# Taxonomic Diversity of Genus *Tor* (Gray 1834) in Kali Gandaki River, Nepal

**Pawan Rana**
**T.U. Registration No. 5-2-49-143-2015**
**T.U. Examination Roll No. Zoo 935/077**
**Batch:2077**

**Central Department of Zoology**
**Institute of Science and Technology**
**Tribhuvan University**
**Kirtipur, Kathmandu**
**Nepal**

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

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**April, 2024**

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**Pawan Rana**

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**Supervisor**

**Santoshi Shrestha**

**Assistant professor**

**Central Department of Zoology**

**Institute of Science and Technology**

**Tribhuvan University**

**Kirtipur, Kathmandu**

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**April 2024**

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E-mail: pawan.ranamagar33@gmail.com

Central Department of Zoology
Institute of Science and Technology
Tribhuvan University
Kirtipur, Kathmandu, Nepal
Website: https://www.cdz.tu.edu.np/

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## Declaration

I hereby declare that the work presented in this dissertation "Taxonomic Diversity of Genus *Tor* (Gray, 1834) in Kali Gandaki River, 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) or institution(s).

Pawan rana
Exam roll No.: 935/077
Email: pawan.ranamagar33@gmail.com

Date: June 2024

TRIBHUVAN UNIVERSITY

INSTITUTE OF SCIENCE AND TECHNOLOGY

CENTRAL DEPARTMENT OF ZOOLOGY

Kirtipur, Kathmandu, Nepal

## Recommendation

This is to recommend that the dissertation entitled "Taxonomic diversity of Genus *Tor* (Gray, 1834) in Kali Gandaki River, Nepal" has been carried out by Pawan Rana for the partial fulfilment of Master's Degree of Science in Zoology with special paper Fish and Fisheries. This is his/her original work and has been carried out under my supervision. To the best of my knowledge, this dissertation work has not been submitted for any other degree in any institutions.

Supervisor
Santoshi Shrestha
Assistant Professor
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

Date: 15/12/2080

**TRIBHUVAN UNIVERSITY**

**INSTITUTE OF SCIENCE AND TECHNOLOGY**

**CENTRAL DEPARTMENT OF ZOOLOGY**

Kirtipur, Kathmandu, Nepal



## Letter of approval

On the recommendation of supervisor Assistant Professor "Santoshi Shrestha" this dissertation submitted by Pawan Rana entitled "Taxonomic Diversity of Genus *Tor* (Gray, 1834) in Kali Gandaki River, Nepal" is approved for the examination in partial fulfilment of the requirements for Master's Degree of Science in Zoology with special paper Fish Biology and Aquaculture.

.....

Head of Department
Kumar Sapkota, PhD
Professor
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

Date: 15/12/2080

**TRIBHUVAN UNIVERSITY**
**INSTITUTE OF SCIENCE AND TECHNOLOGY**
**CENTRAL DEPARTMENT OF ZOOLOGY**
Kirtipur, Kathmandu, Nepal

## Certificate of acceptance

This dissertation work submitted by entitled "Taxonomic Diversity of Genus *Tor* (Gray, 1834) in Kali Gandaki River, Nepal" has been accepted as a partial fulfilment for the requirements of Master's Degree of Science in Zoology with special Fish Biology and Aquaculture.

**Evaluation committee**

.....
Santoshi Shrestha
Assistant Professor

.....
Kumar Sapkota, PhD
Professor

.....
External examiner
Kumar Khatri, PhD
Assistant Professor

.....
Internal Examiner
Archana Prasad, PhD
Associate Professor

Date of examination: 13/02/2081

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## Abstract

*Tor* species is a member of the family Cyprinidae, which is widely recognized as game fish inhabiting in fresh water ecosystem. The aim of this study is to explore the taxonomic diversity, morphometric and meristic characters of Genus *Tor* (Gray, 1834) of Kali Gandaki River, Nepal. Thirty-four (34) *Tor* species were captured from five different sites of Kali Gandaki River. 35 morphometric and 5 meristic characteristics of Genus *Tor* were examined. On the basis of morphometric and meristic count, only *Tor putitora* was identified using identification keys and references. The study examined the relationship between body metrics such as total length, head length, and standard length. All morphometric characteristics showed a positive correlation with head length, standard length, and total length. Meristic counts were almost identical to different sites of *Tor putitora* of Kali Gandaki River. The results of this study may be useful in management and conservation of population of *Tor putitora* in Kali Gandaki River which is listed in IUCN Red List of Endangered species.

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*Tor* प्रजाति सिप्रीनिडिया परिवारको सदस्य हो, जसलाई ताजा पानीको इकोसिस्टममा बसोबास गर्ने माछाको रुपमा व्यापक रुपमा मान्यता दिइन्छ। यस अध्ययनको उद्देश्य नेपालको कालीगण्डकी नदीको जीनस *Tor* (ग्रे, १८३४) को वर्गीकरणीय विविधता, मोर्फोमेट्रिक र मेरिस्टिक वर्णहरुको अन्वेषण गर्नु हो। कालीगण्डकी नदीका विभिन्न पाँच स्थानबाट ३४ *Tor* प्रजाति बरामद गरिएको थियो। जीनस *Tor* को ३५ मोर्फोमेट्रिक र ५ मेरिस्टिक विशेषताहरु जाँच गरियो। मोर्फोमेट्रिक र मेरिस्टिक गणनाको आधारमा, *Tor putitora* लाइ पहिचान कुञ्जीहरु र सन्दर्भहरु प्रयोग गरेर पहिचान गरिएको थियो। अध्ययनले कुल लम्बाइ, हेड लम्बाइ, र मानक लम्बाइ जस्ता शरीर मेट्रिकहरु बीचको सम्बन्धको जाँच गऱ्यो। सबै मोर्फोमेट्रिक विशेषताहरले हेड लम्बाइ, मानक लम्बाइ, र कुल लम्बाइसँग सकारात्मक सम्बन्ध देखाए। मेरिस्टिक गणनाहरु कालीगण्डकी नदीको *Tor putitora* का विभिन्न स्थानहरुमा लगभग समान थिए। यस अध्ययनको नतिजा आइ.यू.सि.एन्. को लोपोन्मुअ प्रजातिहरुको रातो सूचमिा सूचीकृत कालीगण्डकी नदीमा रहेको *Tor putitora* को जनसंख्याको व्यवस्थापन र संरक्षणमा उपयोगी हुन सक्छ।

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# List of abbreviations

| Abbreviated form | Details of abbreviations |
|---|---|
| AF | Anal Fin |
| AFB | Anal Fin Base |
| AFL | Anal Fin Length |
| AFR | Anal FIN Rays |
| BDA | Body Depth Anal |
| BDA | Body Width Anal |
| BDD | Body Depth Dorsal |
| BWD | Body Width Dorsal |
| CPD | Caudal Peduncle Depth |
| CPL | Caudal Peduncle Length |
| D-CL | Dorsal to Caudal Length |
| DF | Dorsal Fin |
| DFB | Dorsal Fin Base |
| DFL | Dorsal Fin Length |
| DFR | Dorsal Fin Rays |
| ED | Eye Diameter |
| GPS | Global Positioning System |
| GW | Gape Width |
| HD | Head Depth |
| HL | Head Length |

| | |
|---|---|
| HL-im | Head Length, Inc. membrane |
| HW | Head Width |
| IOL | Inter Orbital Length |
| IUCN | International Union for conservation of Nature |
| MBL | Maxillary Barbel Length |
| ML | Mentum Length |
| MW | Mentum Width |
| PAL | Pre-anus Length |
| Pan-L | Pre-Anal Length |
| PDL | Pre-Dorsal Length |
| PF | Pectoral Fin |
| PFR | Pectoral Fin Rays |
| PPL | Pre-Pectoral Length |
| PVL | Pre-Ventral Length |
| RBL | Rostral Barbel Length |
| SL | Standard Length |
| Sn-L | Snout Length |
| T | Transverse |
| TL | Total Length |
| VF | Ventral Fin |
| VFL | Ventral Fin Length |
| VFR | Ventral Fin Rays |

# 1. Introduction

## 1.1. Background

*Tor* is a member of the family Cyprinidae, which is widely recognized as 'Game fish'. *Tor* is regarded as a "True Mahseer" due to presence of median lobe (Ng, 2004; Yousaf et al., 2023). Various theories have been put up regarding the meaning of the name Mahseer, including the following: (a) Mahasaul, which refers to huge Scale comes (Hamilton, 2012) from the Hindustani words Maha, which means great, and Seer, which means head (b) Mahi, which means fish, and Sher, which means lion, (Thomas, 1897)(c) Sanskrit word Matsya, which means fish mahsia (Lang, 1923), used by Brahmins, denoting a fish of excellence; and (d) Sanskrit word Mahasalka, which means large scales (Hora, 1943). One of the most significant freshwater fish in Southeast Asia is the mahseer (Cyprinidae). Mahseer is fished for sport, ornamental purposes, and consumption. It is also known as game fish (Muchlisin et al., 2022). Mahseer is found in fast-moving water with stony or rock (Kamboj & Kamboj, 2019).

Eleven species of *Tor* species were reported from Indian region (Pinder et al., 2019) including *T. tor* (Hamilton, 1822), *T. putitora* (Hamilton, 1822), *T. mosal* (Hamilton, 1822), *T. malabaricus* (Jerdon, 1849), *T. neilli* (Day, 1869), *T. progenies* (McClelland, 1839), *T. kundree* (Sykes, 1839), *T. kulkarnii* (Menon, 1992), *T. mussullah* (Sykes, 1839), *T. barake* (Arunkumar and Basudha, 2003) and *T. remadevii* (Kurup and Radhakrishnan, 2007). Among these eleven species , three species *T. mosal* , *T. putitora* and *T. tor* have been reported from Nepal (Shrestha, 2002). Three species *T. tor, T. putitora* and *T. sps*. from Kali Gandaki River (Edds et al., 2002). The economically important fishes from Kali Gandaki River are *Tor tor*, *Tor putitora*, *Clupisoma garua*, and *Neolissocheilus hexagonolepis*. Other significant fish species found in the Kali Gandaki River include *Labeo angra*, *Labeo dero*, *Schizothorax sp.*, and *Schizothoraichthys sp.* (Shrestha & Chaudhary, 2003).

*Tor putitora* that inhabits freshwater rivers and it is a potamodromous species which migrates in the upper regions of freshwater systems, from bigger rivers to smaller streams (Bhatt & Pandit, 2016). These fish are found in many parts of the world, including Nepal, Pakistan, Afghanistan, Indonesia, Malaysia, China, India, and Sri Lanka. It usually feeds upon small fishes, green algae, crustacean, insects, frogs (Mahasetha, 2015). The breeding

sites of *Tor putitora* are these smaller highland streams. The fish's breeding habitats are typically characterized by riverbeds including big stones, gravel, and cobbles(Johnson et al., 2021). In the IUCN, *Tor putitora* is classified as an "endangered species" (IUCN, 2018). Population of *Tor putitora* is decline because to a multitude of external concerns, such as damming of rivers which blocks the migration (IUCN, 2018). The life cycles of *Tor putitora* are intimately linked to migration, whereby it completes the initial stage of life cycle in higher reaches smaller streams following a protracted trek to the breeding grounds (Bhatt & Pandit, 2016).

*Tor tor* (Hamilton 1822) is also known as *Tor* Mahseer. It has a deep body with a red fin. It was discovered in Bangladesh, Bhutan, India, Myanmar, Nepal, and Pakistan. (Pinder et al. 2019). The pectoral fins of *Tor tor* have pelvic fins that are as long as their heads, except the snout, except the snout, while the pelvic fin is shorter. The snout is pointed and slightly the same length as the jaw. There are two sets of barbels, with the maxillary barbel being longer than the rostral but shorter than the eye (Dhu, 1923). Head length of *Tor tor* is slightly smaller than body depth (Nautiyal, 2014). *Tor tor* was included in the IUCN red list categories as a threatened species in previous studies, and it is currently classified as data deficient (IUCN, 2018).

*Tor mosal* (Hamilton, 1822) is known as copper mahseer or yellow mahseer. The head length is almost equivalent to the body depth (Nautiyal, 2014). *Tor mosal* have mild yellowish in the below (Macdonald, 1948). *Tor mosal* is found in India and Myanmar, and according to the earlier status of the IUCN, it is classified as near endangered, and the present state of *Tor mosal* is Data Deficient (IUCN,2019).

Serious concerns to the species include habitat loss, overfishing, and dam development in the Himalayan region (Johnson et al., 2021). *Tor* species of population has declined by more than 50% over the previous 21 years, and more decreases are anticipated if current trends continue and additional dams are constructed (IUCN, 2018). This study aims to understanding the Taxonomic diversity of Genus *Tor* in Kali Gandaki River, Nepal as well as explore species diversity and to analyze the morphometric and meristic traits differ amongst five different sites.

Kali Gandaki River is one of the major River in Nepal. It flows from the upper mustang which touches the Narayani River in Chitwan. The river flows quickly and has different velocities along its course, providing a variety of serene areas. It includes the entire pool,

riffle zone. Its vegetation changes into an attractive jungle, and the rocks surrounding it add to its unique nature. It sustains various aquatic fauna which was poorly documented. Fish are found in various aquatic habitats, from cold to warm environments. Warm-water fish, which thrive in stable temperatures, are abundant due to their feeding habits and ecological preferences (Berra et al., 2007). Freshwater fishes contribute significantly to the remarkable biodiversity of freshwater environments (Saunders et al., 2002).

The first stage in studying a species is taxonomic identification (Langer et al., 2013; Nayman, 1965).The important subject in biology is morphology. For research on fish populations, morphology has been considered to be equally vital as species identification (Deesri et al., 2009). The quantitative measurements are called morphometrics, whereas the serial body counts are called meristic. The dynamic features of morphometrics and meristic counts are used to measure the variances among populations of the same species of fish (Cadrin, 2000; Doherty & McCarthy, 2004). In fisheries biology, morphometric features have been used as powerful tools for precise species identification, measuring discreteness, and exploring interactions between different taxonomic groups (Cavalcanti et al., 1999; Quilang et al., 2007). Meristic counts is also helpful to explain and identifying of species (Gogoi & Goswami, 2014). Few studies have been carried out regarding the diversity of fish in the Kali Gandaki River, particularly on their morphometric and meristic characteristics.

### 1.2. Statement of problem

*Tor* species is an endangered fish inhabiting in fresh water ecosystem and has recreational importance. *Tor* species are often considered bio-indicators of freshwater ecosystems since their existence and abundance are closely associated to specific environmental factors including water quality and habitat characteristics (Desrita et al., 2019). Despite the importance of *Tor* fish, a comprehensive understanding of diversity of this fish species in Kali Gandaki River is still unclear. Morphological changes in mahseer are quite slight from species to species, which contributes to uncertainty in species identification (Laskar et al., 2017). Thus, the identity and distribution of mahseers has become a matter of uttermost concern, which needs more insight through morphometric study and molecular.

## 1.3. Objectives

### 1.3.1. General objective

The general objective of this study was to examine the taxonomic diversity of Genus *Tor* in Kali Gandaki River, Nepal.

### 1.3.2. Specific objectives

- To explore species diversity of Genus *Tor*.
- To analyze the morphometric and meristic traits of Genus *Tor*.

## 1.4. Research question

A possible research question for Taxonomic diversity of Genus *Tor* in Kali Gandaki River is:

- How many species of *Tor* were present in Kali Gandaki River?
- Do head length, standard length, and total length have correlation with the morphometric variables?

## 1.5. Significance of the study

The study of taxonomic diversity of Genus *Tor* in Kali Gandaki River is significant for ecological research as well as gives details on population composition of *Tor* species. The correlation between different body length with head length, total length, and standard length reveals significant details on the physical characteristics and condition. Overall, the study has significant implications for conservation strategies of *Tor* population sustainability.

## 1.6. Limitations of the study

Although the study provided substantial understanding into the taxonomic diversity of Genus *Tor* in the Kali Gandaki River, it is subjected to certain limitations. This study will not cover the entire Kali Gandaki River as the samples were obtained from a limited site, which may not properly represent the diversity of *Tor* species, where the *Tor* species could be present. Sufficient fish samples may not be available due to endangered nature of *Tor*.

The study solely examined morphological differences and disregarded other factors like as genetic differences and behavioral variations, which could only contribute to the observed differences in morphology. The focus of the study in the taxonomic diversity of the Genus

*Tor* which may not provide a comprehensive understanding of the overall biodiversity of the river system. The study's primary focus, the taxonomic diversity of the Genus *Tor*, may not provide a thorough understanding of overall biodiversity of the river system. Furthermore, the study's narrow focus on a certain time period may preclude a comprehensive knowledge of taxonomic diversity within the Genus.

# 2. Literature review

## 2.1. Species diversity of Genus *Tor*

IUCN Red List of Threatened Species explains about 18 species of *Tor* were listed as Endangered species (IUCN, 2023).

In Southeast Asian countries, 13 species of *Tor* were found (Hoang et al., 2015; Moo, 2002; Nguyen et al., 2008; Pinder et al., 2019; Roberts, 1999). Out of 13 species of *Tor*, only 10 species regarded as valid and 3 species as invalid (Fricke et al., 2018; Pinder et al., 2019).

*Tor putitora* and *Tor tor* have been recorded in Pakistan, Bhutan, and Bangladesh (Moo, 2002; Petr, 1999), and a new *Tor* species called *Tor barakae* has recently been discovered in Bangladesh (Haque et al., 2023). 11 species of *Tor* were reported in India (Jaafar et al., 2021; Moo, 2002; Talwar & Jhingran, 1991). Edds (1989) reported 2 species *T. putitora* and *T. tor* from high hills to low land of Kali Gandaki River later reported *T. mosal* and *T. tor* (Edds, 1993) Again, reported 3 species *T. tor*, *T. putitora* and *T. sps*. from Kali Gandaki River (Edds et al., 2002). The study reported *T. putitora* and *T. tor* from low hills region of Kali Gandaki River (Jha, 2018).

## 2.2. Morphometric and meristic traits of Genus *Tor*

The study on morphometric and meristic characteristics of Golden Mahseer- *Tor putitora* collected in the Ujh river of Kathua District (Jammu and Kashmir) to analyze the relationship between total length and related body parameters and observed a noteworthy positive association in body growth between all body metrics and total length. To analyze the growth body metrics three independent variables, specifically the head length, standard length, and total length, were taken into consideration. The most closely associated body metric with the total length was determined to be caudal length, while the least correlated was eye-diameter. Preanal length was shown to be highly correlated body characteristic with the standard length, while eye-diameter was least correlated. Maximum body depth had the lowest correlation with snout length and the highest correlation with head length among body parameters. In the study, every association had a positive correlation, indicating that all aspects of *Tor putitora* had isometric growth (Bansal et al., 2021).

A study conducted on morphometric characters and meristic count of Himalayan Mahseer (*Tor putitora*) in river Chenab of Jammu and Kashmir showed a positive correlation

between total length and external body parts. All the morphometric parameters revealed a proportional increase in the total length of fish. A few morphometric measures and meristic count showed some variations probably most likely as a result of grouping's range effect. Body metrics Pre-Dorsal Length, Standard Length, and Pectoral Fin Base had the highest connection with Total Length, while Maxillary Barbel Length, Eye Diameter, and Maxillary Barbel Length had the lowest correlation. The study demonstrated an isometric pattern in the morphometric and meristic counts, suggesting that the test specimens *Tor putitora* (Langer et al., 2013).

Nam Theun watershed in Central Laos reported 3 new species of *Tor*: *T. tambra, T. sinensis* and *T. ater* which were distinguished based on the scale count, length of mental lobe, and coloration of body and fins (particularly the pelvic, anal and caudal fins). All three species' adults and subadults have striking coloration: *T. tambra* is mostly yellowish-green, *T. sinensis* is red, and *T. ater* is black. In Nam Theun and other areas of the Mekong basin, juvenile *T. tambra* fins are silvery with yellow or yellowish-orange coloration, while *T. sinensis* fins are silvery with red or pink coloration. Unknown T. *ater* juveniles exist. *T. tambra* in the Nam Theun and *T. ater* have short mental lobes, whereas *T. sinensis* has a long mental lobe. *T. tambra* and *T. sinensis* have large scales, whilst *T. ater* has comparatively tiny scales. It is determined that *T. laterivittatus*, a recently reported species from the Mekong basin in Yunnan, is a synonym of *T. sinensis* (Roberts, 1999).

The study examines the morphometric and meristic characteristics of four freshwater fish from the Uttarkhand district of Devprayagto Haridwar in the Ganga River. *Cyprnius carpio*, Mahseer, *Labeo rohita*, and *Xenontodon canceilia* were the four freshwater fish species. Each of the twenty species' morphometric and meristic characteristics was gathered from four Ganga River sample locations.Throughout the investigation, 24 morphometric and 8 meristic characteristics of each species were noted. Calculating the mean, standard deviation, range, correlation coefficient, and regression were the methods used for statistical analysis. The morphometric and meristic characteristics of four fish species were the author's primary focus. All morphometric variables were shown to be directly proportional to the overall length of the fish after the characters of every fish were analyzed. In contrast, meristic characters were found to be consistent throughout all size groups of fish, indicating that they were unrelated to the fish's length (Kamboj & Kamboj, 2019).

The study conducted on the morphometric and meristic traits of Indus mahseer *Tor macrolepis* in several Attock district regions. Calculating the mean, standard deviation, range and coefficient of correlation was the method used for statistical analysis. Five sampling groups of *Tor macrolepis* were used to calculate the morphometric variables of mean and standard. It was found highly correlation between body parameters with total length and head length (Pervaiz et al., 2012).

A prior investigation was carried out on *Tor putitora* from Nepal's midhill lakes and rivers. The primary focus was on morphometric and meristic characteristics, which were referred to as identifying markers. *Tor putitora* was investigated from Phewa Lake and the three main rivers, the Kali Gandaki, Trishuli, and Koshi and were analyzed with morphometrics of 35 individuals of different *Tor* species. ANOVA was used in the statistical analysis of morphometric data to determine the variations in body size between habitats, and linear regression was used to determine the relationship between total length and other features. In order to extract uncorrelated main components from the original variables and investigate which variables are most helpful in differentiating mahseer between habitats, main Components Analysis (PCA) and Discriminant Function (DF) were used. For the regression residuals, both PCA and DF were used. PC1 and PC2 show the fish's capacity for swimming, while PC3 shows their tendencies for foraging and feeding. The capacity of Lake Mahseer to swim was different from that of river populations. In comparison to the Kali Gandaki and Koshi rivers, the Mahseer population in the PC3 of the lake and Trishuli River has a different body form. Equal weight was assigned to each variable's variance based on correlation values for DF. The study concluded that the population of Phewa Lake population was differed from the river population of mahseer in having a smaller head, shorter dorsal and pectoral fin lengths, a larger pelvic fin, and a deeper body (Wagle et al., 2008).

The morphometric study on the golden mahseer population in India's Ganga River Basin found the single homogenous population analyzing by using different statistical tools ANOVA, PCA (Principal Component Analysis), DFA (Discriminant Function Analysis), and CVA (Canonical Variate Analysis) in 149 individuals. A total of 149 *Tor putitora* were collected from seven Ganga River sampling locations and subjected to morphometric measurements (Dwivedi, 2021).

The study focused on three freshwater fish species found in the Rajouri River in the northwestern Himalaya. *Tor putitora*, *Labeo dero*, and *Schizothorax richardsonii* were the three freshwater fish that were evaluated in terms of their length-weight relationship, and morphometric and meristic counts were computed. A regression equation, correlation, mean, standard deviation, range, and range difference were employed in the statistical study. In relation to the overall length and head length of each fish species, correlation and regression equations were used to calculate the pre-orbital, inter-orbital, and snout lengths. The overall length and weight of *T. putitora* and *S. richardsonii* were shown to be extremely significant, however in *L. dero*, the two variables diverged from one another. The morphometric characters that revealed substantial differences among the three species were the meristic characters, while the strongly correlated characters were SL and FL in all three species (Mehmood et al., 2021).

The study on the endangered Golden Mahseer and Zhobi Mahseer from ten different rivers in Pakistan; River Swat, Chakdara, River Panjkora, River Barandu, Terbela Dam reservoir, Skhakot, River Jehlum, River Chanab, Gomal zam Dam and tributaries (Tank-zam stream) of the River Gomal and River Zhob by analyzing morphometric characters using t test at $P<0.05$ from which samples which samples were collected. All morphometric and meristic counts were measured for each sample, with respect to standard length, Total length, and Head length. Statistical analysis was performed with T test at $P < 0.05$ and correlation coefficient and the research confirmed that there were no distinct morphological synapomorphies present in any contemporary populations of either species (Yousaf et al., 2023).

The study on the morphometric and meristic characteristics of ninety individuals of *Tor putitora* from the spawning grounds of the Himalayan foothill river Korang in Islamabad, Pakistan revealed a positive relationship between total length and body characteristics, and meristic counts remains constant with different body length. A statistical analysis of regression coefficient and correlation coefficient was performed to determine whether body parameter had a relationship with overall length. Morphometric tests were revealed a positive relationship between total length and body characteristics and meristic counts remains constant with different body length (Zafar et al., 2002).

An investigation of the morphometric traits and meristic counts of Himalayan Mahseer (*Tor putitora*) in the Chenab River foothills of Jammu and Kashmir was conducted in 2015 by

Sharma et al. The study found some variances in the morphometric metrics and meristic counts among samples and a positive correlation between total length and body parts and follows an isometric pattern of population growth (Sharma et al., 2015).

Research on the racial structure of *Tor putitora* was carried out in the Ganga's foothills. The correlation coefficient (r) was significant at $P<0.005$ for every studied variable, with the exception of the significant relationships between head length and eye diameter (ED) during the monsoon and distance between pectoral and anal fin (DPA) and pre-anal distance (PAD) during winter. For every variable, the F ratio was statistically significant at $P<0.05$. There was homogeneity in the population across the year, season, and sex samples and the standard length (SL) in relation to total length and post-orbital distance (POD) in relation to head length, the statistics r, b, and F were high (Bhatt et al., 1998).

# 3. Materials and methods

## 3.1. Materials

Cast net, hook and line, seine net, formalin, camera, cotton, GPS, measuring tape, divider, gloves, weighing machine, pointed needle, divider, container, refrigerator were used in this study.

## 3.2. Methods

### 3.2.1. Study Area

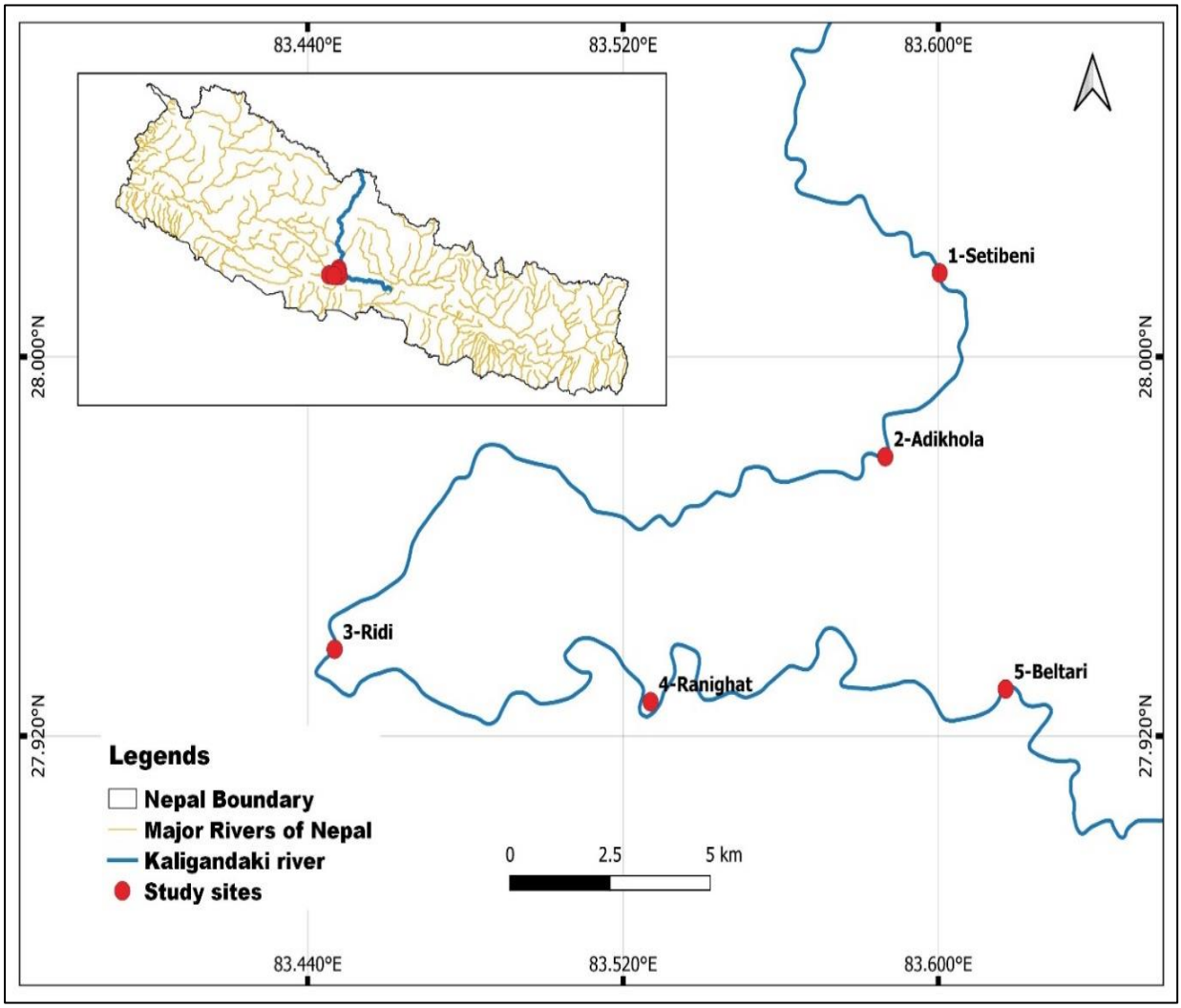
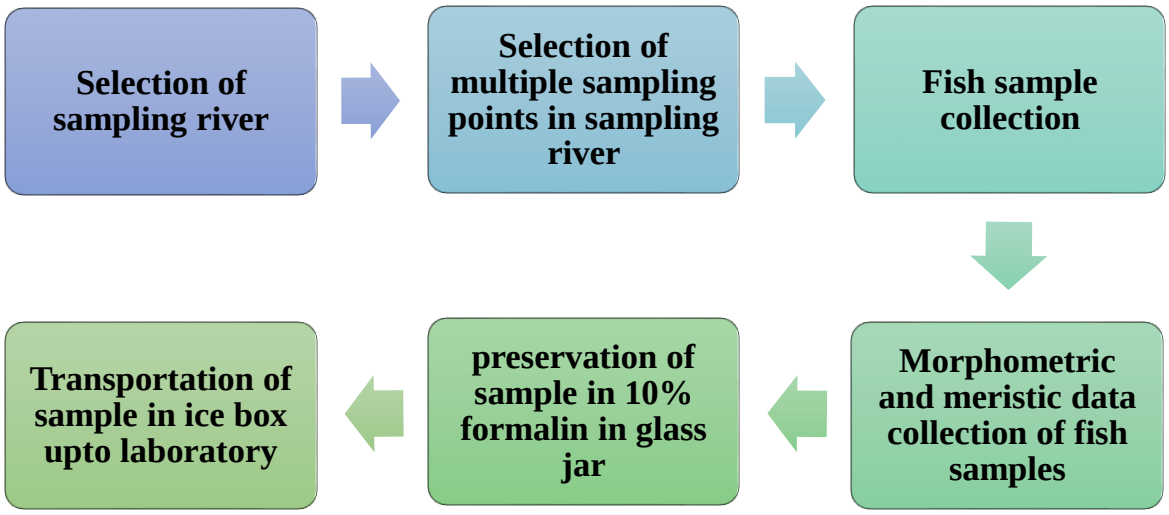



**Figure 1**. Map showing Kali Gandaki River with five different sampling sites

### 3.2.2. Research design




### 3.2.3. Selection of sampling sites

Before beginning the study activity, a preliminary survey was conducted to choose the study sites. The five sampling stations were selected based on variables such as confluence point, human settlement, altitude variation, and physical division. The chosen sampling sites were:

Site I: Setibeni

Setibeni is located in the Galyang municipality of Syangja District, near the villages of Arbeni, Nibuwakharkha, and Pedikhola. It has an elevation of 735 meters and is located at latitude 28°0'40" N and longitude 83°36'20" E. The Kali Gandaki River meets with a small tributary known as Setikhola in Setibeni.

Site II: Adhikhola

Adhikhola is located in the Syangja District of Nepal. It is located at latitude 27°57'17" N and longitude 83°37'34" E, with an elevation of 640m. Adhikhola is a tributary of the Kaligandaki River that meets near the dam's upper portion.

Site III: Ridi khola

Ridi khola lies in Gulmi District of Nepal. It lies on latitude 27°5'62" N and longitude 83°26'21" E and has elevation of 460m. Ridi Khola is a tributary of Kaligandaki River which is the connecting point of Palpa, Gulmi and Syangja Districts

Site IV: Ranighat

Ranighat is located in the Palpa District of Nepal. It is located at latitude 27°55'38" N and longitude 83°31'40" E, with an elevation of 441m. The Kaligandaki River and Barangdi Khola meet near Ranighat.

Site V: Beltari

Beltari is located in Nepal's Palpa District, at latitude 27°54'58" N and longitude 83°36'20" E, with an elevation of 400m. It is well-known for its hydroelectric power plant, which uses water pumped from the Kali Gandaki River to generate electricity by harnessing the energy of the flowing water and returning the water to the river.

**Table 1:** Sampling sites with latitude, longitude and elevation

| SN. | Sites | Latitude | Longitude | Elevation |
|---|---|---|---|---|
| 1 | Site I (Setibeni) | 28°0'40" N | 83°36'20" E | 735m |
| 2 | Site II (Adhikhola) | 27°57'17" N | 83°37'34" E | 640m |
| 2 | Site III (Ridi) | 27°5'62" N | 83°26'21" E | 460m |
| 3 | Site IV (Ranighat) | 27°55'38" N | 83°31'40" E | 441m |
| 5 | Site V (Beltari) | 27°54'58" N | 83°37'20" E | 400m |

### 3.2.4. Fish sampling, preservation

Kali Gandaki River at five distinct sample locations between January to June 2023. Fish were gathered at 200 meters both in the morning and at night in each station. Using a cast net, seine net, and hook and line, species were brought in. A few samples were measured, tagged, and photographed in accordance with the morphometric and meristic characteristics of the sites. GPS was used to collect data of elevation, latitude, and longitude. A measurement tape was used to measure fishes in millimeters. Fishermen helped in gathering fish in the field that fishes were recognized as *Tor* species based on characteristics such as structure, head, scales, mentum, and fin color. Some of these samples were measured on-site to collect morphometric and meristic data. Further measurements were made at the Central Department of Zoology laboratory in order to perform additional analysis. Samples were taken to the laboratory of the Central Department of Zoology by placing them in an ice box and then storing them in glass jars with 10% formalin as voucher specimens. Fish

identification was done with the help of standard identification keys references (T.K. Shrestha, 2008).

### 3.2.5. Morphometric study

Total length (TL), fork length (FL), standard length (SL), head length (HL), snout length (Sn-L), eye diameter (ED), interorbital length (IOL), pre-dorsal length (PDL), caudal peduncle length (CPL), caudal peduncle depth (CPD), pre-pectoral length (PPL), rostral barbel length (RBL), maxillary length (ML), ventral fin length (VFL), anal fin length (AFL), pectoral fin length (PFL), dorsal fin length (DFL), and body depth dorsal (BDD), body depth anal (BDA) were measured for the morphometric study of Genus *Tor*. Each of these measurements was examined in relation to the head, standard, and total length (Haryono, 2001).

### 3.2.6. Meristic study

With the help of dividers, scales, pointed needles, and hand lens, the quantitative calculation of fish traits such as numbers, rays, spines, and fins known as "meristic." The following characteristics were used to count the meristic characters: lateral line scale, transverse scale, pectoral fin rays, anal fin rays, and ventral fin rays, dorsal fin rays (Haryono, 2001).

### 3.2.7. Statistical Analysis

The Shapiro test was done to test whether the data is normally distributed or not. The data were found not normally distributed. So, non-parametric tests were used. The analysis was done using SPSS software version 25. The calculation was done with the mean, standard deviation, correlation coefficient, and regression equation.

### 3.2.8. Regression Analysis

Regression is a statistical method that is highly helpful for examining the relationship between one independent variable and one dependent variable, or between two or more variables. The characters were examined using regression analysis.

Y= a + b X where Y is dependent variable and X is independent variables like standard length, head length, total length, a is the intercept and b is the regression coefficient.

### 3.2.9. Correlation Analysis

The amount that a change in one variable contributes to a change in another is determined through correlation analysis. A correlation between the variables may be positive correlation, a negative correlation, or no correlation.

# 4. Results

## 4.1. Species diversity of Genus *Tor*

Using few reference books, the fish species was initially determined as *Tor* species with a median lobe. In five distinct locations along the Kali Gandaki River, thirty-four (34) *Tor* species have been identified. Using identification keys and references, the species was determined to be *Tor putitora*. Only *Tor putitora* were found from all sampling sites of Kali Gandaki River but no other species of *Tor*.

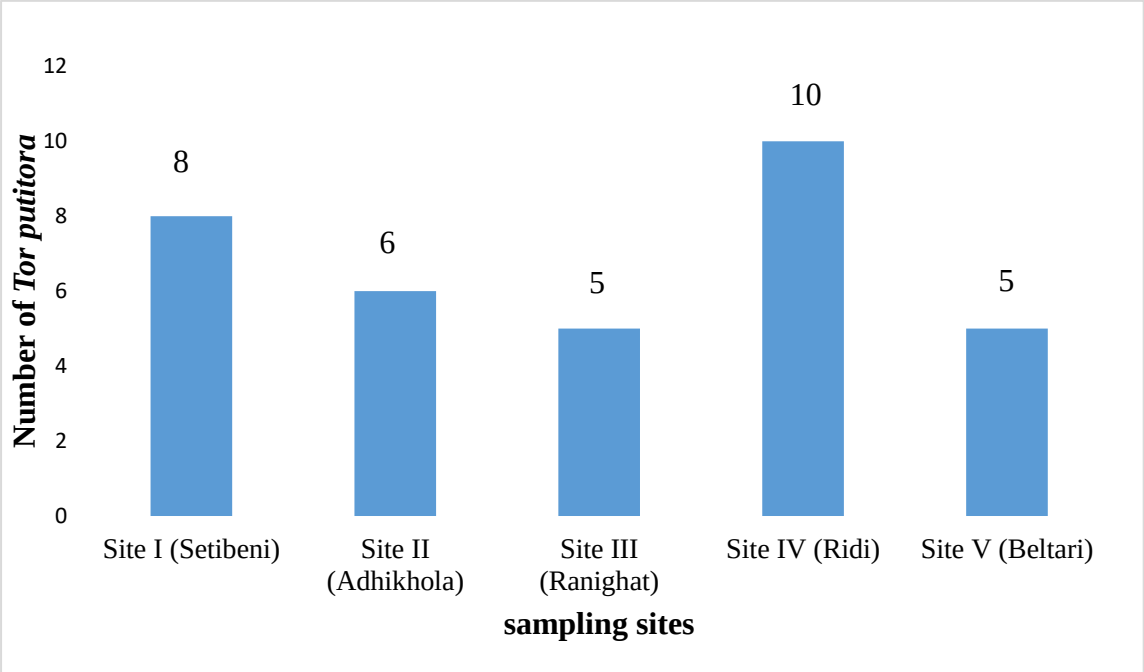



**Figure 2**. Number of *Tor putitora* in different sites

The mean and standard deviation of morphometric characteristics from five different sites of Kali Gandaki River. The minimal sample size for *Tor putitora* is 5 from Ranighat and Beltari, while the maximum size is 10 from Ridi. Setibeni and Adhikhola had a sample size of 8 and 6, respectively (Figure 2).

## 4.2. Morphometric and meristic counts of *Tor putitora*

The statistical examination of how the body variables expand in proportion to the total length of *Tor putitora*. The total length and fork length ratio was varied between minimum 0.903 ± 1.144:1 in Beltari and maximum was 1.102 ± 1.170:1 in Setibeni. Setibeni has the highest total length and mentum width ratio 46.67 ± 86.5:1, while Beltari has the lowest 40.67 ± 67.5:1 (Table 3). The study shows the morphometric character of calculation in

ratio to standard length (Table 4). The minimum ratio of standard length to fork length was 0.822 ± 0.972:1 in Beltari and maximum was 0.889 ± 0.924:1 in Setibeni. The minimum ratio of total length to mentum length ranged from 22.2 ± 88.50:1 in Beltari and maximum was 48 ± 331:1 in Ridi. The ratio of total length and mentum width fluctuated from minimum 32.97 ± 105:1 and maximum 37.67 ± 70:1 in Adhikhola and Setibeni respectively. Body parameter in ratio to head length was calculated and presented (Table 5). Ranighat had the lowest ratio of head length to mentum width at 2.053 ± 3.778:1, while Adhikhola had the highest at 3.400 ± 4.667:1. The ratio of head length to eye diameter varied from minimum 3.545 ± 5.667:1 in Ranighat and maximum 4.111 ± 6.917:1 in Ridi. The ratio of head length to fork length ranged from minimum 2.167 ± 3.400:1 in Ranighat and maximum 2.750 ± 3.444 in Setibeni.

In this comprehensive morphometric analysis of *Tor putitora,* the study explored the relationships between various body measurements and total length. The obtained regression equations provide valuable insights into the proportional changes in different dependent variables with respect to the total length. In a table, the standard length showed a strong positive correlation with total length, as indicated by a high correlation coefficient (r) of 0.986 and an impressive coefficient of determination ($r^2$) of 0.986. This suggests that approximately 98.6% of the variability in standard length can be explained by changes in total length. Similarly, head length, pre-dorsal length, pre-pectoral length, eye diameter, snout length, pre-anal length, caudal peduncle length, caudal peduncle depth, fork length, rostral barbel length, maxillary barbel length, dorsal fin length, pectoral fin length, ventral fin length, anal fin length, and body depth dorsal all exhibited positive correlations with total length, with correlation coefficients ranging from 0.78 to 0.996 and corresponding coefficients of determination ranging from 0.608 to 0.993 (Table 6).

In this study, different morphometric measurements were examined to better understand the relationship between standard length and various dependent variables of a *Tor putitora*. The study found significant correlations between standard length and head length, snout length, eye diameter, pre-anal length, pre-dorsal length, pre-pectoral length, caudal peduncle length, fork length, rostral barbel length, maxillary barbel length, dorsal fin length, pectoral fin length, ventral fin length, anal fin length, and body depth dorsal. The correlation coefficients (r) ranged between 0.780 and 0.995, showing a strong positive linear connection. The coefficient of determination ($r^2$) values ranged from 0.608 to 0.995,

indicating the amount of variance explained in the dependent variable by the independent variable. These findings indicate that standard length is a reliable (Table7).

In this comprehensive analysis of morphometric measurements in a *Tor putitora*, the focus was on examining the relationship between head length and various dependent variables. Eye diameter, for instance, was found to be positively correlated with head length, with a correlation coefficient (r) of 0.907 and a coefficient of determination ($r^2$) of 0.823. Similarly, head depth, snout length, inter-orbital length, gape width, body depth dorsal, mentum length, and another measurement of eye diameter all exhibited strong positive correlations with head length, ranging from 0.877 to 0.957 in correlation coefficient values and 0.769 to 0.916 in coefficient of determination values. The relationship between mentum length and head length showed a weaker positive correlation, with correlation coefficient (r) of 0.331 and coefficient of determination ($r^2$) of 0.109 while ($r^2$) value suggests that head length explains only 10.9% of the variability in mentum length. These findings imply that head length serves as a reliable predictor for a variety of dependent variables in the *Tor putitora* (Table 8). The demonstration of the statistical values of intercept (a), regression coefficient (b), correlation coefficient (r), and coefficient of determination ($r^2$) for various parameters of the body relation to total length, standard length, and head length respectively (Table 6, 7, 8). The study shows the highest positive relationship between the total length with fork length whereas lowest with dorsal fin length respectively (Figure 2 and 3). The result discovered the highest relationship between the standard length with fork length and lowest with dorsal fin length respectively (Figure 4 and 5). Similarly, the highest relationship of heads length was found with head depth and body depth dorsal, and lowest with mentum length respectively (Figure 6 and 7).

**Table 2**: The morphometrics of *Tor putitora* from five different sites

| Site | FL | TL | SL | HL | Sn-L | IOL | ED | RBL | MBL | PDL | PPL | CPL | CPD | DFL | PFL | VFL | AFL | BDD | BDA | ML | MW | No. of fishes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Setibeni | 4.5 ± 2.449 | 169.4 ± 21.796 | 136.6 ± 24.047 | 36.88 ± 20.549 | 11.75 ± 5.976 | 11.88 ± 2.052 | 8 ± 1.642 | 7.625 ± 3.338 | 9.125 ± 1.597 | 70.75 ± 1.959 | 36.62 ± 9.91 | 24.25 ± 5.012 | 14.88 ± 3.845 | 32.14 ± 0.991 | 25.62 ± 1.726 | 23.75 ± 3.814 | 24.5 ± 4.166 | 32.62 ± 3.703 | 22.25 ± 4.373 | 3.875 ± 1.457 | 3 ± 0.755 | 8 |
| Adhikhola | 134.6± 1.870 | 151.4 ± 22.132 | 121.5± 24.95 | 30.92± 19.01 | 10.33 ± 4.6534 | 8.183± 2.206 | 6.9 ± 2.011 | 7.583 ± 0.884 | 9.067 ± 0.998 | 57.83 ± 1.595 | 29.02 ± 10.83 | 13.08± 6.596 | 5.05 ± 2.392 | 27.03 ± 1.513 | 20.28 ± 5.438 | 17.78 ± 7.532 | 19.20 ± 5.399 | 27.17 ± 3.846 | 17.40 ± 7.856 | 5.333 ± 2.804 | 2.5 ± 1.048 | 6 |
| Ranighat | 168.2± 1.581 | 187.4 ± 51.236 | 153 ± 57.17 | 36± 48.14 | 12.2 ± 4.301 | 11.8 ± 3.492 | 7.6 ± 4.207 | 8.8± 2.701 | 10 ± 2.3874 | 67.6 ± 2.345 | 43.8 ± 2.626 | 26.6 ± 5.336 | 16.4 ± 8.82 | 42.6 ± 4.878 | 27.2 ± 4.505 | 23.6 ± 7.395 | 28 ± 4.979 | 33 ± 4.207 | 21.8 ± 14.91 | 3 ± 1.414 | 3 ± 1.414 | 5 |
| Ridi | 237.2± | 263.3 ± | 218.9± | 53.8 ± | 19.16 ± | 17.48± | 9.2 ± | 12.26 ± | 14.6 ± | 102.9 ± | 72.40 ± | 39.10± | 23.2 ± | 41.50 ± | 37.6 ± | 33.80± | 37.7 ± | 51.2 ± | 37.3 ± | 3.2 ± | 4.7 ± | 10 |

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3.027 | 93.143 | 100.559 | 91.78 | 21.311 | 7.266 | 6.172 | 9.342 | 4.551 | 5.4405 | 49.508 | 57.668 | 20.3002 | 9.897 | 11.255 | 14.276 | 12.629 | 7.279 | 22.592 | 1.549 | 1.766 | |
| Beltari | 252.6 ± 1.581 | 278.8 ± 154.9138 | 232.6± 179.938 | 59.4 ± 146.250 | 18 ± 35.159 | 18.4 ± 10.488 | 10.2± 11.76 | 11.8 ± 11.3885 | 14.8 ± 6.87 | 121 ± 9.038 | 58.6 ± 76.382 | 42.2 ± 34.355 | 26.2 ± 28.225 | 53.8 ± 17.601 | 42.6 ± 17.386 | 37.4 ± 27.709 | 41.2 ± 24.3987 | 57.4 ± 10.94 | 42 ± 39.067 | 4.6 ± 2.607 | 5 ± 2.915 | 5 |

**Table 3**: Growth of different body length in ratio of total length of *Tor putitora*

| Site | FL | TL | SL | HL | Sn-L | IOL | ED | RBL | MBL | PDL | PPL | CPL | CLD | DFL | PFL | VFL | AFL | BDD | BDA | ML | MW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Setibeni | 1.128 ± 0.019 | 169.4 ± 24.047 | 1.241 ± 0.019 | 4.618 ± 0.289 | 14.54 ± 1.411 | 14.28 ± 0.823 | 21.24 ± 2.19 | 22.78 ± 4.114 | 18.83 ± 1.726 | 2.39 ± 0.102 | 4.625 ± 0.226 | 7.008 ± 0.401 | 11.371 ± 1.267 | 5.28 ± 0.41 | 6.619± 0.31 | 7.213 ± 0.82 | 6.915± 0.32 | 5.195 ± 0.301 | 7.599 ± 0.348 | 48.76 ± 16.575 | 59.12 ± 15.048 |
| Adhikhola | 1.125 ± 0.019 | 51.4 ± 24.95 | 1.245 ± 0.018 | 4.828 ± 0.768 | 14.87 ± 2.366 | 19.29 ± 5.487 | 22.06 ± 3.975 | 20.25 ± 4.193 | 16.83 ± 2.236 | 2.634 ± 0.227 | 5.347 ± 1.03 | 11.62 ± 0.683 | 31.53 ± 7.697 | 5.594 ± 0.575 | 8.166 ± 2.732 | 9.205 ± 3.219 | 8.394 ± 2.656 | 5.798 ± 1.264 | 9.529 ± 3.489 | 36.58 ± 23.248 | 70.49 ± 31.506 |
| Ranighat | 1.115 ± 0.028 | 187.4 ± 57.177 | 1.227 ± 0.020 | 5.179 ± 1.256 | 15.36 ± 1.06 | 16.11 ± 1.214 | 24.62 ± 1.976 | 21.19 ± 1.04 | 18.59 ± 1.734 | 3.048 ± 1.200 | 4.511 ± 1.188 | 7.092 ± 0.386 | 11.43 ± 0.744 | 4.73 ± 1.473 | 6.858 ± 0.304 | 7.85 ± 0.723 | 6.707 ± 0.242 | 6.203 ± 2.162 | 9.183 ± 2.039 | 68.62 ± 18.832 | 67.52 ± 15.921 |
| Beltari | 1.085 ± 0.101 | 278.8 ± 179.93 | 1.188 ± 0.006 | 4.545 ± 0.406 | 15.272 ± 5.141 | 15.01 ± 1.818 | 25.3 ± 8.732 | 23.33 ± 3.254 | 18.56 ± 2.873 | 2.308 ± 0.167 | 4.606 ± 0.514 | 6.708 ± 0.246 | 10.556 ± 1.248 | 4.99 ± 1.692 | 6.546 ± 0.285 | 7.458 ± 0.446 | 6.792 ± 0.447 | 4.907 ± 0.505 | 7.19 ± 1.174 | 65.51 ± 27.679 | 55.13 ± 9.964 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ridi | 1.116 ± 0.039 | 263.3 ± 100.55 | 1.222 ± 0.082 | 4.908 ± 0.241 | 13.84 ± 1.204 | 15.13 ± 3.29 | 27.91 ± 4.768 | 21.66 ± 3.999 | 18.13 ± 1.776 | 2.573 ± 0.144 | 4.542 ± 1.323 | 7.228 ± 1.221 | 11.757 ± 2.207 | 6.207 ± 0.922 | 7.007 ± 0.276 | 7.77 ± 0.355 | 6.964 ± 0.812 | 5.453 ± 1.443 | 7.731 ± 2.748 | 101.84 ± 83.324 | 57.27 ± 10.446 |
| Average | 1.113 ± 0.041 | 190.06 ± 77.33 | 1.224 ± 0.039 | 4.815 ± 0.592 | 14.776 ± 2.236 | 15.964 ± 2.526 | 24.226 ± 4.328 | 21.842 ± 3.32 | 18.118 ± 2.069 | 2.59 ± 0.368 | 4.726 ± 0.856 | 7.931 ± 0.58 | 15.328 ± 2.63 | 5.36 ± 1.02 | 7.039 ± 0.781 | 7.899 ± 1.112 | 7.154 ± 0.89 | 5.511 ± 1.13 | 8.246 ± 1.95 | 64.26 ± 33.93 | 61.906 ± 16.57 |

**Table 4**: Growth of different body lengths in ratio of standard length of *Tor putitora*

| Site | FL | SL | HL | Sn-L | IOL | ED | RBL | MBL | PDL | PPL | CPL | CPD | DFL | PFL | VFL | AFL | BDD | BDA | ML | MW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Setibeni | 0.9087 ± 1.011 | 136.6 ± 20.549 | 3.72 ± 0.207 | 11.71 ± 1.058 | 11.5 ± 0.650 | 17.13 ± 1.858 | 18.33 ± 3.128 | 15.18 ± 1.478 | 1.926 ± 0.083 | 3.727 ± 0.188 | 5.649 ± 0.358 | 9.168 ± 1.074 | 4.256 ± 0.374 | 5.333 ± 0.239 | 5.819 ± 0.716 | 5.573 ± 0.287 | 4.185 ± 0.218 | 6.125 ± 0.321 | 39.24 ± 13.124 | 47.62 ± 12.042 |
| Adhikhola | 0.903 ± 0.011 | 121.5 ± | 3.96 ± | 11.942 ± 1.859 | 15.47 ± 4.276 | 17.70 ± 3.04 | 16.64 ± | 13.52 ± | 2.115 ± | 4.291 ± | 9.327 ± | 25.33 ± | 4.489 ± | 6.55 ± | 7.379 ± 2.53 | 6.731 ± | 4.653 ± | 7.642 ± | 29.46 ± | 56.9 ± |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 19.015 | 0.588 | | | 3.243 | 1.785 | 0.172 | 0.802 | 0.505 | 6.185 | 0.416 | 2.153 | | 2.083 | 0.985 | 2.752 | 18.764 | 26.487 |
| Ranighat | 0.908 ± 0.027 | 153 ± 48.145 | 4.228 ± 1.068 | 12.52 ± 0.889 | 13.12 ± 0.884 | 20.07 ± 1.58 | 17.28 ± 0.988 | 15.17 ± 1.577 | 2.488 ± 0.992 | 3.676 ± 0.97 | 5.778 ± 0.252 | 9.31 ± 0.487 | 3.851 ± 1.199 | 5.592 ± 0.302 | 6.401 ± 0.638 | 5.469 ± 0.272 | 5.036 ± 1.659 | 7.471 ± 1.563 | 55.96 ± 15.381 | 55.02 ± 12.845 |
| Beltari | 0.912 ± 0.551 | 232.6 ± 146.25 | 3.824 ± 0.268 | 12.753 ± 3.897 | 12.63 ± 1.373 | 21.25 ± 7.055 | 19.59 ± 2.063 | 15.64 ± 2.503 | 1.944 ± 0.135 | 3.876 ± 0.38 | 5.657 ± 0.331 | 8.88 ± 0.937 | 4.217 ± 1.42 | 5.514 ± 0.229 | 6.277 ± 0.194 | 5.715 ± 0.198 | 4.128 ± 0.357 | 6.051 ± 0.907 | 54.83 ± 23.44 | 46.16 ± 6.27 |
| Ridi | 0.914 ± 0.038 | 218.9 ± 91.78 | 4.027 ± 0.25 | 11.36 ± 1.113 | 12.606 ± 4.02 | 23.03 ± 4.648 | 17.77 ± 3.344 | 14.86 ± 1.436 | 2.109 ± 0.087 | 3.677 ± 0.972 | 5.892 ± 0.786 | 9.633 ± 1.745 | 5.111 ± 0.899 | 5.748 ± 0.296 | 6.378 ± 0.428 | 5.729 ± 0.813 | 4.460 ± 1.112 | 6.320 ± 2.145 | 87.83 ± 86.016 | 46.92 ± 8.25 |
| Average | 0.909 ± 0.327 | 172.52 ± 65.14 | 3.95 ± 0.47 | 12.05 ± 1.76 | 13.06 ± 2.24 | 19.83 ± 3.63 | 17.92 ± 2.55 | 14.87 ± 1.03 | 2.11 ± 0.29 | 3.84 ± 0.66 | 6.46 ± 0.44 | 12.46 ± 2.08 | 4.38 ± 0.86 | 5.74 ± 0.64 | 6.45 ± 0.90 | 5.84 ± 0.73 | 4.49 ± 0.86 | 6.72 ± 1.53 | 53.46 ± 31.34 | 50.52 ± 13.17 |

**Table 2**: Growth of different body lengths in ratio of head length of *Tor putitora*

| S.N. | Site | Sn-L | ED | MW |
|---|---|---|---|---|
| 1 | Setibeni | 3.148 ± 0.963 | 4.613 ± 0.212 | 3.101 ± 0.833 |
| 2 | Adhikhola | 3.021 ± 0.211 | 4.472 ± 0.32 | 3.059 ± 0.831 |
| 3 | Ranighat | 3.059 ± 0.831 | 4.902 ± 0.504 | 3.237 ± 0.683 |
| 4 | Beltari | 3.317 ± 1.535 | 5.489 ± 0.894 | 3.301 ± 0.254 |
| 5 | Ridi | 2.821 ± 0.963 | 5.695 ± 0.212 | 3.110 ± 0.833 |
| | Average | 3.073 ± 0.900 | 5.034 ± 0.428 | 3.161 ± 0.686 |

**Table 3**: Regression coefficient and correlation coefficient between total length and dependent variable

| S.N. | Dependent variable | Intercept (a) | Regression coefficient (b) | Correlation coefficient (r) | Coefficient of determination ($r^2$) |
|---|---|---|---|---|---|
| 1 | SL | -6.572 | 0.853 | 0.993 | 0.986 |
| 2 | HL | 2.867 | 0.193 | 0.972 | 0.945 |
| 3 | PDL | -5.128 | 0.423 | 0.981 | 0.962 |
| 4 | PPL | -12.746 | 0.296 | 0.794 | 0.630 |
| 5 | ED | 4.110 | 0.02 | 0.918 | 0.842 |
| 6 | Sn-L | 1.310 | 0.063 | 0.935 | 0.873 |
| 7 | PAL | -5.613 | 0.639 | 0.995 | 0.989 |
| 8 | CPL | -7.733 | 0.176 | 0.964 | 0.929 |
| 9 | CPD | -4.536 | 0.104 | 0.946 | 0.895 |
| 10 | FL | 0.406 | 0.895 | 0.996 | 0.993 |
| 11 | RBL | 1.506 | 0.039 | 0.931 | 0.866 |
| 12 | MBL | 0.900 | 0.051 | 0.977 | 0.945 |
| 13 | DFL | 0.11 | 0.016 | 0.78 | 0.608 |
| 14 | PFL | -0.509 | 0.148 | 0.977 | 0.954 |
| 15 | VFL | 0.840 | 0.127 | 0.957 | 0.917 |
| 16 | AFL | 0.228 | 0.142 | 0.972 | 0.945 |
| 17 | BDD | -5.31 | 0.217 | 0.971 | 0.943 |

Various models and associated statistical variables are as follows:

1. Standard length = -6.572 + 0.853 Total length, correlation coefficient (r) = 0.993 coefficient of determination ($r^2$) = 0.986
2. Head length = 2.867+ 0.193 Total length, correlation coefficient (r) = 0.972 coefficient of determination ($r^2$) = 0.945
3. Pre-Dorsal length = -5.128 + 0.423 Total length, correlation coefficient (r) = 0.981 coefficient of determination ($r^2$) = 0.962
4. Pre-Pectoral length = -12.746 + 0.296 Total length, correlation coefficient (r) = 0.794 coefficient of determination ($r^2$) = 0.630
5. Eye Diameter = 4.110 + 0.02 Total length, correlation coefficient (r) = 0.918 coefficient of determination ($r^2$) = 0.842
6. Snout length = 1.310 + 0.063 Total length, correlation coefficient (r) = 0.935 coefficient of determination ($r^2$) = 0.873
7. Pre-Anal length = -5.613 + 0.639 Total length, correlation coefficient (r) = 0.995 coefficient of determination ($r^2$) = 0.989
8. Caudal Peduncle length = -7.733 + 0.176 Total length, correlation coefficient (r) = 0.964 coefficient of determination ($r^2$) = 0.929
9. Caudal Peduncle Depth = -4.536 + 0.104 Total length, correlation coefficient (r) = 0.946 coefficient of determination ($r^2$) = 0.895
10. Fork length = 0.406 + 0.895 Total length, correlation coefficient (r) = 0.996 coefficient of determination ($r^2$) = 0.993
11. Rostral Barbel length = 1.506 + 0.039 Total length, correlation coefficient (r) = 0.931 coefficient of determination ($r^2$) = 0.866
12. Maxillary Barbel length = 0.900 + 0.051 Total length, correlation coefficient (r) = 0.977 coefficient of determination ($r^2$) = 0.945
13. Dorsal Fin length = 0.11 + 0.016 Total length, correlation coefficient (r) = 0.78 coefficient of determination ($r^2$) = 0.608
14. Pectoral Fin length = -0.509 + 0.148 Total length, correlation coefficient (r) = 0.9877 coefficient of determination ($r^2$) = 0.954

15. Ventral Fin length = 0.840 + 0.127 Total length, correlation coefficient (r) = 0.957 coefficient of determination ($r^2$) = 0.917

16. Anal Fin length = 0.228 + 0.853 Total length, correlation coefficient (r) = 0.972 coefficient of determination ($r^2$) = 0.945

17. Body Depth Dorsal = -5.31+ 0.217 Total length, correlation coefficient (r) = 0.971 coefficient of determination ($r^2$) = 0.943

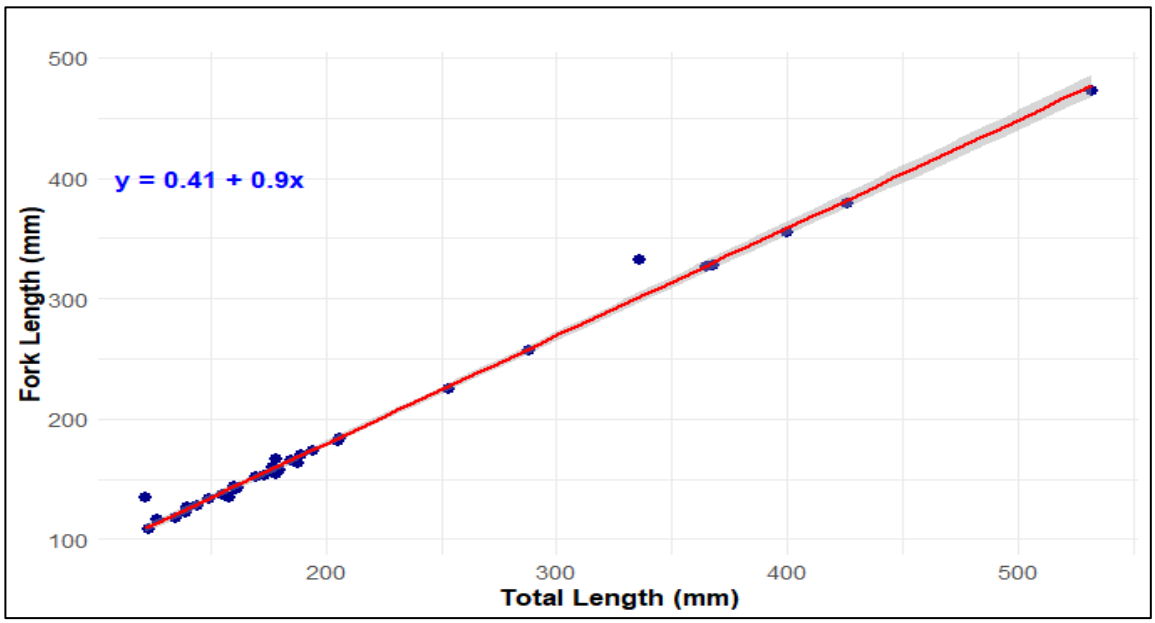



**Figure 3.** Relationship between FL and TL

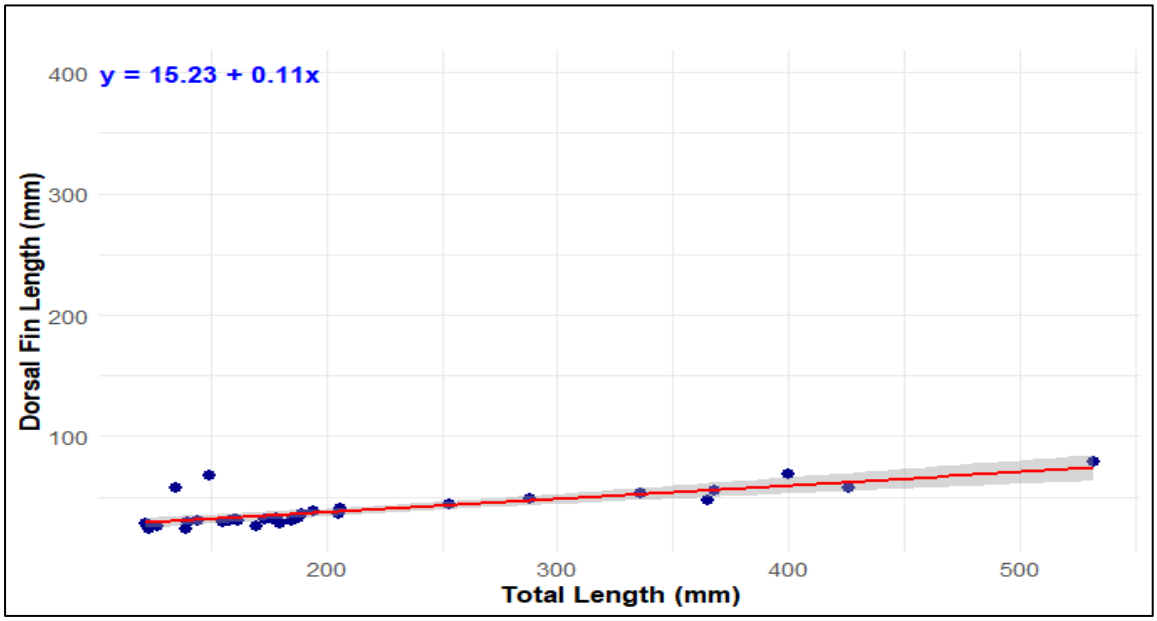



**Figure 4.** Relationship between DFL and TL

**Table 4**: Regression coefficient and correlation coefficient between standard length and dependent variables of *Tor putitora*

| SN | Dependent variable | Intercept (a) | Regression coefficient (b) | Correlation coefficient (r) | Coefficient of determination ($r^2$) |
|---|---|---|---|---|---|
| 1 | HL | 4.61 | 0.225 | 0.973 | 0.947 |
| 2 | Sn-L | 1.746 | 0.074 | 0.945 | 0.893 |
| 3 | ED | 4.294 | 0.024 | 0.918 | 0.843 |
| 4 | PAL | 0.213 | 0.745 | 0.995 | 0.99 |
| 5 | PDL | -1.087 | 0.492 | 0.979 | 0.958 |
| 6 | PPL | -13.447 | 0.364 | 0.839 | 0.704 |
| 7 | CPL | -6.622 | 0.208 | 0.977 | 0.955 |
| 8 | FL | 8.433 | 1.044 | 0.988 | 0.995 |
| 9 | RBL | 1.756 | 0.046 | 0.943 | 0.89 |
| 10 | MBL | 1.343 | 0.059 | 0.975 | 0.95 |
| 11 | DFL | 16.25 | 0.129 | 0.78 | 0.608 |
| 12 | PFL | 0.875 | 0.172 | 0.976 | 0.952 |
| 13 | VFL | 2.028 | 0.148 | 0.957 | 0.916 |
| 14 | AFL | 1.663 | 0.165 | 0.968 | 0.937 |
| 15 | BDD | -3.519 | 0.254 | 0.976 | 0.952 |

Various models and associated statistical variables are as follows:

1. Head length = 4.61 + 0.225 Standard length, correlation coefficient (r) = 0.973 coefficient of determination ($r^2$) = 0.947
2. Snout length = 1.746 + 0.074 Standard length, correlation coefficient (r) = 0.945 coefficient of determination ($r^2$) = 0.893
3. Eye Diameter = 4.294 + 0.024 Standard length, correlation coefficient (r) = 0.918 coefficient of determination ($r^2$) = 0.843
4. Pre-Anal length = 0.213 + 0.745 Standard length, correlation coefficient (r) = 0.995 coefficient of determination ($r^2$) = 0.99
5. Pre-Dorsal length = -1.087 + 0.492 Standard length, correlation coefficient (r) = 0.979 coefficient of determination ($r^2$) = 0.958

6. Pre-Pectoral length = -13.447 + 0.364 Standard length, correlation coefficient (r) = 0.839 coefficient of determination ($r^2$) = 0.704
7. Caudal Peduncle length = -6.622 + 0.208 Standard length, correlation coefficient (r) = 0.977 coefficient of determination ($r^2$) = 0.955
8. Fork length = 8.433 + 1.044 Standard length, correlation coefficient (r) = 0.988 coefficient of determination ($r^2$) = 0.995
9. Rostral Barbel length = 1.756 + 0.046 Standard length, correlation coefficient (r) = 0.943 coefficient of determination ($r^2$) = 0.89
10. Maxillary Barbel length = 1.343 + 0.059 Standard length, correlation coefficient (r) = 0.975 coefficient of determination ($r^2$) = 0.95
11. Dorsal Fin length = 16.25 + 0.129 Standard length, correlation coefficient (r) = 0.78 coefficient of determination ($r^2$) = 0.608
12. Pectoral Fin length = -0.875 + 0.172 Standard length, correlation coefficient (r) = 0.976 coefficient of determination ($r^2$) = 0.952
13. Ventral Fin length = 2.028 + 0.148 Standard length, correlation coefficient (r) = 0.957 coefficient of determination ($r^2$) = 0.916
14. Anal Fin length = 1.663 + 0.165 Standard length, correlation coefficient (r) = 0.968 coefficient of determination ($r^2$) = 0.937
15. Body Depth Dorsal = -3.519 + 0.254 Standard length, correlation coefficient (r) = 0.976 coefficient of determination ($r^2$) = 0.952

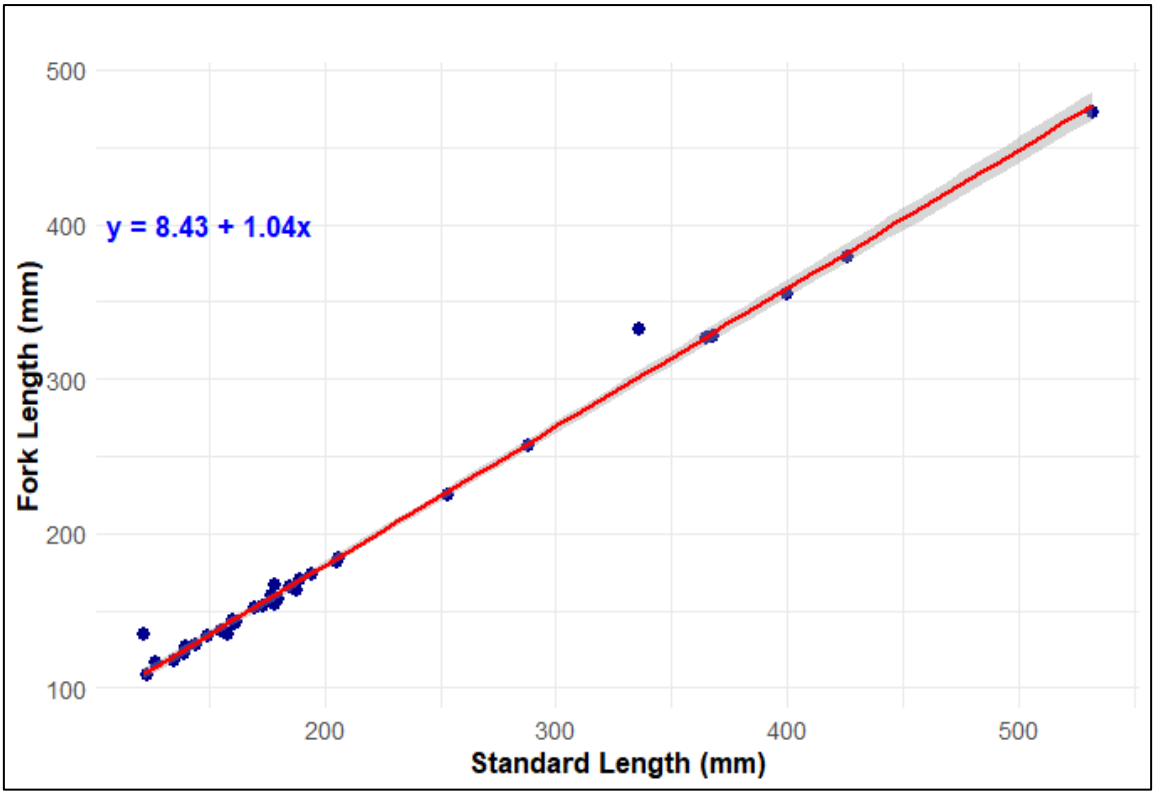



**Figure 5.** Relationship between FL and SL

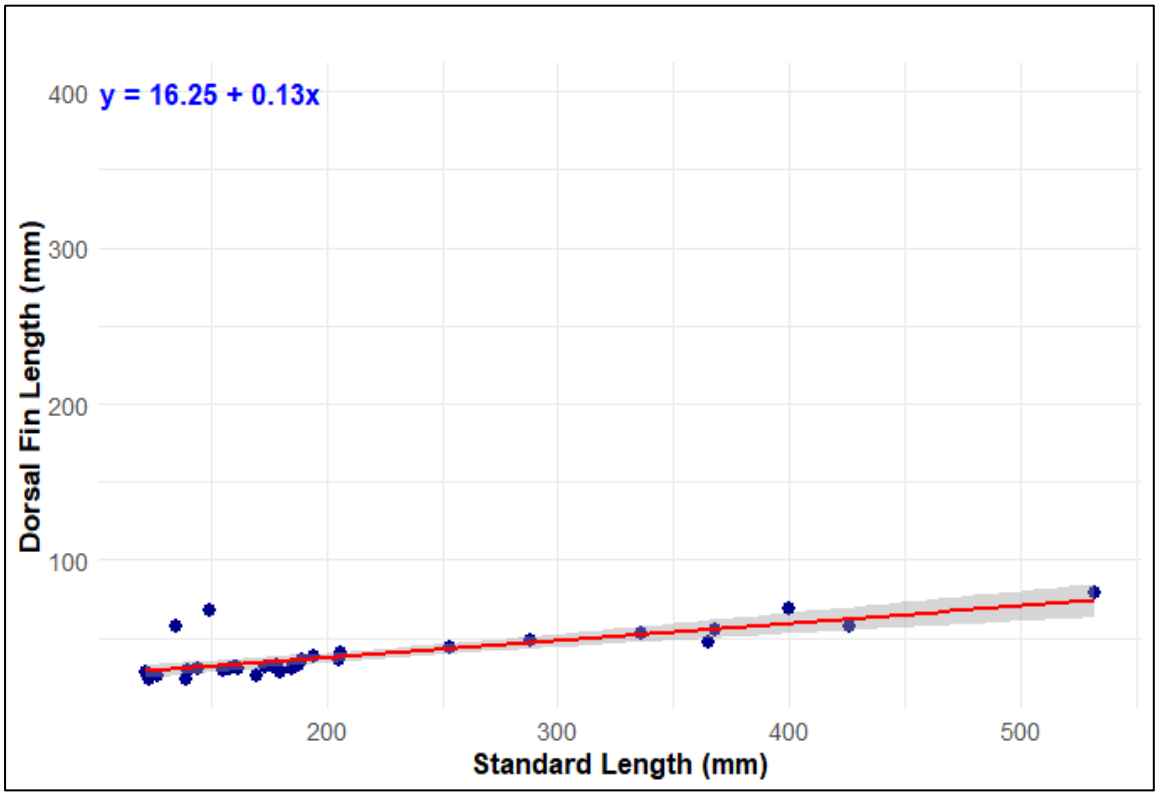



**Figure 6.** Relationship between DFL and SL

**Table 5**: Regression coefficient and correlation coefficient between the head length and dependent variables of *Tor putitora*

| S. N | Dependent variable | Intercept (a) | Regression coefficient (b) | Correlation coefficient (r) | Coefficient of determination ($r^2$) |
|---|---|---|---|---|---|
| 1 | ED | 0.101 | 0.008 | 0.907 | 0.823 |
| 2 | HD | 0.674 | 0.036 | 0.957 | 0.916 |
| 3 | Sn-L | 0.317 | 0.021 | 0.937 | 0.878 |
| 4 | IOL | 0.312 | 0.023 | 0.924 | 0.854 |
| 5 | GW | -3.628 | 0.358 | 0.877 | 0.769 |
| 6 | BDD | -6.464 | 1.075 | 0.957 | 0.916 |
| 7 | ML | 2.478 | 0.033 | 0.331 | 0.109 |
| 8 | MW | 1.13 | 0.087 | 0.932 | 0.868 |

Various models and associated statistical variables are as follows:

1. Eye Diameter = 0.101 + 0.008 Head length, correlation coefficient (r) = 0.907 coefficient of determination ($r^2$) = 0.823
2. Head Depth = 0.674 + 0.036 Head length, correlation coefficient (r) = 0.957 coefficient of determination ($r^2$) = 0.916
3. Snout Length = 0.317 + 0.021 Head length, correlation coefficient (r) = 0.937 coefficient of determination ($r^2$) = 0.878
4. Inter Orbital Length = 0.312 + 0.023 Head length, correlation coefficient (r) = 0.924 coefficient of determination ($r^2$) = 0.854
5. Gape Width = -3.628 + 0.358 Head length, correlation coefficient (r) = 0.877 coefficient of determination ($r^2$) = 0.769
6. Body Depth Dorsal = -6.464 + 1.075 Head length, correlation coefficient (r) = 0.957 coefficient of determination ($r^2$) = 0.916
7. Mentum Length = 2.478 + 0.033 Head length, correlation coefficient (r) = 0.331 coefficient of determination ($r^2$) = 0.109
8. Eye Diameter = 1.13 + 0.087 Head length, correlation coefficient (r) = 0.932 coefficient of determination ($r^2$) = 0.868

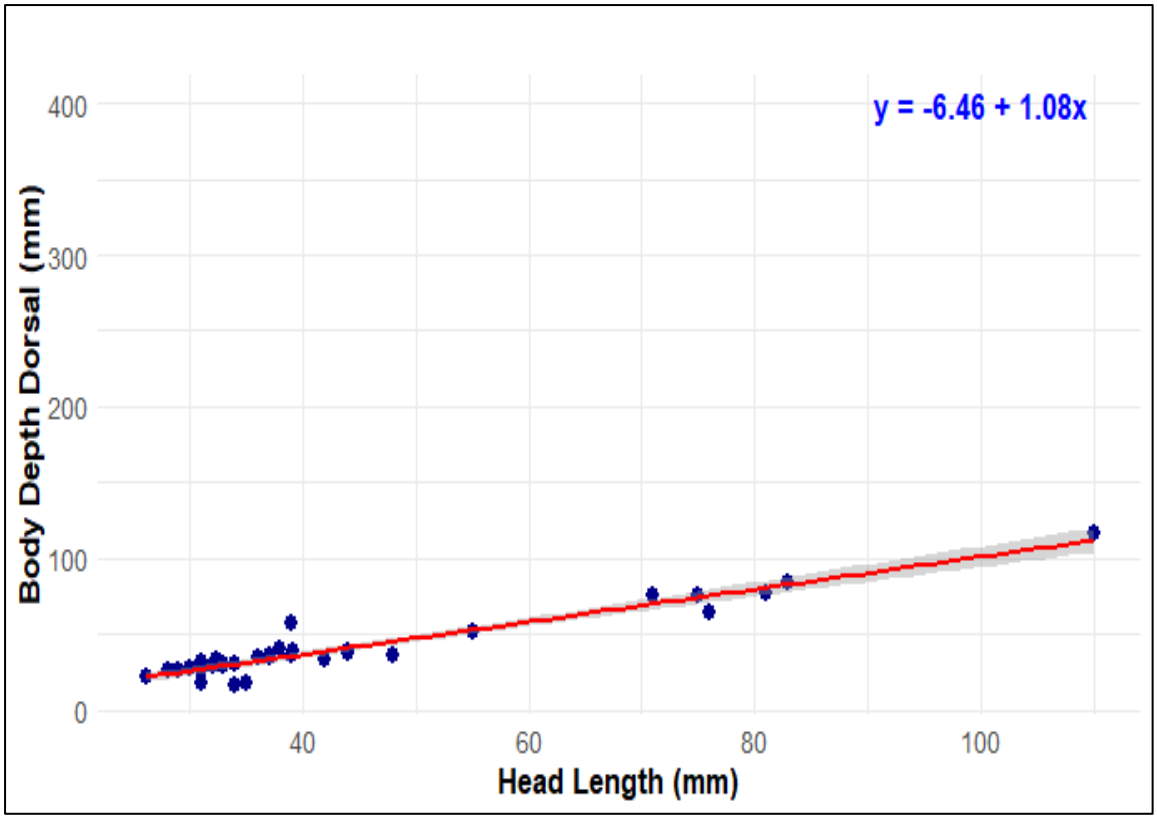



**Figure 7.** Relationship between BDD and HL

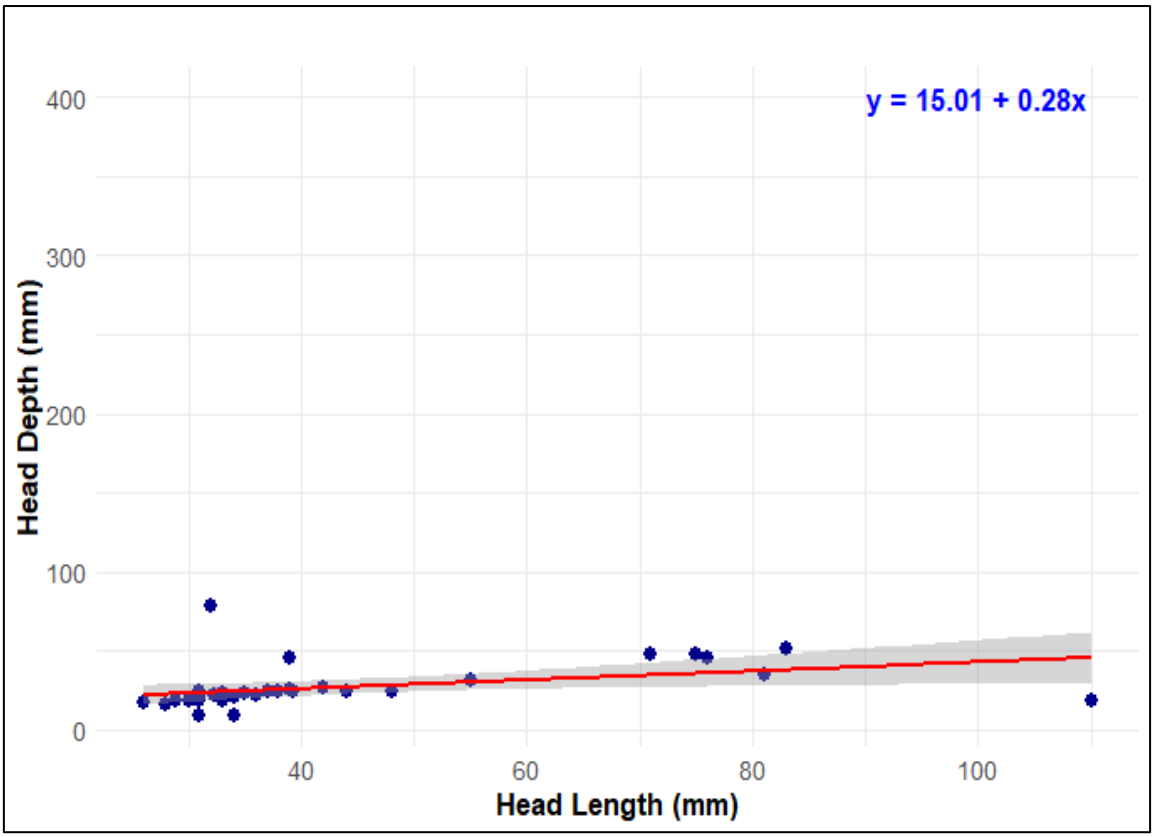



**Figure 8.** Relationship between HD and HL

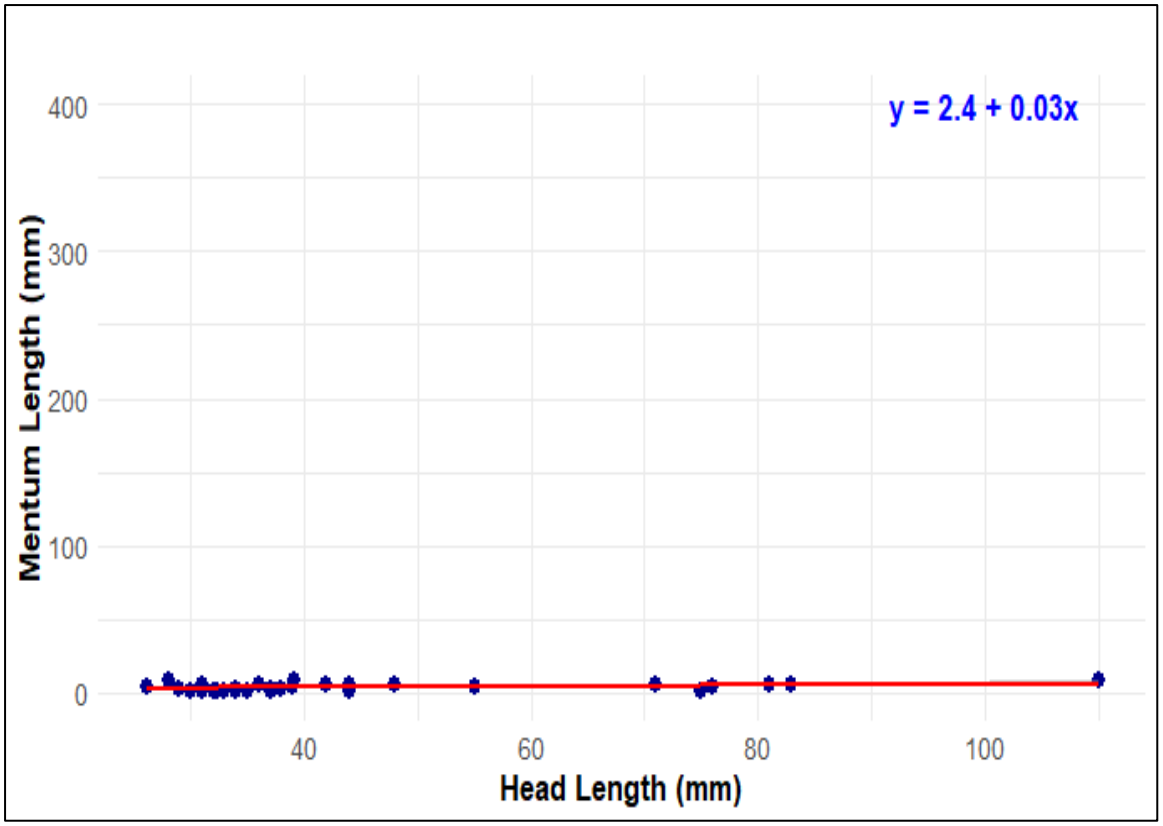



**Figure 9.** Relationship between ML and HL

**Table 6**: Summarized data of meristic counts of *Tor putitora* from different sampling sites

| S. N | Site | DFR | PFR | VFR | AFR | T |
|---|---|---|---|---|---|---|
| 1 | Site I (Setibeni) | 10 | 16-17 | 9 | 7 | 8-9 |
| 2 | Site II (Adhikhola) | 10 | 16 | 7-9 | 6-7 | 7-8 |
| 3 | Site III (Ranighat) | 10 | 17-18 | 9 | 7 | 8-9 |
| 4 | Site IV (Beltari) | 10 | 16-18 | 9 | 7 | 8-9 |
| 5 | Site V (Ridi) | 10 | 15-18 | 8-9 | 6-7 | 8-9 |

The fin formula was summarized as:

D-10, PFR-15-18, VFR-7-9, AFR-6-7, T-8-9

# 5. Discussion

The current research focused on the Taxonomic diversity of Genus *Tor* from the Kali Gandaki River. The study found that only one species of *Tor*, named *Tor putitora*, was present at all five sampling sites of the Kali Gandaki River. 34 individuals *Tor putitora* were gathered and their morphometric and meristic characteristics measured. During the investigation, 35 morphometric and 5 meristic features were measured at five sampling sites. According to morphometrics and meristic counts, it was recognized as *Tor* species and with help of identification keys, the *Tor* species was identified as *Tor putitora* from all the samplings sites of Kali Gandaki River.

The *Tor putitora* population distribution was highest (10) in Ridi and lowest (5) in Beltari and Ranighat. This might be due to Beltari and Ranighat have very high-water velocities and no confluence point, while Ridi has a confluence location between the Kali Gandaki River and Ridi Khola.

The results explore the relationship between total length, standard length, and head length with respect to related body parts respectively (Table 6,7,8).

There was a significant correlation between standard length and head length, snout length, eye diameter, pre-anal length, pre-dorsal length, pre-pectoral length, caudal peduncle length, fork length, rostral barbel length, maxillary barbel length, dorsal fin length, pectoral fin length, ventral fin length, anal fin length, and body depth dorsal. The correlation coefficients (r) ranged between 0.780 and 0.995, demonstrating a significant positive linear relationship.

Furthermore, the head depth, snout length, inter-orbital length, gape width, body depth dorsal, mentum length, and another measurement of eye diameter all showed high positive associations with head length, ranging from 0.877 to 0.957 (Table 8). The association between mentum length and head length revealed a weaker positive correlation, with correlation coefficient (r) of 0.33. The current study demonstrates that all dependent variables are positively correlated with total length, head length, and standard length.

When comparing the parameters of standard length and focal length with total length, the highest positive correlation was found. This result aligns with a study on *Tor putitora* conducted by (Mehmood et al., 2021). In addition, a study demonstrated a strong positive correlation between the morphometric trait and total length, highlighting its crucial

importance in driving increases in body size measurements of *Tor putitora* (Bhatt et al., 1998).

The studies done by (Bansal et al., 2021) and (Langer et al., 2013), found a positive association between dependent variables with head length, standard length, and total length. Similar findings were reported regarding the morphometric and meristic characteristics of *Tor putitora* populations form the Gobindsagar reservoir and Ganga River between Rishikesh and Haridwar (Bhatt, 1997; Nautiyal & Lal, 1988). In contrast an investigation revealed a negative correlation between specific morphometric features, such as head depth, ventral fin base, and anal fin base with the total length (Sharma et al., 2015). Similarly, (Marr, 1955; Tandon, 1962) also found negative correlation between the total length and other morphometric characters of *Alepes vari*. This might be due a numerous causes, including environmental conditions, temperature fluctuations, inadequate nutrition, parasitic organisms, predatory creatures, inbreeding depression, and genetic mutation (Ha & Iguchi, 2022). The most important tool for differentiating fish species present in different habitats is morphometrics than meristic count (Bektas & Belduz, 2009). Modifications in morphometric features can sometimes appear as a sign of water contamination (Singla, 2017).

The meristic counts of *Tor putitora* were nearly identical across different locations in the Kali Gandaki River and were not influenced by body size. During present studies, it also observed that the all meristic counts are independent of body size and there is no change in all meristic counts with increase in body length. (Vladykov, 1934), (Talwar & Jhingran, 1991) and (Masood et al., 2015) found that meristic counts were independent of body size and there is no change in meristic counts with increase in body length where the results of differences in meristic counts may be due to seasonal variation, altitude variation, food availability, river ecology, geographical distribution, biotics and abiotic factors (LAJ, 1987).

# 6. Conclusion and recommendation

## 6.1. Conclusion

The study was conducted on Genus *Tor* from Kali Gandaki River. This study concluded that *T. putitora* was identified from all sampling sites. There was positive relationship between different morphometric characters with total length, standard length and head length which shows isometric pattern of the growth. Total length, standard length and head length serves as a reliable predictor for a variation of dependent variables in the *Tor putitora*. Meristic counts were similar between all sites of kali Gandaki River. These findings will be useful for future research, as well as for conserving and managing the *Tor putitora* population, which is an endangered species.

## 6.2. Recommendations

- Establishing protected areas, regulating fishing practices, monitoring and research initiatives and promoting community-based conservation initiatives are crucial to safeguard an endangered *Tor putitora* population in kali Gandaki River.
- The study emphasizes the need for long-term monitoring programs with standardized sampling approaches.
- Use of molecular technique to accurately identify the *Tor* species.

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# Appendices

## Appendix 1. Photographs

**Photograph 1.** Measurement of *Tor putitora*

**Photograph 2.** Dorsal view of *Tor putitora*

**Photograph 3.** Fish sampling with cast net

**Photograph 4.** Fish sampling with seine net

नेपाल सरकार
वन तथा वातावरण मन्त्रालय
# वन तथा भू-संरक्षण विभाग

फोन नं { ४-२२३५७४ / ४-२२०३०३
फ्याक्स ४-२२३३७४

(कृपया पत्रोत्तरमा प्राप्त पत्र संख्या र मिति उल्लेख गर्नुहोला ।
बबरमहल, काठमाडौं, नेपाल

प्राप्त पत्र संख्या र मितिः-
पत्र संख्याः- ०८०/८१
च. नं.:- ६१

मिति : २०८०/०४/१५

विषयः अनुसन्धान अनुमति सम्बन्धमा ।

श्री प्रवन राना,
पाल्पा, नेपाल ।

प्रस्तुत विषयमा Central Department of Zoology ,Tribhuvan University, Kirtipur Kathmandu मा M.sc 3rd Semester मा अध्ययनरत तपाईले "Taxonomic diversity of Genus Tor (Gray, 1834) in Kaligandaki River, Nepal" को विषयमा अध्ययन अनुसन्धानका लागि अध्ययन अनुमति उपलब्ध गराइदिनु हुन भनि मिति २०७९/०९/२८ गते यस विभागमा दिनु भएको निवेदन साथ प्रपोजल प्राप्त भयो । सो सम्बन्धमा कारवाही हुँदा उक्त प्रपोजलमा उल्लेखित Methodology (Cast net, hook and line, gill net and local fishing gears with the help of local fisherman) अनुसार तपसिलको शर्तहरुको अधिनमा रही डिभिजन वन कार्यालयसँग समन्वय गरि सन् २०२३, अगष्ट देखि सन् २०२४, अगष्ट सम्मका लागि अनुसन्धान गर्नु हुन निर्देशानुसार अनुरोध छ ।

शर्तहरु

१. अनुसन्धानकर्तालि वन ऐन २०७६ तथा वन नियमावली २०७९, राष्ट्रिय निकुञ्ज तथा वन्यजन्तु संरक्षण ऐन, २०२९ र नियमावली २०३० तथा यस मातहतका नियमावलीहरुको पूर्ण पालना गर्नुपर्नेछ ।
२. अनुसन्धान कार्य डिभिजन वन कार्यालयसँगको समन्वयमा गर्नुपर्नेछ ।
३. संकलित नमुनाहरुको परिक्षण कार्य Central Department of Zoology, किर्तिपुर, काठमाण्डौको प्रयोगशालामा गर्नुपर्नेछ
४. अनुसन्धानको क्रममा प्राप्त भएको जैविक विविधता संरक्षणसँग सम्बन्धित संवेदनशिल सूचनाहरु गोप्य राख्नु पर्नेछ अनाधिकृत रुपमा त्यस्ता सूचनाहरु कसैलाई पनि उपलब्ध गराउन पाइने छैन ।
५. अनुसन्धान कार्य समाप्त भए पश्चात एक प्रति रिपोर्ट/प्रतिवेदन (कागजी तथा विद्युतिय) यस विभागमा अनिवार्य रुपमा बुझाउनु पर्नेछ ।
६. तोकिएका शर्तहरुको पालना नगरिएमा विभागले कुनै पनि समयमा अनुसन्धान अनुमति रद्द गर्न सक्नेछ ।

(सचनम पाठक)
सहायक वन अधिकृत

बोधार्थ
श्री डिभिजन वन कार्यालय, पाल्पा, स्याङ्जा, गुल्मी र पर्वत। : जानकारी तथा आवश्यक सहयोगका लागि अनुरोध छ ।

**Photograph 5.** Ethical approval of the study