeo-electronica.org/2001_1/past/issue1_01.htm
- Hora, S.L. and J.C. Gupta: On a collection of fish from kalimpong duars and Siliguri Terai, Northern Bengal. *J. Royal Asiatic Soci. Bengal. Sci.*, **VI**, 77-83 (1940).
- Jayaram, K.C.: The freshwater fishes of the Indian region. 2nd Edn., Narendra Publishing House, New Delhi, India. 616 pages (2010).
- Jhingran, V.G. and K.L. Sehgal: Cold water Fisheries of India. 1st Edn., Inland Fisheries Society of India, Barrackpore, West Bengal, India. ix +239 pages (1978).
- Laffaille, P., A. Acou, B. Guillouet and J. Leuglt: Temporal change in European eel, *Anguilla anguilla*, stock in a small catchment after installation of fish passes. *Fisher. Manag. Ecol.*, **12**, 123-129 (2005).
- Lalramliana, M.C. Zirkunga and S. Lalronunga: Ichthyofauna of Dampa Tiger Reserve Rivers, Mizoram, North-Eastern India. *J. Environ. Biol.*, **41**, 884-895 (2020).
- Paul, M., S. Gupta and S. Banerjee: Fish fauna of the major rivers of Darjeeling district with special reference to their conservation status, *Rec. Zool. Surv. India*, **109**, 15-23 (2009).
- Patra, A. K., S. Sengupta and T. Datta: Physico-chemical properties and Ichthyofauna diversity in Karala River, a tributary of Teesta River at Jalpaiguri district of West Bengal, India. *Int. J. Appl. Biol. Pharmac. Technol.*, **2**, 47-58 (2011).
- Rahman, A., N. Mondal, A. Hannan and K.A. Habib: Present status of fish biodiversity in Talma River at Northern Part of Bangladesh. *Int. J. Fisher. Aqu. Stu.*, **3**, 341-348 (2015).
- Samal, N.R. and A. Majumder: Management of lake ecosystem. *Ekol*, **3**, 123-130 (2005).
- Sarkar, T. and J. Pal: Studies on the diversity of fish in different reservoir and rivers of Terai Region. North Bengal University. *J. Animal Sci.*, **2**, 83-88 (2008).
- Sarkar, T. and J. Pal: Ichthyofaunal diversity and conservation status in the River Teesta, West Bengal, India. *Indian J. Ecol.*, **48**, 1821-1828 (2021a).
- 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.*, **10**, 146-152 (2021b).
- Sengupta, S. and S. Homechaudhuri: Taxonomic and functional diversity of fish assemblage in three interconnected river in India in accordance with limiting similarity hypothesis. *J. Global Biosci.*, **4**, 2842-2858 (2015).
- Sen, T.K.: Fresh Water Fish. State Fauna Series 3: Fauna of West

- Bengal. *Zool. Surv. India*, **2**, 101-242 (1992).
- Shahnawaz, A., M. Venkateshwarlu, D.S. Somashekar and K. Santosh: Fish diversity with relation to water quality of Bhadra River of Western Ghats (INDIA). *Environ. Monito. Assess.*, **161**, 83-91 (2010).
- Shaw, G.E. and E.O. Shebbeare: The fishes of Northern Bengal. *J. Royal Asiatic Soci. Beng. Sci.*, Article, III, **1**, 138 (1937).
- Singh, A. K. and M. S. Akhtar: Coldwater fish diversity of India and its sustainable development. (Ed.:P. Singh). Bio-diversity for Sustainable Development. UP Biodiversity Board, Lucknow. pp. 97-105 (2015).
- Singh, A.K. and D. Sarma: Aquatic Resources and Fish Diversity of the Himalaya. Narendra Publishing House, New Delhi. *Technology*, **2**, 47-58 (2017).
- Smith, R. J., R.D.J. Muir, M.J. Walpole, A. Balmford and N. Leader-Williams: Governance and the loss of biodiversity. *Nature*, **426**, 67-70 (2003).
- Swain, S. K.: Indigenous Ornamental Fish and Their Export Potential. Originally Published as a research article in 8th Indian Fisheries Forum Souvenir Article, Nov (2008).
- Sinha, M.: Impact of environment on fish germplasm. In: Fish Genetics And Biodiversity Conservation (Eds.: A.G. Ponniah, P. Das and S.R. Verma). Natcon Pub. No. 5, Muzaffarnagar, pp. 1-11 (1998).
- Treeck, R., V. Jeroen, V. Wichelen and C. Wolter: Fish species sensitivity classification for environmental impact assessment, conservation and restoration planning. *Sci. Total Environ.*, **708**, 135173 (2020).