Length-Weight Relationship, Condition Factor, Gastro-Somatic- Index and Stomach Content Analysis of *Schizothorax richardsonii* (Gray, 1832) in Setikhola, Parbat, Nepal

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Dissertation submitted in partial fulfilment of the requirements for the degree of Master of Science in Zoology with special paper Fish Biology and Aquaculture

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Declaration

I hereby declare that the work presented in this dissertation "Length-weight relationship, Condition factor, Gastro-somatic index and Stomach content analysis of snow trout *Schizothorax richardsonii* (Gray, 1832) in Setikhola, Parbat, 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).

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Recommendation

This is to recommend that the dissertation entitled "Length-weight relationship, Condition factor, Gastro-somatic index and Stomach contents analysis of *Schizothorax richardsonii* (Gray, 1832) in Setikhola, Parbat, Nepal" has been carried out by Deepak Bhattarai for the partial fulfilment of Master's Degree of Science in Zoology with special paper Fish biology and Aquaculture. This is his original work and has been carried out under my supervision. To the best of my knowledge, this dissertation work has not been submitted for any other degree in any institutions.

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Letter of approval

On the recommendation of supervisor "Mrs. Santoshi Shrestha" this dissertation submitted by (Deepak Bhattarai) entitled "Length-weight relationship, Condition factor, Gastro-somatic index and Stomach contents analysis of *Schizothorax richardsonii* (Gray, 1832) in Setikhola, Parbat, Nepal" is approved for the examination in partial fulfilment of the requirements for Master's Degree of Science in Zoology with special paper Fishery and Aquaculture.

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Certificate of acceptance

This dissertation work submitted by (Deepak Bhattarai) entitled "Length-weight relationship, Condition factor, Gastro-somatic index and Stomach contents analysis of *Schizothorax richardsonii* (Gray, 1832) in Setikhola, Parbat, Nepal" has been accepted as a partial fulfilment for the requirements of Master's Degree of Science in Zoology with special paper fishery and aquaculture.

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Abstract

Schizothorax richardsonii is one of the important major species of an aquatic ecosystem of Setikhola. The main aim of the study is to investigate the length- weight relation, condition factor, gastro-somatic index and Stomach contents analysis of *Schizothorax richardsonii*. A total of 101 fish individuals were collected seasonally from august 2023 to January 2024 using cast net from Setikhola river. The fishes were measured and weighed using stainless scale and weighing machine respectively before dissecting fish. Qualitative analysis of stomach contents and index of fullness methods were applied for gut content examination. The values of total length and weight varies from 10.3 to 19.6cm and 10.3 to 75.79g respectively. The length-weight relationships of *S. richardsonii* as calculated on pulled data can be expressed by the equations: W = 0.0059 × TL^3.11 (R^2 = 0.91) for autumn and W=0.024 × TL^2.70 (R^2 = 0.92) for winter. The condition factor ranges from 0.81 to 1.36 during the both seasons indicating fish in good health condition and shows both isometric growth pattern and allometric pattern during both seasons. The mean value of Gastro-somatic index was 11.29 in autumn and 10.21 winter attributed to fish feeding at different rates. Approximately, 35% of the guts or stomachs were found entirely full followed by moderately full or half-full stomach and only 7% of the stomachs were empty in the winter This fish abundantly feed on green algae most followed by trichopteran and dipteran larvae so consider as omnivore in nature.

शोध सार

Schizothorax richardsonii सेतिखोलाको जलीय पारिस्थितिकी तंत्रको एक महत्वपूर्ण प्रमुख प्रजाति हो । यस अध्ययनको मुख्य उद्देश्य *S. richardsonii* को लम्बाइ-तौल सम्बन्ध, अवस्था कारक, ग्यास्ट्रो-सोमाटिक सूचकांक र पेट सामग्री विश्लेषणको अनुसन्धान गर्नु हो । अगस्ट २०२३ देखि जनवरी २०२४ सम्म कुल १०१ माछाको नमूना संकलन गरिएको थियो । माछा विच्छेदन गर्नु अघि क्रमशः stainless Scale तौल गर्ने मेसिन प्रयोग गरी माछाहरू नाप्ने र तौलिएको थियो । पेट सामग्रीको गुणात्मक विश्लेषण र पूर्णता विधिरूको सुचकांक पेट सामग्री परिक्षाको लागि गरियो । कुल लम्बाइ र वजनको मानहरू क्रमशः १०.३ देखि १९.६ सेमी र १०.३ देखि ७५.७९ ग्राम सम्म भिन्न हुन्छन । *S. richardsonii* को लम्बाइ-वजन सम्बन्धहरू तानिएको डेटामा गणना गरिएको समीकरणहरूद्वारा व्यक्त गर्न सकिन्छ : WO = ०.००५*TL^३.११ (R^2 = ०.९१) शरद ऋतु र WO = ०.०२४*TL^२.७० (R^2 = ०.९२७) जाडो मौसमको लागि क्रमशः अवस्था कारक ०.८१५८ देखि १.३६९७ सम्म दुबै मौसमहरूमा राम्रो स्वास्थ्य अवस्थामा माछालाई संकेत गर्दछ र दुबै मौसममा आइशोमेट्रिक र एलोमेट्रिक वृद्धि ढाँचा दुवै देखाउँदछ । GSI को औसत मान शरद र जाडो मौसममा क्रमशः ११.२९ र १०.२१ थियो जसले विभिन्न दरहरूमा माछाको दानालाई संकेत गर्दछ । लगभग ३५% आन्द्रा वा पेट पूर्ण रूपमा भरिएको पाइयो र त्यसपछि मध्यम रूपमा भरिएको वा आधा भरिएको पेट र जाडो मौसममा केवल ७ % पेट खाली थियो । यो माछाले हरियो शैवाललाई प्रचुर मात्रामा खुवाउँछ र त्यसपछि कीराको लार्भा (ट्राइकोप्टेरन र डिप्टेरन) लाई प्रकृतिमा सर्वाहारी मानिन्छ ।

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List of Abbreviations

Abbreviated form	Details of Abbreviations
GSI	Gastro Somatic Index
K	Condition Factor
LWRs	Length Weight Relationship
TL	Total Length
TW	Total Weight

1. Introduction

1.1 Background

Fishes represent a highly nutritious, visually appealing, and fascinating array of aquatic lifeforms. Nutrition plays a pivotal role in the ecology of fishes, essential for their growth, reproduction, and extensive migrations (Malik et al., 2019). Understanding the food and feeding habits of fish is crucial for both fishery biology and aquaculture endeavors. Scientific insights into these habits are pivotal for augmenting fish production. Moreover, the dietary preferences and feeding habits of fish species fluctuate according to the time of day, season, ecological conditions, and the availability of food resources within the aquatic environment. The Common Snowtrout, also referred to as “Asala” or “Asela” by locals, is scientifically classified as Schizothorax richardsonii (Gray, 1832), a species within the ray-finned belonging to the family Cyprinidae and the order Cypriniformes.   The genus name, *Schizothorax,* originates from the Greek words "schizein," meaning to divide, and "thorax," which denotes breast. *Schizothorax richardsonii,* commonly known as Asala or Snowtrout, is a member of the Cyprinidae family.is a coldwater fish endemic to the Himalayas and a significant component of riverine ecosystems, found in streams, rivers, and lakes across the Himalayan region between 750 to 2500 meters above sea level (Lohani & Ram, 2018).

1.1.1 Length-weight relationship

Length-weight relationships (LWRs) and relative condition factors are very important in fisheries assessment studies because they give information on the fish's development, overall well-being, and fitness in an aquatic ecosystem. Length-weight correlations and condition variables are two crucial components of fish biology that are used to assess individual health and potential variations across populations within the same species (Austin et al., 2008). Length-weight relationship studies are crucial for fish understanding Length, measured in centimeters, and weight, in grams, are closely linked, with weight approximately equaling volume (Rani et al., 2018). This relationship, often expressed as W= aL^b. LWRs establishes the mathematical link between fish length and weight. Examining the biology of particular fish species that are preferred in terms of the condition factor (k) and length-weight relationship (LWR) is a crucial aspect of fish biology (Abdul et al., 2016).

These days, it's also thought that analyzing fish LWRs is a crucial biological marker for gathering data on the growth conditions of fish species that coexist in both wild and cultivated environments and also significantly influences fish biology research, offering insights into the physiological and biological states of fish and their well-being in their natural habitats (Mehmood et al., 2021). Apart from this, it offers insights into fish population growth rates and their dynamics (Nahdi et al., 2016). According to Rani et al. (2018), Beyer (1987), Santos et al. (2002), and Ritcher et al. (2000), LWRs serve as practical indices for diverse research endeavors concerning fish biology and fisheries management.

1.1.2 Condition Factor

Condition factor serves as a pivotal measure within fisheries science and ecology, offering insights into the health and vitality of fish populations. Represented by the symbol (K), it encapsulates the interplay of various factors such as feeding conditions, parasitic infections, and physiological parameters, as outlined by Le Cren (1951). This metric serves as an indicator of changes in food reserves and overall fish condition, crucial for assessing their well-being. In fisheries science, (K) aids in comparing the fatness or overall condition of fish populations, as emphasized by Seher Dirican (2012), who posits that heavier fish of similar length are in better physiological shape. Moreover, it serves as a valuable tool for monitoring feeding intensity, age, and growth rates in fish according to Ujjania et al. (2012).

1.1.3 Stomach content analysis

Analysis of fish gut contents offers crucial insights into their feeding behaviors, with a quantitative study of these patterns being vital for effective fisheries management. Understanding fish diets encompasses key ecological aspects like behavior, health, habitat usage, energy intake, and species interactions. A detailed grasp of fish diets and feeding behaviors lays a strong groundwork for comprehending trophic relationships within aquatic food webs. By evaluating gut contents, researchers can discern habit preferences, prey selection, and the effects of ontogeny, facilitating the development of conservation strategies, as outlined by Chipps & Garvey (2007). Conducting food habit studies helps ascertain frequently consumed prey and gauge the importance of different food types for fish nutrition, along with quantifying individual food ingestion rates.

1.1.4 Gastro-somatic Index

A fish's gastro-somatic index (GSI) is a metric used in fisheries biology to evaluate how big the stomach is in comparison to the body as a whole. The weight of the stomach is divided by the fish's total weight, and the result is multiplied by 100 to get the percentage. The gastro-somatic index (GSI) of a natural population defines their seasonal dietary habits and may be examined by measuring the viscera somatic index (Rana, 2021). The Gastro-somatic index, or GSI, is a measurement of a fish's stomach weight relative to its body weight. The gastro-somatic index can be used to gauge a fish's eating intensity. The monthly variation in GSI represents the change in feeding intensity (Sangma et al., 2019). In general, the gastro somatic index fluctuates according to the season and maturity; it reaches its peak in the post-spawning phase and its lowest point during the breeding phase (Sattar & Adam, 2005).

Schizothorax richardsonii (Gray,1832) is a coldwater fish belongs to the family Cyprinidae and sub-family Schizothoracinae. It is commonly known as Asala or snowtrout. It has a strong body to resist the strong water current of the hill streams. Its food constitutes predominantly of the members of green algae, blue-green algae, diatoms, aquatic macrophytes and decayed organic matter, etc. The Schizothoracine fishes are typical detritophagus herbivore except when they are young. The young ones feed principally on small benthic crustaceans and insect larvae. Due to its high demand as a good sport fish and delightful taste, it is most favored fish among folks. The distribution of this cyprinid species is confined to the rivers and streams across the country. Besides Nepal, this species is distributed in India, Bhutan, Pakistan and Afghanistan (Talwar and Jhingran, 1991). Although is widely distributed along the Himalayan foothills, its populations have been declined from many areas due to introduction of exotic species, damming and overfishing (Negi and Negi, 2010).

1.2 Statement of the problem

The population of the fish is decreasing rapidly due to heavy fishing pressure, natural calamity, current for fishing, human disturbances, dam construction, etc. Along with this the food like algae, aquatic plants and other macroinvertebrates has been declining which has led to the low number of these species. In addition to this, the dynamics of river and stream has changed.

1.3 Objectives

1.3.1 General objective: To study the length-weight relationship, condition factor, gastro-somatic index and stomach contents analysis of *Schizothorax richardsonii* (Gray,1832) in Setikhola, Parbat, Nepal.

1.3.2 Special objectives:

- ✓ To measure the length-weight relationship of *S. richardsonii*
- ✓ To know the condition factor of *S. richardsonii*
- ✓ To analyze the prey base of *S. richardsonii* through gut content analysis

1.3.3 Research questions

- ✓ How is the length-weight relationship of *S. richardsonii* from Setikhola?
- ✓ What is the condition factor of *S. richardsonii* in autumn and winter from Setikhola?
- ✓ What are the stomach contents of *S. richardsonii*?

1.4 Significance of study

The goal of the morphological investigations, development patterns, and feeding habits of *Schizothorax richardsonii* in the field of fisheries research is to offer important insights into the biology and ecology of this species. Knowing the length-weight connection is useful for evaluating the growth patterns and general health of the fish population, and the condition factor is a good way to gauge the health of the fish and the quality of their environment. Furthermore, the examination of the stomach contents provides insight into the food choices and trophic relationships of *S. richardsonii*, which aids in the characterization of its ecological niche and may have consequences for management and conservation tactics. Thus, by carrying out this research, we were able to know the length-weight relationship, feeding habits and overall health condition of *Schizothorax richardsonii.*

2. Literature review

2.1 Length- weight relationship

The length-weight relationship gives critical insights into fish populations' general body condition and growth patterns, making it an important tool for fisheries management and conservation measures. Simultaneously, the condition component, which represents the relative health and well-being of each fish, provides important information about habitat quality, food availability, and ecosystem health. Fish length-weight relationships, or LWRs, are important in fisheries and fish biology because they provide a mathematical link that allows us to determine the average weight of fish within a specific length group. (Beyer, 1991). Similar to other morphometric characteristics, the Length-Weight Relationship (LWR) can serve as a distinguishing feature for taxonomic units, with the relationship undergoing changes during various developmental stages in life, including metamorphosis, growth, and onset of maturity, as highlighted by Thomas et al. (2003). The LWR factors (a and b) are important in fish biology for estimating individual fish weight based on length, calculating condition indicators, and comparing population morphology across areas (Petrakis & Stergiou, 1995) and to research allometric ontogenetic modification (Teixeira De Mello et al., 2006). slim (Riedel et al., 2007). Empirical relationships between fish length and weight help understand the natural history of economically significant fish species, enabling conservation efforts.

Previous research has shown that *S. curvifron's* LWR and condition factor vary throughout the year. The value of b deviated from cube law throughout the year, with the exception of March, July, and October, when b was found to be equal to 3 and fish growth was isometric. The rest of the months showed (da Silva et al., 2014) negative allometric growth of less than 3. The growth coefficient was lowest in February (b = 2.29), and highest in March and July (b = 3.0) (Mir et al., 2012). In the study of LWR of *S. richardsonii*, the length-weight connection of *S. richardsonii* (Snow trout) was examined. The hypothetical value (3) represents the exponential value for snow trout, where the correlation coefficient was (>0.9) and the b value was "2.68." Snow trout's length-weight relation reveals that weight increases in length. Thus it was clear that fishes maintains its shape throughout its life (Goel et al., n.d.). Another study on *S. richardsonii* illustrates that according to Goel et al., another study on *S. richardsonii* reveals a deviation from the cube law in the value of 'b'. In this investigation, estimates of parameter 'b' ranged from 2.40 to 3.08. The coefficient of determination (R^2) reflects the fitness of the regression model. Linear regressions were statistically significant for all species ($p<0.05$), with R^2 values ranging from 0.75 to 0.93. Higher R^2 values indicate a well-fitted relationship (Lohani & Ram, 2018). The investigation into the length-weight relationship and condition factor of *Clarias gariepinus* and *Oreochromis niloticus* in Wudil River, Kano, Nigeria revealed that the growth coefficients ('b') was found to be 0.14 to 0.8 for *Oreochromis niloticus* and 0.11 to 0.54 for *Clarias gariepinus.* These 'b' values significantly differed ($p < 0.05$) from 3, indicating negative allometric growth across all fish species. Additionally, the length-weight relationship parameters were calculated for three carp species, showing significant correlations with correlation coefficients ('r') of 0.91, 0.97, and 0.97 for catla, rohu, and mrigal, respectively, in pooled data. However, within different length groups, 'r' values ranged from 0.66 to 0.90 for catla*,* 0.74 to 0.88 for rohu, and 0.81 to 0.96 for mrigal. The exponent ('b') values in the length-weight relationship equation (W=aL^b) were observed to be 3.27 for Catla*,* 3.37 for Rohu, and 3.36 for Mrigal in pooled data, while ranging from 3.160 to 3.805 for Catla, 3.11 to 4.57 for Rohu, and 2.49 to 3.37 for Mrigal within different length groups, as reported by Ujjania et al. (2012).

2.2 Condition factor

Fulton's condition factor (K) is extensively employed in fisheries and fish biology research. It is derived from the correlation between a fish's weight and length, aiming to characterize the overall "condition" of the individual fish, as elucidated by Froese (2006). The condition factor (K) in fish serves as an indicator of their physiological status and overall wellbeing, offering insights into their environmental adaptability, as highlighted by Lizama & Ambrosio (2002). Widely applied in fisheries and biology studies, the condition factor is influenced by various ecological and biological factors, such as gonadal development, age, food availability, and stress. environmental appropriateness (Moutopoulos & Stergiou, 2002) (Elsayed et al., 2003).

A higher condition factor suggests better health for both species and ecosystems. The calculated condition factor for *Schizothorax niger* was 0.79469 ± 0.014, whereas for *Schizothorax richardsonii*, it was 0.76740 ± 0.024. Additionally, the "b" value for *Schizothorax niger* was 2.572044, while for *S. richardsonii* it was 3.027319. These findings suggest a better physiological condition for *S. richardsonii* and potential physiological stress for *Schizothorax niger* in their natural habitat. (Rani et al., 2018). The *S. curvifrons* condition factor was determined on a monthly basis and varied between 1.0 and 1.95. K peaked in April and fell in December, with further highs and lows occurring in March, May, June, February, and August, July, September, October, November, and January (Mir et al., 2012). Average value of Fulton's K for this species in selected rivers ranged from 0.60 to 1.27. The fish in Sewa Stream had the lowest condition factor value, indicating that their nutrition was inadequate. This might be attributed to inadequate food supply and unfavorable environmental conditions. The K values of *S. richardsonii* varied significantly ($P<0.001$) between the rivers. The Teesta and Indus rivers have higher K values than other rivers, indicating that the fish in these rivers had superior nutritional circumstances (Tyagi et al., 2014).

2.3 Food and feeding habit

In Ichthyology, fish ecology, and fisheries resource management, information on nutrition and dietary habits plays a role in the decision-making process regarding natural resources (Kido, 1996). The diet of fish is an amalgam of several significant ecological elements, such as behavior, health, habitat usage, energy intake, and interactions between and within species, among others and also the foundation for comprehending trophic interactions in aquatic food webs is also provided by a reliable description of fish diets and feeding patterns (V Sagar et al., 2019). Food study may disclose insights about ecological connections between organisms. Fish conditions, growth rates, and population levels are all controlled by their food sources. The majority of fish in the wild are thought to feed on bacteria, desmids, diatoms and other minute plant and animal planktons (Khabade, 2015). An understanding of the fish species true diet and feeding habits may be gained from the gut content study (Madusoodana Kurup, 2004). Fish need on food to fuel their physiological processes which includes growth, reproduction, repair, and other functions, as a result they have highly developed eating habits that make extensive use of readily use of accessible food components (Mishra, 2020). Many writers researched these methods, compared them, picked the best one for use in various settings and to emphasize different elements of feeding ecology (Cortés, 1997). (Hynes, 1950) investigated the food items of fish using various approaches, including the point technique, occurrence method, number method, dominance method, weight and volume method, as well as the fullness of stomach method. According to (Mihindukulasooriya & Amarasinghe, 2015), the frequency of occurrence approach was used to estimate the food composition of *Ehirava fluviatilis*, which revealed that it is omnivorous in nature.

The minimum and maximum (GSI) was (2.29) in summer and (3.70) in spring was reported by (Rana, 2021) in freshwater carb (*Barytelphusa lugubris*) from Kathmandu, Nepal.

3. Materials and Methods

3.1 Study area

The present study was confined along stretch of Setikhola, an important tributary of Kali Gandaki River that lies between Parbat and Syngja district of western part of Nepal. Four sampling zones have been selected. The study was conducted from Setibeni to Pakhapani of the Parbat district where the stream separates the Parbat and Syngja districts. Four sampling stations, Site I Setibeni (28°00′43.38″N longitude and 83°36′25.03″E latitude to 28°00′43.38″N longitude and 83°36′19.62″E lattitude) Site II Triveni (28°01′50.37″N longitude and 83°37′45.01″ E latitude to 28°01′54.57″N longitude and 83°38′25.78″E lattitude) and Site III Huwas (28°04′28.12″N longitude and 83°06′34.94″E latitude) and Site IV Pakhapani(Bhorle) (28°04′20.54″N longitude and 83°41′23.85″E lattitude to 28°04′11.11″N longitude and 83°41′10.27″E lattitude) will be selected to carry out research on the basis human settlement area, upstream and downstream sites of Setikhola hydropower dam and agricultural land.

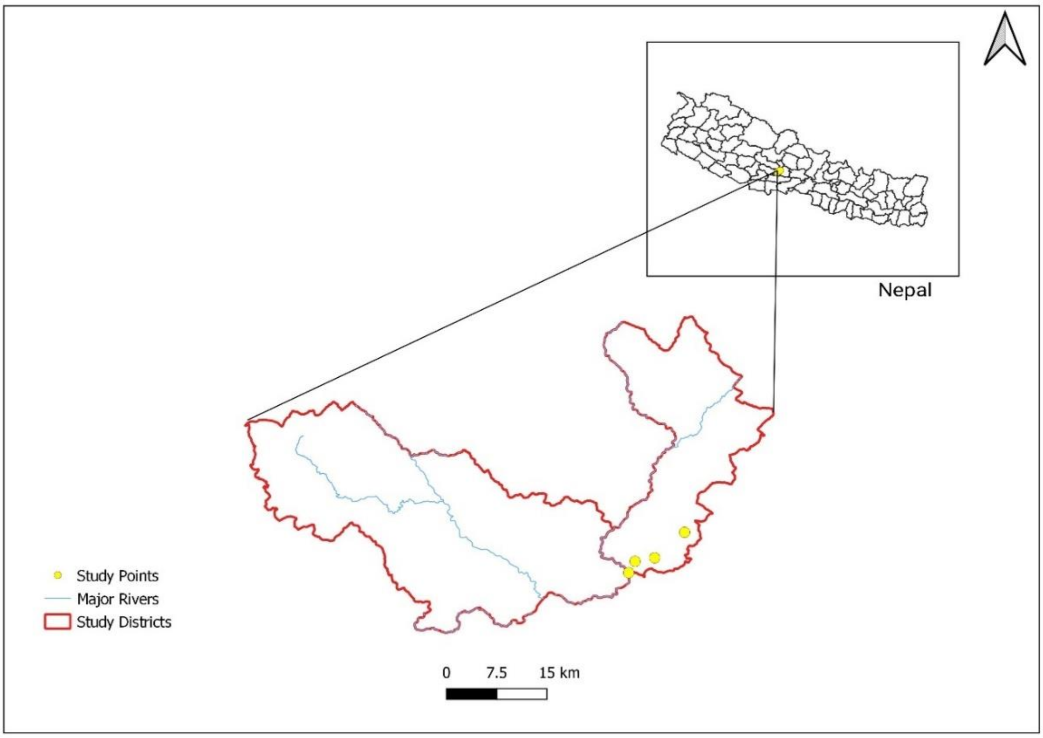

Figure 1: Map of study area

3.2 Materials:

- Cash net (10mm)
- Sample bottles
- Dissecting equipment
- Dissecting pan
- Stereo microscope
- Camera
- Formalin
- Absolute alcohol

3.3 Methods

3.3.1 Sampling

S. richardsonii were collected from the four sampling sites of study area (Setikhola) using cast net of 10mm mesh size. The local fishermen were hired for fish sampling. Standardized fish sampling techniques were applied for fish collection where 200m length of river were separated in each station for fish collection and 20-25 times cast net was thrown from downward to upward with the help of fisherman during morning, daytime and evening.

3.3.2 Preservation and Identification of the specimens:

The collected fishes were first counted, then length and weight of each individual were recorded near sampling sites using stainless scale, board and weighing machine. The fishes were preserved in 10% formaldehyde and transported to the Central Department of Zoology, TU for further study and lab work. The fishes were identified followed by Talwar and Jhingran (1991), Shrestha (1981,1994) and Jayaram (2013) as *Schizothorax richardsonii*. The length and weight of each specimen were recorded using scale and weighing machine. Photographs were taken on site and the gut content of collected sample were taken out and preserved in 10% formalin and brought to the Central Department of Zoology, TU for further study and lab work.

3.3.3 Length and weight measurement

The total length (TL) in centimeters and standard length (SL) in centimeters of collected fishes were measured using a steel ruler nearest to 0.1 cm. The total length of fishes was measured from the tip of the snout to the tip of the longer lobe of the caudal fin, while the standard length was measured from the tip of the snout to the base of the caudal fin.

Additionally, the total weight of the fishes was measured nearest to 0.1 gram using a digital weighing balance.

3.3.4 Dissection of fish

The fishes that were identified as *Schizothorax richardsonii* was later dissected using surgical scissors and other dissecting equipment, and their stomachs were carefully removed, weighed and preserved in 10% formalin for further the examination and analysis of gut contents.

3.3.5 Data analysis

3.3.5.1 Length weight relationship

To understand the length weight relationship, the total length (TL) and total weight (W) were recorded to know the variation from the expected weight of an individual fish with respect to the total length of that particular in order to find out the growth patterns and overall health status or wellbeing of fish. The data of length weight relationship were analyzed by following the (Le cren, 1951) method.

The relationship between total weight (W) and total length (TL) of the fish is described by the equation $W = a\ (TL)^b$. Taking the logarithm of both sides yields $\text{Log } W = \log a + b * \log TL$. Here, W represents the total weight of the fish, TL denotes the total length of the fish, a represents the coefficient related to body form, and b indicates the exponent indicating the growth pattern. A value of $b = 3$ signifies isometric growth, while $b < 3$ or $b > 3$ indicates allometric growth. The degree of association between the variables TL and W is assessed by the coefficient of determination (R square).

3.3.5.2 Condition factor (K)

The condition factor was determined using the formula (Pauly, 1983):

$$\text{Condition Factor (K)} = \frac{1000W}{L^3}$$

Where, W represents the weight in grams (g) and L denotes the total length in centimeters (cm).

3.3.5.3 Gastro-Somatic Index (GSI)

The Gastro-somatic index (GSI) is determined by dividing the weight of the gut by the total weight of the fish and then multiplying by 100, as expressed by formula (Cortés, 1997).

$$\text{Gastro-somatic index (GSI)} = \frac{\text{Weight of gut}}{\text{Total weight of fish}} \times 100$$

3.3.5.4 Stomach content analysis:

The weight of each sample's stomach was recorded using a digital weighing balance to determine the gastro-somatic index. Subsequently, the stomach was dissected vertically, and their contents were extracted into petri dishes for measurement and identification purposes through microscopic examination. Identification of macroinvertebrates was done followed by Deep & Bioassessment, 2021 identification cards. Volumetric and frequency occurrence methods (Hynes, 1950) were utilized to analyze stomach contents, facilitating the determination of diet composition.

Gut content analysis methods are primarily categorized into two types: qualitative and quantitative. Qualitative methods focus on accurately identifying organisms present in the stomach contents, while quantitative methods include numerical, gravimetric, and volumetric approaches. Both qualitative and quantitative methods are widely employed by scientists to analyze the food and feeding habits of various fish species. The analysis was conducted using frequency of occurrence and numerical approaches, as outlined by (Córdova et al., 2009).

3.3.5.4.1 Frequency of occurrence method

Following collection, fishes were dissected, and their stomach contents were carefully removed and placed on a petri dish. Each food organism was sorted and identified individually. The occurrence of each item in the stomachs was recorded, expressed as a percentage of the total number of stomachs examined, as described by Hynes (1950).

Frequency of occurrence (Oi) = (Ni / N) x 100,

Where Ni represents the number of fish containing prey, and N is the total number of fish with food in their stomachs.

3.3.5

.5 Index of fullness

Stomach fullness is classified as empty, moderate full, half- full, or full used by (Shalloof & Khalifa, 2009). The stomach is opened and contents are placed in a petri dish and the relative proportion of each food item present is estimated visually.

4. Results

4.1 Length - weight relationship and Condition factor of fish

One hundred one *Schizothorax richardsonii* samples were collected from August 2023 to January 2024 in two seasons autumn and winter. In the autumn, 57 individuals of *S. richardsonii* were collected, ranging from 10.9 to 19.6 cm TL (mean 14.51) and 10.3 to 67.51g of body weight (mean 26.56). During the winter season, 44 samples of this species were collected starting from 10.3 to 19.6cm in total length and TL (mean 14.53cm) and 11.08-75.79g of body weight (mean 36.21gm) were analyzed (Table1).

Table 1: Length, weight and condition factor of fish in autumn and winter seasons

	Autumn season	Winter season
No. of fish examined	57	44
Total length (cm) range	10.9-19.6	10.3-19.6
Weight (g) (range)	10.3-67.51	11.08-75.79
Total length (Mean)	14.51	14.53
Weight (Mean)	26.56	36.21
ln (TL) (range)	1.03-1.29	1.01-1.29
ln(W) (range)	1.01-1.82	1.04-1.87
Condition factor (K) (range)	0.84-1.28	0.81-1.36
Condition factor (Mean)	1.01	1.004

The mean total length, total weight and condition factor during the autumn seasons was 14.51, 26.56 and 1.01 while that of winter seasons was recorded 14.53, 36.21 and 1.004 respectively which indicates that fish shows great growth pattern, and fish was extremely in good health condition.

4.2 Length- weight relationship

Investigation was conducted on a total of 101 individuals of *Schizothorax richardsonii*, ranging from 10.3 to 19.6 in length (cm) and 10.3 to 75.39 in weight (gm). The length-weight relationships of *S. richardsonii* can be expressed by the equations.: $W = 0.005 \times TL^{3.117}$ ($R^2 = 0.91$) for autumn and $W = 0.024 \times TL^{2.70}$ ($R^2 = 0.92$) for winter.

The R square value is 0.92, indicating that the length measures can account for 92.7% of the variation in weight. The p value for the regression is less than 0.05, this implies that there is a linear relationship between length and weight measurements. Furthermore, the linear regression model is significant. The fitted regression model is: -predicted y value (weight)=6.79*X(length)-62.55(intercept). The coefficients' p-values are significantly less than 0.05, indicating that the intercept or slope is not equal to zero. This suggests that length is a major variable influencing weight (Table 2). In case of autumn, the regression's p value is less than 0.05, indicating a linear relationship between the weight and length measurements. With a R square value of 0.91, the weight change over the autumn, can be explained by 91.5 percent of the length measures. The projected y value (weight) of the fitted regression model is 5.62*X(length)-55.14(intercept). It is possible to conclude that the intercept or slope is not equal to zero and that length is a significant variable that affects weight by looking at the p values of the coefficients, which are significantly less than 0.05 level of significance (Table 3).

Table 2: Linear regression statistical analysis of length-weight relationship of *Schizothorax richardsonii* in autumn season

Regression Statistics	
Multiple R	0.95
R Square	0.91
Adjusted R Square	0.91
Standard Error	3.27
Observations	57

	df	SS	MS	F	Significance F
Regression	1	6428.40	6428.40	598.61	3.06E-31
Residual	55	590.63	10.73		
Total	56	7019.04			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-51.39	3.36	-16.37	8.34E-23	-61.88	-48.39
Length	5.62	0.22	24.46	3.06E-31	5.16	6.08

Table 3: Linear regression statistical analysis of length-weight relationship of *Schizothorax richardsonii* of winter season

Regression Statistics	
Multiple R	0.96
R Square	0.92
Adjusted R Square	0.92
Standard Error	4.60
Observations	44

	df	SS	MS	F	Significance F
Regression	1	11411.32	11411.32	538.77	1.4E-25
Residual	42	889.56	21.18		
Total	43	12300.89			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-62.55	4.311	-14.5	5.83E-18	-71.25	-53.85
Length	6.79	0.29	23.21	1.4E-25	6.2	7.38

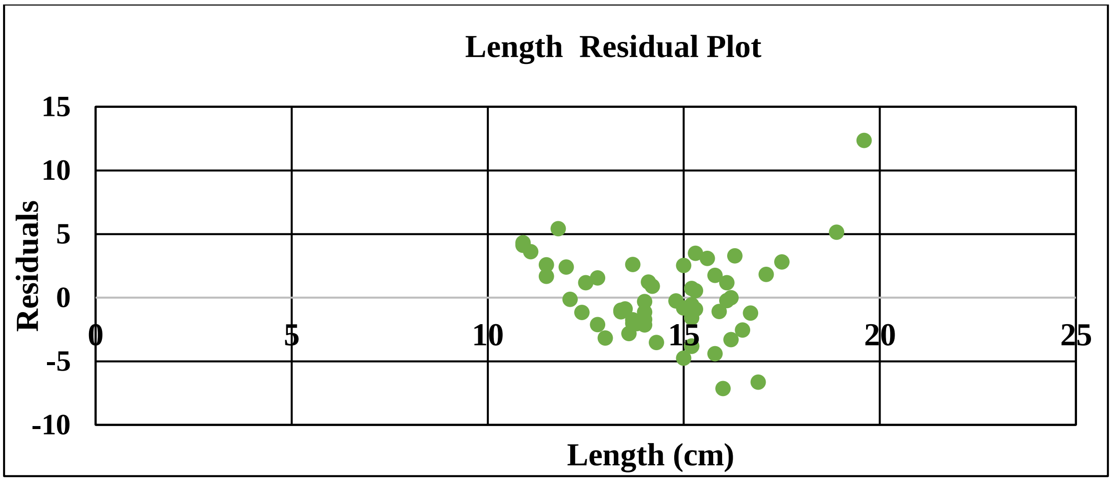

Figure 2: Residuals plot of the length of *Schizothorax richardsonii* to test goodness of fit of regression model of autumn

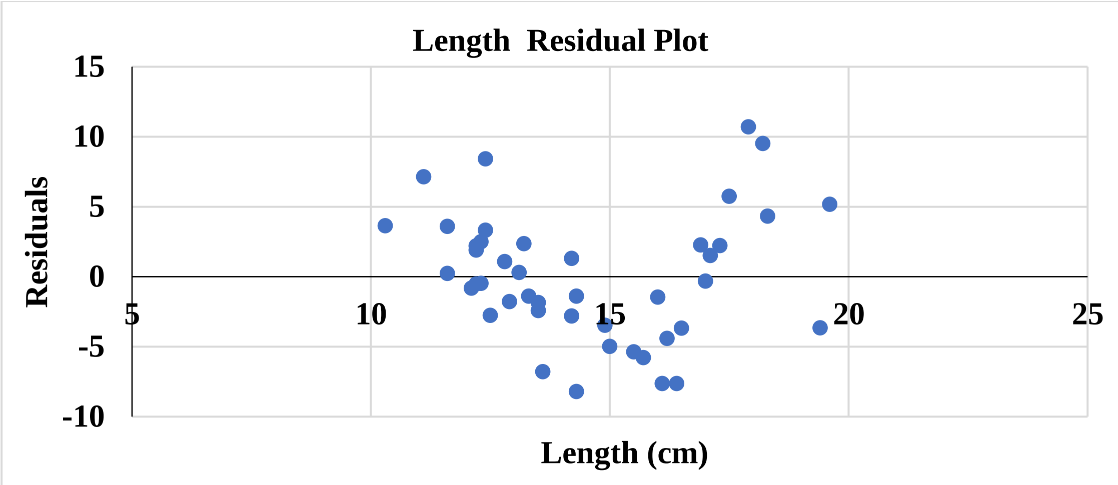

Figure 3: Residuals plot of the length *of Schizothorax richardsonii* to test goodness of fit of regression model of winter

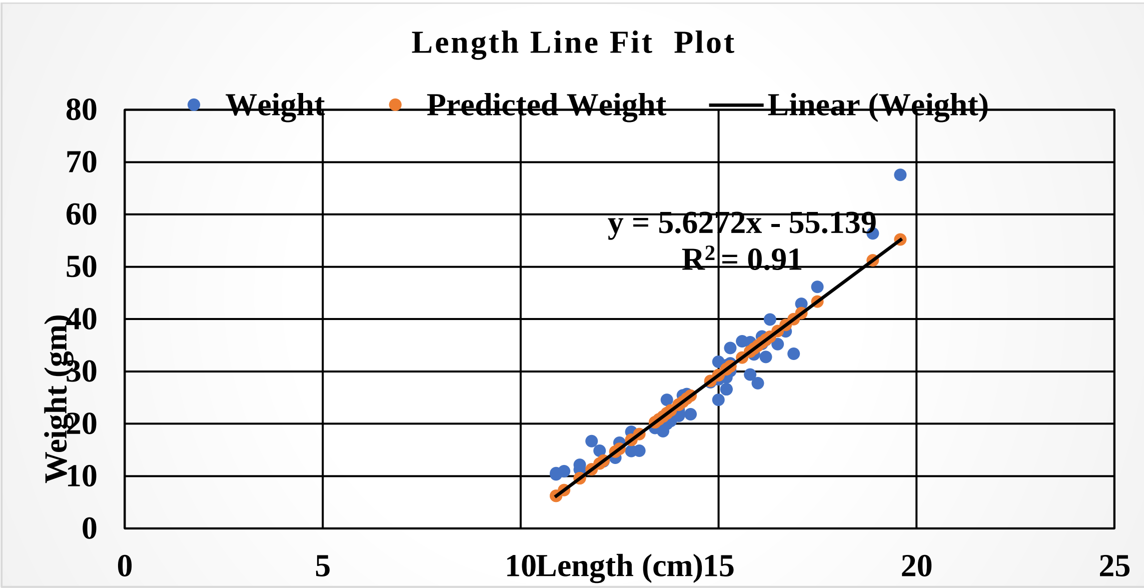

Figure 4: Fitted Linearized length-weight model of snow trout (*S. richardsonii*) of autumn

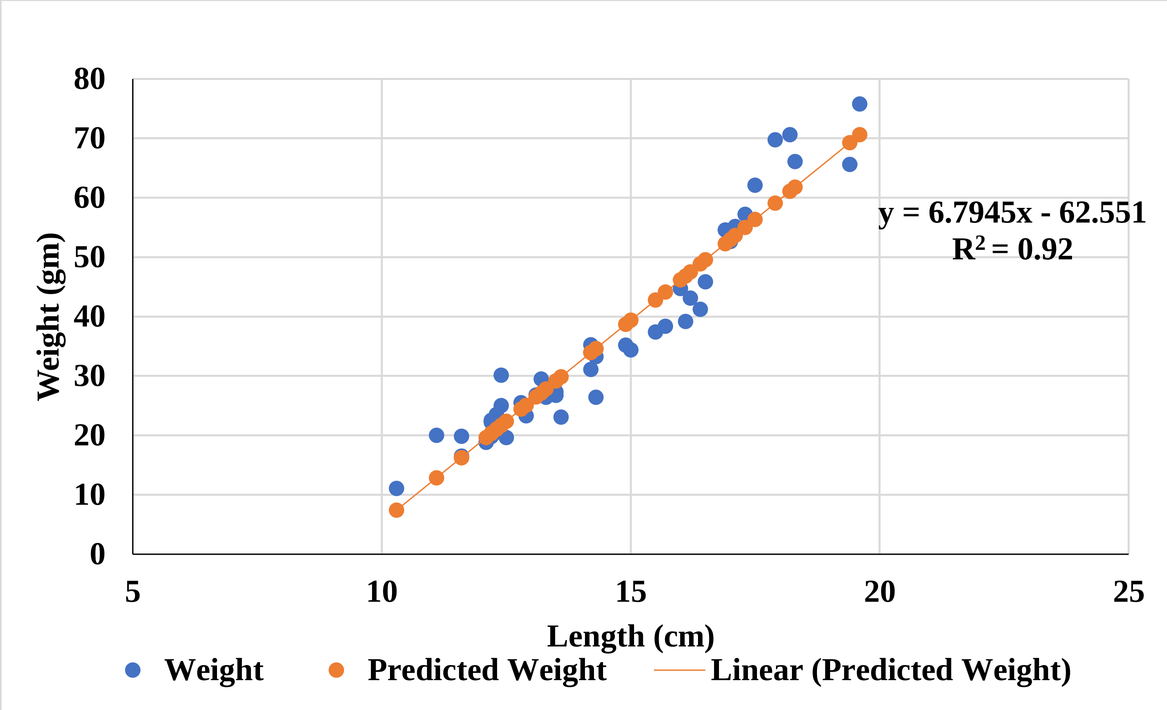

Figure 5: Fitted Linearized length-weight model of snow trout (*S. richardsonii*) of winter

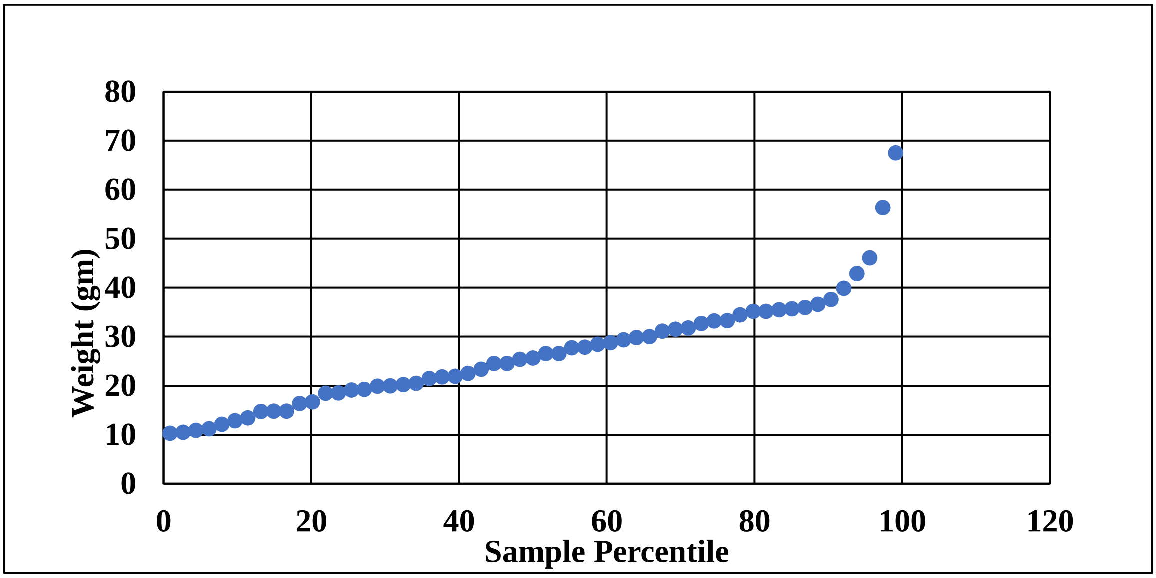

Figure 6: Normal probability plot for the weight of (*S. richardsonii*) of autumn

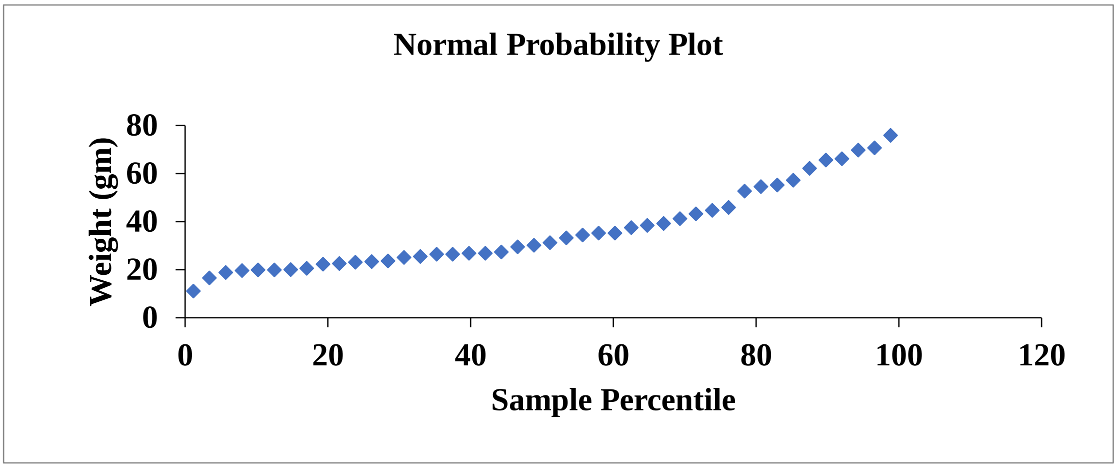

Figure 7: Normal probability plot for the weight of (*S. richardsonii*) of winter

The values of b were found 3.11 and 2.70 in autumn and winter season revealed that the fish had different growth pattern i.e. positive allometric growth pattern and negative allometry in autumn and winter respectively. Apart from this, the value of correlation coefficient (R^2) is close to 1, indicating a positive correlation between length and weight. (Table 4).

Table 4: The length-weight relationship of *S. richardsonii* for two seasons

Season	a	b	R^2	$W= aTL^b$	Growth pattern
Autumn	0.0059	3.11	0.91	$W= 0.0059 \times TL^{3.11}$	Positive allometric
Winter	0.024	2.70	0.92	$W= 0.024 \times TL^{2.70}$	Negative allometric

4.3 Gastro-Somatic Index (GSI)

One hundred and one stomach samples were dissected to determine the gastro-somatic index (GSI) of *S. richardsonii* individually. The mean GSI was 11.29 in the autumn and 10.21 in the winter. The acquired samples had varied GSI values, indicating that fish feed on diverse category of food items at different rates. The average GSI value was determined (Table 5).

Table 5: GSI of *Schizothorax richardsonii* in autumn and winter

Season	No. of fished examined	Mean Total length	GSI (range)	Mean (GSI)
Autumn	57	14.51	5.72-20.03	11.29
Winter	44	14.53	4.28-15.61	10.21

4.4 Index of fullness

Out of 101 samples examined, food was discovered in 94 guts, where 38.59% (Autumn) and 38.69% (Winter) of full stomach were found Similarly, 35.05% and 20.05% of moderate stomach were found in autumn and winter respectively whereas 7 guts were reported to be empty.

Table 6: Percentage of stomach fullness

season	% of full stomach	% of moderate stomach	% of half stomach	% of 25% stomach	% of empty stomach
Autumn	38.59	35.05	17.54	7.07	-
Winter	38.63	20.45	20.45	4.54	15.9

In Autumn season, the highest percentage (38.59%) of full stomach and lowest percentage (7.07%) of 25% full stomach were recorded in contrast to 38.63% of full stomach and 4.54% of 25% full stomach in the winter season. In winter season, 15.9% of stomach were found to be empty while none of the stomach were empty during the autumn season.

4.5 Qualitative and quantitative analysis of stomach contents

The majority of food items comprised of green algae along with aquatic insects, where green algae was the most abundant food item in the stomach of fish. Insects (Trichoptera and Diptera) form the second major component in the stomachs of this species. Apart from this, insect parts, sand and detritus, leaf of dead plants and undigested animal matter were also recorded in the gut of collected samples.

Table 7: Food contents in the gut of *S. richardsonii*

	Food groups	Food items
Animal matter	Insects	Trichoptera, Diptera, Ants, Insect parts (legs, wings, head, body), Plecoptera
Plant matter		Plant leaves, spirogyra, filamentous green algae
Miscellaneous		Sand, mud, detritus and plastic, undigested animal matter, unidentified matter

5. Discussion

5.1 Length-weight relationship

A total of 101 individuals of *S. richardsonii,* ranging between 10.9 and 19.6 cm in length and 10.3g to 67.51g in weight were investigated from Setikhola. Upon analyzing the growth in relation to its length, it was observed that the growth of *Schizothorax richardsonii* in this research exhibited both positive allometric and negative allometric patterns, with the mean value. of 'b' was 2.90 (b = 3.11 and b =2.70, for autumn and winter respectively). During the autumn season, the value of b is greater than 3 indicating that fish are said to be positively allometric. The regression coefficient 'b' was not equal to 3 suggesting the deviation from the cube law and fish didn't follow the cube law. The regression coefficients larger or less than 3 denote allometric growth while equal to 3 indicates isometric growth according to (F.C. Gayanilo et al., 2005). Likewise, the values of regression coefficient in river shaoo (b= 3.11) in the study of *S. richardsonii'*s LWR by Tyagi et al., 2014 exactly matches with the value of 'b' of autumn season of same species of our study. The study in the Alaknanda River exhibiting an isometric growth pattern with a growth coefficient of 3.08, while others displayed negative allometric growth patterns, with growth coefficient (b) values ranging between 2.40 and 3.08 of same species (Lohani & Ram, 2018), closely resembling our findings. When the exponent (b) equals 3 fish are said to have isometric growth. Allometric growth occurs when the 'b' value is not equal to 3. Fishes grow due to changes in form, therefore the 'b' number 3 does not apply to all of them (Abujam, 2015). According to Gonçalves et al. (1997) and Özaydin & Taskavak (2006), the parameter 'b' suggests that unusual variations may occur seasonally, daily, or across ecosystems. Our finding matches to the b values ranged from 1.94 to 3.36 reported by (Thomas et al., 2003) while studying on the length weight relationship of deep sea fish inhabiting along the West Coast of India. The value of 'b' ranged from 2.82 to 3.57 in different seasons for *Macrognathus pancalus* shows both allometric growth pattern (Abujam, 2015) which are comparable to our results. The allometric coefficients 'b' for *Schizopyge curvifrons* (Mir et al., 2012) was found to be negatively allometric($b<3$) for most of the year and while growth was isometric during March, July and October which are comparable to our results.

In present study the value of R^2 for the autumn and winter seasons were 0.91 and 0.92 respectively with mean value of 0.92 revealed that the both seasons had strong almost similar correlation between the length and weight. Similar correlations (R^2 > 0.9) were reported by Goel et al. (n.d.) for the same species from Hill Streams of Uttarakhand India.

(Sarkar et al., 2013) who discovered that LWRs of freshwater fishes of river Ganga, Gomti and Rapti, India was strongly associated with $R^2 > 0.91$ value which are consistent with our results.

5.2 Condition factor

The 'coefficient of condition' also known as condition factor measures the fish's relative resilience and wellness (Lohani & Ram, 2018). Variations in the length-weight relationship are a sign of the general state and are often examined using condition factor. Fish condition, fatness, and overall wellbeing are contrasted using the condition factor, which operates on the basis that larger fish of a given length are in healthier condition (Iqbal Mir et al., 2012). In our study, the values of K varied from 0.81 to 1.36 across the autumn and winter seasons with mean value of K almost similar in both seasons, for autumn season (K = 1.01) and winter season (K = 1.004). Diverse K values in fish represent the age and sex of certain species, the degree of food source availability, and the stage of sexual development (Anibeze, 2000). A K value of 0.5 or above indicates that the fish is healthy (Abdul et al., 2016). Higher K values may suggest more food supply and increased feeding activity during warm seasons with ideal temperatures. Additionally, it is well known that during spawning, fish often reduce their dietary activity and deplete their lipid stores, leading to a decline in condition of fish (Lizama & Ambrosio, 2002). Higher values (K>1) were recorded in *E. fimbriata* by (Abidemi-Iromini et al., 2023) in Coastal Water of Ondo State which is consistence with our results. A condition factor of K > 1 implies that the fish are in good physiological condition in their natural environment (Getso et al., 2018). (Sharma & Mehta, 2010) investigated the condition factor (K) which has values ranging from 0.87 to 1.10 of *S. richardsonii* from Indus River System, India is similar to our results of the present study. Seasonal variations in environmental circumstances may influence K values (Bowers, 1979).

5.3 Gastro-somatic Index

The values of the Gastro-somatic index ranged from 4.28 to 20.03 for the autumn and winter season respectively. The mean value of Gastro-somatic index of winter was slightly greater than that of the autumn. The GSI values varies due to change in the feeding rates in different seasons.

5.4 Qualitative and quantitative analysis of stomach content

The present study revealed that the feeding rate varied with the seasons. In the autumn and winter, in both, almost 38% stomachs were full with food items and 35.05% and 20.45% of stomachs were found moderately filled with food items during autumn and winter respectively while only 15.9% stomachs were empty in winter only. Hence, majority of the fishes had larger amount food contents in their stomach might be due to higher feeding rate. The feeding intensity was slightly high during autumn due to greater food availability and favorable water temperature and food item. The percentage of empty, moderate, half, and full stomachs revealed a seasonal variation in feeding intensity. The most likely cause of this is the insufficient quantity or lack of food items in the fish habitat. Green algae followed by insect's larvae (trichopteran, dipteran) were the major food items in the gut of *Schizothorax richardsonii* which somehow shows little similar type of results reported by (Yadav et al., 2014) who found diatoms, green and blue green algae and also benthic insects larvae like ephemeropterans, sand ,detritus, etc. According to (Malik et al., 2019), *S. richardsonii* mostly feed on food item of plant origin so this was considered as herbivore that matches with our findings which revealed that green algae were the abundant food item in the gut of the species. On the basis of qualitative analysis of gut contents, *Schizothorax richardsonii* acts as omnivore in feeding nature.

6. Conclusion and Recommendations

6.1 Conclusions

In summary, the results revealed that the length-weight relationship varied among the season. *S. richardsonii* from Setikhola showed allometric and isometric growth pattern were seen in autumn and winter. Additionally, for the autumn the value of k was 1.01 and 1.004 during the winter accordingly which revealed that the *S. richardsonii* of Setikhola was in better health condition in autumn in compare to winter due to availability of sufficient food. *Schizothorax richardsonii* of Setikhola mainly feeds on food of plant origin followed by animal matter so acts as omnivore.

6.2 Recommendations

Some of the suggestions and vital recommendations are listed below:

- Encourage local people to maintain existing fish populations in their optimum health condition.
- The ecology Setikhola should be maintained in future in order to conserve existing fish species like *Schizothorax richardsonii*.

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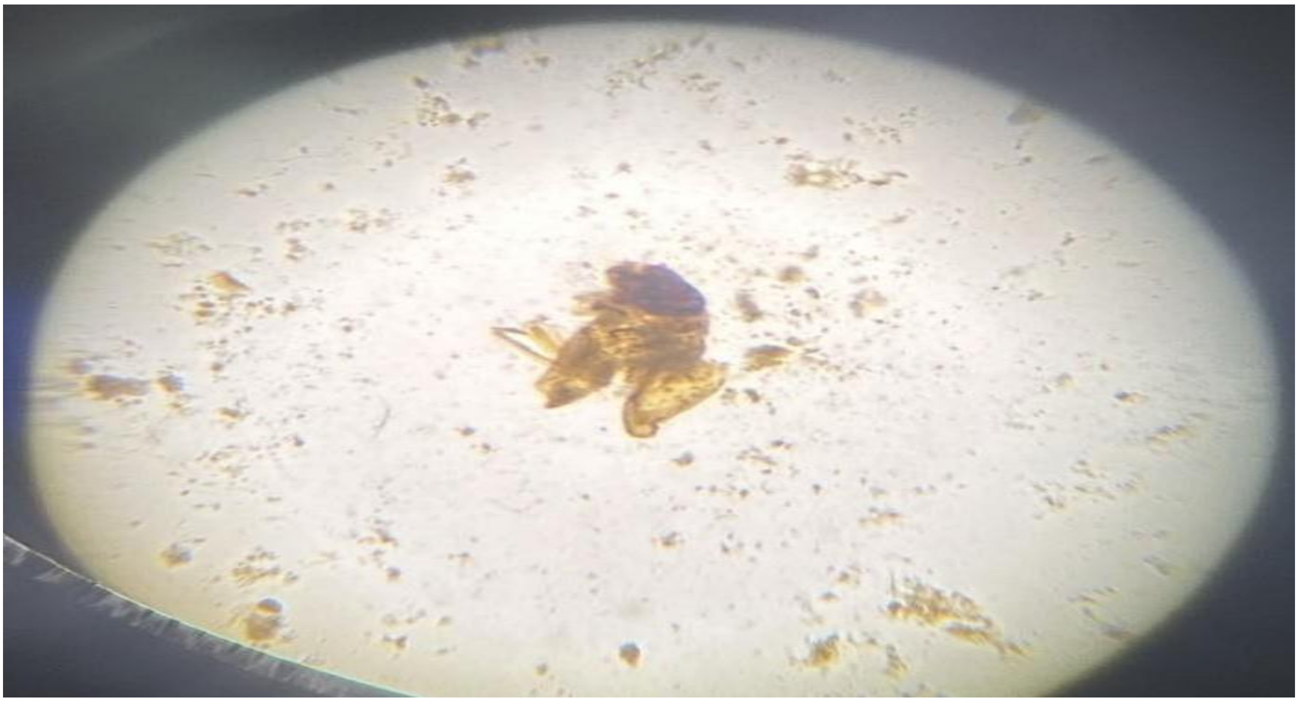
Appendices

Photograph 1: Taking length measurement of fish *S. richardsonii*

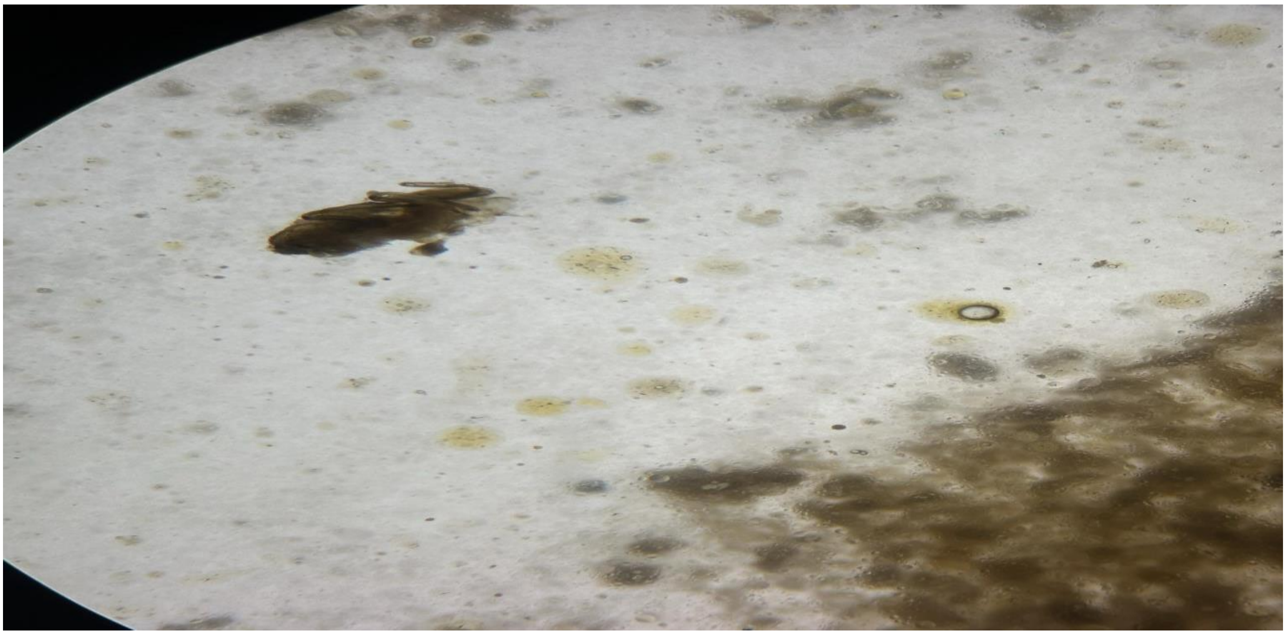
Photograph 2: Throwing cast net for fishing

Photograph 3: Microscopic examination of gut contents

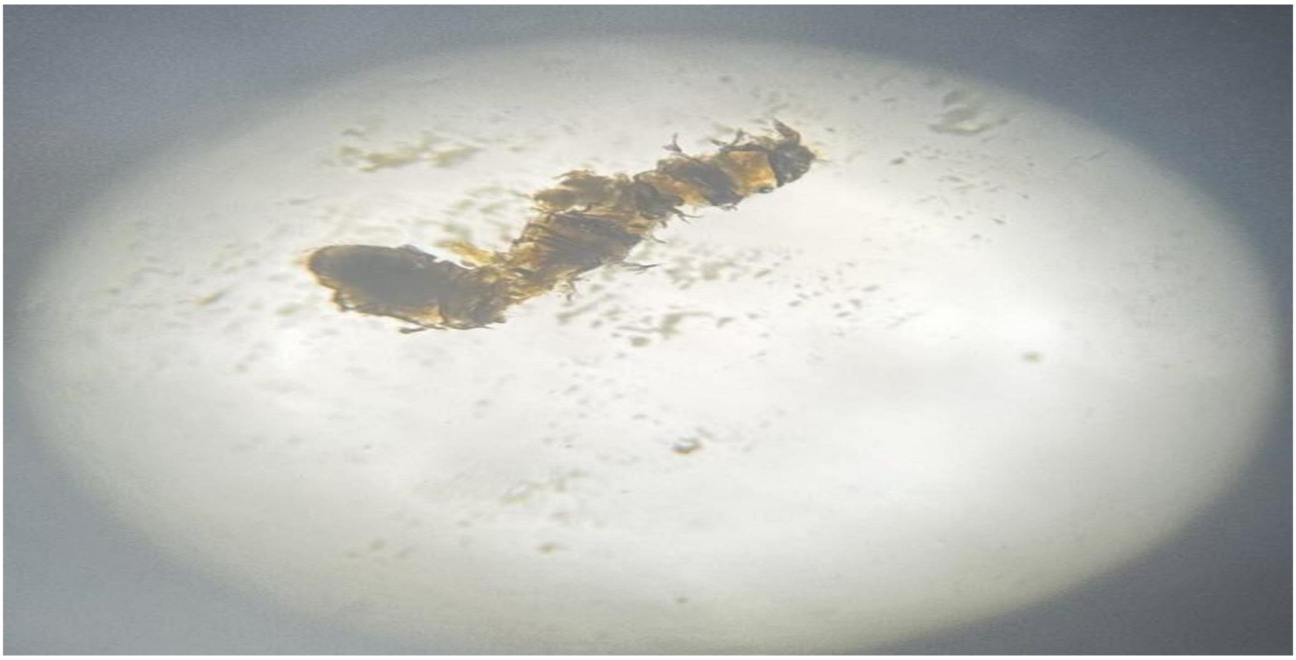
Photograph 4: Insects of Diptera order



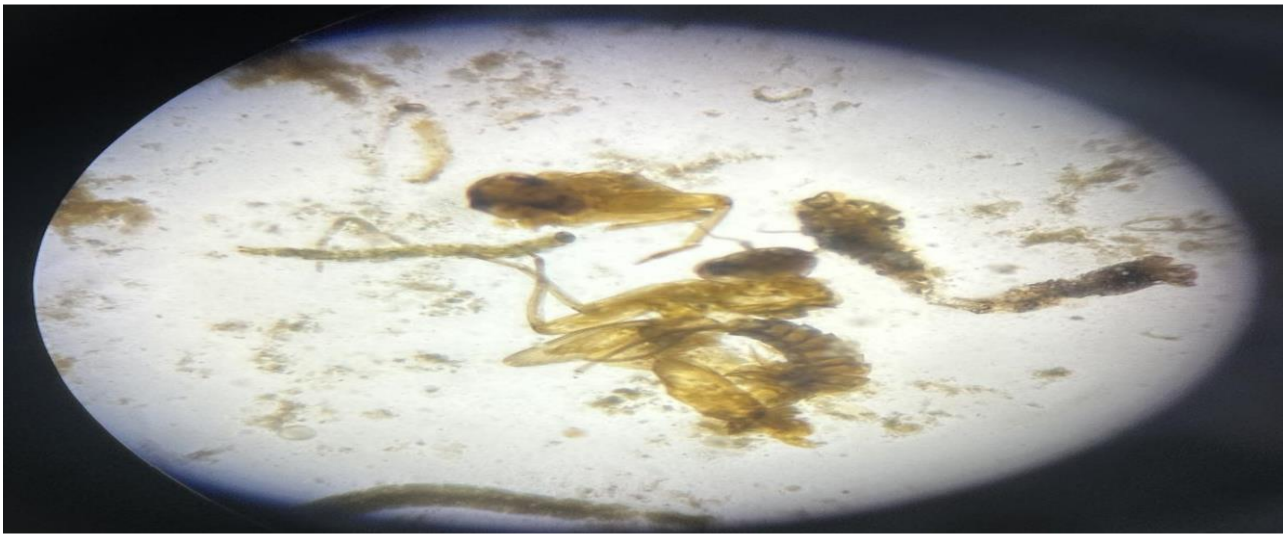
Photograph 5: Stonefly



Photograph 6: Unidentified aquatic insects



Photograph 7: Encased caddisfly



Photograph 8: Larvae and adult of Trichoptera order

Photograph 9: Larvae of Trichoptera order