FISH DIVERSITY OF RAPTI RIVER, CHITWAN, NEPAL

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A thesis submitted in partial fulfilment of the requirements for the award of the degree of Masters of Science in Zoology with special paper Fish Biology and Aquaculture (Course Code-Zoo 653)

Submitted to

Department of Zoology

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DECLARATION

I hereby declare that the work presented in this thesis entitled "**Fish diversity of Rapti River, Chitwan, Nepal**" has been done by myself and has not been submitted elsewhere for the award of any degree. All the sources of the information have been specifically acknowledged by references to the author(s) or institution(s).

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This is to recommend that the thesis entitled "**Fish diversity of Rapti River, Chitwan, Nepal**" has been carried out by **Sagar Tamang** for the partial fulfilment of Master's Degree of Science in Zoology with special paper **Fish Biology and Aquaculture** (Course Code-Zoo 653). 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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Sagar Tamang

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBEREVIATIONS

Short Form	Full Form
DoFD	Department of Fisheries Development
FAO	Food and Agriculture Organization
APHA	American Public Health Association
DO	Dissolved Oxygen
pH	Percentage ion of Hydrogen
GPS	Global Positioning System
C	Common
RDA	Redundancy Analysis
Mg/l	Milligram per liter
EN	Endangered
VU	Vulnerable
R	Rare
LC	Least Concern

LIST OF APPENDICES

Appendix I

- **Photoplate-I**
- **Photoplate-II**
- **Description of photos in photoplate-II**

ABSTRACT

The present study was conducted in Rapti River of Chitwan District located between latitudes of 27°20' to 27°52'N and longitudes of 83°55' to 84°52'E. The field visit was conducted from 23rd February to 28th June, 2020. Samples were collected from four stations, i.e. Manahari, Lothar, Kumroj and Sauraha for fishes and physicochemical parameters such as water temperature, DO, water velocity and pH. Fishes were collected with the help of well-trained local fisherman, by using a cast net of varying mesh sizes (6mm, 2cm). A total of 36 fish species were collected belonging to 5 orders, 11 families and 24 genera. The Cypriniformes was the dominant order with 24 species representing 65.71% of the total collection, followed by Siluriformes (8 species, 22.85%) and Anabantiformes (2 species, 5.7%). Each of Beloniformes and Synbranchiformes was collected a single species representing 2.85 % respectively. The highest species richness (9) was recorded at Kumroj and lowest species (3) at Manahari in rainy season. Similarly, the highest species richness (8) was recorded at Manahari and the lowest species (4) at Sauraha in winter season. The Shannon-Wiener's diversity index was high at Kumroj (1.588) and low at Manhari (1.055) in rainy season. It is high at Kumroj (1.588) and low at Lothar (1.298) in winter. In rainy season, the highest Simpson diversity index (0.75) was found at Sauraha and the lowest (0.611) was at Lothar. In winter, the highest Simpson diversity index (0.768) was found at Kumroj and the lowest (0.702) was at Lothar. In rainy season, the highest Margalef's index (2.09) was found in Kumroj and the lowest (1.243) was at Manhari. In winter, the highest Margalef's index (2.164) was found at Sauraha and the lowest (0.965) was found at Lothar. Dissolved oxygen was recorded as the highest (11.5 mg/l) at Manhari and lowest (8.3 mg/l) at Sauraha in winter season. The dissolved oxygen was comparatively lower in rainy season which ranged from 7.4 mg/l (Sauraha) to 9.8 mg//l (Lothar). The Redundancy Analysis (RDA) showed a strong positive association between species like *Barilius barila, B. bendelisis, B. modestus, C. jaya,* and *T. tor* with DO. *C. chagunio* was found to be negatively associated with pH and the remaining species however showed the average association. It is evident that systematic research on regular interval of time basis is crucial to have more reliable data on fish diversity status. Long term research covering more seasons and more water quality parameters is highly recommended in this river in future.

Keywords: Diversity index, Fish fauna, Rapti River, Water quality

1. INTRODUCTION

1.1 Fish Diversity of Nepal

Rich in water resources of Nepal has contributed for rich freshwater fish diversity (Shrestha, 2008; Shrestha et al. 2009; Shrestha and Edds, 2012). Among several water resources, rivers in Nepal support more fish species than rest of the water bodies. Broadly speaking, three major river systems are present in the country namely the Koshi, the Gandaki and the Karnali in eastern, central and western regions, respectively. Among them, moderate research on fish diversity has been carried out in the Koshi and Gandaki than the Karnali River system. Rivers of the country are more explored for fish diversity than lakes and reservoirs (WWF 2009). The present study lies on the Gandaki River system of central Nepal. Some of the previous researches on fish diversity in Narayani/Rapti River include that of Paudel (2006), Edds (2007) and Rayamajhi (2017). While Edds (2007) and Rayamajhi (2017) focused on the fishes of Chitwan National Park areas, and reported 91 species and 55 species respectively, Paudel (2006) studied the fishes of Rapti River and reported 59 fish species belonging to 8 orders, 18 families and 36 genera.

The Rapti River is a perennial river which is originated from the Mahabharat Range and Churia Hill, which flows from east to west and finally merges with the Narayani River at Golaghat (Singh, 2013). The four sampling sites cover a total of 30 km distance within the river. Except in monsoon season, when the river becomes wide, carry large volume of heavy flooded water with high water current, it becomes comparatively shallower with mild to moderate water current in other seasons. The water is crystal clear during winter season and makes slippery with a layer of algae whereas it becomes muddy during rainy season.

The latest report shows a total of 252 freshwater fishes which belong to 15 orders, 40 families and 120 genera (Shrestha, 2019). Only freshwater fishes inhabit the country as it is not connected to the ocean system. However, the country is also home for some diadromous migratory species like *Anguilla bengalensis*. The study like this enhances the collection and preservation of voucher specimens, and such specimens are essential for taxonomical and other diversity related research for the country.

1.1.1 Topography and Geography

A south Asian country (1, 47,181 sq.km), Nepal is situated between two giant countries, India and China at the transition of two bio-geographical realms, i.e. Palearctic and Oriental (Udvardy, 1975; Shrestha and Edds, 2012). It is rich in fish diversity due to its topography and diverse climatic conditions (Shrestha et al. 2009). Within a short distance of north-south dimension, the country exhibits the drastic elevation gradients ranging from below hundred meters of above sea level to the highest mountain (8,848 m) in north. Because Nepal comprises only fresh aquatic ecosystem, the fishes residing in the country are also freshwater fishes. Nepal has three distinct geographical regions, on the basis of altitudinal variation, i.e. the Himalayan Region, the sub Himalayan Region and lower plain of Terai Region. The Himalayan Region, the sub Himalayan Region and the Terai region contributes about 15%, 68% and 25% respectively of the total area of Nepal. Similarly, by the altitudinal variation of Nepal, the climate is not uniform i.e. tropical in terai, sub-tropical in hills, and temperate in mountains and alpine in Himalayan region. Generally, the temperature rises from March to July and decreases from October to January (Pandey, 1987).

Climatic variability of the country ranges from sub-tropical to alpine zone causing a variety of habitat characteristics based on, for example, altitude is very peculiar. The country's altitudinal gradients include 50 to 8848 metersl (Shrestha and Edds, 2012) between north and south dimensions. Previous studies have shown several river zonation based on the presence of peculiar types of species determined by so called habitat gradients.

1.1.2 IUCN status

Out of 252 fish species, 2 species are Endangered (EN), 9 vulnerable species (VU), 23 rare and threatened species (R), 32 data deficient pristine rare ornamental species (PRO), 27 conservation dependent and rare species (CDR), 53 uncommon or lower risk least concern species (UN), 71 common species (C) and 15 exotic species (Shrestha, 2019).

In Nepal, no any fish species is identified as critically Endangered (CE) and extinct (EX) yet (Shrestha, 2019). Some vulnerable species of Nepal include *Neolissochilus hexagonolepis, Chagunius chagunio, Tor putitora, Danio rerio, Schizothorax plagiostomus, Schizothorax richardsonii, Schizothorax progastus, Psilorhynchus*

pseudecheneis, *Tor tor* and *Anguilla bengalensis*. *Tor tor* is kept in endangered status and these ten species of fishes were recommended for legal protection (Shrestha, 1995).

Table 1: List of Conservation Status of Fishes of Nepal

S.N.	Categories	Designated as	Number of fish species
1.	Common	C	71
2.	Uncommon or Lower Risk/ Least Concern	UN	53
3.	Conservation Dependent and Rare	CDR	27
4.	Data Deficient Pristine Rare Ornamental	PRO	32
5.	Critically Endangered	CE	0
6.	Endangered	EN	2
7.	Extinct	EX	0
8.	Vulnerable	VU	9
9.	Rare or Near Threatened	R	23
10.	Exotic	*	15
	Total		232

(Source: Shrestha, 2008)

1.1.3 Water Resources of Nepal

Nepal is rich in water resources that exist in various wetland types including rivers, lakes, reservoirs, marginal swamps, etc. (DoFD, 2014), and support diverse freshwater fish species. It covers 0.1% of water surface area of the total world water systems and 0.21% fish diversity of total global fish diversity (Shrestha, 1995). River is one of the significance natural water which occupies 47.77% of the total area with lake and reservoir only 0.8%.

Table 2: Water resources of Nepal

S.N	Resources details	Estimated area (ha)	Coverage (%)
1.	Rivers	39,500	47.77
2.	Lakes	5,000	0.6
3.	Reservoirs	1,500	1.38
4.	Ponds	11,396	1.4
5.	Marginal swamps	12,500	1.51
6.	Irrigated paddy fields	3,98,000	48.14
7.	Irrigation canals	3,160	0.38
8.	Highway side ditches	262	0.03
Total		**8,26,818**	**100**

Source: Direction of livestock and fisheries development (2073/074 B.S)

1.2. Objectives

1.2.1. General Objective

The general objective of this study was to explore fish diversity in Rapti River, Chitwan.

1.2.2. Specific Objectives

The specific objectives of this study were:

- To determine fish diversity indices such as Shannon-Wiener's, evenness index and Margalef's richness index.
- To analyze important physico-chemical parameters of Rapti River and
- To study the relationship between important physico-chemical parameters and species richness.

1.3 Justification of the Study

Fish diversity study is very important to the country like Nepal where adverse fishing practices like electro fishing, use of dynamites, use of fish poison, use of small gill nets, fishing during breeding season and overfishing are prevalent. All the aforementioned fishing activities enforce rapid fish decline in the water body, including streams and rivers. Unless fish diversity study, which enlists the number of species present at particular time (e.g. year) at particular place, is carried out, it will be difficult to generalize either number of fish species is increasing or decreasing in specified time period. The present study explored the fish diversity of Rapti River, one of the tributaries of Narayani River System. This study made a significant contribution in updating the diversity of fishes of Chitwan District of Nepal.

1.4 Limitation of the study

Field visit in Rapti River was affected due to COVID-19 Pandemic and nation-wide lockdown. Consequently, the fish samples and water quality parameters could not be collected for more seasons besides rainy and winter from the Rapti River.

2. LITERATURE REVIEW

Previous records show that fishes had been explored during the 18th century in Nepal. However, Hamilton Buchanan in the 19th century started the first historical account of Nepal's ichthyofauna (Shrestha, 1994) especially of the Terai region. It was reported that a small collection of Nepalese fishes was classified teleostean fishes of the order ostariphysi, 5 species of Nepalese fishes. The collection of fishes include 158 specimens of which 22 species were from Nepal was published by Hora (1920-1939). Excellent account of the Mahseer in the series of Journal of Bombay Natural was given by him. The Nepalese "Katle" was reported as *Neolissocheilus hexagonolepis* by Hora (1940).

2.1 Overall diversity

According to Shrestha (2001), Nepal is a very rich country in freshwater resources and these freshwater resources show glorious diversity with 182 fish species belonging to 93 genera, 11 orders and 31 families. Gubhaju et al. (2002) have studied on the contribution of cold water fishes in the livelihood of mountain people of Nepal. Shrestha (2003) reported 184 fish species existing in natural water bodies of Nepal belonging to 93 genera, 11 order and 31 families. Pokharel (2011) reported 42 species of fishes from the lotic and lentic water bodies. Rajbanshi (2012) listed 186 species from Nepal. Recently, a total of 252 fishes belonging to 15 orders 40 families and 120 genera have been reported from the country (Shrestha, 2019).

2.2 Gandaki River system

The previous research has shown that among three major river systems (some prefer four major river systems) of Nepal, fair amount of research, related to fish diversity, has been conducted in the Koshi and the Gandaki river systems. The earlier work on fish diversity study on Gandaki River includes that of Edds (1993) who studied fish assemblage structure in relation to several environmental variables and reported a total of 120 fish species. Dhital and Jha (2002) studied the fish fauna of the Narayani River system and its impact on local fishermen who depend on fishing for their livelihoods. They reported 69 fish species belonging to 9 orders and 20 families. According to them, the lower reaches of that river was more perilous due to siltation, mixing industrial

effluents, and different pesticides coming out from farmlands. As a result, they found fish declination (e.g., *Neolissocheilus hexagonolepis*, *Tor putitora*, etc.) in the river system due to illegal fishing practices including fish poisoning and fishing during breeding seasons. Due to low fish catch, fishermen of that area already began to search for alternative jobs for their livelihoods.

Edds et al., (2002) studied the effects of effluents of hot-soda process paper mill (Bhrikuti) on fishes and macroinvertebrates in the Narayani River and reported 36 fish species belonging to fiver orders and eight families. They found significant difference of fish species richness upstream and downstream from the vicinity of that paper mill.

Paudel (2006) reported 59 fish species that belongs to 7 orders, 19 families and 38 genera from Rapti River of Chitwan, and reported cyprinids were the common species. According to her, the fish population was declined due to human activities and natural disaster such as flood. She also mentioned the socio-economic status of local fisherman as poor.

Oli et al. (2013) reported 22 fish species from the Rampur Ghol and reported Cypriniformes as the most dominanting order with 9 species, followed by Siluriformes with 5 species, Perciformes with 4 species, Synbrachiformes with 3 species and Beloniformes with 1 species. Jha and Bhujel (2014) studied fish diversity of Narayani river system. They reported 108 fish species and classified into 9 orders, 27 families and 70 genera. Large number of species belonged to Cypriniformes, whereas small numbers of fishes were under Anguiliformes, Beloniformes, Clupeiformes and Tetraodontiformes. According to them, Narayani River was extremely affected by alteration of habitats, pollution and overexploitation of water resources impacting river fishes.

Rayamajhi (2017) studied fish assemblage of Chitwan National Park, its buffer and neighboring zone, and described *Pseudolaguvia nepalensis* as a new species for the country. The Cypriniformes constituted highest species whereas orders like Osteoglossiformes, Beloniformes and Tetraodontiformes were found low in number. Jha (2018) reported 111 fish species from the Chitwan district and its adjacent areas, and reported Cypriniformes was the most dominant order while Anguiliformes, Beloniformes, Clupeiformes and Tetraodontiformes represented the low in number.

In comparison to lotic water bodies, fish diversity in lentic water bodies have poorly been explored (WWF, 2009). Gautam et al. (2010) studied fish diversity of Jagadispur Reservoir in Kapilbastu district. They observed 44 species belonging to 6 orders, 18 families and 34 genera, where Cypriniformes was the dominant order. They also examined water quality parameters (CO_2, hardness, etc.) and found within a desirable range to support warm water fishes.

Gautam et al. (2016) studied fish fauna of tectonic lake, Rupa, located in the mid hill region of central Nepal and reported 23 fish species belonging to 5 orders, 6 families and 18 genera, of which 19 species were indigenous and four were exotic. They reported exotic catfishes namely *Clarias batrachus* and *C. gariepinus* for the first time from that lake.

3. MATERIALS AND METHODS

3.1. Study Area

The present study was conducted in Rapti River of Chitwan District. Chitwan District (2,238 km^2) which is located between latitudes of 27°20' to 27°52'N and longitudes of 83°55' to 84°52'E, in the southwestern part under Province No. 3. The total length of the river is about 55km, which merges with the Narayani River at Golaghat. The bank of the Rapti river can be divided into different regions: i) boulder, gravels and pebbles, rubble, cobbles and sand, ii) sand and iii) sand and mud with the growth of grasses.

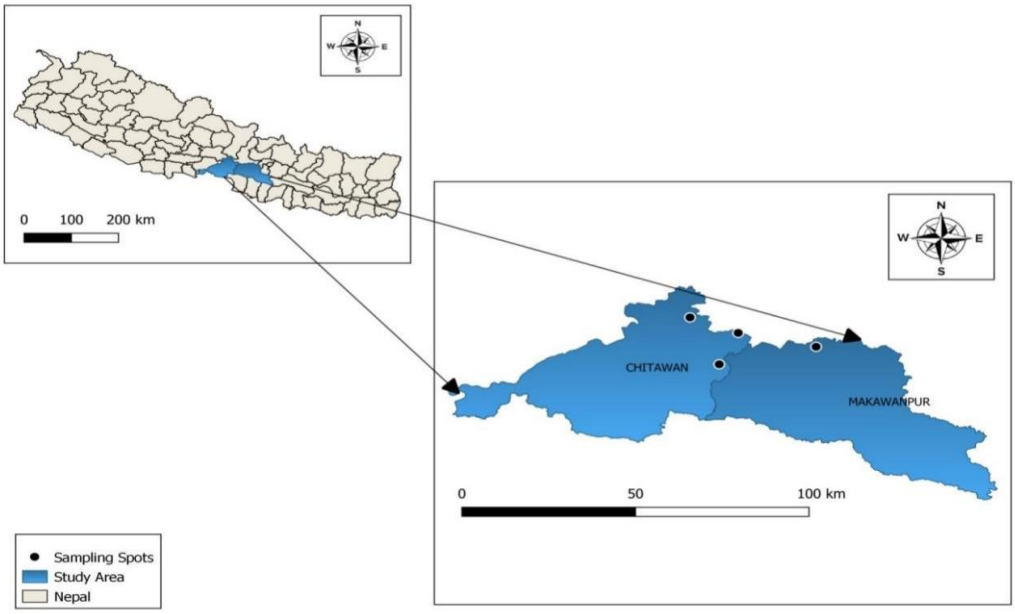

Figure 1: Map of study area with sampling sites

3.2. Data collection and Study Period

The field visit was carried out from 23rd February to 28th June, 2020. The field work was carried out in winter and rainy seasons of the same year. During study period, cast net was used for sample collection by hiring local fisherman. In each sampling stations, about two hours were spent for fish sampling, measurement of water quality parameters and gathering information regarding their local name, behavior and habitat was obtained from fisherman.

3.3. Sampling stations

For the present work, the study sites were selected from Manahari a Rural Municipality of Makawanpur district to Sauraha, a Ratnanagar Municipality of Chitwan district. To study the fish diversity of Rapti River, study area was divided into four sampling stations located at Manahari, Lothar, Kumrojh and Sauraha. The stations were selected on the basis of anthropogenic area, confluence and undisturbed area.

Station A- Manahari

The 1st sampling station was fixed at Manahari a Rural Municipality of Makawanpur district. It located between 27°31'576"N and 84°46'793"E. The Mahendra highway lies in north whereas Chitwan National Park lies in south. Manahari is famous for fish market where most people come to eat fish. The station lies at the confluence of Manahari Khola and Rapti River. The river is wider with higher water velocity i.e. 1.2-1.8 m/sec. The substratum of this site was composed of stones, pebbles and rocks. Khair, *(Acacia catechu)*, Sisso *(Dalbergia Sisso)*, Sal *(Shorea robusta)* etc were the vegetation around this site.

Station B- Lothar

Station B was selected at Lothar about 5 km down from Manahari. It lies between 27°33'624"N and 84°42'222"E. The water velocity of this site was 1.1-1.4 m/sec and the river bed consisted of stones, pebbles and sand. This site was located at confluence between Lothar khola and Rapti River.

Station C- Kumroj

The sampling station C was situated about 8 km west of Station B and it lies on 27°32'872"N 84°33'259"E. This station is undisturbed area, surrounded both side by forest. The water velocity of this site was low in comparison to other stations i.e. 0.6-1.5 m/sec. The river bed mostly consisted of pebbles, sand and mud.

Station D- Sauraha

Sauraha lies on 27°37'004"N 84°32'624"E and it is about 25 km downstream from the station A. The river bed was composed of mostly sand, small stones and pebbles. The water velocity was 0.7-1.3 m/sec. At this station, Buddhi Rapti River joins the Rapti River. There was human settlement and agricultural land near this station.

3.4. Methods

3.4.1 Physico-chemical Parameters

Physical parameter like water temperature was measured at each sampling site. Chemical parameters including dissolved oxygen and pH were also measured. Water velocity at each sampling site was also measured.

3.4.1.1 Temperature

The water temperature was recorded by using a standard alcohol thermometer. It was dipped directly into the water at each sampling site. Three readings of temperature were taken at each sampling site and the average value was used in the analysis.

3.4.1.2 Water velocity

The water velocity was measured with the help of a float method. The float used in this method was a plastic bottle. A measuring tape was used for the measurement of certain length of river stretch (e.g. 10m). The initial and final points of that specific length were marked. Then the plastic bottle was released in the river parallel to the initial point and time taken by that plastic bottle to reach the final point was noted (m/s) by using a stopwatch.

3.4.1.3 Chemical parameters

Dissolved oxygen (mg/l) and pH were measured with the help of DO meter (HANNA HI 9147) and pH meter (HANNA HI98107) respectively. Both the probe of pH and DO meter was dipped at each sampling site and holded sometime till its reading stabilized and then the values were noted down.

3.5 Data Analysis

The constrained ordination technique, Redundancy Analysis (RDA) was used to find out the relationship between environmental variables measured and species richness in the Rapti River. The analysis was carried out in freely available R software (ver. 4.1.2).

3.6. Collection of fishes and Identification

For the present study, fishes were collected from each sampling station with the help of well-trained local fishermen by using a cast net (6mm mesh size). About 400m river stretch was sampled for fishes at each sampling station covering available microhabitats such as pools, riffles, runs. Fish sampling was done twice a day: morning (8am-11am) and evening (4pm-6pm) at each station. The collected fishes were photographed in the field with Nikon Digital Camera (p900). After photography, some fishes were preserved in 10% formaldehyde solution for further study, some were deposited as voucher specimens at Amrit Campus (ASCOL), Lainchaur Kathmandu. The fishes were identified with the help of identification keys according to Shrestha (1981), Talwar and Jhingran, (1991), Jayaram (2010) and Shrestha (2019).

3.7. Statistical Analysis

3.7.1 Diversity Indices

3.7.1.1 Shannon- Weiner's Diversity Index

The Shannon- Weiner diversity index, H' (Shannon and Weaver, 1949) was calculated with the help of following formula:

$$H' = -\Sigma (Pi) \times \ln (Pi)$$

Where,

Pi= ni/N = relative abundance of each species, calculated as the proportion of individual of a given species to the total number of individuals in the community.

ni= No. of all individual species

N=Total no. of all individuals in the sample

ln= Logarithm of base

3.7.1.2 Species Richness Index

The Margalef richness index (d) (Margalef's1968) was calculated by using the following formula:

Margalef richness (d) = S-l/lnN

Where,

S= Number of species

N = Number of individuals

3.6.1.3 Evenness Index

To calculate whether species are distributed evenly across seasons and across sampling sites, evenness index was determined by the following equations (Pielou, 1966).

E= H'/ lnS

Where,

H' = Shannon-Weiner's diversity index

S = Total no. of species in the sample

3.7.1.4 Simpson's Index of Dominance

Simpson's index of Dominance (D) was calculated by using following formula

D=1-ni(ni-1)/N(N-1)

Where, ni is total number of individuals of particular species and N= total number of species

4. RESULTS

4.1 Fish Diversity

A total of 36 fish species (Table 3) were recorded in this study which belong to 5 orders, 11 families and 24 genera. The dominant order was Cypriniformes (65.71%) with 24 species and the dominant family was Cyprinidae (58.33%) with 21 species.

Table 3: Fish species, order, family, common and local names

S. N.	Order	Family	Species	Common name	Local name
1	Cypriniformes	Cyprinidae	*Barilius barila*	Barred baril	Faketa
2	Cypriniformes	Cyprinidae	*Barilius bendelisis*	Hamiltons baril	Faketa
3	Cypriniformes	Cyprinidae	*Barilius modestus*	Indus baril	Chiple faketa
4	Cypriniformes	Cyprinidae	*Barilius vagra*	Vagra baril	Lam faketa
5	Cypriniformes	Cyprinidae	*Cabdio jaya*	Jaya	Bhegna
6	Cypriniformes	Cyprinidae	*Cabdio morar*	Apsidoparia	Chakale
7	Cypriniformes	Cyprinidae	*Chagunius chagunio*	Chaguni	Patharchatti
8	Cypriniformes	Cyprinidae	*Garra gotyla gotyla*	Gotyla	Buduna
9	Cypriniformes	Cyprinidae	*Puntius terio*	One-spot bar	Sidhra
10	Cypriniformes	Cyprinidae	*Cirrhinus reba*	Reba carp	Mrigal
11	Cypriniformes	Cyprinidae	*Danio devario*	Devario danio	Chitharipothi
12	Cypriniformes	Cyprinidae	*Opsarius tileo*	Tileo baril	Faketa
13	Cypriniformes	Cyprinidae	*Osteobrama cotio*	Cotio	Gurda
14	Cypriniformes	Cyprinidae	*Tor putitora*	Golden mahseer	Pahale sahar

15	Cypriniformes	Cyprinidae	*Tot tor*	Deep bodied mahsheer	Falame sahar
16	Cypriniformes	Cyprinidae	*Labeo bata*	Bata labeo	Rohu
17	Cypriniformes	Cyprinidae	*Labeo boga*	Boga labeo	Boga
18	Cypriniformes	Cyprinidae	*Labeo dyocheilus*	Brahmaputra labeo	Gardi
19	Cypriniformes	Cyprinidae	*Labeo fimbriatus*	Fringedlipped peninsula carp	Boi
20	Cypriniformes	Cyprinidae	*Labeo pangusia*	Pangusia labeo	Kalaacha
21	Cypriniformes	Cyprinidae	*Systomus sarana sarana*	Olive barb	Kande
22	Cypriniformes	Nemacheilidae	*Nemacheilius corica*	Stone loach	Raigadero
23	Cypriniformes	Psilorhynchidae	*Psilorhynchus balitora*	Balitora minnow	Patharchatti
24	Cypriniformes	Cobitidae	*Lepidocephalichthys guntea*	Guntea loach	Lata
25	Siluriformes	Amblycipitidae	*Amblyceps mangois*	Torrent catfish	Bokshi macho
26	Siluriformes	Bagridae	*Mystus gulio*	Long-whiskered catfish	
27	Siluriformes	Bagridae	*Sperata seenghala*	Tengara	Tenger
28	Siluriformes	Sisoridae	*Glyptothorax telchitta*	Copper catfish	Telcapre
29	Siluriformes	Sisoridae	*Glyptothorax pectinopterus*		Capre

30	Siluriformes	Sisoridae	*Erethistes pussilus*	Gangetic erethistes	Bhoomi
31	Siluriformes	Sisoridae	*Gagata cenia*	Gagata	Ganfak
32	Siluriformes	Sisoridae	*Glyptothorax kashmirensis*	Catfish	
33	Beloniformes	Belonidae	*Xenentodon cancila*	Freshwater garfish	Kauwa
34	Synbranchiformes	Mastacembelidae	*Mastacembelus armatus*	Spiny eel	Chuche bam
35	Anabantiformes	Nandidae	*Nandus nandus*	Mottled nandus	Dalahai
36	Anabantiformes	Channidae	*Channa striata*	Banded snakehead	Helae

4.1.1 Species Diversity Indices

The diversity indices such as Species richness, Shannon-Weiner's diversity, Simpson, and Margalef's richness are given in Table 4.

Table 4: Species Diversity Indices (Species richness, Shannon Weiner's, Simpson, and Margalef's richness)

S.N.	**Sampling stations**	**Species richness**		**Shannon Weiner's**		**Simpson**		**Margalef's richness**	
		Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy
1.	Manhari	8	3	1.467	1.055	0.706	0.64	1.626	1.243
2.	Lothar	5	5	1.298	1.234	0.7029	0.6111	0.9655	1.61
3.	Kumroj	7	9	1.588	1.582	0.768	0.7155	1.448	2.09
4.	Sauraha	4	5	1.386	1.494	0.75	0.75	2.164	1.924

The highest species richness was recorded at Kumroj (9 species) where the lowest species (3 species) at Manahari in rainy season. The highest species richness was recorded at Manahari (8 species) where the lowest species (4 species) at Sauraha in winter season.In rainy season, the highest Shannon diversity index was found at Kumroj (1.588) and the lowest was found at Manahari (1.055). In winter, the highest Shannon diversity index was found at Kumroj (1.588) and the lowest was found at Lothar (1.298). In rainy season, the highest Simpson diversity index was found at Sauraha (0.75) and the lowest was found at Lothar (0.611). In winter, the highest Simpson diversity index was found at Kumroj (0.768) and the lowest was found at Lothar (0.7029). In rainy season, the highest Margalef's index was found at Kumroj (2.09) and the lowest was found at Manahari (1.243). In winter, the highest Margalef's index was found at Sauraha (2.164) and the lowest was found at Lothar (0.9655).

4.1.2 Order Wise Composition of fishes

The order-wise composition of fishes collected in Rapti River of Chitwan district was shown in figure 2. A total of 5 orders: Anabantiformes, Beloniformes, Cypriniformes, Siluriformes and Synbranchiformes have been recorded. Cypriniformes constituted with 24 species followed by Siluriformes with 8 species and Anabantiformes with two species. Each of Beloniformes and Synbranchiformes comprised with single species.

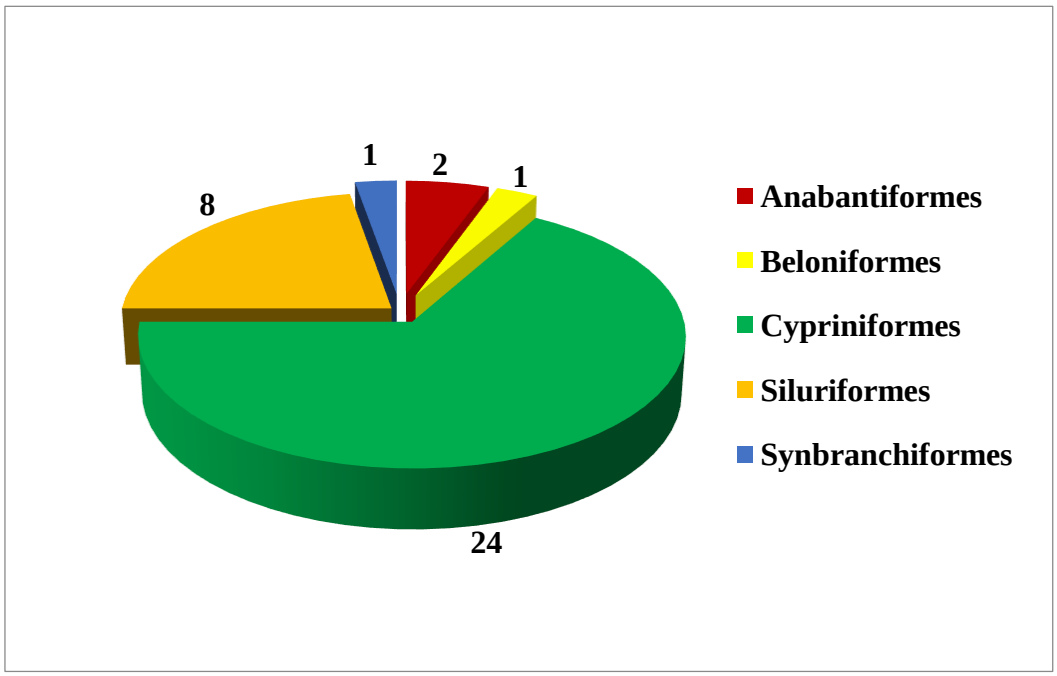

Figure 2: Order-wise composition of Rapti River

4.1.3 Family Wise Composition of fishes

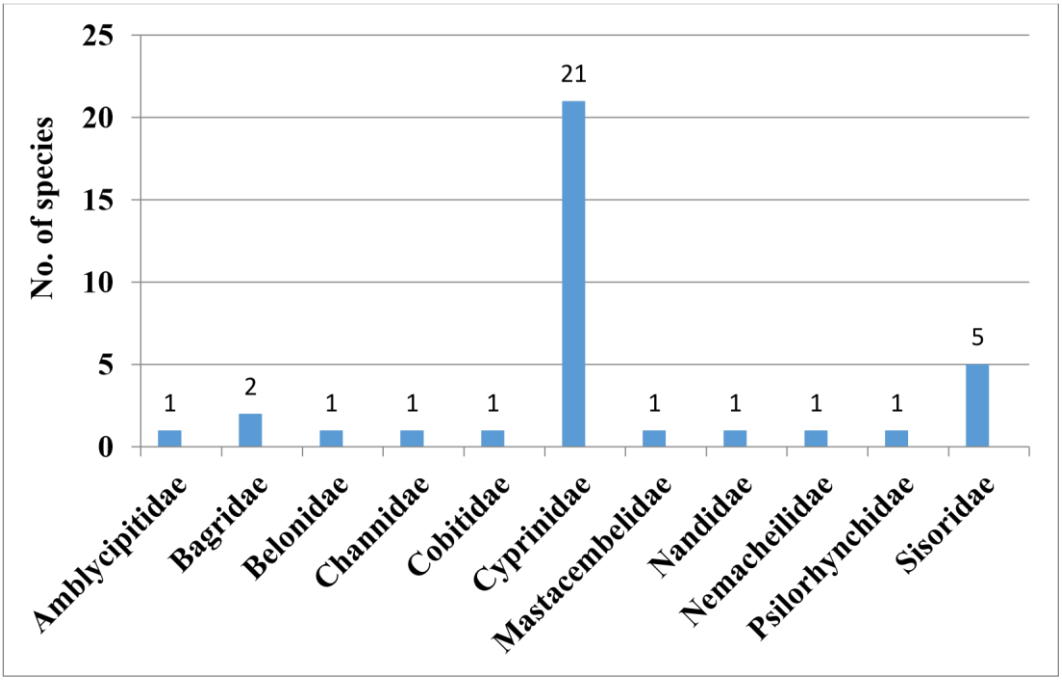

Figure 3: Family-wise composition of fishes

Family-wise representation of fishes collected in Rapti River of Chitwan district is given in Figure 3. Fishes collected during the study period were categorized under 11 families. The maximum species belonged to family Cyprinidae with 21 species followed by Sisoridae with 5 species and Bagridae with two species. Each of Amblycipitidae, Belonidae, Channidae, Cobitidae, Masracembelidae, Nandidae, Nemacheilidae and Psilorhynchidae contained with single species.

4.1.4 Distribution of fishes

Table 5: Fish species collected in Rapti River, Chitwan in two seasons

S. N.	Species	Sampling stations							
		Winter season				Rainy season			
		Manhari	Lothar	Kumroj	Sauraha	Manhari	Lothar	Kumroj	Sauraha
1	*Amblyceps mangois*	-	-	-	-	-	1	-	-
2	*Barilius barila*	3	3	14	-	-	-	1	3

3	*Barilius bendelisis*	27	18	-	-	-	-	-	1
4	*Barilius modestus*	7	-	-	-	2	-	-	-
5	*Barilius vagra*	-	-	-	-	-	-	3	-
6	*Cabdio jaya*	7	19	17	-	-	2	7	2
7	*Cabdio morar*	-	-	-	-	-	-	1	-
8	*Chagunius chagunio*	6	-	19	-	-	-	-	-
9	*Channa striata*	1	-	-	-	-	-	-	-
10	*Cirrhinus reba*	1	-	-	-	-	-	-	-
11	*Danio devario*	1	1	1	-	-	-	-	-
12	*Erethistes pussilus*	-	-	3	-	-	-	-	1
13	*Gagata cenia*	-	-	-	-	-	-	21	-
14	*Garra gotyla gotyla*	-	-	-	-	1	-	-	-
15	*Labeo bata*	-	-	-	1	-	-	-	-
16	*Labeo boga*	-	-	-	1	-	-	-	-
17	*Labeo dyocheilus*	-	-	-	-	-	1	2	-
18	*Labeo fimbriatus*	-	-	-	1	-	-	2	-
19	*Labeo pangusia*	-	-	-	-	2	7	10	-
20	*Lepidocephalichthys guntea*	-	-	-	-	1	-	-	-

21	*Mastacembaleus armatus*	-	-	-	-	-	1	-	-
22	*Mystus gulio*	-	-	-	-	-	3	-	-
23	*Nandus nandus*	-	-	-	1	-	-	-	-
24	*Nemacheilius corica*	1	-	-	-	-	-	-	-
25	*Opsarius tileo*	-	-	3	-	-	-	1	-
26	*Osteobrama cotio*	-	-	-	-	-	-	-	1
27	*Psilorhynchus balitora*	1	-	-	-	-	-	-	-
28	*Puntius terio*	28	22	8	-	2	-	-	1
29	*Sperata seenghala*	-	-	-	-	-	1	-	-
30	*Systomus sarana sarana*	-	-	-	-	2	-	-	-
31	*Tor putitora*	-	-	-	1	-	-	1	-
32	*Tor tor*	1	5	-	-	-	3	-	-
33	*Xenentodon cancila*	-	-	1	-	-	-	-	-
34	*Glyptothorax pectinopterus*	-	-	-	-	1	1	2	-
35	*Glyptothorax telchitta*	-	-	-	-	7	-	-	-
36	*Glyptothorax kashmirensis*	-	-	-	-	-	2	-	-

4.2 Physico-Chemical Parameters

4.2.1 Water Temperature

In winter, the water temperature ranged from 16.1 ^{o}C to 19.2 ^{o}C. The lowest water temperature (16.1 ^{o}C) was recorded at station Lothar and the highest water temperature (19.2 ^{o}C) at the station Sauraha. The average water temperature of station A, station B, station Kumroj and station Sauraha in winter/rainy were (18.1°C), (16.1°C), (18.1°C) and (19.2°C), respectively. During rainy season, the water temperature ranged from 25.1°C to 26.4°C. The highest water temperature (26.4°C) was recorded at station Sauraha, and the lowest water temperature (25.1°C) was recorded at station Lothar. The average water temperature of the station Manhari, station Lothar, station Kumroj and station Sauraha were 25.2°C, 25.1°C, 26.2°C and 26.4°C, respectively.

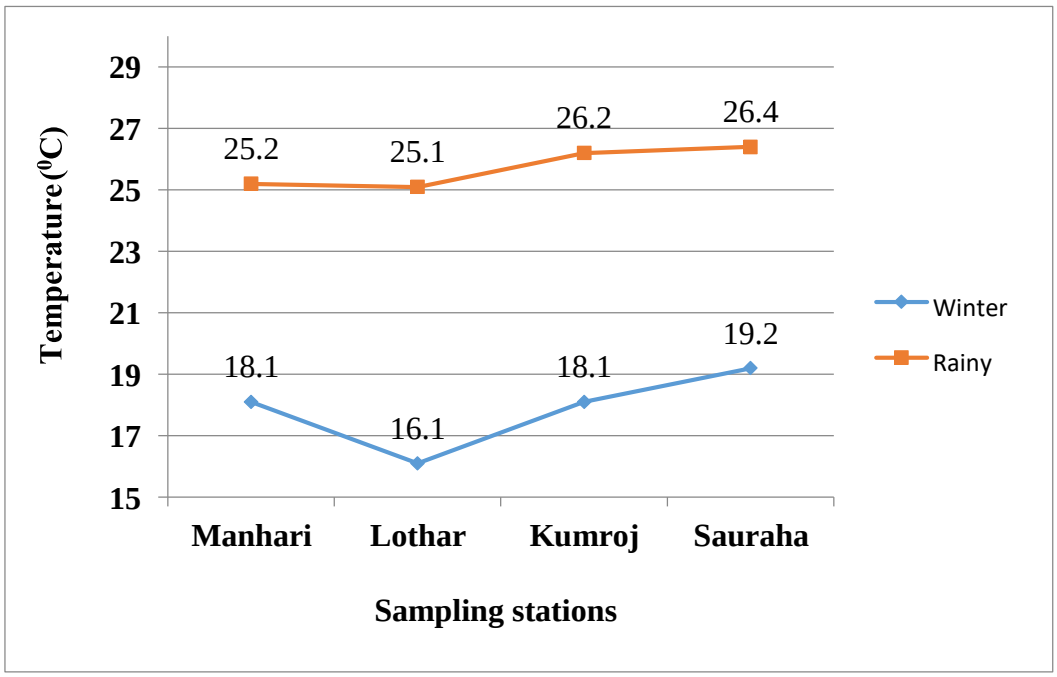

Figure 4: Water temperature recorded at four sampling stations in winter and rainy seasons

4.2.2 pH

The pH of Rapti River was found alkaline in all stations which ranged from 8.1 to 8.6 in winter season, and from 8.6 to 8.8 in rainy season. The lowest value (8.1) was recorded at station Kumroj and the highest value (8.6) was recorded at station Lothar during winter.

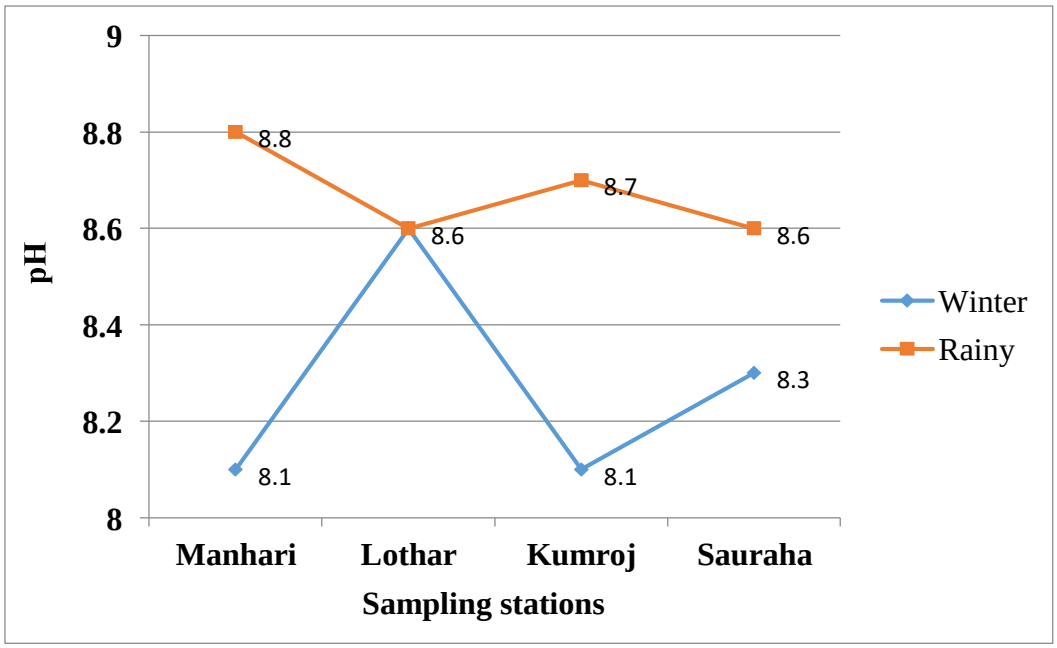

Figure 5: pH recorded at four sampling stations in winter and rainy season

The average pH at of the station Manhari, station Lothar, station Kumroj and station Sauraha in winter/rainy were 8.1, 8.6, 8 and 8.3 respectively. During rainy season, the pH was ranged from 8.6 to 8.8. The lowest value (8.6) was recorded at each of the station Lothar and Sauraha, and the highest value (8.8) was recorded at stations Manhari. The average pH at of the station Manhari, station Lothar, station Kumroj and station Sauraha were 8.8, 8.6, 8.7 and 8.6 respectively.

4.2.3 Dissolved Oxygen (DO)

The dissolved oxygen in winter season ranged from 8.3 mg/l to 11.5 mg/l (Fig. 6). The maximum dissolved oxygen (11.5 mg/l) was recorded at station Manhari and the minimum (8.3 mg/l) was recorded at station Sauraha. During rainy, the maximum dissolved oxygen was recorded as 9.8 mg/l at station Lothar and the minimum dissolved oxygen was recorded as 7.4 mg/l at station Sauraha (Fig. 6).

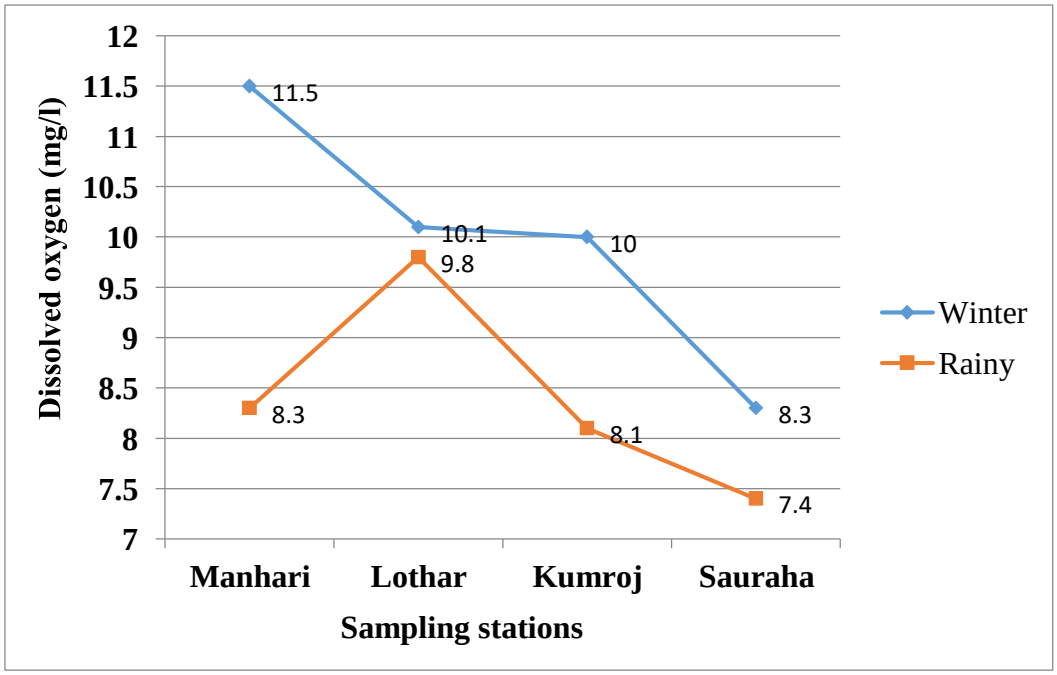

Figure 6: Dissolved oxygen recorded at four sampling stations in winter and rainy seasons

4.2.4 Water Velocity

During winter season, the highest velocity was recorded at station Manhari (1.219 m/s) and the lowest velocity was recorded at station Kumroj (0.645 m/s).

Similarly, during rainy season, the highest velocity was recorded at station Manhari (1.85 m/s) and the lowest velocity was recorded from station Sauraha (1.35 m/s).

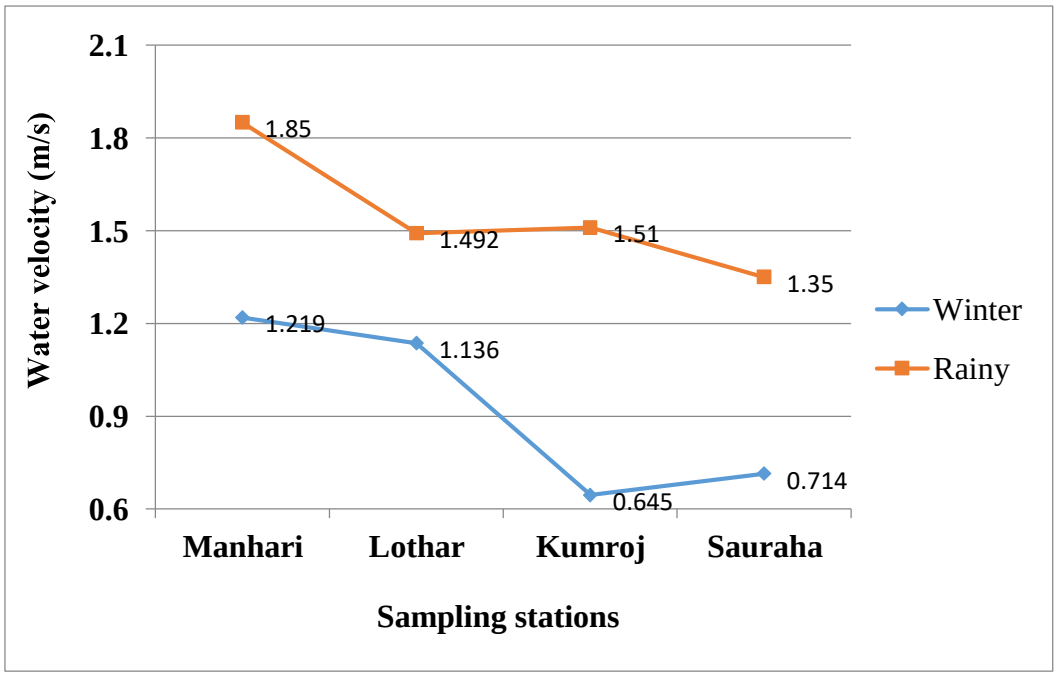

Figure 7: Water velocity recorded at four sampling stations in winter and rainy seasons

4.3 Relationship between species and environmental variables

The relationship between environmental variables and fish species is shown in Figure 8. To find out the relationship, Redundancy Analysis (RDA) was performed in R studio (ver. 4.1.2), one of the freely available software. A total of 94 % variation was explained by both axes, i.e. 55% variation was explained by RDA1 and 39% variation was explained by RDA2. Species like *C. jaya*, *C. chagunio* and *B. bendelisis* were strongly positively associated with RDA1. On the other hand, *P. terio* was strongly positively associated with RDA2. Species like *Barilius barila*, *B. bendelisis*, *B. modestus*, *C. jaya* and *T. tor* were strongly positively associated with DO. *C. chagunio* was found to be negatively associated with pH. The remaining species however showed the average association with the measured water quality parameters.

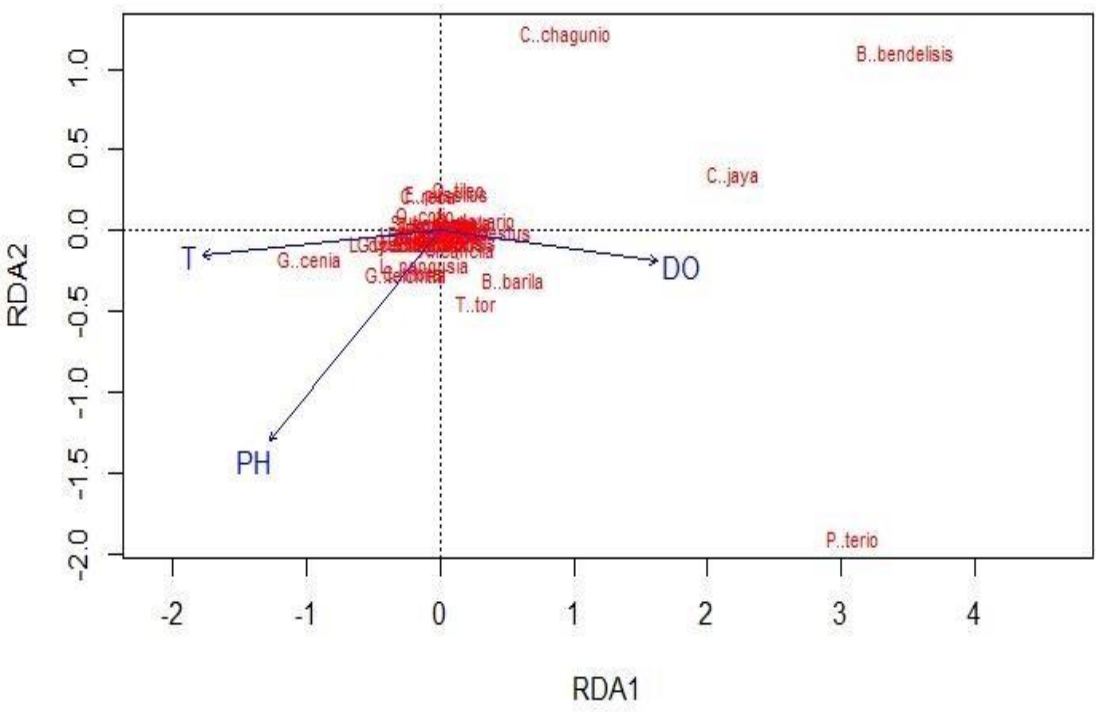

Figure 8: RDA showing relationship between species richness and physico chemical parameters in Rapti River, Chitwan

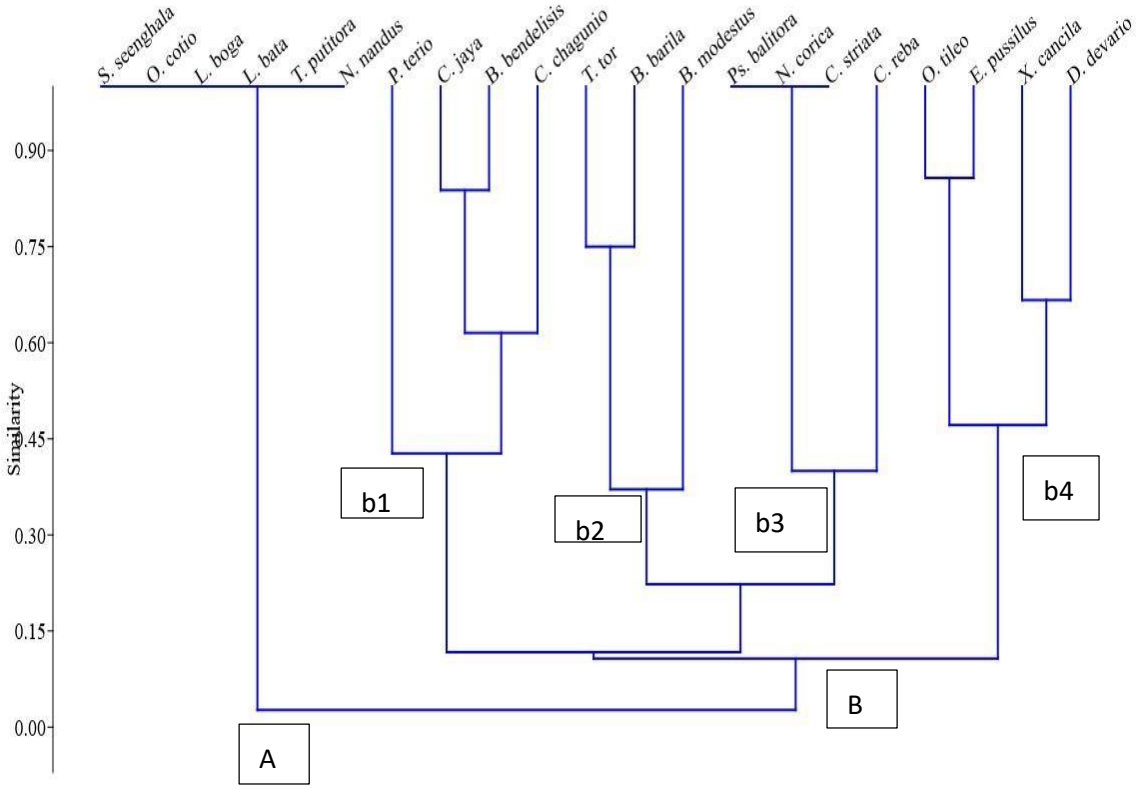

Figure 9: Cluster analysis of fish species collected in Rapti River, Chitwan

A cluster dendrogram on species recorded in winter and rainy seasons in Rapti River of Chitwan district was shown in Figure 9. The dendrogram was generated based on the fish assemblages of the Rapti River. Broadly, all fish species can be categorized into two clusters: Cluster A and Cluster B. Cluster B can again be divided into four sub-clusters: b1, b2, b3 and b4. Therefore, a total of five clusters can easily be seen in the diagram. Cluster A is located at the far left with 6 species such as *Sperata seenghala*, *Osteobrama cotio, Labeo bata, L. boga, Tor putitora* and *Nandus nandus*. Cluster b1 consists of *Puntius terio, Cabdio jaya, Barilius bendelisis* and *Chagunius chagunio*. *T. tor, B. barila* and *B. modestus* were grouped into cluster b2. Cluster b3 included four species: *Psilorhynchus balitora, Nemacheilus corica, Channa striata* and *Cirrhinus reba*. Cluster b4 also consists of four species: *Opsarius. tileo, Erethistoides pussilus, Xenentodon cancila* and *Danio. devario* which is located at the far right in the diagram (figure. 9).

5. DISCUSSION

The current fish diversity research carried out in Rapti River has recorded a total of 36 fish species belonging to 5 orders, 11 families and 24 genera (Table 3). During the study period (23rd February to 28th June, 2020), a total of 250 fishes were collected from four sampling stations: Manhari, Lothar, Kumroj and Sauraha.

Cypriniformes was recorded as the dominant order representing 65.71% of total collection in this study and this result is in line with other studies including Poudel (2006), Jha and Bhujel (2014), Rayamajhi (2017) and Jha (2018). Poudel (2006) had found 59 fish species during her investigation period from the Rapti River. Also, she reported a species *Heteropneustes fossilis* of the family Heteropneustidae from all stations, but I could not find this species during my study. Jha and Bhujel (2014) reported 108 fish species from the range of Kurintar to Golaghat of which 53 species were from the order Cypriniformes. Rayamajhi (2017) documented 55 fish species from Chitwan National Park (CNP), its buffer zone and adjacent areas and order Cypriniformes as a dominant order. Jha (2018) reported 111 fish species from the Chitwan district and its adjacent areas and reported order Cypriniformes was the most dominant order.

The next dominant order was found as Siluriformes (22.85 %) followed by Anabantiformes (5.71%). Likewise, the Cyprinidae (60%) was dominant family followed by Sisoridae (14.28%) and Bagridae (5.71%). Each of remaining families such as Nemacheilidae, Psilorhynchidae, Amblycipitidae, Belonidae, Mastacembelidae, Nandidae, and Channidae contributed for 2.85% with single species respectively. Among fish species, Gadhani was the most dominated species recorded from all stations throughout the investigation period.

Physicochemical variables such as water temperature, dissolved oxygen, pH, and water velocity were correlated with fish abundance and these variables change according to seasons (Sharma et al, 2007, Pokhrel 2011, Alexandre et al, 2010). In the present study the highest water temperature was recorded at Sauraha and lowest at Lothar in rainy and winter seasons. Dissolved oxygen is an important factor which affects the distribution, diversity, physiology and behavior of fishes (Pokhrel et al, 2018). Dissolved oxygen of present study recorded as the highest (11.5 mg/l) in winter season

at Manhari and lowest (8.3 mg/l) at Sauraha. In rainy season, the amount of dissolved oxygen was, however, comparatively lower which ranged from 7.4 mg/l (Sauraha) to 9.8 mg//l (Lothar) which is due to temperature difference between those seasons. According to Bhatnagar and Singh (2010), suitable oxygen level is greater than 5 mg/l for fish. Dissolved oxygen below 0.3 mg/l for a longer period of time is very harmful for fishes (Ekubo and Abowei, 2011). The range of dissolved oxygen found in all sampling sites in Rapti River was well above satisfactory level for fishes.

Natural water of any water bodies may be neutral, acidic or alkaline which is an important environmental factor that influences the metabolic activities of fish (Bhatnagar and Devi, 2013). The pH level above 8.5 is harmful and stressful to the fishes (Bhatnagar and Devi, 2013). The pH of water of Rapti River was measured to be alkaline in all stations in both seasons which were above the threshold level as indicated by Bhatnagar and Devi (2013); therefore, fishes inhabiting there may have suffered from some stress to some extent. Water velocity also plays an important role in the distribution of fishes in particular habitat. The average water velocity in Rapti River was higher in rainy season than winter season.

Only limited water quality parameters were analyzed in this study. They included pH, Temperature and Dissolved Oxygen. Nation-wide locked down due to COVID-19 pandemic, data collection was hampered to great extent. For example, data could not be collected; collected data (water sample) could not be analyzed due to lack of transportation and so on. Most of the species showed a pattern of average association with water quality parameters (Fig. 8). But some species were found to have strong association with those variables like DO, Temperature and pH. For example, *Barilius barila*, *B. bendelisis*, *B. modestus*, *C. jaya*, and *T. tor* were found to be strongly associated with DO. Species like *G. cenia* and *L. guntea* were found to be strongly positively associated with Temperature. And species like *C. chagunio, B. bendelisis* and *C. jaya* were found to be negatively associated with pH.

6. CONCLUSION AND RECOMMENDATIONS

A total of 36 fish species were recorded in this study which belong to 5 orders, 11 families and 24 genera in Rapti River of Chitwan district. The Cypriniformes was the dominant order with 24 species representing 65.71%, followed by Siluriformes (8 species, 22.85%) and Anabantiformes (2 species, 5.7%). Each of Beloniformes and Synbranchiformes contributed for single species representing 2.85 % respectively in the total fish collection during this study. Based on Shannon-Wiener's diversity index, the fish diversity of Rapti River was found to be medium. The Redundancy Analysis (RDA) showed a strong positive association between few species like *Barilius barila*, *B. bendelisis*, *B. modestus*, *C. jaya*, and *T. tor* with DO. *C. chagunio* was found to be negatively associated with pH and the remaining species however showed the average association. Further study incorporating long-term data covering more seasons can contribute for more reliable data on fish diversity in that river. Analysis of more water quality parameters will provide more generalization regarding the association between water quality parameters and fish species.

This study was being carried out after a long gap in the Rapti River of Chitwan district. It is evident that systematic research on regular interval of time basis is mandatory in order to have data on fish diversity status, a critical situation for evaluating biodiversity. On the basis of field visit and interaction with local people, following recommendations could be made:

- Long term research is highly recommended for more precise and reliable data.
- Illegal fishing practices should be strictly prohibited and those who carry out such activities should be punished.
- Public awareness programs to local fishers should be conducted in terms of importance of fish diversity and adverse impacts due to its loss.

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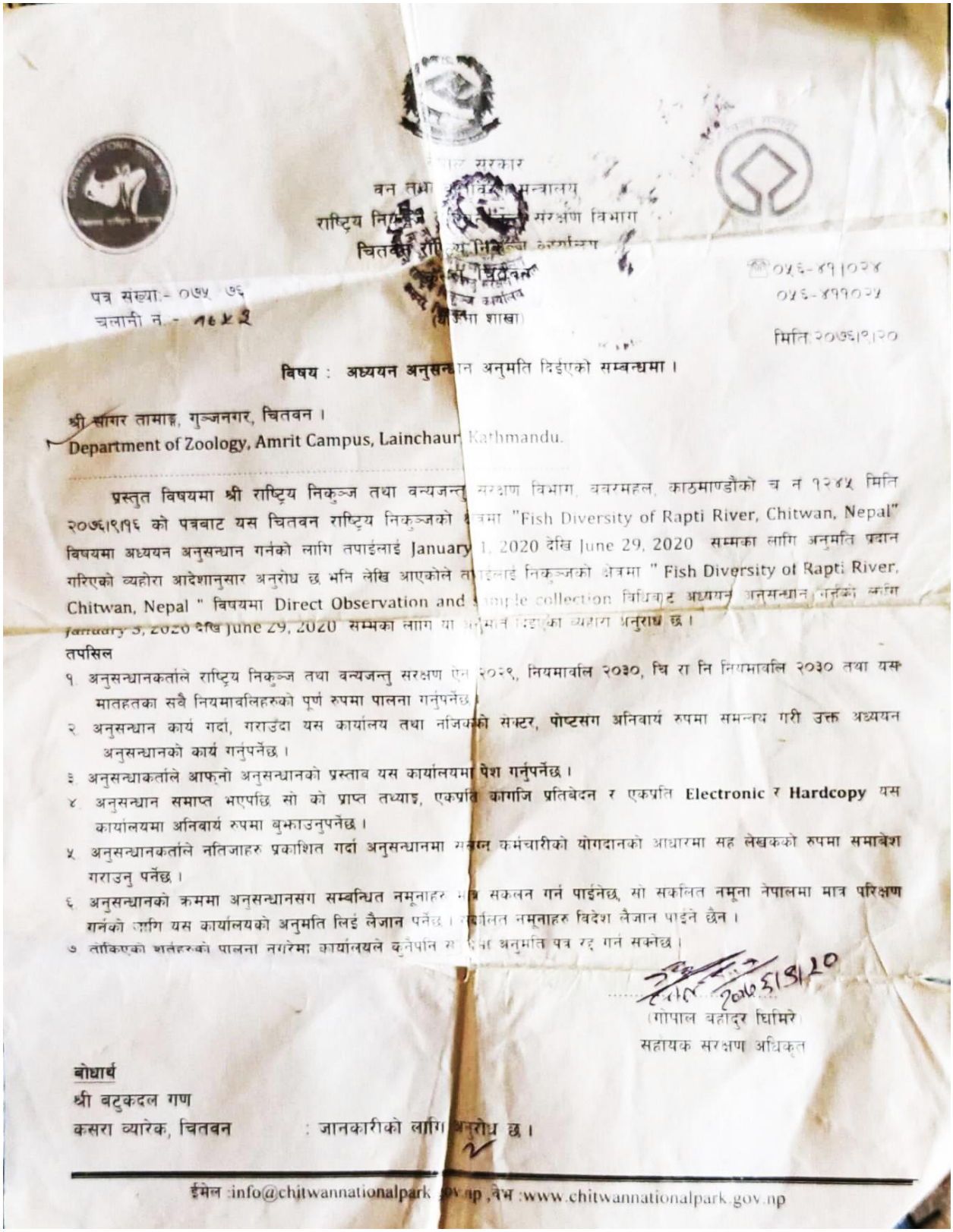
ANNEX

A Permission letter issued from DNPWC



नेपाल सरकार
वन तथा [illegible] मन्त्रालय
राष्ट्रिय निकुञ्ज [illegible] संरक्षण विभाग
चितवन राष्ट्रिय [illegible] कार्यालय
(प्रशासन शाखा)

फोन नं. ०५६-४९१०२४
०५६-४९१०२५

पत्र संख्या:- ०७५/७६
चलानी नं. - १६५२

मिति: २०७६।९।२०

विषय : अध्ययन अनुसन्धान अनुमति दिईएको सम्बन्धमा ।

श्री सागर तामाङ, गुञ्जनगर, चितवन ।
Department of Zoology, Amrit Campus, Lainchaur Kathmandu.

प्रस्तुत विषयमा श्री राष्ट्रिय निकुञ्ज तथा वन्यजन्तु संरक्षण विभाग, बबरमहल, काठमाण्डौको च नं १२४५ मिति २०७६।९।१६ को पत्रबाट यस चितवन राष्ट्रिय निकुञ्जको क्षेत्रमा "Fish Diversity of Rapti River, Chitwan, Nepal" विषयमा अध्ययन अनुसन्धान गर्नको लागि तपाईलाई January 1, 2020 देखि June 29, 2020 सम्मका लागि अनुमति प्रदान गरिएको व्यहोरा आदेशानुसार अनुरोध छ भनि लेखि आएकोले तपाईलाई निकुञ्जको क्षेत्रमा " Fish Diversity of Rapti River, Chitwan, Nepal " विषयमा Direct Observation and Simple collection विधिबाट अध्ययन अनुसन्धान गर्नको लागि ~~January 1, 2020~~ देखि June 29, 2020 सम्मका लागि यो अनुमति दिईएको व्यहोरा अनुरोध छ ।

तपसिल

१. अनुसन्धानकर्ताले राष्ट्रिय निकुञ्ज तथा वन्यजन्तु संरक्षण ऐन २०२९, नियमावली २०३०, चि रा नि नियमावली २०३० तथा यस मातहतका सबै नियमावलिहरुको पूर्ण रुपमा पालना गर्नुपर्नेछ ।
२. अनुसन्धान कार्य गर्दा, गराउँदा यस कार्यालय तथा नजिकको सक्टर, पोष्टसग अनिवार्य रुपमा समन्वय गरी उक्त अध्ययन अनुसन्धानको कार्य गर्नुपर्नेछ ।
३. अनुसन्धाकर्ताले आफ्नो अनुसन्धानको प्रस्ताव यस कार्यालयमा पेश गर्नुपर्नेछ ।
४. अनुसन्धान समाप्त भएपछि सो को प्राप्त तथ्याङ, एकप्रति कागजि प्रतिवेदन र एकप्रति Electronic र Hardcopy यस कार्यालयमा अनिवार्य रुपमा बुझाउनुपर्नेछ ।
५. अनुसन्धानकर्ताले नतिजाहरु प्रकाशित गर्दा अनुसन्धानमा सम्बन्ध कर्मचारीको योगदानको आधारमा सह लेखकको रुपमा समावेश गराउनु पर्नेछ ।
६. अनुसन्धानको क्रममा अनुसन्धानसग सम्बन्धित नमूनाहरु [illegible] सकलन गर्न पाईनेछ, सो सकलित नमूना नेपालमा मात्र परिक्षण गर्नको लागि यस कार्यालयको अनुमति लिई लैजान पर्नेछ । सकलित नमूनाहरु विदेश लैजान पाईने छैन ।
७. लीकिएको शर्तहरुको पालना नगरेमा कार्यालयले कुनैपनि स [illegible] अनुमति पत्र रद्द गर्न सक्नेछ ।

२०७६।९।२०
(गोपाल बहादुर घिमिरे)
सहायक संरक्षण अधिकृत

बोधार्थ
श्री बटुकदल गण
कसरा व्यारेक, चितवन : जानकारीको लागि अनुरोध छ ।

ईमेल :info@chitwannationalpark.gov.np ,वेभ :www.chitwannationalpark.gov.np

LIST OF PHOTOGRAPHS

PHOTOPLATE I

1. *Barilius bendelisis*

2. *Barilius barila*

3. *Barilius modestus*

4. *Barilius vagra*

5. *Channa striata*

6. *Amblycleps mangois*

7. *Chagunius chagunio*

8. *Danio devario*

9. *Lepidocephalichthys guntea*

10. *Mastacembaleus armatus*

11. *Opsarius tileo*

12. *Nemacheilus corica*

13. *Psilorhynchus balitora*

14. *Tor tor*

15. *Xenontodon cancila*

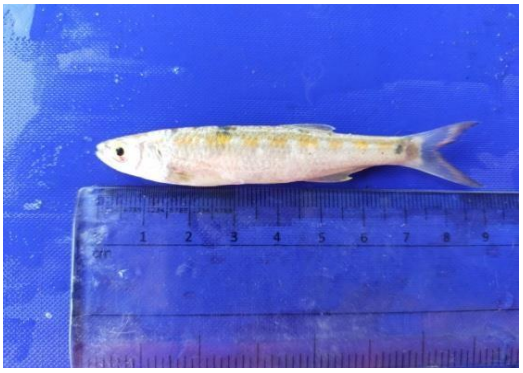
16. *Puntius terio*

17. *Erethistes pussilus*

18. *Gagata cenia*

19. *Glyptothorax kashmirensis*

20. *Mystus gulio*



21. *Cabdio morar*

22. *Labeo fimbriatus*

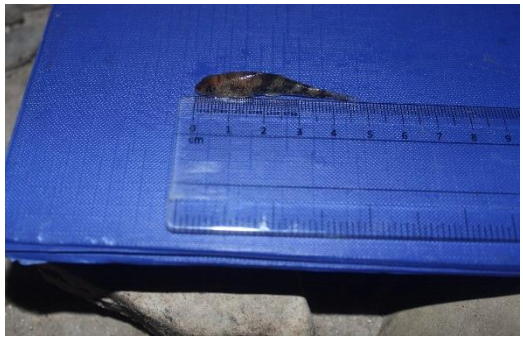
23. *Osteobrama cotio*

24. *Cirrhinus reba*

25. *Cabdio jaya*

26. *Systomus sarana sarana*

27. *Nandus nandus*



28. *Garra gotyla gotyla*

29. *Glyptothorax pectinopterus*

30. *Glyptothorax telchitta*

31. *Labeo dyocheilus*

32. *Labeo pangusia*

33. *Labeo bata*

34. *Labeo boga*

35. *Sperata seenghala*

36. *Tor putitora*

PHOTOPLATE-II

Photo 1

Photo 2

Photo 3

Photo 4

Photo 5

Photo 6

Description of photos in photoplate-II

Photo 1: Measurement of pH by using HANNA HI98107.

Photo 2: Measurement of DO by using HANNA HI9147.

Photo 3: Sampling station of Manhari

Photo 4: Sampling station of Lothar

Photo 5: Sampling station of Kumroj

Photo 6: Sampling station of Sauraha