DIVERSITY AND DISTRIBUTION OF FISH IN LIKHU RIVER OF EASTERN NEPAL

Submitted By

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RECOMMENDATION

This is to recommend that the thesis entitled **"DIVERSITY AND DISTRIBUTION OF FISHES IN LIKHU KHOLA OF EASTERN NEPAL"** has been carried out by **MissSusanaSunuwar** for the partial fulfillment of Master's Degree of Science in Zoology with special paper **'Fish Biology and Aquaculture'**. This is her 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. I recommend that the thesis be accepted for partial fulfillment of the requirements for the Degree of Master of Science in Zoology with special paper Fish Biology and Aquaculture.

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LETTER OF APPROVAL

On the recommendation of supervisor **Prof. Dr. Kumar Sapkota,** this dissertation submitted by **Miss Susana Sunuwar** entitled **"DIVERSITY AND DISTRIBUTION OF FISH IN LIKHU RIVER OF EASTERN NEPAL"** is approved for the partial fulfillment of the requirements for the Degree of Master of Science in Zoology with special paper **'Fish Biology and Aquaculture'.**

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Miss Susana Sunuwar entitled "**DIVERSITY AND DISTRIBUTION OF FISH IN LIKHU RIVER OF EASTERN NEPAL**" has been accepted as a partial fulfillment for the requirements of Master's degree of Science with special paper Fish Biology and Aquaculture.

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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 authors or institutions.

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ABSTRACT

In the present investigation,the fish diversity and distribution was investigated/analyzed in the Likhu River of Okhaldhunga , Nepal. Three sites were sampled in two seasons by using different fishing gears with the help of local fisherman. In the present research work altogether 10 species of fish belonging to 2 orders, 4 families and 8 genera were recorded, of which Order Cypriniformes (70%) was the dominant followed by Order Siluriformes(30%). Occurrence of *Schizothorax* and *Psilorhynchus* species were high in the river in both the sampling seasons. *Schizothorax* species was the most commonly observed fish during the sampling period. While *Glyptothorax pectinopterus*, *Myersglanis blythi* and *Pesudochenesis eddsi* were rarely caught fish species in Likhu River. Relationship between different seasons , sites , environmental variables and abundance of fish species was shown by CCA analysis. Hydrogen ion concentration in site B shows positive relation with fishes like *Psilorhynchus pseudochenesis, Glyptothorax pectinopterus* and *Schistura rupecula*.Other remaining fishes showed positive relation with winter season. Depletion of fish population was observed due to human activities like hydropower project, illegal fishing and pollution.

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LIST OF ABBREVIATIONS

Abbreviated form	Details of abbreviations
FAO	Food & agriculture Organization
HI	Hanna Instrument
□	Summation
UN	Uncommon
AAPH	Aquatic Animal Protection Act
EDR	Eastern Development Region
IUCN	International Union for Conservation of Nature
VDC	Village Development Committee

1. INTRODUCTION

1.1 General Background

Nepal is endowed with rich fishery potential as it has abundance of water bodies like lakes, rivers, reservoirs , ponds, stream , swamps and so on. Among them, rivers are the most important which represents 49% of total water body (Swar, 2002). Freshwater of Nepal supports vast array of fish comprising 252 species, some of which have got food, recreational and academic value (Shrestha, 2019). Fish diversity of Nepal accounts 0.21% of total global fish diversity (Shrestha 1995, Rai 2008, Gubaju 2012). Teleost species form the largest category among vertebrate animals and their members have reached more than 32,500 valid marine and freshwater species under 515 families (Nelson, 2006). There are at least 27,800 species in the world of which 10,000 are freshwater fishes (Shrestha , 2008). Freshwater fish represents nearly 10% of all vertebrate species in the word (Vari and Malabarba, 1998).

Riverine fish assemblage often varies along environmental gradients from headwater to lower mainstreams (Schlosser, 1982). When these gradients are interrupted, however alternate patterns can result. Such interruption can be natural, as in the case of waterfalls (Balon and Stwear, 1983). A number of diversity indices have been used to assess the diversity changes of water in aquatic ecosystem as well as it enhances the formation of various nutrients and their circulation and recharge in the aquatic bodies. The diversity and fish assemblages changes with elevation and seasons. The distribution, abundance and migration of aquatic organisms are also influenced by temperature and dissolved oxygen concentration (Alhassan, 2013). Freshwater fish communities are an essential component of aquatic ecosystems (Albaret et al., 2004; Mann, 2009) and play a crucial role in local subsistence economics in most tropical regions of the globe (FAO 1990; Moses 1992; Sikoki et al., 1998; Leveque and Paugy, 2006).

The diversity pattern observed has been a decrease in species richness and increase of endemism with increase in elevation (Lomoline, 2001). In South America Andes, for instance, studies on fish assemblages have identifies elevational climatic gradients as the main diverse of change in composition and species richness (Pouilley et al., 2006; Jaramillo – Villa et al., 2010 ; Carvajal-Quintero et al., 2015; De La Barra et al., 2016).

Evidence from fish communities at high elevationin the Andes suggests that headwater streams have different compositions despite having similar environments (Carvajal – Quintero et al., 2015). Headwater delivers water, sediments and organic materials to downstream water, contribute to nutrient cycling and water quality; enhance flood protection and mitigation; and provide recreational opportunities (Gomi et al., 2002; Richardson and Danehy 2007; Hill et al., 2014 ; Cohen et al., 2016). Although fish abundance and diversity generally are lower in headwater system compared to downstream reaches (Schlosser 1987), species comparison can be distinct with the rest of the network (Paller 1994).

The decline of freshwater fish is a comprehensive phenomenon noticeable on global, regional and local scales (Moyle and Randall 1998; Duncan and Lockwood, 2001). Habitat loss and pollution are primary causes of extinction of aquatic biota (Miller et al., 1989; Dudgeon et al., 2006; Arthington et al., 2016). Riverine fish species losses due to climate change and reduced water discharge are predicted to reach 75% in some river basins (Xenopoulous et al., 2005). Phenological changes in fish behavior (Otero et al., 2014; Dempson et al., 2017; Hovel et al., 2017) have been also detected and emphasize the powerful change imposed by a changing climate. Within the IUCN Red list, as much as 33% of European freshwater fish species are recognized as threatened by climate change (IUCN, 2017). Manmade barriers to fish migration or dispersal have been linked to the decline of freshwater fish assemblages throughout the world (Starrs et al., 2011). Effective fish management require knowledge of how fish populations are influenced by environmental factors such as water temperature, water depth and physical habitat (Rose, 2000).

Cold water fish of Nepal are facing problems due to an increasing number of hydropower projects. Developmental works such as river damming have a major impact on river ecology, aquatic flora and fauna, including fish. The ichthyology of Nepal is reported within varying account of total number of fish species recording in the country. For instance, Shrestha (2001) reported 182 fish species from Nepal. Rajbanshi (2005) listed 187 fish species from Nepal. In addition Saud and Shrestha (2007) reported 199 fish species from Nepal. Shrestha (2008) reported 217 indigenous and 15 exotic fish species. Similarly, till date Shrestha (2019) has updated total 252 fish species of Nepal with 236 are native species including 16 exotic species and 16 endemic species.

1.2 Objectives

1.2.1 General objective

- To explore the diversity fish of Likhu Khola in Okhaldhunga , Nepal

1.2.2 Specific objectives

- To investigate the abundance and distribution of fish in Likhu Khola
- To determine the influence of environmental variables on fish diversity of Likhu Khola.

1.3 Rationale of the study

Nepal has number of rivers which portray that our country is rich in water resources. There are streams, brooks, canal, reservoirs, ponds and lakes. But rich with the water resources, study on fish diversity, habitat, reproduction, biology and ecology of fishes are still lacking. There are still thousands of rivers and streams not explored. The researchers are not able to reach all these water resources due to the geographical structure of our country and some other reasons like transportation and financial problems. Species identification also has been seen a big problem. This is due to the lack of field observation, meticulous species identification and regular survey on fish diversity, natural photographs and deposition of specimens. There are still lots of tumult regarding the taxonomic characteristics of some fish species of Nepal. Some fish like *Schistura* sps, *Colisa* sps,*Schizothorax* sps, *Mystus* sps, and *Glyptothorax* sps needs to be studied further and taxonomic reconfirmation. Habit and habitat of many fishes are still being not known. On this account, the present study was undertaken to minimize these lacking parts to some extent and I believe that this study will be very helpful for the researchers.

1.4 Limitation of the study

The present study area is not easily approachable place. So, the study was focused only on fish diversity.

2. LITERATURE REVIEW

Ichthyofaunal diversity refers the spatial and temporal patterns of diversity, distribution and species composition of freshwater fishes are useful to examine factors influencing the structure of the fish community (Galactos et al., 2004). Freshwater habitats in rivers, streams,springs and headwaters are heterogeneous due to variation in altitude, flow rate, dissolved oxygen, physical substrate and the riparian zones that provide food, shade and cover (Armantrout,1990). As a result freshwater habitats harbor diverse fauna with fish serving as a prime indicators of ecosystem status (Karr et al., 1986).

The factors which determine the fish assemblages structure in riverine of both temperate and tropical regions are altitude, river size, temperature, water velocity, depth, habitat complexity (Tejerina – Garro et al., 2005). Likewise some factors which causes the reduction of diversity in high altitude are decrease in primary productivity with increase in altitude, reduction of suitable available area for organisms, unsuitable climatic condition and reduction in the food resources (Hutson 1994). In general species diversity decreases with increase in altitude (Lomolino 2001). Studies have shown a monotonic decrease in fish species richness with increasing longitudinal gradient (Jaramillo et al., 2010; June et at., 2015).

Fish assemblage plays an important role in stream ecosystems through top-down control on prey organisms as well as having a strong influence of nutrient dynamics through the uptake and release of nutrients (Vanni et al., 2001; Mcintyne et al., 2007; Wilson and Xenpoulos, 2011). The nutrient regime and available food can regulate fish taxonomic compostion in aquatic ecosystems (Jeppesen et al., 2000; Noble et al., 2007)Freshwater ecosystems are influenced by the animals that inhabit there, such as through the process of nutrient recycling via fish excretion (Vanni 2002; Capps et al., 2015). Fisheries resources are on the decline in Nigeria due to over exploitation and inadequate management of inland water (Godwin et al., 2016). He also added increased fishing pressure exerted by artisanal fisherman that are operating in this water body coupled with the downstream migration of fish in searching food, shelter and spawning, industrialization, urbanization and farming activities around the river are the factors that

contribute variation in fish composition and diversity in Nigera. There are approximately 470 fish species currently known to exist in Malaysia (Chong et al., 2010). Freshwater fishes are one of the threatened species and represent the most diverse group of vertebrates (Bruton, 1995).There is much diversity in freshwater fishes of the equatorial zone and it is difficult to readily characterize them by building clades (Leveque et al., 2008). Maximum fish species are found in the tropical and equatorial areas with an overall decrease in diversity towards temperate and polar regions.

Fresh water is naturally occurring water in canals, rivers, reservoirs, lakes, streams and other land-locked waters (FAO,2014) that comprised of about 0.01% of the total volume of earth water (Stiassny,1996). There is distinctive freshwater fish fauna and fish distribution pattern in each continent (Berra,2001). They play an important role in the field of economy in different countries. The fish diversity of Nepal had been poorly studied by Nepalese ichthyologist relative to other fauna (Bhusal et al., 2017).

Headwater streams are generally shallow, clear and fast flowing water, usually sandy to rocky bottom, cold with highly oxygenated water. Streams are usually flow under forest cover that sometimes provide shade from 60% to 90% (Mohd et al., 2014) and usually only exposed particularly at the middle section between banks of streams. Various microhabits may be observed such as plunge – pools, rapids, riffles, leaf litter depositing, snags and submerged logs and branches and over hanging bank' vegetations. These diverse microhabits provide various needs to many different fish species.

3. MATERIALS AND METHODS

3.1 Study area

The present study area, Likhu River is situated in eastern Nepal of Okhaldhunga district. It has total length of 75 Km from its origin point to end. The river originates from glacier Zurmoche above Gumdel village and surges through the Bhakanje, Bamti, Ragani, Sirse, Dhurchim, Sagutar and finally joins with the Saptakoshi River.

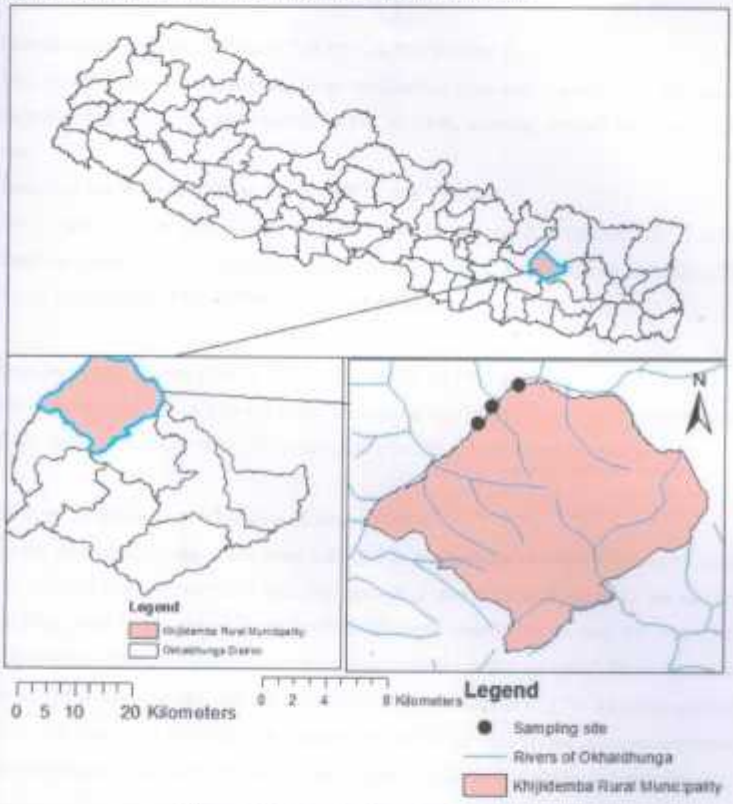

Figure 1: Map showing the Study area

3.2 Sampling sites

Altogether three sampling sites A, B and C (figure. 1) were allocated along the sampling stretch of the Likhu Khola. Sampling was carried out within the river length stretch of about 10 km. Site B is 5 km from from A and 4 km far from C.

Sampling site A Holpu(890 m, 27°32.697' N, 086°04.638' E)

The sampling site A was selected in an undisturbed area and is away from the human encroachment. The river bed consists of big boulders, cobbles, pebbles and a very little sand.

Sampling site B Limti (800 m, 27°26.580' N, 086°15.380 E)

The sampling site B was chosen near the Likhu bridge and it is the vicinity of Likhu Sanibare Bazar area. This sampling area is highly affected by the human activities. The rivulet bed consists of big boulders, cobble, pebble, gravel, mud and sand.

Sampling site C Sirese (710 m, 27°25.200' N, 086°14.583' E)

The sampling site C was selected at the confluence spot of two rivers. Here another small rivulet joins with Likhu river. The rivulet bed consists of cobble, pebble and sand.

3.3 Fish sampling, preservation and identification

For the present study, the fishes were collected in two seasons winter and spring by using cast net of 4 mm ×4 mm mesh size. Fish sampling was done at 9 am to 12 pm in each sampling sites where the total catch effort 45 times installation of cast net was done. Before preservation, collected fishes were photographed with Camera of iPhone 7 mobile phone. After photography, the collected fishes were preserved in 37% formalin solution for 6 to 8 hours and later the fishes were transferred to 10% formalin solution making their head upside for the protection of their caudal fin for further study and the specimens were brought to the laboratory of the Central Department of Zoology (CDZ) in plastic bag for identification. The identification was carried out with the help of taxonomic references Jayaram (2010), and Shrestha (2008, 2019).

3.4 Sampling of Environmental variables

The following Environmental variables were analyzed during each field visit:

3.4.1 Water temperature

Water temperature (°C) was measured with a standard mercury thermometer. It was recorded by placing a thermometer in the water at a depth of 1feet for 1 minute and obtained value was recorded.

3.4.2 Hydrogen ion concentration (pH)

The hydrogen ion concentration (pH) of the water is the measurement of how acidic or basic is it. And it was measured by using a calibrated pH meter (HI 98107, HANNA Instrument). Anterior bulb of pH meter was dipped in 100 ml water collected in a beaker for a minute in each site during fish sampling time and the value was recorded.

3.4.3 Water velocity

Water velocity is the speed at which rate it flows. It was measured by the simple float method.For this a ball, measuring tape and stop watch was used. Ball was moved to flow from initial point to 50 m away and the length was measured by measuring tape and was calculated the water velocity.

3.5 Statistical analysis

Statistical analysis of fish number in relation with the environmental variables was analyzed through multivariate analysis tool where seasonal and site wise Shannon-Weiner diversity index, Simpson index and Evenness were calculated by using R software (Oksanen et al., 2019). The relation between species diversity and environmental variables were analyzed by canonical correspondence analysis (CCA) method (ter Braak 1988a, ter Braak and Prentice 1988) by using vegan library in 'R' (Oksanen et al.2019)

3.5.1 Shannon-Weiner diversity index (H')

Shannon-Wiener Index (H') - is an information index and is the most commonly used diversity index in ecology. Technically, the Shannon-Wiener Index (when applied to ecology) quantifies the uncertainty associated with predicting the identity of new taxa given number of taxa and evenness in abundances of individuals within each taxa.

$H' = -\sum (ni\ N \times \ln ni\ N)$

where ni is the number of individuals of amount (biomass) of each of the i species and N is the total number of individuals (or biomass) for the site. Values of H' can range from 0 to 5, although they typically range from 1.5 to 3.5 The Shannon-Wiener Index assumes that the sample for site was collected randomly. The value of Shannon-Wiener Index was calculated by applying the data in R program in the following ways.

> library(vegan)

> Diversity(diversity)

> Diversity(diversity, index = "Shannon" and Run.

3.5.2 Simpson dominance index

Simpson's Index (λ) is actually a measure of dominance and as such weights towards the abundance of the most common taxa. It is the probability that two individuals drawn at random from an infinitely large community will be different species. Simpson's Index is usually expressed as the reciprocal ($DS=1-\lambda$) so that as a measure of diversity, higher values represent higher diversity. It is less sensitive to rare species than the Shannon-Wiener Index which is sometimes a positive and sometimes a negative.

As it is a probability, the Simpson's index ranges from 0 to 1.

$\lambda DS=\sum ni(ni-1N(N-1)=1-\sum ni(ni-1N(N-1)$

> library (vegan)

> diversity(data[-1], index="simpson")

3.5.3Pielou evenness index

Pilou evenness (J) compares the actual diversity value (such as the Shannon-Wiener Index, H') to the maximum possible diversity value (when all species are equally common, Hmax=ln s where S is the total number of species). For the Shannon-Wiener Index, the Pielou evenness (J):

J=H'Hmax=H'ln S

Pielou evenness (J) is constrained between 0 and 1.0 and the more variation in

abundances between different taxa within the community, the lower J. Unfortunately, Pilou's J is highly dependent on sample size (since S - the estimated number of species is dependent on sampling effort) and is also highly sensitive to rare taxa.

```
> library(vegan)
> S <- apply(data[,-1]>0,1,sum)
> diversity(data[-1], index="simpson")/log(S
```

3.5.4Multivariate analysis

The relationship between species diversity and environmental variables were analyzed by detrended correspondence analysis (DCA) and Canonical correspondence analysis (CCA) method (Tar Break 1988 a, Tar Braak and Prentice 1988) by using Vegan Library in R (Oksanen et at., 2019).

4. RESULTS

4.1 Water temperature

Water temperature of the present study area was recorded in two different seasons (fig.2). It was recorded higher during spring season at site C than winter. During the winter season water temperature ranged between 13°C to 14.75°C. Similarly, in spring season it ranged between 18°C to 20°C.

Figure 2: Water temperature recorded at different sites and season of Likhu River

4.2 Hydrogen ion concentration (H^+)

Hydrogen ion concentration was found different in different seasons. It was recorded between 6.67 to 8 in winter season and from 7.6 to 7.95 in spring season (fig. 3).

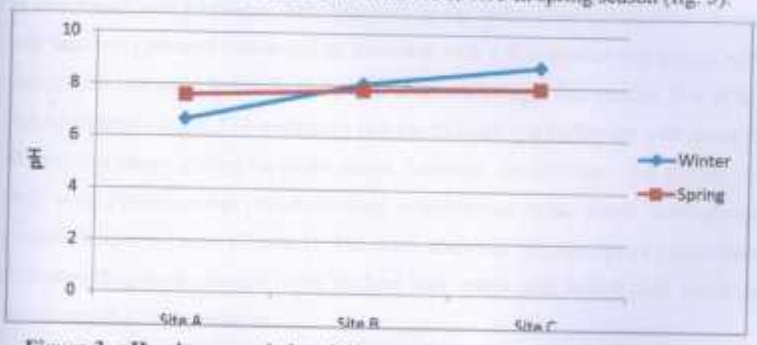

Figure 3: pH value recorded at different sites and season of Likhu River

4.3 Water velocity (m/sec)

Water velocity of the present study area was also recorded in two different seasons. It was comparatively found less in winter season than spring season. It was recorded around 0. 5 m/sec during winter season and during spring it ranges between 0.6 to 0.7 m/sec. (fig 4).

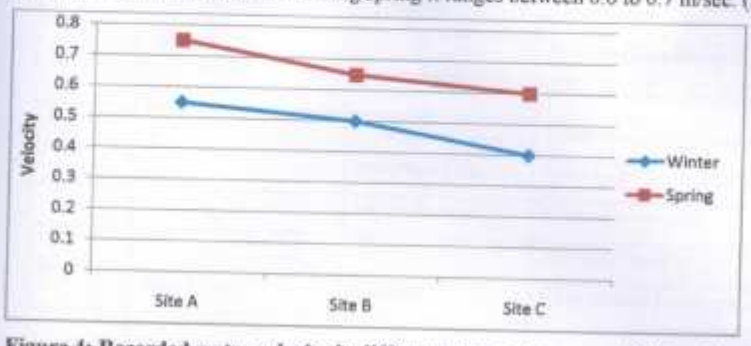

Figure 4: Recorded water velocity in different sites and seasons of Likhu River

4.4 Fish Diversity

Likhu River is a habitat for various types of cold water fish species. A total of 10 different fish species were collected during study period which included 2 order 4 families and 8 genera. The seven fish species belongs to order cypriniformes was found as dominated with frequency 70% followed by the order siluriformes 30%. In the same way family Cyprinidae was found as dominant with 4 fish species and lowest number of fish species belonged to family Psilorhynchidae with single fish species. Out of 612 total fish specimens caught, 534 specimens belongs to order cypriniformes with about 87.25% of total fish caught during the study period. Likewise, the dominant fish species of Likhu river were *Psilorhynchus pseudochenesis, schizothorax richardsonii, Schizothorachthys progastus, Garra lamta* (Tabke 1). The most abundant fish species of Likhu River was *Psilorhynchuspseudochenesis* with highest fish catch and lowest fish catch was of *Neolissochilus hexagonolepis*

Table 1: Fishes species occurrence and diversity in Likhu River of Eastern Nepal

S.N	Order	family	Scientific names
1.	Cypriniformes	Cyprinidae	*Garra lamta*
			Neolissochilus hexagonolepis
			Schizothorax richardsonii
			Schizothorachthys progastus
		Psilorhynchidae	*Psilorhynchus pseudochesis*
		Nemacheilidae	*Schistura rupecula*
			Schistura devdevi
2.	Siluriformes	Sisoridae	*Glyptothorax pectinopterus*
			Pseudochenesis eddsi
			Myersglanis blythi

4.5 Species abundance and distribution

Altogether 612 fish specimens were caught during sampling period. Among them total 10 species belonging to 2 orders, 4 families and 8 genera were recorded. Order Cypriniformes was found to be dominated order which comprised seven (70%) fish species and followed by Order Siluriformes with three species (30%). Out of 612 fishes, the most abundant species with high frequency of occurrence was*Psilorhynchuspseudochenesis* comprises 242 individual with frequency 39.54 and during the study period followed by *Schizothoraxrichardsonii* , *Schizothorachthysprogastus* and *Garralamta* with their frequency 23.69% , 8.16% and 5.88% respectively. The lowest fish caught was single individual fish species includes *Neolissochilushexagonolepis* with lowest frequency i.e 1.47and is shown in Table 2. The maximum fish species belonged to family Cyprinidae (4 spps) and minimum to family Psilorhynchidae (1sp) species was more in spring season compared to winter.

Table 2: Species abundance, distribution and frequency occurrence of fishes in Likhu River

S.N	Name of the fish	Code	Seasons		Total	Frequency
			Winter	Spring		
1	*Pseudocheneiss eddsi*	Pseu_edd	20	6	26	4.24
2	*Schizothorax richardsonii*	Sch_rich	93	52	145	23.692
3	*Schizothoraclulhys progastus*	Sch_pro	14	36	50	8.169
4	*Garra lamta*	Gar_lam	20	16	36	5.88
5	*Myersglanis blythi*	Myr_bly	5	15	20	3.267
6	*Psilorhynchus pseudochenesis*	Psilo_pseu	86	156	242	39.542
7	*Schistura rupecula*	Schi_rup	24	10	34	5.555
8	*Schistura devdevi*	Schi_dev	13	5	18	2.941
9	*Neolisschilus hexagonolepis*	Neo_hex	0	9	9	1.57
10	*Glyptothorax pectinopterus*	Gly_pec	25	7	32	5.228

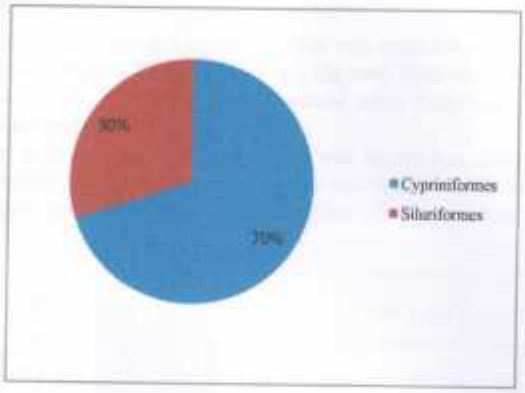

Figure 5: Order-wise percentage composition of fishes of Likhu River

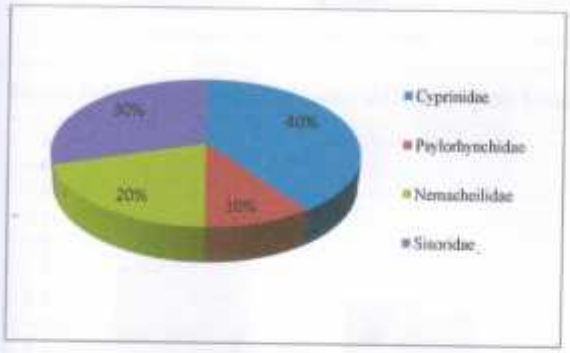

Figure 6: Family – wise percentage composition of fishes of Likhu River

4.6 Diversity status

The highest Shannon diversity index was recorded at site C and lowest at site B. In contrast, highest Simpson index was recorded from site C and lowest value was observed from site A. Similarly, highest evenness index value was recorded from site and lowest value was found from site A (Fig. 4).

The highest Shannon diversity index was recorded in winterseason and lowest in spring. Similarly, highest Simpson index was observed in winter and lowest during spring. The highest evenness index was reported from winter season and lowest in spring (Fig. 5).

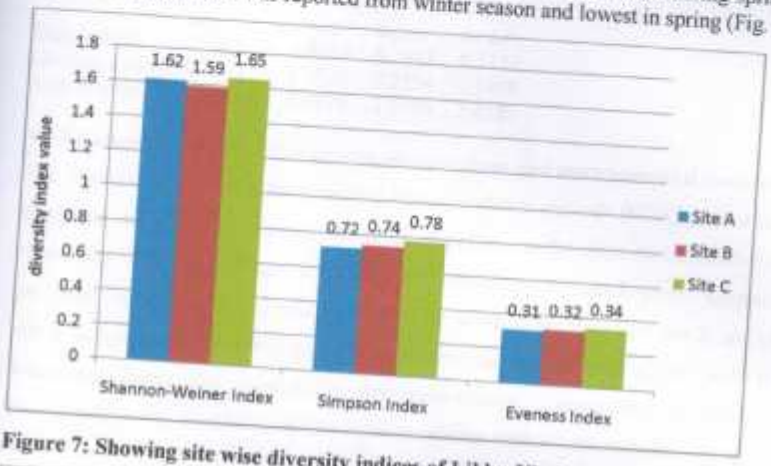

Figure 7: Showing site wise diversity indices of Likhu Khola.

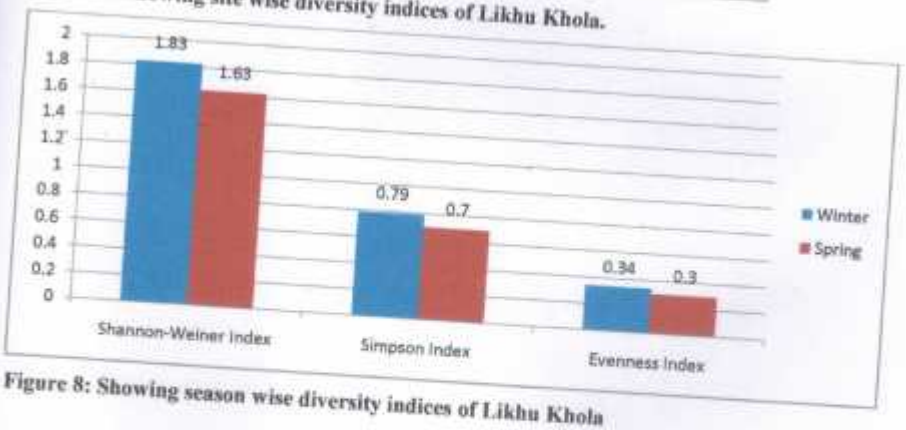

Figure 8: Showing season wise diversity indices of Likhu Khola

4.7 Ordination

The axis length of the first axis of Detrended Correspondence Analysis (DCA) was found 3.68 standard deviation unit (SD unit) followed by 3.97 by the second DCA axis (Table3). The overall varience explained by the data matrix was above 50%. Thus, application of RDA was not justified. So, CCA was applied.

Table 3: DCA summary

	DCA1	DCA2	DCA3	DCA4
Eigenvalues	0.5603	0.4019	0.2461	0.2133
Decorana values	0.6674	0.3925	0.2154	0.1488
Axis lengths	3.6837	3.9778	2.1396	2.4380

4.8 Relationship between fish species, sites, seasons and environmental variables

The results obtained from the canonical correspondence analysis (CCA) plotted in fig. 9 suggested that the environmental variables of pH and water plays an imperative role to shape the fish assemblage structure. *Psilorhynchus pseudochenesis*, *Glyptothorax pectinopterus* and *Schistura* species showed the positive relation with site B and pH. At site C occurrence of *Neolissochilushexagonolepis* and *Schizothorax* species were higher. Remaining fishes like *Garralamta*, *Myersglanisblythi*, *Pseudochenesiseddsi*etc. were recorded from site A and showed the positive relation with winter season.

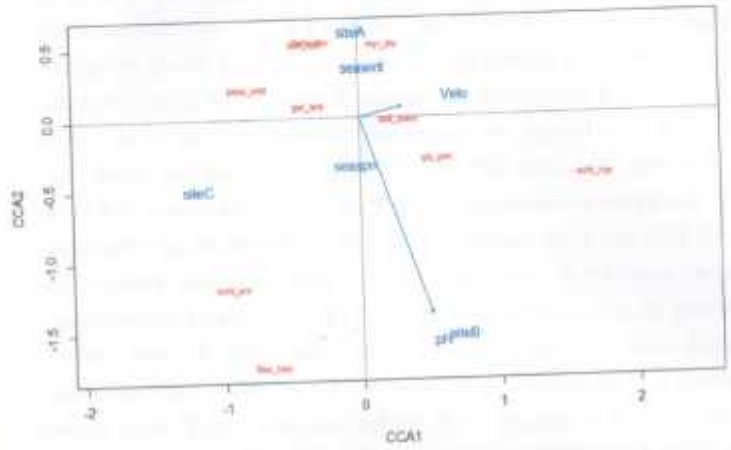

Figure 9: CCA analysis of species abundance, sites and environmental variable

5. DISCUSSION

The pH value of the present study shows basic which is similar with Shrestha et al., (2009), Mishra and Baniya (2016), Limbu et al., (2018) and Rashed et al., (2016). Value of pH observed ranges 6.67 to 8.8 (winter) and 7.6 to 7.95 (spring) indicates that water was slightly alkaline in nature. Maximum water temperature was reported at site C and minimum at site A. Water velocity of the present study was found to be 0.55 m/sec to 0.6 m/sec. Here, the site A was selected higher elevation as compared to site B and Site C but water current was found to be higher in site B. This study shows that water velocity cannot fully depends upon the altitude. Water velocity mainly depends upon the structure, characteristic features and water volume of rivers, streams etc. A total of 10 fish species were reported during the study period. Among them, *Schizothorax richardsonii, Schizothorachthys progastus and Psilorhynchus pseudochenesis* were the most abundant species. Limbu et al., (2019) reported about 151 species from Eastern Nepal. Limbu et al., (2016), Limbu and Prasad (2017), Limbu et al., (2018) identified 16, 9 and 8 species from Deumai Khola, Phewa Khola and Bakraha River. Shrestha et al., (2009) have also recorded 30 fish species from Tamor River. Subba et al., (2017), Yadav (2017), Shrestha (2016), Shah (2016) reported 118, 26, 48 and 59 species from Morang district, Singhiya River, Triyuga River and Saptakoshi River of Eastern Nepal.

Till date 252 fish species have been reported in Nepal including 15 orders, 35 families and 104 genera (Shrestha, 2019). Among 15 orders, Cypriniformes is the most dominating order. The present study also revealed the same result as of Shrestha (2019). Because among 10 species Order Cypriniformes includes 7 species as a dominant species. The result of this study is also consistent with the findings of Shrestha (2009), Pokheral (2011), Edds (1986) and and Limbu et al., (2016). Majority of the fish species collected from the River fall under the order Cypriniformes, this is the order of fresh water fishes, which includes 2,422 species (Nelson, 1984).

Highest number of individuals were found from Site A than site B and C. It is because this site was found undisturbed with the human activities and also the volume of water was high.The present study was conducted for a short period of time as the study area is not easily approachable. So, chemical analysis of the water was not done. And the research was mainly focused on fish diversity. Sampling of fishes is done in two different season i.e winter and spring due to the same reason. According to the local community

and fisherman there, fishes like *Anguilla bengalensis* and *Tor* spp. were also found. But neither of them were caught when we sampled. Because those are migratory freshwater species which migrates upward during monsoon for protection from heavy flow at lowlands. So, it is obvious of not finding those species during my sampling period. Literatures also suggest naturally flowing river water keeps discharging continually so enough oxygen is available which ensure sufficient oxygen is present in the river for the fishes inhabiting there. Local people and local fisherman also indicated that the hydroelectricity project brought in process in the river has become one of the reason in less availability of fishes as before. It is seen the distribution of the fishes are declining along with their population.

We have to consider this and put hands together for its conservation how we can. A biodiversity index seeks to characterize the diversity of sample or community by a single number (Magurran, 1988). The concept of the species diversity involves two components: the number of species or richness and the distribution of individuals among species. However, the formal treatment of the concept and its measurement is complex (Williamson, 1973). The biodiversity index values (H') obtained from present study is not so very high according to Shannon-Weiner biodiversity index values and they do not exactly show the differences occurring among the Sites either. According to Keskin and Unsal (1998) the reason for showing lower species biodiversity is that fishing gears used have high selectivity effect. Highest Shannon-Weiner diversity index (1.65), (1.83) was found in site C and Winter (February) whereas lowest was observed at Site B and spring (April) i.e (1.59) and (1.63). Simpson dominance diversity index value was highest in site C and lowest value observed in site A. In the saw way highest evenness was recorded in Site C and winter season. While lowest evenness at site A and spring.It may be the seasonal effect and more disturbances at site B brought by the developmental works there at present. Likhu, Hill Stream River is one of the yet unexplored water resourcesof a country which is found to support good habitat for the cold water fresh water fishes.

6. CONCLUSION

A total of 10 fish species belonging to 2 orders, 4 families and 8 genera was recorded from the present research work. Research concluded that the Likhu, Hill Stream River supports the good habitat for hill stream fresh water fishes. Frequently observed fish in the study area was *Schizothorax* and *Psilorhynchus* species. Two different orders comprises Order Cypriniformes and Siluriformes. Order Cypriniformes (70%) was the dominant and Siluriformes (30%). Rarely caught fishes during the research were *Pseudochenesis eddi, Myersglanis blythi and Glyptothorax pectinopterus*. Cast net was commonly used fishing gear by the fishermanin the river.The highest diversity index (1.65) was recorded in site C and lowest in site B (1.59). Similarly, during winter season diversity was high with 1.83 and during spring it was 1.63.

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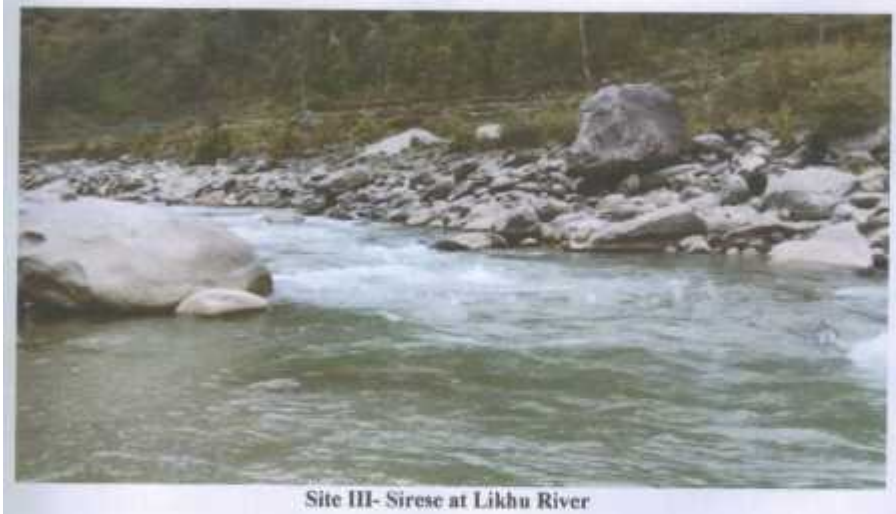
PLATE I

Sampling sites

Site I- Holpu at Likhu River

Site II – Limti at Likhu River



Site III- Sirese at Likhu River

PLATE II

Fish Diversity

Schizothorax richardsonii

Pseudochenesis eddsi

Schizothorachthys progastus

Glyptothorax pectinopterus

Garra lamta

Psilorhynchus pseudechenesis

PLATE III

Fish Diversity

Shistura devdevi

Myersglanis blythi

Neolissochilus hexagonolepis

Shistura rupecula