SPATIO TEMPORAL VARIATION IN THE FISH ASSEMBLAGE STRUCTURE OF THE MECHI RIVER, EASTERN NEPAL

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A Thesis submitted
In partial fulfillment of the requirements for the award of the degree of Master of Science in Zoology with special paper Fish Biology and Aquaculture.

Submitted To:
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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.

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RECOMMENDATIONS

This is to recommend that the thesis entitled, "spatio temporal variation in the fish assemblage structure of the Mechi River, Province No. 1 Eastern Nepal " has been carried out by Ashim Adhikari for the partial fulfilment of Master's Degree of Science in Zoology with special paper fish Biology and Aquaculture. 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

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CERTIFICATE OF ACCEPTANCE

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ACKNOWLEDGEMENTS

First of all I would like to acknowledge my respected Supervisor Prof. Dr. Kumar Sapkota for his overall Support and help during the research era as well during the time of thesis formulation and submission.

Similarly, I would like to thanks to our HOD, Prof. Dr. Tej Bahadur Thapa for his help and support and guidance as well, I would also like to praise our Central Department of Zoology and its overall teaching and non teaching staffs for their help and support.

In the same way I would like to present my special gratitude towards my friend Mr. Jash Hang Limbu for helping me with analysis part.

Last but not the least I would like to present my special thanks to my friends viz.Tenzing Sherpa, Shruti Shakya, Ankushree Mallik, Prabha Ale Magar and all the mates who Supported me for the completion of this work.

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LIST OF ABBREVIATIONS

Abbreviated form	Details of Abbreviations
BOD	Biological oxygen demand
CO_2	Free carbon dioxide
Conc.	Concentrate
DO	Dissolved Oxygen
KI	potassium iodide
Km	Kilometer
M	meter
Mg/l	Milligram per liter
Ml	Milliliter
$MnSO_4$	Manganese Sulphate
M/s	meter per second
N	Normality
NaOH	Sodium hydroxide
pH	Potential of Hydrogen ion
S.N.	Serial number
Spp.	Species
°C	Degree Celsius
%	Percentage
DCA	Detrented correspondence analysis
CCA	Canonical correspondence analysis

CONTENTS

ABSTRACT:

Species diversity is widely recognized as an important trait of ecosystem functioning and resilience. Spatio-temporal patterns of fish assemblage structure in Mechi River were studied based on Stratified random survey conducted during September 2108 to April 2019. The survey was conducted on three different sampling stations at three different seasons. The spatial and temporal patterns of fish assemblage were analyzed by using Shannon Weinner index, the Simpson index and evenness. To examine the fish assemblage structure, fish samples were collected in seasonal basis from three sites of the River by using cast net and gill net. A total of 1772 individuals belonging to 4 orders, 8 families, 16 genera and 33 species were collected from Salakpur, Gadagalli and Nakalbanda of Mechi River. The most abundant species were *Schistura devdevi* followed by *Puntius sophore* and *Barilius barila.* The highest diversity index (2.93) and Simpson index (0.93) was recorded during winter season for seasonal diversity. The highest diversity index (92.69) and Simpson index (0.9) of fish were recorded from station 2 for the station wise diversity. The CCA analysis (fig.12) showed that the fish assemblage was highly correlated with temperature. Velocity and DO whereas negatively correlated with carbon dioxide and slightly correlated with pH. This study may help to maintain native fish adapted to these conditions in the Mechi River as well as it may help in expansion of knowledge regarding the fish diversity of Nepal.

1. INTRODUCTION

1.1. Background

Fishes are the group of vertebrates which share many common characters that helps them to adapt in various aquatic ecosystem. There are at least 27,800 species in the world of which 10,000 are freshwater fishes (Shrestha 2008). Fish form almost half of the total number of vertebrates in both fresh and marine aquatic ecosystems (Gupta 2006). The Florida museum of natural history estimates 27650 species of extant fishes of which 41% are freshwater occupying less than 0.01% of Earth's volume. Over two thirds freshwater fish belongs to single clad Otophysi (i.e. minnows, characins, and catfish). In the Indian subcontinent there are more than 2500 species with approximately 930 species belonging to freshwater ecosystem (Jayram, 2013). Spatial and temporal variation of fish assemblage structure in river occur at scales from micro-habitat to basin and diel to decadal or longer (Adams et al, 2004). Knowledge of spatial and temporal variation is valuable for identifying sources of assemblages' regulation across the river and interpreting time series data on fish assemblages (Schlosser 1990). Fish assemblage variation is function of many interconnecting factors, including hydrologic regime, geo climatic region, and species composition, biotic versus abiotic regulation, channel type, disturbance history and frequency (Gossmann et al. 1998). Fish assemblage plays a vital role in maintaining the good condition of water in aquatic ecosystem as well as it enhances the formulation of various nutrients and their circulation and recharge in the aquatic bodies. Fish assemblage provides indication for the quality of freshwater ecosystem since it is sensitive to a broad range of stressors (Karr 1981). The diversity and distribution pattern of fish has been widely related with the environmental factors like dissolved oxygen, free Carbon Dioxide, pH, alkalinity and more critically with the temperature (Brown 2000).

Studies on spatiotemporal patterns of diversity are critical for preserving hot spots of biodiversity, predicting diversity variations with environmental changes and anthropogenic impacts on communities or ecosystem function (de Bore et al. 2001; Knobby et al. 2010, Lucifer et al. 2102). A number of diversity indices have been used to assess the diversity changes with environmental gradients (Rector et al. 2001). Species diversity has strong implications on the functioning and conservation state of the ecosystems. Its preservation should therefore be a priority in conservation and management, and indeed many protected areas are established based on the diversity hotspots they sustain. Understanding the causes of underlying diversity patterns and their interaction with the environmental conditions are paramount of importance for its conservation (Keller 2016).

Riverine fish assemblage often varies along environmental gradients from head water to lower mainstreams (Schlosser 1982). When these gradients are interrupted, however alternate patterns can result. Such interruptions can be natural, as in the case of waterfalls (Balon and Stwear 1983).

Although the number of free flowing riverine ecosystem in the world continues to decline (Poff et al. 1997), more research is required to understand the spatial pattern of fish assemblage structure in the rivers. The fish species are distributed in various water bodies such as rivers, lakes and ponds. The diversity and fish assemblages changes with elevation and seasons. The fish diversity is low in high mountains, moderate in mid hills but high with endemic species and highest in lower foot hills. Animals often shift their

diet in response to change in resource availability, abiotic environmental conditions and ontogenetic stage (Stuart et al. 2004, Werner 1988). Availability of food resources varies in both space and time, variation in precipitation is another important factor which influencing fish assemblages in tropical streams and rivers. In rainy seasons water bodies expands and forms flood plains due to which habitat of fish expands which support for feeding, spawning and refuge from predators but in dry season habitat shrink results in food resource depletion and higher in consumers densities (Winemiller and Jepseni 1998).The Himalayan Kingdom of Nepal is rich in freshwater resources comprising both lotic, that is running (raceways, fountains, glaciers, springs, rivulets, tunnels, streams, and rivers) and lentic, that is, confined or stagnant or still (ponds, pools, ditches, dahas, reservoirs, swamps or marshy lands, and nullahs). Many workers explored available freshwater fish fauna of Nepal, the review of which has been described by Bhagat (1979, 1984), Menon (1974), Majupuria (1998), Shrestha (1991, 1994), and Shrestha (1995). Again, these explorers presented location-wise check-lists of freshwater fish fauna of different regions of Nepal, with particular references to places, districts, zones, regions, rivers, streams, lakes, and so on. 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 (Dufendorf, 2006). This study aims to achieve a crucial goal in finding assemblage Structure of fish in Mechi River and to determine the diversity of fish in this river system. It will also help to expand the knowledge of fish richness in less explored rivers like Mechi.

1.2. Justification of the study

There are over 6000 rivers in Nepal. As compared to the size of our country, the number of River portrays that our country is rich in water resources. Except rivers, there are streams, brooks, canal, reservoirs, ponds and lakes. Being rich in water resources study on fish diversity, habitat, reproduction, biology and ecology of fish are lacking. It is due to the lack of ichthyological activity. Till date, researchers have conducted their work in limited rivers, streams and lakes only. There are still thousands of rivers and streams are unexplored. The researchers are not able to reach all these water resources which provide the habitat of fish. The main reason is due to the geographical structure of our country. There might be some other reasons like rustic, transportation problem, and due to the lack of enough funding. In our country, study of spatial and temporal distribution is strongly needed. By studying this, we may know that the seasonal variation and habitat of the fish. On this topic, very few numbers of research works has been carried out by Nepalese ichthyologist. Due to this, lot of fishes of spatial and temporal distribution is still unknown. On the contrary, the fish species confirmation of Nepal 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 characteristic of some fish species of Nepal. Habit and habitat of many fish are still not known. On this account, the present study was undertaken to fulfill all these lacking parts to some extent and I believe that, this study will be very helpful for beginners as well.

1.3. Objectives

a) General Objectives

- To explore the spatial and temporal variation in fish assemblage structure of Mechi River.

b) Specific objectives

- To investigate the spatial and temporal variation in species composition and abundance of fish of Mechi River.
- To identify the factors influencing the fish assemblage structure of Mechi River.

1.4. Research questions

- How does the fish assemblage change according to the longitudunal and temporal gradient from the river upstream to the reservoir in downstream?
- What factors are responsible for determining the fish diversity in a stream?

2. LITERATURE REVIEW

2.1. Spatial variation of fish assemblage structure

There are different factors which causes the reduction of diversity in high altitude. Some of them are decrease in primary productivity with increase in altitude, reduction of suitable available area for organism, unsuitable climatic condition and reduction in the food resources (Hutson 1994). The diversity and distribution of organisms including vertebrates, invertebrates and plants are correlated with altitude. Generally species diversity decrease with increase in altitude (Lomolino 2001). The factor 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). Many factors such as climatic, spatial, and biotic have been suggested as underlying causes of elevation patterns of fish species distribution. The dynamics of water flow bodies determined by the climate and topography (Allan 1995). In the mountain latitudinal gradient, the water of river and stream is cold, turbulent and highly oxygenated in the highest reaches while in the lowest reaches the water is warmer, less turbulent and oxygen amount is less. Due to these changes structure greatly affect on diversity and fish assemblages according to the altitudinal variation (Joccobsen 2008). The diversity of mountain fishes are highest in the northern Andes region including 37% of endemic fish of 220 species and in every 1000 m increase in altitude, 19.7 species were found to be decreased in Columbia (Rodriguez et al. 2016, Jaramillo et al. 2010). Biotic assemblages of aquatic floodplain system have great potential to randomly reshuffle during annual flood periods and have been described both stochastically and deterministically assembled (Layman et al. 2003). Studies have shown a monotonic decrease in fish species richness with increasing longitidunal gradient. (Jaramillo et al, 2010, Juna et al. 2015).

The taxonomic study and researches based on scientific experiments are being studied on parallel basis in context of Nepal. The study of fish ecology and behavior and their various patterns of fishes and fishery are conducted in the various parts of the country. In Nepal, the diversity and species richness were also decreased with increased in elevation (Shrestha 2008). The warm water fish species such as *Labeo rohita, Catla catla, Cirrhinus mrigala, Cyprinus carpio, Cytnopharyngodon idellus* are important cultivated fish species are highly dominated in terai region (DOFD 2006/07). The cold water fish species such as *Neolissocheilus hexagonolepis, Schizothoraichthys spp, Schizothorax* spp, and *Tor* spp are most economically important and are dominated in hilly streams (Shrestha 1981). The endemic fish species of Nepal like *Schizothorax macropthalmus, S. nepalensis, S. raraensis* are found in highest elevation about 3200 m in Rara lake (Shrestha, 2008).

2.2. Temporal variation of fish assemblage structure:

The temperature is one of the most important factor, limiting the fish diversity in the tropical and great altitude (Jacobsen 2008). All aquatic organisms like fish, insects, zoo

plankton,phytoplankton have different temperature ranges. The water temperature greatly influences on water chemistry and high water temperature cause the fluctuation in DO and pH. Riverine fish assemblage often varies along environmental gradients from head water to lower main stream (Schlosser 1982, Gelwick 1990, Edds 1993). The water temperature influence on aquatic life cycle, metabolism and behaviour of fish and high water temperature leads to the thermal stratification in the river and lake which may lead reduction in diversity and unequal distribution of fish (Jain et al. 2013).The temperature decrease with increase in altitude. The daily fluctuation of temperature is high at highland area in comparison to low land area (Bussion et al. 2008).

The physico-chemical and microbiological characteristics of water described the quality of water. According to Bhandari and Nayal (2008) the physico -chemical variables such as chloride with pH, Mg, Na, hardness, total suspended solid are positively correlated while the negative correlation was found with potassium, chloride, hardness and turbidity. The fish assemblage structure more or less correlated with different environmental variables. The fish assemblage structure in the Seti Gandaki River was positively correlated with the environmental variables like conductivityCO_2, and other compounds like phosphate and ammonia (Pokhrel et al. 2018). Both stochastic and ecological factors are important in structuring freshwater communities with the relative importance of each depending on the temporal and spatial scale of investigation (Grossman et al. 1982, 1998, Tonn and Maguson 1982, Kodric- Brown & Brown 1993). The different physical and chemical parameters can be analyzed by various multivariate tools for the productive results. Thus selection of appropriate tool is important for exploring spatial and temporal patterns of physical and chemical parameters of water (Yemane et al. 2010).

The fish communities and physiochemical parameters including temperature in rivers and lakes are fluctuating according to seasons (Mehner et al. 2005). The fish assemblages are typically dynamic, reflecting- the changing suit of environmental conditions to which they are exposed on short term or seasonal bases (Termain and Adams, 1995). The fish is cold blooded animals, according to environment its body temperature changes and high fluctuation of water temperature affect on fish health (Bhatnagar et al, 2013). The global level of temperature for tropical fishes is 28°C to 32°C for cold water fishes less than 12°C is suitable and greater than 35°C is lethal to the maximum number of fishes (Bhatnagar et al, 2004) while for the carp culture 24°C to 30°C temperature is suitable (Santosh and Singh, 2007). The fish like *Labeo, Mystus, Puntius, Channa* are warm water fish species which are dominated in the river of warm water and the *Labeo, Catla, cirrhinus* and carps are major fish species which are use for aquaculture in Terai region of Nepal because these species can survive in high temperature (Rai, et al, 2008).While the *Schizothorax, Gara, Glypothorax, Pseudocheneis* fish species are dominated in cold water river of hilly region, these fish species have low capacity to resist in high temperature (Petr et al. 2002).

3. MATERIALS AND METHODS

3.1. STUDY AREA

The Mechi River starts from south of Pashupatinagar mainly from eustaries being mixed at different points and also a small river coming from kalingpong(a place in India) and flows through different places of Illam and Jhapa and finally to India as Mahananda River.

The study area for this research includes 14 Km of river basin starting from Salakppur (Jirmale) of Illam to Nakalbanda, Jhapa.

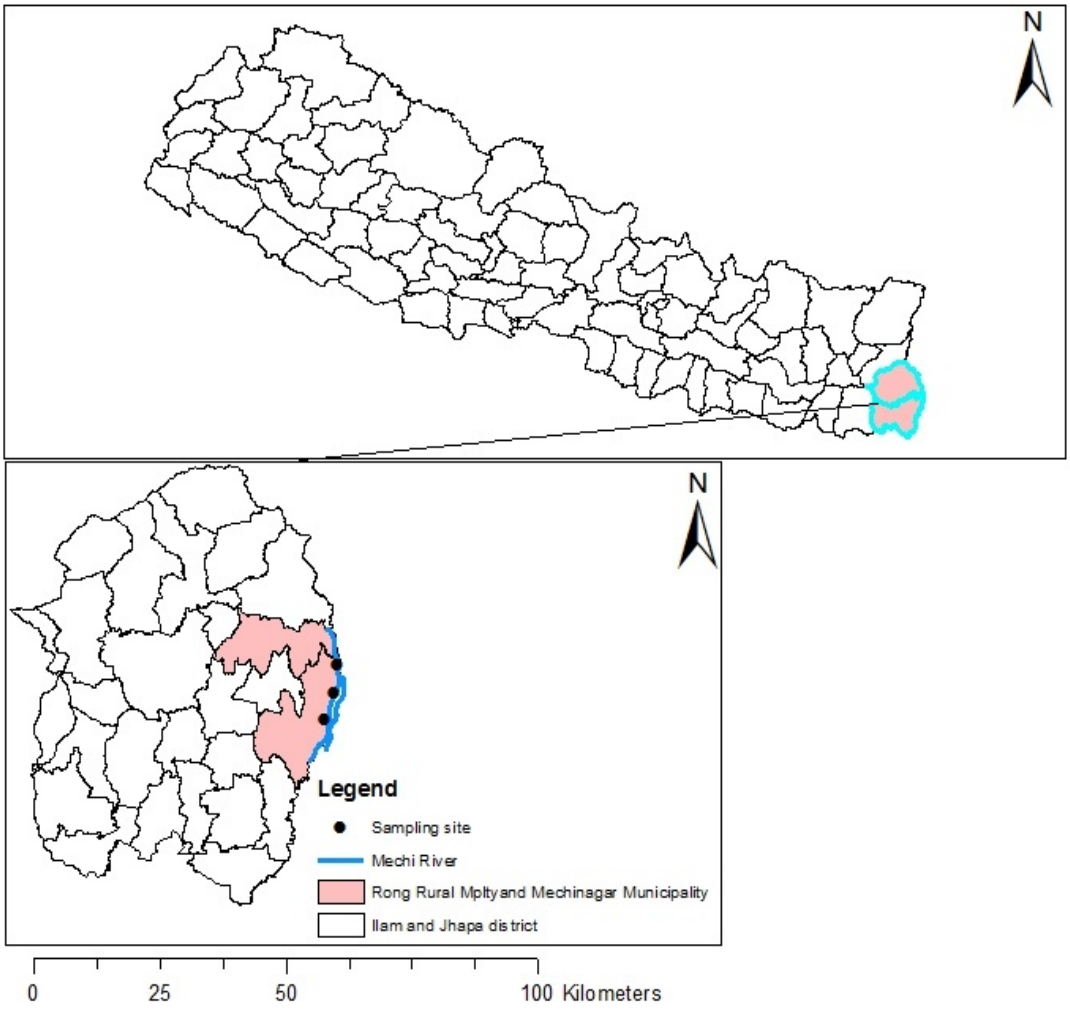

Fig 1: Map of Nepal showing Mechi River and sampling sites:

3.2. SAMPLING SITES

There were 3 sampling sites in total. All the sites were at a distance of 3.5 km (approx) from each other. These sites were selected on the basis of physical division, human approach and River confluence point. These are illustrated as:

1.Site 1- Salakpur (452m, 26.81881 N, 088.16525 E)

It is located at Illam district having high velocity of water and has many cold water fishes.

2.Site 2- Gadagalli (256m, 25.77664 N, 088.18203 E)

It lies in the edge of Jhapa and Illam districts with many pools and comparatively warmer water than site 1.

3.Site 3 - Nakalbanda (126 m, 26.40311 N, 088.09822 E)

Being located at Mechinagar Municipality, it is the area having human settlement and has more approach to fisher mans.

3.3. MATERIALS

3.3.1. Fishing Gears

The major gear used for the research work is cast net of monofilament type made by hemp fiber. Two cast nets of different sizes was used one having large mesh size of 0.5 cm, 3m diameter and 2 kg weight, and another having mesh size of 2cm, 6m diameter and 6 kg weight. The smaller one was used in the upper streams having low volume of water and larger one was used in down streams having high volume of water.

Beside cast net a drag net made by local mosquito net of mesh size 0.2 cm was used for collecting smaller fish species and besides these tools some local methods were also applied for the fish collection.

The tools like canon EOS 200D camera with kit lens of 18-55mm and zooming quality of 24.2 megapixels was used for photography. Similarly lab thermometer, digital pH meter, BOD bottles , manganese sulphate, sulphuric acid, sodium thiosulphate and potassium iodide azide were used for analysis of different physical and chemical parameters.

3.3.2. Fish sampling

The collection was done seasonally (autumn,winter and spring). Each site was visited for 3 times in a season and thus total visit to 3 sites was 9 times in a season. About 500 m of each site was surveyed. The fishes were sampled during the morning time (7AM to 12 AM).The fishes were collected with the help of local fisherman using a cast net and Gill net of mesh size 1cm and dimension of 2 X 3 m having weight 2 kg in general. Besides these methods other gears like scoop net having diameter of 50 cm, local traps, hook and line and often handpicking were used for collection. The fishing gears were operated within 500m length at each sampling station from 7:A.M to 12: AM. A total of 25 total throws was made for cast net and 15 hauls for gill net to catch the fishes. For estimation of abundance of fishes, two pass removal method Seiber and Le.cren (1967) was used. Each removal pass include moving first upstream then downstream within a pre-

determined length (500m) with equal effort of 30 minutes for each pass at the each side of river.

3.3.3. Fish identification and preservation

The collected fishes were identified using Shrestha (1981, 1994), Shrestha (2008) ,K.C. (2010) and Talwar and Jinghram (1995) at the spot and at the CDZ lab.

The collected fishes were photographed in fresh condition on the spot whenever possible. They were preserved in 10% formalin solution in plastic jars and carefully labeled for further study in the CDZ lab.

3.4. WATER QUALITY ANALYSIS

3.4.1. Physical parameters

Basically two physical parameters were observed which were temperature and Velocity. For the measurement of temperature a lab thermometer was used. Temperature was measured by dipping the thermometer inside the water at 5 different strata in a sampling site and average value of temperature was noted.

Similarly velocity was measured by floatation method i.e. a ping pong ball was allowed to float in the water surface at fixed distance and time taken by the ball to cover the distance was noted. The experiment was repeated for five times and average of time was calculated. Then the velocity of water was calculated by the formula:

$\boldsymbol{v = \frac{d}{t}}$**,** Where, '**V'** denotes velocity,'**d**' denotes distance and '**t**' denotes time taken.

b) **Chemical parameters**

Different chemical parameters like Hydrogen ion concentration (pH), dissolved oxygen and free Carbon dioxide was determined by using standard measuring kits and titration.

pH was measured by dipping the pH meter into the water after buffering its bulb. Then the reading was noted from the screen of the pH meter.

Similarly, 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:

$$DO\left(\frac{mg}{l}\right) = \frac{ml \times normality\ of\ titrant}{V_2\{(V_1 - V)/V_1\}} \times 800$$

Where, V = Volume of $MnSO_4$ and KI added

V_1= Volume of BOD bottle

V_2= Volume of the part of the content titrated.

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

$$Free\ CO_2 = \frac{(ml \times N) of\ NAOH \times 44 \times 1000}{V}$$

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

3.5. STATISTICAL ANALYSIS

a) Shannon's diversity index was used to find out the fish diversity.

- It is calculated by using following formula: (Shannon and Weiner, 1949).
- $\overline{H} = -\sum_{i=1}^{k} pi \log(pi)$

Where:

H = The Shannon diversity index

P_i = fraction of the entire population made up of species i

S = numbers of species encountered

$\sum$ = sum from species 1 to species S

Note: The power to which the base e (e = 2.718281828.....) must be raised to obtain a number is called the **natural logarithm** (ln) of the number.

b) Species richness index (d)

The species richness is calculated by using Margalef Species richness (Margalef's 1968). Margalef richness index is designated as d, which is calculated as:

Margalef species richness (d) = S-1/ log N

Where, S= Number of species

N = Number of individuals

c) Evenness index

To calculate whether species are distributed evenly across seasons and across landscapes elements, evenness index was determined by the following equation (Pieleu 1966).

E= H'/ log S

Where,

H' = Shannon-Wiener's diversity index.

S= Species richness is the number of species and is the simply a count of the number of different species in a given area.

d) Multivariate analysis

The relation between species diversity and environmental variables were analyzed by detretended correspondence analysis (DCA) and canonical correspondence analysis

(CCA) method (Tar Break 1988a, Ter Braak and Prentice 1988) by using vegan library in ‘R’ (Oksanen et al. 2019).

4. RESULTS

4.1. Spatio Temporal Variation of fish assemblage structure

In this investigation altogether 33 species of fish belonging to 4 orders, 8 families and 16 genera were collected from three different stations of the Mechi river during three different seasons.(table.1) During the study period, a total of 1772 fish individuals belonging to 33species were recorded. *Schistura devdevi* was most dominant fish followed by *Puntius sophore, Barilius barila, and Brachydario rareo* and *Bengala elanga* was least abundant species followed by *Labeo dero* and *Xenontedon cancila*. All the fishes recorded in all the sampling stations and their frequency distribution are given. (Table. 2)

Table 1: Fish species and their order, family and genera

SN	ORDER	FAMILY	SUBFAMILY	GENUS	SPECIES	SUB SPECIES	Locale NAME
1	Cypriniformes	Cyprinidae	Cyprininae	*Labeo*	*Dero*		Rohu
2					*Boga*		Rohu
3				*Puntius*	*sophore*		Pothi
4					*Terio*		Pothi
5			Danioninae	*Barilus*	*Barila*		Faketa
6					*Bendelensis*		Thople
7				*Bengala*	*elanga*		
8				*Brachydanio*	*Rareo*		Mosquito fish (Dharke)
9				*Daneo*	*dangila*		
10				*Esomus*	*dandricus*		Sidre
11			Garrinae	*Garra*	*Gotyla*	*gotyla*	Buduna
12					*mullaya*		Buduna
13					*annandelei*		Buduna
14		Psilorhynchidae	Psilorhyncinae	*Psilorhynchus*	*gracilis*		
15		Cobitidae	Nemacheilinae	*Achantobotis*	*Botia*		Loach(Gadelo)
16				*Schistura*	*beavani*		Gadaai
17					*devdevi*		Gadelo
18					*rupicola*		
19					*afasciata*		
20					*montanus*		
21					*Horai*		
22			Cobitinae	*Lepidocephalus*	*guntea*		Paiya

23			Botinae	*Botia*	*lochata*		
24					*Geto*		
25	Siluriformes	Sisoridae	Sisorinae	*Gagata*	*Cenia*		
26				*Gyplothorax*	*cornistore*	*Cornistore*	Tite
27					*alkanandi*		
28		Olyridae	Olyrinae	*Olyra*	*Longicaudata*		
29	Beloniformes	Belonidae	Beloninae	*Xenontodon*	*cancila*		Chuche Bam
30	Perciformes	Anabantidae	Anabantinae	*Anabus*	*testiduens*		Chepte
31					*cojubus*		
32		Channidae	Channinae	*Channa*	*gaucha*		Hile
33					*puncatus*		Garai
34							

4.1.1 . Species wise distribution of fish in the Mechi River

There was higher abundance of *Schistura devdevi* which was followed by *Brachyderio rareo, Barilius barila Schistura beavani* and *Puntius sophore.* Similarly, *Xenontedon cancila, Anabus testiduens, Olyra longicaudata* and *Gagata cenia* were least abundant species (fig. 2).

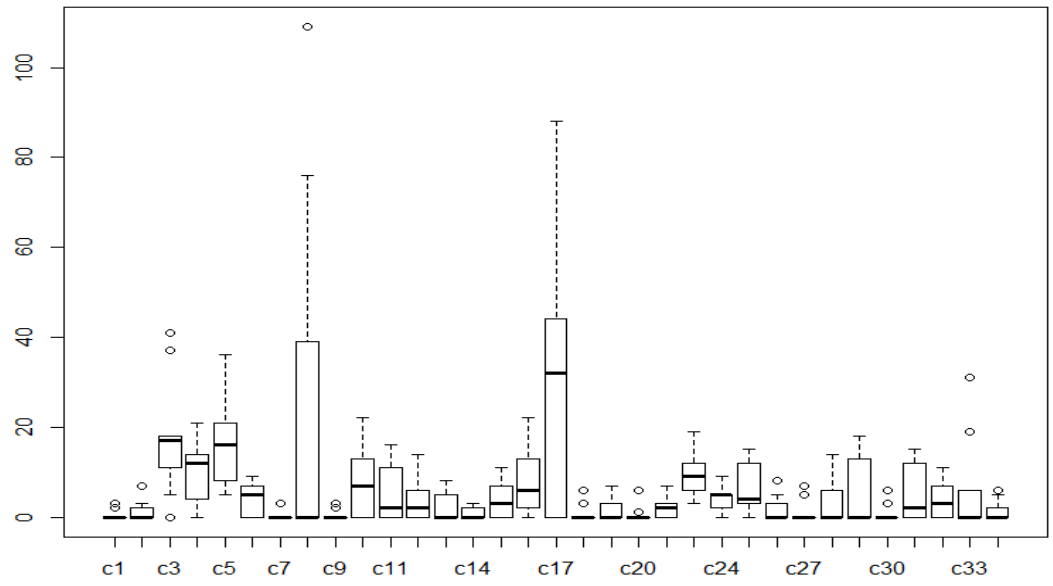

Fig 2: Box plot showing species distribution in the Mechi River.

4.1.3. Diversity Index and Evenness

The sampled data was analysed by using Shannon's diversity index and Simpson index along with its evenness. The data was categorized into seasonal and strata wise (station wise) pattern and thus obtained data was fed to calculate Shannon's index, Simpson's index and evenness (fig.4) by using R statistical software.

4.1.4. Seasonal diversity and distribution

The season wise assemblage structure of fish was calculated and analyzed by finding out values of Shannon's diversity index, the Simpson index and evenness (fig.3).The value of Shannon's index was highest in the winter season which valued to be 2.93 followed by autumn 2.82 and spring 2.66 respectively. Similarly Simpson index was also higher in winter season with value of 0.93 and evenness of 0.40.

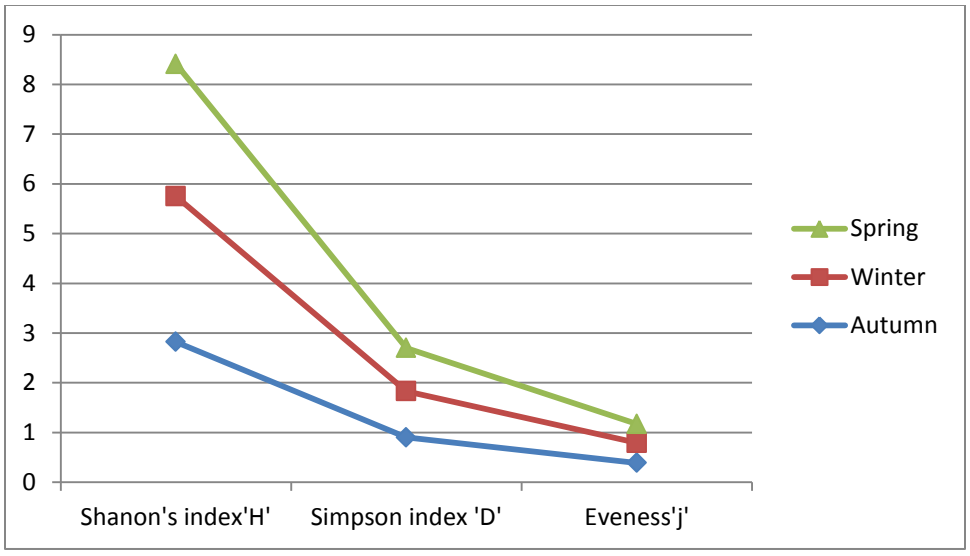

Fig 3: Season wise diversity and evenness pattern of fish species.

4.1.5. Station Wise diversity and Distribution

The station 2 showed high value of 'H' i.e. Shannon index valued to be 2.69 followed by station 1 and station 3 (fig.4). Similarly Simpson index and evenness was also high at winter season having value of 0.9 and 0.39 respectively.

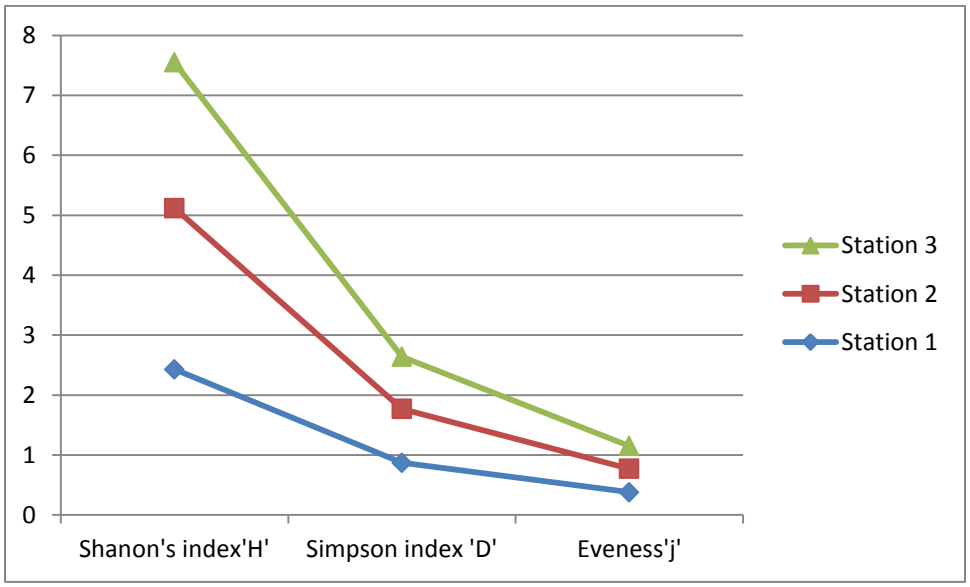

Fig 4- Station wise diversity and evenness of fish species

4.2: Spatio temporal variation of physical and chemical parameters

Different physical and chemical parameters like temperature, DO, free carbon dioxide, velocity and pH was measured during the data collection process.

Among the different physical and chemical parameters temperature and dissolved oxygen were found to be inversely proportional with each other. This means that the decrease in Temperature increases the value of DO and vice-versa. Similarly the highest fluctuation in temperature was seen during Spring season especially at station 3 as shown in fig:6. Similarly temperature and free carbon dioxide were found to be positively correlated with each other as seen in fig.5. Similarly Velocity was also higher at stations having low temperature and high DO (fig. 5)

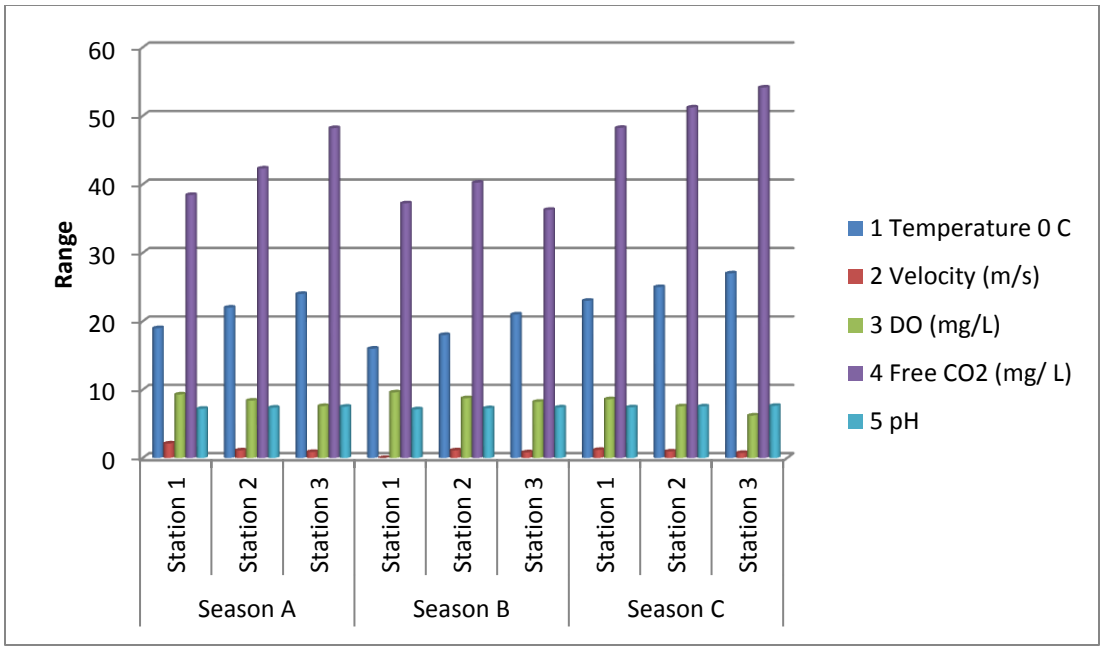

Figure 5: Variation in different physical and chemical parameters of Mechi River.

4.2.1. Temperature

The highest range of temperature was recorded at station 3 during spring season with value of 27 ^{0}C and lowest was recorded at station 1 during winter season with value of 16^{0}C and average value of temperature recorded during the whole study period was 21.66^{0}C (fig. 6)

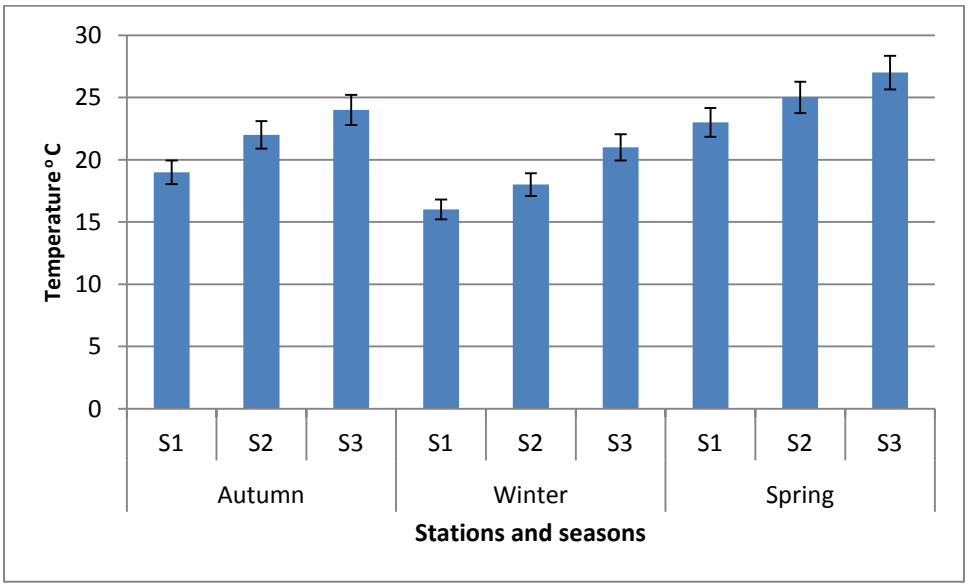

Fig 6: Variation in temperature in different stations and seasons.

4.2.2. Dissolved Oxygen (DO)

The level of dissolved oxygen was found to be highest (9.6 mg/l) at station 1 during winter season and lowest (6.21) at station 3 during spring season and average value of dissolved oxygen was found to be 8.24 during the study period (fig.7).

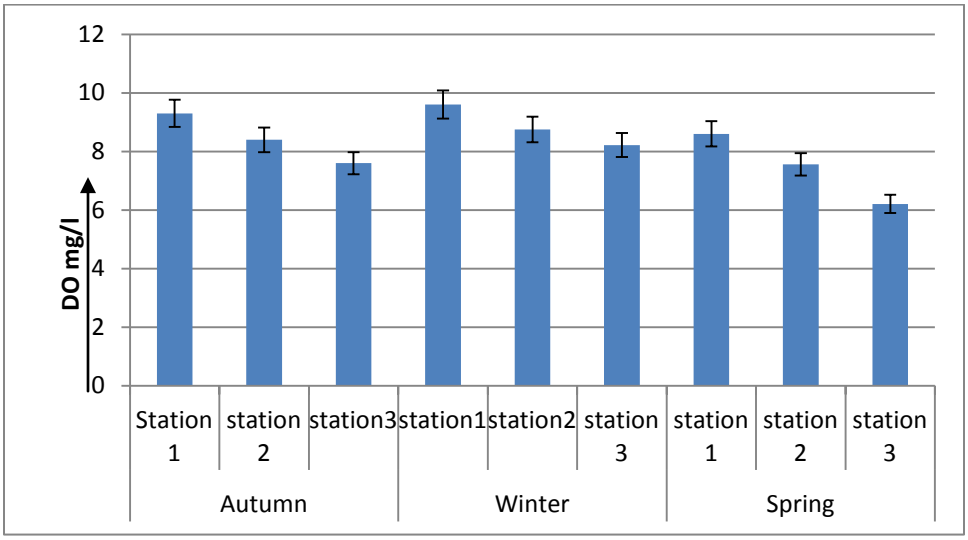

Fig 7: Variation in DO according to different seasons in different sites.

4.2.3. Velocity

Velocity was recorded with highest value (2.12 m/s) at station 1 during autumn season and lowest 90.74 (m/s) at station 3 during spring season. The average value of velocity was 1.22 m/s during the study period. (fig. 8)

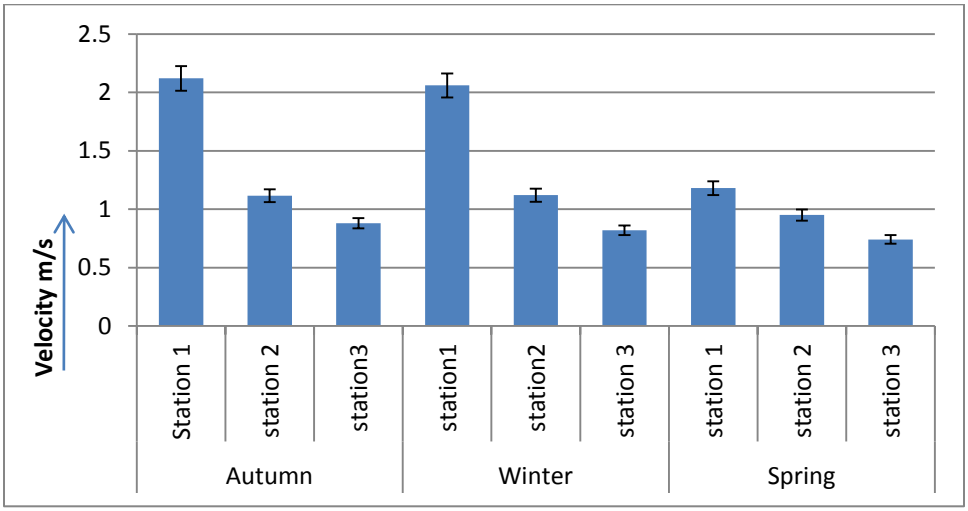

Fig 8: Variation in velocity in different seasons and stations

4.2.4. Proportion of hydrogen ion concentration (pH)

pH of the water was recorded highest (7.63) at station 3 during spring season and lowest (7.12) at station 1 during winter season. The average value of pH during the study period was 7.38 (fig. 9).

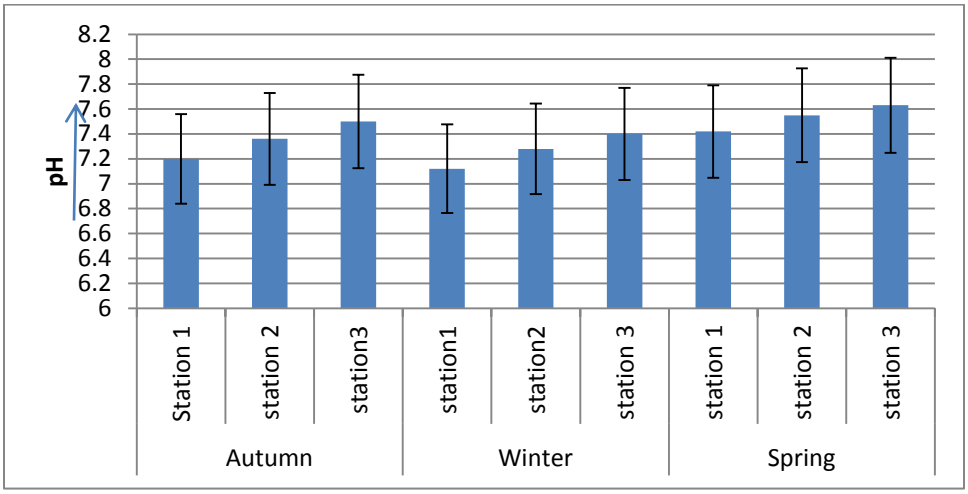

Fig 9: Variation of pH in different seasons and stations

4.2.5. Free Carbon dioxide (CO_2)

The highest value of free carbon dioxide was recorded to be 54.14 mg/l at station 3 during spring season and lowest value was recorded to be 36.28 mg/l at station 1 during winter season. The average value of free carbon dioxide was 44.14 during the study period (fig.10)

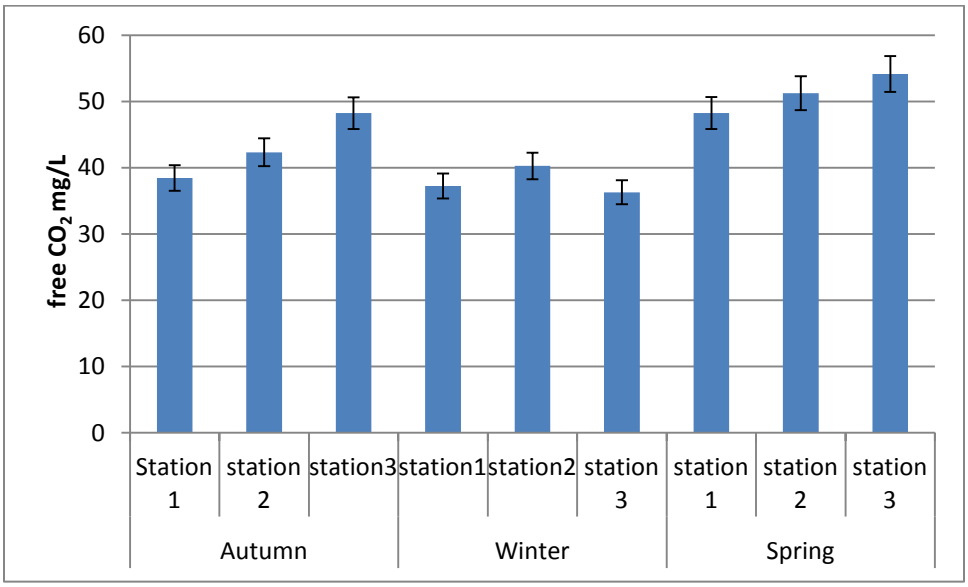

Fig 10: Variation of free carbon dioxide in different stations and seasons.

4.3. Correlation between the environmental variables and fish species.

4.3.1.. DCA (Detrended correspondence analysis with 26 segments.)

The detrended corresponding values indicated that there is strong correlation between the environmental variables and fish diversity (Table 3). The value of axis length was calculated to be between 2-4 which indicated that further analysis has to be done by using multi-variant tool i.e. CCA for more fruitful results.

Table 3: Values of DCA with their axes lengths.

	DCA1	DCA2	DCA3	DCA4
Eigenvalues	0.5471	0.08947	0.07355	0.070756
Decorana values	0.5674	0.07508	0.02523	0.008709
Axis lengths	2.7673	1.44644	0.98116	1.184164

4.3.2. . Cannonical Correspondence Analysis (CCA)

In the correlation of abundance of fish species towards different environmental variables were different and the positioning the 33 captured fish species in relation to environment variable is shown in fig.12. There is strong influence of dissolved oxygen basically in site A i.e. at upper stream of the river Mechi where cluster of fishes like *Daneo dangila, Schistura beavani, Schistura rupicola, Schistura afasciata, Schistura montanus, Glyplothorax cornistore, Glyplothorax alkanandi and Garra annandelei* were found to be strongly correlated with those parameters. Similarly, Autumn season was found to be more favuorable for the distribution of fishes like *Barilus barila, Puntius sophore, Channa spp., Labeo spp., Anabus spp.,* and *Colisa fasciatus.* The suitability of climatic condition, clearness of water, appropriate range of dissolved oxygen (8.0 to 11.5) mg/L and less availability of free carbon dioxide has lead to diverse distribution of most fishes in all three sampling stations during autumn season. But fish species belonging to genera Schistura were more abundant during winter season. Similarly spring season was the time at which less no. of fishes were captured. The fishes like *Puntius terio, Botia lochata, Anabus testiduens, Puntius sophore, Acantobotis botia* and *Barilius barila* showed positive correlation towards temperature and free carbondioxide. In the same way, fishes like *Garra gotyla, Botia geto, Schistura devdevi* and *Psilorynchus gracilis* showed negative correlation with temperature and free carbondioxide and positive towards DO and Velocity. These fishes were mostly abundant during winter season. During the autumn season the fishes like *Esomus dandricus, Xenontedon cancila, Channa punctatus,*

Channa gaucha, *Brachyderio rareo*, *Labeo dero* and *Bengala elanga* showed slightly positive correlation with DO and velocity as well as they showed negative correlation with free carbon dioxide.

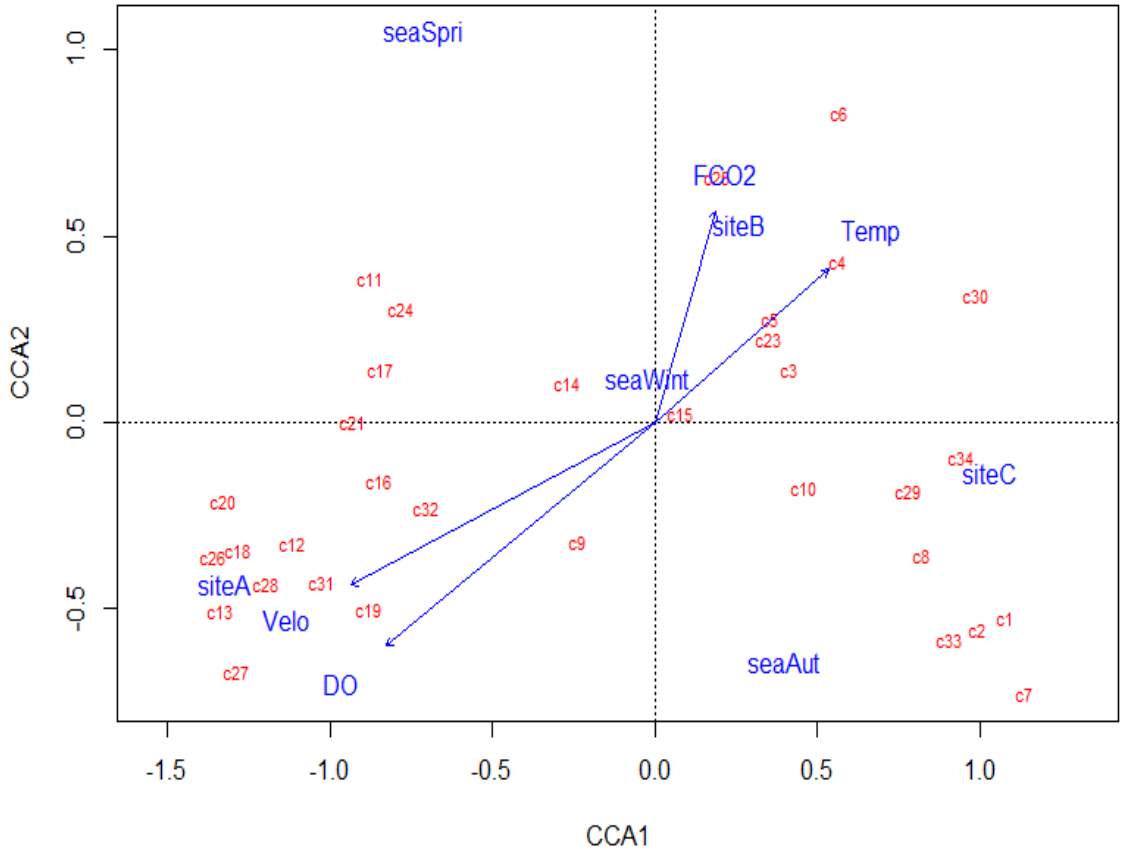

Fig 11: CCA plot of environmental variables Vs Fish diversity.

5. DISCUSSION

5.1. Spatio- temporal variation in fish assemblage structure

The present study analyzed the spatio-temporal assemblage structure of fish species in the Mechi River. From the study altogether 1772 fish individuals categorized as 33 species of fishes belonging to 4 orders, 8 families and 16 genera were captured. This indicated that Mechi River supports a major source of livelihood and food to those fisherman and fishing communities depending upon fishery practice in the Mechi River. The freshwater loaches belonging to *Schistura* genus were found to be tolerating pH of 6-11. These loaches are unique then other fishes in adaptive modification structure. The present author also recorded these species at similar elevation and pH value of 5-11 from lower terai region of Ratuwa River, Damak (Limbu and Gupta 2019). A mixed variety of fish species were mostly occurring low water flow periods with increase in fish diversity. (Winemiller 1986, 1989). In the present study fish assemblage was highly diverse during spring season which is a low flow period at which mixed variety of fishes like *Channa, Colisa, Garra,* etc were recorded. This study differs with findings of Limbu, et al. (2018) and Hossain et al. (2018) according to which abundance of fish is high in month of February (spring season) and gradually decreases with rise in summer. The present study shows the spatial distribution of fishes of Mechi River was found to be significantly difference. Fishes like *Barilius barila, Lepidocephalus guntea* and *Schistura* spp. were found in deep clear water with high velocity whereas fishes like *Channa punctatus, Channa gaucha, Colisa fasciatus and Anabus* spp. were found in shallower and muddy water and were capable to tolerate increase in temperature range as they were recorded from water with higher temperature $(22\text{-}27)^0$C. This results contradicts with findings of Keskin and Unsal (1998) This might be due to the development of many adaptational features in fishes to sustain in the surrounding they belong. Similarly fish like *Acanthobotis botia, Botia lochata* and *Botia geto* were found at station 2 and 3 i.e. mostly at lower stream from shallow pools, paddy field drainage, puddles and runs

The result of this study showed that most species of fishes were found to be abundant during winter season and in station 2 which has approach to both warm and cold water fishes. Hence the diversity index at station 2 was found to be highest among all where the value of H was found to be 2.69 followed by D = 0.9 and j = 0.39. It meant that the fishes at station 2 were highly abundant during all three seasons and were evenly distributed as well. The result contradicts with the findings of Keskin ans Unsal (1998) The possible reason could be due to the availability of sufficient volume of water which is comparatively untouched as compared with other sites. It might be due to availability of sufficient dissolved oxygen and favorable temperature. Besides this station is cool during winter and can adjust many cold water fish species and in autumn and spring the water over here becomes slightly warmer which allows most warm water fishes to adjust at the same station.

Habitat diversity in the Mechi was found to be greatest during the low flow period. i.e. during the winter season at which the river has less volume of water which suits the assemblage of many small indigeneous fishes like *Schistura* spp*, olyra longicaudata, Anabus* spp*, Channa* spp*, Glypothorax* spp and *Barilus* spp.

During the winter there is formation of many pools, rifles and run habitats. This pattern produced by variation in flow, also appeared to affect the spatial and temporal variation in the lower streams.

A similar pattern of spatial and temporal variation was reported by Closs and Lake (1994) in a stream in Australia. They showed the low flow period created a filter that was responsible for structuring the fish and aquatic ecosystem of the River. Spatial variation in fish communities has been reported to be influenced by variation in the velocity, Stream size and covariate of these factors such as cover and substrates (Meffe and Sheldon, 1988). In the same way the spatial pattern observed in the fish community of Mechi River showed same result with highest rank of Shannon's index during the winter season. This was also shown by low variability in the DCA values and by the strong relationship of fish assemblage with the environmental variables shown by the CCA plot.

From the results obtained during this study it has became clear that the fish River Mechi lying in the easternmost part of Nepal is rich in fish Fauna along with other aquatic components. Since the research work was carried out for three consecutive seasons i.e. Autumn, winter and spring season among which the species occurrence was found to be highest in the autumn season. Though it showed high diversity of fishes in the autumn season most fishes were inhabiting the seasonal patterns according to their adaptational characteristics. In winter species like *Schistura* spp*, Glyplotrhorax* spp*, olyra* spp, were found to be mostly occurring from uppermost to lower belts which was due to their capacity of toleration low temperature of water in the Mechi River.

In the same way, the survey was carried out in the three sampling sites making the sampling strata of 500 m at each sampling site. The fishes were sampled on the basis of habitat preference of fishes.

5.2. Spatio temporal variations in the environmental variables:

The results showed that many physiochemical parameters like DO,CO_2 , temperature and velocity were playing the important role in fish diversity and distribution and beside these other factors like pH, transparency were significant in trace level for fish distribution. The diversity of local species of river is greatly influenced by temperature as it changes species distribution at short time scales (Fisher et al. 2008). Thus the fishes like *labeo* spp. *Barilius* spp. *Channa* spp. *Xenontedon cancila* and *Lepidocephalus guntea* were found at higher temperature zones in this present study. In the present study the variation in diversity with environmental change between the cold water species and warm water species of fishes were different. This is also suggested by Tian et al (2006). Previous work done in the diversity of Mechi river by pokhrel (2006) explored 32 species of fishes

in the Mechi River from the lower streams ranging below 150m elevation. He had recorded the freshwater eel *Anguila bengalensis* and *Magrognathus macropthalmus* which were not captured during the investigation. Instead this study was able to record cold water species like *Schistura afasciata*, *Schistura montanus*, etc. which were not recorded previously (Pokhrel, 2006). It was because this study was conducted basically at upper stream of the River Mechi and previous study was done in lower streams. The physiochemical parameters of water like temperature, transparency, velocity, pH, DO, CO_2 and hardness play vital role in abundance and species richness and these parameters are greatly affected by seasons and elevations **(**Pokharel *et al*. 2018).In the present study the highest temperature, lowest DO and lowest velocity were observed during spring season basically at station 3. This could be due to the rise of atmospheric temperature during the spring season and also due to the change in altitude. From the results the velocity of water was observed to be decreasing at lower stream. This could be due to the plain area of lower stream that supports flow of water with less velocity. It also might be due change in longitudinal gradients i.e. slope of the landscape. The pH was observed between the range of 7.12 to 7.63 with an average of 7.38. This showed that pH is favorable for distribution of most fish species in the Mechi River. Similarly DO was also observed to be at good condition in the river as it is the most critical parameter that plays vital role in the distribution of aquatic organisms. From the study the average value of DO was 8.24 mg/L. This showed that the range of dissolved oxygen in the river is good for most types of fishes. DO is important factor which affects the distribution, diversity, physiology and behavior of fishes (Pokhrel et al. 2018). The amount of dissolved oxygen is different for different fishes depending upon season and weathers. Bhatnagar et al. (2004) reported that suitable amount of dissolved oxygen should be greater than 5mg/L for fish while according to Santosh and Singh (2007) cat fishes and air breathing fishes can sustain oxygen less than 4 mg/L.

Different environmental variables influences on fish health as well as diversity and distribution of fishes in water bodies. Among different environmental variables the temperature and DO are mostly responsible to the observed changes in species diversity and these variables are responsible for creating change in fresh water assemblages according to seasons and elevations gradients. In the present study the amount of DO was highest in the summer and fish abundance was also highest in this season. The temperature as well as fish abundance were recorded less in winter season (Santosh and Singh 2007). Similar types of result was observed from running water of Champman and Hall, London (Allen 1995), from lakes of France and north-east USA (Irz et al. 2007), from stream of the central Andes of Columbia (Jaramillo-Villa et al. 2010). The most important environmental variables structuring the fish assemblages in the Mechi river were water velocity, DO, pH, CO2 and fish assemblages structures mostly correlated with DO and temperature. Pokhrel et al. (2018) observed that the most important environmental variables were conductivity, water depth, free carbon dioxide, pH, and

dissolved oxygen in Seti Gandaki river basin. The fish assemblage structures mainly correlated with free carbondioxide, water discharge, and stream size in North Tiaoxi River China (Koel and peterka 2003).

6. CONCLUSIONS

In the study period a total of 33 species of fish were recorded from three different stations. *Schistura devdevi* was found to be most abundant fish species and *Xenontedon cancila* was least abundant during the study period. The fishes of Mechi River were found to be biologically diverse and evenly distributed except few species which belonged to different type of habitat and behavior. Understanding the relationship between fish diversity and environmental factors could better explain spatio-temporal patterns in the fish diversity. The results in the present study showed that spatial and seasonal variations in the fish diversity were mainly related to environmental gradients like DO, Temperature, velocity, free carbon dioxide and pH of the water. Furthermore single diversity index could not completely represent the diversity as each diversity component had different environmental effects. So the present study has tried to employ several other diversity indices to explore the spatial and temporal patterns in fish diversity. Lastly, the present study with previous investigation could be paramount importance to be used as a base line scenario for future analyses of Mechi River and related water bodies over the next decades.

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APPENDIX

i. Table showing fish distribution in Mechi River

Table 2: Distribution of fishes according to season and stations

	Autumn			Winter			Spring			
Fishes	Station 1	Station 2	Station 3	Station 1	Station 2	Station 3	Station 1	Station 2	Station 3	Total
Labeo dero	0	0	3	0	0	2	0	0	0	5
Labeo boga	0	2	7	0	0	3	0	0	0	12
Puntius sophore	5	37	41	0	12	18	17	11	17	158
Puntius terio	4	16	21	0	14	12	0	8	14	89
Barilius barila	5	29	36	8	21	16	6	18	13	152
Barilius bendalensis	0	7	5	0	3	7	0	6	9	37
Bengala elanga	0	0	3	0	0	0	0	0	0	3
Brachydanio rareo	0	76	109	0	32	39	0	0	0	256
Daneo dangila	0	3	0	0	0	0	2	0	0	5
Esomus dandricus	13	19	22	0	0	11	0	3	7	75
Garra gotyla	2	0	0	16	11	0	14	9	0	52
Garra mulaya	6	2	0	14	3	0	8	0	0	33
Garra annandelei	7	0	0	8	0	0	5	0	0	20
Psilorynchus gracilis	3	0	2	0	0	0	0	2	0	7
Acantobotis botia	7	5	0	0	7	11	3	2	0	35
Schistura beveani	13	7	0	15	6	2	22	0	3	68
Schistura devdevi	44	33	0	32	12	0	88	44	0	253
Schistura rupicola	3	0	0	0	0	0	6	0	0	9
Schistura afasciata	7	3	0	0	0	0	5	0	0	15
Schistura montanus	1	0	0	0	0	0	6	0	0	7
Schistura horai	3	2	0	5	0	1	7	3	0	21
Lepidocephalus guntea	6	12	19	5	11	14	3	7	9	86
Botia lochata	5	2	0	9	5	0	8	5	2	36

Botia geto	4	6	12	0	15	0	3	12	4	56
Gagata cenia	3	0	0	5	0	0	8	0	0	16
Glyplothorax cornistore	7	0	0	5	0	0	0	0	0	12
Glyplothorax akanandi	11	2	0	6	0	0	14	0	0	33
Olyra longicaudata	0	13	18	0	12	14	0	0	0	57
Xenontodon cancila	0	0	6	0	0	0	0	0	3	9
Anabus testiduens	15	6	0	13	2	0	12	0	0	48
Anabus cojubus	11	8	0	5	3	0	7	2	0	36
Channa gaucha	0	19	31	0	0	6	0	0	0	56
Channa punctatus	0	2	6	0	0	5	0	0	2	15
									Total	1772

ii. Chart showing different physical and chemical parameters of mechi River;

Table 3: Physiochemical parameters of Mechi river according to various stations and seasons

SN	Parameters	Season A			Season B			Season C		
		Station 1	Station 2	Station 3	Station 1	Station 2	Station 3	Station 1	Station 2	Station 3
1	Temperature ^{0}C	19	22	24	16	18	21	23	25	27
2	Velocity (m/s)	2.12	1.115	0.88	2..06	1.12	0.82	1.18	0.95	0.74
3	DO (mg/L)	9.3	8.4	7.6	9.6	8.75	8.22	8.6	7.56	6.21
4	Free CO_2 (mg/ L)	38.45	42.32	48.22	37.23	40.25	36.28	48.25	51.23	54.14
5	pH	7.2	7.36	7.5	7.12	7.28	7.4	7.42	7.55	7.63
6	Transparency	Crystal clear	Crystal clear	Crystal clear	Crystal clear	Crystal clear	Crystal clear	Crystal clear	Slightly muddy	Muddy

PHOTOPLATES:

Fish sampling at station 2, Mechi river

Fish Sampling at station 3, Mechi river

Gagata cenia

Schistura devdevi

Acanthobotis botia

Glyplothorax cornistiore

Lepidocephalus guntea

Xenontedon cancila

Anabus cojubus

Channa punctatus

Botia lochata

Channa gaucha

Schistura savona

Olyra longicaudata

Puntius sophore

Barilius bandelensis

Barilius barila

Labeo dero

Psilorhynchus gracilis