ICHTHYOFAUNAL DIVERSITY OF BARJU LAKE, SUNSARI, NEPAL

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(Course Code- Zoo. 653)

Submitted to

Department of Zoology
Amrit Campus
Institute of Science and Technology
Tribhuwan University
Kathmandu, Nepal
November 2022

DECLARATION

I hereby declare that the work presented in this thesis entitled **"ICHTHYOFAUNAL DIVERSITY OF BARJU LAKE, SUNSARI, NEPAL"** has been done by myself and has not been submitted elsewhere of the award any degree. All source of the information have been specially acknowledged to the author(s) and institution(s).

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LETTER OF RECOMMENDATION

This is to recommend that the thesis entitled "**ICHTHYOFAUNAL DIVERSITY OF BARJU LAKE, SUNSARI, NEPAL**" has been carried out by Mr. Kamal Kumar Choudhary for the partial fulfillment 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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Kamal Kumar Choudhary

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LIST OF ABBEREVIATIONS

Abbreviated form	Details of Abbreviations
DO	Dissolved Oxygen
DoFD	Directorate of Fisheries Development
EN	Endangered species
Ex	Extinct
Fig	Figure
H	Shannon Weiner diversity index
Mg/L	Milligrams per liter
ha	Hector
HCL	Hydrochloric Acid
Km	Kilometer
^0C	Degree Celsius
%	Percentage
∑	Summation
APHA	American Public Health Association
C	Common
CDR	Conservation dependent and rare species
Cm	Centimeter
CN	Critically Endangered
CO_2	Carbon-dioxide
S	Species richness
r	Coefficient of correlation
J	Species evenness
R	Rare Near Threatened
SN	Serial Number

ABSTRACT

Barju lake is situated at Barju rural municipality of Sunsari district. This study was conducted from January to June 2022 covering winter, spring and summer seasons. The study area was divided into four stations for fish sampling and physio-chemical parameter was also analyzed. Local fishermen were hired for fish collection in sampling sites using cast net, drag net and traps. A total of 27 fish species (25 indigenous and two exotic) were recorded belonging to seven orders, 14 families and 20 genera. Out of which Cypriniformes (62.97%) and Cyprinidae (57.43%) were the dominant order and family respectively. *Puntius chonchonius* was the dominant species followed by *Puntius sophore*, *Mystus tengara*, *Puntius ticto* whereas *Channa gachua*, *Mastacembelus puncalus*, *Esomus dendricus* and *Heteropneutes fossilis* were found occasionally. The maximum numbers of species were captured during summer season (25) and minimum (10) in winter and site wise maximum species (25) from site II and minimum (10) from Site I and IV respectively were collected. The highest Shannon diversity index is 3.06 in summer; Margalef's richness index was 25.82 in summer whereas highest evenness index was 0.52 in spring. The RDA results showed that environmental variables such as pH, free carbon dioxide, DO, Transparency and Water temperature slightly influence the fish community structure. *Puntius chonchonius* shows strong positive correlation with transparency and dissolved oxygen in Barju Lake, Sunsari, Nepal. *Puntius chonchonius*, *Puntius sophore*, *Lepidocephalis guntea*, *Puntius ticto*, *Mystus tengra* and *Pseudombasis baculis* form disparate cluster as these fish species are most abundant species among all seasons. Although the exotic fish species were cultured there, the abundance of indigenous species was not hampered as the catch was nominal in case of exotic species (% catch indigenous species 97.08% and exotic species 2.91 %).

Keywords: Cypriniformes, Ichthyofaunal diversity, Water quality parameters etc

1. INRODUCTION

1.1 General background

Nepal is a small country situated on the southern slopes of the mid Himalayan range. It is surrounded by Tibetan region of China from northern side and by India on the South, East and West. Nepal is rectangular and elongated in shape with a total area of 1, 47,516 sq. Km and Its geographic position lies between 26.22" to 30.27" north latitudes and 80.4" to 88.12" east longitude. Nepal is topographically diverse country which is divided into three distinct regions: Himalayan region, Sub Himalayan region and Terai region (K.C 2015).

Fishes are the most well-known aquatic lower vertebrates, and their diversity are abundant in all form of surface water resources i.e. from Antarctic water that is below freezing point to hot springs of approximately 40-44°C (Shukla & Pandey 2005) . Fish are cold-blooded, jawed, aquatic vertebrates which breathe by means of gills and show movement by means of fins (Shrestha & Pandit 2017). Fishes are important indicator of water quality (Husan 2016). Fish diversity and distribution are highly influenced by environmental parameters such as temperature, dissolved oxygen (DO), free carbon dioxide (CO2), pH, alkalinity etc. (Yan et al. 2010). Both physico-chemical and biological properties I.e. Planktons are necessary for an aquatic environment to be healthy (Venkatesharaju et al., 2010). Freshwater fish populations in natural water bodies are declining by different factor such as pollution, flood, unsafe fishing methods, habitat destruction, over exploitation etc. (Shrestha 1994). In Nepal, majority of farmers follows conventional fishing methods such nets (cast nets, gill nets, and scoop nets), fishing rods (hook and line), loops, and fish spearing. But, the use of destructive fishing methods has increased recently which includes the use of electric fishing, explosions, and toxins (Pinkey 2016).

Freshwater ecosystems are already declining its biodiversity at a faster rate when compared to than terrestrial systems (Tickner et al. 2020), and they are subject to different anthropogenic influences such as climate change and the development of structures in water resources on a global scale (Reid et al. 2019). Therefore, it is important to conserve

and preserve the primitive ecosystems to understand the link between the environment and fish species distributions (Tickner et al. 2020).

1.1.1 Water Resources of Nepal

Nepal is a landlocked country having 2.27% of the world's freshwater resources that covers around 5% of its overall territory (Gandhiv & Isidro, 2009). This geographically diverse country has abundant freshwater resources including nearly 6,000 rivers (Gautam 2015) and 5,000 standing water such as lakes , ponds, marshes, reservoir, irrigated paddy fields etc. (Bhuju, Sharma 2012). Majority of those lakes or ponds are either in the high elevation (above 3000 m) or in low land plain (below 500 m) (Bhuju, Sharma 2012).

Table - 1 Available water resources in Nepal

S.N.	Resource detail	Estimated area (ha)	Coverage (%)	Potential for fisheries (area in ha)
1	Natural resources	401,500	49	-
1.1	Rivers	395,000	48.21	-
1.2	Lakes	5,000	0.61	3,500
1.3	Reservoirs	1,500	0.012	78,000
2	Ponds	7,300	0.89	14,000
3	Swamps and wetlands	12,500	1.52	12,500
4	Irrigated paddy fields	398,000	48.57	1,00,000
	Total	819,300	100	

Source: fisheries development (DoFD, 2014)

1.1.2 Lake system of Nepal

Recent report of the (National Lakes Conservation Development Committee 2015) has reported that 5,358 is the total number of lakes in Nepal (including 2323 glacial lakes). There are nine wetlands which are identified as Ramsar sites in Nepal. The lakes and wetlands of Terai region of Nepal holds suitable habitat for 28 species of fish (Shrestha 2011). Few studies have been done on the fishes of Nepal's marshland known as *Ghol*, Which also serve as good habitat for fish (Oli et al. 2013). This freshwater ecosystem provides protein rich environments for aquatic creatures and plants, especially freshwater fishes, to survive (Gubhaju 2012).

1.1.3 Barju Lake of Nepal

Barju lake is situated at Barju rural municipality ward no. 6 ,Chimadi of Sunsari district, Koshi zone, Province no. 1, Eastern Nepal. It is 12 km northwest from Biratnagar. It covers an area of 165 Bigaha and lies at 26°29'19"N; 87°10'33" E. Barju gaupalika of Sunsari district in eastern Nepal covers an area of 69.43 km2 with population of 31,178. Tharu indigenous community dominates population in this Gaupalika. Majority of local people are landless and economically poor. Barju Lake is one of the main sources of water for household activities and fishing to local people and it has tremendous potential to change likelihoods of entire gaupalika through fishery and tourism etc. A preliminary survey was done prior to the selection of sampling station.

1.1.4 Fishes of Nepal

First scientific data on total fish species of Nepal was reported by Hamilton (1822) was 267 fish species. In 20th century, with the rising of academic institutions related to fish and fisheries, study on fisheries and fish fauna of Nepal was flourished. Rajbanshi (2012) reported a list of 228 fish species in Nepal. Recently, Shrestha (2019) provided a checklist of 252 species (236 indigenous and 16 exotic) of fish from Nepal in his book "Ichthyology of Nepal".

Table - 2 List of conservation status of fishes of Nepal

S.N.	Categories	Designation	No. of fish species
1	Common	C	71
2	Uncommon or lower risk/Least concern	UN	59
3	Conservation dependent and rare	CDR	28
4	Data deficient pristine rare ornamental	PRO	42
5	Critically endangered	CE	0
6	Endangered	EN	2
7	Extinct	EX	0
8	Vulnerable	VN	11
9	Rare or near threatened	R	23
	Total native species		236
10	Exotic		16
	Total native and exotic fishes of Nepal		252

Source: Ichthyology of Nepal (Shrestha, 2019)

1.2 Objectives

A) General objective

The general objective is to explore the fish diversity in Barju Lake Sunsari, Eastern Nepal.

B) Specific objective

The specific objectives are:

- To analyze physico-chemical parameters of Barju Lake.
- To assess fish diversity of Barju Lake by using diversity indices.
- To analyze relationship between fish diversity and physico-chemical parameters.

1.3 Significance of the study

Nepal is rich in context of fresh water resources including Sunsari District which is bounded by Koshi River from western side. Also there are several natural and artificial water resources in the Sunsari district. The study of fish diversity has benefited significantly from the various researches that have been conducted on these water resources. Barju Lake is one of the largest lakes of lowland of eastern Nepal. Several studies were conducted on the Wetlands flora and higher vertebrates such as birds, but the Fish diversity have not been studied yet of Barju Lake. There was a lack of knowledge on the diversity of fish species, abundance, frequency, and physico-chemical properties of water of Barju Lake. Therefore, the purpose of this research is to study the fish diversity and water quality of Barju Lake which help to report the ichthyo-faunal diversity and seasonal variation of fish and water quality parameters.

1.4 Limitation of the study

The study area was limited to selected sampling site of Barju Lake. One of the major limitations during the study was the time period which was only of six months. Another limitation was the only use of traditional and locally available fishing gear which was not helpful in capturing some species.

2. LITERATURE REVIEW

The history of ichthyology evolved along with Zoology which dates back from the time of Aristotle (384-322). He had a great knowledge of the general morphology of fishes and his gathered information regarding the different group of aquatic amphibians, mammals as well as aquatic invertebrates. His nomenclature of ichthyology was of only 115 species of fishes, where all of were native of Angina Sea adjacent to Greece. After Aristotle, regression period was seen in the science of Ichthyology till 1800 AD as no fruitful work was recorded.

Fish Diversity

Fish study in Nepal about fish diversity began in the 1800s, with (Hamilton 1822) who is known as the first individual to provide genuine information about Nepalese fishes where he identified 269 species in his book titled "An account of the fishes found in the River Ganges and its branches".

Saund & Shrestha (2007) studied on Biodiversity of fish and benthic fauna in Kulekhani reservoir, Makwanpur and reported only 2 indigenous fish species in the reservoir *Neolissocheilus hexagonolepis* and *Nazirator chelynoides* which contributed 2.4% and 1.36% whereas exotic fish species Bighead carp (*Aristichthys nobilis*) and Silver carp *(Hypophthalmichthys molitrix*) contributed 96.24%. Gautam et al. (2010) recorded 42 fish species belonging to six orders, 18 families and three genera in Jagadispur reservoir, one of the Ramsar sites of Nepal. Cypriniformes and Cyprinidae were the dominant orders and family in terms of species composition as well as catch composition respectively.

Mandal and Jha (2013) found a total of 26 species of fish belonging to five orders, six families and 18 genera from the different stations of Marshyangdi River in Lamjung district. Gautam et.al (2016) has done a study on a Rupa lake where he found that 23 different species were holding the Icthyo-faunal diversity graph. It was mentioned that these were from five orders, six families and 18 genera. In this list, 19 fish species were indigenous and four species were exotic fish species. The order cypriniformes was dominant fulfilling 69.56 % of total catch. *Tor putitora* was found to be only 0.12 % of the catch.

Joshi (2017) reported that the Ghodaghodi Lake of Kailali district hold a total of 13 species of fishes out of which Cypriniformes consists of 40% total species and the dominant species of this lake was *Labeo gonius* which was followed by *Mystus tengra*, *Nandus nandus*, and *Channa stratius*. Adhikari and Chhetri (2017) has done the research work on Sisauli Wetland area of Belbari Municipality, Morang from first week of April to last week of August, 2018 where they found that it harbour 19 species of fishes and also marked Sisauli wetland as productive land for agriculture and rich from the point of view of biological diversity.

Limbu et al. (2018) investigated ichthyofaunal diversity on Dewmai khola of Ilam district, Nepal. A total of 16 fish species belonging to three orders, six families and 11 genera were recorded. The dominant order was Crypniformes, followed by Cobitidae and Psilorhynchidae. Shrestha (2019) has reported the recent fish species data in Nepal which stated that the total number of fish species of Nepal is 252 with 236 native species including 16 exotic species and 16 endemic species. For scientific monitor, functional management and better conservation of the fisheries, there is a need to update the information on total assemblance of fish diversity, community structure and distribution patterns (Ngor et al. 2018). Pokharel and Chand (2019) reported 17 species of fishes from Begnas Lake of Pokhara which includes five orders, seven families and 17 genera out of which 11 species were indigenous, while six species were exotic. They recorded Family Cyprinidae was dominant in terms of both species composition and occurrence.

Chaudhary (2019) studied on fish diversity of Koilahee taal, Kailali, Nepal and reported a total of 13 species which includes 5 orders, 8 families and 11 genera. Out of total species, Order Cypriniformes (46%) and family Cyprinidae (28.08%) were the dominant order and family in terms of both species composition as well as individual captured. The most dominant fish species was *Amblyphryngodon microlepis* contributing 28.08% of the total catch.

A total of 28 fish species (27 indigenous and one exotic) were identified by (Chalise 2020) from Gajedi Lake, Rupandehi, Nepal where the dominant order and family were Cypriniformes and Cyprinidae whereas *Amblypharyngodon mola* was the most dominant species accounting 25.05% of the total catch followed by *Trichogaster fasciata* (18.88%), *Puntius chola* (9.26%). Kumar et al. (2022) reported 72 fish species from Lohandra River

in their study "Spatial and temporal variation of ichthyo-faunal diversity with relation to environmental variables in the Lohandra River, Eastern, Nepal".

Physico-chemical parameter of Water

The pH of water is defined as the logarithm of the reciprocal of hydrogen ion concentration which measures the acidity, alkalinity and neutrality of water. The suitable pH range for fish is 6.5-9 and pH more or less than this is not favorable, though some can survive outside of this range (Swingle 1967). DO concentration is the most vital factor and DO above 5mg/l is suitable to support diverse biota (APHA 1998). The dissolved oxygen (DO) indicates the level of free, non-compound oxygen present in water. The value of dissolved oxygen DO increases in winter due to circulation of cold water as well as high solubility of O_2 at low temperature (Praveen & Mudasir 2014). It is an important parameter of water quality because of its influence on the organisms living within a body of water (Fondriest Environmental Inc. “Dissolved Oxygen” 2013). When the temperature is Higher, the amount of dissolved oxygen will be lower and vice versa in the water (Dutta & Patra 2013).

According to Santosh and Singh (2007), the favorable water temperature for fish is between 24^0C to 30^0C .Thapa (2008) recorded the different water quality parameter of Dipang Lake in the Mid- hill of Kaski District, Nepal ranged from water temperature;23 ℃-30℃, pH; 6.2ppm-8ppm, DO; 5.1 mg/l-8.38 mg/l, CO_2; 0.8 mg/l-3.2 mg/l, total alkalinity; 50 mg/l- 100 mg/l, total hardness; 12 mg/l- 36 mg/l. Fish variety was observed to be declining daily as a result of pollution, illegal fishing, overgrowth of aquatic weeds, human activity, and the introduction of foreign fish.

Thapa (2018) study in Betana Wetland, Belbari, Morang in different physico-chemical parameter for two year and reported that air temperature showed a positive and negative significant co-relation with water temperature (r=0.947, p<0.01) but the co-relation with free CO2 water (r=-0.68, p<0.05), pH(r=0.563, p<0.05and DO (r=-0.582, p<0.05) was inverse. Choudhary (2019) studies water quality parameters of Koilahee taal, Kailali, Nepal and found the following results i.e. temperature: 26.5 ℃ - 31 ℃, pH: 7.5 - 8.5, DO: 5.5 mg/l - 6.8 mg/l, CO2: 2.08 mg/l - 4.7 mg/l, hardness: 42 mg/l - 46.5 mg/l) were observed within desired range which was favorable for lentic fishes.

Sharma and Gurung (2020) examined seasonal trends of fish catch with some environmental variables in Lake Phewa situated in mid hills of Nepal where they collected data of water quality parameters such as water temperature (C), rainfall (mm), Chlorophyll a (mg. L-1), and dissolved oxygen (DO, mg. L-1) once in a month. Their fish catch yield marked up to 20 time higher biomass in December comparing to August. Chalise (2020) found that the suitable range of water quality in Gajedi Lake, Rupandehi, Nepal for aquatic life was (temperature: 18℃-33.3 ℃; pH: 7.9- 8.4, transparency: 20.4 cm- 49.7 cm, DO; 7.7 mg/l- 8.92 mg/l; total alkalinity: 92.4 mg/l- 130 mg/l; total hardness: 79 mg/l- 160 mg/l).

3. MATERIALS AND METHODS

3.1 Materials

3.1.1 Equipment

GPS, Cast net, Drag net, pH meter (HANNA- HI98107), Thermometer, Do meter (Teknik EM-83D), Sampling bottles.

3.1.2 Chemicals

- 5-10% formalin
- NaOH, HCl, EDTA, Phenolphthalein, Methyl orange, Buffer, Starch.

3.2 Study Area

The present study was carried out in the Barju Lake which is situated at Barju rural municipality-6 of Sunsari district, Koshi zone, Province no.1, Eastern Nepal. It is also known as Chimdi Lake in local region. It is 12 km northwest from Biratnagar. It covers an area of 152 Bigaha and lies at 26°29'19"N, 87°10'33" E. The study area was divided into four sampling station.

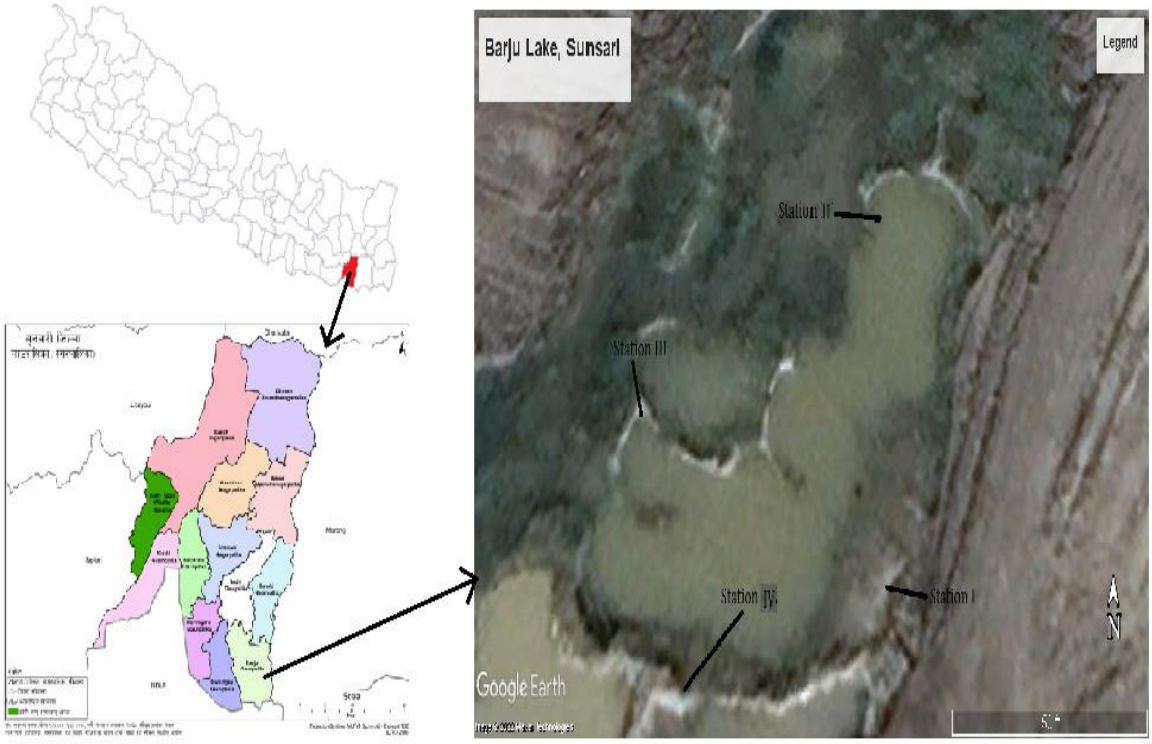

Figure - 1 Map of Study area.

3.3 Study Period

In order to cover three different seasons, the fieldwork for this study was done from January to June 2022. The sample sites were visited in the month of January-February, March-April and May- June.

3.3.1 Selection of sampling sites

The preliminary survey was done before starting the sample collection. Based on the physical characteristics of the lake and its environment, four sampling statins were chosen for the current study.

Station I

The sampling station I was selected at North-East side of lake. At this station, the water was clear and plenty of Zooplankton and Phytoplankton was found. This site was near human settlement.

Station II

The sampling station II was at North-West side. At this station, the water was clear and plenty of Zooplankton and Phytoplankton was found. This site was near agricultural land.

Station III

The sampling station III was at South-West side of lake. Here the water was clear and more quantity of Zooplankton and Phytoplankton were present. This site was near tourist spots and agricultural land.

Station IV

The sampling station IV was selected at South-East of Barju lake. At this station, the depth of lake was less and the water was not clear. This site was near to human settlements and traces of pollution can be noticed.

3.4 Sampling Method

3.4.1 Sample Collection

The survey was conducted thrice in six months between 2022/01/05 - 2022/06/11. For fish collection from sampling site, local fishermen were hired. Cast net with different mesh size, drag net, traps etc. were used for fish collection at each sampling station. Two-three hours was spent in each sampling site in order to cover maximum area of lake. Excess live fish were released back to the river after required sample species collection. Information about local name and their special features was obtained from the fishermen and field guidebook. Fish species available at the local market caught by local fishermen from Barju were also purchased and detail information was recorded.

3.4.2 Identification of specimens

The fish species collected from the sampling station of study area were identified using standard field guide of Shrestha (2008, 2019) and Jayaram (1981).

3.4.3 Preservation of specimens

The collected samples from sampling site were preserved in 10% formalin solution and stored in plastic jar. All set of identified fish species are kept in the Zoology Department of Amrit campus.

3.5 Statistical analysis

Statistical analysis of fish number in relation with the temperature, pH, carbon dioxide and dissolved oxygen was done by calculating correlation coefficient by the Karl Pearson method (1988).

$$\text{Correlation coefficient(r)} = \frac{\sum xy}{\sqrt{\sum x^2 . \sum y^2}}$$

where,

x and y are deviation of the data from their mean.

$$\text{Probable Error(P)} = \frac{(1 - r^2)}{\sqrt{N}} \text{x } 0.6745$$

The better analysis of fish species was carried out. The statistical methods used here are the Shannon-Weiner index, Evenness index and species richness (Gautam et. al 2016).

Shannon-Weiner index:

Shannon-Weiner diversity index is denoted by H' which is given as:

$H' = -\Sigma P_i \log P_i$

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 one to species S

Evenness index:

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

Evenness (J) =H'/ln S

Where,

J = Evenness index,

H' is the Shannon-Weiner index,

H_{max}=log S, 'S' is the number of species.

Species richness index:

The species richness is calculated by (Margalef 1968).

Species richness (S) = s-1/ln N

Where,

S= index of species richness

N= total number of species

s= Individual number of species

3.6 Water Parameters Analysis

Water sample of Barju lake were collected during morning time. The physical parameters such as temperature, transparency and chemical parameters such as pH and dissolved oxygen were analyzed immediately in the field. Other chemical parameters were analyzed in the laboratory of Amrit Science Campus, Lainchaur, Kathmandu followed by standard method of APHA (1998) and Trivedy & Goel (1984).

3.6.1 Physical parameters analysis

(a) Water colour:

The colour of water determined taking water in a beaker from the lake and placed on a white paper and thus the colour was observed.

(b) Water Depth:

The depth was measured by using rope with hanging the stone and measuring tape was used to recorded depth in centimeters (cm).

(c) Water Transparency

A secchi disc was used to determine transparency. The secchi disc is a metallic plate with four quadrants (alternating black and white) and a rope-tying hook in the center. The lake's transparency was determined using the formula below.

$$\text{Transparency (D)} = \frac{X+Y}{2} \text{ (cm)}$$

Where, D = Transparency in cm.

X = Depth at which Secchi disc disappears.

Y = Depth at which Secchi disc reappears.

(d) Temperature

The temperature of the water was measured by dipping the bulb of a standard mercury thermometer into the water.

3.6.2 Chemical parameters analysis

(a) Hydrogen ion concentration (pH):

During the investigation, the Hydrogen ion concentration in water was measured using a battery-powered digital pH meter (HANNA- HI98107).

(b) Dissolved Oxygen:

The dissolved oxygen in the water was measured directly using a digital dissolved oxygen meter (Teknik EM-83D) by dipping the probe into the surface water.

(c) Free Carbon- dioxide (CO_2)

The amount of free carbon dioxide was done by titrating a water sample against a standard alkali titrant (NaOH 0.05N) and using the phenolphthalein indicator and calculated by,

$$\text{Free } CO_2 \text{ mg/l} = \frac{(\text{ml} \times \text{N}) \text{ of NaOH} \times 1000 \times 44}{\text{Volume of sample used (ml)}}$$

Where,

ml = Amount of NaOH used during the Titration

N= Normality of NaOH

V= Volume of water sample taken (ml)

4. RESULT

4.1 Physical parameter

4.1.1 Water Colour

The water colour of Barju Lake was clear and transparent. During monsoon season, due to heavy flooding the colour of river was greyish and muddy but in other season it was clear.

4.1.2 Water Depth

The depth of Barju lake during study period and ranged from 150 cm to 95.3 cm. Highest depth was recorded in winter season 150 cm at station II, lowest was recorded 95.3 cm in Summer at station IV. The average depth was recorded as 118.8cm.

Table - 3 Station and Season wise water depth

Months	Stations				Max	Min
	I	II	III	IV		
Winter	115.0	150.0	125.4	100.1	150.0	115.0
Spring	101.3	105.2	103.6	99.7	105.2	99.7
Summer	96.7	101.4	99.5	95.3	101.4	95.5
Average	104.4	118.8	109.5	98.7	118.8	103.1

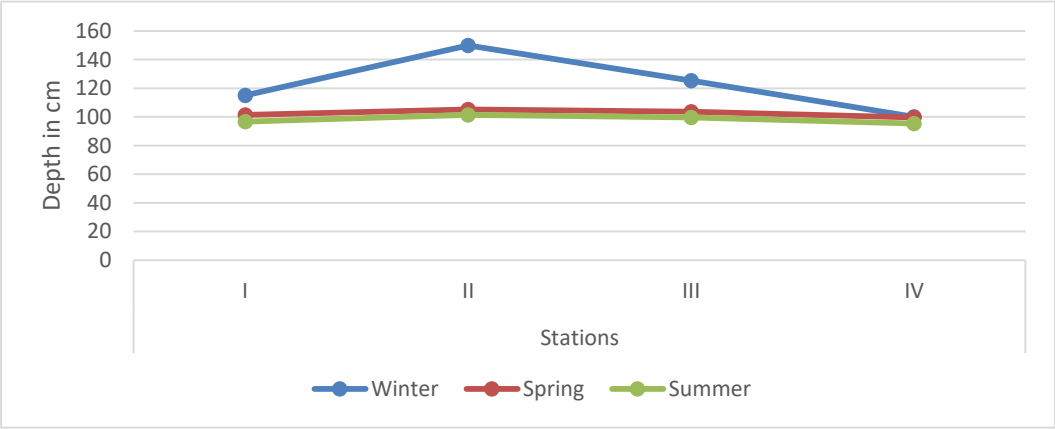

Figure - 2 The relation of fish diversity with water depth

4.1.3 Water Temperature

The surface water temperature ranged from 16.20-31.90 ^{0}C. During the study period, lowest temperature was recorded in winter 16.20 ^{0}C at station I and highest in summer 31.90 ^{0}C at station IV. The average value of water temperature was 26.60 ^{0}C.

Table - 4 Station and Season wise water temperature

Months	Stations				Max	Min
	I	II	III	IV		
Winter	16.20	16.40	17.30	17.50	17.5	16.2
Spring	25.40	25.30	25.90	30.40	30.40	25.40
Summer	28.60	28.90	30.30	31.90	31.90	28.60
Average	23.4	23.5	24.5	26.6	26.6	23.4

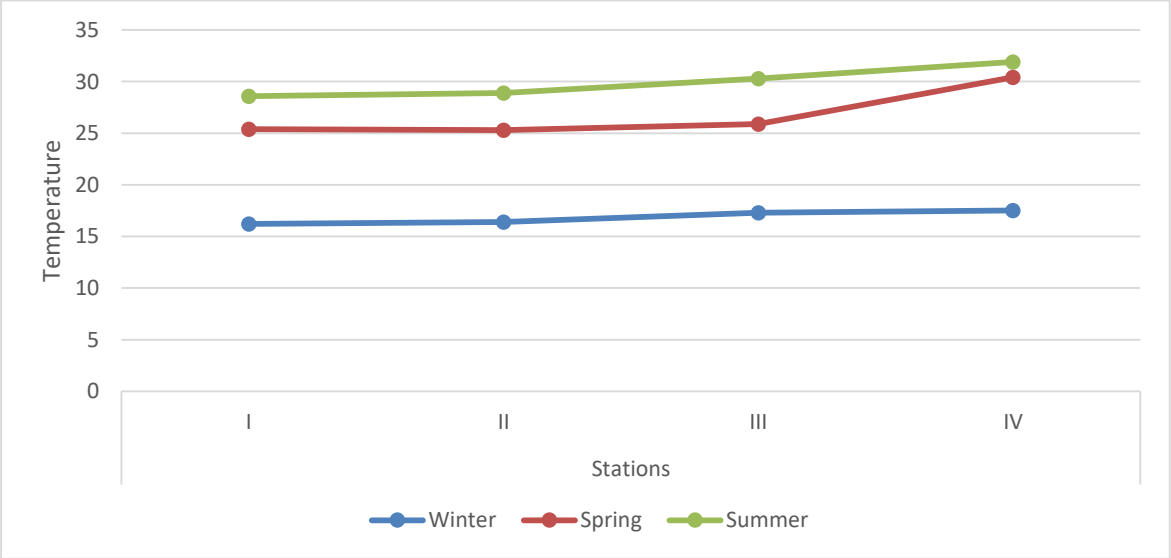

Figure - 3 The relation of fish diversity with water temperature

4.1.4 Transparency

The water was almost clear and transparent throughout the year except in rainy seasons. The transparency ranged from 26.1 to 33.9 cm. The highest transparency was 33.9 cm recorded in summer at station IV and lowest transparency was 26.1 cm recorded in winter at station I. The average transparency was recorded in 29.83 cm.

Table - 5 Station and Season wise Transparency

Months	Stations				Max	Min
	I	II	III	IV		
Winter	26.1	26.2	26.5	26.9	26.9	26.1
Spring	28.2	28.3	28.5	28.7	28.7	28.2
Summer	32.2	32.6	32.2	33.9	33.9	32.2
Average	28.83	29.03	29.06	29.83	29.83	28.83

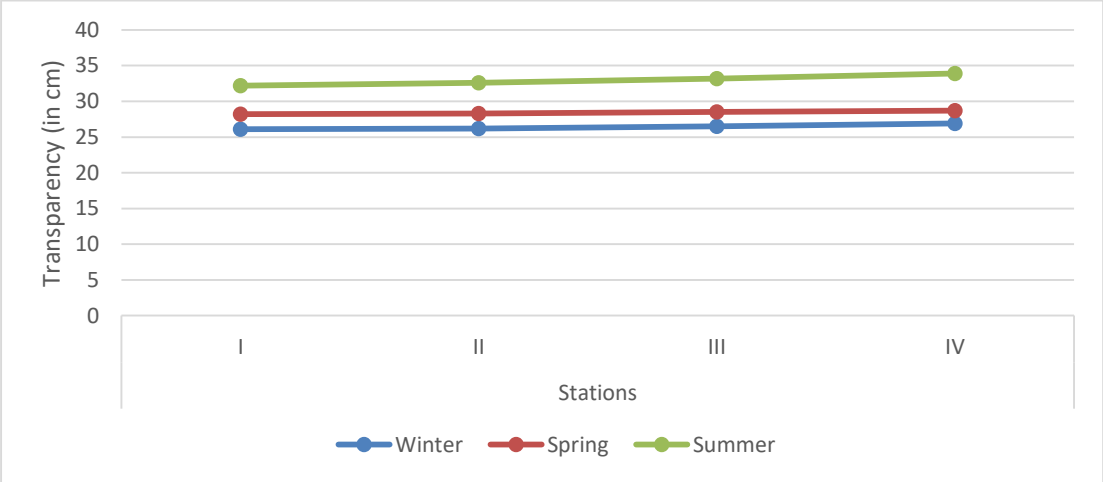

Figure - 4 The relation of fish diversity with Transparency

4.2 Chemical Parameter

4.2.1 Hydrogen ion concentration (pH)

The pH of water ranged from 7.1 - 7.9 ppm. The lowest pH was 7.1 ppm in winter at station I. The pH was recorded highest in summer 7.9 ppm at station IV. The average pH value was recorded in 7.7 ppm.

Table - 6 Station and Season wise pH value

Months	Stations				Max	Min
	I	II	III	IV		
Winter	7.1	7.3	7.5	7.6	7.6	7.1
Spring	7.3	7.5	7.5	7.7	7.7	7.3
Summer	7.2	7.6	7.8	7.9	7.9	7.2
Average	7,2	7.4	7.6	7.7	7.7	7.2

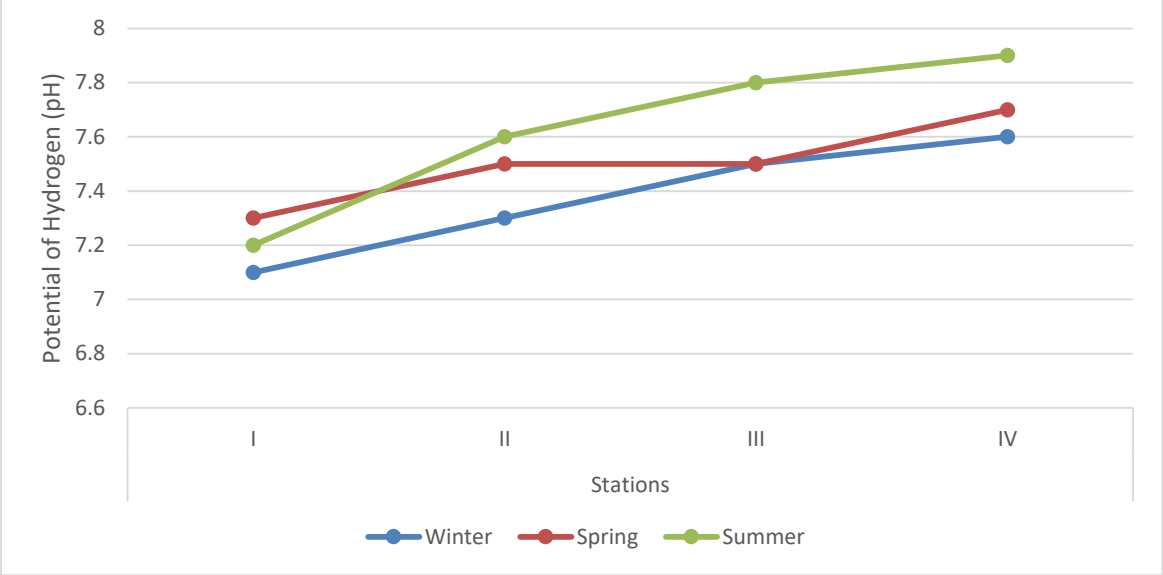

Figure - 5 The relation of fish diversity with water pH

4.2.2 Dissolved Oxygen (DO):

The oxygen is most important for the fish distribution in the lakes. During the study period DO value ranges from 9.0- 10.1 mg/l. The highest DO was found to be 10.1 mg/l at site I in winter season and minimum DO was found to be 9.0 mg/l at site I and II in spring and summer with an average dissolved oxygen of 9.7 mg/l.

Table - 7 Station and Season wise Dissolved Oxygen

Months	Stations				Max	Min
	I	II	III	IV		
Winter	9.2	9.5	9.6	10.1	10.1	9.2
Spring	9.0	9.2	9.21	9.4	9.4	9.0
Summer	9.1	9.0	9.2	9.6	9.6	9.0
Average	9.1	9.2	9.3	9.7	9.7	9.06

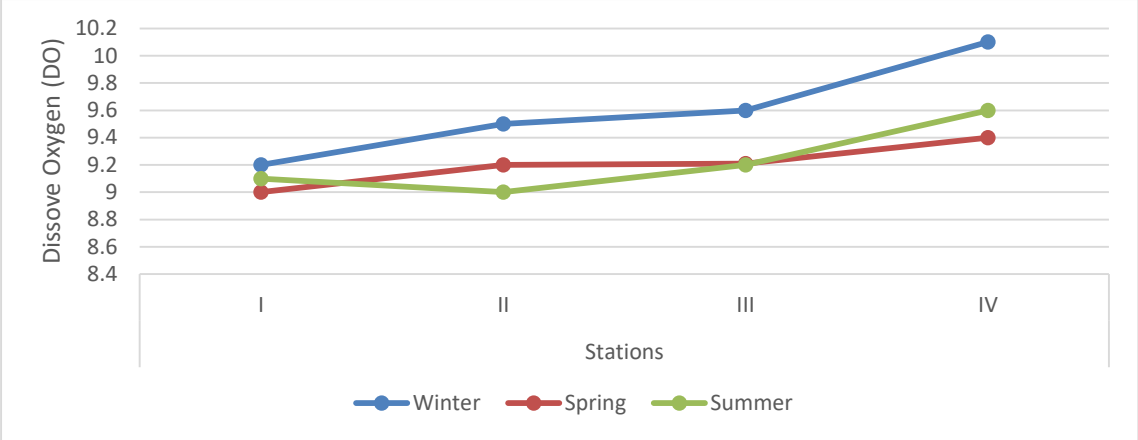

Figure - 6 The relation of fish diversity with water DO

4.2.3. Free Carbon dioxide (CO2):

The free carbon dioxide of the ranged from 2.3-2.9 mg/l. The highest Free CO_2 was 2.9 mg/l recorded in winter season at station IV. Lower value of 2.3 mg/l at station I in winter with an average value of 2.8 mg/l.

Table - 8 Station and Season wise Free Carbon dioxide.

Months	Stations				Max	Min
	I	II	III	IV		
Winter	2.3	2.4	2.8	2.9	2.9	2.3
Spring	2.4	2.5	2.4	2.7	2.7	2.4
Summer	2.8	2.6	2.7	2.8	2.8	2.6
Average	2.5	2.5	2.6	2.8	2.8	2.4

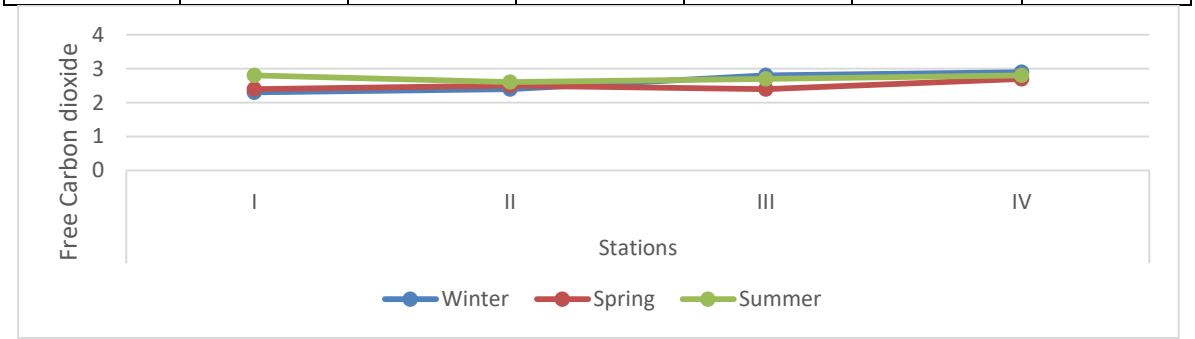

Figure - 7 The relation of fish diversity with water CO_2

4.3 Fishery resources of Barju Lake

4.3.1 Fish diversity of Barju Lake

During the study period of Barju Lake, 343 individual fishes were recorded belonging to seven orders, 14 families, 20 genera and 27 species. The total number of captured fish was highest at station II, III, I respectively and Station IV had the lowest capture count whereas species diversity was highest at Station II and lowest at Station IV. Among total species *Puntius sophore, Puntius chonchonius, Mystus tengra, Puntius ticto, Channa gachua* were the dominant species. Out of them 25 indigenous species and two exotic species were found.

4.3.2. Systematic Position of Fishes

During the study period of Barju Lake, 343 individual fishes were recorded belonging to seven orders, 14 families, 20 genera and 27 species. The total number of captured fish was highest at station II, III, I respectively and Station IV had the lowest capture count whereas species diversity was highest at Station II and lowest at Station IV. Among total species *Puntius sophore, Puntius chonchonius, Mystus tengra, Puntius ticto, Channa gachua* were the dominant species. Out of them 25 indigenous species and two exotic species were found.

Table - 9 Systematic Position of Fishes

S.N.	Order	Family	Genus	Species	Name
1.	Cypriniformes	Cyprinidae	*Labeo*	*rohita*	Rahu
			Puntius	*chonchonius*	Sidre
				sophore	Pothi
				ticto	Pothi
				sarana	Darahi
			Cirrhinus	*mrigala*	Naini
				reba	Kursha
			Hypophthalmichthys	*molitrix*	Silver carp

			Catla	*catla*	Bhakur
			Pseudombassis	*baculis*	Chanda sps.
			Esomus	*dandrica*	Dedhuwa
		Cobitidae	*Lepidocephali*	*guntea*	Lata
		Cichlidae	*Cyprinus*	*carpio*	Common carp
2.	Siluri-formes	Siluridae	*Wallago*	*attu*	Buwari
		Claridae	*Clarias*	*batrachus*	Magur
		Hetero-pneustidae	*Heteropneustes*	*fossilis*	Singi
		Bagridae	*Mystus*	*tengara*	Tengra
3.	Syn-branchi-formes	Masta-cembelidae	*Mastacembelus*	*puncalus*	Kath Gaichi
		Syn-branchidae	*Monopterus*	*cuchia*	Andha bam
4.	Anaban-tiformes	Channidae	*Channa*	*orientalis*	Chenga
			Channa	*gachua*	Chenga
			Channa	*punctata*	Garai
			Channa	*striata*	Saura
		Osphrone-midae	*Tricogaster*	*lalius*	Kotri
5.	Gobi-iformes	Gobidae	*Glossogobius*	*guiris*	Bhulla
6.	Anguil-lifomes	Anguillidae	*Anguilla*	*bengalensis*	Raj Bam
7.	Clupei-formes	Clupeidae	*Sardinella*	*longiceps*	Chelha

4.4 Fish distribution and frequency occurrence in the Barju Lake.

Barju Lake reported a total of 27 fish species, including 25 indigenous and two exotic species. Site II reported a total of 25 fish species, the most prominent of which were *Puntius sophore*, *Esomus dendricus*, *Puntius chonchonius*, *Mystus tengra*, and *Channa ga-*

chua respectively. At site IV, 10 species were recorded among which *Channa gachua* and *Puntius sophore* were the dominant species. A total of 14 fish species are recorded at Site III, with *Puntius sophore*, *Pseudombassis baculi*s, and *Puntius chonchonius* being the three most abundant species respectively. There were only 10 species of fish reported at site I, the most common of which were *Mystus tengra*, *Puntius chonchonius* and *Puntius sophore* respectively. Similarly, *Puntius chonchonius* provided around 13.41% of the overall catch composition, *Puntius sophore* 11.37%, and *Esomus dandrica* 9.03%. However, the remaining fish species contributed around 66.19% of the overall catch.

Table - 10 Fish frequency distribution of Barju Lake.

S N.	Scientific name	Local name	Stations				Total no. of fish	Frequency %
			I	II	III	IV		
1.	*Labeo rohita*	Rahu	2	6	6	0	14	4.08
2.	*Puntius chonchonius*	Sidre	9	21	8	8	46	13.41
3.	*Puntius sophore*	Pothi	13	11	9	6	39	11.37
4.	*Puntius ticto*	Pothi	4	6	4	4	18	5.25
5.	*Puntius sarana*	Darahi	3	4	2	1	10	2.92
6.	*Cirranus mrigala*	Naini	1	3	0	0	4	1.17
7.	*Cirranus reba*	Kursha	2	2	2	0	6	1.75
8.	*Catla catla*	Silver carp	1	2	1	0	4	1.17
9.	*Hypophthalmichthys molitrix*	Bhakur	0	3	3	0	6	1.75
10.	*Pseudombassis baculis*	Chanda sps.	4	5	7	3	19	5.54
11.	*Esomus dandricus*	Dedhuwa	7	7	8	9	31	9.04
12.	*Cyprinus carpio*	Common carp	0	2	2	0	4	1.17
13.	*Lepidocephalis guntea*	Lata	5	5	3	2	15	4.37
14.	*Wallago attu*	Buwari	0	2	2	0	4	1.17
15.	*Clarias batrachus*	Magur	1	5	3	2	11	3.21
16.	*Heteropneustes fossilis*	Singi	3	7	3	4	17	4.96
17.	*Mystus tengara*	Tengra	0	3	4	0	7	2.04
18.	*Channa orintalis*	changa	3	2	1	0	6	1.75

19.	*Channa puntata*	Garai	3	5	4	4	16	4.66
20.	*Channa striata*	Saura	1	1	1	1	4	1.17
21.	*Channa gachua*	Changa	4	4	3	0	11	3.21
22.	*Tricogaster lalius*	Kotri	1	4	1	1	7	2.04
23.	*Mastacembelus puncalus*	Kath Gaichi	2	3	7	4	16	4.66
24.	*Monopterus cuchia*	Andha bam	0	0	3	2	5	1.46
25.	*Glossogobius guiris*	Bhulla	0	1	3	0	4	1.17
26.	*Anguilla bengalensis*	Raj Bam	0	4	1	0	5	1.46
27.	*Sardinella longiceps*	Chelha	4	5	4	1	14	4.08
			73	122	95	53	343	100%

4.4.1 Genus wise fish distribution and frequency occurrence of Barju lake.

During the research period, fish species belonging to 20 genuses were recorded. The distribution and frequency of *Puntius* 32.94%, *Channa, Labeo, Cirrhinus, Hypophthalmichthys, Pseudombassis, Esomus, Lepidocephalis, Clarias, Heteropneuster, Mystus, Trigogater, Mastacembelus, Monopterus, Anguilla, Sardinella, Catla, Cprinus, Wallago* and *Glossogobius* 1.17% the fishes were recorded.

Table - 11 Shown the result of fish frequency distribution by genus wise.

S.N.	*Genus*	No. Of fish caught	Average no. (%)
1.	*Labeo*	14	4.08
2.	*Puntius*	113	32.94
3.	*Cirrhinus*	10	2.92
4.	*Catla*	4	1.17
5.	*Hypophthalmichthys*	6	1.75
6	*Pseudombassis*	19	5.54
7..	*Esomus*	31	9.04
8.	*Cyprinus*	4	1.17
9.	*Lepidocephalis*	15	4.37
10.	*Wallago*	4	1.17
11.	*Clarias*	11	3.21
12.	*Heteropneuster*	17	4.96
13.	*Mystus*	7	2.04

14.	*Channa*	37	10.79
15.	*Trigogaster*	7	2.04
16.	*Mastacembelus*	16	4.66
17.	*Monopterus*	5	1.46
18.	*Glossogobius*	4	1.17
19.	*Anguilla*	5	1.46
20.	*Sardinella*	14	4.08
	Total		100

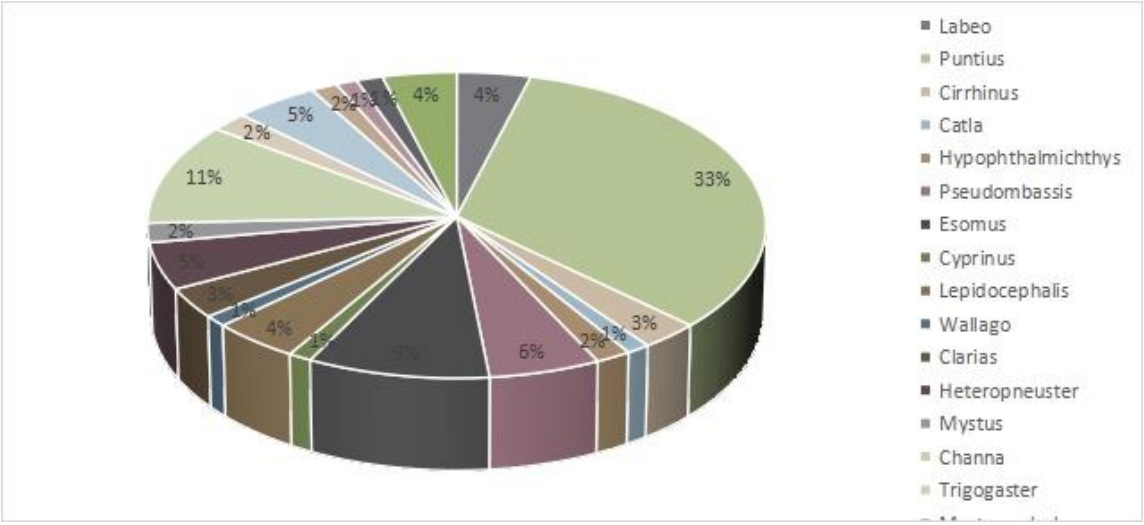

Figure - 8 Genus wise Fish Diversity

4.4.2. Family wise distribution pattern of Barju Lake in Sunsari.

Throughout the course of the investigation, a total of 14 Families were recorded. The most significant family was Cyprinidae, contributing 57.43%. Families Cichlidae, Cobitidae, Siluridae, Claridae, Heteropneustidae, Bagridae, Channidae, Osphronemidae, Mastacembelidae, Synbranchidae, Anguillidae, Clupeidae and Gobidae each provided an equal number of species by 1.17% (Table - 12).

Table - 12 Family wise fish distribution and pattern

S.N.	Family	No.of fish	Average no. (%)
1.	Cyprinidae	197	57.43
2.	Cichlidae	4	1.17
3.	Cobitidae	15	4.37
4.	Siluridae	4	1.17

5.	Claridae	11	3.21
6.	Heteropneustidae	17	4.96
7.	Bagridae	7	2.04
8.	Channidae	37	10.79
9	Osphronemidae	7	2.04
10.	Mastacembelidae	16	4.66
11.	Synbranchidae	5	1.46
12	Gobidae	4	1.17
13.	Anguillidae	5	1.46
14.	Clupeidae	14	4.08
	Total		100

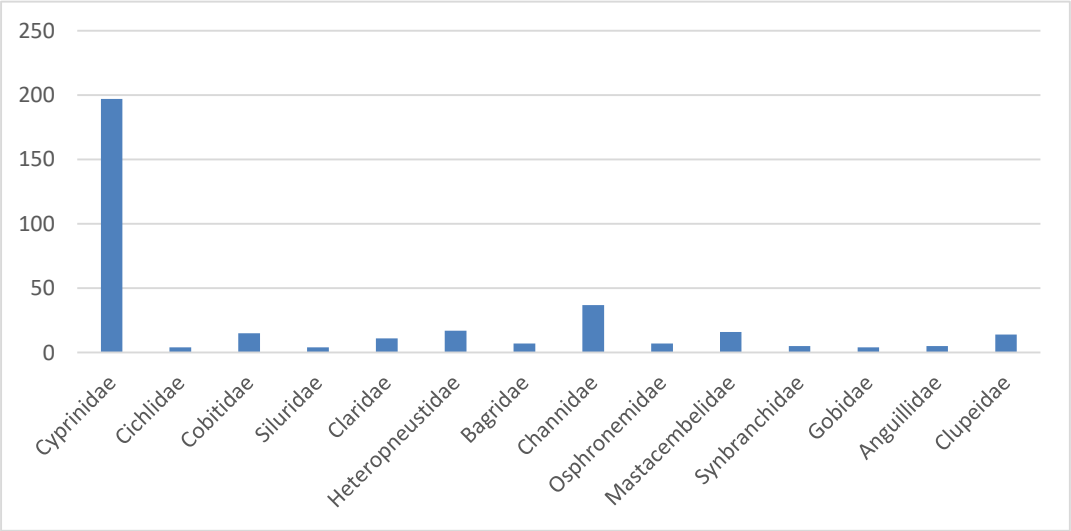

Figure - 9 Family-wise species composition.

4.5 Statistical Analysis

4.5.1 Correlation Coefficient and Parabola error in different variables

The statistical analysis to determine the coefficient of correlation and probable error between the different physico-chemical parameter and number of fish species for all the stations have been calculated by Karl Pearson method with the help of Ms . Excel 2010 as shown in table 13.

Table - 13 Correlation value of the physico-chemical and fish density.

S. N.	Correlation between fish number and …….	Station I		Station II		Station III		Station IV	
		r	P.Er.	r	P.Er.	r	P.Er.	r	P.Er.
1.	water depth	-0.98	0.01	-0.73	0.18	-0.94	0.04	-0.94	0.04
2.	water temperature	0.98	0.01	0.86	0.10	0.99	0.01	0.86	0.10
3.	water transparency	0.97	0.03	0.99	0.01	0.98	0.02	0.99	0.01
4.	free carbon dioxide	0.91	0.06	0.95	0.03	-0.28	0.36	0.91	0.07
5.	pH	0.57	0.26	0.88	0.09	0.85	0.11	0.92	0.06
6.	DO	-0.57	0.26	-0.91	0.06	-0.89	0.08	-0.61	0.25

4.5.2 Diversity abundance of species in communities

Table - 14 The diversity abundance of different communities.

Stations	No. of Individuals (N)	Shannon Wiener Index of Diversity (H')	Species Evenness (J)	Species Richness (S)
Station I	73	2.73	0.467	19.83
Station II	122	3.01	0.516	25.826
Station III	95	3.06	0.524	25.829
Station IV	53	2.47	0.424	14.829

The value of Shannon Wiener diversity index, Species richness and Evenness were calculated individually at each station. The highest Shannon Wiener diversity index was found in station III (3.06) and lowest value was found in station IV (2.47). The maximum Species richness value was observed lowest (14.829) at station IV whereas highest value was observed (25.829) at station III. Evenness index was found to be highest at station III (0.524) and lowest at station IV (0.424). The value of Shannon-Wiener diversity, Species richness and the Evenness in different stations data are presented in the table 14.

4.6 Relationship between different sites, seasons, environment variables and abundance of fish species

4.6.1 Ordination

Detrended Correspondence Analysis (DCA) had an axis length of 1.16 which is less than 3.5 and eigenvalues is also less than 50%, therefore RDA's application was applicable.

4.6.2 Relationship between fish diversity and physico-chemical parameters

The result obtained from redundancy analysis (RDA) showed that Transparency (Trans) and Temperature were found significantly correlated and the same way dissolved oxygen (Diss_Oxy) and free carbon dioxide (Free_car) were also found significantly correlated (Fig 10) .Water depth had strong negative realtion to dissolved oxygen (Diss_Oxy) and free carbon dioxide (Free_car). *Puntius sophore* shows strong positive correlation with Water depth where as it shows negative relation dissolved oxygen (Diss_Oxy) and free carbon dioxide (Free_car). In the same way *Mastacembelus puncalus* and *Mystus tengra* shows strong positive correlation with to Transparency (Trans) and Temperature (Tem) but they are not negatively related with any water quality parameter. Channa pun, Chan_pun =*Chana punctatus* was strongly positvly related with alkality of water whereas it was negatively related with *Chan_gac= Channa gachua.*

Abbreviations: *Labe _roh= Labeo rohita, PunT_chon= Puntius chonchonius, Punt_sop= Puntius sophore Punt_tic= Puntius ticto, Punt_sar= Puntius sarana, Cirr_mri=Cirrhinus mrigala Cirr_reb= Cirrhinus reba, Catl_cat= catla catla, Hypo_mol= Hypophthalmichthys molitrix, Pseu_bac= Pseudombassis baculis, Cyp_car= Cyprinus carpio, Lepi_gun= Lepidocephali guntea,Wal_atu= Wallago attu, Esom_dan= Esomus dandricus, Cla_bat= Clarias batrachus,Hete_fos= Heteropneustes fossilis, Mys_ten= Mystus tengara, Chan_orin= Channa orientalis, Chan_pun= Channa punctate, Chan_str= Channa striata, Chan_gac= Channa gachua,Tric_lal= Tricogaster lalius, Mast_pun= Mastacembelus puncalus, Mono_cuc= Monopterus, cuchia, Glos_gui= vbGlossogobius guiris, Angu_ben= Anguilla bengalensis, Sard_lon= Sardinella.*

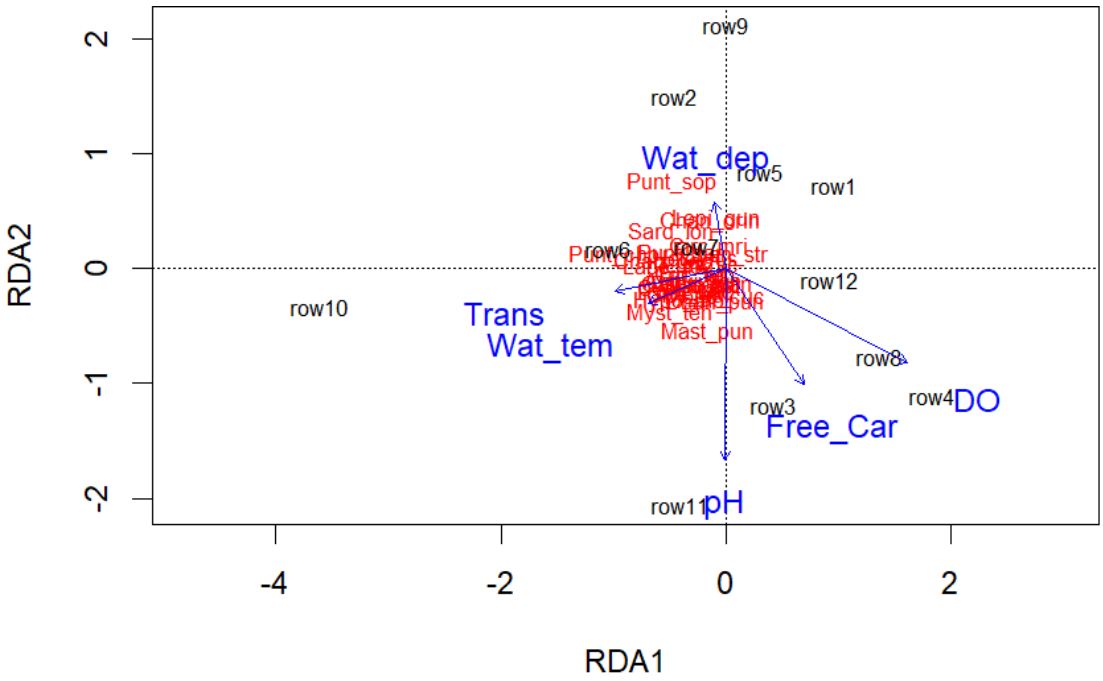

Figure - 10 RDA analysis of fish species with environmental variable

4.6.3 Cluster Analysis

The cluster analysis comparing fish species on the basis of fish assemblage (Fig 11). *Cirrhinus reba, Cirrhinus mrigala, Channa gachua, Channa striata* and *Channa orientalis form* disparate cluster in the right part of cluster dendrogram. These species are observed throughout the seasons and have the average frequency among all species. *Esomus dendrica, puntius sophore and puntius chonchonius* remains in the same cluster dendrogram since it was the most dominant species in lake. *Glossogobius guiris, Wallago attu, and* Monopterus *cuchia* forms disparate cluster as these species are least catches and absents from station I and IV. *Catla catla* and *Cyprinus carpio* were placed in same cluster as both the species were absent from station IV. *Hypophthalmicchthys molitrix* and *Anguilla bengalensis* were also placed in same cluster along with *Mystus tengra* as they have less catches or no catches from station IV. *Puntius sarana* and *Clarias batrachus* shares the same clusters as they share the same number of fish catch at station III. In the same way *Pseudombassis baculis, Puntius ticto* and Channa punctate were placed in same cluster as they share the same number of fish catches from station III.

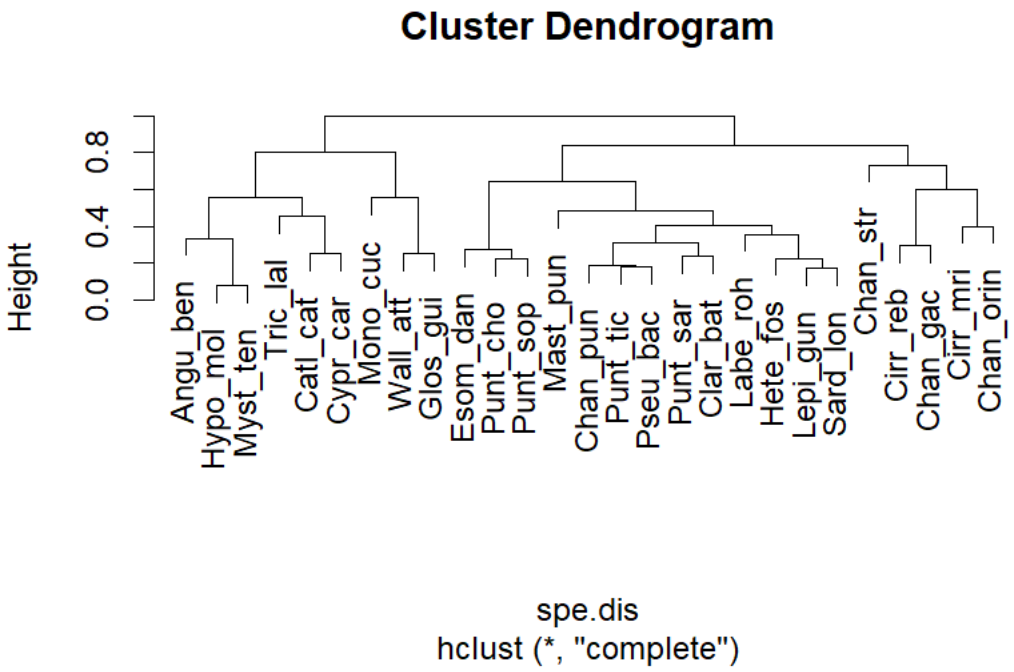

Figure - 11 Dendrogram of cluster analysis comparing fish species on the basis of fish assemblage.

Abbreviations:

Labe _roh= Labeo rohita, PunT_chon= Puntius chonchonius, Punt_sop= Puntius sophore, Punt_tic= Puntius ticto, Punt_sar= Puntius sarana, Cirr_mri=Cirrhinus mrigala, Cirr_reb= Cirrhinus reba, Catl_cat= catla catla, Hypo_mol= Hypophthalmichthys molitrix, Pseu_bac= Pseudombassis baculis, Cyp_car= Cyprinus carpio, Lepi_gun= Lepidocephali guntea,Wal_atu= Wallago attu, Esom_dan= Esomus dandricus, Cla_bat= Clarias batrachus, Hete_fos= Heteropneustes fossilis, Mys_ten= Mystus tengara, Chan_orin= Channa orientalis, Chan_pun= Channa punctate, Chan_str= Channa striata, Chan_gac= Channa gachua, Tric_lal= Tricogaster lalius, Mast_pun= Mastacembelus puncalus, Mono_cuc= Monopterus cuchia, Glos_gui= Glossogobius guiris, Angu_ben= Anguilla bengalensis, Sard_lon= Sardinella

5. DISCUSSION

Nepal is rich in water resources which provides shelter for valuable freshwater fish diversity. The lentic ecosystem system of this Himalayan landlock country gives diverse range of habitats for different type of indigenous fishes. The aquatic habitat and Physico-chemical parameters play significant role in growth, development and diversity of fish. Although the aquatic animals are well known for having well-defined temperature tolerance limits, it has a significant influence on the physical activity of fish and their developmental rate. The rise of temperature directly or indirectly has impacts on species distribution and the seasonality of production in fish (FAO, 2010).

5.1. Fish Species Diversity of the study area

Study revealed total species of fishes belonging to 27 species, seven orders, 14 families and 20 genera. The most common fish species on the basis of total number of catch during the study period were *Puntius chonchonius* (46) followed by *Puntius sophore* (39), *Esomus dandricus* (31*), Clarias batrachus* (11), *Heteropneustes fossilis* (17*), Channa puntata* ((16) and *Mastacembelus puncalus* (16). The result shows that order Cypriniformes as the dominant order comprising 62.98% of species composition which is 13 fish species among 27 recorded species out of 343 captured fishes. Pokharel et al., (2019) found 17 fish species belonging to 5 order, 7 families and 17 genera, in Begnas Lake of Pokhara where out of which 11 species were indigenous, while six species were exotic. Here, in Barju lake only two species of fish were found exotic whereas other 25 species of fish were indigenous. This may be because Barju Lake management committee do not release the exotic fish for commercial purposes whereas Begnas Lake is massively popular for commercial fish farming of exotic species. In the same way, order Cypriniformes and family Cyprinidae recorded as dominant in terms of both species composition and occurrence.

Nelson (2016) states Cyprinidae as the largest freshwater family of fishes in the world with 210 genera and about 2010 species. Similarly, Sharma et al. (2020), Chalise, (2020), Husen et al. (2019), Joshi and Bijaya (2017), Dubey et al. (2017), Bera et al. (2014) also

reported the Cypriniformes and Cyprinidae were the leading order and family. Similarly, Order Anabantiformes had second highest species composition (12.83%) i.e. two families, two genera and five species followed by order Siluriformes (11.37%) belonging to four families, four genera and four species and the order Synbranchiformes, Clupeiformes, Anguiliformes and Gobiformes had lowest species composition (6.12%, 4.08%, 1.45% and 1.16%) respectively.

Whereas *Anguilla bengalensis, Glossogobius guiris, Sardinella longiceps and Wallago attu* were recorded at least rate compare to others throughout the study period. This result might be because of smaller number of fish in the lake. This also marks that this species of fish need a good conservation campion and preservation.

One species categorised in IUCN Red list; *Anguilla bengalensis* which was caught only at station IV and I and this might be due to inefficient performance of fishing gear as well as due to presence of aquatic vegetation which made it difficult to catch. In case of other fish, many types of fishing gears of different mesh size were used and sufficient time was also taken in capture by covering more than 500 in every station so higher number of fish species could have been recorded.

Husen et al. (2019) also reported Puntius spp. were the most dominant fish species in Phewa lake and Begnas lake while *Lepidocephalichthys guntea, Acanthocobitis botia, Esomus dendricus, Mastacembelus armatus* were found occasionally. Chaudhary (2019), (Salam et al. 2021), (Chalise 2020) also found genus *Amblyphryngodon and Puntius sophore* were the dominant species.

Puntius chonchonius (46), *Puntius sophore* (39) and *Esomus dandricus* (31*)* were marked as most dominant fish species from Barju lake during the study. In the same way, (Husen et al. 2019) also reported *Puntius* spp. were the most dominant fish species in Phewa Lake and Begnas Lake while *Lepidocephalichthys guntea, Acanthocobitis botia, Esomus dendricus, Mastacembelus armatus* were found occasionally. Also, (Chaudhary 2019), (Salam et al. 2021), (Chalise 2020) found *Puntius sophore* was the dominant species from their followed study area.

Mangur (*Clarias batrachus*) was also captured from lake. According to fishermen, this fish was cultured in different commercial pond and they may have escaped from there during monsoon flood and are found in this Taal. They are available in the lake in good

number due to high tolerance capacity in them towards adverse water quality conditions (Rao 2017).

Station II had the high number of fish species collected (122 fishes). This may be because the water of station II was clear and large number of Zooplankton and phytoplankton was present there which attracts the fish for food. Overall ecology of station II was suitable for spawning, breeding, rearing for fish. Similarly, less quantity of planktons was available in station IV which may the reason behind the less collection (53 fishes) of fish from station IV.

The value of Shannon-Weaver diversity ranges between 1.5-3.5 in this study period in all stations which indicated that Barju lake was highly diverse with the fish species. Similary, Evenness index ranges from 0-1 (Pielou, 1966) where near to one indicate species are distributes evenly across the season with different stations. The value of evenness analyzed in this study was between 0.42 and 0.52, which shows that only a few fish species are distributed evenly across the seasons in different stations.

5.2 Variation in water quality parameters

The water temperature of study ranged from 16.20-31.90 ^{0}C throughout the year. During the study period, lowest temperature was recorded in winter 16.20 ^{0}C and highest in summer 31.90 ^{0}C as the most favorable water temperature for fish is 24^{0}C to 30^{0}C (Santosh & Singh 2007).

The highest DO was found to be 10.1 mg/l at site I in winter season and minimum DO was found to be 9.0 mg/l at site I and II in spring and summer with an average dissolved oxygen of 9.7 mg/l. During the study period DO value ranges from 9.0- 10.1 mg/l which means the water of the study is favorable for the living organism including fish (APHA 1998).

The pH of water during the study ranged from 7.1 - 7.9 ppm. The lowest pH was 7.1 ppm in winter at station I. The pH was recorded highest in summer 7.9 ppm at station IV. The average pH value was recorded in 7.7 ppm and its suitable for fish as mentioned by Swingle (1967). The water of Barju lake has a normal range of pH. It is nor Acidic nei-

ther strong basic rather it lies above the neutral range. It may be due to balanced ecosystem and free from massive pollution.

Free carbon dioxide in water is mostly formed by the decomposition of organic matter and respiration of organism. Maximum free carbon dioxide during summer may be because of decomposition of organic matter by microbes in bottom resulting in the rapid production of free Carbon dioxide. But, during winter there is slow decomposition of organic matter which results less CO_2 production (Patra et al. 2010). The free carbon dioxide of the study area ranged from 2.3-2.9 mg/l which was probably comparable to (Thapa 2008). The highest Free CO_2 was 2.9 mg/l recorded in winter season at station IV. Lower value of 2.3 mg/l at station I in winter with an average value of 2.8 mg/l.

Transparency also helps out to evaluate the quality of water and turbidity ranging from 30 to 80 cm is good for fish health (Bhatnagar et al. 2004). Transparency between 30 and 40 cm indicated optimum productivity of the pond for good fish culture (Santhosh and Sing 2007). The transparency in Barju lake was found between 26 cm to 34cm which is more or less satisfactory. The highest transparency value was found during winter season i.e. 33.9 cm at station IV which is similar to (Chaudhary 2020). This measurement of transparency quite differs from (Saund and Shrestha 2007) work from the Kulekhani Dam as their result ranged from 75 cm – 245 cm.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The lentic ecosystem of Barju Lake is a good habitant for different fish such as carps, barbs, mussels, catfishes etc. A total of 343 number of fishes were collected from four different sampling sites which belongs to 27 species (25 indigenous and two exotic), seven order, 14 families and 20 genera. The most prominent fish species of Barju lake were *Puntius, Esomus, Channa* etc and the least catch species were *Catla , Cyprinus, wallago, Glossogobius , cirranus* etc. The most significant family was Cyprinidae, contributing 57.43%. and other Families such as Cichlidae, Cobitidae, Siluridae, Claridae, Heteropneustidae, Bagridae, Channidae, Osphronemidae, Mastacembelidae, Synbranchidae, Anguillidae, Clupeidae and Gobidae provided an equal number of species by 1.17% which was considered as low.

The Shannon Wiener diversity index value was found between 1.5 and 3.5 which shows that Barju lake is rich in fish diversity. The maximum Species richness value was observed lowest (14.829) at station IV and the highest value was observed (25.829) at station III which indicates that stations III have high variation in fish species whereas station IV has less fish diversity. Evenness index was found to be highest at station III (0.524) and lowest at station IV (0.424) which denotes that only few species are evenly distributed in different station in all season. The result obtained from redundancy analysis (RDA) shows that free carbon dioxide (Free_car) and DO (Diss_Oxy), of water had strong negative relation to water depth (Wat-dep). *Puntius sophore* shows strong positive correlation with water depth (Wat-dep) whereas *Mystus tengra* shows strong positive correlation with water transparency (Trans), dissolved oxygen (Diss_Oxy) and alkalinity (Tota_alk). The physico-chemical properties of the Barju Lake meet acceptable range for aquatic habitat. Barju Lake water temperature, pH, and dissolved oxygen have an impact on seasonal variation in fish structure. So, it is concluded that the Barju lake has a suitable habitat for aquatic life.

6.2 Recommendations

According to lake management committee of Barju Lake, this type of research work was not performed in previous time and the fish population is steadily declining as a result of floods, anthropogenic activities and exploitation. Few recommendations are listed as per study:

- Illegal human activities and the use of small mesh-sized nets in the lake should be prohibited.
- Non- conventional fishing method must be strictly prohibited in order to preserve the declining population of indigenous fish species.
- Discourage to keep the invasive fish species such as Tilapia for tourist attraction. they are considered as biohazards which destroys the indigenous species.
- A strong preservation campion from local government body is required as its overall aquatic ecosystem and Biodiversity is at declining zone.
- A community and school-based awareness campaign about aquatic habitat conservation should be implemented by management committee of Barju Lake.

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ANNEX- I

Classification of fish species

1. Order - Cypriniformes

Family - Cyprinidae

Genus - *Puntius* (Hamilton-Buchannan, 1822)

Species - *P. chonchonius*

Local name - Sidhre

2. Order - Cypriniformes

Family - Cyprinidae

Genus - *Puntius* (Hamilton-Buchannan, 1822)

Species - *P. sophore*

Local name - Pothi

3. Order - Cypriniformes

Family - Cyprinidae

Genus - *Puntius* (Hamilton-Buchannan, 1822)

Species - *P. ticto*

Local name - Sidhre

4. Order - Cypriniformes

Family - Cyprinidae

Genus - *Esomus* (Hamilton-Buchannan, 1822)

Species - E. *dandricus*

Local name - Dedhuwa

5. Order - Cypriniformes

Family - Cyprinidae

Genus - Pseudombassis

Species - *P. baculis*

Local name - Chanda species

6. Order - Cypriniformes

Family - Cyprinidae

Genus - *Labeo*

Species - *L. rohita*

Local name - Rahu

7. Order - Cypriniformes

Family - Cyprinidae

Genus - *Catla*

Species - *C. catla*

Local name - Bhakur

8. Order - Cypriniformes

Family - Cyprinidae

Genus - *Hypophthalmichthys*

Species - *H. molitrix*

Local name - Slver carp

9. Order - Cypriniformes

Family - Cyprinidae

Genus -Puntius (Hamilton-Buchannan, 1822)

Species - *P. sarana*

Local name - Darahi

10. Order - Cypriniformes

Family - Cyprinidae

Genus - *Cirrhnus*

Species - *C. reba*

Local name - Kursa

11. Order - Cypriniformes

Family - Cyprinidae

Genus - *Cirrhinus*

Species - *C. mrigala*

Local name - Naini

12. Order - Cpriniformes

Family - Channidae

Genus - *Channa*

Species - *C. puntata*

Local name - Garai

13. Order - Cypriniformes

Family - Cobitidae

Genus - *Lepidocephali* (Hamilton-Buchannan, 1822)

Species - *L. guntea*

Local name - Lata

14. Order - Cypriniformes

Family - Cichlidae

Genus - *Cprinus* (Hamilton-Buchannan, 1822)

Species - *C. carpio*

Local name - Common carp

15. Order - Siluriformes

Family - Siluridae

Genus - *Wallago* (Schneider)

Species - *W. attu*

Local name - Buwari

16. Order - Siluriformes

Family - Claridae

Genus - Clarias (Linnaeus)

Species - C. batrachus

Local name - Magur

17. Order - Siluriformes

Family - Heteropneustidae

Genus - Heteropneustes

Species - *H. fossilis*

Local name - Singi

18. Order - Siluriformes

Family - Bagridae

Genus - Mystus

Species - M. tenraga (Hamilton_Buchana)

Local name - Tengra

19. Order - Synbranchiformes

Family - Mastacembelidae

Genus - Mastacembelus

Species - M. puncalus

Local name - Kath Gaichi

20. Order - Synbranchiformes

Family - Synbranchidae

Genus - *Monopterus*

Species - *M. cuchia*

Local name - Andha Bam

21. Order - Anabantiformes

Family - Channidae

Genus - Canna (Bloch)

Species - *C. orintalis*

Local name - Chenga

22. Order - Anabantiformes

Family - Osphronemidae

Genus - *Trichogaster*

Species - *T. lalius*

Local name - Kotri

23. Order - Anabantiformes

Family - Chnnidae

Genus - *Channa*

Species - *C. striata*

Local name - Saura

24. Order - Gobiiformes

Family - Gobidae

Genus - *Glossogobius*

Species - *G.guiris*

Local name - Bhulla

25. Order - Angilliformes

Family - Anguillidae

Genus - *Anguilla*

Species - *A. bengalensis*

Local name - Raj Bam

26. Order - Clupeiformes

Family - Clupeidae

Genus - *Sardinella*

Species - *S. longiceps*

Local name - Chelha

27. Order - Channiformes

Family - Channidae

Genus - *Channa*

Species - *C.gachua*

Local name - Chenga

ANNEX II

Diversity abundance of the Shannon index, Species richness and Species evenness of fish.

Station –I (North East)

S. N.	Species	Local name	No. of fishes	Relative abun-dance(P_i)	ln(P_i)	P_i x ln(P_i)
1.	*Labeo rohita*	Rahu	3	0.030928	-3.476	-0.10751
2.	*Puntius chonchonius*	Sidre	16	0.164948	-1.802	-0.29726
3.	*Puntius sophore*	Pothi	16	0.164948	-1.802	-0.29726
4.	*Puntius ticto*	Pothi/ two spot barb	4	0.041237	-3.188	-0.13148
5.	*Cirrhinus mrigala*	Naini	0			
6.	*Cirrhinus reba*	Kursha	2	0.020619	-3.882	-0.08003
7.	*Puntius sarana*	Darahi	3	0.030928	-3.476	-0.10751
8.	*Hypophthalmicthys molitrix*	Silver carp	2	0.020619	-3.882	-0.08003
9.	*Catla catla*	Bhakur	0			
10	*Pseudombassis baculis*	Chanda sps.	5	0.051546	-2.965	-0.15285
11	*Esomus dandrica*	Dedhuwa	9	0.092784	-2.377	-0.22059
12	*Channa puntata*	Garai	5	0.051546	-2.965	-0.15285
13	*Lepidocephali guntea*	Lata	4	0.041237	-3.188	-0.13148
14	*Cyprinus carpio*	Common carp	0			
15	*Wallago attu*	Buwari	0			
16	*Clarias batrachus*	magur	2	0.020619	-3.882	-0.08003
17	*Heteropneustes fossilis*	Singi	4	0.041237	-3.188	-0.13148
18	*Mystus tengara*	tengra	3	0.030928	-3.476	-0.10751
19	*Mastacembelus punca-lus*	Kath Gaichi	5	0.051546	-2.965	-0.15285
20	*Monopterus cuchia*	Andha bam	1	0.010309	-4.575	-0.04716
21	*Channa orantalis*	chenga	2	0.020619	-3.882	-0.08003
22	*Tricogaster lalius*	Kotri	2	0.020619	-3.882	-0.08003
23	*Channa striata*	Saura	1	0.010309	-4.575	-0.04716

24	*Glossogobius guiris*	Bhulla	-			
25	*Channa gachua*	Garai	3	0.030928	-3.476	-0.10751
26	*Anguilla bengalensis*	Raj Bam	1	0.010309	-4.575	-0.04716
27	*Sardinella longiceps*	Chelha	4	0.041237	-3.188	-0.13148
Total:			97			-2.77126
Species Richness (S):		21.496				
Number of Individuals (N):		97				
Shannon-Wiener Index of Diversity (H'):		2.77				
Species Evenness (H'/ln(S)):		1.395				

ANNEX III

Diversity abundance of the Shannon index, Species richness and Species evenness of fish.

Station –II (North West)

S.N.	Species	Local name	No. of fishes	Relative abun-dance(P_i)	ln(P_i)	P_i x ln(P_i)
1.	*Labeo rohita*	Rahu	0			
2.	*P. chonchonius*	Sidre	11	0.123596	-2.091	-0.25841
3.	*Puntius sophore*	Pothi	14	0.157303	-1.85	-0.29095
4.	*Puntius ticto*	Pothi/ two spot barb	6	0.067416	-2.697	-0.18181
5.	*Cirrhinus mrigala*	Naini	1	0.011236	-4.489	-0.05043
6.	*Cirrhinus reba*	Kursha	0			
7.	*Puntius sarana*	Darahi	2	0.022472	-3.795	-0.08529
8.	*H. molitrix*	Silver carp	1	0.011236	-4.489	-0.05043
9.	*Catla catla*	Bhakur	2	0.022472	-3.795	-0.08529
10.	*Pseudombassis baculis*	Chanda sps.	2	0.022472	-3.795	-0.08529
11.	*Esomus dandrica*	Dedhuwa	8	0.089888	-2.409	-0.21656
12.	*Channa puntata*	Garai	8	0.089888	-2.409	-0.21656
13	*Lepidocephali gun-tea*	Lata	6	0.067416	-2.697	-0.18181
14	*Cyprinus carpio*	Common carp	2	0.022472	-3.795	-0.08529
15	*Wallago attu*	Buwari	2	0.022472	-3.795	-0.08529
16	*Clarias batrachus*	magur	2	0.022472	-3.795	-0.08529
17	*Heteropneustes fos-silis*	Singi	5	0.05618	-2.879	-0.16175
18	*Mystus tengara*	tengra	2	0.022472	-3.795	-0.08529
19	*Mastacembelus puncalus*	Kath Gaichi	4	0.044944	-3.102	-0.13943
20	*Monopterus cuchia*	Andha bam	0			
21	*Channa orantalis*	chenga	1	0.011236	-4.489	-0.05043

22	*Tricogaster lalius*	Kotri	0			
23	*Channa striata*	Saura	0			
24	*Glossogobius guiris*	Bhulla	2	0.022472	-3.795	-0.08529
25	*Channa gachua*	Garai	2	0.022472	-3.795	-0.08529
26	*Anguilla bengalensis*	Raj Bam	0			
27	*Sardinella longiceps*	Chelha	6	0.067416	-2.697	-0.18181
Total:			89			-2.74801
Species Richness (S):		20.487				
Number of Individuals(N):		89				
Shannon-Wiener Index of Diversity (H'):		2.75				
Species Evenness (H'/ln(S)):		1.411				

ANNEX IV

Diversity abundance of the Shannon index, Species richness and Species evenness of fish.

Station –III (South West)

S. N.	Species	Local name	No. of fishes	Relative abun-dance(P_i)	ln(P_i)	P_i x ln(P_i)
1.	*Labeo rohita*	Rahu	6	0.077922	-2.552	-0.19886
2.	*Puntius chonchonius*	Sidre	10	0.12987	-2.041	-0.26509
3.	*Puntius sophore*	Pothi	5	0.064935	-2.734	-0.17756
4.	*Puntius ticto*	Pothi/ two spot barb	4	0.051948	-2.958	-0.15364
5.	*Cirrhinus mrigala*	Naini	0			
6.	*Cirrhinus reba*	Kursha	2	0.025974	-3.651	-0.09482
7.	*Puntius sarana*	Darahi	2	0.025974	-3.651	-0.09482
8.	*H. molitrix*	Silver carp	0			
9.	*Catla catla*	Bhakur	0			
10.	*Pseudombassis baculis*	Chanda sps.	9	0.116883	-2.147	-0.2509
11.	*Esomus dandrica*	Dedhuwa	7	0.090909	-2.398	-0.21799
12.	*Channa puntata*	Garai	1	0.012987	-4.344	-0.05641
13	*Lepidocephali guntea*	Lata	3	0.038961	-3.245	-0.12644
14	*Cyprinus carpio*	Common carp	2	0.025974	-3.651	-0.09482
15	*Wallago attu*	Buwari	2	0.025974	-3.651	-0.09482
16	*Clarias batrachus*	magur	2	0.025974	-3.651	-0.09482
17	*Heteropneustes fossilis*	Singi	4	0.051948	-2.958	-0.15364
18	*Mystus tengara*	tengra	1	0.012987	-4.344	-0.05641
19	*Mastacembelus punca-lus*	Kath Gaichi	4	0.051948	-2.958	-0.15364
20	*Monopterus cuchia*	Andha bam	3	0.038961	-3.245	-0.12644
21	*Channa orantalis*	chenga	0			
22	*Tricogaster lalius*	Kotri	3	0.038961	-3.245	-0.12644
23	*Channa striata*	Saura	1	0.012987	-4.344	-0.05641

24	*Glossogobius guiris*	Bhulla	0			
25	*Channa gachua*	Garai	2	0.025974	-3.651	-0.09482
26	*Anguilla bengalensis*	Raj Bam	1	0.012987	-4.344	-0.05641
27	*Sardinella longiceps*	Chelha	3	0.038961	-3.245	-0.12644
Total:			77			-2.87164
Species Richness (S):		21.469				
Number of Individuals (N):		77				
Shannon-Wiener Index of Diversity (H'):		2.87				
Species Evenness (H'/ln(S)):		1.522				

ANNEX V

Diversity abundance of the Shannon index, Species richness and Species evenness of fish.

Station –IV (South East)

S.No.	Species	Local name	No. of fishes	Relative abundance(P_i)	ln(P_i)	P_i x ln(P_i)
1.	*Labeo rohita*	Rahu	5	0.063291	-2.76	-0.17468
2.	*Puntius chonchonius*	Sidre	9	0.113924	-2.172	-0.24747
3.	*Puntius sophore*	Pothi	4	0.050633	-2.983	-0.15105
4.	*Puntius ticto*	Pothi/ two spot barb	4	0.050633	-2.983	-0.15105
5.	*Cirrhinus mrigala*	Naini	3	0.037975	-3.271	-0.12421
6.	*Cirrhinus reba*	Kursha	2	0.025316	-3.676	-0.09307
7.	*Puntius sarana*	Darahi	3	0.037975	-3.271	-0.12421
8.	*Hypophthalmicthys molitrix*	Silver carp	2	0.025316	-3.676	-0.09307
9.	*Catla catla*	Bhakur	2	0.025316	-3.676	-0.09307
10.	*Pseudombassis baculis*	Chanda sps.	3	0.037975	-3.271	-0.12421
11.	*Esomus dandrica*	Dedhuwa	7	0.088608	-2.424	-0.21474
12.	*Channa puntata*	Garai	2	0.025316	-3.676	-0.09307
13	*Lepidocephali guntea*	Lata	2	0.025316	-3.676	-0.09307
14	*Cyprinus carpio*	Common carp				
15	*Wallago attu*	Buwari				
16	*Clarias batrachus*	magur	5	0.063291	-2.76	-0.17468
17	*Heteropneustes fossilis*	Singi	4	0.050633	-2.983	-0.15105
18	*Mystus tengara*	tengra	1	0.012658	-4.369	-0.05531
19	*Mastacembelus puncalus*	Kath Gaichi	3	0.037975	-3.271	-0.12421
20	*Monopterus cuchia*	Andha bam	1	0.012658	-4.369	-0.05531

21	*Channa orantalis*	chenga	3	0.037975	-3.271	-0.12421
22	*Tricogaster lalius*	Kotri	2	0.025316	-3.676	-0.09307
23	*Channa striata*	Saura	2	0.025316	-3.676	-0.09307
24	*Glossogobius guiris*	Bhulla	2	0.025316	-3.676	-0.09307
25	*Channa gachua*	Garai	4	0.050633	-2.983	-0.15105
26	*Anguilla bengalensis*	Raj Bam	3	0.037975	-3.271	-0.12421
27	*Sardinella longiceps*	Chelha	1	0.012658	-4.369	-0.05531
Total:			79			-3.07151
Species Richness (S):		24.473				
Number of Individuals (N):		79				
Shannon-Wiener Index of Diversity (H'):		3.07				
Species Evenness (H'/ln(S)):		1.618				

PLATE I

Puntius chonchonius

Esomus dandrica

Pseudombassis baculis

Mystus tengara

Heteropneustes fossilis

Channa gachua

PLATE II

Puntius ticto

Tricogaster lalius

Monopterus cuchia

Glossogobius guiris

Mastacembelus puncalus

Channa orantalis

PLATE III

Lepidocephali guntea

Labeo rohita

Hypophthalmichthys molitrix

Puntius sophore

Catla catla

PLATE IV

Barju Lake

Field visit of Barju Lake

PLATE V

Fishing with Fisher man

With Coordinator of Barju Lake

PLATE VI

Data Analysis

Water Quality Analysis

Fish Identification

PLATE VII

DO Analysis

pH Analysis

PLATE VIII

Fish Identification

Fish Identification