Fish Diversity and Water Quality Parameters of Mechi River, Jhapa, Province No. 1, Nepal

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ABSTRACT

Species diversity is widely recognised as an important trait of functioning and resilient ecosystem. Spatio-temporal patterns of fish community structure in the Mechi River was studied based on stratified random survey, conducted between September 2018 and April 2019. The survey was conducted at three different sampling stations in three different seasons. For the fish sampling, two cast nets of different sizes were used, one having large mesh size of 0.5 cm, 3 m diameter and 2 kg weight and another having mesh size of 2 cm, 6 m diameter and 6 kg weight. In addition, drag net and gill net were also used to collect the fish samples. A total of 1,772 fishes belonging to 4 orders, 8 families, 16 genera and 33 species were documented. The results from the similarity percentage analysis indicated that, the species *Schistura devdevi*, *Brachydanio rerio*, *Puntius sophore*, *Barilius barila*, *Schistura beveani* and *Puntius terio* were the most copious fish species recorded from the Mechi River. One-way analysis of similarity testing for space and time variations in fish community indicated that there was a significant difference in space ($R = 0.66$, p<0.01) but no significant difference in time ($R = -0.0123$, p>0.433). The Canonical Correspondence Analysis hinted that dissolved oxygen, water velocity and pH have shown to influence the fish assemblage structure in Mechi River.

Keywords: Fish diversity, freshwater, Jhapa, stream, water quality

INTRODUCTION

Both fresh and marine ecosystems harboured almost half of the total number of vertebrates (Gupta, 1988). The Florida Museum of Natural History calculated 27,650 species of extant fishes of which 41% are freshwater occupying less than 0.01% of Earth's volume. Over two thirds freshwater fish belong to single clade Otophysi (i.e. minnows, characins, and catfish). In the Indian sub-continent there are more than 2,500 species with approximately 930 species exclusively occupied freshwater ecosystem (Jayaram, 2010). Fish community structure plays an imperative role in keeping the good condition of water in aquatic ecosystem as well as it intensifies the articulation of different nutrients and their circulation and recharge in the aquatic bodies. Fish community gives signal for the status of freshwater ecosystem since it is tactful to a broad range of stressors (Karr, 1981). The diversity and distribution pattern of fish are widely related to the environmental factors like dissolved oxygen (DO), free carbon dioxide (CO_2), pH, alkalinity and more critically to the temperature (Yan *et al.,* 2010; Limbu *et al.,* 2020; Limbu & Prasad, 2020; Prasad *et al.,* 2020).

In the context of Nepal, there is rich diversity of freshwater aquatic fauna including fishes and plankton. Nevertheless, fish diversity of Nepal has been poorly studied or understood compared to other fauna (Shrestha *et al.,* 2009; Limbu *et al.,* 2018a; 2021). There is a strong relationship between different water quality parameters and the diversity, distribution and abundance of species. In the shallow and polluted water, some hardy species of fish like catfish and larvivorous fishes were found to be residing and schooling. Similarly, the type of water bottom, bed substrate, depth of water bodies, density of water and temperature along with its velocity play vital roles in diversity and distribution patterns of the fish species (Kadye *et al.,* 2008; Li *et al.,* 2012). There has been a considerable debate in recent literature as to the

relative importance of physical and biological factors in structuring fish assemblages in streams and rivers (Gorman & Karr, 1978; Yan *et al.,* 2010). This study aimed to determine the assemblage structure of fish in the Mechi River and also to quantify the diversity of fish in this river system. The findings are expected to enhance knowledge on fish richness in less explored rivers like the Mechi River.

MATERIALS AND METHODS

Study Area

The Mechi River starts from the south of Pashupatinagar from a place called Fakfokthum in Illam district (Figure 1). It is a perennial river that is fed by small streams at different points and also a rivulet coming from Kalingpong (a place in India) and flows through different places of Illam and Jhapa and finally to India as Mahananda River. The river has lower volume of water but has higher velocity at upper portions. Similarly, the volume of water increases while it reaches the lower stream forming many pools that provide good habitat for warm water fish and aquatic fauna. The water in the Mechi River is crystal clear in most parts, but some parts of the river are muddy due to increased

anthropogenic activities near the area of human settlement. Large rocks, boulders and pebbles occupy the river bottom at the upper stream, while gravels, sand and mud are the bottom substrates in the lower part of the river. The study area for this research includes 14 km of river basin starting from Salakppur (Jirmale) of Illam to Nakalbanda, Jhapa.

Sampling Sites

For the fish sampling, three sampling stations were identified along the 11 km stretch of the Mechi River and each station was 3.5 km in distance. These stations were selected on the basis of physical division, human approach and river confluence point. These are illustrated as Station A, B and C. Station A, Salakpur (453 m asl, 26º49'48"N, 88º09'38"E) is located at Illam district, which has high velocity of water and many cold water fishes. Station B, Gadagalli (255 m asl, 26º46'47"N, 88º10'55"E), lies at the edge of Jhapa and Illam districts with many pools and comparatively warmer water than station A. Station C, Nakalbanda (126 m asl, 26º38'50"N, 88º09'50"E), is located at Mechinagar Municipality, and the area has human settlement and is easily accessible by fisherman.
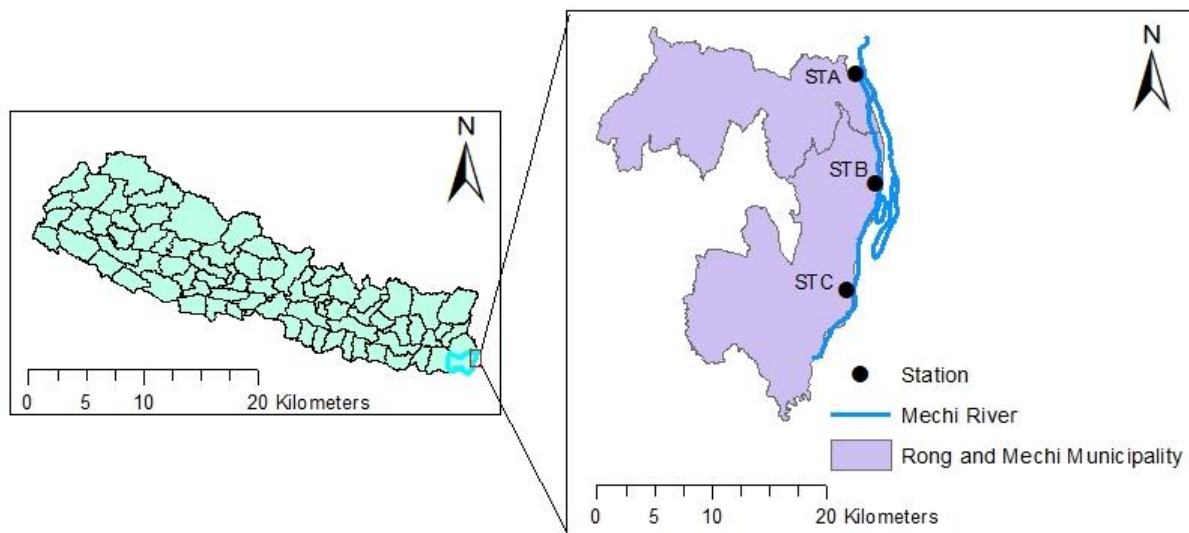

Figure 1. Map of study area showing location of sampling station along the Mechi River (STA = station A, upstream; STB = station B, middle; STC = station C, downstream)

Data Collection, Preservation and Identification

The major gear used for the present research work was cast net of monofilament type made by hemp fiber. Two cast nets of different sizes were used, one having large mesh size of 0.5 cm, 3 m diameter and 2 kg weight, and another having mesh size of 2 cm, 6 m diameter and 6 kg weight. The smaller net was used upstream with low water volume, while the larger was used downstream with high water volume. Besides, a drag net made from a local mosquito net of mesh size 0.2 cm was used for collecting small fish species. The collection was done seasonally (autumn, winter and spring, summer) from September 2018 to April 2019. Fishing gears were operated within 500 m length at each sampling station from 7 am to 1 pm. A total of 100 throws were made for cast net and 50 hauls for gill net to catch the fishes.

To estimate abundance of fishes, two removal pass method (Seber & Le Cren, 1967) was used. Each removal pass includes moving first upstream then downstream within a pre-determined length (500 m) with equal effort of 30 minutes for each pass at each side of river. The collected fish samples were photographed and preserved in 10% formalin solution in plastic jar and brought to Central Department of Zoology (CDZ) lab, Tribhuvan University, Kirtipur, Kathmandu, Nepal for further identification. The collected fishes were identified using standard taxonomic references (Talwar & Jinghram, 1991; Jayaram, 2010).

The environmental variables measured *in situ* during the field visit included: water temperature, dissolved oxygen (DO), free carbon-dioxide (CO_2) and water velocity. Water temperature (ºC) was measured with a digital thermometer (Hanna, HI98501, UK) by placing it in the water at a depth of 1 foot. The DO was measured by the Winkler titra-metric method, while the pH was measured using a pH meter (HI98107, Hanna Instrument, UK). Free carbon dioxide (CO_2) was analysed by titrating water sample against a strong alkali (NaOH), and phenolphthalein indicator was used in the titration. Water velocity was measured by the float method with the help of a stop watch, plastic ball and a measuring tape.

Data Analysis

To highlight the differences in the environmental parameters (i.e, pH, water temperature (°C), DO (mg/L), CO_2 (mg/L) and water velocity (m/s) and fish community attributes (i.e, Shannon index and Dominance index) between different months and sites, we executed analysis of variance (ANOVA) using the function *aov* in R software (R core Team, Vienna, Austria). In the event of significance, a post hoc Tukey HSD test was used to determine which means were significantly different at a 0.05 level of probability (Spjøtvoll & Stoline, 1973).

The correlation study between fish community structure and environmental variables was first done by selection of appropriate test a Detrended Correspondence Analysis (DCA). The axis length (2.7) and eigen value (0.54) acquired from DCA suggested that the uni-model of Canonical Correspondence Analalysis (CCA) was more applicable. Therefore, a direct multivariate ordination method (ter Braak, 1986) based on a linear response of species to environmental gradients was applied by using vegan library in R (Oksanen, 2015). One-way analysis of similarity (ANOSIM) was used to conclude the significance of space and time variation of fish community structure (Clarke, 1993). Similarity percentages analysis (SIMPER) was executed to notice the percentage of similarity in temporal scale (Clarke, 1993).

RESULTS AND DISCUSSION

Water Parameters

Different hydrographic conditions of different stations at different seasons are shown in Table 1. Maximum water temperature of 27 °C was recorded at station C during spring while the minimum temperature of 16 °C was recorded at station A during winter. No significant difference ($p > 0.05$) was found in temperature among the space and time. Water velocity showed significant difference ($F = 7.9$, $p > 0.05$) among the stations. The maximum water velocity of 2.12 m/s was recorded at station A during autumn whereas, the minimum water velocity of 0.74 m/s was recorded

at station C during spring. Dissolved oxygen (DO) ranged from 6.21 mg/L to 9.3 mg/L. No significant difference was found among the stations and seasons. Maximum free CO_2 of 54.14 mg/L was recorded at station C during spring whereas the minimum value of 36.28 mg/L was observed at station A during winter. There was also no significant difference ($p > 0.05$) found in free CO_2 among the stations and seasons. Similarly, the maximum pH of 7.63 was reported at station C during spring whereas, the minimum pH of 7.12 was recorded at station A during winter. Similarly, no significant difference ($p > 0.05$) in pH was found among the stations and seasons.

Fish Community Structure

In the present study, a total of 1,772 fishes were collected, which belonged to 4 orders, 8 families, 16 genera and 33 species (Table 2). The Cyprinidae family had the most species (13 species), followed by Cobitidae (10 species), Sisoridae (3 species), Anabaantidae (2 species), Channidae (2 species), Psilorhynchidae (1 species), Olyridae (1 species) and Belonidae (1 species). On the basis of

SIMPER, *Schistura devdevi*, *Brachydanio rerio, Puntius sophore, Barilius barila, S. beveani* and *P. terio* were the most copious fish species recorded from the Mechi River (Table 3). One-way ANOSIM for space and time variations in fish community indicated that there was a significant difference in space ($R = 0.66$, $p < 0.01$) but no significant difference in time ($R = -0.0123$, $p > 0.433$) was observed. The highest Shannon diversity index was recorded at station A and the minimum value was found at station C. There were no significant differences ($p > 0.05$) found in the three stations. Similarly, highest Simpson dominance index was also found to be at station A while the minimum was at station C. There is also no significant difference ($p > 0.05$) was observed among the stations (Figure 2). In terms of temporal variation, highest Shannon diversity index was reported in autumn whereas minimum was in spring. In contrary, highest Simpson dominance index was also observed in autumn and minimum was in spring (Figure 3). There was also no significant difference ($p > 0.05$) in the value of Shannon and Simpson diversity index observed among the three seasons.

Table 1. Values of water parameters

Stations	Seasons	Temperature (°C)	Velocity (m/s)	Dissolved oxygen (mg/L)	Free carbon dioxide (mg/L)	pH
A	Autumn	19	2.12	9.3	38.45	7.2
B	Autumn	22	1.115	8.4	42.32	7.36
C	Autumn	24	0.88	7.6	48.22	7.5
A	Winter	16	2.06	9.6	37.23	7.12
B	Winter	18	1.12	8.75	40.25	7.28
C	Winter	21	0.82	8.22	36.28	7.4
A	Spring	23	1.18	8.6	48.25	7.42
B	Spring	25	0.95	7.56	51.23	7.55
C	Spring	27	0.74	6.21	54.14	7.63

Table 2. Coding of the Mechi River fishes by order, family and species

Order	Family	Code	Species
Cypriniformes	Cyprinidae	Sp1	*Labeo dero* Hamilton, 1822
		Sp2	*Labeo boga* Day, 1837
		Sp3	*Puntius sophore* Hamilton, 1822
		Sp4	*Puntius terio* Hamilton, 1822
		Sp5	*Barilius barila* Hamilton, 1822
		Sp6	*Barilius bendelisis* Hamilton, 1807
		Sp7	*Bengala elanga* Hamilton, 1822
		Sp8	*Brachydanio rerio* Hamilton, 1822
		Sp9	*Danio dangila* Hamilton, 1822
		Sp10	*Esomus danrica* Hamilton, 1822
		Sp11	*Garra gotyla* Gray, 1832
		Sp12	*Garra mullya* Sykes, 1941
		Sp13	*Garra annandalei* Hora, 1921
	Psilorhynchidae	Sp14	*Psilorhynchus nudithoracicus* Tilak and Husain, 1980
	Cobitidae	Sp15	*Acanthocobitis botia* Hamilton, 1822
		Sp16	*Schistura beavani* (Gunther, 19868)
		Sp17	*Schistura devdevi* Hora, 1935
		Sp18	*Schistura rupecula* McCllelland, 1839
		Sp19	*Schistura fasciata* Lokeshwor and Viswanath, 2010
		Sp20	*Schistura himachalensis* Menon, 1987
		Sp21	*Schistura horai* Menon, 1951
		Sp22	*Lepidocephalus guntea* (Hamilton, 1822)
		Sp23	*Botia lohachata* Chaudhuri, 1912
		Sp24	*Botia geto* Day, 1878
Siluriformes	Sisoridae	Sp25	*Gagata cenia* Day, 1877
		Sp26	*Glyptothorax cornirostris* Steindachner, 1867
		Sp27	*Glyptothorax alaknandi* Tilak, 1969
	Olyridae	Sp28	*Olyra longicaudata* McClleland, 1842
Beloniformes	Belonidae	Sp29	*Xenontodon cancila* Hamilton, 1822
Perciformes	Anabantidae	Sp30	*Anabas testudineus* Bloch, 1795
		Sp31	*Anabas cobojius* Hamilton, 1822
	Channidae	Sp32	*Channa gachua* Hamilton, 1822
		Sp33	*Channa punctatus* Bloch, 1793

Table 3. The checklist of fish by species, abundance, sampling stations and seasons

| Fish species	Autumn			Winter			Spring			Total
	STA	STB	STC	STA	STB	STC	STA	STB	STC	
Labeo dero	0	0	3	0	0	2	0	0	0	5
Labeo boga	0	2	7	0	0	3	0	0	0	12
Puntius sophore	5	37	41	0	12	18	17	11	17	158
Puntius terio	4	16	21	0	14	12	0	8	14	89
Barilius barila	5	29	36	8	21	16	6	18	13	152
Barilius bendelisis	0	7	5	0	3	7	0	6	9	37
Bengala elanga	0	0	3	0	0	0	0	0	0	3
Brachydanio rerio	0	76	109	0	32	39	0	0	0	256
Daneo dangila	0	3	0	0	0	0	2	0	0	5
Esomus danrica	13	19	22	0	0	11	0	3	7	75
Garra gotyla	2	0	0	16	11	0	14	9	0	52
Garra mullya	6	2	0	14	3	0	8	0	0	33
Garra annandalei	7	0	0	8	0	0	5	0	0	20
Psilorhynchus nudithoracicus	3	0	2	0	0	0	0	2	0	7
Acanthocobitis botia	7	5	0	0	7	11	3	2	0	35
Schistura beveani	13	7	0	15	6	2	22	0	3	68
Schistura devdevi	44	33	0	32	12	0	88	44	0	253
Schistura rupecula	3	0	0	0	0	0	6	0	0	9
Schistura fasciata	7	3	0	0	0	0	5	0	0	15
Schistura himachalensis	1	0	0	0	0	0	6	0	0	7
Schistura horai	3	2	0	5	0	1	7	3	0	21
Lepidocephalus guntea	6	12	19	5	11	14	3	7	9	86
Botia lohachata	5	2	0	9	5	0	8	5	2	36
Botia geto	4	6	12	0	15	0	3	12	4	56
Gagata cenia	3	0	0	5	0	0	8	0	0	16
Glyptothorax cornirostris	7	0	0	5	0	0	0	0	0	12
Glyptothorax alaknandi	11	2	0	6	0	0	14	0	0	33
Olyra longicaudata	0	13	18	0	12	14	0	0	0	57
Xenontodon cancila	0	0	6	0	0	0	0	0	3	9
Anabas testudineus	15	6	0	13	2	0	12	0	0	48
Anabas cobojius	11	8	0	5	3	0	7	2	0	36
Channa gachua	0	19	31	0	0	6	0	0	0	56
Channa punctatus	0	2	6	0	0	5	0	0	2	15
									Total	1772
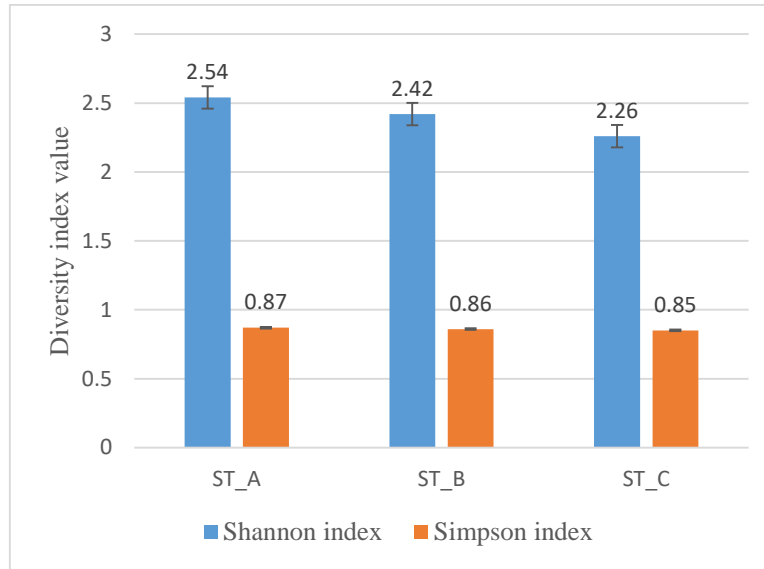
Figure 2. Spatial variation of Shannon and Simpson index values (ST_A =station A, ST_B = station B, ST_C = station C)
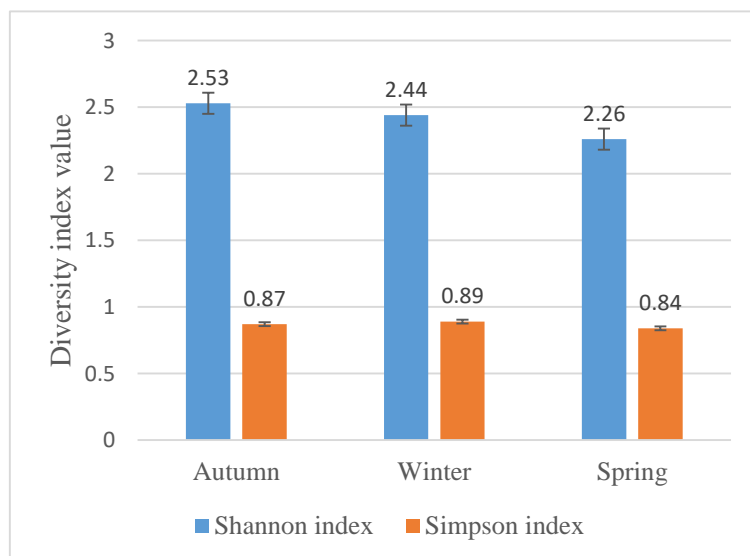

Figure 3. Temporal variation of Shannon and Simpson index values during the three seasons

Relationship Between Fish Community Structure and Environmental Variables

The first and second axis of CCA accounted for 67% of the total variance (56% on the first axis and 11% on the second). The CCA after the plot showed the relationship between fish species and environmental variables (Figure 4). The plot indicated that, *S. beavani* (sp16), *Psilorhynchus nudithoracicus* (sp14), *Anabas testudineus* (sp30), *Botia lohachata* (sp23), *Garra gotyla* (sp11), *G. mullya* (sp12), *G. annandalei* (sp13) and

Glyptothorax cornirostris (sp26) are positively related to water velocity and DO but are negatively related to free CO_2, water temperature and pH. In contrast, *Esomus danrica* (sp10), *Bengala elanga* (sp7), *Labeo dero* (sp1), *P. sophore* (sp3), *B. rerio* (sp8), *L. boga* (sp2) and *Channa gachua* (sp32) are positively related to free CO_2, water temperature and pH but negatively related to water velocity and DO. The plot also revealed that fish community structure of *Gagata cenia* (sp25), *Acanthocobitis botia* (sp15), *B. barila* (sp5), *Lepidocephalus guntea* (sp22), *P. terio* (sp4), *Olyra longicaudata*
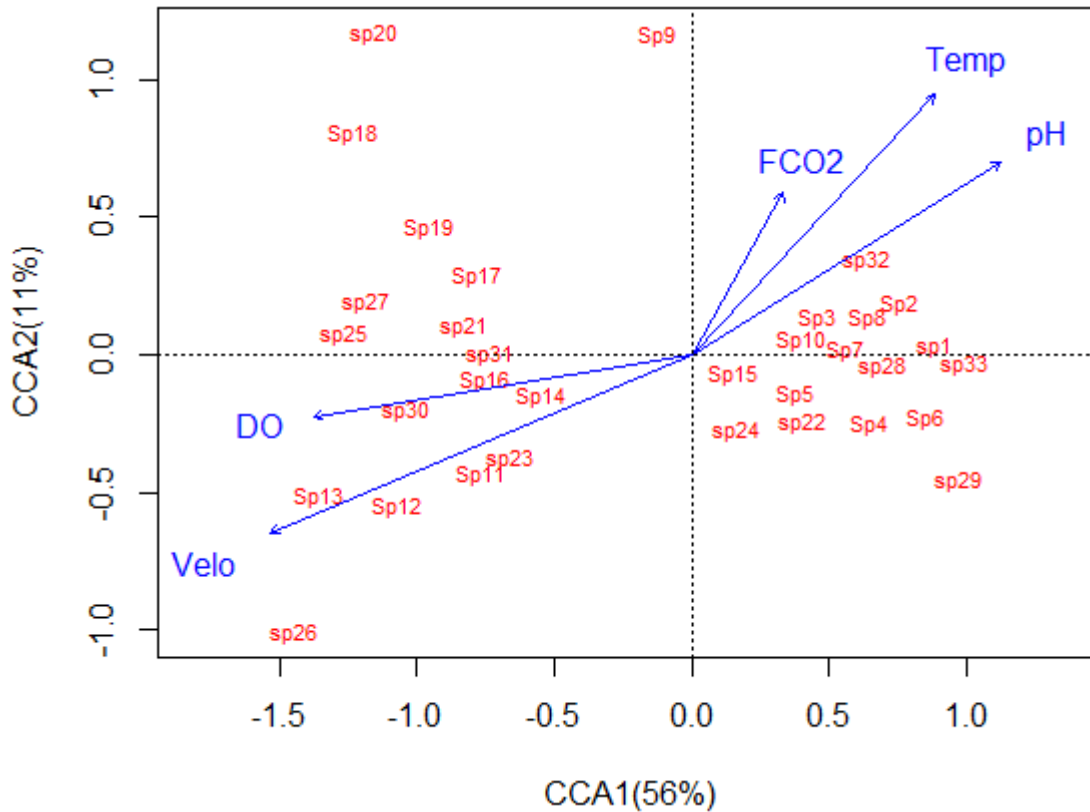
Figure 4. Biplot from canonical correspondence analysis (CCA) for the fish assemblages in the Mechi River (DO = dissolved oxygen, Velo = velocity, FCO2 = free carbon-dioxide, and Temp = temperature, for species code see Table 1)

(sp28), *B. bendelisis* (sp6), *Xenontodon cancila* (sp29), *C. punctatus* (sp33), *S. horai* (sp21), *G. alaknandi* (sp27), *S. devdevi* (sp17) and *S. fasciata* (sp19) are not influenced by the selected variables. Moreover, a CCA indicated that DO, water velocity and pH influenced the fish assemblage structure of the Mechi River.

DISCUSSION

The present study analysed 1,772 fishes categorized as 33 species of fishes belonging to 4 orders, 8 families, and 16 genera. This indicated that the Mechi River supports a major source of livelihood and food to those fishermen and fishing communities depending upon fishery practice in the Mechi River. The results showed that Cypriniformes was the most abundant order comprising 72.72% and Beloniformes was the least abundant order comprising 3.03%. The spatial distribution of fishes of the Mechi River was found to be a significant difference. Fishes like *B. barila, L. guntea,* and *Schistura* were found in deep clear water with high velocity, whereas fishes like *C. punctatus, C. gaucha, Colisa fasciatus,*

Anabas testudineus, and *A. cobojius* were found in shallower and muddy water and were capable to tolerate an increase in temperature range as they were recorded from the water with higher temperature (22 - 27 °C). This could be due to the development of many adaptational features in fishes to sustain in the surrounding they belong. Similarly, fishes like *Acanthocobitis botia, Botia lohachata,* and *Botia geto* were found at station B and C, that is mostly at the lower stream from shallow pools, paddy field drainage, puddles, and runs. The results of this study showed that species of fishes belonging to order Cypriniformes were abundant during the winter season at station B, which lies at base of hilly area thus serves as overlapping niche for both warm and cold water fishes. This result matches with the findings by Edds (1986), Chaudhary *et al.* (2020), Limbu & Prasad (2020) and Limbu *et al.* (2018a, 2018b, 2020), which might be due to the same elevation patterns of the rivers investigated and the similar water quality parameters of the rivers. The possible reason could be due to the availability of sufficient volume of water which is comparatively less disturbed as compared

to other sites. It could be due to the availability of sufficient DO and favorable temperature. Besides that, this station is cool during winter, thus can accommodate many cold-water fish species. In autumn and spring, the water over here becomes slightly warmer, which allows most warm-water fishes to occupy the same station. The habitat diversity in the Mechi River was found to be at the greatest during the low flow period, that is during the winter season, of which the river has less volume of water which suits the assemblage of many small indigenous fishes like *Schistura, Olyra longicaudata, Anabas, Channa, Glypothoraxs,* and *Barilus.* During winter, there is formation of many pools, rifles, and run habitats. This pattern produced by variation in flow also appeared to affect the spatial and temporal variation in the lower streams.

The result showed that many physico-chemical parameters like DO, free CO_2, temperature, and water velocity were found to be the factors that influence fish diversity and distribution. Besides, other factors like pH and transparency were significant in trace level for fish distribution. The diversity of local species of the river is greatly influenced by temperature as it changes species distribution at short time scales (Fisher *et al.,* 2008). The physico-chemical parameters of water like temperature, transparency, velocity, pH, DO, CO_2, and hardness play a vital role in abundance and species richness, and these parameters are greatly affected by seasons and elevations (Pokharel *et al.,* 2018). In the present study the highest temperature, lowest DO, and lowest velocity was observed during spring season basically at station C. This could be due to the rise of atmospheric temperature during the spring season and also due to the change in altitude.

From the results, the velocity of water was observed to decrease at the lower stream. This could be due to the plain area of the lower stream that supports the flow of water with less velocity. It also might be due to changes in longitudinal gradients i.e. slope of the landscape. The pH was observed in the range of 7.12 to 7.63 with an average of 7.38. This showed that pH is favorable for the distribution of most fish species in the Mechi River. Similarly, DO was also observed to be in good condition in the river as it is the most critical parameter that plays a vital role in the distribution of aquatic organisms. From the study, the average value of DO was 8.24 mg/L. This showed that the range of DO in the river is good for

most types of fishes. DO is an important factor that affects the distribution, diversity, physiology, and behavior of fishes (Pokharel *et al.,* 2018). The amount of DO is different for different fishes depending upon season and weather. Bhatnagar *et al.* (2004) reported that a suitable amount of DO should be greater than 5 mg/L for fish while according to Santosh and Singh (2007) catfishes and air-breathing fishes can sustain oxygen less than 4 mg/L.

Different environmental variables influence fish health as well as the diversity and distribution of fishes in water bodies. Among different environmental variables, temperature and DO are mostly responsible for the observed changes in species diversity and these variables change in freshwater assemblages according to seasons and elevation gradients. The relationship between fish and water quality parameters were examined by Canonical correspondence analysis CCA.

In the present study, parameters like DO and free CO_2 were found to be important parameters for shaping the fish assemblage structure of the Mechi River. The DO (Limbu & Gupta, 2019; Limbu *et al.,* 2019) and water temperature (Kadye *et al.,* 2008) have been mentioned as important factors for shaping the fish community structure. The amount of DO was highest in summer and fish abundance was also highest in this season. Temperature, as well as fish abundance, was recorded to be lower in winter season (Santosh & Singh, 2007). Similar types of the result were observed from lakes of France and northeast USA (Irz *et al.,* 2007) and the stream of the central Andes of Columbia (Jaramillo-Villa *et al.,* 2010). The most important environmental variables structuring the fish assemblages in the Mechi River were water velocity, DO, pH, and CO_2. Among these variables, fish assemblage structures are mostly correlated with DO and temperature. Pokharel *et al.* (2018) observed that, in Seti Gandaki river basin, the most important environmental variables were conductivity, water depth, free CO_2, pH, and DO. The fish assemblage structures are mainly correlated with free CO_2, water discharge, and stream size in North Tiaoxi River China (Koel & Peterka, 2003).

CONCLUSION

The Mechi River exhibits a good ichthyofaunal diversity represented by 33 species of fish belonging to 4 orders, 8 families, and 16 genera.

The highest Shannon diversity index was recorded at station A during autumn season, whereas the minimum was found to be at station C during spring. At the same time, the highest Simpson dominance diversity index was also observed in autumn at station A while minimum was in spring at station C. The fishes of the Mechi River were found to be biologically diverse and evenly distributed except for a few species, which belonged to a different type of habitat and behavior. Understanding the relationship between fish diversity and environmental factors could better explain the relationship between the fish and environmental parameters.

In the present study, the CCA results revealed that spatial and seasonal variations in the fish diversity were mainly related to environmental gradients like water DO, temperature, velocity, free CO_2, and pH of the water. Among the variables, DO, temperature, and free CO_2 were important variables to shape the fish diversity structure. Furthermore, a single diversity index could not completely represent diversity as each diversity component has different environmental effects. Therefore, the present study employed several other diversity indices to explore the spatial and temporal patterns in fish diversity.

Moreover, species like *Anguila bengalensis* was not recorded during the study but, according to local people, it used to be the abundant species a few years back. This might be due to the impacts of bouldering, mining, and unmanaged fishing. Such activities caused the loss of habitat of most fishes, which made most fishes vulnerable. Hence, activities like bouldering and unmanaged mining should be minimised, monitored and stopped if necessary in order to preserve the aquatic flora and fauna and the natural ecosystem of the Mechi River.

Lastly, the present study with the previous investigation could serve as a baseline scenario for future analysis of the Mechi River and other related water bodies over the next decades.

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