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Fish Diversity, Conservation Status and its Relationships with Environmental Variables in Umtrew River System, Northeast, India

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ABSTRACT

Background: River water and its faunal diversity are regarded as an integral part of the environmental stability and river ecosystem. To know the abundance and diversity of fin fishes in relation to their environmental parameters, a hilly river Umtrew in Meghalaya and Assam was investigated during January, 2019 to December, 2020.

Methods: Fish, plankton and water samples were collected regularly at monthly intervals for a period of 24 months. Standard protocols were followed for analysis of the collected samples.

Result: A total of 49 fish species under 36 genera, 20 families and 10 orders were recorded. Among them Cypriniformes (42%) is the dominated order followed by Siluriformes (24%). As per IUCN status 1 species falls under critically endangered, 4 species are near threatened, 2 species under vulnerable and 42 species are of least concern. A significant correlation between species distribution and environmental variables was also reported. Our findings clearly oppose the tendency for species composition to increase from the source to the mouth of the river, which is probably prohibited by two major anthropogenic activities. These activities could constitute in the future a real threat for the fish population and other aquatic organisms.

Key words: Diversity, Environmental variables, Palmer, Pollution, Threatened.

INTRODUCTION

Protection of the natural environment is one of the prime focus for preservation and conservation of living species. Unfortunately, throughout the World and in India in particular, aquatic ecosystems are continuously altered by human activities (Ahmed *et al*., 2013). This alteration is thought to play an important role in fish community structures and in other aquatic organisms (Resh *et al*., 1988; Poff and Ward, 1989) and may be responsible for extinction of numerous species.

Hilly river ecosystem and biodiversity is very important due to the source of origin of different colourful fin fishes which live in diversified habitats consisting of clay, sand, rock, gravel, stone and boulders. Habitat characteristics are correlated with presence and absence of fishes (Gorman and Karr, 1978). Again, water qualities of a river influence the fish diversity (Kow *et al.* 2016).

Among such Umtrew river system is one of the major river systems in Meghalaya and Assam, India, which supports a diverse range of flora and fauna making the river a valuable resource for the region. However, the river is facing tremendous pressure through many anthropogenic factors like construction of dams and constant dumping of municipal and industrial waste generated by industries (Pranjit *et al.,* 2012). Thus, looking into the pathetic condition and with a hope for restoration of the river natural ecosystem present study was undertaken to evaluate the fish diversity and abundance in relationship to its environmental variables. This study might also be helpful to the researchers, fish managers and policy makers to understand the water quality and ichthyofaunal status of hill streams for its better management to maintain and sustain the running water ecosystem and its resources.

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MATERIALS AND METHODS

Study area

The river Umtrew is originated by the confluence of two streams, one of which originates near Mawrong hamlet on the Sohpetbneng Peak and the other one is the Umium dam's outflow (Fig 1). These two streams meet at the Nongkhyllem Wildlife Sanctuary and run through Byrnih, a small town of Meghalaya. The river then enters into the state Assam at Sonapur, where it is known as Digaru until merging with the Brahmaputra near Chandrapur, Kamrup of Assam. River. The Digaru river covers a distance of about 30 km

from the Umtrew hydroelectric power station and along its periphery numerus industries like cement, drinks, iron and PVC are located. At a latitude of 26°13′51.8″N and a longitude of 91°37′28.8″E, elevation ranging from 738.5 to 58 m when it meets the Kopili river, a tributary of the Brahmaputra.

Collection of fish

Fish specimens were collected with the help of local fishermen by using cast net and gill net of different mesh sizes. The collected fish specimens were preserved in 10% formaldehyde in the Fish Museum of Department of Aquatic Environment Management, College of Fisheries, Assam Agricultural University, Raha, Nagaon. Morphological identification of the fish was done according to (Talwar and Jhingran, 1991; Jayaram, 2010; Pauly and Froese, 2012). Assessment conservation status of the fishes was carried out using IUCN Red list of threatened species (2014).

Plankton analysis

The plankton's sample were collected and identified using standard methods (Santhanam, 1989; Philipose, 1967). Palmer index was for organic pollution was also calculated according to Palmer (1969).

Water quality analysis and habitat characterisation

Water samples was collected regularly on monthly intervals from January, 2019 to December, 2020. Physico-chemical parameters of water like water velocity using rheometer, surface water temperature, turbidity, pH, TDS, dissolved oxygen, electrical conductivity was estimated using water testing Kit (Systronics, Model Type 371), whereas alkalinity, hardness, Nitrite, Phosphate, BOD_3 and COD were estimated according to (APHA, 2005; CPCB, 2001) using titration method. Other environmental variables like water depth, width, substrate types (mud, sand, clay, gravel, rock and leave-wood as percent of stream bottom surface covered by each substrate type at each sample site) were also measured in the same sites according to Kouamelan *et al.* (2003) where fishes were sampled.

Statistical analysis

Canonical correspondence analysis (CCA) (Ter Braak, 1988) was used to examine a longitudinal gradient in species composition in the river system. All the average data are represented as mean±S.E. Statistical difference were considered significant when $p<0.05$. CCA analysis was preformed using the Palaeontological Statistics (PAST) Programme.

RESULTS AND DISCUSSION

Fish diversity

During the present investigation a total of 49 fish species belonging to 36 genera, 20 families and 10 orders are recorded from 6 selected sampling stations of the river Umtrew, Maghalaya and Assam, India. The number and percentage composition of order and family under are shown (Table 1 and 2). Among the orders, the Cypriniformes formed the largest group with a contribution of 4 (20.00%) families, 15 (41.66%) genera and 21 (42.85%) species. Similar kind of results were also reported by Umesh *et al.,* 2012; Gurumayum *et al.,* 2016; Kar *et al.,* 2006 during the study of the different north-eastern rivers in India.

The IUCN conservation status of the 49 recorded species with their number under different category are shown in Table 3. The highest species were recorded under least concern (LC) category with a total no of 42 and contributed 85.71%. Under near threatened (NT) category Cyprinidae 2 (4.08%), Sissoridae and Alidae contributed 1 (2.38%) each (Table 3). Ramanujam *et al.*, 2010 studied the ichthyofaunal diversity of the Khasi hills and found 68 species belonging 45 genera, 20 families and 6 orders. Where Cyprinidae was the most dominant group dominated by 30 species. The trophic level index indicates that most of the fishes are omnivore (48.97%) with their feeding habit followed by

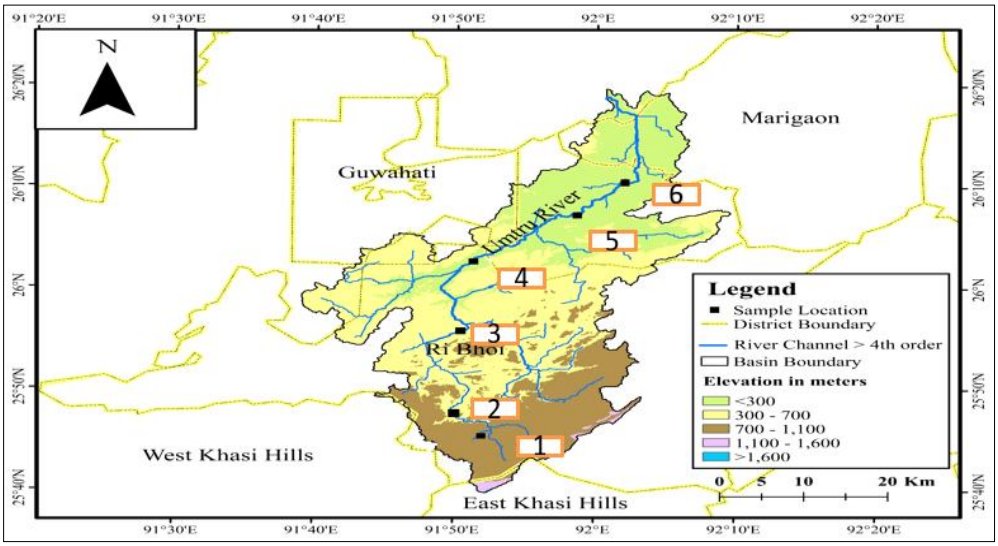

Fig 1: GIS Map of umtrew river indicating sampling sites.

Table 1: Composition of fish community by order.

Taxa	Number of species	Percentage (%)
Cypriniformes	21	42.85
Siluriformes	12	24.48
Anabantiformes	5	10.20
Synbranchiformes	3	6.12
Perciformes	2	4.08
Osteoglossiformes	2	4.08
Gobiformes	1	2.04
Mugliformes	1	2.04
Clupiformes	1	2.04
Beloniformes	1	2.04

Table 2: Composition of fish community by family.

Taxa/family	Number of species	Percentage (%)
Cyprinidae	11	22.44
Bagridae	5	10.20
Danionidae	5	10.20
Channidae	4	8.14
Mastacembelidae	3	6.12
Siluridae	2	4.08
Botidae	2	4.08
Sisoridae	2	4.08
Aridae	2	4.08
Daninidae	2	4.08
Notopteridae	2	4.08
Belonidae	1	2.04
Nandidae	1	2.04
Osphronemida	1	2.04
Claridae	1	2.04
Cobidae	1	2.04
Ambasidae	1	2.04
Gobidae	1	2.04
Muglidae	1	2.04
Clupide	1	2.04

26.53% for herbivore category and 24.48% for carnivore. According to Karr *et al.* (1987) the Umtrew river environment falls under poor category since more than 45% fish species comes under omnivore.

Palmer index

The total score of Algal Genus Pollution Index (AGPI) of sites S1<S2<S3< S6<S5< S4 are calculated to be 3, 5, 8, 10, 11 and 13 respectively (Table 4). The score of S1, S2 and S3 indicates probable lack of organic pollution while S4, S5 and S6 showed moderate pollution which might be due to anthropogenic factors like human interference. Chlorella, Nitzschia and Synedra Closterium was found to be the most active participant in most of the sites which may be the good indicator of contaminated water. Oscillatoria was recorded repeatedly in station 4, 5 and 6 and consider as indicators of pollution in view of the results of Palmer pollution index.

Seasonal discharge trends of the umtrew river

The variation of the water quality mainly depends on river regime, catchment characteristics and human activities which are system specific. The average water quality of Umtrew river showed that the pollution indicating parameters like BOD_3 and COD values are higher than the optimum value given by BIS and WHO (Table 5). Besides BOD_3 and COD values other parameters found under the congenial range indicate the that river water is preferable for ichthyofaunal diversity. Variations in the water quality parameters of the Umtrew river system might be due to heavy rainfall during the monsoon season which increases the volume of the river from the nearby catchment area.

Patterns of species composition in relation to environmental variables

The main pattern shown by the CCA is a longitudinal gradient in species composition. Forward selection and Monte Carlo permutation (199 iteration) allowed to identify 14 environmental variables accounting for 50% of the variance explained by 15 variables: width, velocity, oxygen, depth, mean% of leaves wood and% rocks (Table 6). These variables were considered as the best predictors of the species environmental relationships in the Umtrew River. For data analysis, we considered the first two axis expressing the highest variability of species data. In the CCA performed, axis 1 (eigenvalue=0.48) and axis 2 (eigenvalue=0.14) expressed 72.01% of the cumulative variance in the species data. Monte Carlo permutation tests showed that both axis were significant (p=0.005) (Fig 2). From these selected variables, DO, water velocity, pH, turbidity, BOD_3, COD, width, Depth, Sand clay and mud and mean% of mixed leaves-wood in the substrate seem to be the important variables explaining longitudinal change in species composition both upstream and downstream gradient. In the present study, high mean% of leaves-wood, sand, clay and mud reflect a habitat located in river system. Based on CCA axis 1, there is a high correlation between position of sampling sites and position along an upstream-downstream gradient. In the river Tangon and Kulik, a similar result was found by Islam *et al.* (2017).

Species distribution

Fishes were collected in all 6 sampling sites. Species composition differed from one site to another (Table 7). To study the longitudinal distribution of fishes, we used data from the main river sites only and followed the upper-lower gradient. Species composition was seen more in site 1, decreases from sites 2 to 4 and finally increases from site 5 to 6. The tendency for species composition to increase from the source to the mouth of the river has been widely observed by community ecologists (Kouamelan *et al.,* 2003). However, following the upper-lower gradient of the main channel of the Umtrew River, we observed an irregular distribution of fishes. This is most likely due to the impact of different anthropogenic factors. In site 2 and 3, two dams (Kyrdemkulai and Umtrew) dam has been built to retain water

Table 3: Fish fauna of Umtrew river, their taxonomic status, trophic level, feeding habits, relative abundance and IUCN status.

Species	Family	Order	Trophic level (Based on food items)	Feeding habit	IUCN status
Sperata aor	Bagridae	Siluriformes	3.6±0.53	Carnivorous	LC
Mystus vittatus	Bagridae	Siluriformes	3.1±0.1	Carnivorous	LC
Mystus cavasius	Bagridae	Siluriformes	3.4±0.5	Carnivorous	LC
Rita rita	Bagridae	Siluriformes	3.7±0.57	Carnivorous	LC
Mystus tengara	Begridae	Siluriformes	3.20.40	Carnivorous	LC
Wallago attu	Siluridae	Siluriformes	3.7±0.56	Carnivorous	VU
Heteropneustes fossilis	Siluridae	Silurifomes	3.6±0.3	Omnivorous	LC
Bagarius bagarius	Sisoridae	Siluriformes	3.7±0.59	Carnivorous	NT
Gagata cenia	Sisoridae	Siluriformes	3.3±0.5	Omnivorous	LC
Allia coilia	Ailidae	Silurifomes	3.6±0.6	Omnivorous	NT
Clupisoma garua	Ailidae	Siluriformes	3.7±0.59	Carnivorous	LC
Clarias batrachus	Claridae	Siluriformes	3.4±0.50	Omnivorous	LC
Channa marulius	Channidae	Anabantiformes	4.5±0.80	Carnivorous	LC
Channa punctata	Channidae	Anabantiformes	3.8±0.70	Omnivorous	LC
Channa striata	Channidae	Anabantiformes	3.4±0.45	Omnivorous	LC
Channa gachua	Channidae	Anabantiformes	3.8±0.62	Omnivorous	LC
Macrognathus pancalus	Mastacembelidae	Synbranchiformes	3.1±0.33	Omnivorous	LC
Macrognathus aral	Mastacembelidae	Synbranchiformes	3.1±0.33	Omnivorous	LC
Mastacembelus armatus	Mastacembelidae	Syubranchiformes	2.8±0.27	Herbivorous	LC
Puntius sophore	Cyprinidae	Cypriniformes	2.6±0.1	Omnivorous	LC
Cirrhinus mrigala	Cyprinidae	Cypriniformes	2.2±0.12	Herbivorous	LC
Systomus sarana	Cyprinidae	Cypriniformes	2.9±0.2	Herbivorous	CR
Osteobrama curma	Cyprinidae	Cypriniformes	2.9±0.3	Herbivorous	LC
Amblypharyngodon mola	Cyprinidae	Cypriniformes	3.2±0.4	Herbivorous	LC
Petihia ticto	Cyprinidae	Cypriniformis	2.2±0.0	Herbivorous	LC
Neolissochilus spinulosus	Cyprinidae	Cypriniformes	3.0±0.37	Omnivorous	NT
Cirrihinus reba	Cyprinidae	Cypriniformes	3.6±0.59	Herbivorous	LC
Garra gotyla	Cyprinidae	Cypriniformes	2.0±0.00	Herbivorous	LC
Garra annandalei	Cyprinidae	Cypriniformes	2.0±0.00	Herbivorous	LC
Labeo dyocheilus	Cyprinidae	Cypriniformes	2.0±0.0	Herbivorous	NT
Salmostoma bacaila	Danionidae	Cypriniformes	3.2±0.40	Omnivorous	LC
Salmophasia balookee	Danionidae	Cypriniformes	3.2±0.4	Omnivorous	LC
Danio dangila	Daninidae	Cypriniformes	3.0±0.4	Omnivorous	LC
Deverio aequipinatus	Daninidae	Cypriniformes	2.9±0.33	Herbivorous	LC
Barilius bendelisis	Danionidae	Cypriniformes	3.4±0.4	Omnivorous	LC
Barilius barila	Danionidae	Cypriniformes	3.2±0.4	Omnivorous	LC
Lepidocephalichthys guntea	Cobidae	Cypriniformes	2.7±0.2	Herbivorous	LC
Barilius barna	Danionidae	Cypriniformes	3.4±0.4	Omnivorous	LC
Botia rostrata	Botidae	Cyriniformes	3.4±0.4	Omnivorous	VU
Botia dario	Botidae	Cyriniformes	3.2±0.4	Omnivorous	LC
Nandus nandus	Nandidae	Perciformes	3.9±0.63	Omnivorous	LC
Chanda nama	Ambassidae	Perciformes	3.6±0.54	Carnivorous	LC
Notopterus chitala	Notoptaridae	Osteoglossiformes	3.5±0.0	Carnivorous	LC
Notopterus notopterus	Notopteridae	Osteoglossiformes	3.5±0.0	Carnivorous	LC
Xenentodon cancila	Belonidae	Beloniformes	3.9±0.62	Omnivorous	LC
Trichogaster fasciata	Osphronemida	Anabantiformes	3.1±0.3	Omnivorous	LC
Glossogobius giuris	Gobidae	Gobiformes	3.7±0.2	Omnivorous	LC
Rhinomugil corsula	Muglidae	Mugliformes	2.4±0.2	Herbivorous	LC
Gudusia chapra	Clupidae	Clupiformes	3.1±0.3	Omnivorous	LC

LC: Least concern; VU: Vulnerable; NT: Near threatened; CR: Critically endangered.

Table 4: Pollution index of Algal genera level according to Palmer, (1969) at six sites of river Umtrew.

Phytoplankton	Pollution index (Palmer, 1969)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Chlorophyceae							
Volvox	-	+	+	+	+	+	+
Ulothrix	-	+	+	+	+	+	+
Chlorella	3	-	+(3)	+(3)	+(3)	+(3)	+(3)
Cladophora	-	+	-	+	-	-	-
Chlamydomonas	-	-	+	+	+	-	-
Bacillariophyceae							
Navicula	-	+	+	+	+	+	-
Fragillaria	-	+	+	+	-	-	+
Nitzschia	3	+(3)	-	+(3)	+(3)	+(3)	-
Synedra	3	-	+(2)	+(2)	+(2)	-	+(2)
Melosira	-	+	+	+	-	+	-
Cynophyceae							
Anabaena	-	+	+	+	+	+	+
Oscillatoria	3	-	-	-	+(5)	+(5)	+(5)
Nostoc	-	+	+	+	-	-	+
Spirulina	-	+	+	+	+	+	-
Total	3	5	8	13	11	10	

Following numerical values for pollution classification of Palmer (1969), 0-10= Lack of organic pollution 10-15= Moderate pollution 15-20= Probable high organic pollution 20 or more = Confirms high organic pollution.

Table 5: Comparative study of experimental water quality data with BIS and WHO (24 months average data).

	Winter	Pre monsson	Monsoon	Post monsoon	BIS	WHO
Surface water velocity (m/s)	0.832±1.08	1.21±1.13	1.50±1.20	1.26±0.99	-	-
Surface water temperature (°C)	18.45±1.08	22±2.7	27.58±2.6	24.41±1.4	-	40
DO (ppm)	7.97±1.67	6.97±0.77	6.02±1.27	7.63±0.6	-	>5
pH	7.42±0.7	7.5±0.29	7.34±0.28	7.03±0.3	6.5-7.5	6.5-7.5
Alkalinity (ppm)	30.41±9.13	43.77±10.5	56.55±23.8	38.11±2	200	-
Hardness(ppm)	45.89±13.20	50.84±2.70	41.69±3.2	34.11±8.1	300	500
Turbidity (NTU)	7.16±2.38	18.43±7.7	34.67±18.1	17.69±7.5	1	-
TDS (ppm)	41.58±14.97	75.88±26.32	152±54.9	98.22±46.1	500	1000
BOD_3 (ppm)	9.92±2.06	13.90±4.04	21.16±8.0	14.88±4.9	-	20
COD (ppm)	19.53±5.04	24.31±5.9	38.13±12.3	27.33±8.6	-	5
Nitrate (ppm)	0.17± 0.04	0.17±0.03	0.14±0.01	0.18±0.04	45	10
Nitrite (ppm)	0.05± 0.01	0.04±0.009	0.05±0.005	0.06±0.01	0.06	-
Ammonia (ppm)	0.598±0.33	0.593±.33	1.301±0.80	0.591±0.27	0.5	0.015-0.045
Phosphate (ppm)	0.14±0.022481	0.237±0.03	0.24±0.04	0.15±0.01	-	5
EC (μScm^{-1})	97.83±28.2	92.97±20.75	97.97±19.2	98.03±13.50	-	300

Table 6: Different environmental variables (in%).

Sampling station	Rock (%)	Sand (%)	Gravel (%)	Mud (%)	Clay (%)	Leave dead wood (%)	Depth (%)	Width (%)
Station 1	98.00	0.00	2.00	0.00	0.00	90.00	0.91	6.24
Station 2	80.00	10.00	10.00	0.00	0.00	85.00	1.76	25.55
Station 3	90.00	5.00	5.00	0.00	0.00	25.00	0.78	32.53
Station 4	2.00	65.00	33.00	20.00	5.00	30.00	1.64	40.13
Station 5	0.00	95.00	5.00	30.00	10.00	20.00	4.29	47.53
Station 6	0.00	2.00	0.00	80.00	30.00	20.00	6.73	42.13

Table 7: List of freshwater fish species sampled in the Umtrew river system.

Fish species	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Sperata aor					+	+
Channa marulius				+	+	+
Channa punctata				+	+	+
Channa striata				+	+	+
Channa gachua				+	+	+
Heteropneustes fossilis				+	+	+
Macrognathus pancalus		+			+	+
Notopterus chitala			+		+	+
Mystus vittatus		+			+	+
Mystus cavasius			+		+	+
Wallago attu					+	+
Xenentodon cancila			+	+	+	+
Macrognathus aral			+	+	+	+
Puntius sophore		+			+	+
Cirrhinus mrigala			+	+	+	+
Trichogaster fasciata				+	+	+
Botia dario	+	+	+		+	+
Amblypharyngodon mola		+	+		+	+
Systomus sarana					+	+
Nandus nandus					+	+
Mystus tengara					+	+
Puntius ticto					+	+
Chanda nama					+	+
Osteobrama cotio			+		+	+
Salmostoma *bacailla*					+	+
Neolissochilus hexagonolepis	+	+			+	+
Ailia coila					+	+
Devario aequipinnatus	+	+			+	+
Glossogobius giuris					+	+
Rhinomugil corsula					+	+
Clupisoma garua					+	+
Mastacembelus armatus				+	+	+
Lepidocephalichthys guntea	+	+			+	+
Bagarius bagarius					+	+
Rita rita					+	+
Gagata cenia					+	+
Chanda nama					+	+
Cirrihinus reba					+	+
Gudusia chapra					+	+
Salmostroma balookee.					+	+
Danio dangila						+
Clarias batrachus				+	+	+
Garra gotyla	+					
Garra annandalei	+	+				
Labeo dyocheilus	+	+				
Barilius bendelisis	+	+				
Barilius barila	+	+				
Barilius barna	+	+				
Botia rostrata	+	+			+	+
Notopterus notopterus					+	+

+ = Presence.

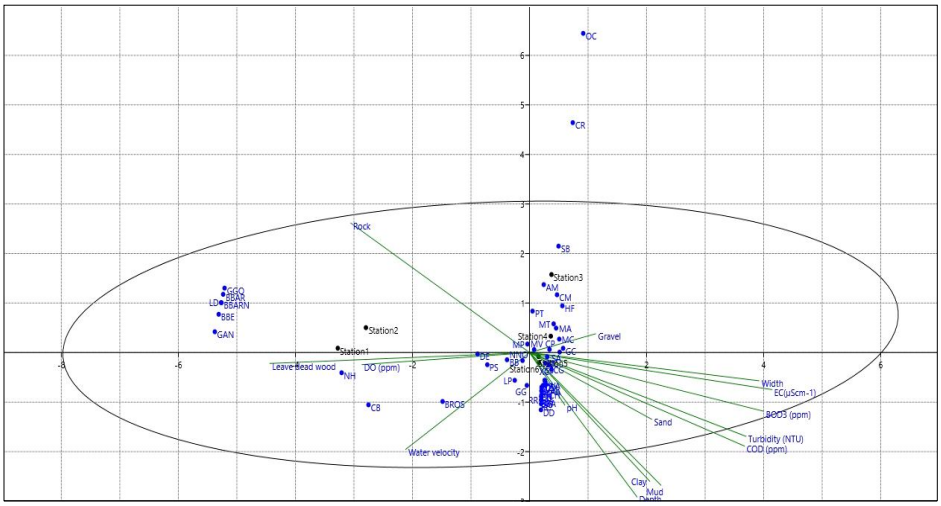

Fig 2: Canonical correspondence analysis showing correlation between species composition and environmental variables.

SA- *Sperata aor,* CM-*Channa marulius,* CS-*Channa striata,* CG-*Channa gachua,* HF-*Heteropneustes fossilis,* MP-*Macrognathus pancalus,* NP-*Notopterus Chitala.* MV-*Mystus vittatus,* NNO-*Notopterus notopterus,* MC-*Mystus cavasius,* WA-*Wallago attu,* XC-*Xenentodon cancila,* MA-*Macrognathus aral,* PS-*Puntius sophore,* CM-*Cirrhinus mrigala,* TF-*Trichogaster fasciata,* BB-*Botia Dario,* AM-*Amblypharyngodon mola,* SS-*Systomus sarana,* NN-*Nandus nandus,* MT-*Mystus tengara,* PT-*Puntius ticto,* CN-*Chanda nama,* OC-*Osteobrama cotio,* SB-*Salmostoma bacailla,* NH-*Neolissochilus hexagonolepis,* AC-*Ailia coila,* DE-*Devario aequipinnatus,* GG-*Glossogobius giuris,* RC-*Rhinomugil corsula,* CG-*Clupisoma garua,* MAA-*Mastacembelus armatus,* LP-*Lepidocephalichthys guntea,* BBA-*Bagarius bagarius,* RR-*Rita rita,* GC-*Gagata cenia,* CN-*Chanda nama,* CR-*Cirrihinus reba,* GCH-*Gudusia chapra,* SB-*Salmostroma balookee.* DD-*Danio dangila,* CB-*Clarias batrachus,* GGP-*Garra gotyla,* GAN=*Garra annandalei,* LD-*Labeo dyocheilus,* BBE-*Barilius bendelisis,* BBAR-*barilius barila,* BBARN-*Barilius barna,* BROS-*Botia rostrata.*

for generation of electricity and other purpose uses. The immediate consequence of the construction of a dam, whatever its size in an aquatic ecosystem, is the modification of the hydrological regime, creating thus a lentic environment. This artificial lacustrine habitat is unfavourable to rheophilic species that migrate to the upper part of the river. Moreover, the discharge of industrial waste, sand and boulder mining activities were observed in sampling site 3 and 4, which cause serious affects in the freshwater ecosystem and consequently threatens fish biodiversity in the Umtrew River, which is also evident from the presence of some high tolerant fish species like *Heteropneustes fossils* in sampling site 4. Apart from the two major factors linked to human activities (dam construction and industrial pollution), degradation of the forest along the Umtrew River for creating space for industrial estate should be noted.

CONCLUSION

Results obtained allowed to note that species responded to the general environmental quality (water quality and environmental variables) of the freshwater aquatic ecosystem. Dam construction in the main channel and especially industrial pollution that may modify water quality, are major factors affecting fish assemblage in the Umtrew river, which was also evident from Palmer index. The present study is amongst the first step of a long process on freshwater fish conservation in Umtrew river system. For the success of this conservation process, the industrial estate and the local population must be informed of their responsibility in the alteration of the Umtrew River. For the benefit of a long-time conservation of freshwater and its natural resources in present river, it is essential that the government develop curricula at all levels of education (Family, School, University) that will ensure the understanding and maintenance of aquatic biodiversity. This will lead to active involvement of local communities in this important issue.

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