CORRELATIONS BETWEEN FISH ASSEMBLAGE STRUCTURE AND ENVIRONMENTAL VARIABLES IN THE LOHORE RIVER OF DAILEKH, WESTERN NEPAL

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DECLARATION

I hereby declare that the work presented in this thesis has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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RECOMMENDATION

This is to recommend that the thesis entitled "**Correlations between fish assemblage structure and environmental variables in the Lohore River of Dailekh, Western Nepal**" has been carried out by Sushil Kumar Shrestha for the partial fulfillment of Master's Degree of Science in Zoology with special paper Fish and Fishery. This is his original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

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LETTER OF APPROVAL

On the recommendation of supervisor Prof. Dr. Kumar Sapkota, Central Department of Zoology, Tribhuvan University this thesis submitted by Sushil Kumar Shrestha entitled **"Correlations between fish assemblage structure and environmental variables in the Lohore River of Dailekh, Western Nepal**" is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of requirements for Master's Degree of Science in Zoology with special paper Fish and Fisheries.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Sushil Kumar Shrestha entitled **"Correlations between fish assemblage structure and environmental variables in the Lohore River of Dailekh, Western Nepal"** has been accepted as a partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Fish and Fishery.

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ABBREVIATIONS

Abbreviated form	Details of Abbreviations
AU	Automatic Unbiased
BOD	Biological oxygen demand
BP	Bootstrap probability
BS	Bikram sambat
CCA	Canonical correspondence analysis
SIMPER	Similarity percentage
DCA	Detrended correspondence analysis
DFD	Directorate of fisheries development
DNPWC	Department of National Park and Wildlife Conservation
DO	Dissolved oxygen
DOFD	Directorate of fisheries development
F- CO_2	Free carbon dioxide
IUCN	International union for conservation of nature
MANOVA	Multivariate analysis of variance
pH	Hydrogen ion concentration
RDA	Redundancy analysis

ABSTRACT

The correlations between fish assemblage structure in Lohore River, Karnali Province is poorly understood. To examine the fish diversity structure, fish samples were collected in seasonal basis from three sites of the river by using cast net. A total of 201 individuals belonging to 2 orders, 3 families, 8 genera and 11 species were collected from Tallo Dungeshwor, Mathillo Dungeshwor and Chupra of Lohore River. Majority of the fishes belonged to the family Cyprinidae (72.72 %) followed by Sissoridae (18.18 %) and Nemacheilidae (9.09 %). the most abundant species were *Tor chelynoides*, *Barilius barila and Schizothorax plagiostomus*. The highest Shannon diversity index (2.29) was found at station C (Chupra) in Summer, Lowest Shannon diversity index (1.72) at station A (Tallo Dungeshwor) in Autumn there was no significant difference ($p>0.05$) was found in the value of Shannon Winer diversity index for both space and time. The redundancy analysis (RDA) revealed significant correlations between fish abundance and environmental variables. The environmental variables such as water temperature, water velocity, dissolved oxygen, free carbondioxide were most strongly correlated with the fish community composition. The difference in fish diversity structure in Lohore River are probably related to habitat type, altitude, seasons, several environmental factors and anthropogenic activities.

1. INTRODUCTION

1.1. Background

A fundamental features of the earth is an abundance of water, which covers 71% of its surface to an average depth of 3800 meters of the total water about 97% remains in the seas as salt water and remaining 3% exist as fresh water in rivers, lakes, streams, reservoirs, underground water, polar and permanent glaciers (Wetzel, 1983). Nepal is a land locked country and is very rich in biodiversity and natural resources. In spite of its small area Nepal is endowed with a wide range of renewable water resources in the form of rivers, rivulets and streams, lakes, reservoirs, ponds, swamps and wetland and paddy field. The inland water resources of Nepal totaling 8, 17,100 hector which covers about 3% of Nepal land area and consist of natural water (rivers, lakes, reservoirs etc.), village ponds, and marginal swamps and irrigated paddy fields (Directorate of Fisheries Development, 2007). Various types of inland water resources existing in the country provide great scope for the expansions of fisheries.

Fishes are one of the major wetland resources harvested by the local populace living adjacent to the reservoir (Department of National Park and Wildlife Conservation / International Union for Conservation of Nature, 2002). Various forms of water resources of the country prove to be good shelter areas to a large number of indigenous fish species of high economic and academic values. A review on the current taxonomic status of the indigenous of the fish species reveals that there are 232 fish species identified till now in Nepal (Shrestha, 2008). These fish species are found in various water bodies at different altitudes ranging from a few hundred meter above sea level to as high as 4,000 meters. The river and stream of hilly region dominated by cold water fish species while warm water fish species are dominated in Terai recorded 230 species of freshwater fish, approximately 59 species categorized as cold water fish (Petr and Swar et al, 2002) and 21 species are in the International Union for Conservation of Nature Red List. The fishes of Nepal are very similar to those of Southeast Asia, consisting mainly of carps, catfishes, eels and hill stream fishes (Mishra and Kunwar, 2014).

A central challenges in fisheries ecology is to understand why species abundance changes over time (Sissenwine, 1984; Cushing, 1990). Consequently the majority of fisheries research focuses on temporal variability of fish populations. Within the distribution of fish

(Population abundance) and environmental variables are averaged over laege geographic areas and their degree of correlation is then examined (Ciannelli et al., 2004a; mackenzie and Koster, 2004). All biological communities vary greatly in space and time the control of abundance and distribution of species in space and time by the abiotic and biotic environment remains a central problem in ecology (Brown, 1984). The distribution of fish species and other living things are directly dependent on ecological time. Habitat features such as depth, current and substratum (Schlosser, 1982; Bain, Finn and Booke, 1988), water quality (Matthews, 1998), presence of shelter, or habitat diversity may play a major role in shaping fish communities in space. Water temperature (Baltz et al., 1987; Matthews, 1998) are the main physical parameters structuring fish assemblages in time. these physical parameters, together with biotic interactions such as competition for food and avoidance of predation (Angermeier, 1987; Govoni, Hoss and Colby, 1989), have strong effects on fish survival, leading to high fluctuations in the abundance of individuals, and thus, in the composition of fish communities in space and time.

Fish assemblage is an important element in aquatic ecosystem. It provides a good biological indication for the quality of freshwater ecosystems since it is sensitive to a broad range of stressors (Karr, 1981; Oberdorff et al., 2002). It has been widely reported that the distribution and abundance of fish species are strongly related to environmental factors (Tejerina-Garro et al., 1998; Brown 2000). These factors include topographical characteristics (Platts, 1979), climate (Eaton and Scheller, 1996), hydrological regime (Poff and Allan, 1995), riparian land use (Lammert and Allan, 1999) and water physical-chemical variables such as dissolved oxygen and pH (Matthews and Hill 1979). Apart from abiotic factors, biotic factors such as predation and competition could also affect fish assemblage's direct and indirect mechanisms (Jackson et al., 2001).

In the context of Nepal there is rich diversity of freshwater aquatic fauna including fishes and plankton. Moreover, fish diversity of Nepal has been poorly studied or understood relative to other fauna (Shrestha et al., 2009; Limbu et al., 2018). There is a strong relationship between different water quality parameters with 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 played vital role in diversity and distribution patterns of the fish species (Kadye *et al.,* 2008; Li *et al.,* 2012). There has been considerable debate in recent

literature as to the relative importance of physical and biological factors in structuring fish assemblages in streams and rivers (Gorman and Karr, 1978).

1.2. Objectives

1.2.1. General objective

- The general objective this research was to carry out the correlations between fish assemblage structure and environmental variables in the Lohore River of Dailekh, Western Nepal.

1.2.2 Specific objectives

- To assess the fish assemblage structure at Lohore River.
- To identify the factors affecting on the fish abundance of Lohore River.

1.3. Signification of the study

Recently fishes in Lohore River have steeply declined due to pollution, harmful fishing practices, habitat modification, environmental degradation and barrier effects of dams and impact of other developmental activities. The physicochemical parameters are also changing in these recent years which are also the cause for the loss in fish diversity. Since this river contributes habitat for wide variety of aquatic species, the status of fish species yet to be known. Therefore, this study will provided information about the diversity of the fish and identify the factors affecting on the fish abundance of the Lohore River.

2. LITERATURE REVIEW

The diversity and fish assemblages structure are determine by both temperate and tropical regions are altitude, river size, temperature, water velocity, depth, habitat complexity (Tejerina – Garro et al., 2005). Fish assemblage is an important element in aquatic ecosystem. Plafkin et al (1989) observed that there are many advantages of using fish assemblage as biological indicator. Many fish species have become highly endangered, particularly in rivers where heavy demand is placed on freshwater. However, the important of anthropogenic activities, habitat degradation, exotic species indication, water diversions, pollution and global climate change are the main causative agents for the aquatic species rapid decline.

Reservoirs play important role in the geochemical cycling of elements and influence the chemical composition and material transfer of the river system (Abhay et al., 2005). They are high ecological, economic and recreational importance (Carol et al., 2006). Most freshwater ecological studies have strongly suggested biological monitoring of water bodies along with the environmental characteristics (Dudgeon 1999; Wetzel 2001; Wu et al 2011). Spatio-temporal variations of aquatic characteristics such as Dissolved oxygen (DO) and pH are often higher at upstream but lower at urban and downstream reaches in contrast to free carbon dioxide (F-CO_2), conductivity and compounds of phosphorus and nitrogen which were lower at upstream reaches but higher at urban and downstream reaches due to environmental pollution (Osmundson et al., 2002; Kannel et al 2008; Bu et al 2010). Fish assemblage structure in several studies was best correlated usually with the environmental variables stream size, discharge and free carbon dioxide (Koel and Peterka 2003; Fernandez and Bechara – conicet 2010; Negi and Mamgain 2013) with variability conductivity, DO, pH and alkalinity (Edds 1993; Kouamelan et al. 2003; Li et al. 2012), and with nutrients (phosphates, nitrates and silicates; Goldstein et al. 1993-1995; Rashleigh 2004; Lin et al. 2013). The above-mentioned environmental variables exhibit significant patterns with the fluvial gradient from upstream to downstream reaches influenced by urbanization with either an increase or decrease in abundance and species richness (Edds et al. 2002; Shrestha et al. 2009; Pease et al. 2012).

Nepal is the second richest country in the world in freshwater resources occupying at least 5.5% of its area with different types of wetlands (Shrestha 1981). Wetlands in Nepal

contribute about 816954 ha of inland water resources comprising of rivers and streams (48.38%), lakes (0.61%), reservoirs (0.18%), village ponds (0.80%), marginal/swamps/gholes (1.36%) and irrigated paddy fields (48.71%) (DOFD 2007). Shrestha (2003) studied the fishes of Nepal from their recent taxonomic point of view and reported 186 species while Rajbansi (2005) prepared a checklist of Nepalese fishes from published literature and reported 187 species. Ng and Edds (2004-2006) studied the fishes of Nepal and reported some new species. Therefore 184 fish species of Nepal increased to a total number of 199 as earlier identified two species (*Batasio batasio and Pseudechensis sulcatus*) have been abolished from the list of Shrestha (2003) (Saund and Shrestha 2007). Shrestha (2008) has reported a total of 217 species from Nepal. Despite a number of studies related with aquatic diversity from different parts of Nepal, there is still no study has been conducted on the fish assemblage structure in Lohore River. Therefore, this study is designed to describe the relationship between certain environmental variables with the fish assemblage structure of Lohore River Karnali Province, Nepal.

3. MATERIALS AND METHODS

3.1. Study area

Lohore River is located in Karnali Province Dailekh Nepal. The study was carried out from Dungeshwor to Chupra covering the length of 19 km. the Lohore River originates from Mahabu lekth on North and finally joins with Karnali River at Tallo Dungeshwor on South. It lies between 28°.45' and 28°.45' North latitude and 81°.34' and 81°.41' East Longitude.For the present study, altogether three sampling sites were allocated on the basis of its topography, geographical structure, and concentration of cobbles, pebbles, boulders, sand and mud. These sites were designated as site A, site B and site C (Fig.1).

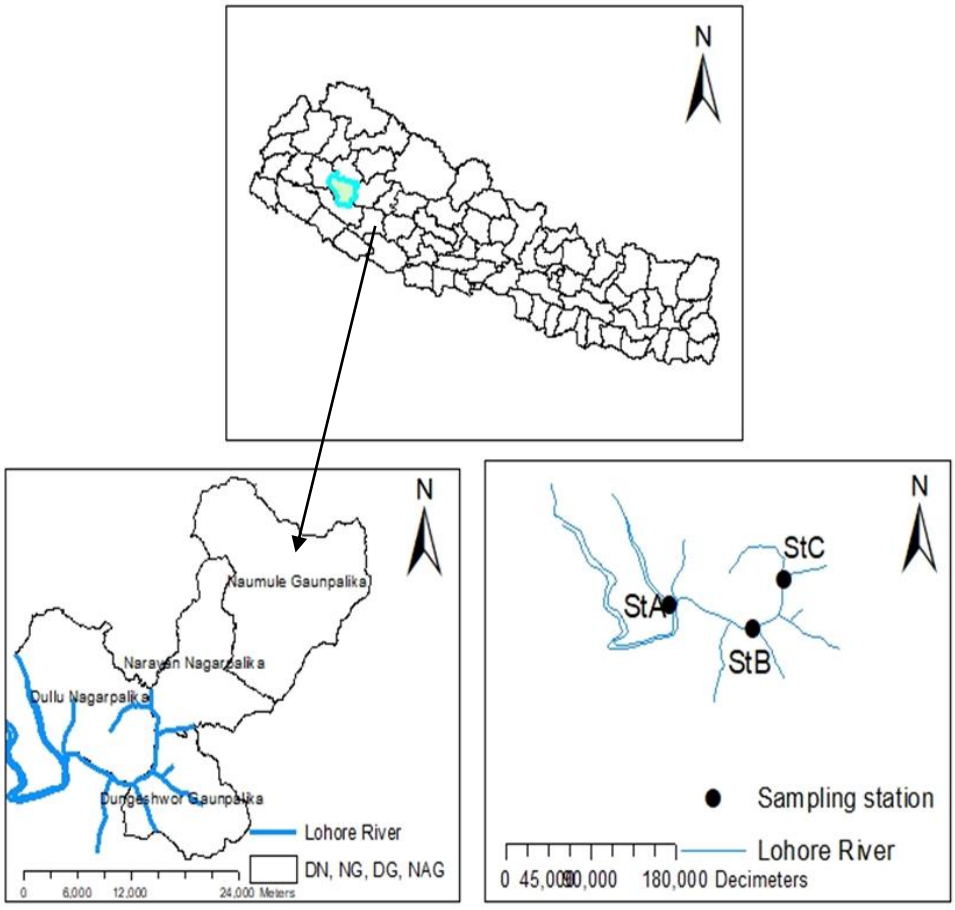

Figure 1. Location of the study area

Sampling site A:

This site is situated in Tallo Dungeshwor, and consists of big boulders, cobbles, pebbles, mud and sand with the deep pool of water.

Sampling site B:

This site is situated in Mathillo Dungeshwor, and consists of dominated by flowing water and small patches of islands.

Sampling site C:

This site is situated in Chupra, which contains stagnant water with, water coverage wider area compared with other sampling sites.

3.2. Sampling

For the present identification the field work was conducted from September 2019 to August 2020 with four seasons such as Autumn (September, October and November), Winter (December, January and February), Spring (March, April and May) and Summer (June, July and August). Fishes were sampled from three sampling sites using cast net with the help of local fisherman. The cast net was operated for 2 hours in each station from 8-10 AM. A total of 50 throws were made for cast net to catch fishes.

3.3. Identification of specimen

The collected fish specimens were counted, examined and identified based on their key morphological characters. Fish samples that seems difficult to identify in the spots were preserved in 10% formalin and brought to the Central Department of Zoology, Tribhuvan University for further study. Finally identification of fishes were carried out on the basis of the taxonomic keys of Talwar and Jhingran (1991), Jayaram (1999) and Shrestha (2008).

3.4. Physical analysis of water

Water samples were collected and different physical properties were analyzed following the standard methods of Adoni (1985), Trivedy and Goel (1984).

Water temperature:

Water temperature (℃) was measured by the standard mercury thermometer.

Water velocity:

Water velocity was measured by the float method with the help of a stop watch and measuring tape.

Water depth:

The depth was measured using thread with weight and a measuring tape was used to record depth in meter.

3.5. Chemical analysis of water

The chemical parameters were analyzed after (APHA 1998), (Adoni 1985) and (Trivedy and Goel 1986).

Hydrogen ion concentration:

The pH was measured to record the hydrogen ion concentration of water during the study period at every station of the Lohore River.

Dissolved oxygen:

The dissolved oxygen of water was calculated using Winkler's method. The sample of water from every station was collected in a BOD bottle without bubbling. Two milliliters of manganese sulphate and similar quantity of alkaline- iodide- azide solution were added and shaken. Brown precipitation was obtained which was again dissolved by adding 2ml of conc. Sulphuric acid. Then this solution was titrated against standard sodium thiosulphate solution (0.025N) and the calculation was carried out using formula.

$$\text{DO (mg/l)} = \frac{ml \times normality\ of\ titrant \times 8 \times 1000}{V_2\{(V_1\text{-}V)/V_1\}}$$

Free Carbon dioxide:

To determine the free CO_2, 50 ml of sample water was taken and few drops of phenolphthalein indicator were added. Thus obtained colourless solution indicated the availability of carbondioxide. Now this solution was titrated against standard alkali titrant (Sodium hydroxide 0.02272 N) to the slight pink end point. Free carbondioxide in the water sample was calculated using formula.

$$\text{Free CO2} = \frac{(ml \times N)\ of\ NaOH \times 1000 \times 44}{V}$$

Where, V = Volume of water sample taken (ml)

Hardness

To determine the hardness of water, 100 ml of sample water was added, 1 ml of hardness buffer and 100-200 mg of Erichrome Black T indicator, the solution was turns wine red. Titrate the contents against EDTA solution. At the end point colour was changes from wine red to blue. The hardness of water sample was calculated by using following formula.

$$\text{Total hardness as } C_aCO_3 \text{ (mg/l)} = \frac{ml\ of\ EDTA\ used \times 1000}{ml\ of\ sample}$$

3.6. Data Analysis

Shannon-Weiner diversity index (Shannon and Weaver, 1963) considers both the number of species and the distribution of individuals among species. The Shannon-Weiner diversity was calculated by following formula:

$$H = \sum_{i=1}^{S} Pi * logPi$$

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

The dominance index (Harper 1999) was calculated by using following formula:

$$D = \sum_i \left(\frac{ni}{n}\right)^2$$

Where n_i is number of individuals of species i.

Evenness index (Pieleu 1966) was determined by the following equation:

$$E = H'/ \log S$$

Where, H' = Shannon- Weiner diversity index

S = Total number of species in the sample.

One-way permutational multivariate analysis of variance (perMANOVA) (Clarke 1993) was used to test the significant difference among the spatial and temporal scales. To visualize the major contributing species both to space and time, similarity percentage (SIMPER) (Clarke 1993) analysis was performed. Samples by species, sites and environmental variables were analyzed through multivariate analysis tool. Detrended correspondence analysis (DCA) (Hill and Gouch, 1983) was performed to determine whether redundancy correspondence analysis (RDA) or canonical correspondence analysis (CCA) would be the most appropriate model to describe the association between species, sites and environmental variables. The value of axis length and eigen values obtained from DCA suggested that the linear model associated with RDA was more applicable. Therefore, a direct multivariate ordination method (Legendre and Legendrem, 1998) based on a linear response of species to environmental gradients was applied.

Fish species were analyzed into different assemblage clusters based upon abundances of each fish species by utilizing *pv*clust package in R (Suzuki and Shimoddaira, 2019

4. RESULTS

4.1. Systematic position of fishes

Lohore River was found to be enriched by various types of fishes. A total numbers of 201 individuals were collected from three stations during the four different seasons. These fishes were grouped into 11 species belonging to 2 orders, 3 families and 8 genera. Systematic position of fishes shown in Table 1

Table 1. Systematic position of fishes

Order	Family	Code	Species
Cypriiformes	Cyprinidae	C1	*Barilius barila*
		C2	*Puntius chola*
		C3	*Tor chelynoides*
		C4	*Schizothorax plagiostomus*
		C5	*Schizothoralchthys labiatus*
		C6	*Garra annandalei*
		C7	*Garra gotyla*
		C8	*Garra nasuta*
	Nemacheilidae	C9	*Schistura sovana*
Siluriformes	Sissoridae	C10	*Glyptothorax pectinopterus*
		C11	*Pseudechenesis sulcatus*

4.1.1. Fish distribution and frequency occurrence in the Lohore River

Table 2. Distribution and frequency of fishes

S.N	Scientific name	Local name													Total	Freq.%
			Station A				Station B				Station C					
			Sep	Dec	Mar	July	Sep	Dec	Mar	July	Sep	Dec	Mar	July		
1	*Barilius barila*	Faketa	6	3	-	2	5	2	-	4	7	1	-	1	31	15.42
2	*Puntius chola*	Sidhre	-	-	-	-	2	-	1	-	3	2	1	2	11	5.47
3	*Tor chelynoides*	Mahseer	8	2	3	4	2	3	6	2	1	3	2	7	43	21.39
4	*Schizothorax plagiostomus*	Asla	7	-	-	-	4	1	-	2	4	6	2	1	27	13.43
5	*Schizothoralchthys labiatus*	Kunar	-	-	-	2	1	3	-	-	2	3	-	2	13	6.46
6	*Garra annandalei*	Lahare buduna	2	3	-	-	2	-	-	-	-	2	4	3	14	6.96
7	*Garra gotyla*	Dhumke budina	-	-	-	-	1	-	1	-	2	-	-	3	7	3.48
8	*Garra nasuta*		1	-	2	-	-	-	-	3	-	6	-	4	16	7.96

9	*Schistura sovana*	Gadela	-	2	1	2	-	1	4	-	-	2	3	5	20	9.95
10	*Glyptothorax pectinopterus*	Caper	-	-	-	-	-	-	-	-	-	1	-	3	4	1.99
11	*Pseudechenesis sulcatus*	Kane machha	-	1	-	-	2	-	-	4	-	3	1	4	15	7.46
	Total														**201**	**100**

4.1.2. Order wise frequency occurrence of fish in Lohore River

The collected fish were classified into two orders i.e. cypriniformes and siluriformes. The dominated order cypriniformes comprised 81.81% with 9 fish species whereas order siluriformes comprised 18.18% with 2 species (Figure 2).

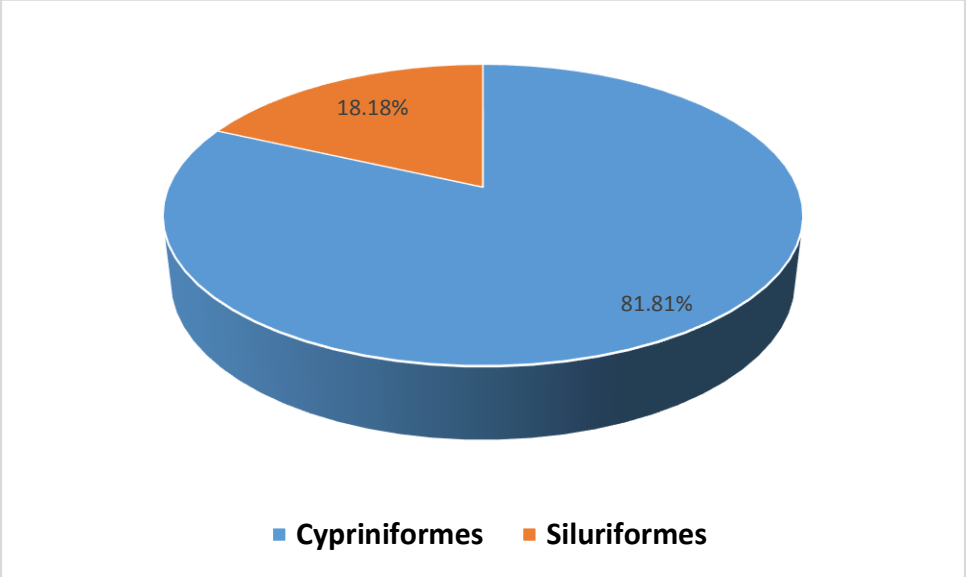

Figure 2. Order wise frequency occurrence of fish

4.1.3. Family wise occurrence of fish in Lohore River

At the family level, three families of fish species in which Cyprinidae family was most abundant (72.72%) followed by Sissoridae (18.18%) and Nemacheilidae (9.09%) (Figure 3).

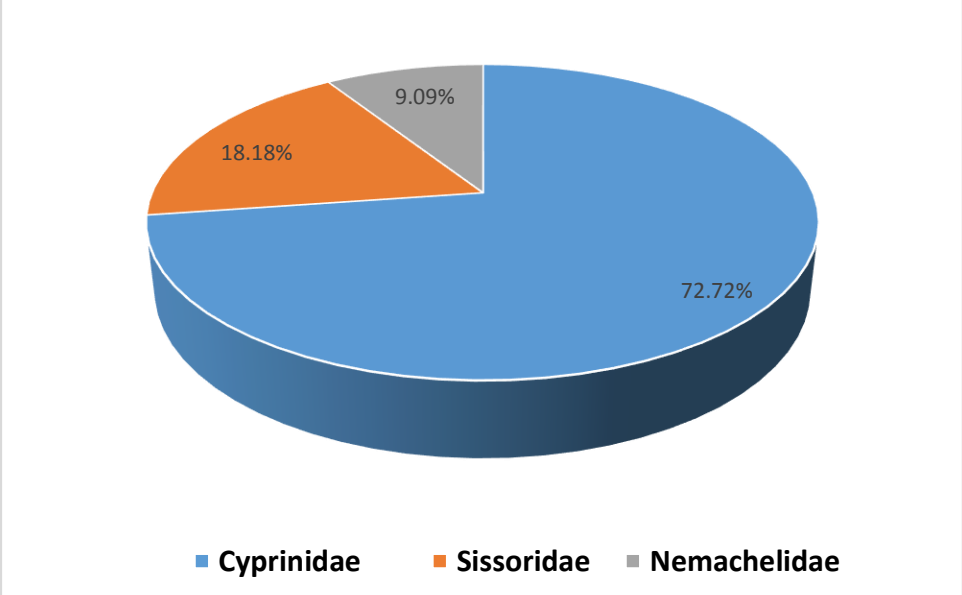

Figure 3. Family wise frequency occurrence of fish

4.1.4 Physico-chemical parameters

Water temperature

During the study period the average temperature of Lohore River was recorded 19.5°C. The highest temperature 25°C was recorded at station B in March. The lowest temperature 14°C was recorded in station B in December. The variation of temperature at different stations in different month of study period is given in (Figure 4).

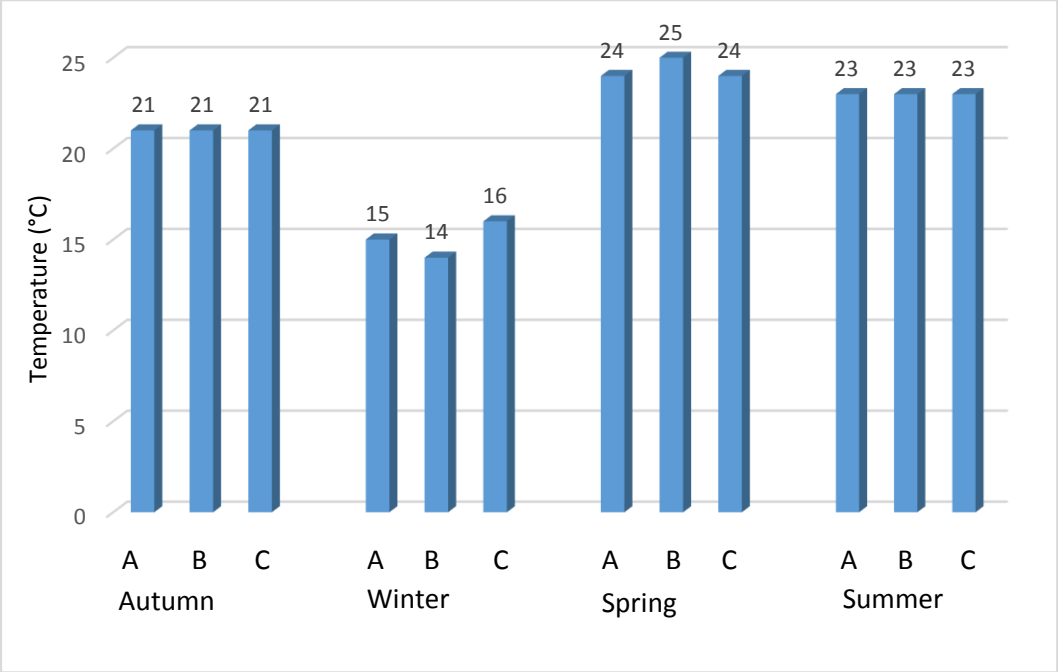

Figure 4. Seasonal Variation of water temperature in different stations

Water velocity

During the study period the average water velocity of Lohore River was recorded 0.97 m/s. The velocity of Lohore River ranged minimum from 0.14 m/s at station C in the month of March to maximum of 1.8 m/s at station A in the month of July. The variation in velocity of River water in different station is given in the (Figure 5)

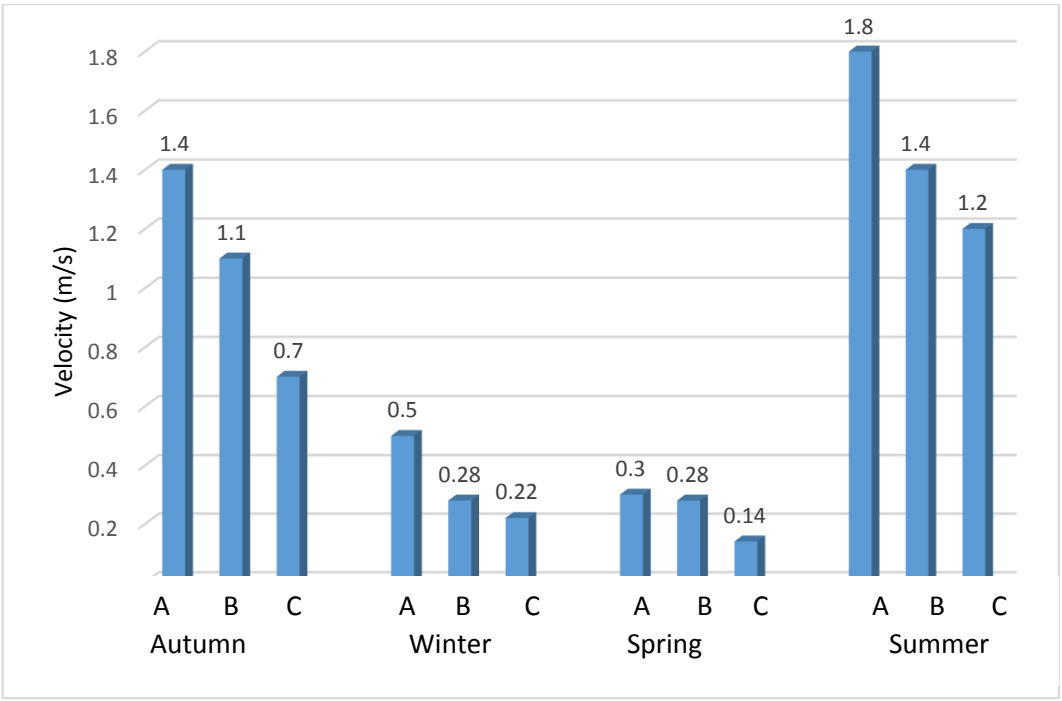

Figure 5. Variation in water velocity (m/s) at different stations

Hydrogen ion concentration (pH)

The hydrogen ion concentration (pH) of Lohore River remains slightly alkaline at all stations throughout year. The concentration of pH was highest (8.8) in station B during the month of March. While the lowest value (7.2) of pH were recorded in station B during the month of July. The variation in pH of River water in different station is given in the (Figure 6).

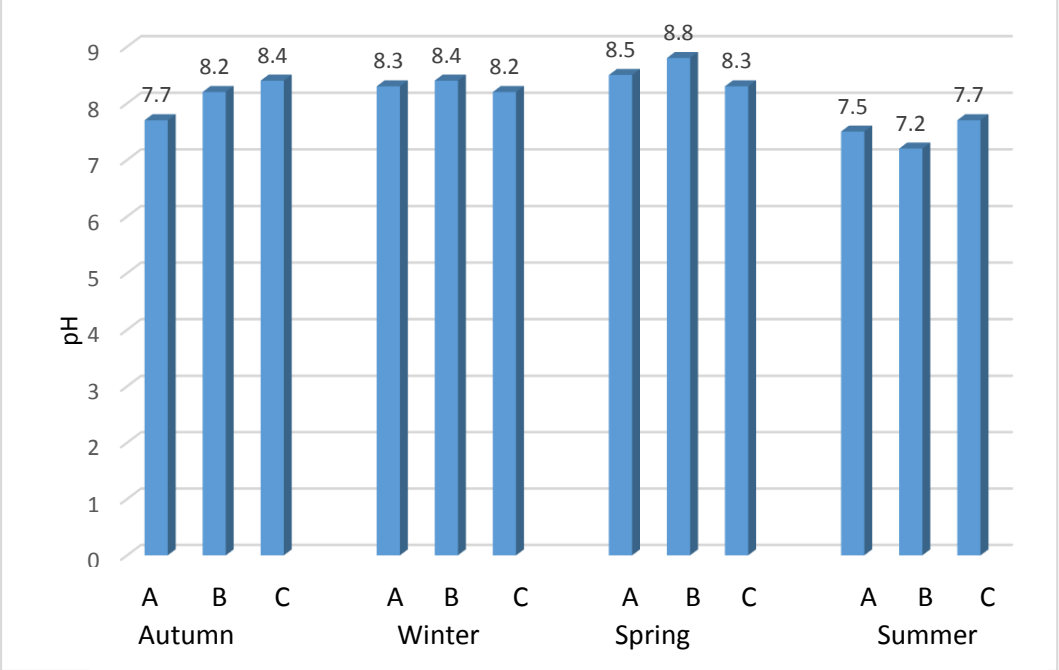

Figure 6. Variation in pH value at different stations

Dissolved oxygen (DO)

The main source of oxygen in water is photosynthetic plankton and atmospheric air, the concentration of DO was highest (10.66mg/l) in station C during the month of July. While the lowest concentration of DO (6.53mg/l) was seen at the station A in December. The variation in DO of River in different station is given in (Figure 7).

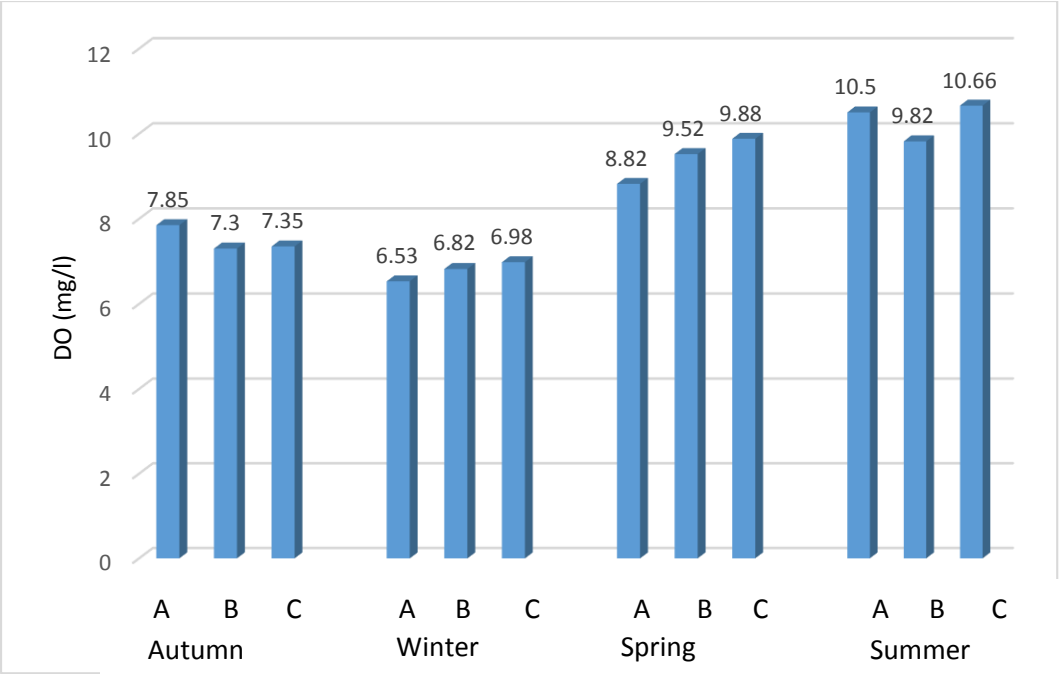

Figure 7. Variation in dissolved oxygen at different stations

Free Carbon dioxide (CO_2)

The highest calculated value of free carbondioxide was found to be 12.85 mg/l in station A in December. Free carbondioxide value was detected to be lowest (6.21 mg/l) in station C in March. The variation in CO_2 of River in different station is given in (Figure 8).

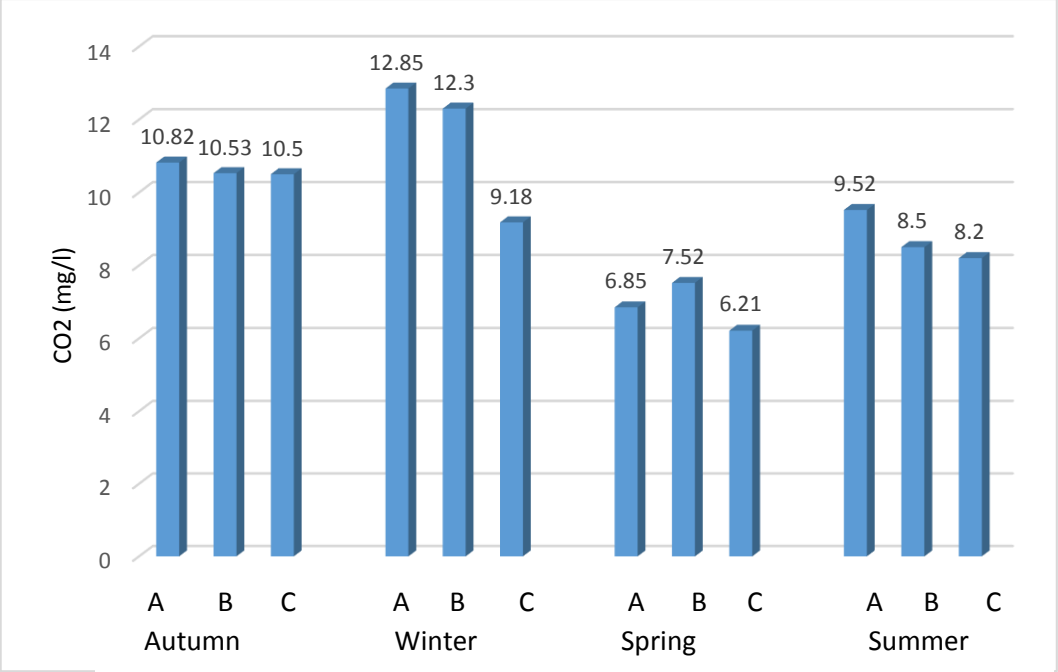

Figure 8. Variation in free carbon dioxide at different stations

Total Hardness

The hardness of the water ranged from 63 mg/l to 85 mg/l. the hardness of the water was found to be highest at site B in summer season (July) and lowest hardness was found to in station A in spring season March (Figure 9).

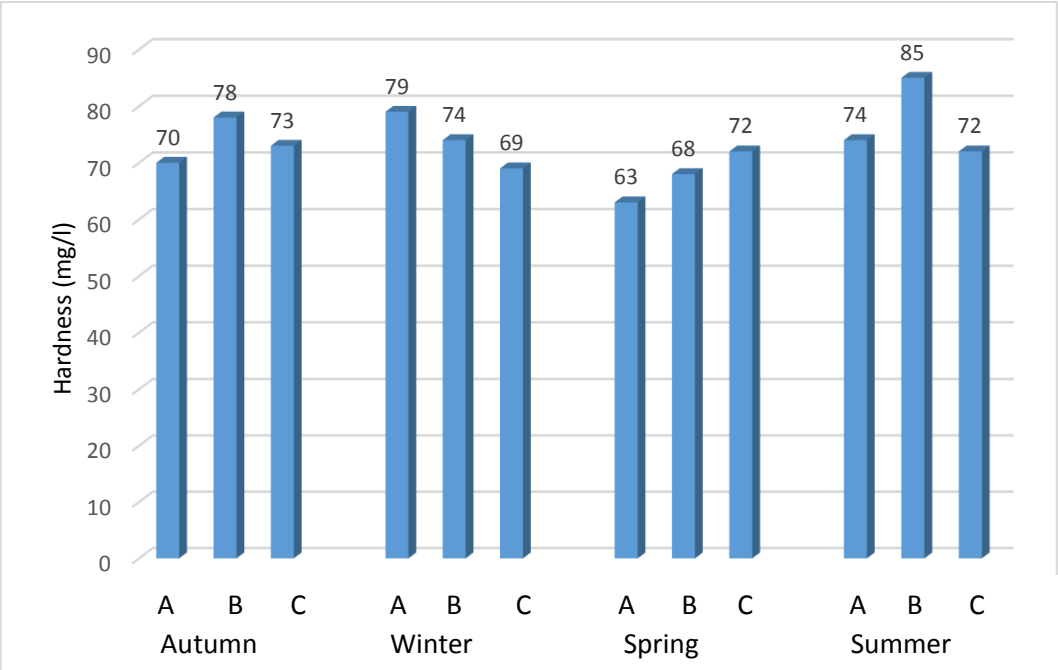

Figure 9. Variation of total hardness at different sampling sites and seasons

4.1.5. Diversity status

The value of diversity indices such as Shannon Weiner diversity index (H), Simpson dominance index (d) and evenness index (E) were calculated according to space and time (Fig. 10 and 11). Highest Shannon diversity index 2.29 was found at station C and lowest was found at station A. Higher Shannon Weiner diversity index value was found in summer (2.28) where low in autumn (1.72). There was no significant difference (P>0.05) was found in the value of Shannon Weiner diversity index both for time and space. Highest Simpson dominance index was found at station C (0.88) where low at station A (0.84). Maximum dominance index value was determine in summer (0.89) where minimum in autumn (0.79). No significant difference (P>0.05) was observed among the seasons and stations. Maximum evenness index value was recorded at station B (0.86) and minimum was at station A (0.81). Similarly, highest evenness value was found in autumn (0.94) where low in summer (0.85). There was also no significant difference (P>0.05) among the space and time.

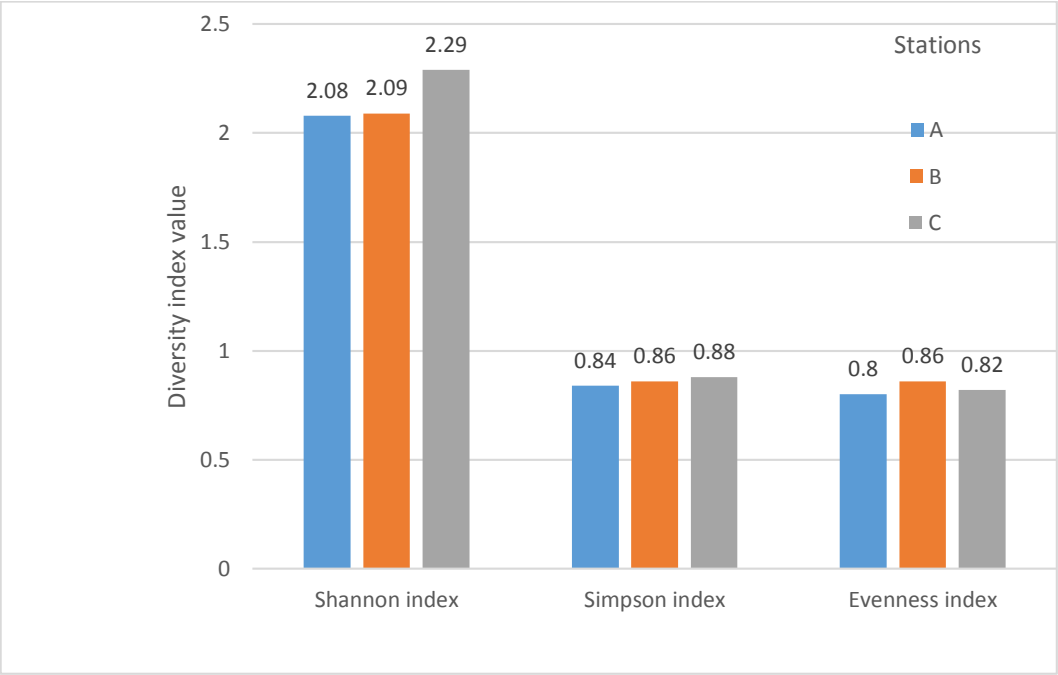

Figure 10. Spatial variation of Shannon, Simpson and evenness index values

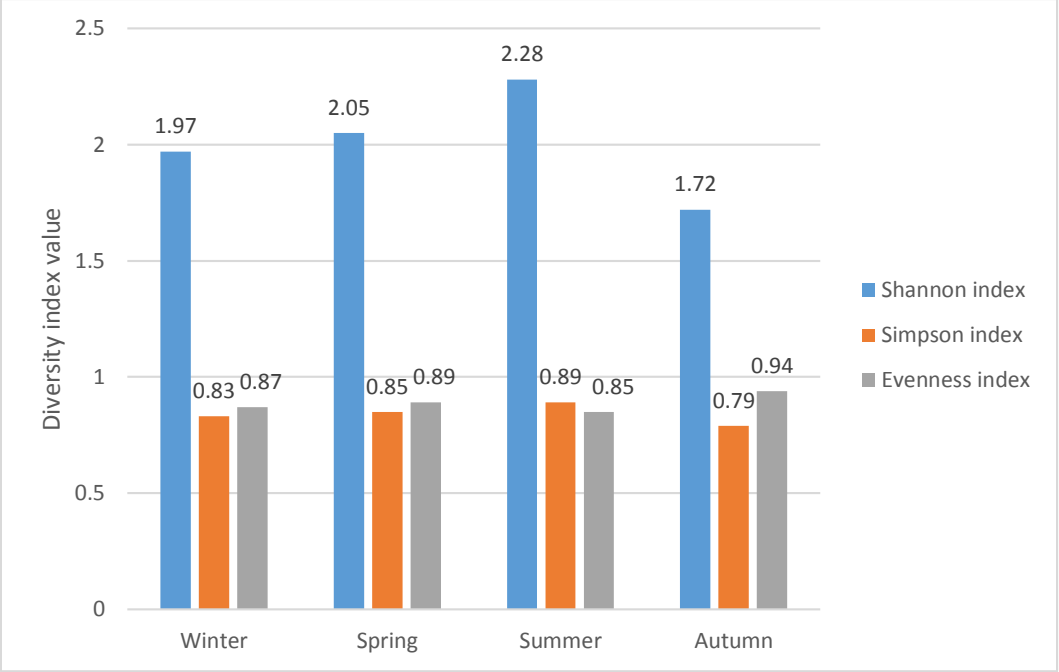

Figure 11. Temporal variation of Shannon, Simpson and evenness index values

4.2. Environmental variables and fish abundance

The first and second axis of the redundancy analysis (RDA) accounted for 37% of the total variance (25% on the first axis and 13% on the second axis). The RDA biplot pointed the relationships between environmental conditions and fish community structure (Figure 12). The first axis explained water velocity, water temperature, dissolved oxygen, pH and total hardness whereas second axis showed free carbon-dioxide. Fish species, *Glyptothorax pectinopterus* (C10), *Garra nasuta* (C8), *Garra annandalei* (C6), *Pseudechenesis sulcatus* (C11), *Puntius chola* (C2), *Schizothoralchthys labiatus* (C5), *Schistura sovana* (C9) and *Garra gotyla* (C7) are highly associated with dissolved oxygen, water velocity and water temperature but negatively related to free carbon-dioxide (CO_2). In contrary, single species *Puntius gelius* (C1) is positively related to free carbon-dioxide but negative to dissolved oxygen, water velocity and water temperature whereas two fish species *Tor chelynoides* (C3) and *Schizothorax plagiostomus* C4 are related to any variables. Similarly, among the selected variables pH and total hardness are not related to any variables.

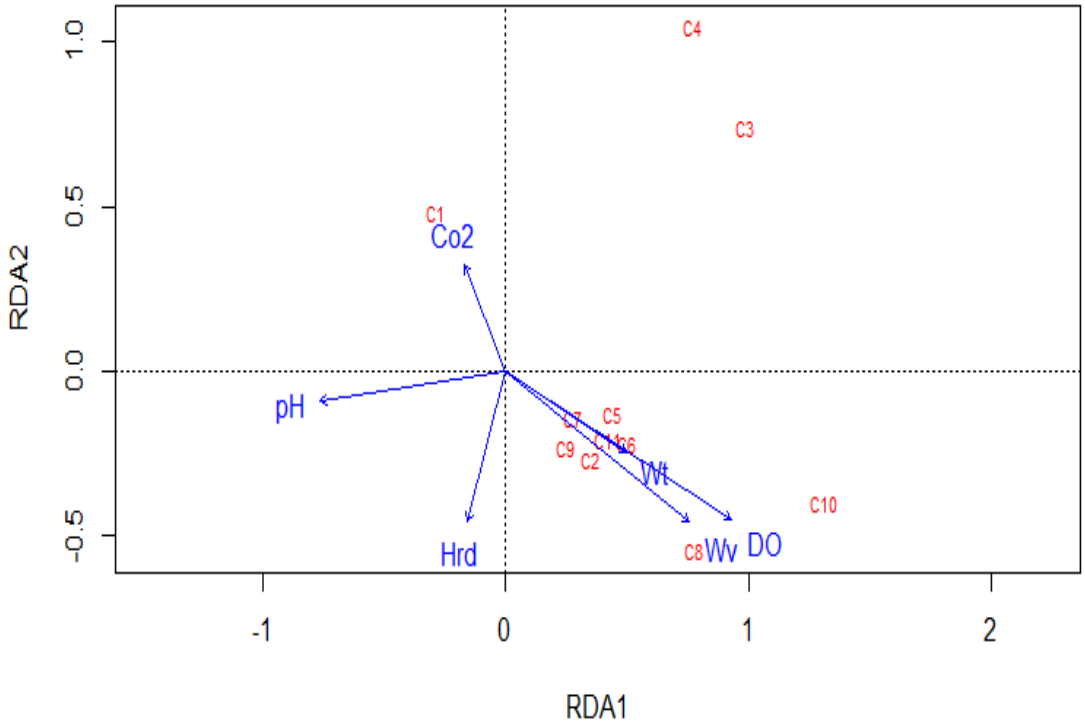

Figure 12. Biplot from redundancy analysis (RDA) for the fish assemblages in the Lohore River (CO_2 = Carbon-dioxide, Hrd = Total hardness, Wt = Water temperature, Wv = water velocity, DO = Dissolved oxygen)

4.3. Cluster analysis of fish species of Lohore River

There are altogether nine cluster groups were formed thee major clusters 3, 4 and 7 shown in (Fig. 13). In the left side, the cluster number 1 and 2 formed the significant cluster group. In second cluster number *Puntius gelius* and *Gara gotyla* formed the significant cluster group with cluster number 7 do not formed significant cluster group. In the middle part the cluster number 1 formed significant cluster group but number 3 and 5 do not formed significant cluster group. In contrary, cluster number 4 delineates that species of *Barilius barila* and *Schizothorax plagiastomus* formed a significant cluster.

Hierarchial clustered dendrogram of fish species from the Lohore 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.

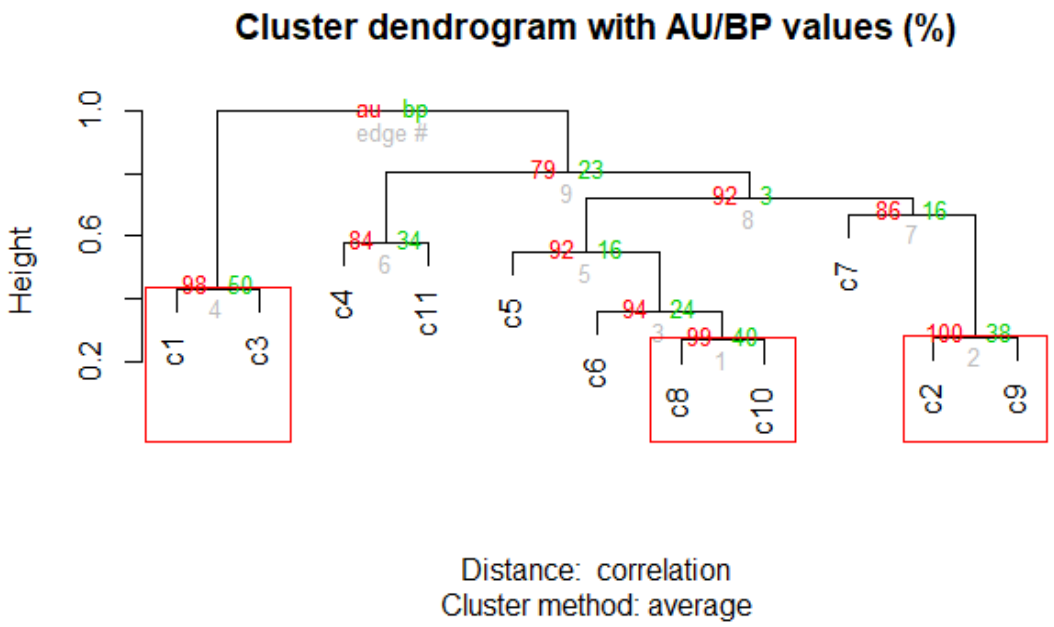

Figure 13. Dendrogram of cluster analysis comparing fish species on the basis of fish assemblage (for species codes, see Table 1).

5. DISCUSSION

In the present study, Cypriniformes and Cyprinidae were the most diverse order and family. This result is consistent with the findings of several previous studies (Mishra and Baniya, 2016; Subba et al., 2017; Limbu et al., 2018, 2019a, 2019b, 2019c; Limbu and Gupta, 2019; Punam and Limbu, 2019; Limbu et al., 2020; Limbu and Prasad, 2020; Prasad et al., 2020; Limbu et al., 2021a; 2021b; 2021c). The majority of the freshwater fish fall under the order Cypriniformes and family Cyprinidae (Nelson, 2016). A biodiversity index seeks to characterize the diversity of samples by a single number (Magurran, 1988). The biodiversity index values, obtained from the present study, was neither so high according to Shannon-Weiner diversity index, nor showing any differences among the stations and seasons. The reason for showing lower species biodiversity is that fishing gears have high selectivity effect (Keskin and Unsel, 1998). The highest Shannon-Weiner diversity index was recorded in summer, while the minimum was in autumn. On the other hand, the maximum Shannon diversity value was recorded at station C, and the minimum was at station A. In each case, high Shannon-Weiner diversity index was involved with low individuals, and low diversity was involved with high number of individuals. The main causes of the differences occurring in the biodiversity indexes are the seasonal variations of nutrients at the sea grass beds affecting the coexistence of many fish species (Huh and Kitting, 1985; Hossain et al., 2012), the seasonal fish migration (Ryer and Orth, 1987), the atmospheric air currents and the environmental conditions (Keskin and Unsel, 1998).

The result showed that many physio-chemical parameters like DO, free CO_2, temperature, and water velocity were found to be influencing factors for 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 physicochemical 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).

Different environmental variables influence fish health as well as the diversity and distribution of fishes in water bodies. Among different environmental variables, the temperature and DO are mostly responsible for the observed changes in species diversity and these variables are changes in freshwater assemblages according to seasons and

elevation gradients. The relationship between fish and water quality parameters were checked by Canonical correspondence analysis CCA. In the present study the parameters like DO, water velocity and water temperature were found to be important parameters for shaping the fish assemblage structure of the Lohare River. The dissolved oxygen and water temperature have been mentioned as important factors for shaping the fish community structure (Limbu et al., 2019, Kadye et al., 2008). Pokharel *et al*. (2018) observed that the most important environmental variables were conductivity, water depth, free carbon dioxide, pH, and DO in the Seti Gandaki river basin. The fish assemblage structures are mainly correlated with free carbon-dioxide, water discharge, and stream size (Koel and Peterka, 2003).

6. CONCLUSION

In the present study, a total of 11 species were recorded. The Cyprinidae was recorded the dominated family which includes 72.72% followed by Nemacheilidae 9.09%. The *Tor chelynoides, Barilius barila* and *Schizothorax plagiastomus* species were highly abundant while *Glyptothorax pectinopterus* and *Garra gotyla* species were less abundant. The highest Shannon winner diversity index (2.29) of fish were recorded from station C (Chupra) in summer season (July) while lowest diversity index (1.72) of fish were recorded from station A (Tallo Dungeshwor) in Autumn season (September). The Lohore River's fish diversity has been found to be threatened by the extraction and transportation of rocks, cobbles, and pebbles, chaotic continuous road construction, and dam construction for irrigation without fish ladders. On the basis of redundancy analysis (RDA), dissolved oxygen (DO), water velocity and water temperature were found to be influencing factors to determine the fish assemblage structure of Lohare River. Three large clusters, numbers 3, 4, and 7, were combined to produce nine cluster groupings. The important cluster group on the left side was made up of clusters 1 and 2. *Puntius chola* and *Gara gotyla* created a large cluster group in the second cluster number, whereas cluster number 7 did not. The cluster number 1 produced a major cluster group in the center section, however numbers 3 and 5 did not. The species of *Barilius barila* and *Schizothorax plagiastomus*, on the other hand, are shown to have formed a significant cluster in cluster number 4.

REFERENCES

Angermeier, P.L. 1987. Spatiotemporal variation in habitat selection by fishes in small Illinois streams. Community and Evolutionary Ecology of North American Stream Fishes (eds W.J. Matthews & D.C. Heins), 52-60.

Bain, M.B., Finn, J.T. and Booke, H.E. 1988. Streamflow regulation and fish community structure. Ecology, **69:** 182-192.

Baltz W.M., Vondracek, B. Brown, R.L. and Moyle, P.B. 1987. Influence of temperature on microhabitat choice by fishes in a California stream. Transactions of the American Fisheries Society, **116:** 12-20.

Brown, J.H. 1984. On the relationship between abundance and distribution of species. American naturalist, **124:** 255-279.

Brown, L.R. 2000. Fish communities and their associations with environmental variables, lower San Joaquin River drainage, California. Environ. Biol. Fishes, **57:** 251-269.

Bu, H., Tan, X., Li, S. Zhang, Q. 2010. Temporal and spatial variations of water quality in the Jinshui River of the South Qinling Mountains, China. Eco-toxical Environ Saf, **73**(5): 907-913.

Carol, J., Benejam, L., Alcaraz, C., Vilagispert, A., Zamora, L., Navarro, E., Armengol, J. and Garcia-Berthou, E. 2006. The effects of limnological features on fish assemblages of 14 Spanish reservoirs. Ecological freshwater fishes, **15**: 66-77.

Ciannelli. L., Chan, K.S., Bailey, K.M. Stenseth, N.C. 2004a. Nonadditive effects of the environment on the survival of a large fish population Ecology, **85**: 3418-3427.

Cushing, D.H. 1990. Plankton production and year-class strength in fish populations_an update of the match mismatch hypothesis, **26**: 249-293.

Department of National Park and Wildlife Conservation (DNPWC)/International Union for Conservation of Nature (IUCN). 2002. Information sheet on Ramsar wetlands (RIS) – Jagadispur Reservoir. DNPWC/IUCN-Nepal.

Directorate of Fisheries Development (DOFD). 2007. Annual progress report. Fisheries Sub-sector, Directorate of Fisheries Development, Department of Agriculture, HMG, Hariharbhavan, Lalitpur, Nepal.

Directorate of Fisheries Development 2007/2008. Country Profile Nepal, Central Fishing Building, Balaju, Kathmandu.

Dudgeon, D. 1999. Tropical Asian streams: zoobenthos, ecology and conservation.Hong kong: Hong kong Universityp press.

Eaton, J.G. and Scheller, R.M. 1996. Effects of climate warming on fish thermal habitat in streams of the United States. Limnol. Oceanogr, **41**: 1109-1115.

Edds, D.R. 1993. Fish assemblage structure and environmental correlates in Nepal's Gandaki River. Copeia, **1993**(1): 48-60.

Edds, D.R., Gillette, D.P., Maskey, T.M. and Mahato, M. 2002. Hot-soda process paper mill effluent effects on fishes and macro-invertebrates in the Narayani River, Nepal. J Freshw Ecol, **17**(4): 543-554.

Fernandez, L. and Conicet, J. 2010. An assessment of fish communities along a piedmont River receiving organic pollution (Aconquija Mountains, Argentina). Acta Biol Colombia, **15**(2) 79-100.

Fisher, B., Turner, K. and Zylstra, M. 2008 Ecosystem Services and Economic Theory: Integration for Policy Relevant Research. Ecological Applications, **18**: 2050-2067.http://dx.doi.org/10.1890/07-1537.1

Goldstein, R.M., Stauffer, J.C., Larson, P.R. Lorenz, D.L. 1993-1995. Relation of physical and chemical characteristics of streams to fish communities in the Red River of the North Basin, Minnesota and North Dakota, water resources investigations report. Minnesota (MN): National Water-Quality Assessment Program (NWQAP), U.S. Geological Survey.

Govoni, J.J., Hoss, D.E. and Colby, D.R. 1989.The spatial distribution of larval fishes about the Mississippi River plume. Limnology and Oceanography, **34**:178-187.

Hill, M.O. and Gauch, H.G. 1980. Detrended correspondence analysis: an improved ordination technique, Vegetatio, **42**: 47-58.

Hossain, M.S., Das, N.G., Sarker, S. and Rahaman, M.Z. 2012. Fish diversity and habitat relationship with Environmental vriables at Meghna river estuary, Bangladesh. Egyptian Journal of Aquatic Research. **38**: 213-226.

Jackson, D.A., Peres-Neto, P.R. and Olden, J.D. 2001. What controls who is where in freshwater fish communities-the roles of biotic, abiotic and spatial factors. Journal of Fish Aquatic Science, **58**: 157-170.

Jayaram, K.C. 1999. The freshwater fishes of the Indian region. Narendra Publishing House, Delhi-110006, India. 551 p.

Kadye, W.T., Magadza, C.H.D., Moyo, N.A.G. & Kativu, S. (2008). Stream fish assemblages in relation to environmental factors on a montane plateau. Environmental Biology of Fishes, **83**: 417-428.

Kadye, W.T., Magadza, C.H.D., Moyo, N.A.G. and Kativu, S. 2008. Stream fish assemblages in relation to environmental factors on a montane plateau. Environmental Biology of Fishes, **83**: 417-428.

Kannel, P.R., Lee, S. and Lee, V.S. 2008. Assessment of spatial-temporal patterns of surface and ground-water quality and factors influencing management strategy of ground-water system in an urban river corridor of Nepal. J Environ Manag, **86**(4): 595-604.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries, **6**: 21-27.

koel, T.M. and peterka, J.J. 2003. Stream fish communities and environmental correlates in the Red River of the North Min-nesota and North Dakota. Environ Biol Fish, **67**(2): 137-155.

koel, T.M. and peterka, J.J. 2003. Stream fish communities and environmental correlates in the Red River of the North Min-nesota and North Dakota. Environ Biol Fish, **67**(2): 137-155.

Kouamelan, E.p., Teugels, G.G., Douba, V.N., Goore, G. Bi.and Kone, T. 2003. Fish Diversity and its relationships with environmental variables in a West African basin. Hydrobiologia, **505**: 139-146.

Lamart, M. and Allan, J.D. 1999. Assessing biotic integrity of streams: effects of scale in measuring the influence of land use/cover and habitat structure on fish and macroinvertebrates.Environmental Management, **23**: 257-270.

Legendre, P. and Legendre, L. 1998. Numerical Ecology. Second Edition. Elsevier, Amsterdam, Netherlands. 853 pp.

Li, J., Huang, L., Zhou, L., Kano, Y., Sato, T. and Yahara, T. 2012. Spatial and temporal variation of fish assemblages and their associations to habitat variables in a mountain stream of North Tiaoxi River, China. Environ Biol Fish, **93**(3) 403-417.

Limbu, J. H. Acharya, G. S. and Shrestha, O. M. (2018). A brief report on ichthyofaunal diversity of Dewmai Khola of Ilam district, Nepal. Journal of Natural History Museum **30**: 312-317.

Limbu, J.H., Chapagain, N., Gupta, S. and Sunuwar, S. 2019b. Review on fish diversity of eastern Nepal. International Journal of Fisheries and Aquatic Studies. **7**(3): 177-181.

Limbu, J.H., Gurung, J.K., Subba, S., Khadka, N., Adhikari, A. and Baniya, C.B. 2021. An Impact Assessment of Betani Irrigation Dam on Fish Diversity of Damak Municipality, Jhapa, Nepal. Egyptian Jour nal of Aquatic Biology and Fisheries, **25**(2): 163-175. https://dx.doi.org/10.21608/ejabf.2021.161363

Lin, S.J., Tasi, S.T., Lin, J.H., Jong, K.J. and Wang, Y.K. 2013. Changes in structure and function of fish assemblages along environmental gradients in an intensive agricultural region of subtropical Taiwan. Pacific Science, **68**(2): 1-33.

MacKenzie, B.R. and Koster, F.W. 2004. Fish production and climate: sprat in the Baltic Sea. Ecology, **85**: 784-794.

Magurran, A.E. (1988). Ecological Diversity and its Measurement. Princeton University Press, Princeton.

Matthews, W.J. 1998.Ptterns in Freshwater Fish Ecology. Chapman & Hall, London.

Matthews, W.J. and Hill, L.G. 1979. Influence of physico-chemical factors on habitat selection by red shiners, Notropis Iutrensis (Pisces: Cyprinidae). Copeia, **1**: 70-81.

Mishra, A.R. and Baniya, C.B. 2016. Ichthyofaunal diversity and physico-chemical factors of Melamchi River, Sind-upalchok, Nepal. Journal of Institute of Science and Technology, **21**(1): 10-18.

Mishra, R.N. and Kunwar, P.S. 2014. Status of Aquaculture in Nepal.Journal of Aquaculture and Fisheries, **2:** 1-17.

Negi, R.K. and Mamgain, S. 2013. Species diversity, abundance and distribution of fish community and conservation status of Tons River of Uttarakhand State,India. J Fish Aquatic Science, **8**: 617-626.

Ng, H.H. 2006. The identify of *Pseudechenis sulcata* (McClelland) with description of two new species of Rheophitic cat fish (Teleostei: Sissoridae). Zootaxa, **1254**: 45-68.

Ng, H.H. and Edds, D.R. 2004. *Batasio macronotus*, a new species of Bagrid cat fish from Nepal (Teleostei: Bagridae). Ichthyological Exploration Freshwaters, **15**(4): 295-307.

Oberdorff, T., Pont D., Hugueny, B. and Porcher, J.P. 2002. Development and validation of a fish-based index fo the assessment of 'river health' in France. Freshwater Biology, **47**: 1720-1734.

Osmundson, D.B., Ryel, R.J., Lamarra, V.L. and Pitlick, J. 2002. Flow-sediment-biota relations: Implications for river regulation effects on native fish abundance. Ecol Appl, **12**(6): 1719-1739.

Pease, A.A., Gonzalez-Diaz, A.A.,Rodiles-Hernandez, R. and Winemiller, K.O. 2012. Functional diversity and trait-environment relationships of stream fish assemblages in a large tropical catchment. Fresh water Biology, **57**: 1060-1075.

Petr, T. and Swar, D.B. 2002. Cold water fisheries in the trans-Himalayan countries. FAO Fisheries Technical Paper. No. 431 Rome, pp 376.

Platts, W.S. 1979. Relationships among stream order, fish populations, and aquatic geomorphology in an Idaho river drainage. Fisheries, **4**: 5-9.

Poff, N.L.R. and Allan, J.D. 1995. Functional organization of stream fish assemblages in relation to hydrological variability. Ecology, **76**: 606-627.

Pokhrel, k. k., Basnet, K.B., Majupurai, T.C. and Baniya, C.B. 2018.Correlation between fish Assemblages structure and environmental variables of the Seti Gandaki river basin, Nepal. Journal of fresh water Ecology, **33**(1): 31-43.

Rajbanshi, K. G. 2005. Review on current taxonomic status and diversity of fishes in Nepal. Occasional paper No. 10. Royal Nepal Academy of Science and Technology. 41pp.

Rajbanshi, K.G. 2013. Review on current taxonomic status and diversity of fishes in Nepal. Nepal Academy of Science and Technology, pp 41.

Rashleigh, B. 2004. Relation of environmental characteristics to fish assemblages in the Upper French Broad River-Basin, North Carolina. Environ Monit Assess, **93**(1-3): 139-156.

Saund, T.B. and Shrestha, J. 2007. Fish and benthic fauna in Kulekhani reservoir. Nepal Journal of Science and Technology, **8**: 63-68.

Schlosser, I.J. 1982. Fish community structure and function along two habitat gradients in a headwater stream. Ecological Monographs, **52**: 395-414.

Shannon, C.E. and Weave, W. 1963. The mathematical theory of communication. Urbana, University of Illinois Press.

Shrestha, J. 1981. Fishes of Nepal. Curriculum Development Centre, Tribhuvan University, Kathmandu, Nepal.

Shrestha, J. 2003. Taxonomic revision of fishes of Nepal. In: cold water fisheries in the trans-Himalayan countries. FAO. Fisheries Technical Paper **43**1: 273-288.

Shrestha, J., Singh, D.M. and Saund, T.B. 2009. Fish diversity of Tamor River and its major tributaries of eastern Himalayan region of Nepal. Nepal J Sci Technol, **10:** 219-223.

Shrestha, T.K. 2008. Ichthyology of Nepal, Published by Himalayan Ecosphere, G.P.O. Box 1633, Kathmandu Nepal.

Shrestha,T.K. 2008. Icthyology of Nepal. A study of fishes of the Himalayan waters. Himalayan Ecosphere. Kathmandu, Nepal.

Siessenwine, M.P. 1984. Why do fish population vary? In: May, R.M. (Ed), Exploitation of marine communities. Springer, Heidelberg, 55-94.

Singh, A.K., Mondal, G.C., Singh.,P.K., Singh, S., Singh, T.B. and Tewary, B.K. 2005. Hydrochemistry of reservoirs of Damodar river basin, India: Weathering processes and water quality assessment, Environmental Geology**, 48**: 1014-1028.

Subba, B.R., Pokharel, N. and Pandey, M.R. 2017. Ichthyofaunal diversity of Morang district, Nepal. Our Nature, **15**(12): 55-67.

Suzuki R, Shimodaira H. 2019. Pvclust: Hierarchical clustering with P-Values via Multiscale Bootstrap Resampling. R package version 2.0-0. https://CRAN.R-project.org/package= pvclust.

Tejerina-Garro, F.L., Maldonad, M. Ibanez, C., Port, D., Roset, N. and Oberdroff, T. 2005. Effects of natural and anthropogenic environmental changes on riverine fish assemblages. Brazalian archives of Biology and Technology, **48**: 91-108.

Tejerrina-Garro, F.L., Fortin, R. and Rodriguez, M.A. 1998. Fish community structure in relation to environmental variation in floodplain lakes of the Araguaia River, Amazon Basin. Environmental Biology. Fishes, **51**: 399-410.

Wetzel, R.G. 1983. Limnology, W.B.Saunders Company, Philadelphia.

Wetzel, R.G. 2001. Limnology: lake and river ecosystems. 3rd. San Diego (CA): Academic Press.

Wu, J., Wang, J., He, Y. and Cao, W. 2011. Fish assemblage structure in the Chisui River, a protected tributary of the Yangtze River. Knowl Manag Aquatic Ecosystem, **400**:11p 1-14.

APPENDICES

1. Physico-chemical parameters in different stations

S.N	Parameters	Autumn			Winter			Spring			Summer		
		St I	St II	St III	St I	St II	St III	St I	St II	St III	St I	St II	St III
1	DO(Mg/l)	7.85	7.3	7.35	6.53	6.82	6.98	8.82	9.52	9.88	10.50	9.82	10.66
2	Free CO_2(mg/l)	10.8	10.53	10.5	12.85	12.3	9.18	6.85	7.52	6.21	9.52	8.5	8.2
3	Hardness(mg/l)	70	78	73	79	74	69	63	68	72	74	85	72
4	pH	7.7	8.2	8.4	8.3	8.4	8.2	8.5	8.8	8.3	7.5	7.2	7.7
5	Water temp.(°C)	21	21	21	15	14	16	24	25	24	23	23	23
6	Water Vel.(m/s)	1.4	1.1	0.7	0.5	0.28	0.22	0.3	0.28	0.14	1.8	1.4	1.2

PHOTO PLATE OF COLLECTED FISH SPECIES

Photo plate 1: *Puntius chola*

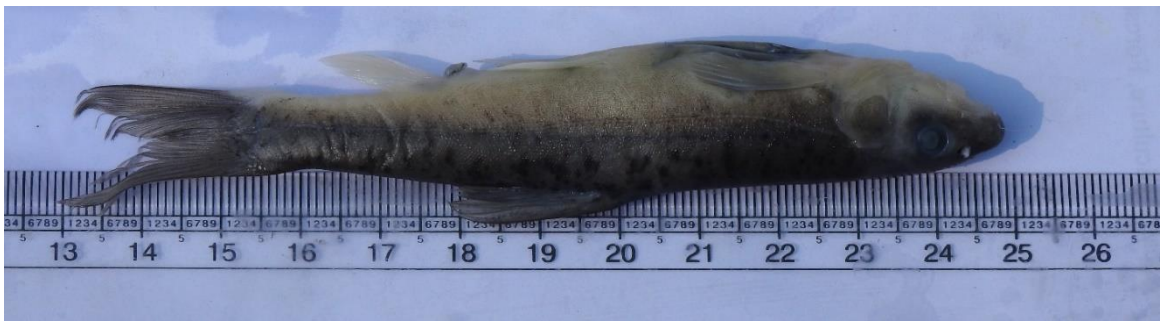

Photo plate 2: *Schizothorax plagiostomus*

Photo plate 3: *Tor chelynoides*

Photo plate 4: *Garra annandalei*

Photo plate 5: *Glyptothorax pectinopterus*

Photo plate 6: *Schizothoraichthys labiatus*

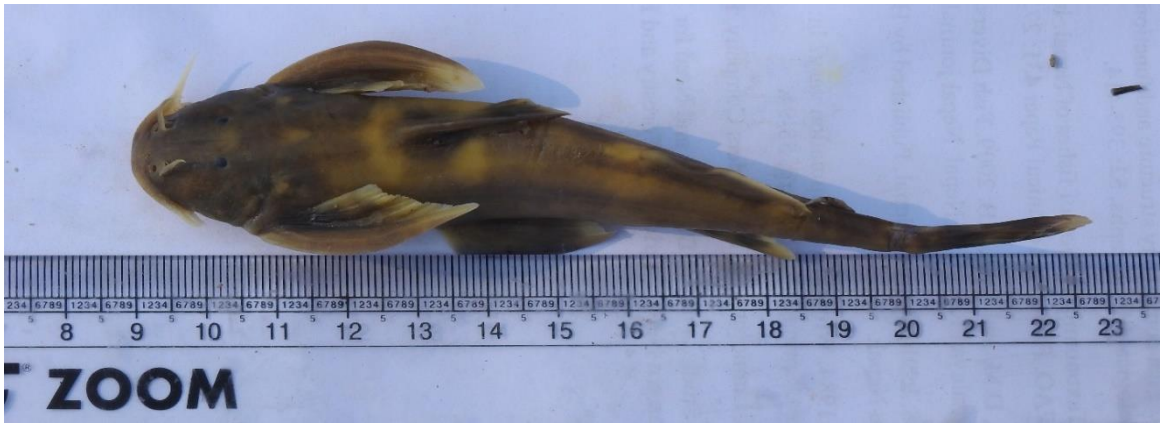

Photo plate 7: *Pseudecheneis sulcatus*

Photo plate 8: *Garra gotyla*

Photo plate 9: *Garra nasuta*

Photo plate 10: *Barilius barila*

Photo plate 11: *Schistura savona*

Photo late of field and lab work

Photo 1: Fishermen using cast net for collection of fishes

Photo 2: Site A: fisherman throwing cast net

Fig 3: Photo plate of Lab work

Fig 4: Photo plate of pH detection