FISH DIVERSITY OF DEUMAI KHOLA, ILAM DISTRICT, NEPAL

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ABSTRACT

This study aims to investigate fish assemblage structure and environmental variables across the five sites from January 2019, April 2019, June 2019 and October 2019 in Deumai river, Province No.1, Nepal. In total, 5757 specimens were caught, representing 16 species and *Barilius barila* (15.68%), *B. bendelisis* (12.44%), *Schistura multifaciatus* (10.35%), *S. scaturigina* (10.07%), *Nazirator chelynoids* (8.94%), *Schistura rupecula* (8.9%), *Channa punctatus* (6.56%), *Glyptothorax pectinopterus* (5.66%), and *Schizothorax plagiostomus* (5.08%) are the major contributory species for Deumai river. The ANOSIM analysis indicated that the fish assemblage structure had significant differences among the sample sites ($p<0.05$) but not with temporal variation ($p>0.05$). Redundancy Analysis (RDA) suggested that environmental variables of dissolved oxygen, free-carbon dioxide, ammonia, and pH were found to be important variables in shaping the fish assemblage structure of Deumai River. The distance correlation cluster method obviously portrayed that the similarity of fish species lessen when their distance of sites increased.

Keywords: fish diversity, environmental variables, RDA, cluster, freshwater, Nepal

INTRODUCTION

The diversity of the natural population is partially dependent on the environmental variables which always affect the competing populations (Chowdhury *et al.* 2010; Hossain *et al.* 2012). The factors influencing fish assemblages involve the environmental variables which are spatially heterogenous and temporally variable and biotic interactions such as competition and predation (Gorman, 1988; Harvey and Stewart, 1991; Grossman *et al.* 1998). Most important environmental variables are temperature, dissolved oxygen, pH, depth, free carbon-dioxide, total hardness, and water velocity (Yu and Lee, 2002, Pessanha and Araujo, 2003, Kadye*et al.* 2008, Limbu *et al.* 2019) and fisheries diversity of river are also affected by chlorophyll-a, altitude, conductivity, substrata, distance to source, and climate (Blanc *et al.* 2001; Magalhaes *et al.* 2002; Yu and Lee, 2002; Vlach *et al.* 2005). 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).

Fish assemblage structure in the rivers and streams of Nepal has not been well studied. The spatial and temporal variations of the fish assemblages in rivers and streams of Nepal are poorly understood (Limbu *et al.* 2019) and still thousands of rivers, streams and lakes are being unexplored (Limbu *et al.* (2018).

To the best of our knowledge, there is no any report of fish diversity of Deumai river. So, to overcome above research gaps we have initiated the present research to determine the spatio-temporal fish assemblages of Deumai River, Ilam, East Nepal and the physico-chemical variation of their aquatic habitats.

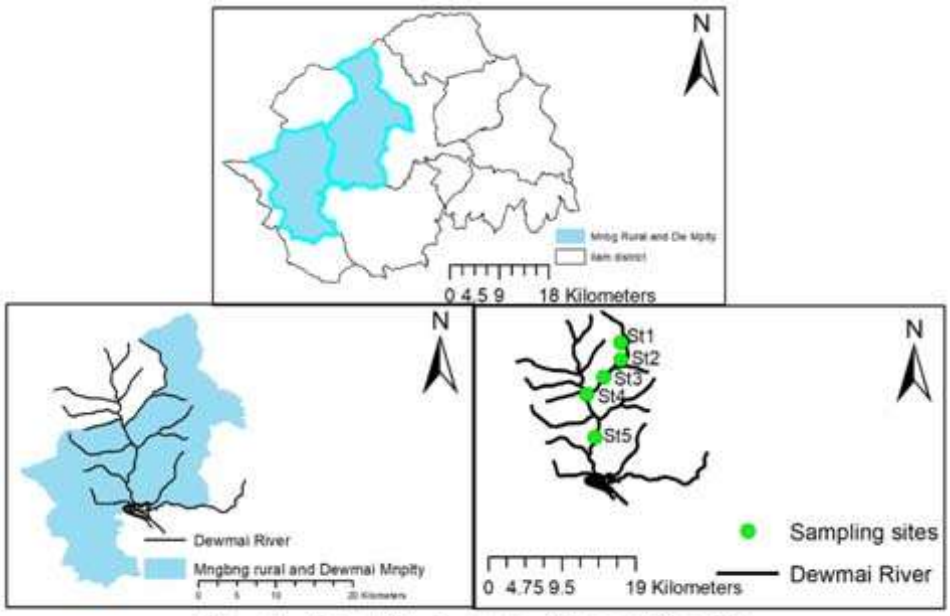

Figure 1. Map of study area with sampling sites.

MATERIALS AND METHODS

Study area and sampling

The study area lies between latitude 26º98' and 26º87' N and longitude 87º81' and 87º78'E. The river Deumai is one of the major rivers of Ilam District and it is used for drinking, irrigation and to generate hydroelectricity. It originates from Chamaita and joins with Phakphok river at Dobhan then flows south wards touching Deumai municipality,in the east ,mangsebung Rural municipality in the west and ultimately joins with the river Kankai at Phulungi. Fish samples were collected from five sites (site1 to site5). Site1 at Ale Dhobhan (26º59.17' and 87º48.51'), site2 at Singalapa Fedi (26º57.54' and 87º49.00'), site3 at Phakphok Dobhan (26º56.46' and 87º47.34'), site4 at Gajurmukhi Dham (26º55.39' and 87º46.43'), and site5 at Wallong (26º52.21' and 87º46.50') were chosen for fish agglomeration. Fish samples were collected seasonally in winter 2019, spring 2019, summer 2019 and autumn 2019. A sample reach of 100m was fished for 30 min at every site using caste net of 4mm × 4mm and 6mm × 6mm mesh size with 500m area for 2:30 hrs (7:00 – 9:30 am) to reduce the biasness of sampling. The fishes were identified to species level, counted and then were returned to the site from where they were captured. Unidentified fishes were kept in 10% formaldehyde solution and brought to the laboratory of Central Department of Zoology, T.U. Kirtipur, Kathamndu, Nepal for further identification. The specimens were identified using standard taxonomic references (Jayaram, 2010 and Talwar and Jhingran, 1981).

Following environmental variables were determined during each field visits: water velocity, water temperature, pH, dissolved Oxygen, ammonia, total hardness and fee carbon-dioxide. Water velocity was measured by the float method with the help of a stop watch and measuring tape. The float material was squeezed lemon which was tied to a rope and left in the river for 30 sec and the time to cross the point was calculated and this velocity was expressed in m/s.Water temperature (ºC) was measured with a digital thermometer by placing it in the water at a depth of 1feet within 1 minute and obtained value was recorded. The pH was measured using a calibrated pH meter (HI 98107, HANNA Instrument). Dissolved oxygen was measured adopting Winkler's titrimetric method. The value of ammonia was measured using freshwater master kit (PA, 19204). Total hardness (mg/l) was determined titrimetrically by EDTA method. The proportion of substrates were categorized (substrate size1 = sand, silt < 2mm, 2 = gravel < 2-16mm, 3 = pebble < 17-64 mm, 4 = cobble < 65-256 mm, 5 = boulder > 256 mm) and estimated visually, according to Bain et al. (1985).

Data analysis

Site and season wise diversity indices were calculated by using library Vegan in R (Oksanen *et al.* 2019). Detrended correspondence analysis (DCA) was formed to determine whether redundancy analysis (RDA) or canonical correspondence analysis (CCA) would be the most appropriate model to describe the association between species and environmental variables. The value of axis length and eigen values obtained from DCA suggested that the linear model of RDA was more applicable. Therefore, a direct multivariate ordination method (Ter Break and Prentice, 1988) based on a linear response of species to environmental gradients (Gauch, 1982; Ter Break, 1986 and Palmer, 1996) was applied by using vegan library in R (Oksanen *et al.* 2019). One way analysis of similarity (ANOSIM) (Clarke, 1993) was used to conclude the significance of spatial and temporal variation of fish assemblage structure. To know the distance correlation of each species, cluster analysis was performed into different assemblage clusters based upon the abundance of each fish species by utilizing pv-clust package in R (Suzuki and Shimodaira, 2015). To visualize the major contributing species both to space and time, similarity percentage (SIMPER) (Clarke, 1993) analysis was performed.

RESULTS

Environmental variables

Distinct environmental variables of different sites at different seasons are shown in table 1. Maximum dissolved Oxygen (mg/l) recorded was 10 mg/l at site 4 during winter where minimum was found 6.9 mg/l at site 4 during summer. Maximum water velocity 2 m/sec was recorded during autumn at site 5 where minimum water velocity was at site 1 during summer. Maximum Hardness was obtained at site 1 during summer where minimum hardness value 88 mg/l was found at site 3 and site 4 during winter and summer. In contrast, the value of ammonia was ranged between 0-0.25 ppm. At site 1 level of ammonia was recorded 0 ppm but the ammonia was recorded from site 2 during spring and summer, at site 3 during Spring, at site 4 during Summer and at site 5 during Summer. Maximum pH value was recorded from site 2 & site 4 during summer. Maximum water temperature 23℃ was recorded from site 5 during summer and minimum 8℃ was recorded at site 1 during winter.

Table 1: Observed environmental variables from Deumai River.

Sites	Season	pH	Water velocity (m/sec)	Dissolved oxygen (mg/l)	Temperature (℃)	Ammonia (ppm)	Hardness (mg/l)	Free-carbondioxide (mg/l)
site 1	Winter	7.7	1	8	8	0	79	8
site 2	Winter	7.8	1.12	8.4	13	0.25	89	8.6
site 3	Winter	8	1.12	7.9	20	0.25	88	9
site 4	winter	7.9	1.13	10	17	0	88	6
site 5	winter	7.8	1.6	8	8.3	0	99	8
site 1	spring	8	1.7	7	13.5	0.25	101	6.7
site 2	spring	9	1.56	7	21.5	0	96	7
site 3	spring	8	1.59	7.8	17.2	0	112	9.5
site 4	spring	7.9	1.67	7.9	10	0	89	11
site 5	spring	8	1.89	8	16	0	111	12
site 1	summer	6.8	0.55	7	22	0	120	9
site 2	summer	8	0.99	7.8	19	0	95	8

site 3	summer	7.9	0.99	7.6	12	0	112	9
site 4	summer	8	1	6.9	14	0	88	7.8
site 5	summer	9	1.45	9	23	0.25	109	8.5
site 1	autumn	8	1.2	8	21	0	98	9
site 2	autumn	7.8	1.3	8.7	12.8	0	110	11
site 3	autumn	8	1.56	9	16	0	116	13
site 4	autumn	6.6	1.89	8.8	23	0.25	95	10
site 5	autumn	8	2	8	21	0	99	9

Species abundance and distribution

A total of 5,757 individuals were enumerated during the study, representing 16 species. According to Similarity percentage (SHRIMPER) analysis (Table 2), the major contributing species are *Barilius barila* (15.68%), *B. bendelisis* (12.44%), *Schistura multifaciatus* (10.35%), *S. scaturigina* (10.07%), *Nazirator chelynoids* (8.94%), *Schistura rupecula* (8.9%), *Channa punctatus* (6.56%), *Glyptothorax pectinopterus* (5.66%), and *Schizothorax plagiostomus* (5.08%). Copious number of 1571 individuals were recorded in site 4 throughout the study period and the lowest number of individuals was counted in site 3. Maximum number 1877 individuals were counted in winter and lowest number 970 individuals were counted in autumn (Table 3). The temporal abundance variation for each sampling site gradually subsided from summer to autumn and turgid in winter and spring. The analysis of similarity (ANOSIM) showed significant difference in spatial variation (R=0.61, P<0.05) but no significant difference in temporal variation (R=-0.17, P>0.05).

Table 2. Result of major contributing fish species using SHRIMPER analaysis.

Species	**Contribution (%)**
Barilius barila	15.68
B. bendelisis	12.44
Schistura multifaciatus	10.35
S. scaturigina	10.07
Nazirator chelynoids	8.94
Schistura rupecula	8.9
Channa punctatus	6.56
Glyptothorax pectinopterus	5.66
Schizothorax plagiostomus	5.08
S. labiatus	4.75
Schistura horai	4.21
Danio aquapinnatus	2.06
Mastacembelus armatus	1.74

Table 3: Spatio-temporal variation of fish assemblages of Deumai River.

Scientific name	**Code**	**Total number caught**	**%**	**St1**	**St2**	**St3**	**St4**	**St5**	**Wint**	**Spr**	**Sum**	**Aut**
Naziritorchelynoides	Nc	446	8.02	-	-	-	258	188	175	142	48	81
Bariliusbarila	Br	763	13.91	-	-	-	348	415	255	187	188	133
Barilius bendelisis	Brn	874	15.72	-	-	-	405	469	345	183	200	146
Danio aequipinnatus	Da	96	1.72	-	-	-	52	44	43	26	12	15
Schixzothoraichthys labiatus	Sl	198	3.56	-	168	30	-	-	56	45	85	12
Schizothorax plagiostomus	Sp	197	3.54	-	189	8	-	-	67	47	78	5
Garra gotylagotyla	Gg	281	5.05	-	-	-	159	122	106	72	46	57
Psilorhynchus sucatio	Ps	59	1.06	-	-	-	37	22	28	23	8	-
Schisturahorai	Sh	138	2.48	79	23	36	-	-	30	19	55	34
S. multifaciatus	Sm	824	14.82	297	339	188	-	-	208	220	187	209
S. scaturigina	Ssc	535	9.62	331	150	54	-	-	170	148	119	98
S. rupecula	Sr	285	5.12	258	9	18	-	-	93	92	53	47
S. sovana	Ss	605	10.88	262	237	106	-	-	192	200	147	66
Glyptothorax pectinopterus	Gp	145	2.6	-	-	-	145	-	-	-	78	67
Mastacembelus armatus	Mar	50	0.89	-	-	-	-	50	-	30	20	-
Channa punctatus	Cp	261	4.69	-	-	-	167	94	109	89	63	-
Total		**5,757**	**100**	**1227**	**1115**	**440**	**1571**	**1404**	**1877**	**1523**	**1387**	**970**

Diversity status

The value of Shannon-Weiner diversity index (H), Simpson Dominance index (D) and Pielou's Evenness index (E) were calculated according to sites and seasons (Figure 2, 3). Highest Shannon diversity index (1.71) was found at site 4 and in spring (2.37) whereas lowest (1.53) was found at site 5 and in autumn (2.27). In contrast, highest Simpson Dominance index value was observed at site 4 (0.791) and in spring (0.892) whereas lowest value was observed at site 3 and 5 and in autumn (0.87). Similarly, highest value of Evenness index was observed at site 4 and in summer (0.39) whereas lowest value of Evenness index was observed at site 3 and in autumn (0.38).

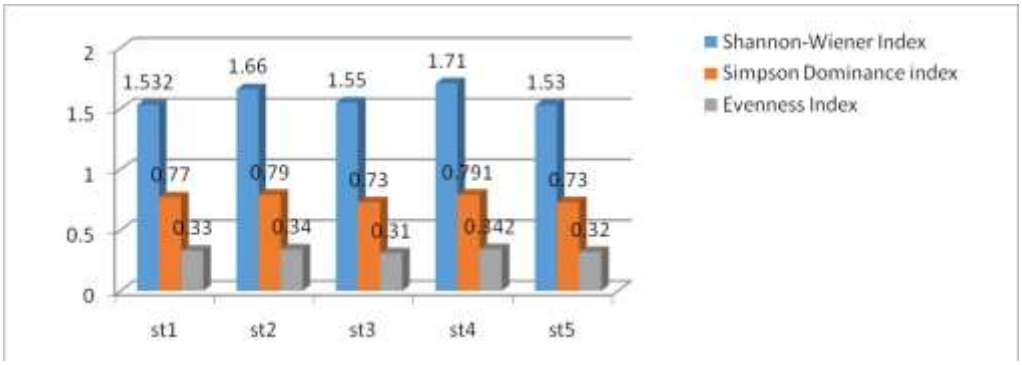

Figure 2. Spatial variation of different fisheries diversity status at Deumai River.

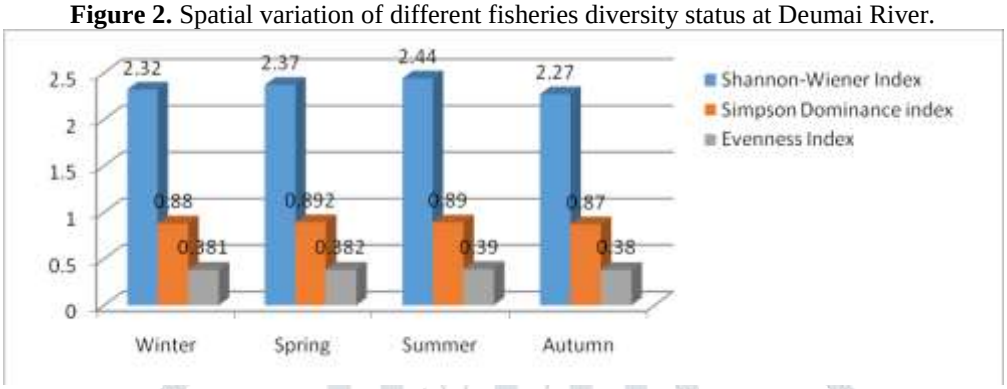

Figure 3. Temporal variation of different fisheries diversity status at Deumai River.

Correlation between fish assemblages and environmental variables

The result obtained after the redundancy analysis (RDA) was plotted in figure 4. The vector length of environmental variables pointed out importance of that variable. The water parameters such as dissolved oxygen (DO), free-carbon dioxide, ammonia, and pH were found to be pivotal variables to shape the fish assemblage structure. Dissolved oxygen and free carbon dioxide were found to be associated with the occurrence of *Barilius barila, B. bendilisis, Nazirator chelynoids, Garra gotyla, Channa punctatus, Danio aequipinnatus* and *Mastacembelus armatus.* The value of pH is associated with *Schizothorax plagiostomus* and *Schixzothoraichthys labiatus.* Value of ammonia was found to be associated with the occurrence of *Schistura multifaciatus, S. scaturigina, S. sovana, S. horai* and *S. rupecula*. In contrast, the variables of water temperature, total hardness and water velocity portrayed the positive relation with *Glyptothorax pectinopterus.*

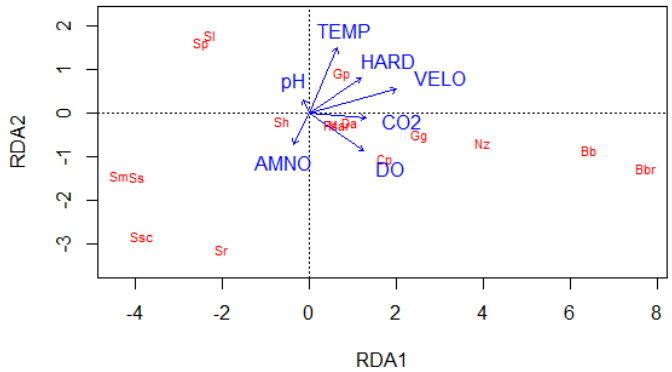

Figure 4. RDA analysis of fish assemblages with environmental variables (TEMP, temperature; HARD, hardness; VELO, velocity; AMNO, ammonia; CO_2, carbon dioxide; DO, dissolved Oxygen) of Deumai River (*for species code see table 1*).

Pv-Cluster analysis of fish species of Deumai River

Hierarchial clustered dendrogram of fish species from the Deumai River, black and bold colored number represents the cluster number, red represents probability of Automatic Unbiased (AU) value and blue colored number represents Bootstrap Probability (BP) value.

AU value > or = 95 represents significant cluster.

The pv-Cluster of fish species generated a dendrogram with two significant major clusters. Except cluster number 5, all the cluster groups showed significant cluster groups. One of the major cluster was ordinate at the left end of the plot and also formed 5 sub-cluster groups. The cluster number 2 was formed of *Schizothorax plagiostomus* and *Schizothoraichthys labiatus* with 100% Automatic Unbaised (AU) value which indicated the significant cluster between these two species. Similarly, Cluster number 6, 8, 10 and 12 also formed significant cluster group with 100% Automatic Unbaised (AU) value. In contrast, at the right side of the plot the cluster number 13 has 8 sub-cluster groups. Cluster number 1 was formed by *Barilius barila and B. bendelisis* with 100% AU value. Similarly, cluster number 3, 4, 7, 9 and 11 were also formed significant cluster group with 100% AU value. The distance correlation cluster method obviously portrayed that the similarity of fish species lessen when their distance of sites increased.

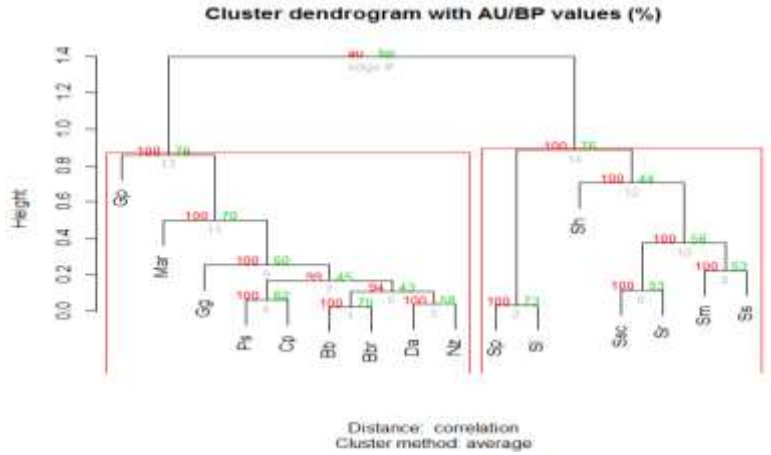

Figure 5. Dendrogram of cluster analysis comparing fish species on the basis of fish assemblage (*for species code see table 1)*

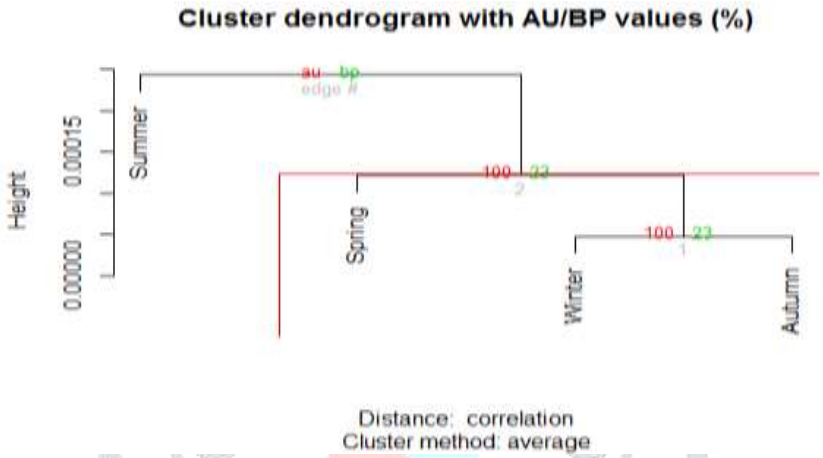

Figure 6. Dendrogram of cluster analysis comparing seasons on the basis of fish assemblage (*for species code see table 1*)

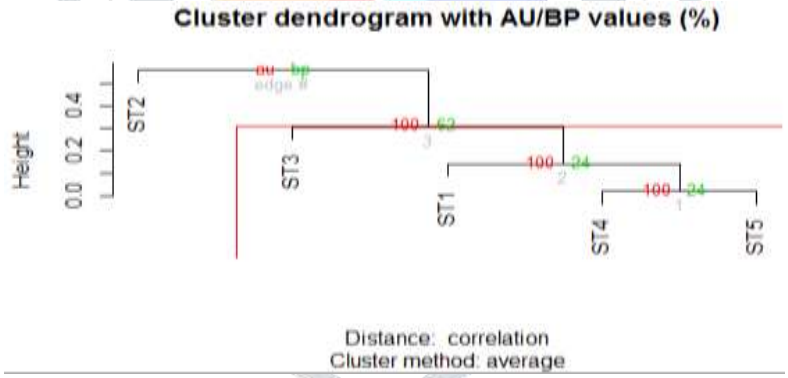

Figure 7. Dendrogram of cluster analysis comparing sampling sites on the basis of fish assemblage (*for species code see table 1)*

DISCUSSION

Dissolved oxygen ranged between 6.9 to 10 mg/l and was consistent with the findings of, Shrestha *et al*. (2009); Mishra and Baniya (2016); Limbu *et al.* (2018) and Limbu *et al*. (2019). Dissolved oxygen is directly associated with the water temperature and water velocity. However, the value of the dissolved oxygen recorded from the present study is inconsistent with the findings of Hossain *et al.* (2012) and Ahammad (2004). Water velocity of the present study ranged between 0.55 to 2 m/sec which shows the similarity with Limbu *et al*. (2019). Maximum water velocity was recorded at ST5. This is due to heavy rainfall which leads to increase water volume. Maximum total hardness of temporal variation found between 88 to 120 mg/l which is almost similar to the value reported by Limbu *et al.* (2018); Limbu *et al*. (1019) and Limbu and Prasad (2020). The value of ammonia was ranged between 0-0.25 ppm and was recorded at site 2, 3, 4 and 5. Ammonia was recorded from these four sites, it might be due to human perturbation. Anthropogenic activities produce increasing amounts of nitrogenous material and a significant proportion is in the form of ammonia or compounds which can yield ammonia (Eddy, 1999; Alabaster & Lloyd, 1982). pH of the present study shows the similarity with Shrestha *et al.* (2009); Limbu *et al.* (2019); Martin (1970); Noori (1999); Rshid (1999) and Limbu *et al.* (2018).High pH value at site 2 and site 4 was attributed to the presence of extreme human perturbation with domestic waste disposal. Water temperature of the present study varied from 8-23C° which is consistent with the findings of Mishra and Banita (2016), Limbu *et al*. (2019), and shows the dissimilarity with Hossain *et al*. (2012).

A total of 16 fish species were recorded during the study period. Among them *Barilius barila, B. bendelisis, Schistura multifaciatus, S. sovana* and *Nazirator chelynoids* were the dominating species recorded from the Deumai River. Limbu and Prasad (2017) reported 11 species from Phewa Khola. Limbu *et al.* (2018, 2019a, 2019b, 2019c) recorded 9, 18, 151 and 10 species from, Bakraha River, Ratuwa River, Eastern Nepal and Likhu River. Subba *et al.* (2017) reported 118 species from Morang district.

Based on our ANOSIM fish assemblages in the Deumai River differed in spatial variation but not in temporal variation. The R value for spatial variation (0.61) is larger than for temporal variation (-0.17) which is similar with Yan et al. (2010).

In terms of spatial and temporal variation of fish assemblages of Deumai River, highest number of individuals were reported at ST4 and this was due to low human perturbation, optimum environmental condition, and food availability and on the other hand lowest number of individuals were found at ST3 and this is due to extreme human activities. In addition, *Shistura multifaciatus, S. horai, S. sovana, S. scaturigina* and *S. rupecula* were ubiquitously plenitude for site 1 site 2 and site 3. Among them, *Schistura multifaciatus* was found to be dominated species from three sites. Limbu and Prasad (2017) also reported the species to be the most dominating species from the Phewa Khola which is the main tributary of Deumai River. Fish species like *Nazirator chelynoids, Barilius barila, B. bendelisis, Danio aquipinnatus, Garra gotyla, Psylorhynchus sucatio, Glyptothorax pectinopterus, Channa Punctatus* and *mastacembelus armatus* were recorded from site 4 and site 5. Among them *Barilius bendilisis* and *B. barila* were the common species and most dominated species recorded from Deumai River where Subba *et al.* (2017) and Limbu *et al.* (2019) have also reported the same species as a most dominated species from Morang district and Ratuwa River of Jhapa district. Site 4 and site 5 were found to be more diverse than the site 1, 2 and 3. The site 1, 2 and 3 were situated headquater of upstream of Deumai River where site 4 and 5 located downstream of Deumai River. Fish assemblages in the Deumai River displayed a gradual accretion in species richness and abundance along gradient from headwater to downstream which followed the same pattern of Yan et al. (2010).

For spatial variation, wealth of individuals were recorded during winter whereas less number of individuals were enumerated in autumn season. Except *Psylorhynchus sucatio, Glyptothorax pectinopterus* and *Channa puctatus* all the species were recorded from all four seasons. Generally, these three species are hard to catch because of their differing habitats compared to the other species. *Psylorhynchus sucatio* and *Glyptothorax pectinopterus* were recorded during summer and autumn. In summer and autumn because of heavy rainfall, water volume of rivers increased and these species came out at the edges of the river and irrigation canals. *Channa puctatus* was recorded in spring and summer only. The probable reason might be this species prefers lentic water system and inhabits the pools, puddles and edges of the river.

A biodiversity index seeks to characterize the diversity of a sample (Magurran, 1988) and easily influenced by the specimen number, sampling size and ecological factors (Leonard *et al.* 2006). Shannon diversity index considers the richness and proportion of each species while Evenness and Dominance indices represents the relative number of individuals in the sample and the fraction of common species (Hossain *et al.* 2012). The biodiversity index values obtained from present study is not high. According to Keskin and Unsal (1988) the reason for showing lower species biodiversity is that fishing gears have high selectivity effect. Highest Shannon diversity index (1.71) was found at site 4 and in spring (2.37) whereas lowest (1.53) was found at site 5 and in autumn (2.27). According to Hossain *et al.* (2012) high Shannon diversity index is involved with low individuals and low diversity involved with higher number of individuals. In contrast, highest Simpson Dominance index value was observed at site 4 (0.791) and in spring (0.892) whereas lowest value was observed at site 3 and 5 and in autumn (0.87). Similarly, highest value of Evenness index was observed at site 4 and in summer (0.39) whereas lowest value of Evenness index was observed at site 3 and in autumn (0.38). The diversity indices of the present study are similar to the study of Mishra and Baniya (2016), Limbu *et al.* (2018), and Limbu *et al. (*2019).

To conclude, the Deumai River of Ilam district, harbors 16 fish species. Among them, *Barilius barila, B. bendilisis, Schistura multifaciatus,* and *S. sovana* were found to be the dominant species the dominated species recorded from Deumai River. The redundancy analysis (RDA) depicted that the environmental variables of dissolved Oxygen, free-carbon dioxide, ammonia, and pH plays imperative role to shape the fish assemblage structure of Deumai River.

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