

Spatial and Temporal Variation of Fish Assemblages in Seti Gandaki River, Tanahu, Nepal

ARCHANA PRASAD*¹, ANJANA SHRESTHA¹, JASH HANG LIMBU² & DEEP SWAR³

¹Central Department of Zoology, Tribhuvan University, Kirtipur, Kathmandu, Nepal; ²D.A.V College, Faculty of Science and Humanities, Tribhuvan University, Dohighat Lalipur, Nepal; ³Nepal Fisheries Society Balaju, Machhapokhari Kathmandu, Nepal.

*Corresponding author: archanaprasad001@gmail.com

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ABSTRACT

The space and time variations of the fish community structure in hill streams of Nepal are poorly understood. This research aims at studying the space and time variation of fish community structure in the Seti Gandaki River, Tanahu, Nepal. The field survey was conducted from July 2017 to June 2018 and the fishes were sampled from six sites using a medium size cast net of mesh size ranging from 3 mm to 6 mm mesh size, 25-33 feet length and 3.5-5 feet width, with the help of local fisherman. A total of 1,440 individuals were caught representing 46 species belonging to three orders, nine families and 23 genera. The analysis of similarity (ANOSIM) showed significant difference in space ($R = 0.824$, $P = 0.001$) but not in time ($R = 0.135$, $P = 0.021$). On the basis of similarity percentage (SIMPER) analysis, 85.43% similarity was found among the seasons and major contributing species were *Barilius bendelisis* (8.44%) followed by *B. vagra* (7.79%), *Tor putitora* (7.27%), *Garra gotyla* (7%), *Acanthocobitis botia* (6.7%), *Neolissochilus hexagonolepis* (6.64%), *Barilius shacra* (6%), *B. barila* (4.5%) and *Opsarius barna* (4.37%). On the other hand, 85.24% similarity was found among the sites and major contributing species were *B. bendelisis* (8.8%) followed by *B. vagra* (7.6%), *G. gotyla* (7.27%), *T. putitora* (7.17%), *A. botia* (6.97%), *N. hexagonolepis* (6.7%), *B. shacra* (6.34%), *B. barila* (4.7%) and *O. barna* (4.39%). Results from the Canonical Correspondence Analysis indicated that the environmental variables, such as pH, total hardness, alkalinity, dissolved oxygen and water temperature have shown to determine the fish community structure of Seti Gandaki River.

Keywords: Fish diversity, freshwater, habitat, spatio-temporal, stream

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INTRODUCTION

The physical-chemical environmental parameter influences the fish community structure, which are spatially different and temporally diverse, and biotic interactions such as competition and predation (Gorman, 1988; Harvey & Stewart, 1991; Grossman *et al.*, 1998). Habitat variables such as water temperature, depth (Kadye *et al.*, 2008), water velocity (Yu & Lee, 2002; Limbu & Prasad, 2020), stream width (Gerhard *et al.*, 2004), substrate, altitude, conductivity (Yu & Lee, 2002; Kadye *et al.*, 2008), dissolved oxygen, pH, free-carbon dioxide (Limbu *et al.*, 2019b) and climate (Magalhaes *et al.*, 2002) have all been shown to affect fish community. However, changing environmental parameters can affect biotic

communities in multiple ways and function of ecosystems (McGill *et al.*, 2006; Conversi *et al.*, 2015). Environmental variables are reported to shape the spatial distribution of species (Perry *et al.*, 2005) and influence the temporal variation of communities (Rouyer *et al.*, 2008).

The space and time variations of the fish community structure in the rivers and streams of Nepal are poorly understood (Limbu & Gupta, 2019). Some related studies done in the Nepal's rivers include Edds (1986), Shrestha *et al.* (2009), Shah (2016), Shrestha (2016). Subba *et al.*, (2017), Limbu *et al.* (2018b; 2019a; 2019b). However, these studies did not mention, which factors (physio-chemical factors, current velocity, substrate composition, stream width, water

temperature, water volume, etc.) contribute most to fish community variations. Some aspects of the fisheries and fish ecological studies such as their diversity, space and time distribution and abundance in rivers of Nepal are needed (Mishra & Baniya, 2016). To better monitor, manage and conserve, and to know their status of the fisheries, there is an urgent need to update the information on the spatial and temporal fish diversity, community structure and distribution patterns (Ngor *et al.*, 2018). Therefore, the present study was conducted to determine spatial and temporal variation of fish assemblages with environmental correlates in Seti Gandaki River, Tanahu, Nepal.

MATERIALS AND METHODS

Study Area

The present study area, the Seti Gandaki River is situated in Western Nepal, which rises from the base of the Annapurna massif and surges through south and south-east part of Pokhara and Damauli which finally joins with Trisuli River near Devghat.

To study fish and environmental parameters, six sampling sites of A, B, C, D, E and F (Figure 1)

were allocated along the sampling stretch of the Seti Gandaki River. The sampling site A was selected at upstream of Bhimad Bazar (Changthandi confluence to 2 km upstream). The second sampling site B was chosen near confluence spot of Seti and Jidi Khola (downstream at Bhimad Bazar). The third sampling site C was selected at confluence spot of Seti and Phedi Khola. The sampling site D was selected at dam site of Seti Gandaki River. The sampling site E and site F were chosen at confluence spot of Seti and Madi Khola and downstream of proposed powerhouse in Seti River (Table 1).

Sampling

Sampling was conducted four times a year covering all seasons (winter in January, spring in April, summer in June and autumn in October) over one year of 2018. In this study, each sampling site was 200-250 m long and fish agglomeration was done approximately 2 hours by cast net at each sampling site. The fishes were sampled using cast net of mesh size ranging from 3 mm to 6 mm mesh size, 25-33 feet length and 3.5-5 feet width, with the help of local fisherman. Before preservation, collected fishes were photographed with Nikon Digital Camera (D5600, DX, 24.2 megapixels, Japan). After photography, about 10% collected fishes were

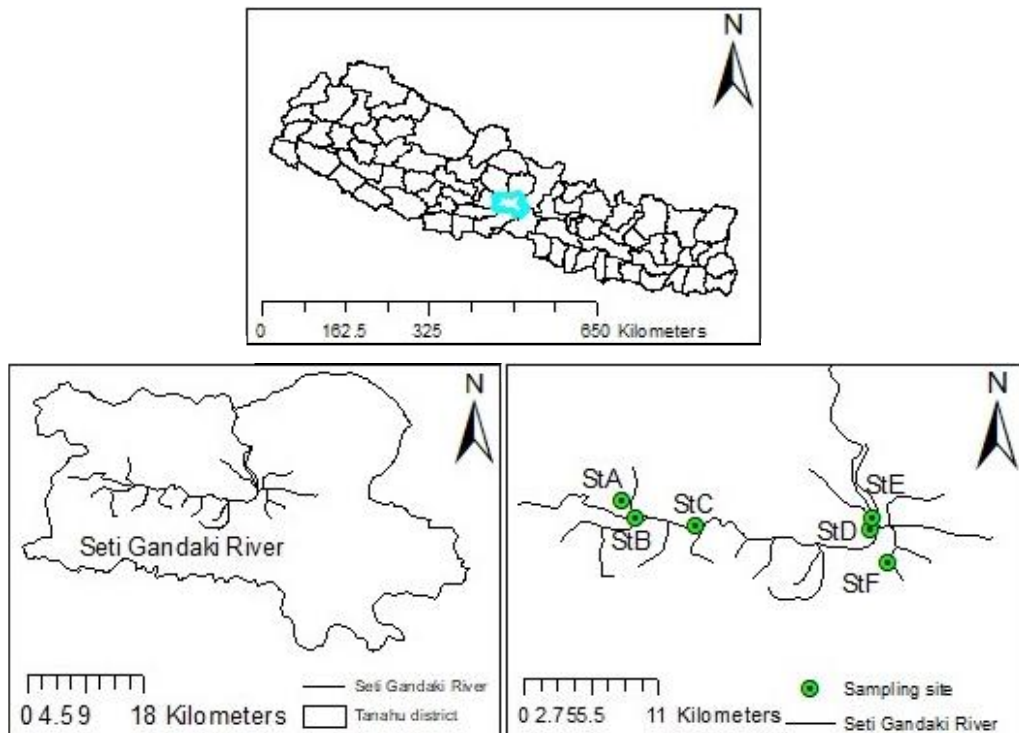


Figure 1. Sampling sites in Seti Gandaki River

Table 1. Information of different stations

Sites	Sampling spot	Location	GPS Location
A	Before Reservoir in Seti river	Myagde and Bhimad, Tanahun	27°59.9''N 84°04.56''E
B	Confluence of Seti and Jidi khola	Bhimad, Tanahun	27°58.26''N 84°5.34''E
C	Confluence of Seti and Phedi khola	Bhimad, Tanahun	27°58.3''N 84°8.10''E
D	Proposed Dam site in Seti River	Patan, Damauli	27°57.52''N 84°15.54''E
E	Confluence of Seti and Madi	Byas	27°58.25''N 84°15.57''E
F	Downstream of proposed Power house in Seti river	Damauli	27°56.25''N 84°16.40''E

preserved in 10% formaldehyde solution in plastic jar by making their head upside for the protection of their caudal fin and remaining samples were returned to their own natural habitat from where they were captured. Afterwards, preserved specimens were taken to the laboratory of the Central Department of Zoology (CDZ), Tribhuvan University, Institute of Science and Technology, Kirtipur, Kathmandu, Nepal. The identification was carried out with the help of standard taxonomic references (Talwar & Jhingran, 1991; Jayaram, 2010).

The following environmental variables were analyzed during each field visit: water temperature, dissolved oxygen (DO), pH, hardness, and alkalinity. Water temperature (°C) was measured with a digital thermometer (Hanna, HI98501, UK) by placing it in the water at a depth of one feet. The DO (mg/l) was measured by the Winkler titrimetric method, while pH was measured using a pH meter (HI98107, Hanna Instrument, UK). Total hardness (mg/l) was determined using EDTA titrimetric method. To determine alkalinity water sample of 10 ml was taken in a conical flask and one drop of phenolphthalein was added to it and mixed well. Bromocresol Green-methyl Red (1 packet) was added to it and stirred properly. It was then titrated with sulfuric acid and end point was recorded.

Data Analysis

The Shannon-Weiner diversity (Shannon & Weaver, 1963) was calculated by the following Eq. (1):

$$H = \sum_{i=1}^S Pi * \log Pi \quad (1)$$

Where S is the total number of species and Pi is the relative cover of i_{th} of species.

Margalef index (d) (Margalef, 1968) was used to measure species richness by using the following Eq. (2):

$$d = (S/1) = \log(N) \quad (2)$$

where S is the total species and N is total individuals.

The dominance index (Harper, 1999) was calculated by using the following Eq. (3):

$$D = \sum_i \left(\frac{n_i}{n}\right)^2 \quad (3)$$

Where n_i is number of individuals of species i .

One-way analysis of similarities (ANOSIM) (Clarke, 1993) was used to test the significant difference among the space and time scales. To visualize the major contributing species both to space and time, similarity percentage (SIMPER) analysis was performed (Clarke, 1993). The correlation between fish community structure and environmental variables were first done using Detrended correspondence analysis (DCA). The axis length (≥ 2.5) and eigen value (≥ 0.5) acquired from DCA suggested that the linear model of Canonical Correspondence Analysis (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).

RESULTS AND DISCUSSION

A total of 1,440 fish individuals were collected in the Seti Gandaki River, representing 46 fish species belonging to four orders, nine families and 23 genera (Table 2 and 3). Among the four orders, Cypriniformes was found to be the most dominating order with 33 species (71.7%), followed by Siluriformes with 10 species (21.7%), Perciformes with two species (4.34%) and Synbranchiformes with a single species (2.17%). Gautam *et al.* (2016) and Pokharel (2011) also reported that Cypriniformes as the dominant order in terms of both species composition, and individuals captured. Besides that, Jha (2006) reported 18 fish species, environment impact assessment of Upper Seti Hydropower Project (Nepal Electricity Authority/ Tanahu Hydropower Limited, 2012) reported 36 fish species, and Pokharel *et al.* (2018) reported 30 fish species, belonging to five orders, nine families and 24 genera from Seti Gandaki River.

The diversity in terms of number (46 species) observed in the present study was 16 species greater than Pokharel *et al.* (2018). It might be due to the limited study areas covered in the earlier report. Cypriniformes and Cyprinidae were the most abundant and species rich order and family, respectively. This is in consistent with the findings of previous studies reported from different rivers and streams of Nepal. For example, Shrestha *et al.* (2009), Shrestha (2016), Mishra and Baniya (2016), Subba *et al.* (2017), Limbu *et al.* (2018a), Limbu *et al.* (2019a, 2019b), and Limbu and Prasad (2020) from Tamor, Triyuga, Dewmai, Melamchi, Morang district, Damak, Ratuwa, Eastern Nepal and Nuwa River. Nelson (2007) also indicated that the majority of the fishes from the river fall under the order Cypriniformes, the huge order of freshwater fishes, which includes 2,422 species.

In terms of temporal variation of fish assemblages, fish species *Chagunius chagunio*, *Neolissochilus hexagonolepis*, *Tor putitora*, *Puntius sophore*, *Barilius barna*, *Barilius shacra*, *Garra gotyla*, *Acanthocobitis botia* and *Nemacheilus corica* were recorded from all four seasons (Table 2). The present finding is in consistent with previous studies (Limbu *et al.*, 2018b; Limbu *et al.*, 2019a; 2019b). Species like *Glyptothorax indicus* and *Nangra viridescens* were

recorded from summer only. The highest individuals were recorded in summer and lowest in spring.

In terms of spatial variation (Table 3), exotic fish, *Oreochromis niloticus* was recorded from site C and site E. According to the local fishermen, this fish was introduced in different lakes of Pokhara Valley (Fewa Lake and Begnas Lake) and have escaped from there and were found in river. Thapa (2018) also reported that 25.13% of *O. niloticus* in Diplang Lake. It is due to high tolerance capacity of this fish in adverse water quality conditions (Rao, 2017). According to local fishermen, there are large sized *Anguilla bengalensis* in the river, but during study it was not recorded. It may be due to decline in their number or obstruction in their regular migrating pathways due to constructions of different barriers (hydro dams) in the river.

The ANOSIM showed significance difference in space ($R = 0.824$, $p = 0.001$), but not in time ($R = 0.135$, $p = 0.021$), which is similar to the findings of Yan *et al.* (2010). According to SIMPER analysis, 85.43% similarity was found among the months with major contributing species, *Barilius bendelisis* (8.44%), *Barilius vagra* (7.79%), *T. putitora* (7.27%), *G. gotyla* (7%), *A. botia* (6.7%), *N. hexagonolepis* (6.64%), *B. shacra* (6%), *B. barila* (4.5%) and *Opsarius barna* (4.37%). An 85.24% similarity was found among the sites with major contributing species, *B. bendelisis* (8.8%), followed by *B. vagra* (7.6%), *G. gotyla* (7.27%), *T. putitora* (7.17%), *A. botia* (6.97%), *N. hexagonolepis* (6.93%), *B. shacra* (6.34%), *B. barila* (4.61%) and *O. barna* (4.39%) (Table 4).

Species Diversity

The Shannon-Weiner diversity index of temporal variation ranged in between 1.17 to 1.83. The highest diversity index was recorded during autumn and lowest in winter (Figure 2). In term of spatial variation of diversity index, highest diversity index was found to be at site C and lowest at site D (Figure 3). The evenness index was reported highest in autumn and lowest in winter (Figure 2), whereas highest evenness index was found to be at site D and lowest at site E (Figure 3). There is no significant difference ($p < 0.05$) observed for temporal and spatial variation. The highest value of species richness was found in winter and lowest value was found in summer and spring respectively (Figure 2), whereas the highest richness value was reported from site D and lowest value was recorded at site A (Figure 3).

Table 2. Temporal variation of fish assemblages of Seti Gandaki River

Family	Species	Code	Summer	Autumn	Winter	Spring	Total individuals
Cyprinidae	<i>Chagunius chagunio</i>	C1	+	+	+	+	30
Cyprinidae	<i>Neolissochilus hexagonolepis</i>	C2	+	+	+	+	119
Cyprinidae	<i>Tor putitora</i>	C3	+	+	+	+	110
Cyprinidae	<i>Tor tor</i>	C4	+	+	-	+	31
Cyprinidae	<i>Puntius conchoniis</i>	C5	+	+	-	-	14
Cyprinidae	<i>Puntius guganio</i>	C6	-	+	-	-	1
Cyprinidae	<i>Puntius sophore</i>	C7	+	+	+	+	31
Cyprinidae	<i>Puntius terio</i>	C8	+	+	+	-	19
Cyprinidae	<i>Puntius ticto</i>	C9	+	-	-	-	32
Cyprinidae	<i>Labeo dyocheilus</i>	C10	+	+	-	-	3
Cyprinidae	<i>Labeo dero</i>	C11	+	+	+	-	25
Cyprinidae	<i>Labeo pangusia</i>	C12	+	+	-	+	6
Cyprinidae	<i>Aspidoparia morar</i>	C13	+	-	+	+	18
Cyprinidae	<i>Barilius barila</i>	C14	+	+	-	+	61
Cyprinidae	<i>Opsarius barna</i>	C15	+	+	+	+	59
Cyprinidae	<i>Barilius bendelesis</i>	C16	+	+	+	+	137
Cyprinidae	<i>Barilius radiolatus</i>	C17	+	+	-	-	12
Cyprinidae	<i>Barilius shacra</i>	C18	+	+	+	+	79
Cyprinidae	<i>Barilius vagra</i>	C19	+	-	+	+	127
Cyprinidae	<i>Brachydanio rerio</i>	C20	-	+	-	-	1
Cyprinidae	<i>Esomus danricus</i>	C21	-	+	-	-	2
Cyprinidae	<i>Crossocheilus latius</i>	C22	+	-	+	+	7
Cyprinidae	<i>Garra annandalei</i>	C23	+	+	+	-	26
Cyprinidae	<i>Garra gotyla</i>	C24	+	+	+	+	108
Cyprinidae	<i>Garra lamta</i>	C25	+	+	-	-	29
Cyprinidae	<i>Garra mullya</i>	C26	+	+	-	-	14
Balitoridae	<i>Acanthocobitis botia</i>	C27	+	+	+	+	120
Cobitidae	<i>Nemacheilus corica</i>	C28	+	+	+	+	22
Cobitidae	<i>Schistura multifasciata</i>	C29	-	+	-	-	2
Cobitidae	<i>Schistura savona</i>	C30	-	+	-	-	3
Cobitidae	<i>Botia almorhae</i>	C31	+	+	-	-	10
Cobitidae	<i>Botia geto</i>	C32	-	+	-	+	9
Cobitidae	<i>Botia lohachata</i>	C33	-	-	-	+	4
Bagaridae	<i>Mystus bleekeri</i>	C34	-	+	-	+	3
Schilbeidae	<i>Clupisoma garua</i>	C35	+	+	+	-	16
Schilbeidae	<i>Clupisoma montana</i>	C36	-	-	-	+	2
Sisoridae	<i>Bagarius yarrelli</i>	C37	-	-	+	-	1
Sisoridae	<i>Glyptothorax alaknandi</i>	C38	+	-	-	+	19
Sisoridae	<i>Glyptothorax cavia</i>	C39	+	+	-	-	2

Table 2. Continue...

Family	Species	Code	Summer	Autumn	Winter	Spring	Total individuals
Sisoridae	<i>Glyptothorax indicus</i>	C40	+	-	-	-	1
Sisoridae	<i>Glyptothorax telchitta</i>	C41	+	-	-	+	11
Sisoridae	<i>Nangra viridescens</i>	C42	+	-	-	-	2
Sisoridae	<i>Pseudecheneis sulcatus</i>	C43	-	+	-	+	9
Mastacembelidae	<i>Mastacembelus armatus</i>	C44	+	+	-	+	7
Cichlidae	<i>Oreochromis niloticus</i>	C45	+	+	-	-	76
Channidae	<i>Channa orientalis</i>	C46	+	+	-	-	20
Total			415	338	374	313	1,440

Table 3. Spatial variation of fish assemblages of Seti Gandaki River

Family	Species	Sites						Total individuals
		A	B	C	D	E	F	
Cyprinidae	<i>Chagunius chagunio</i>	-	+	-	+	+	+	30
Cyprinidae	<i>Neolissochilus hexagonolepis</i>	+	+	+	-	+	+	119
Cyprinidae	<i>Tor putitora</i>	+	+	+	+	+	+	110
Cyprinidae	<i>Tor tor</i>	+	-	+	+	-	+	31
Cyprinidae	<i>Puntius conchoniis</i>	+	-	+	-	-	-	14
Cyprinidae	<i>Puntius guganio</i>	-	-	+	-	-	-	1
Cyprinidae	<i>Puntius sophore</i>	+	+	+	-	-	-	31
Cyprinidae	<i>Puntius terio</i>	+	-	-	-	+	-	19
Cyprinidae	<i>Puntius ticto</i>	-	-	+	-	+	-	32
Cyprinidae	<i>Labeo dyocheilus</i>	-	+	-	+	-	+	3
Cyprinidae	<i>Labeo dero</i>	-	+	-	+	+	+	25
Cyprinidae	<i>Labeo pangusia</i>	-	+	-	+	+	-	6
Cyprinidae	<i>Aspidoparia morar</i>	+	+	-	+	-	-	18
Cyprinidae	<i>Barilius barila</i>	+	+	+	+	+	+	61
Cyprinidae	<i>Barilius barna</i>	+	+	+	+	+	+	59
Cyprinidae	<i>Barilius bendelesis</i>	+	+	+	+	+	+	137
Cyprinidae	<i>Barilius radiolatus</i>	-	-	+	-	-	-	12
Cyprinidae	<i>Barilius shacra</i>	+	+	+	-	+	+	79
Cyprinidae	<i>Barilius vagra</i>	+	+	+	+	-	+	127
Cyprinidae	<i>Brachydanio rerio</i>	-	+	-	-	-	-	1
Cyprinidae	<i>Esomus danricus</i>	-	-	+	-	-	-	2
Cyprinidae	<i>Crossocheilus latius</i>	-	+	-	-	+	+	7
Cyprinidae	<i>Garra annandalei</i>	+	+	+	-	-	+	26
Cyprinidae	<i>Garra gotyla</i>	+	+	+	+	+	+	108

Table 3. Continue...

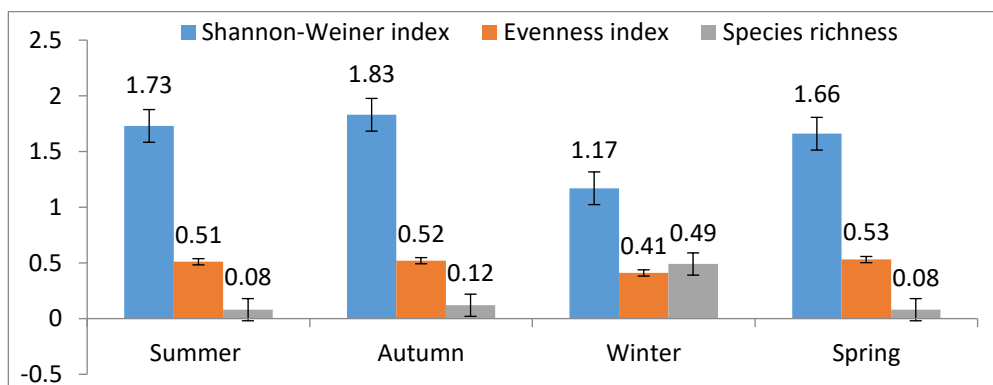
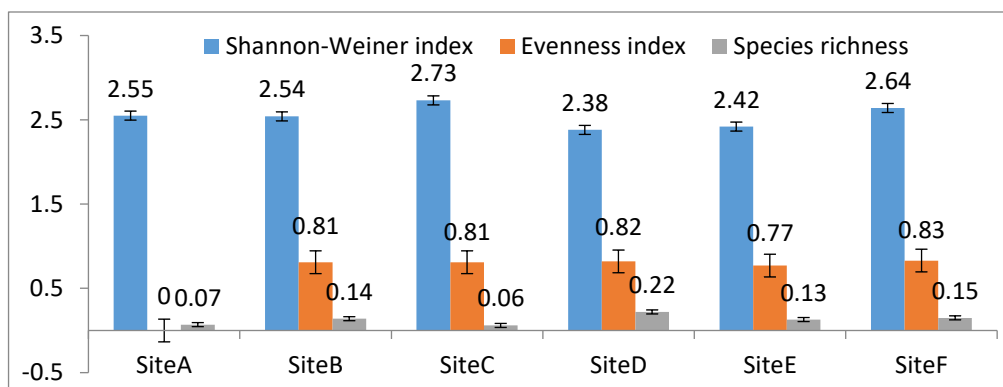
Family	Species	Sites						Total individuals
		A	B	C	D	E	F	
Cyprinidae	<i>Garra lamta</i>	+	+	-	-	-	-	29
Cyprinidae	<i>Garra mullya</i>	-	+	-	-	+	+	14
Balitoridae	<i>Acanthocobitis botia</i>	+	+	+	+	+	-	120
Cobitidae	<i>Nemacheilus corica</i>	+	+	+	-	-	-	22
Cobitidae	<i>Schistura multifasciata</i>	-	-	+	-	-	-	2
Cobitidae	<i>Schistura savona</i>	-	-	+	-	-	-	3
Cobitidae	<i>Botia almorhae</i>	-	-	-	-	+	+	10
Cobitidae	<i>Botia geto</i>	-	-	+	-	+	+	9
Cobitidae	<i>Botia lohachata</i>	-	-	-	+	+	-	4
Bagaridae	<i>Mystus bleekeri</i>	+	-	-	-	-	-	3
Schilbeidae	<i>Clupisoma garua</i>	-	-	+	+	-	+	16
Schilbeidae	<i>Clupisoma montana</i>	-	-	-	-	+	+	2
Sisoridae	<i>Bagarius yarrelli</i>	-	-	+	-	-	-	1
Sisoridae	<i>Glyptothorax alaknandi</i>	+	+	+	-	+	+	19
Sisoridae	<i>Glyptothorax cavia</i>	-	-	-	+	-	-	2
Sisoridae	<i>Glyptothorax garhwali</i>	-	-	-	-	-	+	1
Sisoridae	<i>Glyptothorax indicus</i>	-	-	+	-	+	+	11
Sisoridae	<i>Nangra viridescens</i>	-	-	-	+	-	+	2
Sisoridae	<i>Pseudecheneis sulcatus</i>	-	-	+	+	-	-	9
Mastacembelidae	<i>Mastacembelus armatus</i>	-	+	+	-	+	+	7
Cichlidae	<i>Oreochromis niloticus</i>	-	-	+	-	+	-	76
Channidae	<i>Channa orientalis</i>	+	-	-	-	+	-	20
Total		290	167	568	90	170	155	1,440

Table 4. Average similarity and discriminating fish in each month and site using SIMPER analysis

Month (85.43%)		Site (85.24%)	
Contributory species	%	Contributory species	%
<i>Barilius bendelesis</i>	8.39	<i>Barilius bendelesis</i>	8.72
<i>Barilius vagra</i>	7.69	<i>Barilius vagra</i>	7.60
<i>Tor putitora</i>	7.27	<i>Garra gotyla</i>	7.27
<i>Garra gotyla</i>	7.08	<i>Tor putitora</i>	7.17
<i>Acanthocobitis botia</i>	6.85	<i>Acanthocobitis botia</i>	6.97
<i>Neolissochilus hexagonolepis</i>	6.54	<i>Neolissochilus hexagonolepis</i>	6.93
<i>Barilius shacra</i>	6.08	<i>Barilius shacra</i>	6.34
<i>Barilius barila</i>	4.90	<i>Barilius barila</i>	4.61
<i>Opsarius barna</i>	4.37	<i>Opsarius barna</i>	4.39
<i>Labeo dero</i>	3.80	<i>Labeo dero</i>	3.59

Table 4. Continue...

Month (85.43%)		Site (85.24%)	
Contributory species	%	Contributory species	%
<i>Barilius radiolatus</i>	3.14	<i>Garra lamta</i>	2.98
<i>Garra lamta</i>	2.96	<i>Barilius radiolatus</i>	2.91
<i>Chagunius chagunio</i>	2.89	<i>Chagunius chagunio</i>	2.89
<i>Nemacheilus corica</i>	2.51	<i>Nemacheilus corica</i>	2.52
<i>Tor tor</i>	2.00	<i>Tor tor</i>	2.10
<i>Clupisoma montana</i>	1.92	<i>Clupisoma montana</i>	1.99
<i>Aspidoparia morar</i>	1.92	<i>Aspidoparia morar</i>	1.92
<i>Pseudecheneis sulcatus</i>	1.729	<i>Pseudecheneis sulcatus</i>	1.70
<i>Garra mullya</i>	1.67	<i>Garra mullya</i>	1.63
<i>Garra annandalei</i>	1.61	<i>Garra annandalei</i>	1.55
<i>Glyptothorax indicus</i>	1.56	<i>Puntius terio</i>	1.49
<i>Puntius terio</i>	1.51	<i>Glyptothorax indicus</i>	1.48
<i>Botia lohachata</i>	1.50	<i>Botia lohachata</i>	1.38
<i>Puntius conchonius</i>	1.24	<i>Puntius conchonius</i>	1.25

**Figure 2.** Temporal variation of species diversity index of Seti Gandaki River.**Figure 3.** Spatial variation of species diversity index of Seti Gandaki River.

Canonical Correspondence Analysis

The result obtained after the CCA was plotted in Figure 4. The first and second axis of the CCA accounted for 42% and 30%, respectively. The CCA tri-plot indicated the correlation between species and environmental variables. The species of *T. putitora* (C3), *Tor tor* (C4), *P. sophore* (C7), *Puntius ticto* (C9), *Labeo dero* (C11), *Aspidoparia morar* (C13), *B. vagra* (C19), *Crossocheilus latius* (C22), *Botia lohachata* (C33), *Bagarius yarrelli* (C37), and *G. indicus* (C40) were positively related to pH but negatively related to hardness and DO. The fish species of *Chagunius chagunio* (C1), *Puntius terio* (C8), *Garra mullya* (C26), *A. botia* (C27), *Botia geto* (C32), *N. viridescens* (C42), *O. niloticus* (C45) and *Channa orientalis* (C46) were positively related to dissolved oxygen and hardness but negatively related to pH.

In contrast, fish species of *Puntius conchonius* (C5), *Labeo dyocheilus* (C10), *Labeo pangusia* (C12), *Barilius barila* (C14), *O. barna* (C15),

Brachydanio rerio (C20), *Garra lamta* (C25), *Clupisoma montana* (C36), *Glyptothorax telchitta* (C41) and *Mastacembelus armatus* (C44) were positively related to alkalinity and water temperature. The fish species of *N. hexagonolepis* (C2), *B. benedelesis* (C16), *Barilius radiolatus* (C17), *B. shacra* (C18), *Garra annandalei* (C23), *G. gotyla* (C24), *N. corica* (C28), *Schistura multifasciata* (C29), *Schistura savona* (C30), *T. putitora* (C3) and *Glyptothorax cavia* (C39) were not related to any environmental parameters.

Physical and chemical characteristics are important determinants of the situation of fish community (Li *et al.*, 2012). Results from the CCA indicated that the environmental parameters, such as pH, total hardness, alkalinity, DO and water temperature have shown to determine the fish community structure of Seti Gandaki River. The previous studies, such as (Yu & Lee, 2002; Kadye *et al.*, 2008; Mishra & Baniya, 2016; Limbu *et al.*, 2019a). Limbu and Prasad (2020) have also mentioned that these variables play a crucial role in shaping the fish community structure.

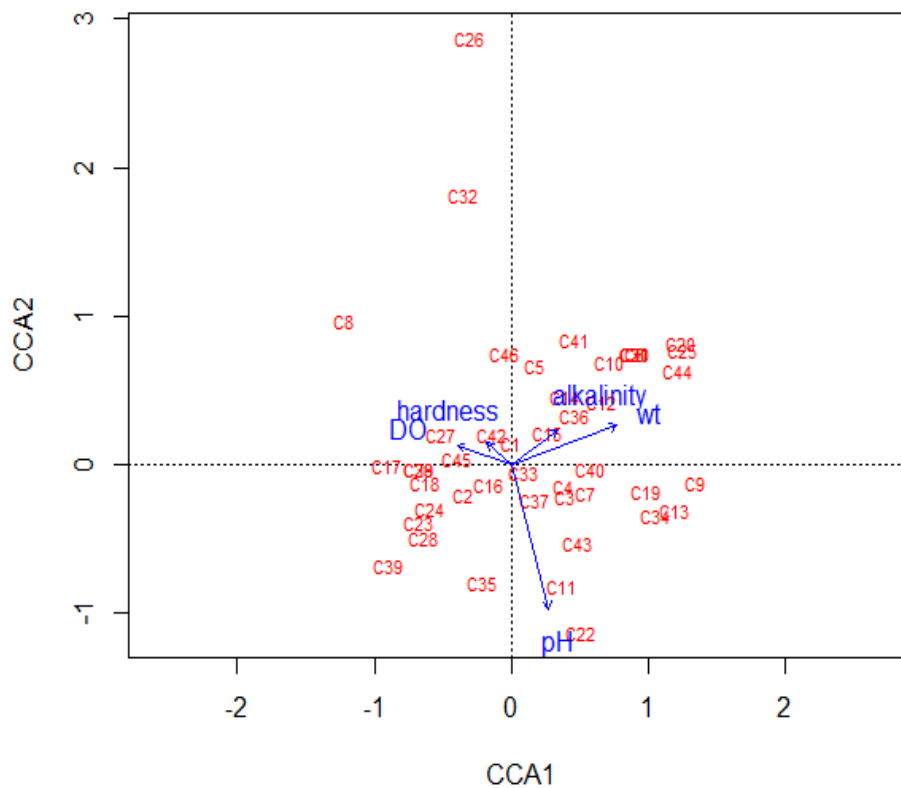


Figure 4. Canonical correspondence analysis (CCA) ordination showing fish species in relation to sites, seasons and environmental variables of Seti Gandaki River (DO = dissolved oxygen, Wt = water temperature) For species code, please refer Table 1.

CONCLUSION

In this study, 46 fish species were reported. Among them *B. bendelisis*, followed by *B. vagra*, *Tor putitora*, *Garra gotyla*, *Acanthocobotis botia*, *Neolisochilus hexagonolepis*, *B. shacra*, *B. barila* and *Opsarius barna* were the major contributory fish species reported from the Seti Gandaki River. Results from the Canonical Correspondence Analysis (CCA) ordination indicated that dissolved oxygen (DO), pH, hardness, and water temperature are the pivotal environmental parameters to determine fish community structure in the Seti Gandaki River, Tanahu, Nepal. River dam constructions were found to be major threats to long (for example, *Anguilla bengalensis*, *Bagarius* spp) and short (*Neolisochilus hexagonolepis*) distance migratory fishes. Besides, dynamiting, extraction and transportation of boulders, cobbles, pebbles, sand mining were also found to be existing threats to the fish diversity of Seti Gandaki River. So, for the better protection and conservation of the native species including migratory fish species, habitat rehabilitation, and construction of fish ladders are necessarily needed.

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