FISH DIVERSITY OF TULSIHAWA LAKE, RUPANDEHI, NEPAL

TARA RAUT

T.U. Registration No.:5-0-52-448-2014

Exam Roll No.: Zoo.780/075

Batch: 2075

A thesis submitted

In Partial fulfilment of the requirements for the award of the degree of Master of Science in Zoology with special paper Fish Biology and Aquaculture

Submitted to

Amrit Campus

Institute of Science and Technology

Tribhuvan University

Kathmandu, Nepal.

January, 2023

DECLARATION

I hereby declare that the work presented in this thesis has been done by myself and has not been submitted elsewhere for the award of any degree. All the source of information has been specially acknowledged by reference to the authors and institutions. Every reasonable effort has been made to gain permission and acknowledge the owner of copyright materials.

Tara Raut

Date: 2079-10-17

Tribhuvan University
Institute of Science and Technology
AMRIT CAMPUS
P.O Box No: 102, Thamel, Kathmandu, Nepal.
E-mail: amritcampus@nfc.net.np

RECOMMENDATIONS

It is hereby recommended that **Tara Raut**, M.Sc. Zoology student from **'Fish Biology and Aquaculture'** at Amrit Campus, Institute of Science and Technology, Lainchaur, Kathmandu, Nepal has carried out the research work entitled **"Fish Diversity of Tulsihawa Lake, Rupandehi, Nepal"** under my supervision. The entire work is based on the field work performed by her and brings out some useful findings in the field of fish diversity.

As per knowledge, this work has not been submitted for any other academic degree. I therefore recommend this dissertation to be accepted for the partial fulfillment of the requirement of Master's Degree in Zoology, at the Institute of Science and Technology, Tribhuvan University.

……………………………………

Supervisor

Santoshi Shrestha

Assistant professor

Central Department of Zoology

Tribhuvan University

Date: 2079-10-17

Tribhuvan University
Institute of Science and Technology
AMRIT CAMPUS
P.O Box No: 102, Thamel, Kathmandu, Nepal.
E-mail: amritcampus@nfc.net.np

Coordinator
M. Sc. Program
Department of Zoology
Amrit Campus
IOST, Tribhuvan University

LETTER OF APPROVAL

On recommendation of supervisor, the thesis submitted by **Ms. Tara Raut** entitled **"Fish Diversity of Tulsihawa Lake, Rupandehi, Nepal"** is approved for examination and submitted to the Amrit Campus in partial fulfillment of the requirements for the Degree of Master of Science in Zoology with special paper Fish Biology and Aquaculture.

……………………

Co-ordinator

Barun Panthi

Assistant professor

Amrit Campus

Department of Zoology

Kathmandu, Nepal

Date: 2079-10-17

Tribhuvan University
Institute of Science and Technology
AMRIT CAMPUS
P.O Box No: 102, Thamel, Kathmandu, Nepal.
E-mail: amritcampus@nfc.net.np

M. Sc. Program
Department of Zoology
Amrit Campus
IOST, Tribhuvan University

CERTIFICATE OF ACCEPTANCE

This thesis work submitted by **Ms. Tara Raut** entitled **"Fish Diversity of Tulsihawa Lake, Rupandehi, Nepal"** has been accepted as the partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Fish Biology and Aquaculture.

EVALUATION COMMITTEE

....

Supervisor

Asst. Prof. Santoshi Shrestha

Central Department of Zoology

Tribhuvan University

Kirtipur, Nepal.

....

Coordinator

Asst. Prof. Barun Panthi

Amrit Campus

Kathmandu, Nepal

....

External Examiner

....

Internal Examiner

Date of Examination: 16 February, 2023

ACKNOWLEDGEMENTS

First of all, I would like to express my sincere gratitude to respective Supervisor Assistant Professor Santoshi Shrestha, Central Department of Zoology, T.U., Kirtipur for her supervision, guidance, inspiration and continuous valuable suggestions for the completion of my thesis work.

I would like to express my sincere gratitude to Asst. Prof. Barun Panthi, Coordinator of Masters programme in Zoology, Amrit Campus, Kathmandu for his kind suggestions and academic support. I am also thankful to head of department Assot. Prof. Shambhu Prasad Shah and former coordinators Asst. Prof. Rakshya Thapa and Asst. Prof. Babita Maharjan for provided facilities during their tenure.

I am also thankful to all the faculties of Department of Zoology, Amrit Campus for their support during completing Master degree. I would like to thank, Mr. Ram Maharjan, Lab Asst. for his help to carry out the lab work.

I am thankful to Mr. Alok Singh and the entire management committee of Tulsihawa lake for providing permission to carry out this study. I would like to pay special thanks and due respect to the fishermen and local people of Tulsihawa Rural Municipality for helping and sharing their experience and knowledge.

Finally, I am grateful to my friends, parents and family members for their support, love and inspiration. I am highly obliged to all the individuals who have contributed directly or indirectly their valuable suggestions, guidance for completion of my research work.

Tara Raut

TABLE OF CONTENTS

DECLARATION ii

RECOMMENDATIONS iii

LETTER OF APPROVAL iv

CERTIFICATE OF ACCEPTANCE v

ACKNOWLEDGEMENTS vi

TABLE OF CONTENTS vii

LIST OF TABLES x

LIST OF FIGURES xi

LIST OF APPENDICES xii

LIST OF PHOTOPLATES xiii

LIST OF ABBREVIATIONS xiv

ABSTRACT xv

1. INTRODUCTION 1

  1.1 Background 1

  1.2 Tulsihawa Lake 2

  1.3 Objectives 3

    1.3.1 General objective 3

    1.3.2 Specific objectives 3

  1.4 Significance of the study 3

2. LITERATURE REVIEW 4

3. MATERIALS AND METHODS 7

  3.1 Materials 7

    3.1.1 Equipments 7

  3.2 Study Area 7

  3.3 Study Period 8

    3.3.1 Selection of sampling sites 8

3.4 Water Parameters Analysis 8
3.4.1 Physical Parameters 8
3.4.1.1 Temperature 8
3.4.1.2 Transparency 9
3.4.1.3 Turbidity 9
3.4.2 Chemical parameters analysis 9
3.4.2.1 Hydrogen ion concentration (pH): 9
3.4.2.2 Dissolved Oxygen: 9
3.4.2.3 Total Alkalinity 9
3.4.2.4 Total Hardness 10
3.5 Fish sampling and identification 10
3.6 Species diversity index 10
3.6.1 Shannon-Weiner diversity index (H') 10
3.6.2 Species richness index (d) 11
3.6.3 Evenness index 11
3.7 Statistical Analysis 11
4. RESULTS 12
4.1 Physico- chemical parameters 12
4.1.1 Physical parameters of water 12
4.1.1.1 Water Temperature 12
4.1.1.2 Water transparency 12
4.1.1.3 Water Turbidity 13
4.1.2 Chemical parameters of water 14
4.1.2.1 pH 14
4.1.2.2 Dissolved oxygen 14
4.1.2.3 Total Alkalinity 15

4.1.2.4 Total Hardness 16
4.2 Fish diversity of Tulsihawa lake 16
4.2.1 Distribution and frequency occurrence of fishes in Tulsihawa lake 18
4.2.1.1 Order wise fish diversity of Tulsihawa lake 20
4.2.1.2 Family wise fish diversity of Tulsihawa lake 20
4.2.2 Diversity status of fish 21
4.2.2.1 Site wise diversity indices of Tulsihawa lake 21
4.2.2.2 Season wise diversity indices of Tulsihawa lake 22
4.2.3 Correlation between Physico-chemical parameters and fish diversity 23
5. DISCUSSION 24
6. CONCLUSIONS 29
6.1 Conclusions 29
6.2 Recommendations 29
REFERENCES 30
PHOTOPLATES 38
APPENDICES 42
Appendix I Physico- chemical parameters during different seasons at selected sampling station 42
Appendix II: Order-wise fish species and total fish catch composition (%) 43
Appendix III: Family-wise fish species and total fish catch composition (%) 43
Appendix IV: Distribution pattern and frequency occurrence of fishes in Tulsihawa lake 44
Appendix V: Station wise species diversity indices in different seasons 45
Appendix VI: Season wise species diversity indices in different seasons 45

LIST OF TABLES

Table 1: Systematic position of fishes with its local name and conservation status..17

Table 2: List of species recorded in different stations during different seasons.........19

Table 3: Correlation between Physico-chemical parameters and fish diversity in Tulsihawa lake...23

LIST OF FIGURES

Figure 1: Map of study area 7

Figure 2: Variation of water temperature at five sampling sites in four seasons 12

Figure 3: Variation of water transparency at five sampling sites in four seasons 13

Figure 4: Variation of water turbidity at five sampling sites in four seasons 13

Figure 5: Variation of pH at five sampling sites in four seasons 14

Figure 6: Variation of dissolved oxygen at five sampling sites in four seasons 15

Figure 7: Variation of total alkalinity at five sampling sites in four seasons 15

Figure 8: Variation of total hardness at five sampling sites in four seasons 16

Figure 9: Order wise species composition (%) of Tulsihawa lake 20

Figure 10: Family wise species composition (%) of Tulsihawa lake 21

Figure 11: Site wise species diversity indices in different sites 22

Figure 12: Season-wise species diversity indices in different sites 22

LIST OF APPENDICES

Appendix I Physico- chemical parameters during different seasons at selected sampling site

Appendix II: Order-wise fish species and total fish catch composition (%)

Appendix III: Family-wise fish species and total fish catch composition (%)

Appendix IV: A list of species recorded in different sites during various seasons.

Appendix IV: A list of species recorded in different sites during various seasons.

Appendix VI: Site wise species diversity indices in different seasons

Appendix VII: Season wise species diversity indices in different seasons

LIST OF PHOTOPLATES

Plate I: *Puntius sophore, Puntius chola, Pethia conchonius, Amblypharyngodon microlepis, Chanda nama* and *Salmostoma acinaces*

Plate II: *Channa punctata, Mystus tengra, Trichogaster fasciatus, chela cachius, Esomus danrica* and *Glossogobius guiris*

Plate III: *Macrognathus pancalus, Mastacembalus armatus, Cirrhinus mrigala, Labeo rohita, Labeo bata, Hypophthalmichthys molitrix* and *Cyprinus carpio*

Plate IV: Tulsihawa lake, Fish sampling, Silver fish in cast net, Collection of capture fish, Measuring pH of water and Analysis of water parameter

LIST OF ABBREVIATIONS

APHA	American Public Health Association
masl.	Meter above sea level
DFO	Divisional Forest Office
DO	Dissolved oxygen
DD	Data Deficient
CFPCC	Central Fisheries Promotion and Conservation Center
GPS	Global Positioning System
IUCN	International Union for Conservation of Nature
LC	Least Concern

ABSTRACT

The study on the fish diversity of Tulsihawa Lake, Rupendehi, Nepal was carried out four different seasons from October 2021 to July 2022. The cast net was used to collect fish samples hiring local fishermen. Physico-chemical parameters were also analyzed. A total species richness of 19 species was collected from Tulsihawa Lake, out of which 2 species were nonnative. Order Cypriniformes and family Cyprinidae were dominant both in species composition and individual capture. *Amblyphryngodon microlepis* was dominant species accounting 50.53% followed by *Puntius sophore* (14.99%) and *Chanda nama* (8.21%). The water quality parameters were found within suitable range that supports fish diversity. Fish diversity was positively correlated with temperature, transparency, dissolved oxygen, and alkalinity whereas turbidity, pH, and total hardness negatively correlated. The Shannon - Weiner diversity index, Margalef's richness and evenness index indicated a strong relationship with overall species richness. So, it is concluded that Tulsihawa Lake harbors suitable habitat for variety of fish species and aquatic inhabitants.

Keywords: *Species diversity, Diversity indices, Water quality parameters, Cypriniformes*

1. INTRODUCTION

1.1 Background

Wetlands are natural or artificially created areas, such as marsh, swamps, river floodplains, lakes, water storage areas and agricultural land that contain water from underground water resources or atmospheric precipitation that can be permanent or temporary, static or flowing, and fresh or saline water (National wetland policy, 2003). Wetlands provides favorable habitat of fish, wildlife and aquatic inhabitants and are crucial in terms of their ecological, economic, cultural, social, recreational, religious, and artistic benefits and serves as a transition between open water and terrestrial systems providing a significant ecological benefit to the environment in terms of biodiversity, habitat for aquatic flora and fauna, hydrological regime, sustaining of local communities and storing large quantities of water recharge (Suwal and Shrestha, 1990). Within Nepal's inland water resources, wetland areas make up roughly 828171 hectares, comprising rivers and streams (48.38%), lakes (0.60%), reservoirs (0.18%), village ponds (1.38%), marginal/swamps/Gholes (1.51%), low land irrigated paddy fields (48.14%), irrigation canal (0.38%) and highway side ditches with 0.03% (CFPCC, 2077/78). Lakes are the most significant supply of fresh water and locations for recreation activities and some of them have religious significance for people. Based on their origin, the lakes are divided into three categories: tectonic, oxbow, and glacial lakes of which 17 glacial lakes are located over 4000 meters and in the southern part of the country more than two dozen ox-bow lakes are present (Sharma, 1977).

Fish serve as one of the most important indicators of the quality of the water and demonstrate the abundance of biodiversity (Hussain *et al*., 2016) and play a significant function in the aquatic ecosystem as a gauge of ecological health (Hamzah, 2007). Fish mass in rivers and lakes demonstrating geographical and temporal variation as a result of anthropogenic activities and environmental variations (Jackson *et al.,* 2001, Tonn *et al.,* 1990). Studies of ecological habitat, regular pattern of distribution, and species composition of freshwater fishes are important elements that are crucial for the fish community (Galactos and Barriga-Salazar, 2004). Swar and Gurung, 1988; Gautam *et al.,* 2010; Kumar *et al*., 2011 investigated the diversity of fishes from different wetlands of Nepal. Shrestha (2001) reported 182 fish species from Nepal and later in the year 2013, 228 native fish species were reported. Recently, Shrestha (2019) reported 252 species (236 indigenous and 16 exotic) from Nepal in his book “Ichthyology of Nepal”. Gautam *et al*., (2010) reported that 42 fish species from Jagadishpur Reservoir and Oli *et al*., (2013) reported 22 species from Rampur Ghol, Chitwan.

A number of variables including food, breeding grounds, water current, depth, terrain, and the physio-chemical characteristics of the water, were almost always connected to the accessibility, distribution, and species composition of fish in each human settlement (Harris, 1995). The biggest risks to fish biodiversity include overfishing, altered flow patterns, habitat degradation, siltation, invasion by foreign species, pollution, eutrophication, and sedimentation (Helfman *et al*., 2009). Temperature and dissolved oxygen concentration influence the distribution, abundance, and movement of aquatic organisms (Alhassan, 2013). The water temperature, salinity, dissolved oxygen content, and depth were significantly correlated with a number of different fish species (Marshall and Elliott, 1998). According to Blaber and Blaber (1980) the turbidity is associated with rich feeding grounds and offers fishes shelter while macrophyte complex and water depth, significantly influence the spatial and temporal variation of the fish community (Ye, 2007).

1.2 Tulsihawa Lake

The Tulsihawa Lake (latitude 27° 37'27.9", longitude 83° 19'08.3" and altitude 117 masl) is located in Lumbini province, Rupendehi district. There is little information on diversity of Tulsihawa Lake. The eastern part of the lake, that was nearby the road, and encircled by some large trees. The northern portion of the lake was close to residential areas and was surrounded by smaller reservoirs. The western part of lake was surrounded by agricultural land and also with small inlets. The southern portion of the lake was surrounded by several bamboo trees and little herbs.

1.3 Objectives

1.3.1 General objective

The general objective is to investigate the Fish diversity of Tulsihawa Lake, Rupandehi, Nepal.

1.3.2 Specific objectives

The specific objectives are**:**

a. To analyze the physico-chemical characteristics of Tulsihawa Lake.
b. To explore fish diversity of Tulsihawa Lake.
c. To analyze the relationship between fish diversity and physico-chemical parameters in Tulsihawa Lake.

1.4 Significance of the study

Tulsihawa Lake is the largest and most important lake located in Rupandehi, Nepal. It is crucial for the various aquatic vegetation and wildlife. According to local people, the biodiversity especially aquatic inhabitants are declining in present days due to pollution, habitat alteration and overfishing and little information on fishes so this study explores the fish diversity of Tulsihawa lake with its water quality. This information will help to update the fish diversity of Nepal and will provide baseline data for further studies on ichthyofauna.

2. LITERATURE REVIEW

In Nepal, the oldest record on fishes was discovered on 18th century by Colonel Kirkpatrick from Rapti river, Makwanpur district during his political mission from East India Company in the year of 1793 A.D. Later, in the beginning of 19th century, the fish fauna of Nepal was recorded by Hamilton in his book" An account of the Kingdom of Nepal" during the year 1822. Besides Hamilton (1822) a number of other Ichthyologist such as Gunther (1861), Beaven (1877) and Day (1878) have also studied and reported the fish fauna of Nepal.

Saund and Shrestha (2007) found exotic species *Aristichthys nobilis* and *Hypophthalmichthys molitrix* to be dominant group whereas only two indigenous fish *Neolissocheilus hexagonolepis* and *Nazirator chlynoides* were reported from Kulekhani reservoir. The water quality parameters (surface temperature: 13.4 ℃ - 24.5 ℃, pH: 8.2-9.4, transparency: 75.2 cm- 245.1 cm, DO: 6.2 mg/l- 10.4 mg/l, CO_2: 0.1mg/l – 0.15 mg/l, total alkalinity: 38 mg/l - 85 mg/l, total hardness: 36mg/l - 65 mg/l) were found in satisfactory level during their study. Gautam *et al*., (2010) recorded 42 species belonging to 6 orders, 18 families and 34 genera from Jagadishpur Reservoir where order Cypriniformes and family Cyprinidae were dominant both in species as well as catch composition. *Nandus nandus* was the most dominant species with 16.50% of the total catch. The water quality parameters were found in a desirable range favorable for warm water fishes (surface water temperature: 20.7 °C–31°C; pH: 6.8– 7.6; dissolved oxygen: 5.2mg/l–8.7mg/l; free carbon-dioxide: 11.1mg/l–23.6mg/l; total hardness: 68.2mg/l–137.5mgl; total alkalinity: 69.6mg/l–192mg/l). Kumar (2012) recorded 9 orders, 18 families, 27 genera and 40 species from the Turkaulia Lake, Bihar, India where family Cyprinidae was the most abundant, consisting 14 species *Puntius* was the dominant genus. Murugan and Prabaharan (2012) carried out the study in Kamala Basin of Darbhanga District, Bihar and reported 35 species with dominancy of family Cyprinidae. The water quality parameters were found suitable to fishes (temperature: 22.2 °C - 31.4 °C; pH: 6.1 - 7.6; dissolved oxygen: 5.4 to 6.6 mg/l; free carbon dioxide: 2.6 - 4.8 mg/l; total hardness: 76.4 mg/l -114.2 mg/l; and total alkalinity: 93.0 - 110.0 mg/l).

Oli *et al*., (2013) listed 22 species (13 families and 5 orders) from Rampur Ghol, Central Nepal and water quality parameters were found to be suitable range for aquatic habitat (temperature: 17.35- 30.53 ℃, pH 6.8-7.1, DO 5.97-8.57 mg/l, total alkalinity 120-164.29 mg/l, and total hardness 121.36-160.29 mg/l). Bhattacharya et al., (2014) found Cypriniformes as dominant group with 7 orders, 15 families, 26 genera and 39 species from the Kangsabati Reservoir, West Bengal, India and concludes the chemical and physical characteristics of the water (temperature 18.33 ℃-33.66 ℃; pH 7.32 -8.45; DO 7.20 - 12 mg/l; CO_2 3.33 mg/l- 9.66 mg/l; total alkalinity 40.67 mg/l 94.44 mg/l, and total hardness 112.60 mg/l - 195.36 mg/l) favors for fish cultivation and high ichthyofaunal diversity. Lamsal *et al*., (2014) reported 19 fish species from Ghodaghodi Lake, Kailali, Nepal.

Twenty-one species of fishes under 6 orders, 11 families and 17 genera were reported from the Sagar Lake, India by Gupta and Wani, 2015. Family Cyprinidae (48%) was found to be the most abundant family and *Puntius sophore, Pethias chonchonius* and *Puntius ticto* were found to be the most abundant species of Sagar Lake. Joshi and K.C. (2017) were studied the fish diversity in Ghodaghodi Lake, Kailali and reported 13 distinct fish species including 5 orders, 8 families, and 11 genera with dominancy of *Labeo gonius, Mystus tengara*, and *Nandus nandus*. The study found highest diversity index, species richness and evenness in January and lowest in October Pradhan (2017) studied the fish faunal diversity and occurrence from Waldi Dam, Parbhani, India and reported 17 species belonging to 3 orders and 12 genera where Cypriniformes showed dominancy over rest orders.

Thapa (2018) reported 15 fish species; 5 orders, 7 families and 12 genera from Dipang Lake of Kaski district. Cypriniformes was the dominant order consisting 46% in terms of species composition and individual capture while Cyprinidae was the dominant family contributing 29.43%. *Puntius sophore* was the most dominant species, which made up 18.33% of the total catch. The water quality parameters ranged from water temperature; 23 ℃-30 ℃, pH; 6.2-8, 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. Pokharel and Chand (2019) reported 15 species (11 indigenous and 6 exotic) in Begnas lake, Pokhara Nepal. Regarding composition and occurrence, the family Cyprinidae was dominating over others. Chaudhary (2019) studied the fish diversity of Koilahee taal, Kailali Municipality, Nepal and reported 13 species of fishes belonging to 5 orders, 8 families and 11 genera dominated by Order Cypriniformes (46%) and family Cyprinidae (28.08%) regarding species composition as well as individual. *Amblyphryngodon microlepis* was found to be dominant fish species. The water quality parameters (temperature: 26.5 ℃-31 ℃, pH: 7.5 -8.5, DO: 5.5 mg/l-6.8 mg/l, CO_2: 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.

Gedam *et al.*, (2019) carried out study on Sanjul Lake, India and found 15 species under 12 genera and 4 families where Cypriniformes (10) dominated over Siluriformes (1) and Perciformes (3). *Catla catla, Labeo rohita, Cyprinus carpio* and *Cirrhinus mrigala* were most abundant species from Sanjul Lake, India. Husen *et al*., (2019) collected a total of 26 fish species (20 native and 6 non - native) from three lakes (Phewa, Rupa and Begnas) of Pokhara valley. Tharu (2020) studied on diversity of fishes in Jagdishpur reservoir Kapilbastu, Nepal and reported that 31 indigenous and 1 exotic species under 25 genera. Species and catch composition were dominated by order Cypriniformes with 17 species and family Cyprinidae with 15 species and *Rasbora daniconius* was the most dominant species whereas *Badis badis* was the lowest in catch compositon. The water quality parameters temperature 19.5 °C-32.1°C, pH 6.8-7.6, DO 5.2mg/l - 8.7mg/l, hardness 68.2mg/l-137.5mg/l and alkalinity 69.6mg/l-192 mg/l were found that was favorable for aquatic inhabitants of Jagdishpur reservoir. Tripathi and Yadav (2020) collected 23 fish species from the Seetadawr Lake, Uttar Pradesh, India; family Cyprinidae was most abundant of all. Genus *Mystus* and *Channa* were the dominant species. Singh and Bhattarai (2021) studied in Jakhor Taal, Kailali district, Nepal, reported 24 species (16 native and 8 exotic species) and concluded the order Cypriniformes and family Cyprinidae was dominant among all followed by Siluriformes and Perciformes; Clariidae (2) and Channidae (2).

3. MATERIALS AND METHODS

3.1 Materials

3.1.1 Equipments

GPS (Garmin e Trex 10), Cast net, pH meter (HANNA- HI98107), Thermometer, DO meter (Teknik EM-83D) and sampling bottles.

3.1.2 Chemicals

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

3.2 Study Area

The Tulsihawa Lake lies in Rupandehi District, Province No. 5, Ward No. 9 of Gaidahawa Rural Municipality. It covers 15 bigha of land and approximately 6 feet deep. The location, at latitude and longitude of 27°37'27.9" N and 83°19'08.3" E, is notable for its low height (117m above sea level). There is only one outlet but no inlets in the lake. According to local people excess water during monsoon season is discharged to the Emuriya River. The lake is bordered by tiny grasses, trees, bamboo trees, cultivated land, human settlement on four sides whereas fifth site is close to the road. The lake water is occasionally utilized for irrigation.

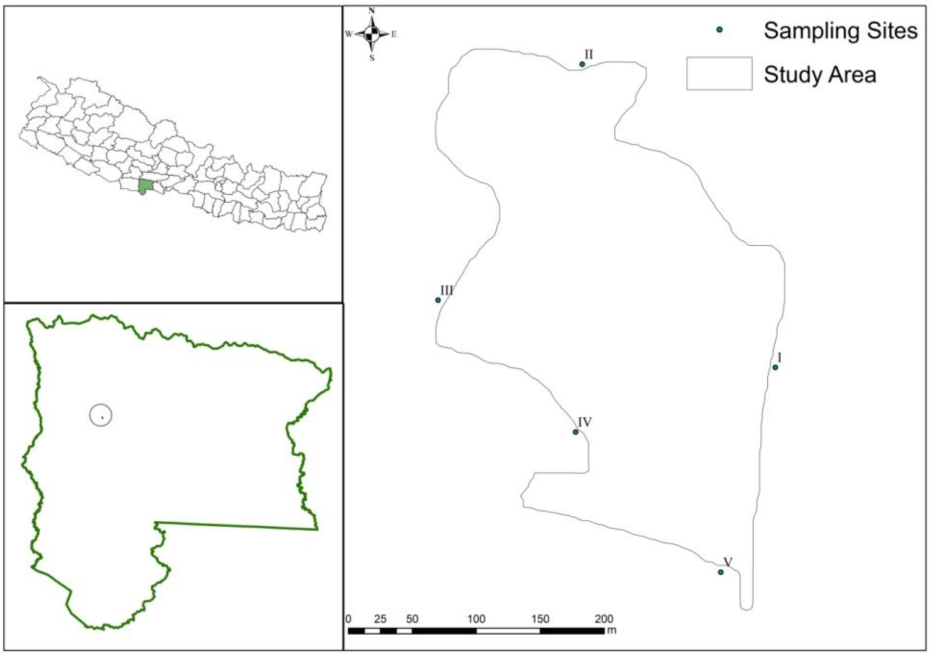


Figure 1: Map of study area with sampling sites

3.3 Study Period

The field work was conducted from October 2021 to July 2022 covering four seasons and each sampling sites were visited in October, February, April and June.

3.3.1 Selection of sampling sites

Site I: Sampling site I was chosen in the eastern part of the lake which is nearby the road and encircled by large trees.

Site II: The northernmost portion of the lake was selected as site II. This location was close to residential areas.

Site III: The sampling site III was selected on western part of lake and surrounded by agricultural land.

Site IV: The southernmost section of the lake was chosen for sampling site IV near the shores of the lake. Several bamboo trees and little herbs are all around this location.

Site V: The sampling site V was selected in an outlet region of the lake which is surrounded by small grasses.

3.4 Water Parameters Analysis

Water samples of Tulsihawa Lake were collected during morning time (7:00 to 11:00 AM). The physico-chemical parameters (temperature, transparency, pH and dissolved oxygen) were analyzed immediately in the field. Other chemical parameters alkalinity and hardness were analyzed in the laboratory of Amrit Science Campus, Lainchaur, Kathmandu followed by standard method of APHA (1998) and Trivedy & Goel (1986).

3.4.1 Physical Parameters

3.4.1.1 Temperature

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

3.4.1.2 Transparency

The Secchi disc was used to measure transparency by lowering in the water until it becomes invisible and record the depth in centimeters (cm). Then, the disc was gradually pulled up and while reappearing next reading was noted. The transparency was calculated by,

Transparency (D) = A+B/2

Where, D = Transparency in cm.

A= Depth at which Secchi disc disappears.

B= Depth at which Secchi disc appears.

3.4.1.3 Turbidity

The turbidity of the water is inversely proportional to the transparency and calculated by following equation.

Turbidity(X) =1000/1.568Y-1.275

Where, X = turbidity

Y = transparency

3.4.2 Chemical parameters analysis

3.4.2.1 Hydrogen ion concentration (pH):

The pH was measured by using pH meter (HANNA- HI98107).

3.4.2.2 Dissolved Oxygen:

The DO in the water was calculated using a digital DO meter (Teknik EM-83D).

3.4.2.3 Total Alkalinity

Total alkalinity (Carbonate) of lake water was determined by titration against a standard H_2SO_4 solution (0.02 N) with phenolphthalein and methyl orange and calculated using the formula.

$$\text{Total alkalinity (mg/1 as } CaCO_3) = \frac{(\text{ml x Normality) of } H_2SO_4 \text{x } 50 \text{x } 1000}{\text{Vol. of sample used in ml}}$$

Where,

ml = Amount of H_2SO_4 used during the Titration

N= Normality of H_2SO

V= Volume of water sample taken (ml)

3.4.2.4 Total Hardness

It is the overall quantity of salt in the water (i.e., Chloride and Sulphate of Calcium and Magnesium). The hardness of water was calculated by using the EDTA Titrimetric method and calculated by,

$$\text{Total Hardness (mg/1 as } CaCO_3) = \frac{\text{Vol. Of EDTA used in ml x 1000}}{\text{Vol. of sample used in ml.}}$$

3.5 Fish sampling and identification

The fishes were collected from five sites of Tulsihawa Lake in the morning with water parameters. Local fishermen were hired for fish sampling. Locally prepared cast net (mesh size 0.5 inch) was used to capture fishes. Five attempts were made for the fish sampling with the help of the cast net in each station. Each species was counted and local name of the fish species were noted from the local fishermen. The morphological features like shape, bands, colour and patches were noted in the field. Measurement and photographs were also taken and preserved in 8-10% formalin solution, then brought to the Central Department of Zoology and identified using keys (Shrestha ,1994/1981; Shrestha, 2019 and Jayaram, 2013). Later it was deposited in the laboratory of Amrit Campus, Thamel, Kathmandu.

3.6 Species diversity index

The seasonal and sites wise diversity indices (Shannon - Weiner diversity index, Margalef's richness index and Pielou's evenness index) were analyzed.

3.6.1 Shannon-Weiner diversity index (H')

The Shannon-Weiner diversity index (Shannon - Weiner, 1949) was used to estimate the species diversity in a community.

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

Where,

Pi= ni/N

ni = Number of individuals in each species

N= Total no. of all individuals in the sample.

ln= Logarithm of base e.

3.6.2 Species richness index (d)

The richness of species was calculated using Margalef's species richness index (Margalef, 1968) and denoted as d.

Margalef species richness (d) =S-1/ lnN

Where,

S= Total number of species.

N= Total number of individuals.

3.6.3 Evenness index

To assess the species distribution of species among sample sites and seasons, the Pielou's evenness index (Pielou, 1966) was used. It is denoted by J and calculated as,

Pielou's species evenness (J) = H'/ lnS

Where,

H'= Shannon- Wiener's diversity index.

S= Total number of species in the sample.

3.7 Statistical Analysis

The relation between fishes with water parameters were calculated by Karl Pearson correlation coefficient formula (Gupta 1988).

Coefficient of correlation (r) = $$\frac{N\Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{N\Sigma X^2 - (\Sigma X)^2}\sqrt{N\Sigma Y^2 - (\Sigma Y)^2}}$$

Probability of Error (P.Er.) = $$\frac{1-r^2}{\sqrt{N}}0.6745$$

4. RESULTS

4.1 Physico- chemical parameters

The physical parameters (temperature, transparency, turbidity, and color) and chemical parameters (pH, dissolved oxygen, total hardness, and total alkalinity) were measured.

4.1.1 Physical parameters of water

4.1.1.1 Water Temperature

The water temperature varied from 16°C to 31 °C throughout the year. The highest temperature was recorded (31°c) in summer season at site V and lowest temperature in winter (16°C) at site I. (Fig.2).

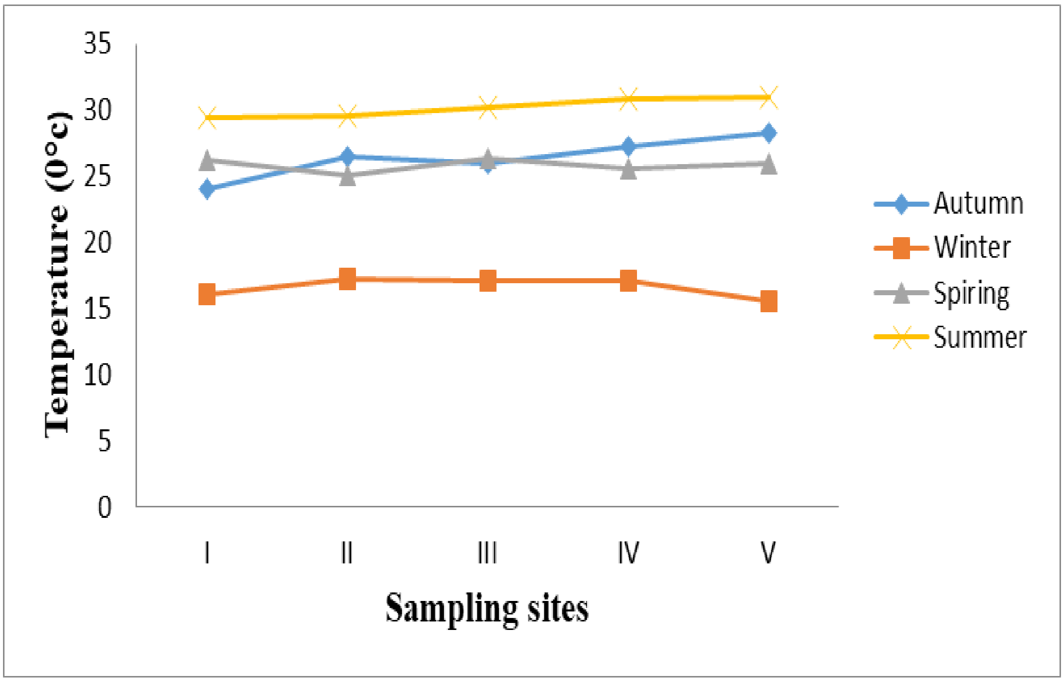


Figure 2: Variation of water temperature at five sampling sites in four seasons

4.1.1.2 Water transparency

The water transparency was recorded in each season from all sites. During the study period, transparency value ranged from 26cm-35 cm. The maximum value (35cm) was recorded at site I in autumn season and minimum value (26cm) was recorded at site V in summer season (Fig.3).

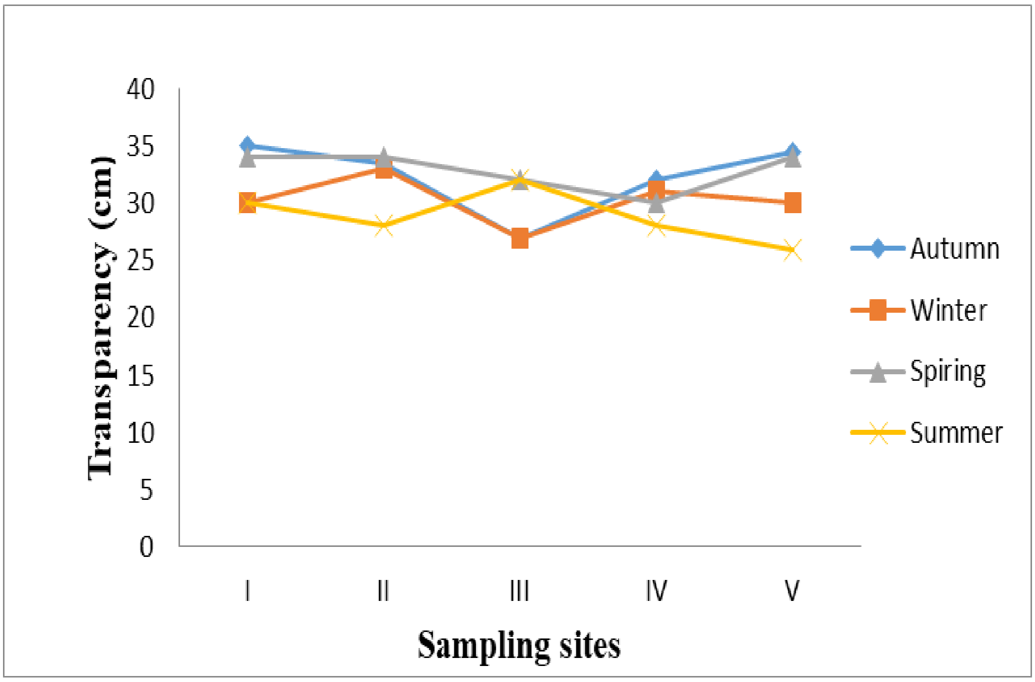


Figure 3: Variation of water transparency at five sampling sites in four seasons

4.1.1.3 Water Turbidity

The water turbidity was also recorded in each season from all sites. During the study period, turbidity value ranged from 18.65cm-25.32cm. Water turbidity was found higher (25.32cm) in summer season at site V and lower (18.65cm) in autumn season at site I (Fig.4).

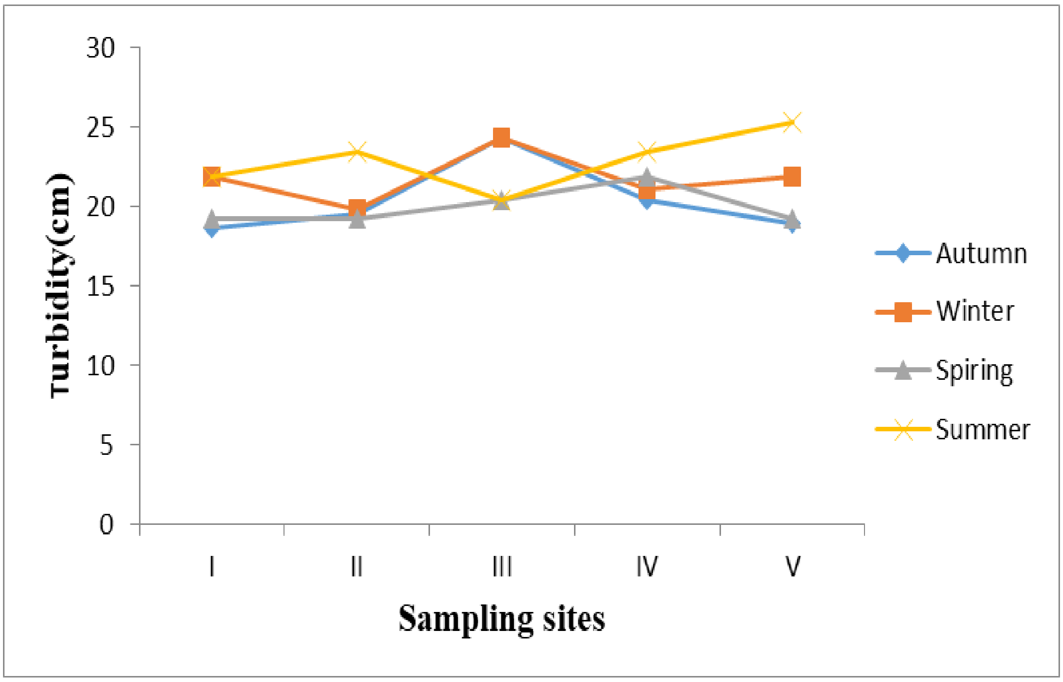


Figure 4: Variation of water turbidity at five sampling sites in four seasons

4.1.2 Chemical parameters of water

4.1.2.1 pH

The pH value varied from 6.8-9 throughout the year. The highest value of pH recorded at site IV (9) in winter season and lowest value at site I (6.8) in autumn. The pH value fluctuates throughout the study period (Fig.5).

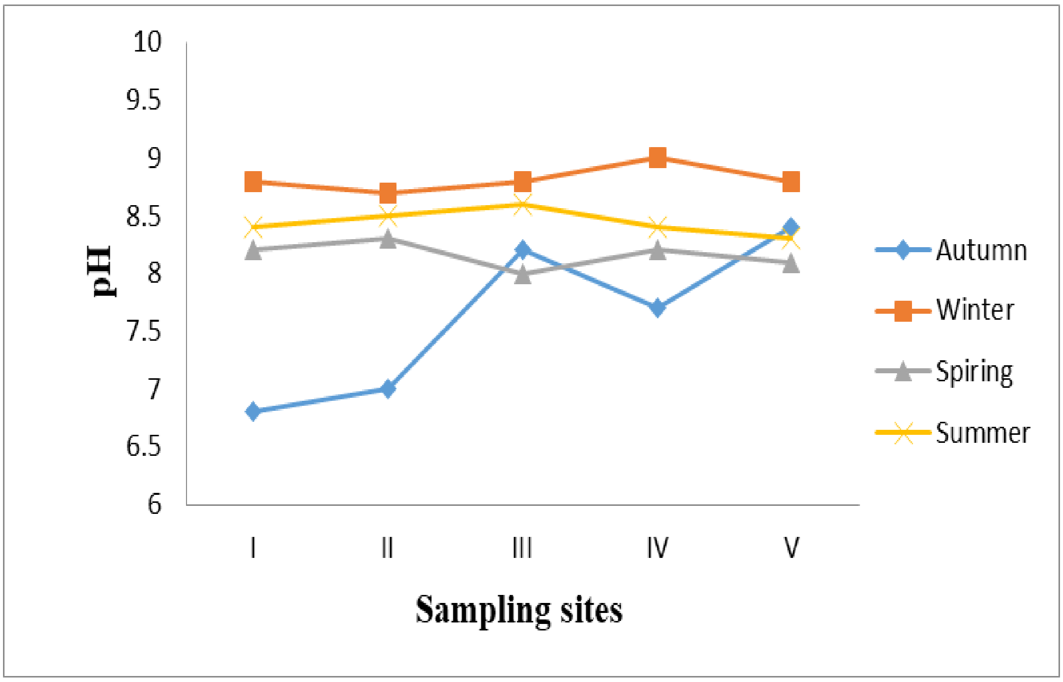


Figure 5: Variation of pH at five sampling sites in four seasons

4.1.2.2 Dissolved oxygen

The DO was also recorded in each season from all sites. During study period DO was ranged from 6.9-8.9(mg/l). The concentration of dissolved oxygen was found highest (8.9 mg/l) in spring at site I and lowest value (6.9 mg/l) at site II in summer season (Fig.6).

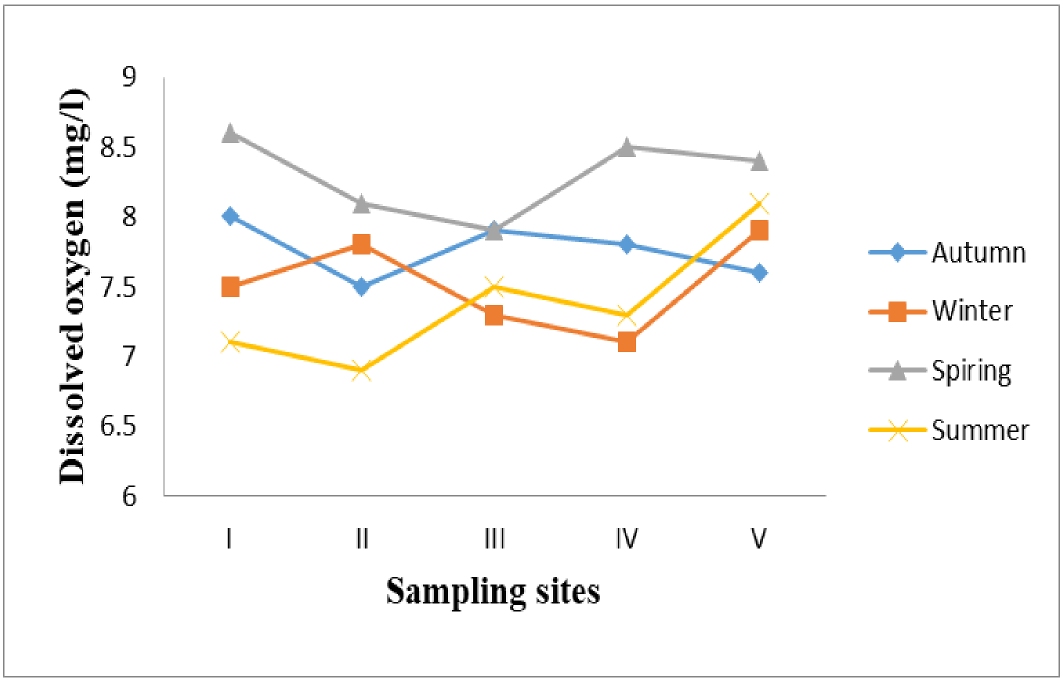


Figure 6: Variation of dissolved oxygen at five sampling sites in four seasons

4.1.2.3 Total Alkalinity

The total alkalinity of the water ranged from 115mg/l-156mg/l. The alkalinity was found to be maximum at site I (156 mg/l) in winter and minimum at site II (115 mg/l) in summer season (Fig.7).

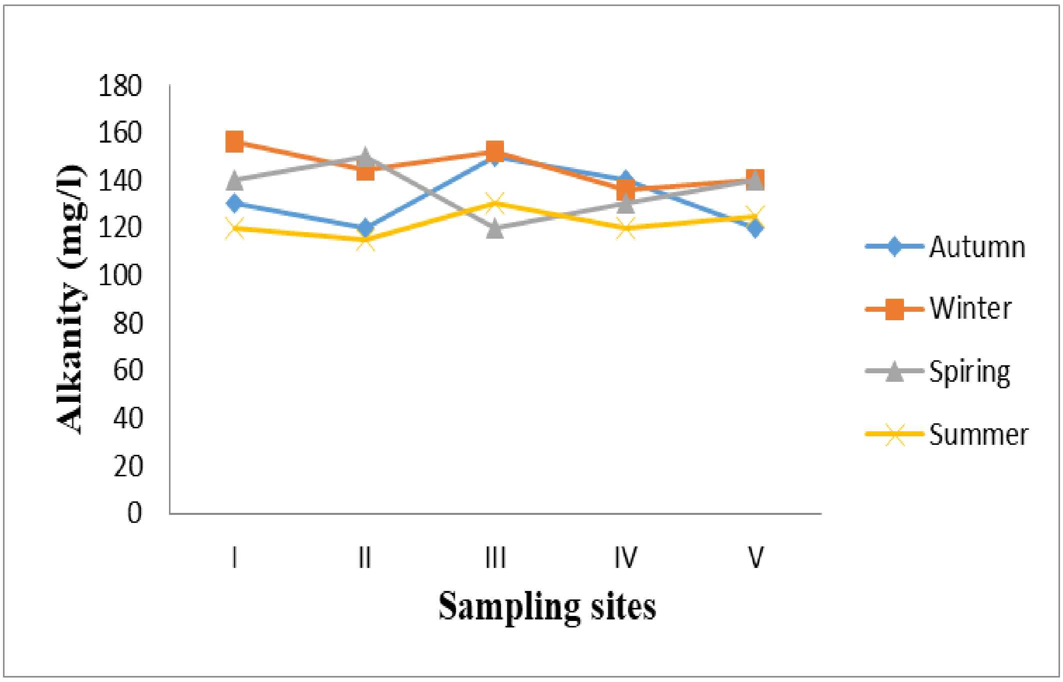


Figure 7: Variation of total alkalinity at five sampling sites in four seasons

4.1.2.4 Total Hardness

The total hardness of water ranged from 68 mg/l - 115mg/l. The hardness was found to be highest at site V (115 mg/l) in summer and lowest at site III (68 mg/l) in autumn season (Fig.8).

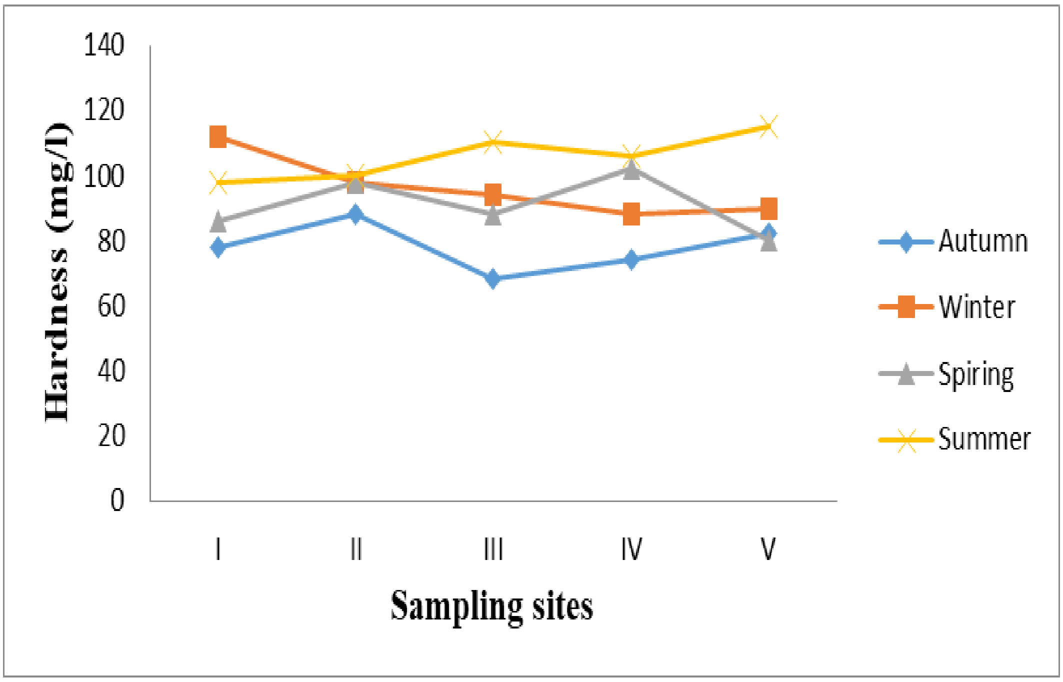


Figure 8: Variation of total hardness at five sampling sites in four seasons

4.2 Fish diversity of Tulsihawa lake

The Tulsihawa Lake is a habitat for fresh water fishes of various types. A total of 19 different fish species (17 were indigenous and 2 were exotic) were found during the study period belonging to 6 orders, 7 families and 16 genera (Table 1). Among the total species *Puntius sophore*, *Amblyphryngodon microlepis,* and *Chanda nama* were the dominant species. Among 17 indigenous species all species were found under Least Concerned (LC). The conservation status was adopted from IUCN red list (2019).

Table 1: Systematic position of fishes with its local name and conservation status

S. N	Order	Family	Name of Species	Local name	Threat status
1.	Cypriniformes	Cyprinidae	*Pethia conchonius* (Hamilton, 1822)	Sidhre	LC
2.			*Puntius sophore* (Hamilton, 1822)	Sidhre	LC
3.			*Puntius chola* (Hamilton, 1822)	Sidhre	LC
4.			*Salmostoma acinaces* (Valenciennes, 1844)	Chelawa	LC
5.			*Amblyphryngodon microlepis* (Bleeker, 1853)	Dhawai	LC
6.			*Esomus danrica* (Hamilton,1822)	Dudahi	LC
7.			*Labeo rohita* (Hamilton,1822)	Rohu	LC
8.			*Labeo bata* (Hamilton,1822)	Rohu	LC
9.			*Chela cachius* (Hamilton,1882)	Chane	LC
10.			*Cirrhinus mrigala* (Hamilton,1822)	Naini	LC
11.			*Cyprinus carpio* (Linnaeus, 1758)	Common carp	*
12.			*Hypophthalmichthys molitrix* (Valenciennes,1844)	Silver carp	*
13.	Anabantiformes	Osphronemidae	*Trichogaster faciatus* (Bloch and Schneider,	Khasti	LC

			1801)		
14.	Siluriformes	Bagridae	*Mystus tengra* (Hamilton,1822)	Tenger	LC
15.	Perciformes	Channidae	*Channa punctata* (Bloch,1793)	Bhoti	LC
16.		Ambassidae	*Chanda nama* (Hamilton,1822)	Chaneri bijuwa	LC
17.	Gobiiformes	Gobiidae	*Glossogobius guiris* (Hamilton, 1822)	Lato mancha	LC
18.	Synbranchiformes	Mastacembelidae	*Macrognathus pancalus* (Hamilton,1822)	Bam	LC
19.			*Mastacembalus armatus* (Lacepede, 1800)	Bam	LC

(Note: * indicates exotic species)

4.2.1 Distribution and frequency occurrence of fishes in Tulsihawa lake

Among 19 fish species, a higher number of total catches occurred as *Amblyphryngodon microlepis* (664) and followed by *Puntius sophore* (197) and *Chanda nama* (108) in total catch. On the basis of frequency distribution, the most dominant species were *Amblyphryngodon microlepis* that contributed (50.53%) of total number of catches followed by *Puntius sophore* (14.99%) and *Chanda nama* (8.21%) respectively. From Site I 17 fish species were reported of which the most prominent species were *Puntius sophore, Chanda nama, Pethia conchonius*, and *Amblyphryngodon microlepis*. A total of 12, 13, 16 and 11 species were reported from site II, III, IV and V respectively among which *Amblyphryngodon microlepis, Puntius sophore,* and *Chanda nama* were the most dominant species. *Chela cachius* found only in summer season (n=2) at site I.

Table2: List of species recorded in different sites during different seasons

S. N	Scientific Name	Autumn season					Winter season					Spring season					Summer season				
		Sites					Sites					Sites					Sites				
		I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
1	*Amblyphryngodon microlepis*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+
2	*Puntius sophore*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3	*Puntius Chola*	-	-	-	-	-	-	+	-	-	-	-	-	-	+	+	+	+	+	-	+
4	*Pethia conchonius*	+	+	+	-	+	+	+	+	+	+	-	-	+	+	+	-	-	-	+	-
5	*Chela cachius*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
6	*Mystus tengra*	-	+	+	+	+	+	+	-	+	-	-	+	+	+	+	+	-	+	+	+
7	*Salmostoma acinaces*	-	-	+	-	-	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-
8	*Glossogobius guiris*	-	-	-	-	-	-	+	+	+	+	-	-	+	+	+	+	+	+	+	+
9	*Chanda nama*	+	+	+	+	+	-	-	+	-	+	+	+	+	+	+	+	+	-	+	+
10	*Chana punctatus*	+	-	-	+	-	+	-	-	+	-	+	-	-	-	+	-	-	-	+	-
11	*Trigogaster fasciatus*	-	-	+	+	-	-	-	+	-	-	-	-	-	+	-	-	-	+	+	-
12	*Macrognathus pancalus*	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
13	*Labeo bata*	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-
14	*Esomus danrica*	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
15	*Cirrhinus mrigala*	+	-	+	+	-	+	+	+	-	-	-	-	+	-	-	+	+	-	+	-
16	*Labeo rohita*	-	-	-	-	-	+	+	-	-	+	-	+	-	-	-	+	+	+	+	-
17	*Hypophthalmicchthys molitrix**	+	-	+	-	+	+	-	-	-	+	-	-	-	+	-	-	-	-	-	-
18	*Cyprinus carpio **	+	-	-	-	-	-	+	-	+	-	-	-	-	+	-	-	-	-	+	-
19	*Mastacembalus armatus*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-

(Note: * indicates exotic species)

4.2.1.1 Order wise fish diversity of Tulsihawa lake

During the study, 19 species were captured with dominancy of order Cypriniformes, which was 63.15% frequency and 12 out of total fish species. Similarly, Equal number of (2) fish species belong to orders Perciformes and Synbranchioformes which were about 10.52% of total fish species each respectively. The lowest number of fish species belonging to order Siluriformes, Gobiiformes, and Anabantiformes which were 5.26% each respectively. The most dominant order was found to be Cypriniformes in Tulsihawa lake.

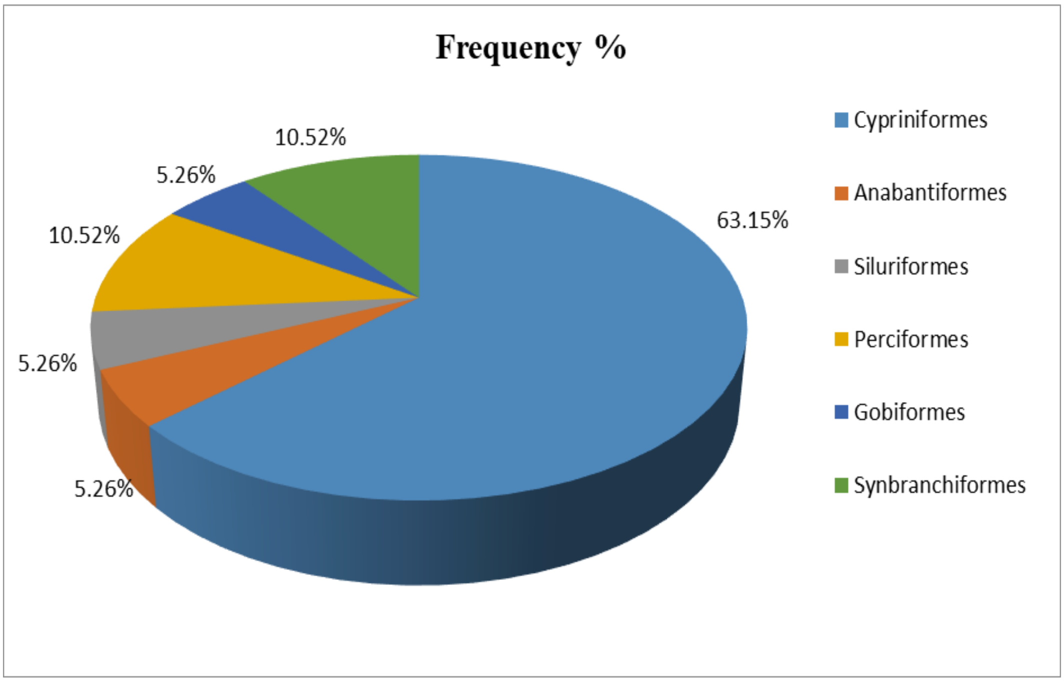


Figure 9: Order wise species composition (%) of Tulsihawa Lake

4.2.1.2 Family wise fish diversity of Tulsihawa lake

During the study period altogether 7 families were enumerated. The highest number of species belongs to the family Cyprinidae (63.15%) in the Tulsihawa lake, followed by Mastacembelidae (10.52%) while the lowest number of fish species belonged to family Osphronemidae, Bagridae, Channidae, Ambassidae, Gobiidae which were contributing equals percentage of species by (5.26%) each respectively.

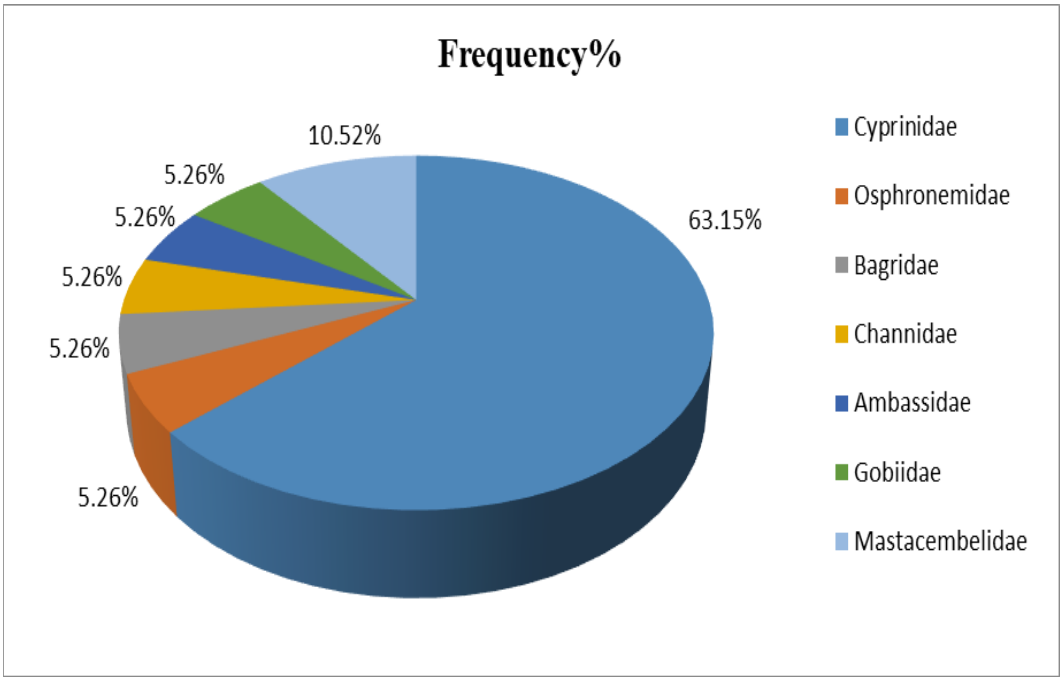


Figure 10: Family wise species composition (%) of Tulsihawa Lake

4.2.2 Diversity status of fish

Seasonally and site wise, the Shannon-Weiner diversity index (H'), Margalef's richness index (d) and Pielou's evenness index were calculated.

4.2.2.1 Site wise diversity indices of Tulsihawa lake

The highest number of fish species was recorded at site I whereas the lowest number recorded at site V. The value of highest Shannon Weiner diversity index found at site IV and the lowest at site I. The maximum Margalef's richness value was observed in station IV, whereas the minimum was found at site V. Similarly, the highest evenness index was recorded in site IV and the lowest in site I.

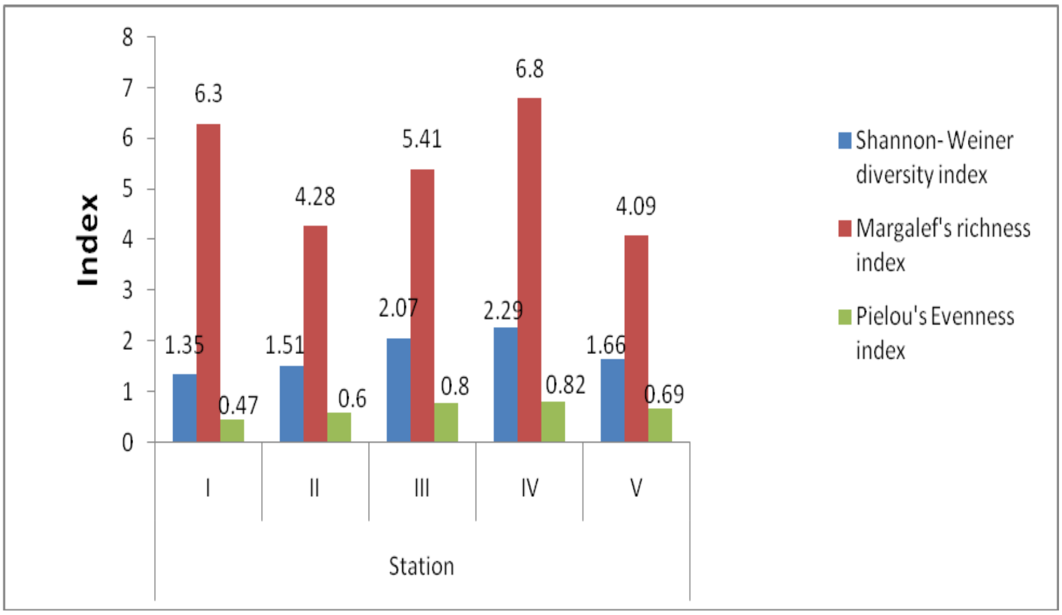


Figure 11: Site wise species diversity indices in different sites

4.2.2.2 Season wise diversity indices of Tulsihawa lake

The highest catch 17 species was recorded in the spring season whereas the lowest catch was recorded in autumn season only 13 species. The summer season had the greatest Shannon-Weiner diversity index value (2.24) while the autumn season had the lowest value (1.49). The maximum Margalef's richness value was observed (6.78) during the summer season and lowest value (4.73) was found during the winter season. Highest evenness index was found to be (0.80) during the summer season and lowest value was found to be (0.56) during the autumn season.

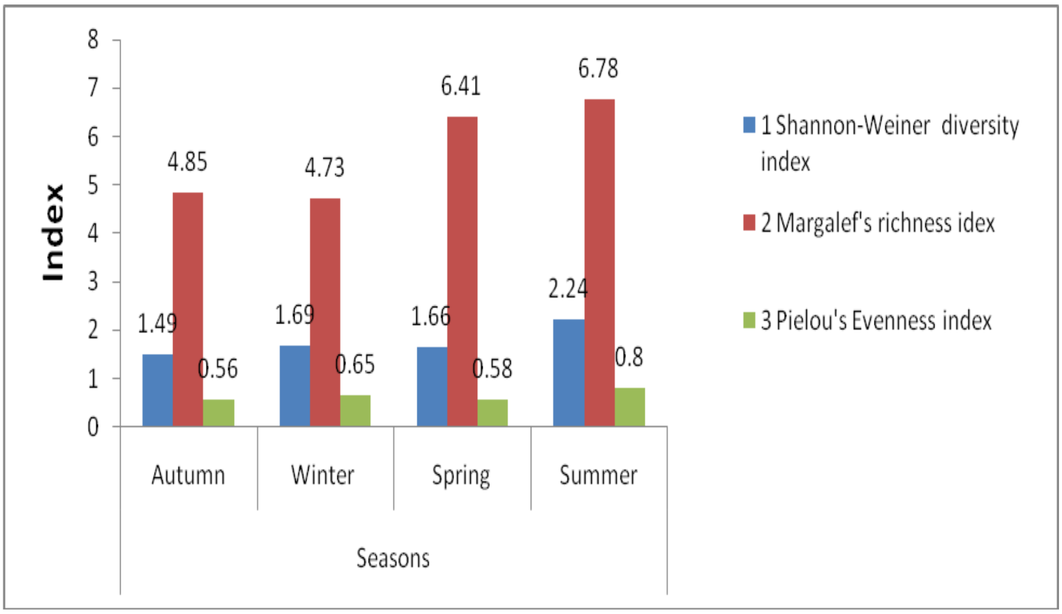


Figure 22: Season-wise species diversity indices in different sites

4.2.3 Correlation between Physico-chemical parameters and fish diversity

The coefficient of correlation between several physico-chemical parameters and species diversity was analyzed using MS Excel. There positive correlation was found between fish diversity and water temperature, dissolved oxygen, total alkalinity and transparency whereas a negative correlation was found between fish diversity and turbidity, pH and total hardness (Table 3).

Table 3: Correlation between Physico-chemical parameters and fish diversity in Tulsihawa Lake

S. N	Variables	Correlation(r)	Probable Error (PE.r)
1	Temperature with Fish diversity	0.08	0.15
2	Transparency with Fish diversity	0.20	0.14
4	Turbidity with Fish diversity	-0.21	0.14
5	Dissolved oxygen with Fish diversity	0.05	0.15
6	pH with Fish diversity	-0.42	0.12
7	Water hardness with Fish diversity	-0.39	0.13
8	Total alkalinity with Fish diversity	0.09	0.15

5. DISCUSSION

The study was conducted in Tulsihawa Lake Rupandehi, Nepal. The data was accumulated over the course of one year, from October 2021 to July 2022 covering four different seasons of autumn, winter, spring, and summer. The distribution and metabolic processes of the many fish species in the lake are influenced by the chemical and physical characteristics; temperature, pH, total alkalinity, total hardness, conductivity, dissolved oxygen, and turbidity of the water.

The physical and chemical parameters like temperature, pH, transparency, turbidity, dissolved oxygen, hardness and alkalinity were analyzed during the study. According to Hutchinson (1957), the meteorological conditions are responsible for seasonal water temperature. The temperature of natural water bodies may vary seasonally, daily and vertically, all of which are correlated with changes in the atmosphere (Kundanagar*et al*., 1996). The water temperature ranges from 16°C to 31°C highest in summer season at station V and lowest in winter season at station I. Murugan and Prabaharan (2012) were also found temperature highest in summer and lowest in winter from Kamala basin, Bihar while Thapa (2018) found highest in summer but lowest in autumn from Dipang lake. Chaudhary (2019) from Taruwa pond and Chaudhary (2019) from Koilahee taal recorded maximum temperature in spring season and minimum temperature in winter season. Gautam *et al*., (2010) reported water temperature ranged from 20.7°C to 31°C from the Jagdishpur reservoir. There is a positive correlation between temperature and fish diversity (r=0.08). Joshi (2015) from Ghodaghodi lake and Chaudhary (2019) from Koilahee taal also found positive correlation between temperature and fish diversity which means the temperature favors the diversification of fish species.

The rain fed turbidity, reflection of light and restriction of light penetration in an aquatic environment are responsible for the transparency status (Stepanek, 1959) and Gregory *et al*., 1991). Water transparency was found to be highest (35 cm) in the autumn at station I and lowest (26cm) in the summer at station V but Tharu (2020) recorded the highest value of transparency in the winter season and lowest in the summer season due to the depth of the lake. Transparency of Tulsihawa Lake was determined to be the lowest in comparison to other lakes, probably as a result of decreased phytoplankton production and inorganic and organic material deterioration.

Fish species and transparency had a positive correlation. Chaudhary (2019) also found positive correlation between fish and transparency in autumn but negative in summer season from Koilahee taal. The turbidity of the water was found to be higher (25.32 cm) in the summer at station V and lower (18.65 cm) in the autumn at station I. Fish species was negatively correlated with turbidity during the study period while Tharu (2020) reported the maximum value in summer and the minimum in winter season with positive correlation between fish diversity and turbidity.

The pH value below 5 and above 9.5 was unsuitable for aquatic life (APHA, 1998). The diurnal fluctuation of pH should remain in the range of 6.8 to 8.5 to support the optimum fish growth (Das, 1996). During the study, the highest pH value was recorded at station IV (9) in the winter and the lowest value at station I (6.8) in the autumn. Murugan and Prabaharan (2012) recorded the highest pH value in winter (7.6) but found lowest in summer (6.1) from Kamala basin India. Bastola (2013) observed the pH value ranged from 6.5 to 7.5 from Dipang lake and concluded that pH value depends upon the precipitation of the calcium carbonate by planktons. The pH value of Tulsihawa Lake indicates that it is mildly acidic to alkaline. Gautam *et al*., (2010) recorded the pH value of the water ranged from 6.8-7.6 from Jagdishpur reservoir. The correlation between pH and fish diversity of Tulsihawa lake was negative (r=-0.42) while Joshi (2015) found positive correlation between fish diversity and pH of Ghodaghodi lake.

Dissolved oxygen content is one of the most crucial variables that may be utilized as an indicator for water quality, pollution, and plant growth in an aquatic habitat and diverse aquatic biota can be supported by dissolved oxygen levels exceeding 5 mg/l (APHA, 1998). The DO level in warm water habitats should not be less than 5 mg/l as an animal will suffocate at a DO level of less than 5 mg/l (Boyd, 1982). The concentration of dissolved oxygen was found highest in spring at station I (8.9 mg/l) and lowest value at station II in summer season (6.9 mg/l) in Tulsihawa lake which was similar to the Murugan and Prabaharan (2012) from Kamala basin, Thapa (2018) from Dipang lake, Chaudhary (2019) from Taruwa pond, Tharu (2020) from Jagdishpur reservoir and Joshi (2015) from Ghodaghodi lake. The positive correlation was found between dissolved oxygen and fish diversity (r = 0.05). Thapa (2018) from Dipang lake, Tharu (2020) from Jagdishpur reservoir and Joshi (2015) from

Ghodaghodi lake also reported, the fish diversity and DO was positively correlated. The DO of Tulsihawa Lake was found to be at the ideal level for fish.

The desirable range of water hardness is 50 mg/l to 150 mg/l and acceptable range is above 10 mg/l as calcium carbonate (Stone and Thomforde, 2004). During the study, the total hardness of water ranged from 68 mg/l to 115 mg/l. The highest hardness was found at station V in summer and lowest at station III in autumn**.** Similar findings were found in Dipang lake by Thapa (2018), in Jagdishpur Reservoir by Tharu (2020) and Gautam *et al*., (2010). The fish diversity was negatively correlated with total hardness (r = -0.39). Joshi (2015) also found negative correlation from Ghodaghodi lake.

Wurts and Durbo (1992) reported the alkalinity between 75 mg/l and 100 mg/l, but no less than 20 mg/l, was recommended for aquaculture ponds. During the present study the total alkalinity of the water ranged from 115 mg/l to 156 mg/l. The alkalinity was found to be highest at station I in winter and lowest at station II in summer season but Thapa (2018) from Dipang lake and Tharu (2020) from Jagdishpur reservoir found higher value of alkalinity in spring season and lowest in autumn season. Bhattacharya *et al*., (2014) and Murugan and Prabaharan (2012) found a very low range of alkalinity; 40.67 mg/l - 94.44 mg/l and 93.0 - 110 mg/l respectively. The total alkalinity and fish diversity had a positive correlation (r= 0.09) in Tulsihawa lake. In Jagdishpur reservoir Tharu (2020) also found positive correlation between fish diversity and alkalinity.

During the study period, 19 fish species (17 indigenous and 2 exotic) belonging to 6 orders, 7 families, and 16 genera were collected from different sampling stations of Tulsihawa Lake. Cypriniformes, Anabantiformes, Siluriformes, Perciformes, Gobiformes, and Synbranchiformes are six orders that were found during the study period. Cypriniformes (63.15%) was the most dominant order holding maximum number of species and contributing maximum catch in percentage in comparison to other five orders followed by Perciformes and Synbranchiformes (10.52 % of each) as second dominant and Siluriformes, Gobiformes and Anabantiformes (5.26% of each) as third dominant orders. Murugan and Prabaharan (2012), Tharu (2020), Chaudhary (2019), Chalise (2020), Husen and Sherpa (2017) and Joshi and K.C (2017) also reported similar results that mentioned Cypriniformes the most dominant order from

Kangsabati reservoir, Jagadishpur reservoir, Taruwa pond, Gajedi lake, Begnas lake and Ghodaghodi lake respectively. *Amblypharyngodonmicrolepis*, *Puntius sophore*and *Chanda nama*were found to be dominant forms as they were found at most of the study sites of the lake.

In context of family level, Cyprinidae contributed 63.15% followed by Mastacembalidae (10.52%), Osphronemidae, Bagridae, Channidae, Ambassidae, and Gobiidae (5.26% of each) respectively. Thapa (2018) from Dipang lake, Chaudhary (2019) from Taruwa pond and Chaudhary (2019) from Koilahee taal also found Cyprinidae as the most dominant family. Chaudhary (2019) reported Mastacembelidae as least dominant family form Koilahee taal but in Tulsihawa lake Bagridae, Channidae, Ambassidae, and Gobiidae had lowest catch during study period that might be due to inefficient implementation of fishing gears.

Out of 19 species, *Amblypharyngodonmicrolepis* (50.53%) had the highest frequency than *Puntius sophore* (14.99%) and *Chanda nama* (8.21%). The highest frequency distribution of *Amblypharyngodonmicrolepis*, may be due to suitable habitat, sufficient food supply and favorable water quality of the lake. Chaudhary (2019) in Koilahee taal, Chalise (2020) in Gajedi lake and Thapa (2020) in Dipang lake also found *Amblypharyngodonmicrolepis*and *Puntius sophore*as the most dominant species. Tripathi and Yadav (2020) found that genus *Mystus* and *Channa* were the dominant species from the Seetadawr Lake. The lowest frequency distribution was observed in *Macrognathuspancalus* (0.07%) and *Mastacembelusarmatus*(0.07%). Joshi (2015) found *Macrognathuspancalus*as lowest catch composition in Ghodaghodi lake and Chaudhary (2019) found lowest catch of *Mastacembelus* in Taruwa pond; both genera fall under same family Mastacembelidae.

In Tulsihawa Lake, the maximum fish species was found in the spring seasons (17) while least species were reported in autumn season (13). The highest numbers of fish species recorded in the spring season was due to favorable conditions such as suitable habitat and food availability. The total catch number was found to be high in station II compared to other stations. *Mastacembalusarmatus* was only recorded during spring season at station I. Similarly, *Macrognathuspancalus* was found only during spring season at station II. The important indigenous fish species *Pethiaconchonius*, *Salmostomaacinaces*, *Chanda nama*, *Mystustengra* were found to be dominant from most of the present study sites. According to local fishermen, *Esomusdanrica* is easily found anywhere in this lake but during the study period low catches 0.53% out of total catch was found.

The Shannon- Weiner diversity index specifies the comparative occurrence of many species was used to associate species abundance and relative richness amongst species (Whittaker, 1977). Biodiversity indexes aspire to characterize the diversity of a sample or community by a single number (Margurran, 1998). The concept of species diversity involves two components i.e., the number of species or richness and the distribution of individuals among species. Shannon - Weiner diversity index considers the richness and the proportion of each species while the evenness index represents the relative numbers of individuals. High scores of Shannon - Weiner diversity index (close to 1) indicate the high diversity and low scores indicates (close to 0) indicates low diversity that means the Tulsihawa Lake is very rich in fish diversity. The highest evenness index was found to be (0.82) at station IV and during the summer season (0.80) whereas the lowest value (0.47) was found at station I and during the autumn season (0.56). The maximum Margalef's richness value was observed (6.80) at station IV and during the summer season (6.78), whereas the minimum value was found to be (4.09) at station V and during the winter (4.73). Joshi and K.C. (2017) found the highest diversity index (2.46), species richness (6.14) and evenness (0.96) in January and lowest diversity index (1.75 in October), lowest species richness (3.91in July) and lowest evenness (0.88 in October) from Ghodaghodi Lake.Chaudhary (2020) also recorded the higher Shannon - Weiner index (1.17) and Margalef's richness index (9.86) in the summer season, whereas higher evenness index in winter season (0.84). Chalise (2020) was recorded highest Shannon - Wiener diversity index at site V (1.78) during the summer season (1.15), Margalef evenness index at site V (7.03) during the summer season (9.19) and evenness index (1.39) was found at site V (1.39) during the winter season.

6. CONCLUSIONS

6.1 Conclusions

Altogether 19 species from 6 orders, 7 families, and 16 genera, were reported from the Tulsihawa Lake. Cypriniformes, Cyprinidae, and *Amblypharyngodon microlepis* were the most dominant order, family, and genus. *Puntius sophore, Pethia conchonius, Chanda nama, Salmostoma acinaces* were found commonly whereas the *Mastacembelus armatus and Macrognathus pancalus* were found rarely. Maximum numbers of fish species were captured during the spring season compared to other seasons. The water quality parameters were found within suitable range that supports fish diversity. The diversity indices show Tulsihawa lake have high diversity, richness and evenly distributed fish species. So, it is concluded that Tulsihawa Lake harbors suitable habitat for variety of fish species.

6.2 Recommendations

According to local people, Fish species in Tulsihawa lake are declining according to the locals. If we are unaware of the biodiversity situation today, it is challenging to quantify the loss of fish biodiversity. So, there are some recommendations that help to conserve diversity and habitat of aquatic biota.

- The aquatic environment has been degraded due to anthropogenic activities such as use of pesticides, unusual way of disposal of wastes so it is recommended to minimize such activities by participation of locals and local authorities.
- Fish poaching is a common problem in the lake and is responsible for fish decline so a community and school-based conservation awareness campaign should be conducted at regular intervals.
- Restriction of fishing in fish breeding season.
- As the lake is leased for fish farming by the management committee, the Aquatic Animal Protection Act, 2017 and National Fisheries Development Policy, 2079 should be followed strictly.

REFERENCES

Alhassan, E.H. 2013. Hydro-biology and fish production of the Black Volta near the Bui Dam during the pre- and post-impoundment periods. PhD Dissertation, University of Ghana, Legon, 209pp.

APHA, 1998. Standard Methods for examination of water and waste water, including bottom sediment and sewage 18th ed. American Public Health Association, Washington D.C.

Bastola, S. 2013. Study of physico- chemical parameters of Dipang lake in Pokhara valley, Nepal. Janapriya Journal of Interdisciplinary Studies, **2**(1).

Beavan, R. 1877. Handbook of the Freshwater Fishes of India; Giving the Characteristic Peculiarities of All the species at Present Known, and Intended as a Guide to Students and District Officers, L. Reeve and Company.

Bera, A., Bhattacharya, M., Patra, B. C., and Sar, U. K. 2014. Ichthyofaunal diversity and water quality in the Kangsabati Reservoir, West Bengal, India. Advances in Zoology, 2014.

Bhandari, B. 1994. Institution and capacity ccin wetland management in Nepal. In safeguarding wetlands in Nepal. Proceeding of the national workshop on wetlands management in Nepal IUCN- Nepal, Kathmandu, 136-199pp.

Blaber, S.J.M. and Blaber, T.G. 1980. Factors affecting the distribution of juvenile eatuarine and inshore fish. Journal of fish Biology **17**:143-162.

Boyd, C.E. 1982. Water quality in wann water fishpond. Department ofFisheries and Allied Aqua-cultures, Auburn University, USA,15-20pp.

CFPCC. 2078. Annual Progress Report (2077-2078), DOA Directorate of Fisheries Development, Balaju, Kathmandu.

Chaudhary, G.P. 2019 Fish diversity of Koilahee taal, Kailali rural Municipality, Kailali, Nepal. M.Sc. Thesis. Central Department of Zoology, Tribhuwan University, Kritipur Kathmandu, Nepal.

Chalise, P. 2020. Fish diversity of Gajedi Lake, Rupandehi, Nepal, M.Sc. Thesis. Amrit Campus, Tribhuwan University, Kathmandu, Nepal.

Das, R.K. 1996. Monitoring of water quality, it's importance in disease control. National workshop on Fish and Prawn diseases, CICFRI, 51-55pp.

Day, F. 1878. The fishes of India being a natural history of the fishes known to inhabit the seas and fresh waters of India, Burma and Ceylon. London, vols. I and II.

Dugan, P. 1993. Wetlands in danger: a world conservation atlas. New York, Oxford University Press.

Galactos, K. and Barriga- Salazar, R. 2004. Seasonal and habitat influences on fish communities within the lower Yusuni River Basin of the Educadorian Amazon. Environmental Biology of Fishes, **71**(9):35-51.

Gaston, K.J. 2000. Global pattern in biodiversity. Nature, 405(6783): 220-227.

Gautam, D., Saund, T. B., and Shrestha, J. 2010. Fish Diversity of Jagadispur Reservoir, Kapilbastu District, Nepal-a Ramsar Site. Nepal Journal of Science and Technology, **11**: 229-234.

Gautam, G., Jain, R., Poudel, L., and Shrestha, M. 2016. Fish faunal diversity and species richness of tectonic Lake Rupa in the mid-hill of central Nepal. International Journal of Fisheries and Aquatic Studies, **4**(3): 690-694.

Gedam, A. K., Andhle, A. V., and Phulwade, D. N. 2019. Study of fresh water fish diversity of Sanjul Lake, Aurangabad. (MS). India. International Journal of Life Sciences (Amravati), (Special Issue A13): 273-275.

Gregory, S.V., Swanson, F.J., McKee, W.A. and Cummins, K.W. 1991. An ecosystem perspective of Riparian Zonws Bioscience, **42**: 540-551.

Gunther, A.G. 1861. List of the cold-blooded vertebrate collected by B.H. Hodgson, Esp., in Nepal. Proc. Zool. Soc. London, PP. 213-227.

Gupta, S.P.1988. Advanced Practical Statistics, Published by S. Chand and Company(pvt) Ltd. New Delhi.

Hamzah, H. 2007 Assessment of water quality and biodiversity within Sangai Batu Pahat. Master of Thesis, University of Technology Malaysia.

Hamilton, F.B. 1822. An account of the fishes found in the river Ganges and its branches, P. VII, 405, 39 pls.

Harris, J.H. 1995. The use of fish in ecological assessments. Australian Journal of Ecology, **80**: 20-65.

Helfman, G.S., Collete, B.B., Facey, D.E. and Bowen, B.W. 2009. The diversity of fishes: biology evolution and ecology, Helfman, G.S., Collete, B.B., Facey, D.E. and Bowen, B.W. second ed. Wilely-Blackwell, 270pp.

Husen, M.A. and Sherpa, L. 2017. Native fish species of Begnas and Rupa Lakes. Pokhara, Nepal: LI-BIRD.

Hussain, M.Z., Latif, Ahmad, S.W., Hussain, S., Iqbaal, R. and Ali, M. 2016. Diversity, Abundance and Seasonal Variation of Fish Community in Lentic Water Bodies of Indus River at Ghazi Ghat, Pakistan. Pakistan Journal of Zoology, **48**(1):59-65.

Husen, M. A., Gurung, T. B. and Nepal, A. P. 2019. Drivers of fisheries and their management in the lakes of Pokhara, Valley. Journal of Fisheries 7(2):706-713.

Hutchinson, G.E. 1957. A Treatise on Limnology. L Geography, Physics and Chemistry John Wiley and Sons, New York, 1105 pp.

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

Jayaram, K.C. 2013. The freshwater fishes of Indian region, second edition, Narendra Publishing House, Dehli, India

Jha, D. K. 2018. Species diversity, distribution and status of fishes in Chitwan district and adjacent areas, Nepal. Journal of Natural History Museum, **30**: 85-101.

Joshi, D. 2015. Fish diversity and community structure in Ghodaghodi lake, Kailali District, Nepal. M.Sc. Thesis. Central Department of Zoology, Tribhuwan University, Kirtipur Kathmandu, Nepal.

Joshi, D., and Bijaya, K. C. 2017. Fish diversity of Ghodaghodi lake in Kailali, far-west Nepal. Journal of Institute of Science and technology, **22**(1).120-126.

Karki, G.B. 2000. Technical report. Fisheries development programme, Markhu, Kulekhani, Nepal. 20 pp.

Keskin, C. and Unsal, N. 1998. The Fish Fauna of Gokceada Island, NE Aegean Sea, Turkey. Italian Journal of Zoology, **65**: 299–302.

Kumar, N. (2012). Study of ichthyofaunal biodiversity of Turkaulia Lake, East Champaran, Bihar, India. International Research Journal of Environmental Sciences, **1**(2): 21-24.

Kumar, P., S.K. Barma and B.R. Subba. 2011. A checklist of fishes of Eastern Terain of Nepal. Nepal Journal of Biosciences, **1**: 63-65.

Kundangar, M.R.D., Sarwar, S.G. and Hussain J. 1996. Zooplanlton population and nutrient dynamic of wetlands of Wular Lake, Kasmir, India. In: Environment and biodiversity in the context of South Asia. Ecological Society (ECOS), Nepal, 128-134.

Lamsal, P., Pant, K. P., Kumar, L., and Atreya, K. 2014. Diversity, uses, and threats in the Ghodaghodi Lake complex, a Ramsar site in western lowland Nepal. International Scholarly Research Notices, 12pp.

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

Margalef, R. 1968. Perspectives in Ecological Theory, University of Chicago press, Chicago, II, 111pp.

Marshall, S. and Elliott, M. 1998. Environmental influences on the fish assemblages of the Humber Estuary. U.K. Estuarine, Coastal and Shelf Science**, 46**: 175-184.

Murugan, A. S., and Prabaharan, C. 2012. Fish diversity in relation to physico-chemical characteristics of Kamala Basin of Darbhanga District, Bihar, India. International Journal of Pharmaceutical and Biological Archives, **3**(1): 211-217.

National Wetlands Policy, 2003. His Majesty's Government of Nepal Ministry of Forest and Soil Conservation.

Nepal Tourism Board. 2009. Tourism Development Endeavors (TUDE) For sustainable, Ethical and Decentralized tourism in Nepal.

Oli, B. B., Jha, D. K., Aryal, P. C., Shrestha, M. K., Dangol, D. R., and Gautam, B. 2013. Seasonal variation in water quality and fish diversity of Rampur Ghol, a wetland in Chitwan, Central Nepal. Nepalese Journal of Biosciences, **3**(1): 9-17.

Piolou, C.E. 1996. The measurement of diversity in different types of biological collections. Journal of Theoritical Biology, **13**:131-144.

Pradhan, R.G. 2017. Fish faunal diversity and occurrence from Wakdi dam district, Parwani, India. Journal of Medical Chemistry and Drugs Discovery, **2**(3):228-232.

Pokharel, P. L. 2011. Biodiversity and Livelihood of the PangreJhalas Wetland, Morang District, Nepal. Geographical Journal of Nepal, 63-72.

Pokharel, K.K and Chand, S. 2019. Diversitty, distribution and occurrence of fishes in Begnas lake, Pokhara, Nepal. Zoo-Journal, **5**: 16-22.

Rajbanshi, K.G. 1982. A general bibliography on fish and fisheries of Nepal. Royal Nepal Academy .

Rajbanshi, K. 2012. Biodiversity and distribution of freshwater fishes of Central/Nepal Himalayan Region. Nepalese Journal of Aquaculture and Fisheries. The Journal of NEFIS, 136 pp.

Rutter, F. 1953. Fundamental of limnology (Translate D.G. Frey and F.E.J. Fry). Torond Univ. Toronto Press, 6 pp.

Santosh, B. and Singh, N.P. 2007. Guidelines for water quality management for fish culture in Tripura, ICAR Research Centre Complex for NEH. Region. Tripura Centre, Publication No.29.

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

Shannon, C.E. and Wiener, E.W. 1949. The mathmatical theory of communication. University of Illinois.

Sharma, C. K. 1977. River system of Nepal. S. Sharma, Kathmandu, Nepal.

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

Shrestha, J. 2001. Taxonomic revision of fishes of Nepal. Environment and Agriculture: Biodiversity, Agriculture and Pollution in South Asia. Ecological Society (ECOS), Kathmandu, Nepal, 171-180.

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

Shrestha, T.K. 1994. Status, ecology and behavior of fishes of Arun river (Nepal). In: Recent Advancement in Fish Ecology Limnology and Eco conservation. Daya Publishing House, Delhi, India. P. 1-26.

Shrestha, T.K. 2019. Ichthyology of Nepal. A study of fishes of the Himalayan waters. Himalayan Ecosphere, Kathmandu, Nepal, 388pp.

Singh, K.D. and Bhattarai, B.P. 2021. Ichhyodiversity and conservation importance of the Jalhor Taal in Kailali district, far western Nepal. Journal of Animal Diversity, **3**(3):93-108.

Stepanek, M. 1959. Limnological Sedlic near Zeliv. IX. Transmission and transparency of water. Scientific papers of the Institute of Physical and Chemical. Technical, Prague, Fac. Technol. Fuel water, **3**: 363-430.

Stone, N.M. and Thomforde, H.K. 2004. Understanding Your Fish Pond Water Analysis Report. Cooperative Extention Program, University of Arkansas at Pine Bluff Aquacuturaes/Fishries.

Suwal, R.N. and Shrestha, M.K. 1990. Large Waders and Wetlands of Terai: A Survey Report. US Fish and Wildlife Service and King Mahendra Trust for Nature Conservation, Kathmandu, Nepal.

Swar, D. B. 1994. A study on the ecology of katle, *Neolissochilushexagonolepis* (McClelland), in a Nepalese reservoir and river.

Swar, D. B., and Gurung T. B. 1988. Introduction and cage fish culture of Chinese carps in Lake Begnas. Hydrobiologia, **166**(3): 277-283.

Thapa, D. 2018. Fish diversity of Dipang lake in the mid-hill of Kaski District, Nepal. M.Sc. Thesis. Central Department of Zoology, Tribhuwan University, Kirtipur Kathmandu, Nepal.

Tharu, S.C. 2022. Diversity of Fishes in Jagdishpur Reservoir Kapilvastu, Nepal. M.Sc. Thesis. Central Department of Zoology, Tribhuwan University, Kirtipur Kathmandu, Nepal

Tonn, W.M., Magnuson, J.J., Rask, N. and Doivonen, J. 1990. Intercontinental comparison of small-lake fish assemblages: the balance between local and regional processes. The American Naturalist, **136**: 345-375.

Tripathi, R.B., and Yadav, k. 2020. Fish Diversity at Seetadawr Lake of District Shravasti, Uttar Pradesh, India. International Journal of Advanced Research in Biological Sciences ,7(12): 69-74.

Trivedy, R. K. and Goel, P.K. 1986. Chemical and biological methods for water pollution studies, Enviro-media, Karad, India.

Wani, O. A. and Gupta, U. S. 2015. A study in icthyofaunal diversity of Sagar lake, Mandhya Pradesh, India. International Journal of Biodiversity and Conservation, **7**(3): 126-129.

Wetzel, R.G.1983. Limnology. Saunders College Publishing,Philadelphia, PA, USA.

Whitettaker, R.S. 1977. Evolution of species diversity on land communities. Evolutionary Biology, **10**: 1-67.

Wurts, W.A. and Durborrow, R.M. 1992. Interaction of pH, Carbon Dioxide, Alkalinity and Hardness in Fish Pond Southern Regional Aquaculture Centre, SRAC, Publication No. 464.

Ye, S. 2007. Studies on fish communities and trophic network model of sallow lakes along the middle reach of Yanjtze River PhD. Institute of Hydrobiology, Chinese Academy of Sciences, Wuh

Electronic references

http://www.fishbase.org/Assessed on 5 December 2022

http://www.iucnredlist.org/ Assessed on 10 December 2022

PHOTOPLATES

PLATE I

Puntius sophore, (Hamilton, 1822)

Puntius chola, (Hamilton, 1822)

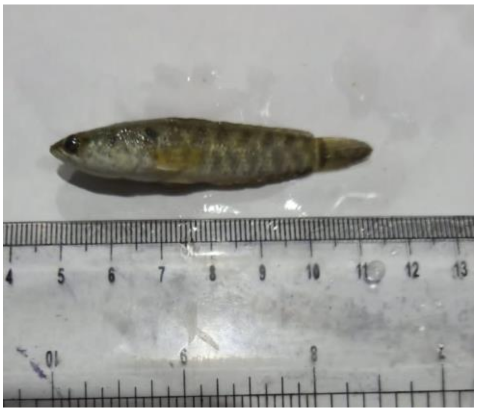
Pethia conchonius, (Hamilton, 1822)

Amblyphryngodon microlepis, (Bleeker, 1853)

Chanda nama, (Hamilton, 1822)

Salmostoma acinaces, (Valenciennes, 1844)

PLATEII

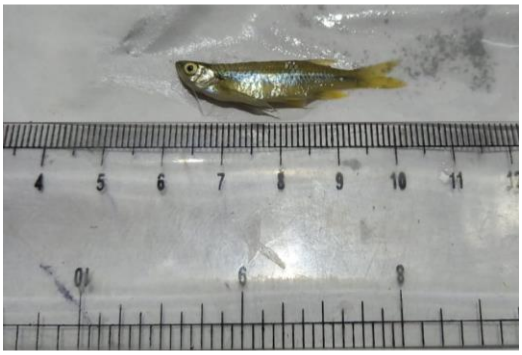


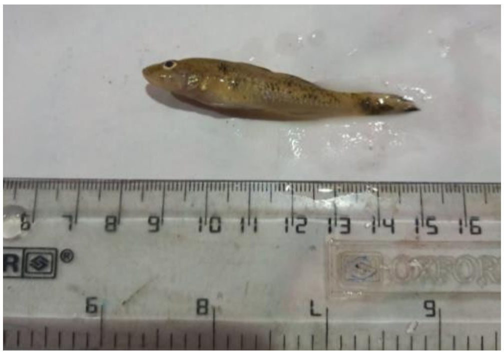
Channa punctata(Bloch,1793)

Mystus tengra (Hamilton, 1822)

Trichogaster fasciatus (Bloch, and Schneider,1801)

Chela cachius (Hamilton, 1822)





Esomus danrica (Hamilton, 1822)

Glossogobius guiris (Hamilton, 1822)

PLATE-III

Macrognathus pancalus (Hamilton, 1822) *Mastacembalus armatus* (Lacepede, 1800)

*Cirrhiinus mrigala (*Hamilton, 1822) *Labeo bata* **(**Hamilton, 1822)

Labeo rohita (Hamilton, 1822) *Hypophthalmichthys molitrix* (Valenciennes,1844)

Cyprinus carpio (Linnaeus, 1758)

PLATE- IV

Tulsihawa lake

Fish sampling

Silver fish in cast net

Collection of capture fish

Measuring pH of water

Analysis of water parameter

APPENDICES

Appendix I Physico- chemical parameters during different seasons at selected sampling station

S.N	Parameters	Seasons/Stations																			
		Autumn					Winter					Spring					Summer				
		I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
1	Temperature (0°c)	24	26.5	26	27.3	28.3	16	17.2	17.1	17.1	17.5	26.2	25.1	26.4	25.6	26	29.4	29.6	30.2	30.8	31
2	Transparency (cm)	35	33.5	27	32	34.5	30	33	27	31	30	34	34	32	30	34	30	28	32	28	26
3	Turbidity (cm)	18.65	19.51	24.35	20.44	18.93	21.85	19.81	24.35	21.12	21.85	19.21	19.21	20.44	21.85	19.21	21.85	23.45	20.44	23.45	25.32
4	pH	6.8	7	8.2	7.7	8.4	8.8	8.7	8.8	9	8.8	8.2	8.3	8	8.2	8.1	8.4	8.5	8.6	8.4	8.3
5	Dissolved oxygen(mg/l)	8	7.5	7.9	7.8	7.6	7.5	7.8	7.3	7.1	7.9	8.6	8.1	7.9	8.5	8.4	7.1	6.9	7.5	7.3	8.1
6	Total hardness (mg/l)	78	88	68	74	82	112	98	94	88	90	86	98	88	102	80	98	100	110	106	115
7	Total alkalinity (mg/l)	130	120	150	140	120	156	144	152	136	140	140	150	120	130	140	120	115	130	120	125

Appendix II: Order-wise fish species and total fish catch composition (%)

S. N.	Order	Numberof species	Frequency
1	Cypriniformes	12	63.15%
2	Siluriformes	1	5.26%
3	Anabantiformes	1	5.26%
4	Perciformes	2	10.52%
5	Synbranchiformes	2	10.52%
6	Gobiformes	1	5.26

Appendix III: Family-wise fish species and total fish catch composition (%)

S. N	Family	No. of species	Species composition
1	Cyprinidae	12	63.15%
4	Bagridae	1	5.26%
5	Osphronemidae	1	5.26%
6	Channidae	1	5.26%
7	Gobiidae	1	5.26%
8	Ambassidae	1	5.26%
11	Mastacembelidae	2	10.52%

Appendix IV: Distribution pattern and frequency occurrence of fishes in Tulsihawa lake

S. N	Name of species	Stations					Total	Frequency (%)
		I	II	III	IV	V		
1.	*Puntius sophore*	45	52	24	21	55	197	**14.99**
2.	*Pethia chonchonius*	17	30	17	11	23	98	**7.45**
3.	*Puntius chola*	1	3	2	2	2	10	**0.76**
4.	*Amblyphryngodon microlepis*	228	205	55	50	126	664	**50.53**
5.	*Salmostoma acinaces*	3	13	10	8	18	52	**3.95**
6.	*Chanda nama*	12	33	19	19	25	108	**8.21**
7.	*Channa punctata*	3	-	-	5	1	9	**0.68**
8.	*Trichogaster fasciatus*	-	-	6	3	-	9	**0.68**
9.	*Mystus tengra*	2	5	10	10	3	30	**2.28**
10.	*Esomus danrica*	2	-	1	4	-	7	**0.53**
11.	*Glossogobius guiris*	1	2	7	9	11	30	**2.28**
12.	*Macrognathuss pancalus*	-	1	-	-	-	1	**0.07**
13.	*Chela cachius*	2	-	-	-	-	2	**0.15**
14.	*Labeo bata*	4	-	-	3	-	7	**0.53**
15.	*Labeo rohita*	8	15	9	7	-	39	**2.96**
16.	*Cyprinus carpio*	2	2	-	3	-	7	**0.53**
17.	*Cirrhinus mrigala*	5	6	1	3	1	16	**1.21**
18.	*Hypophthalmicthys molitrix*	10	-	3	2	12	27	**2.05**
19.	*Mastacembalus armatus*	1	-	-	-	-	1	**0.07**
	Total	346	367	164	160	277	1314	

Appendix V: Station wise species diversity indices in different seasons

S. N	Diversity indices	Station				
		I	II	III	IV	V
1	Shannon- Weiner diversity index	1.35	1.51	2.07	2.29	1.66
2	Margalef's richness index	6.30	4.28	5.41	6.80	4.09
3	Pielou's Evenness index	0.47	0.60	0.80	0.82	0.69

Appendix VI: Season wise species diversity indices in different seasons

S.N	Diversity indices	Seasons			
		Autumn	Winter	Spring	Summer
1	Shannon-Weiner diversity index	1.49	1.69	1.66	2.24
2	Margalef's richness idex	4.85	4.73	6.41	6.78
3	Pielou's Evenness index	0.56	0.65	0.58	0.80