



**FISH DIVERSITY OF DARAUNDI RIVER, GANDAKI RIVER  
SYSTEM, NEPAL**

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**A dissertation submitted**

**In partial fulfillment of the requirements for the award of degree of Master of  
Science in Zoology with special paper Fish Biology and Aquaculture (Course Code-  
Zoo 653)**

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**March 2025**



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SYSTEM, NEPAL**

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**March 2025**

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## Declaration

I hereby declare that the work presented in this dissertation “Fish Diversity of Daraundi River, Gandaki River System, Nepal” has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) and institution(s).

  
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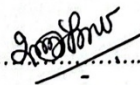
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
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Shanti Tamang

## Abstract

The present study was carried out to explore fish diversity in the Daraundi River, Gandaki River system, Nepal. The study covered three seasons, including the post-monsoon and autumn of 2023 and spring of 2024. Five permanent sampling sites were selected to collect fish and measure water quality parameters. Fishes were collected using cast net (3 mm to 6 mm mesh size) and hook & line with the help of local fishermen. The collected fish samples were identified by using keys (Shrestha 2019, Jayaram 1977). The study collected 21 fish species belonging to 4 Orders, 6 families and 15 genera, with a total of 780 individuals. Seasonal diversity showed the highest fish diversity in post-monsoon compared to autumn and spring seasons. Cypriniformes was the dominant order with 18 species and 1 each species from Anabantiformes, Siluriformes and Synbranchiformes. This study recorded 14-23 °C water temperature, DO (7-11 mg/l), Free CO<sub>2</sub> (2-5.2 mg/l), water velocity (1-1.9 m/s), and pH (7.5-10) during its study period. Shannon-Weiner's, Simpson's, and Margalef's was highest during post-monsoon season but Pielou's evenness was high in spring season. The Karl Pearson's coefficient of correlation affirmed that water temperature, DO and water velocity positively correlated with fish diversity whereas pH and Free CO<sub>2</sub> showed negative correlation with fish diversity. This study establishes foundational data crucial for future investigations concerning fish diversity, distribution, and water quality in the Daraundi river of Gorkha district.

**Keywords:** *Daraundi River, Fish Diversity, Gandaki River System, Water Quality Parameters*

## शोध सार

प्रस्तुत सोधकार्य गोरखा जिल्ला अवस्थित दरौदी खोला गण्डकी नदी प्रणाली स्थित माछाको प्रजातीको विविधताको अध्ययनमा केन्द्रीत रहेको छ। यस शोधकार्यमा माछाका नमूनाहरू र पानीका मापकहरू सन् २०२३ को अगष्ट देखि सन् २०२४ को अप्रिलसम्म संकलन गरिएको थियो। नमूना संकलनका लागि प्रमुख पाँच साइटहरू मनसुनपछीको समयमा, बसन्त, र शरद ऋतुमा भ्रमण गरिएको थियो। नमूना संकलनका लागि जाली र बल्छीको प्रयोग स्थानीय माभीहरूको सहयोगबाट गरिएको थियो। यसका साथै पानीका प्यारामिटरहरू पनि स्यामपलिङ साइटहरूमा मापन गरिएको थियो। संकलीत माछाका नमूनाहरू (क्षेष्ठ (२०१९), जयराम (१९७७) का काञ्जीहरूको सहायताले पहिचान गरिएको थियो। यस अध्ययनमा २१ माछाका प्रजाती जसमा ४ अर्डर, ६ फ्यामिलीज र १५ जेनेराका, ७८० माछाहरू संकलन गरिएको थियो। साइप्रिनिफर्मिसले सबैभन्दा प्रतिभाशाली अर्डर भएको देखायो, जसमा १८ प्रजाति भएको पाइयो, आनावन्टीफर्मिस, सिलुरीफर्मिस र सिन्ब्राङ्गीफर्मिसका एउटामात्र प्रजाति पाइयो। यस अध्ययन अनुसार साइप्रिनीडे प्रतिभाशाली फ्यामिली भएको पाइयो भने सबैभन्दा कम प्रतिभाशाली चन्नाडी र मास्तासेमवेलीडे पाइयो। यस अध्ययनले आफ्नो अध्ययन अवधिमा १४-२३ °C पानीको तापक्रम, DO (७-११ mg/l), फ्री CO<sub>2</sub> (२-५.२ mg/l), पानीको वेग (१-१.९ m/s), र pH (७.५-१०) रेकर्ड गरेको छ। श्यानन-वेनर, सिम्पसन र मार्गालेफको मनसुनपछीको मौसममा सबैभन्दा बढी थियो तर बसन्त ऋतुमा पिलोउको समानता उच्च थियो। कार्ल पियर्सनको सहसम्बन्धको गुणांकले पानीको तापक्रम, DO र पानीको वेग माछाको विविधतासँग सकारात्मक रूपमा सम्बन्धित रहेको पुष्टि गर्‍यो जबकि pH र free CO<sub>2</sub> ले माछाको विविधतासँग नकारात्मक सम्बन्ध देखाएको छ। यो अध्ययनले गोरखा जिल्लाको दरौदी नदीमा माछाको विविधता, वितरण र पानीको गुणस्तर सम्बन्धी भविष्यको अनुसन्धानको लागि महत्त्वपूर्ण आधारभूत डेटा स्थापित गर्दछ।

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## List of abbreviations

APHA	American Public Health Association
WECS	Water and Energy Commission Secretariat
WWF	World Wide Fund for Nature
IUCN	International Union for Conservation of Nature
°C	Degree Centigrade
Σ	Summation
%	Percentage
R	Coefficient of correlation
P. E	Probable Error
Km	Kilometers
Mg/l	Milligram per liter
NaOH	Sodium Hydroxide
Ppm	Parts per million
DO	Dissolved Oxygen
Free CO <sub>2</sub>	Free Carbon dioxide
m/s	meter per second
AAPA	Aquatic Animal Protection Act

# 1. Introduction

## 1.1 General Background

Located along the southern slopes of the central Himalayas, Nepal endows diverse freshwater water resources accessible for direct human uses (WECS, 2011). This is the water found in the glaciers and snow covers, lakes, rivers, reservoirs and those underground sources (Ghimire & Koju, 2021). Globally, only 2.5% of total areas constitute of freshwater resources, while 97.5% of the total area is covered by ocean and seas (Ghimire & Koju, 2021). Despite the fact that oceans and seas cover more area, Nepal's water resources share no connection to these water bodies. Nevertheless, it's location where the Palearctic and Oriental biological regions meet, combined with diverse landscapes, creates a wide range of aquatic habitats, resulting in a rich variety of fish species (Rajbanshi, 2005). Additionally, Nepal's varied landscapes results in significant differences in climate because the altitude changes quickly over short distances (ADB, 2018). Because of this drastic elevation gradients, the aquatic resources of Nepal also differ morphologically in their origin, flow, magnitude, and sediment load (Adhikari, 2013).

### 1.1.1 River Systems of Nepal

Nepal shares Ganga and Brahmaputra as basins along with other nations like India, Pakistan, Bangladesh, Bhutan and China (Bhusal, 2024). Nepal is estimated to have network of over streams, rivers, wetlands, lakes, and estuaries that flows through 70% of the nation's total area, all originating from altitude over 5000m above sea level (Chitrakar et al., 2024). The rivers of Nepal have been classified into three grades depending upon their origin. Grade 1 rivers are large and perennial rivers, originating from the high Himalayas, while Grade 2 rivers are also perennials but medium originating from middle mountains and grade III rivers are the small rivers originating from the Siwalik/Churia range flowing directly to India (Bhattarai & Goutam, 2003). The rivers are further classified in three major river systems: The Koshi, Gandaki, and Karnali. These rivers are the Sapta Koshi in the east, the Sapta Gandaki (Narayani) in the central region, the Karnali in the west, and the Mahakali in the far western part of the country (Khatri et al., 2020).

### 1.1.2 Fish Diversity of Nepal

Nepal's abundant water resources support over 252 fish species (236 native species and 16 exotic fish species) across various river systems of Nepal (Shrestha, 2019). The country's

diverse topography, from lowland plains to high-altitude Himalayan streams, provides varied habitats that support a wide range of fish species, enhancing the overall biodiversity (Shrestha, 2019). Similarly, as a landlocked country, Nepal's fish diversity is confined to freshwater habitats, yet despite this limitation, catadromous species such as *Anguilla bengalensis*, have been reported in the Marshyangdi river (Mandal & Jha, 2014). Research and studies conducted over the years have highlighted significant aspects of fish diversity in Nepal. However, the biodiversity of these rivers is under threat from various anthropogenic activities, such as hydropower development, which can fragment and degrade aquatic habitats (Manandhar et al., 2023).

### **1.1.3 Influence of Ecological Factors on Fish Diversity**

The diversity and distribution of aquatic communities are greatly influenced by the system's biochemical and environmental parameters. Gaining a better understanding of these factors and the ecosystem's response to environmental variables has been a focal point for environmentalists over the years (Odule et al., 2014). Similarly, habitat features, either biotic or abiotic components and are the major determinants in distribution and abundance of fishes from way back (Arunachalam, 2000). Environmental factors such as Dissolved oxygen, pH, salinity, water temperature, and flow rate are primary determinants of fish distribution and diversity as they influence metabolic rates, reproductive cycles, and habitat suitability (Moyle, 1993). Similarly, seasonal variations in water temperature and flow can significantly affect fish community structures, especially in rivers and streams (He et al., 2020; Nhat et al., 2024). In alpine rivers, rapid warming, glacier melt, and changes in land cover due to climate change are particularly impactful, leading to altered habitats and increased vulnerability of fish species (He et al., 2020). Human activities such as excessive extraction of river sediments, and the introduction of chemicals for agricultural have substantially degraded water quality and biodiversity in freshwater habitats (Mohd et al., 2021).

### **1.1.4 Conservation Challenges and IUCN status of Freshwater Fishes of Nepal**

The conservation of fish and fish communities has been relatively neglected compared to other vertebrates. Across Eurasia and North America, many significant fish stocks have been lost, resulting in thousands of lakes and rivers that are either devoid of fish communities or on the verge of degradation (Maitland, 1995). And in case of Nepal, it's freshwater fish diversity faces significant conservation challenges, primarily due to habitat

degradation, pollution, overfishing and climate change (Gurung, 2013). Similarly, urbanization and industrial activities have led to the destruction and alteration of natural habitats, especially in the southern and urban regions, resulting in alarming decline of fish population (Jana, 2007; Shrestha, 1994). Additionally, anthropogenic activities like river mining are one of the major threats to freshwater fish diversity as it significantly degrades water quality by releasing sediments, altering flow patterns, and increasing turbidity, which also adversely affects environmental factors such as nutrient cycles, dissolved oxygen level, ecosystem health and disrupts of aquatic habitats (Damseth et al., 2024). To add, introduction of non-native fishes as well as river fragmentation in temperate rivers are also one of the causes for change in the biodiversity (Su et al., 2021).

Nepal homes 252 fish species of which IUCN lists 2 species as endangered (EN), 9 vulnerable species (VU), 23 rare and threatened species (R), 32 data deficient pristine rare ornamental species (PRO), 27 conservation dependent and rare species (CDR), 53 uncommon or lower risk least concern species (UN), 71 common species (C) and 15 exotic species (Shrestha, 2019). IUCN's first global assessment of freshwater fish revealed that 25% (3,086 out of 14,898 assessed species) are threatened with extinction, highlighting them as one of the most-at-risk vertebrate groups (WWF, 2023). Out of the 4 major river systems, the Gandaki system has been known to harbor the highest number of species (171) (Khatri et al., 2020), yet very little is known about fish diversity status of many major river tributaries and streams of Gandaki river system including Daraundi. Henceforth, for constructing effective conservation plans for freshwater fishes, investigation of fish diversity status by incorporating species richness, diversity indices, and conservation concerns is necessary.

## **1.2 Objectives**

### **1.2.1 General objective**

The main objective of the study was to explore the fish diversity of Daraundi River of Gandaki River System.

### **1.2.2 Specific objectives**

The specific objectives of the study are as follows:

- To assess the seasonal fish diversity of the river.
- To investigate the seasonal Water Quality Parameters.

- To analyze the relationship between water quality parameters and fish diversity.

### **1.3 Significance of the Study**

Although numerous studies have focused on large fish species in Nepal's major rivers, smaller rivers and tributaries remain understudied. Additionally, there is limited understanding of the ecological roles fish play in their habitats. This study provides baseline data on the fish species of this river, offering valuable insights for fish conservation and examining the relationship between fish diversity and water quality parameters.

## **2. Literature review**

Nepal is filled with beautiful aquatic habitats all across the country. These habitats are home to various plants and animals of varied behaviors. Among the many species that adorns these habitats fishes are one of the lower vertebrates that calls them home. The research study to identify all the available species is still going on as biodiversity studies of all water bodies has not been conducted. Nevertheless, over the time period several works have been done to learn about freshwater fish science of Nepal.

### **2.1 Gandaki River Basin**

One of the major river systems of Nepal, the Gandaki River Basin which extends from 83°10' to 85°30'E and latitude 27°30' to 29°20'N in the central region of Nepal (Gaudel, 2013), with a total of drainage area of 34960 Km<sup>2</sup> of which about 84.74% (29262 Km<sup>2</sup>) lies in Nepal, and the remaining 5334 Km<sup>2</sup> lies in Tibet (Dixit & Shukla, 2021). The river in its upper reaches is known as Kali Gandaki and when it reaches the Terai-plains of Nepal, it is known as Narayani River. The Kali Gandaki, Marshyangdi, Daraundi, Seti Gandaki, Madi, Budhi Gandaki, and Trishuli are the major seven tributaries of Gandaki River Basin. Also, east Rapti river also is part of Gandaki River System which join River Rapti in Chitwan (Jha, 2018).

### **2.2 Fish Diversity of Gandaki River System**

Edds (1993) was among the pioneering researchers to explore the Gandaki River System. His work focused on the spatial and temporal patterns of fish assemblages in the Kali Gandaki/Narayani River, emphasizing the impact of geographic and environmental factors on species distribution. From his study, he reported that more than 182 fish species known to occur in Nepal inhabit the Kali Gandaki/Narayani River.

Mardi Stream, one of the major tributaries of Seti Gandaki River is home to 10 species belonging to 3 orders, 3 families and 9 genera. Cypriniformes is the major contributing species of the river (Edds, 1993).

A study examining the impact of a dam on the fish diversity of the Marshyangdi River in Lamjung identified 26 fish species across 5 orders, 6 families, and 18 genera. The most dominant family was Cyprinidae, followed by Cobitidae, Sisoridae, and Channidae (Mandal & Jha, 2014).

A total of 111 species, spanning 9 orders, 27 families, and 71 genera, were documented in various tributaries of the Trisuli, Rapti, and Narayani Rivers in the Chitwan district and surrounding regions. Of these orders, Cypriniformes had the most species, followed by Siluriformes, Perciformes, Synbranchiformes, and Osteoglossiformes, with Anguilliformes, Beloniformes, Clupeiformes, and Tetraodontiformes having fewer species (Jha, 2018).

Modi Khola, a tributary of the Kali Gandaki River, is home to a total of 7 fish species. Among these, 5 species (*Schizothorax richardsonii*, *Schizothorax plagiostomus*, *Schizothorax progastus*, *Garra annandalei* and *Garra gotyla*) are carps, while the remaining 2 species (*Pseudecheneis sulcata* and *Glyptothorax pectinopterus*) are catfish (Bhandari, 2019).

Pokharel et al. (2018) reported a total of 30 fish species of 5 orders, 9 families and 24 genera in the Seti Gandaki River, where, Cyprinids were the abundantly found family followed by Silurids, Belonids, Balitorids, Channids, Mastacembelids and Cobitids.

Prasad et al. (2020) in the same river reported 46 fish species belonging to 4 Orders, 9 families and 23 genera and stated that DO, pH, hardness, and water temperature are the pivotal water quality parameters to determine the fish community structure in the Seti Gandaki River, Tanahu, Nepal.

### 3. Materials and methods

#### 3.1 Study area

The study was conducted in the Daraundi River of Gorkha district, and is one of the seven tributaries of Gandaki River. The river flows across the district of Gorkha and meets with Marshyangdi river at Abu Khaireni. The geographical location is  $27^{\circ} 59' 11.68''$  N and  $84^{\circ} 33' 55.32''$  E to  $28^{\circ} 2' 8.96''$  N and  $84^{\circ} 36' 10.50''$  E. The upper part of Daraundi river basin lies in Manaslu Conservation Area and it flows in Mahabharat region. The main source of the river is Glacier Lake which originates from Narad Pokhari. This area lies in Siranchowk Gaunpalika, Palungtar Nagarpalika and Gorkha Nagarpalika. There are altogether 37 river tributaries in which 16 form major river tributaries.

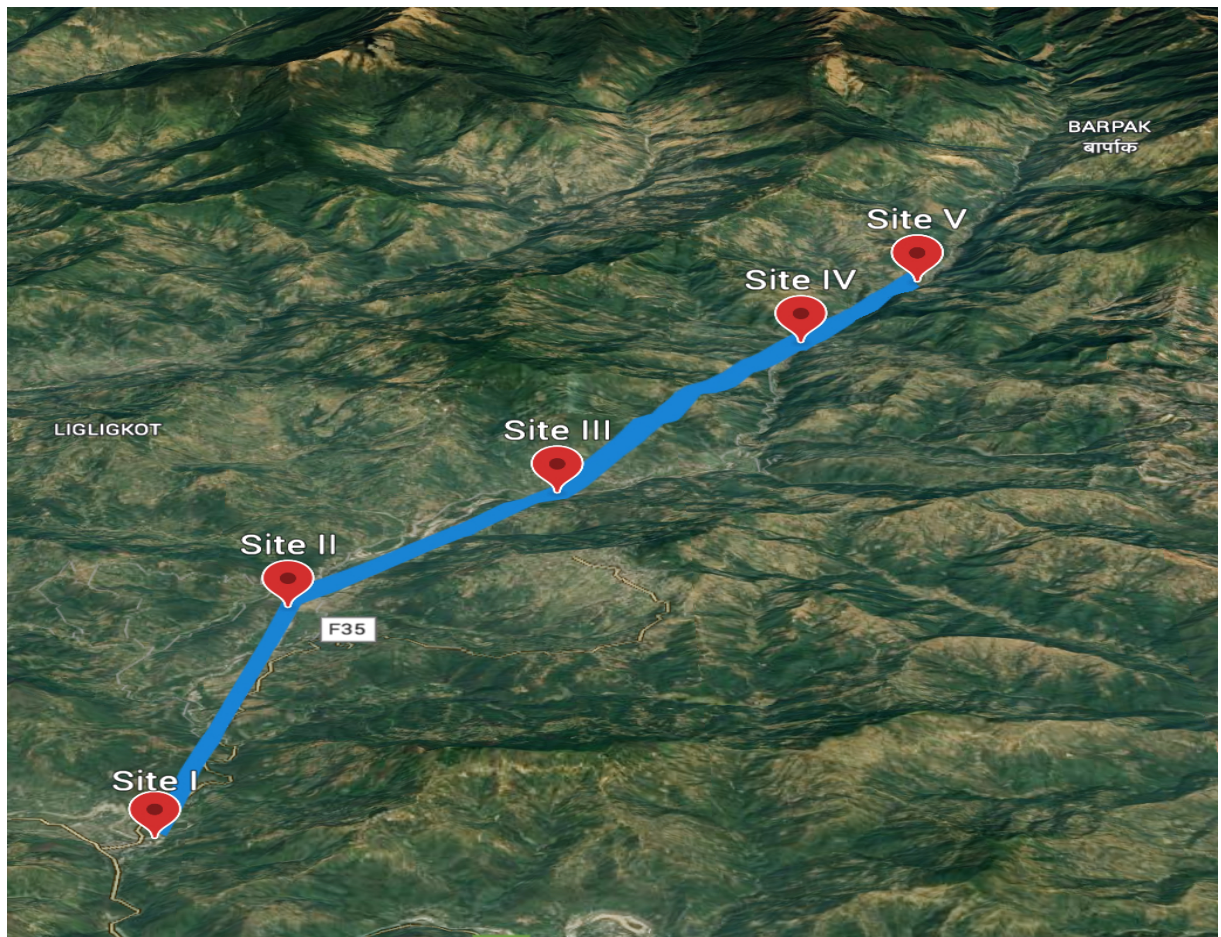


Figure 1. Map showing the sampling sites of the study

### **3.2 Study period**

The fieldwork was conducted in three seasons (post-monsoon, autumn and spring) between August 2023 to April 2024. Sampling was carried out in August, November and April to collect the seasonal fish and environmental conditions.

### **3.3 Sample collection**

The fish was collected with the assistance of fisherman. Sampling was done from 7 AM to 11 AM at each sampling sites in all season. Cast net of mesh size (3 mm to 6 mm mesh size, 25-33 feet length and 3.5-5 feet width) were used to collect the fish samples. Cast net was thrown at intervals of 10-20 meters away, each throw takes 2-3 minutes to recover. The hook & line was also used for the collection of the fish sample. The gear was set at the river banks in different spots of each sampling around the 5 PM to 6 PM in the evening and taken out around 7 AM the next morning. About 4 hook and line were used in one sampling station. At each sampling site, approximately 2-3 hours was spent for fish sampling. Before fish sampling, measurement of water quality parameters was carried out.

### **3.4 Sampling sites**

To study the fish diversity of Daraundi River, five sampling sites were selected. These sampling sites were at Anbu Khaireni, Chhebetar, Siranchowk, the confluence of Syangdi and Daraundi Rivers, and upstream of Kalika Hydropower Dam. These sites were selected based on the several key criteria such as geographical variability, habitat variability, human intervention, accessibility, disturbed and undisturbed area, etc. Similarly, location that varied in terms of water flow, depth, and surrounding vegetation were also considered while selecting sampling sites to capture a broad spectrum of ecological conditions. The precise geographic coordinates of the sampling sites were determined by using Google Earth (version 10.59.0).

#### **3.3.1 Site I – Confluence of Daraundi and Marshyangdi River**

The first sample site was fixed at Anbu Khaireni of Anbu Khaireni Rural Municipality of Tanahu district. It is located between 27°54'17"N 84°32'44"E. Anbu Khaireni is a busy town as it is on the Prithvi Highway and is one of the gateways to neighboring districts like Lamjung, Chitwan, Tanahu, and more. Many people in this area are engaged in aquaculture thus fish is one of the common diets of the people in this part. With farmed fishes, people also enjoy fishes from the river. Similarly, as the settlement and fish ponds are quite near to the river, people directly use the river for various domestic as well as irrigation purpose.

### **3.3.2 Site II – Chhebetar**

The second sampling site was fixed at Chhebetar of Gorkha Municipality. The sampling site is located between 27°59'20"N 84°33'53"E. This site is about 10 km far from the first sampling site. The area around the river is mostly agricultural land. This site particularly used to be a picnic site but not anymore. Similarly, this is a cremation site as well. Moreover, this specific section of the river is subject to active sand and stone mining operations.

### **3.3.3 Site III – Siranchowk**

The third sampling site was selected at Siranchowk of Siranchowk Rural Municipality. The sampling site is located between 28°02'15"N 84°36'53"E. This sampling site is about 7 km away from the sampling site II. The area around the river is mostly forested area. There is a thin village near the sampling site thus cattle grazer is common occurrence of this area.

### **3.3.4 Site IV – Syagdi and Daraundi River Confluence**

The fourth sampling site was fixed at Syagdi and Daraundi River confluence of Chanaute village of Ajirkot Rural Municipality. The sampling site is located between 28°06'31"N 84°39'58"E. This sampling site is about 10 km away from the sampling site III. The sampling site has a small tributary river called Syagdi Khola. The river width of this sample site is narrow. Similarly, sample site is just few kilometers before the Kalika Hydropower House.

### **3.3.5 Site V – Above Kalika Hydropower Dam**

The last sampling site was fixed at above Kalika Hydropower Dam station located in Muchoktar village of Ajirkot Rural Municipality. The sampling site is located between 28°08'20"N 84°41'34"E. And this sampling is about 5 km away from the sampling station IV.

## **3.4 Materials and Chemicals used**

- Cast net and hook & line
- Plastic jars
- Mobile phone
- Measuring tape
- pH meter
- Thermometer
- Formalin (10%)

- Phenolphthalein and NaOH (0.01N) for Free CO<sub>2</sub>
- Digital DO meter

### **3.5 Sampling Methods**

#### **3.5.1 Sampling and preservation of fish**

Fishing was mostly done during morning time from 7-10 AM. Cast net and hook & line were used in capturing the fishes. The cast net used had a mesh size of 3-6mm, which is permitted for fishing the Daraundi River. Cast nets were repeatedly thrown at each sampling site. Fish trapped in the nets were collected and temporarily kept in a bamboo basket. Species were identified in the field whenever possible, and those that could not be identified were brought to the laboratory of the Zoology Department of Amrit Campus for further identification. Fish were photographed in the field, and the collected specimens were preserved in a 10% formalin solution in plastic jars.

#### **3.5.2 Identification and deposition of specimen**

The collected fish samples were identified using FishBase (fishbase.org) and standard identification keys developed by Talwar & Jhingran (1991), (Jayaram, 1977), and Shrestha (2019). The field specimens were then deposited in the ASCOL laboratory.

### **3.6 Water Quality Parameters**

For this study, the water quality parameters were measured and determined using the guideline strategies of (APHA, 1926) and (Trivedy & Goel, 1984). pH of the water was determined using pH meter (HANNA HI98107) and Dissolved Oxygen (DO) was determined using DO meter (HANNA 9147) in the field. Free CO<sub>2</sub> was analyzed by titrating water sample against a strong alkali Sodium hydroxide (NaOH) and Phenolphthalein indicator. Water temperature was measured using a standard alcohol thermometer in the field. And water velocity was determined by the float method with the help of a stop watch, and plastic bottle.

#### **3.6.1 Water temperature**

The water temperature was recorded using a standard alcohol thermometer. The temperature was measured by dipping the bulb of the thermometer inside the water at a depth of 1 foot for several times. The reading was taken multiple times until the reading was stable.

### 3.6.2 Water velocity

Water velocity at each sampling site was calculated using the float method. A plastic bottle and a measuring tape were used to determine the length of the river stretch. The plastic bottle served as the float, and the initial and final points of the stretch were marked. The bottle was then released at the starting point, and the time it took to reach the endpoint was recorded in meters per second (m/s) using a stopwatch on a phone.

### 3.6.3 pH

A pH meter was used to measure the water's pH level at all sampling sites. The pH was measured by immersing the meter's probe in the water at a depth of 1 foot and repeating the process several times. The average of the readings was then taken to obtain a stable reading.

### 3.6.4 Dissolved Oxygen (DO)

The dissolved oxygen (DO) level of the water was measured using a DO meter. The probe was immersed in the water and left for approximately 1 minute to measure the DO level. The process was repeated multiple times, and the average of the readings was taken to obtain a stable measurement.

### 3.6.5 Free CO<sub>2</sub>

Free CO<sub>2</sub> was determined in situ. To calculate free CO<sub>2</sub>, 50 ml of the water sample was taken in a conical flask, and a few drops of phenolphthalein were added. The appearance of a pink color after adding phenolphthalein indicates the absence of free CO<sub>2</sub>. The solution was then titrated with a 0.05 M NaOH solution from the burette. The endpoint was reached when the solution changed color from colorless to pink. This process was repeated three times, and the average value was recorded. The free CO<sub>2</sub> concentration in the water sample was then calculated using the following formula:

$$\text{Free CO}_2 \text{ (mg/l)} = \frac{(\text{ml} \times \text{N}) \text{ of NaOH} \times 1000 \times 4}{\text{Volume of sample used (ml)}} \text{ where;}$$

V = Volume of water sample taken (ml)

ml = Amount of NaOH used during the titration

N = Normality of NaOH

### **3.7 Diversity Indices**

#### **3.7.1 Shannon-Weiner Diversity Index**

The diversity of species was calculated by using Shannon-Weiner diversity index (Shannon, 1949). Shannon-Weiner diversity index is designated as  $H'$ , which was calculated as:

$$H' = -\sum(P_i) \ln(P_i) \text{ where;}$$

$$P_i = n_i/N$$

$n_i$  = Number of all individuals in the species

$N$  = Total number of all individuals in the sample

$\ln$  = natural logarithm

#### **3.7.2 Species Richness Index**

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

$$\text{Margalef's species richness (d)} = S-1 / \ln N \text{ where;}$$

$S$  = Total number of species

$N$  = Total number of individuals in the sample

#### **3.7.3 Evenness Index**

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

$$E = H' / \ln S \text{ where;}$$

$H'$  = Shannon-Weiner's diversity index.

$S$  = Total number of species in the sample

#### **3.7.4 Simpson's Diversity Index**

Simpson's Diversity index ( $D$ ) was calculated by using following formula

$$D = 1 - n_i(n_i - 1) / N(N - 1) \text{ (Simpson, 1949) where;}$$

$n_i$  = Total number of individuals of particular species

$N$  = total number of species

### 3.8 Data analysis

All the water quality parameters and number of fish species with their diversity indices (Shannon-Wiener, Simpson's, Pielou's and Margalef's) were calculated using Microsoft excel. The relation between fish diversity and water quality parameters were calculated using Karl Pearson correlation coefficient formula (Gupta, 1979).

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

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

## 4. Results

### 4.1 Fish Diversity

A study in Daraundi River revealed the presence of a diverse aquatic ecosystem, hosting a total of 21 different fish species. These species were taxonomically distributed across 4 orders (Anabantiformes, Cypriniformes, Siluriformes and Synbranchiformes), 6 families (Channidae, Cyprinidae, Nemacheilidae, Cobitidae, Schilbeidae and Mastacembelidae) and 15 genera. Among 21 fish species documented in this study, 3 species (*Channa Orientalis*, *Schizothorax richardsonii* and *Tor chelynoides*) fell in the vulnerable category, and 18 species in the least concern (LC) category according to the National Red Data Book of Nepal.

**Table 1. Checklist of fish species recorded from the Daraundi river with order, family, Scientific names, IUCN status and their common names**

Orders	Family	Scientific Names	Common/Local Name	IUCN Red List status
Anabantiformes	Channidae	<i>Channa orientalis</i> Bloch & Schneider 1801	Bhoti	VU
Cypriniformes	Cyprinidae	<i>Barilius barila</i> (Hamilton, 1822)	Faketa	LC
		<i>Barilius bendelisis</i> (Hamilton, 1807)	Faketa	LC
		<i>Barilius vagra</i> (Hamilton, 1822)	Lam Faketa	LC
		<i>Garra annandalei</i> Hora, 1921	Buduna	LC
		<i>Garra gotyla gotyla</i> (Gray, 1830)	Buduna	LC
		<i>Labeo dyocheilus</i> (McClelland, 1839)	Gardi	LC
		<i>Neolissochilus hexagonolepis</i> (McClelland, 1839)	Copper Mahseer/ Katlae	LC

		<i>Puntius sophore</i> (Hamilton, 1822)	Phothi	LC
		<i>Puntius terio</i> (Hamilton, 1822)	Titey	LC
		<i>Schizothorax richardsonii</i> (Gray, 1832)	Asla	VU
		<i>Schizothorax plagiostomus</i> (Heckel, 1834)	Buchhe Asala	LC
		<i>Systemus sarana sarana</i> (Hamilton, 1822)	Kande	LC
		<i>Tor chelynooides</i> (McClelland, 1839)	Karanga	VU
	Cobitidae	<i>Lepidocephalichthys guntea</i> (Hamilton, 1822)	Nakata	LC
	Nemacheilidae	<i>Acanthocobitis botia</i> (Hamilton, 1822)	Gadelo	LC
		<i>Schistura rupecula</i> McClelland, 1838	Bhotee Gadelo	LC
		<i>Schistura savona</i> (Hamilton, 1822)	Gadela	LC
		<i>Nemacheilus corica</i> (Hamilton, 1822)	Gadela	LC
Siluriformes	Schilbeidae	<i>Clupisoma garua</i> (Hamilton, 1822)	Jal kapoor	LC
Synbranchiformes	Mastacembelidae	<i>Mastacembelus armatus</i> (Lacepède, 1800)	Chuche Bam	LC

#### 4.2 Season-wise composition of fish abundance of Daraundi River

A total of 780 individual fish, belonging to different species were collected from five sampling sites along the Daraundi River. The data reveals that Sampling site I yielded 14 species (n=173 individuals), site II hosted 16 species (n=177 individuals), site III hosted 15 species (n=138), site IV hosted 15 species (n=147 individuals), and Site V hosted 13 species

(n=145 species). Seasonal variation in fish diversity was also observed, with 16 species (n=210 individuals) collected during the post-monsoon season, 15 species (n=303 individuals) during autumn, and 16 species (n=267 individuals) in the spring season. Among the collected species, *Barilius bendelisis* was the most dominant, constituting 10.9% of the total catch, followed by *Barilius barila* at 10.8%. Notably, the species *Labeo dyocheilus* and *Clupisoma garua* exhibited the lowest frequencies, each accounting for only 0.1% of the total catch collected, as shown in table 2.

**Table 2. Season-wise fish composition of Daraundi River**

Species	Post-monsoon					Autumn					Spring					Total	Frequency (%)
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V		
<i>Acanthocobitis botia</i> (Hamilton, 1822)	5	3	2	2	-	3	2	5	3	-	3	2	6	2	-	38	4.9
<i>Barilius barila</i> (Hamilton, 1822)	3	4	4	3	3	5	7	2	9	7	9	6	6	7	9	84	10.8
<i>Barilius bendelisis</i> (Hamilton, 1807)	5	6	3	3	4	9	6	6	4	8	5	9	5	5	7	85	10.9
<i>Barilius vagra</i> (Hamilton, 1822)	5	3	4	2	2	9	5	7	4	-	6	7	8	4	3	69	8.8
<i>Channa orientalis</i> Bloch & Schneider 1801	2	2	-	-	-	4	2	3	2	3	3	2	4	2	3	32	4.1
<i>Clupisoma garua</i> (Hamilton, 1822)	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.1
<i>Garra annandalei</i> Hora, 1921	-	4	8	1	-	2	3	3	4	6	5	5	3	2	1	47	6.0
<i>Garra gotyla</i> (Grey, 1830)	3	4	2	1	-	3	6	5	5	3	4	4	3	4	5	52	6.7
<i>Labeo dyocheilus</i>	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.1

(McClelland, 1839)																		
<i>Lepidocephalichthys guntea</i> (Hamilton, 1822)	-	-	-	1	1	-	1	-	-	7	-	-	-	-	-	10	1.3	
<i>Mastacembelus armatus</i> (Lacepède, 1800)	-	2	-	1	-	-	-	-	-	2	-	3	-	-	-	8	1.0	
<i>Nemacheilus corica</i> (Hamilton, 1822)	6	7	2	1	-	6	3	2	8	-	7	5	3	2	-	52	6.7	
<i>Neolissochilus hexagonolepis</i> (McClelland, 1839)	-	2	1	3	3	3	4	1	3	7	2	2	1	3	3	38	4.9	
<i>Puntius sophero</i> (Hamilton, 1822)	6	6	-	-	-	1	-	2	-	-	-	3	4	-	-	22	2.8	
<i>Puntius terio</i> (Hamilton, 1822)	4	5	-	-	-	4	-	-	-	3	-	3	4	-	-	23	2.9	
<i>Schistura rupecula</i> (McClelland, 1838)	3	4	3	1	2	4	2	3	4	9	3	3	2	1	1	45	5.8	
<i>Schistura savona</i> (Hamilton, 1822)	2	5	4	3	2	5	4	1	6	6	7	3	3	2	2	55	7.1	
<i>Schizothorax richardsonii</i> (Gray, 1832)	1	-	2	5	6	1	3	4	8	1	6	3	-	3	4	47	6.0	
<i>Schizothorax plagiostomus</i> Heckel, 1838	-	-	2	6	6	-	5	1	9	10	5	4	-	4	5	57	7.3	
<i>Systemus sarana</i> (Hamilton, 1822)	-	-	1	-	-	-	-	1	3	-	2	-	-	-	-	7	0.9	

<i>Tor chelynoides</i> (McClelland, 1839)	2	-	2	1	1	-	1	-	-	-	-	-	-	-	-	7	0.9
<b>Total</b>	47	59	40	34	30	59	54	46	72	72	67	64	52	41	43	780	100

### 4.3 Species Diversity Indices

The highest species richness was recorded during post-monsoon with 16 species collected at sampling site II. However, the least species richness was found in spring with 10 species collected at sampling site I. The highest (2.651) Shannon-Weiner's Index (H') was recorded at sampling site II in post-monsoon, while the lowest (2.14) was recorded at sampling site V in post-monsoon. The highest Simpson's diversity (D) (0.939) was at II in post-monsoon and lowest (0.897) was recorded at V in each of the post-monsoon and spring season. The maximum (2.561) and minimum (2.141) values of Margalef's index (d) was both recorded during post-monsoon at sampling site II and V respectively. Pielou's evenness (E) was high (0.965) at sampling site II and low (0.925) at V in spring season.

**Table 3. Species diversity indices (species richness, Shannon-Weiner's, Simpson, Pielou's and Margalef's richness) of Daraundi River**

Indices	Post-Monsoon					Autumn					Spring				
	Sampling sites														
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Species Richness	13	16	14	15	10	14	15	15	14	13	10	15	13	13	11
Shannon Wiener's Diversity	2.462	2.651	2.484	2.504	2.141	2.479	2.575	2.523	2.540	2.428	2.218	2.613	2.463	2.449	2.219
Simpson's Diversity Index	0.928	0.939	0.926	0.930	0.897	0.921	0.934	0.929	0.927	0.917	0.901	0.934	0.925	0.927	0.897
Pielou's Evenness Index	0.960	0.956	0.941	0.925	0.930	0.939	0.951	0.932	0.962	0.947	0.963	0.965	0.960	0.955	0.925
Margalef's richness Index	3.11	3.44	3.52	3.97	2.64	3.81	3.5	3.65	3.03	2.8	3.09	3.84	3.03	3.23	2.65

#### 4.4 Order-wise composition of fish

A total of 4 orders: Cypriniformes, Anabantiformes, Siluriformes and Synbranchiformes have been recorded. Cypriniformes constituted with 85% (18 species) followed by Siluriformes, Anabantiformes and Synbranchiformes with 5% (1 each species).

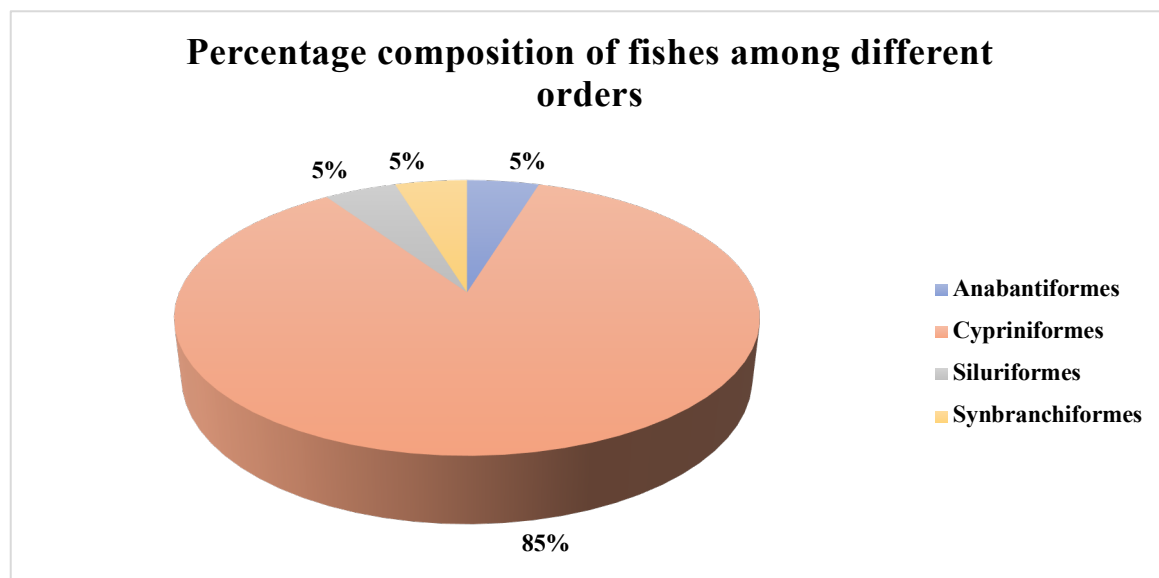


Figure 2. Order-wise fish composition of Daraundi River

#### 4.5 Family-wise fish composition of Daraundi river

The Cyprinidae family is the most dominant, representing 72.28% of the total fish population in spring and 68.1% and 67% in post-monsoon and autumn respectively. Nemacheilidae remain constant in all three seasons with 27.14%, 25.08% and 21.35% in post-monsoon, autumn and spring respectively. Channidae is the least found family with 1.9% (post-monsoon), 4.62% (autumn) and 5.24% (spring). Mastacembelidae family remained consistently low (1.43%, 0.66% and 1.12%) across all seasons. While cobitidae was recorded during post-monsoon (0.95%) and autumn (5.24%), it was absent in spring. And Schilbeidae was recorded only in post-monsoon (0.48%).

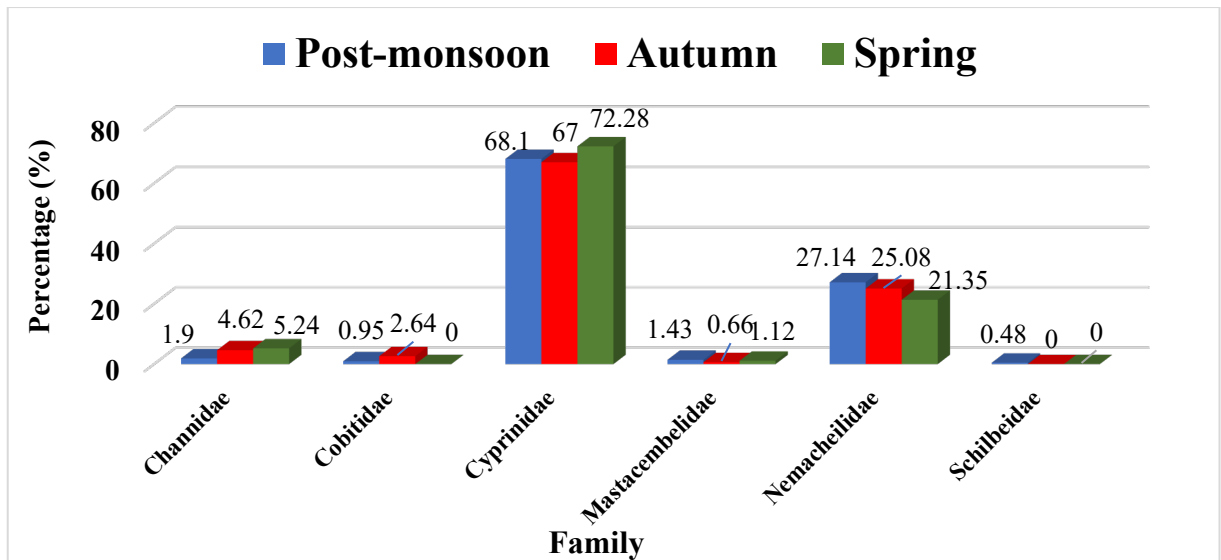


Figure 3. Family-wise fish composition of Daraundi River

#### 4.6 Water Quality Parameters

Water temperature, pH, water velocity, DO and Free CO<sub>2</sub> were determined to check water quality parameters of Daraundi River in all three seasons. The highest water temperature (23°C) was noted at post-monsoon season, while the lowest (14°C) was noted at autumn season. Similarly, highest (10) pH was noted in autumn season and the lowest (7.5) was noted in post-monsoon season. DO ranged between 7 mg/l to 11 mg/l, where spring recorded the lowest and the post-monsoon recorded the highest respectively. Water velocity was highest (1.9 m/s) during autumn and the lowest (1m/s) in post-monsoon season. And lastly, the Free CO<sub>2</sub> was highest (5.2 mg/l) during post-monsoon and the lowest (2.9 mg/l) in autumn season.

**Table 4. Water quality parameters of Daraundi river in three seasons**

Water Quality Parameters	Seasons														
	Post-monsoon					Autumn					Spring				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
pH	7.6	7.5	7.7	7.8	8	9.5	9.3	9.4	9.6	10	8	9	8.7	9	9.5
Water temperature (°C)	23	23	22	22	22	17.2	17.1	16.2	14.3	14	18.1	17.7	17.4	16.7	16.8
DO (mg/l)	10	9.7	11	10	9	8.1	8.4	8.7	9.2	9.3	8.1	8	7.8	7.5	7
Water velocity (m/s)	1.5	1.4	1.4	1.1	1	1.9	1.3	1.5	1.3	1.2	1.9	1.6	1.4	1.3	1.2
Free CO <sub>2</sub> (mg/l)	4.1	4.4	5.1	5.2	4.4	3.2	3.1	2.9	2.1	2.5	3.1	3.5	2.9	3.6	3.2

#### 4.6.1 Water temperature

Sampling site I and II recorded highest (23 °C) temperature in post-monsoon season while the lowest (22 °C) was recorded at sampling site III, IV and V. In autumn, the highest temperature (18.1 °C) was recorded at sampling site I and lowest (16.8 °C) at sampling site V. The notable temperature variation with consistent drop was seen in spring. The lowest being 12 °C at sampling site V and highest being 17.2 °C at sampling site I.

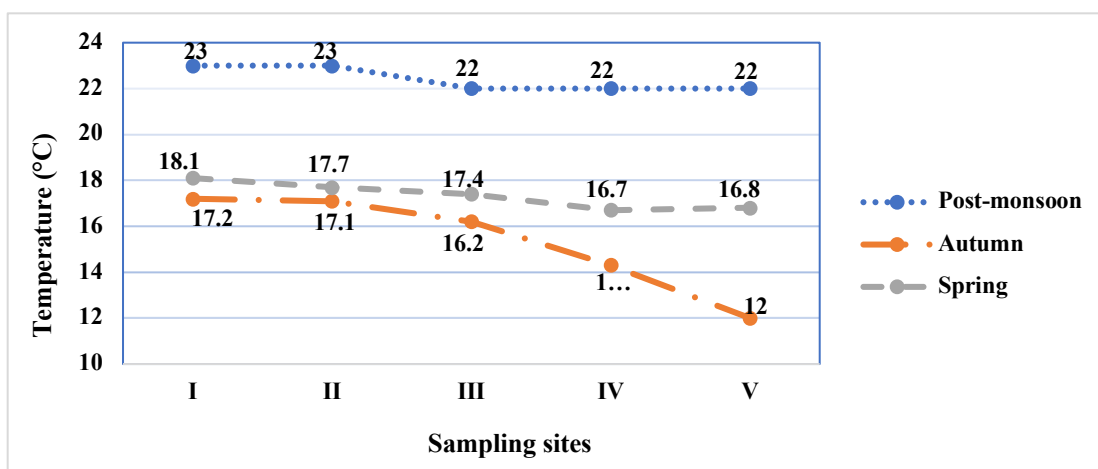


Figure 4. Water temperature recorded at five sampling sites in three seasons of the Daraundi river

#### 4.6.2 pH

The pH level in post-monsoon was almost similar in all five-sampling sites with 7.6 (I), 7.5 (II), 7.7 (III), 7.8 (IV) and 8 (V). In autumn, the pH was recorded highest (10) at sampling site V while lowest (9.3) at sampling site II. However, the most fluctuation was seen during spring season with 8 being lowest at sampling site I, sampling sites II and IV had the similar pH value at 9 and the highest pH value 9.5 was recorded in sampling site V.

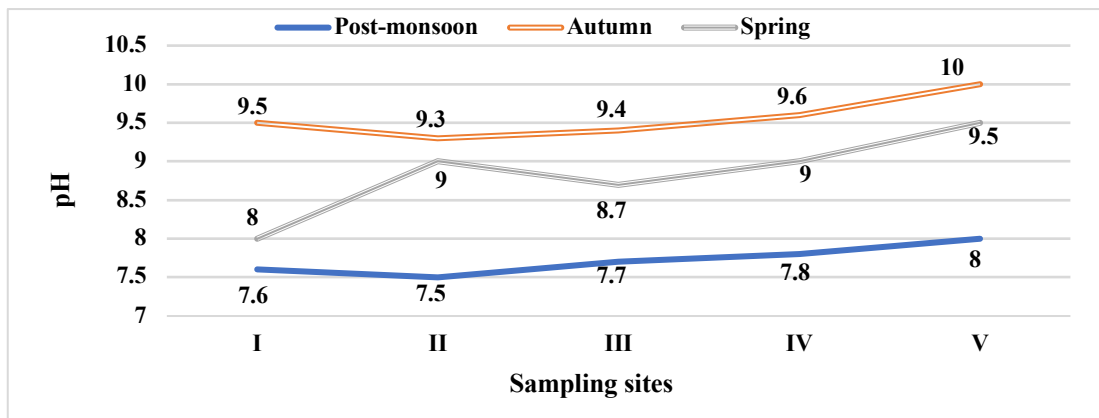


Figure 5. pH level recorded at five sampling sites in three seasons of Daraundi River

#### 4.6.3 Dissolved oxygen (DO)

The highest (11 mg/l) DO was recorded at sampling site III during post-monsoon and the lowest (9 mg/l) at sampling site V. However, in autumn, the highest (9.3 mg/l) was recorded at sampling site V and the lowest (8.1 mg/l) at sampling site I. In spring, the DO level significantly dropped to 7 mg/l at sampling V, making it the lowest recorded data among all season and highest at 8.1 mg/l at sampling site I.

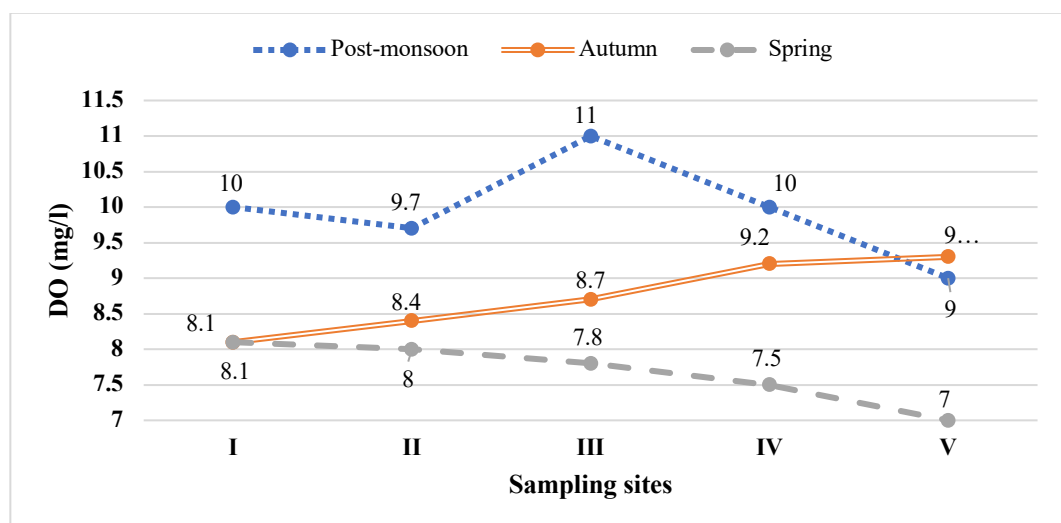


Figure 6. DO level recorded at five sampling sites in three seasons of Daraundi River

#### 4.6.4 Free CO<sub>2</sub>

Post-monsoon season showed the highest (5.2 mg/l) free CO<sub>2</sub> levels at site IV and lowest (4.1 mg/l) at site I. In contrast, the autumn season records the lowest concentration, especially at sites IV and V, where CO<sub>2</sub> drops to 2.1 mg/l and 2.5 mg/l respectively. The spring season showed more stable CO<sub>2</sub> levels, fluctuating moderately between 2.9 to 3.6 mg/l across all sites.

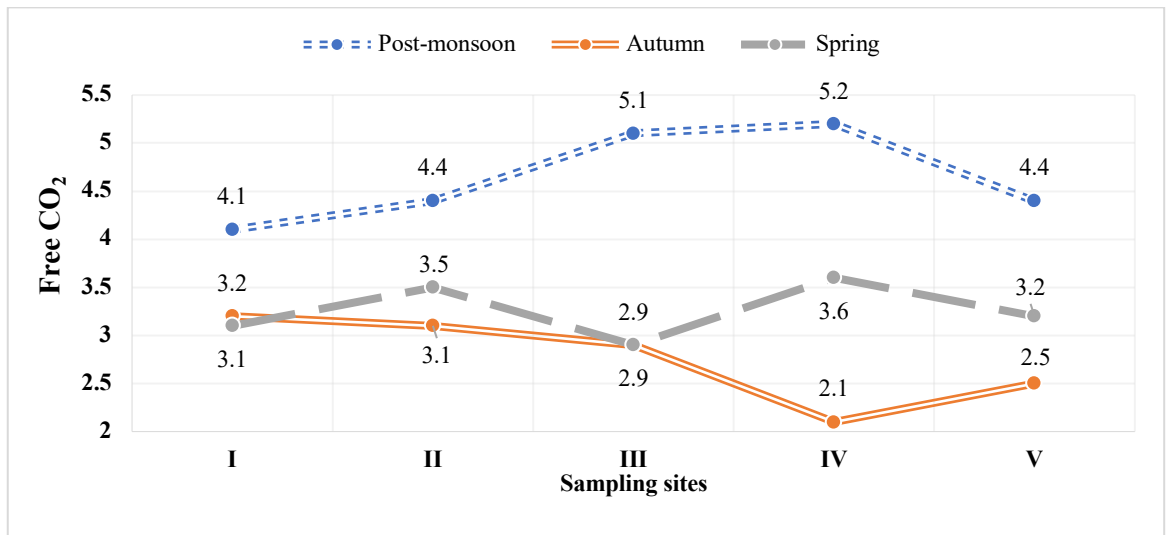


Figure 7. Free CO<sub>2</sub> recorded at five sampling sites in three seasons of Daraundi River

#### 4.6.5 Water velocity

The highest water velocity was recorded at Sampling site I with 1.5 m/s in post-monsoon and lowest at sampling site V with 1 m/s. In autumn, the highest (1.9 m/s) was found at sampling site I and the lowest at sampling site II and IV with 1.3 m/s. And in spring season, the highest (1.9 m/s) was recorded at sampling site I and the lowest (1.2 m/s) was recorded in sampling site V.

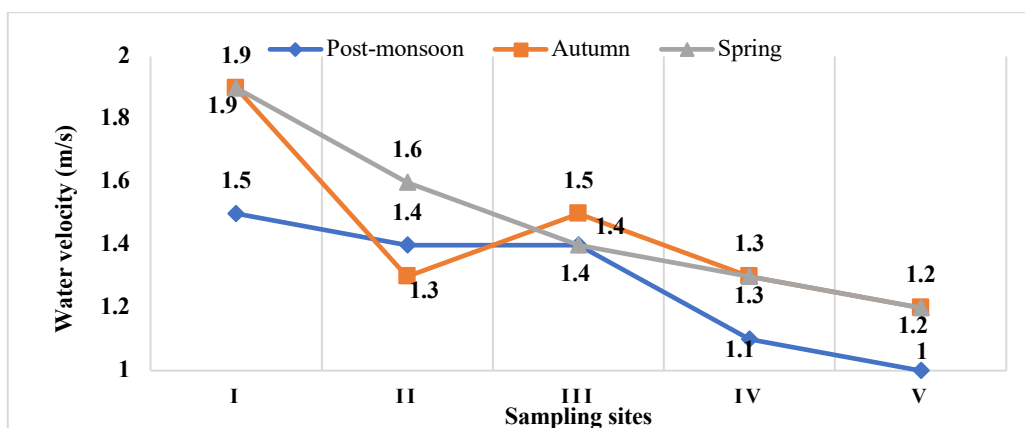


Figure 8. Water velocity recorded at five sampling sites in three seasons of Daraundi River

#### 4.7 Correlation between fish diversity and Water quality parameters

Using the Karl Pearson method, the coefficient of correlation between several water quality parameters and fish diversity in three seasons: post-monsoon, autumn and spring was determined. In this study, the correlation between pH and fish diversity was found to be strongly negative (-0.9407 and -0.7048) during post-monsoon and spring but showed strong positive correlation (0.7813) in autumn season. The correlation between temperature and fish diversity was strongly positive (0.8757 and 0.9812) in the post-monsoon and spring seasons, respectively. However, the study found a strong negative correlation (-0.7815) in the autumn season. A strong positive correlation (0.6624 and 0.8674) was seen between DO and fish diversity in autumn and spring season while weak strong positive correlation (0.1484) was seen during post-monsoon season. However, a strong negative correlation was seen between Free CO<sub>2</sub> and fish diversity in all three seasons: post-monsoon, autumn and spring season with -0.4200, -0.7448 and -0.1993 respectively. And lastly, water velocity and fish diversity showed strong positive correlation (0.7743 and 0.9310) during post-monsoon and spring but negative correlation (-0.3944) during autumn season.

**Table 5. Correlation Between Fish Diversity and Water Quality Parameters**

S. N	Variables	Post-monsoon		Autumn		Spring	
		r	P.E(r)	r	P.E(r)	r	P.E(r)
1	pH and Fish Diversity	-0.9407	0.0347	0.7813	0.4904	-0.7048	0.5247
2	Temp and Fish Diversity	0.8757	0.4432	-0.7815	0.4903	0.9812	0.3841
3	DO and Fish Diversity	0.1484	0.2950	0.6624	0.1693	0.8674	0.0747
4	Free CO <sub>2</sub> and Fish Diversity	-0.4200	0.6213	-0.7448	0.5072	-0.1993	0.6625
5	Water velocity and Fish Diversity	0.7743	0.1208	-0.3944	0.2547	0.9310	0.0402

## 5. Discussion

### 5.1 Species diversity and abundance

A total of 21 species belonging to four orders, six families and 15 genera were collected from five sampling sites making a total 780 individuals. This study serves as the baseline study for the research on fish diversity of the Daraundi river so species comparison was not possible as no prior work was available for comparison. The study was carried out from August 2023 to April 2024, over a nine-month period covering three different seasons: post-monsoon, autumn and spring.

According to Khatri et al. (2020) Nepal's freshwater system supports a total of 255 fish species, with 213 species inhabiting the country's lotic (flowing water) ecosystems. Among Nepal's four major river systems, the Gandaki River system hosts the highest diversity, with 171 fish species. However, fish diversity data for the Daraundi River, a tributary of the Gandaki River system, was previously unavailable. This study addressed this gap by recording a total of 21 fish species in the Daraundi River.

The current study identified Cypriniformes as the dominant order, comprising 18 species, which represents 85% of the total species sampled. This result aligns with findings from multiple studies on fish diversity within the Gandaki River system. For example, Jha et al. (2014) reported that Cypriniformes constituted 49% of the fish community in their study, Shah et al. (2022) documented 67% Cypriniformes in the Narayani River, Chapagain et al. (2021) observed 92.6% in the Mardi Stream, and Prasad et al. (2020) recorded 71.7% Cypriniformes in the Seti-Gandaki. These findings collectively underscore the dominance of Cypriniformes within various freshwater systems of the Gandaki Basin.

The Cyprinidae family emerged as the most dominant among the six families documented across the study sites (Fig. 1), with 13 species, followed by Nemacheilidae with four species. The families Mastacembelidae, Channidae, Cobitidae, and Schilbeidae each contributed a single species. These findings align with previous studies done in the rivers of Gandaki River System. For example, Shah et al. (2022) also reported Cyprinidae as the predominant family in the Narayani River, represented by 21 species. Similarly, Mandal & Jha (2014) found Cyprinidae to be the most dominant family in Marshyangdi river, accounting for 53.8% of the species observed. Sharma et al. (2001) also reported Cyprinidae as the most common family representing 18 fish species and constituting 51.42% of fish species in Tinau river.

The present study recorded *Barilius vagra*, *Schistura rupecula*, *Schistura savona*, *Barilius barila*, *Schizothorax plagiostomus*, *Barilius bendelisis*, *Garra annandalei*, *Nemacheilus corica*, and *Neolissochilus hexagonolepis* as the most common fish species as they were recorded in all three seasons from all five sampling sites. However, *Labeo dyocheilus* (McClelland, 1839) and *Clupisoma garua* (Hamilton, 1822), were found only in the post-monsoon season and that too in sampling site II only.

The highest (16) and lowest (10) fish species was observed in post-monsoon season at sampling site II and V respectively. This finding is inconsistent with the study done by Chapagain et al. (2021) who reported lowest (9) fish species in spring, but highest (10) fish species in summer season in the Mardi Stream of Gandaki River.

## 5.2 Diversity status

The Shannon-Wiener diversity index ( $H'$ ) during the study period ranged from 2.658 to 2.828. The highest value (2.828) was seen during the post-monsoon season and the lowest (2.658) was found in spring season. The findings of this study differ with the result of Shrestha et al. (2023) who reported a peak diversity index of 2.568 in pre-monsoon and the low diversity index of 0.637 in post-monsoon in Dudh Koshi River. This variation in diversity index may be due to the sample size, spatial dissimilarity with different water quality parameters and selection of gears (Hossain et al., 2012; Huh & Kitting, 1985).

For Margalef's index ( $d$ ), the highest value (3.74) was recorded in post-monsoon and the lowest value (2.86) in the spring season. The findings were consistent with the study of Prasad et al. (2021) who also reported lowest (0.08) value of species richness in spring but highest (0.49) in winter. The discrepancy between these findings could be attributed to differences in sampling efforts such that, the greater the sampling effort, the higher the Margalef's index (Shrestha et al., 2023).

The highest value (0.938) of evenness index ( $E$ ) was recorded during the spring, while the lowest (0.928) was observed in the post-monsoon period. This finding contrasts with the results of Tumbahangfe et al. (2021), who reported the highest evenness (0.65) in summer and the lowest (0.62) in winter in the Tamor River. The inconsistency may be attributed to differences in the number of specimens, sampling sites, and ecological conditions (Magurran, 2013).

A high value (0.97) of Simpson's diversity index ( $D$ ) was found during post-monsoon while the low value (0.92) was seen during spring season. However, the result contradicts with

the findings by (Shrestha et al., 2021) who reported maximum diversity index value in summer (0.89) whereas minimum value in autumn (0.79) in Lahore river of Dailekh. Then again, fish assemblages show seasonal variation so one-time studies often fail to capture the overall assemblages.

### **5.3 Seasonal variation in Water Quality Parameters**

Water Quality Parameters such as water temperature, pH, water velocity, dissolved oxygen (DO), and Free CO<sub>2</sub> are correlated with fish abundance and these variables changes according to seasons (Alexandre et al., 2010; Sharma et al., 2007).

Water temperature exhibited seasonal variation, with higher temperature (23°C) in post-monsoon and lower temperature (14°C) in spring season. The findings were consistent with previous studies conducted by Prasad et al. (2020), Chapagain et al. (2021) and Shrestha et al. (2023).

DO, another important regulating parameter in stream ecology (Keshtegar & Heddami, 2018; Rajwa-Kuligiewicz et al., 2015), for supporting diverse aquatic life, with levels above 5 mg/l considered optimal (APHA, 1978). In this study DO was highest (11 mg/l) at sampling site III during post-monsoon and the lowest (7 mg/l) in spring season recorded at sampling site V.

Similarly, the pH in freshwater should be ranged between 4.4 to or more than 11 for freshwater organisms to survive. And this study found a maximum pH of 10 during spring, and the minimum of 7.5 during post-monsoon indicating suitable condition for the fish communities.

Water velocity another important water quality parameter was measured and it was found highest (1.9 m/s) in post-monsoon season while the lowest (1 m/s) in spring season. Lastly, Free CO<sub>2</sub>, one of the abundant and influencing factor which affects the nature of the plant and animal communities in freshwater (Moss, 2010) was high (5.2 mg/l) in post-monsoon season and low (2.1 mg/l) in spring season in this study.

### **5.4 Correlation between fish diversity and Water Quality Parameters of Daraundi River**

The diversity of fish is influenced by seasonal variation in freshwater stream which is reflected in varied water quality parameters. The water temperature, pH, dissolved oxygen, water velocity and Free CO<sub>2</sub> showed significant role in shaping the fish richness pattern in

the Daraundi River as well. The water temperature and fish diversity showed strong positive correlation ( $r= 0.9812$ , P.E.= 0.3841), which is consistent with records of Chapagain et al. (2021) who also reported positive correlation of fish richness with temperature in Mardi stream. They also reported that pH exhibited negative relationship with fish diversity in Mardi Stream, which is consistent with our finding of strong negative correlation between fish diversity and pH ( $r=-0.9407$ , P.E.= 0.3016) in the Daraundi River. Similarly, strong positive correlation ( $r= 0.8674$ , P.E.= 0.0747) between fish diversity and DO was documented in this study, which aligns with the records of Adhikari et al. (2021), who also reported high fish abundance in presence of high DO value in Mechi river. Pokharel et al. (2018) observed that, in Seti Gandaki River basin, Free CO<sub>2</sub> was one of the important water quality parameters, but in this study, there was a strong negative correlation between Free CO<sub>2</sub> and fish diversity ( $r=-0.7448$ , P.E.= 0.5072). A strong correlation was observed between water velocity and fish diversity ( $r = 0.7743$ , P.E. = 0.3016) across all three seasons in this study. Previous research has also highlighted the significant role of water velocity in shaping fish community structure (Yu & Lee, 2002).

## 6. Conclusions and recommendations

The survey documented a total of 21 fish species belonging four orders, six families and fifteen genera with Cypriniformes as the dominant order with 16 species, and Cyprinidae (69.10%) as the dominant family with 13 species. Fishes like *Barilius vagra*, *Schistura rupecula*, *Schistura savona*, *Barilius barila*, *Schizothorax plagiostomus*, *Barilius bendelisis*, *Garra annandalei*, *Nemacheilus corica*, and *Neolissochilus hexagonolepis* were recorded in all three seasons, while *Labeo dyocheilus* (McClelland, 1839) and *Clupisoma garua* (Hamilton, 1822), were found only in the post-monsoon season. Post-monsoon season had the highest Shannon diversity index (2.828), Margalef's index (3.74) and Simpson's diversity index (0.97) but lowest evenness index (0.928). Spring had the lowest (2.658) Shannon's diversity index, Margalef's index (2.86) and Simpson's diversity index (0.92), but highest Evenness index (0.938). The results from Karl Pearson's coefficient of correlation showed that water quality parameters like water temperature, DO, and water velocity showed positive influence for fish diversity while, pH and Free CO<sub>2</sub> was found negatively correlated with fish diversity of Daraundi river.

As this study serve as the foundational research study done in the river to understand the fish diversity and its relationship with water quality parameters, no prior research work was available to make comparison about the fish species data. So, on the basis of field visit and interaction with local people, following recommendations could be made:

- Regular monitoring of fish species diversity in Daraundi river, should be conducted by the local authorities and ichthyologists.
- Care should be given by the local authorities as well as the residents, and visitors regarding sustainable use of water for irrigation and daily use.
- Studies that examine longitudinal aspects across various seasons are essential to understand spatial and temporal variations of Daraundi river.
- Fish diversity studies should also consider studying about range of abiotic and biotic variables.
- Ensuring effective implementation of the Aquatic Animals Protection Act, 2017 (AAPA, 2017) by the government authorities is crucial for controlling illegal fishing activities.

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## Photo plate I

Order: Anabantiformes

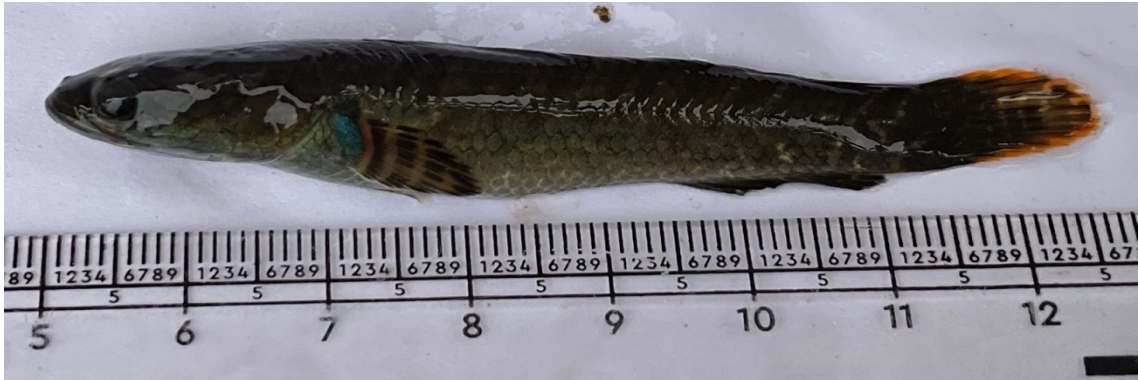


Photo 1: *Channa orientalis*

Order: Cypriniformes



Photo 2: *Barilius barila*



Photo 3: *Barilius bendelisis*



Photo 4: *Barilius vagra*



Photo 5: *Garra annandalei*



Photo 6: *Garra gotyla gotyla*



Photo 7: *Labeo dyocheilus*

Photo plate II



Photo 8: *Neolissochilus Hexagonolepis*



Photo 9: *Puntius Sophore*

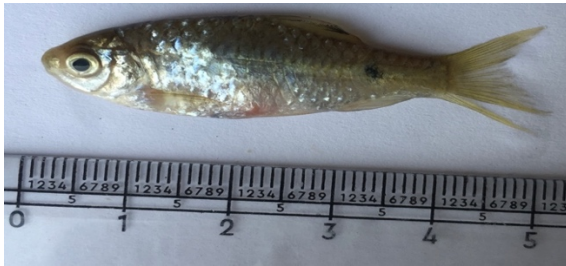


Photo 10: *Puntius terio*



Photo 11: *Schizothorax richardsonii*



Photo 12: *Schizothoraxx plagiostomus*



Photo 13: *Systemus sarana sarana*



Photo 14: *Tor chelynooides*



Photo 15: *Lepidocephalichthys guntea*



Photo 16: *Acanthocobitis botia*

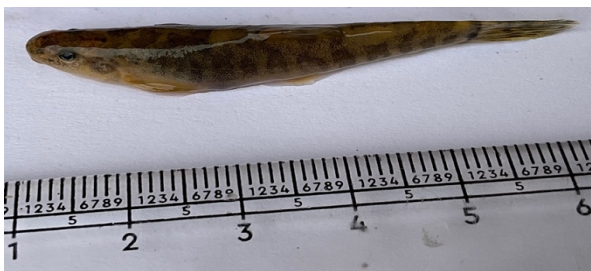


Photo 17: *Schistura rupecula*

Photo plate III



Photo 18: *Schistura savona*



Photo 19: *Nemacheilus corica*

Order: Siluriformes



Photo 20: *Clupisoma garua*

Order: Synbranchiformes



Photo 21: *Mastacembelus armatus*

## Photo plate IV



Photo 22: Sampling site I



Photo 23: Sampling site II



Photo 24: Sampling site III

## Photo plate V



Photo 25: Sampling site IV



Photo 26: Sampling site V

## Photo plate VI



Photo 27: A fisherman throwing a cast net



Photo 28: A fisherman coming out the water



Photo 29: Taking out captured fishes



Photo 30: Checking the DO of the water



Photo 31: Titration for the measurement  
the of free CO<sub>2</sub>



Photo 32: Identifying unidentified fishes  
at the lab