



Biometric Insights and Growth Patterns of the Endangered Golden Mahseer (*Tor putitora*) Inhabiting the Gobind Sagar Reservoir

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Abstract: The aim of this study is to document the life history parameters of the endangered and widely distributed fish, *Tor putitora* (Golden Mahseer) in Gobind Sagar Reservoir, Himachal Pradesh toward effective conservation and management. Specimens were collected monthly at the two sites during 18 months (April 2023-September 2024). Biometric characteristics (morphometric and meristic parameters), length-weight relationship, length-length relationship, condition factor and truss networking analysis were evaluated. More than 70% of the species in the reservoir were planktivores, which clearly indicates that the plankton plays an important role for the successful management of the reservoir with Intra and Interspecies competition among other planktivore fish species and targeted fish species. Mahseer species were significantly declined in this reservoir and reported fish weight varied between 425g and 2710g and length between 31.9 cm and 63.1 cm (The calculated regression coefficient (b) were 3.162, indicating a positively allometric growth pattern-where body weight increases at a greater rate than length, resulting in a more robust body shape as the fish grows. The condition factor (K) and relative condition factor (K_n) reflected overall good health and growth performance. PCA of the truss network system showed that the first three components-PC1, PC2, and PC3-explained 78.38, 18.38, and 13.03% of the total variance, respectively. The information can provide an extensive knowledge of fish welfare, allowing for the development of a suitable and cost-effective plan to manage and conserve fish populations and biomass. The present findings would be of prime importance for conservation and management of *T. putitora* in the Himalayan aquatic ecosystems.

Keywords: *Tor putitora*, Gobind Sagar Reservoir, Truss networking analysis.

1. INTRODUCTION

Gobind Sagar Reservoir, a prominent aquatic ecosystem, supports a wide variety of fish, including 51 species native to the Sutlej River. This collection includes rare trout, snow trout, and numerous hill stream fish species (Bhatnagar, 1964). Among them, the golden mahseer, *Tor putitora*, stands out as a significant species in the region, often recognized as a prized game fish in India (Thomas, 1897). The landings in the Gobind Sagar reservoir are clearly declining due to intense competition from exotic carps (*Cyprinus carpio* and *Hypophthalmichthys molitrix*) (Johal et al., 2003). The majority of fish species found in the Himalayan region are small in size, and factors affecting their size, growth, and distribution includes water temperature, current velocity, type of substrate, food availability, and feeding patterns (Yousuf et al., 2003).

The mahseer belonging to the order cypriniforms, is native to this reservoir. The genus *Tor* contains a group of game/sport fish and is significant endemic to the Indian

subcontinent and economically exploited in their natural habitat. The fish called the golden mahseer, or *Tor putitora*, found in South and Southeast Asia, including Afghanistan, Pakistan, India, Bangladesh, Nepal, Bhutan, Myanmar, Sri Lanka, western Iran and Thailand. It is generally located between 8°N and 36°N and 70 to 1,891 meters altitude (Jha et al., 2018). Despite its significance, this fish species is facing a decline in its wild populations caused by the anthropogenic activities. The status of species was listed Endangered (EN) in International Union for Conservation of Nature (IUCN) Red List with the species facing high threat from over fishing, habitat loss, decline in habitat quality leading to loss of breeding grounds and environmental damages such as construction of dams which has disabled their migration and had adverse effects on breeding (Jha et al., 2018).

Biometric characteristics are one of the common and cheap methods which is used for identification of stock. Morphometric variation for phenotypic stock discrimination in fisheries biology has attracted the attention

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of ichthyologists (Miyan et al., 2016; Dwivedi, 2019). In response to the shortcomings of traditional morphometric analyses, image analysis methods have also been developed to supplement the development and heterogeneity of morphometric approaches, advancing the potential for stock identification (Reyes-Valdez et al., 2011). The “Truss Network System” based on precise measured coordinates of morphometric reference points or “landmarks”, is widely used for stock identification (Miyan et al., 2016). The truss network approach is a useful method to detect geographically diverging stocks. Isolation can generate morphological, meristic, and form differences among stocks of a species to the point of meeting criteria for recognition of populations of that species. The traits could have more importance for investigating short term computation off generated differences in the environment and the result may be useful for fish management (Cadrin, 2005). The current study conducted an effort to determine the *T. putitora* biometrics characteristics, length–weight relationship and truss networking analysis from the Gobind Sagar reservoir.

2. MATERIALS AND METHODS

2.1. Study Area and sampling

The present study was conducted in the Gobind Sagar Reservoir, and samples were collected from two sites. Site I was located at Bhakra Road, Bilaspur, Himachal Pradesh, at a latitude of 31°42'46"N and a longitude of 76°43'82"E. Site II was situated at Paroyan, Birhu Kalan, Una, Himachal Pradesh, at a latitude of 31°42'46"N and a longitude of 76°43'82"E. The present study was conducted for a period of 1.5 years from April 2023 to September 2024.

2.2. Collection of Fish Samples and Assessment of Biometric Data

The current investigation examined fish biodiversity and population structure in the Gobind Sagar Reservoir, highlighting the status of the native golden mahseer (*T. putitora*). In the present study, 50 fish specimens each of *T. putitora* were collected monthly from landing centers to cover the pre-spawning, spawning, and post-spawning phases. Length, weight and other biometric parameters have been estimated on the landing site using measuring board, Vernier calliper and weighing balance. Nineteen morphometric and 5 meristic characters were studied. Total length, standard length, head length, pre-orbital (snout length), eye diameter, and post-orbital length, pre-dorsal length, post-dorsal length, pre-pelvic length, pre-pectoral length, post-pelvic length, and pre-anal length were measured in the same manner, along the specimen left side.

Measurements of morphometric parameters were taken to the nearest 0.1 cm with the aid of a wooden measuring board and measuring scale. Weight (g) was measured on a digital balance (accuracy ±0.01 g).

2.3. Length-Weight and Length-length Relationship

Cubes equations were used to compute the relationship between length and weight Froese (2006).

$$W = aL^b$$

Where,

W = weight of the fish (g)

L = length of the fish (mm)

a = constant

b = exponential coefficient

A linear function was used to the data to estimate the morphometric relationship between these factors (Ricker, 1975) (Eq 1).

$$\text{Log } Y = \text{Log } a + b \text{ Log } X \dots\dots\dots(1)$$

The length-weight relationship parameters 'a' and 'b' were determined using linear regression analysis, and the coefficient of correlation (r) and determination coefficient (r²) were computed to determine the degree of link between two parameters.

Growth can be classified as positive allometric when b>3 and negative allometric when b<3 in length-weight relationships. The length-length relationships (LLRs) between Total length (TL) and Fork length (FL), Standard length (SL), Head length (HL) were calculated using linear regression analysis (FL). The equation 2 was used to express these length relationships.

$$Y = a + bX \dots\dots\dots(2)$$

Where,

Y = a dependent variable (various body lengths)

X = an independent variable (total length)

a = constant (intercept)

b = regression coefficient (slope)

2.4. Condition factor (K) and Relative Condition Factor (Kn)

Condition factor (K) was calculated using the formula (Eq 3) of Froese (2006)

$$K = W * 100 / L^3 \dots\dots\dots(3)$$

Where,

W = weight of the fish (g)

L = length of fish (cm)

The ratio between the actual weight (observed weight) and the calculated weight based on the length-weight equation 4 was defined as the relative condition factor (Kn) (Froese, 2006).

$$Kn = W/W^{\wedge}$$

Where,

W = Observed weight (g)

$$W^{\wedge} = \text{Calculated weight } (\log W * \log L / \log L^2) \dots \dots \dots (4)$$

2.5. Truss Network System

Fish specimens were routinely oriented on their right side on laminated graph paper with bodies and fins gently coaxed into a natural configuration. All samples were coded to protect their identity. The digital images were taken using an image acquisition system (Sony Cyber-shot DSC-W300 digital camera). After photographing, a sex was developed on each fish by external observation. TPSUTIL, version 1.52 (Rohlf, 2006; available at <https://bit.ly/3fjhyDA>) was used to convert JPEG images of photographed fish to TPS format. The program TPSDIG version 2.16 was applied to digitize 12 landmarks in the two-dimensional Cartesian coordinate format on each sample (Rohlf, 2006). Each specimen had its scale factor calculated using the set scale option for reference length.

The software Paleontological Statistics (PAST, v. 1.89) was utilized to produce truss-typed data by connecting each of the landmarks. Distances between landmarks generated 90 inter-landmark morphometric variables. Log transformation of the PAST data was used to maintain allometric relationships and similarity of variances (Hammer, 2001) and employed the following formula to account for size dependence (Eq5):

$$Madj = M(L_s/L_0)^b \dots \dots \dots (5)$$

Where, M was the original measure, L₀ was the fish's standard length, L_s was the average of standard length for all fish in each analysis, and b was calculated for each character from the data that was observed as the slope of the regression of log(M) on log(L₀) using all fish from each group. The final analysis excluded standard length (SL; character codes 1-6) as it was employed as a basis for transformation, providing 90 morphometric variables (Rohlf 2006).

Size-adjusted morphometric traits of *T. putitora* were compared with standard length to test significant differences, while sex was used as a class variable to assess male–female variation. Highly significant variables were subjected to principal component analysis (PCA) and discriminant function analysis (DFA) to examine morphometric variation. PCA reduced redundancy following Veasey et al. (2001) and Samaee et al. (2006), whereas LTD identified independent variables explaining inter-population differences. Principal components with eigenvalues >0.70 and factor loadings ≥0.30 were retained.

Wilks' λ tested group differences, revealing significant morphometric variation (P < 0.001) across populations. The data from Discriminant Function Analysis (DFA) were used to calculate the percentage of correctly categorized cases. To estimate the predicted error rates of classification functions, cross-validation was performed by calculating the proportion of correctly classified cases. Morphometric data were analyzed using SPSS version 16.0.

Two-dimensional X-Y coordinate data for 12 landmarks on all 50 specimens were obtained using ImageJ version 1.50i (<http://imagej.nih.gov/ij/>) and exported in TPS format. Procrustes superimposition was applied to translate landmarks into shape, standardizing each specimen based on centroid size, which serves as an estimate of the total body size coordinates (Rohlf and Slice, 1990). Partial Least Squares (PLS) analysis identified significant differences (P < 0.001) between shape and size, and shape and sex. Relative warp analysis (TPSRELW) with wireframe visualizations illustrated form variations linked to seasonal migration. Canonical Variate Analysis (CVA) and Principal Component Analysis (PCA) were applied to assess and classify shape differences across populations. CVA-derived Mahalanobis and Procrustes distances confirmed significant inter-population variation. All analyses, including visualization and statistical tests, were performed using MorphoJ version 1.06d, providing robust insights into morphological divergence and the main axes discriminating groups.

3. RESULTS AND DISCUSSION

3.1. Assessment of Historical Database stock of *T. putitora* in Gobind Sagar Reservoir

The fish biodiversity and stock structure of the Gobind Sagar Reservoir, focused on the status of the indigenous golden mahseer (*Tor putitora*). Eighteen commercially important species were identified based on abundance, economic value and market demand. Exotic species dominated the catch, with silver carp (*Hypophthalmichthys*



Figure 1. Locations of 12 landmarks used for shape analysis for *T. putitora*

molitrix) comprising 65.1%, common carp (*Cyprinus carpio*) 13.27% and bighead carp (*H. nobilis*) 6.58%. In sharp contrast, native species such as *T. putitora* constituted only 2.22% of the total fish population, while *Catla* and *Labeo rohita* made up 0.58 and 0.03%, respectively (Figure 2). This marked decline in *T. putitora* on the basis of number and weight of fish species which reflects habitat degradation, loss of spawning grounds, overfishing, and hydrological modifications restricting migration. Filter-feeding and benthic-foraging behaviors of exotic species have further altered nutrient balance, water clarity and native spawning habitats. Compared to historical records, the present findings indicate a serious ecological shift from native to exotic dominance (Strayer, 2009). These results highlight the urgent need for conservation, habitat restoration and management interventions to protect *T. putitora* and preserve indigenous fish biodiversity.

3.2. Biometric Characteristics

Fresh specimens exhibited distinctive greenish body coloration, transitioning to silvery along the flanks, with noticeable reddish-yellow or golden hues on the anal and pectoral fins. The species is characterized by a slightly prognathous upper jaw, with the lower jaw being marginally shorter. As per the meristic characters of fish studied, the dorsal fin ray of the specimens found to be 17; pectoral fin ray was 7-9, anal fin ray 8, pelvic fin ray count 10-11 while caudal fin ray count was 21-22. Based on this, the derived fin formula of *T. putitora* is D/17; P/7-9; V/10-11; C/22. All meristic characters observed in the present study were in the same ranges with few modifications (in no. of rays) as described by (Talwar and Jhingaran, 1991; Jayaram, 1999). In total, 19 morphometric and five meristic characters were documented for the selected species (Table 1). The total weight of fish ranged from 2710g (max) to 425g (min), while total length ranged from 31.9 cm (min) to 63.1 cm (max). Average standard length and fork length were 39.75 cm and 42.39 cm, respectively.

The biometric data of *T. putitora* indicates a healthy and balanced population structure. Juveniles (28% length, 34% weight) show strong growth and successful recruitment. Mature individuals make up the largest group (50% length, 44% weight), reflecting reproductive vitality, though slightly less developed in weight. Over-aged fish (22% for both length and weight) have reached a growth plateau, indicating natural aging with no excessive dominance, suggesting a well-distributed age composition (Table 2).

Studies suggest that mahseer attains sexual maturity at around 40-50 cm in length and 1-2 kg in weight, with larger

females contributing significantly to population recruitment (Nautiyal, 2014). The gonadosomatic index (GSI), a key reproductive metric, tends to peak during the pre-monsoon and monsoon seasons, aligning with optimal spawning conditions such as increased water flow and temperature stability (Sharma et al., 2021). The higher body weight and

Table 1. Morphometric and meristic characters of *T. putitora* during April, 2023 – September, 2024

Measurements	Max.	Min.	Mean ±S.E.
Morphometric characters			
Total weight (g)	2710	425	1054.84±90.92
Total length (TL) (cm)	83.1	31.9	45.76± 1.067
Standard length (SL)	55.8	28.6	39.75±0.978
Fork length (FL)	58.5	29.1	42.39±1.009
Eye diameter (ED)	1.2	0.3	0.856±0.071
Dorsal fin length (DFL)	8.2	4.2	6.352±0.435
Pelvic fin length (PeFL)	8.5	2	4.111±0.351
Pectoral fin length (PFL)	6.2	5.1	5.621±0.175
Pre- Dorsal fin length (PDFL)	26.1	20.1	19.348±0.388
Pre- Pelvic fin length (PPeFL)	14.6	8.5	10.141±0.23
Pre- Pectoral fin length (PPFL)	31.3	15.5	20.98±0.526
Pre-orbital length (POL)	4.7	3	3.652±0.108
Post- orbital length (PoOL)	7.7	4.5	6.19±0.222
Snout length (SL)	4	2.1	3.656±0.162
Head length (HL)	18.2	5.5	7.623±0.199
Head diameter (HD)	5.2	3.1	4.508±0.281
Body depth (BD)	10.3	4.7	9.471±0.587
Anal fin length (AFL)	7.3	5.5	6.539±0.218
Pre-anal fin length (PAL)	43.4	26.7	30.566±0.79
Meristic characteristics			
Dorsal fin rays (DFR)	17	8	16.137±0.314
Anal fin rays (AFR)	8	8	7.431±0.117
Pectoral fin rays (PFR)	9	7	8.762±0.147
Pelvic fin rays (Pe.FR)	11	10	11.058±0.161
Caudal fin rays (CFR)	22	21	20.117±0.255

All measurements of length were made in centimeters. Mean values ± Standard Error are used to express the results (n=50)

Table 2. Stock structure of *T. putitora* in Gobind Sagar reservoir

Life stages	Length (%)	Weight (%)
Newly recruitment stage	28	34
Mature individuals	50	44
Over-aged size	22	22

larger length groups in the studied population indicate the presence of mature individuals with significant reproductive contributions. The presence of smaller individuals (31.9 cm, 425 g) suggests an active recruitment process within the population, demonstrating successful spawning and juvenile survival. However, growth rates can be influenced by environmental factors, including water quality, food availability, and anthropogenic.

All meristic parameters, including dorsal fin rays (DFR), pectoral fin rays (PFR), pelvic fin rays (PeFR), anal fin rays (AFR), and caudal fin rays (CFR), are consistent across species with different body lengths. Therefore, it is evident that meristic counts do not change as body length increases and are not impacted by body size). Morphometric characters like total length (TL), standard length (SL), fork length (FL), head length (HL), head depth (HD), snout length (SL), body depth (BD), and eye diameter (ED) all exhibited symmetrical growth when observed in different length groups. Bannikov and Tyler (2008) demonstrated that observable physical characteristics are essential for species recognition. Johal et al.(2003) reported 18 morphometric characters and 7 meristics characters from 16 specimens of *T. putitora* in the pong reservoir, Himachal Pradesh with 79.55 cm of maximum standard length followed by head

length of 19.23 cm, maximum body width of 17.60 cm, which showed a high degree of association coefficient, although the head depth, caudal fin length, and caudal peduncle length showed the least correlation. In present study standard length ranged from 14 to 32 cm, while the fork length (FL) ranged from 15.2-34 cm. with correlations of 0.977 and 0.976, respectively, were the parameters that had the strongest relationship with total length. The meristic counts of *T. putitora* stayed constant as body length increased. These counts included the number of lateral line scales, pectoral fin rays, pelvic fin rays, dorsal fin rays, anal fin rays, and caudal fin rays.

3.3. Length – Weight Relationship

In the present investigation, the determined regression coefficient 'b' for *T. putitora* was found to be 3.162 whereas the logarithmic equation is calculated as $\text{Log } W = -2.278 + 3.162 \text{ Log } L$, suggest that species are exhibiting a positively allometric growth pattern, in which weight increases with length and fish become more rotund as length increases (Figure 3).

Significant portion of the studied population comprises pre-mature and mature individuals, indicating a functioning breeding population within the ecosystem. Regression coefficient 'b' for *T. putitora* was found to be > 3; and

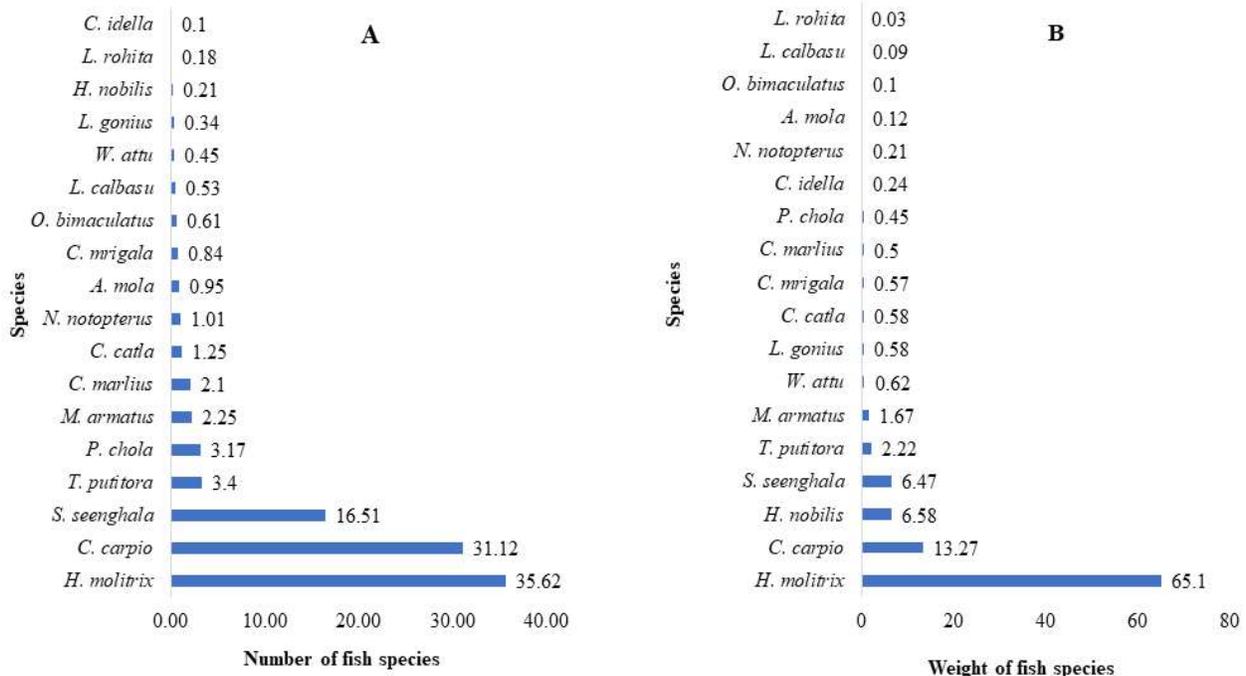


Figure 2. Fish catch composition based on number and weight (A&B) recorded in Gobind Sagar reservoir (April 2023 to September 2024)

exhibiting positively allometric growth pattern. Arslan et al. (2004) indicated that the "b" value in fish length-weight correlations is a crucial biological measure of growth pattern that takes into consideration dietary intake and shifting ecological conditions. Froese (2006) observed that fish maintains its specific gravity constant throughout its life by maintaining its shape and growing isometrically with regression coefficient 'b'=3. In the present study b value indicates as positive allometric growth pattern.

Similarly, *T. putitora* "b" value from the Ladhya River in Uttarakhand was 2.99, indicating isometric growth through a strict cubic law (Patil et al., 2010). Ali et al. (2014) documented the isometric development pattern of golden mahseer from four distinct Himalayan River regions in India. Some of the samples grown more in weight than in length, suggesting that they were in very nutrient-rich environments when they were sampled (Froese, 2006).

3.4. Length - Length Relationship (LLRs) of *T. putitora*

All LLRs in *T. putitora* were highly correlated with 'r' values ranging from 0.816 to 0.992. The highest correlation between SL and FL ($r^2=0.984$) followed by TL-FL (and TL-SL) relationships. All LLRs were highly significant, with

most of the coefficient of determination values being >0.666 (Figure 3). Various environmental (water depth, temperature, pH, turbidity) and biological factors (size, genetic profile) are responsible for variations between the body measurements (Ezeafulukwe et al., 2015; Ramasamy and Rajangam, 2016). Khan et al. (2012) correlated the length-length relationships of four species (*L. bata*, *C. punctata*, *O. pabda*, *M. armatus*) from river Ganga with coefficient of determination of >0.9 , which was slightly different with findings of present study ($r^2=0.827-0.982$).

3.5. Condition Factor and Relative Condition Factor

During the monsoon, the condition factor (K) and relative condition factor (Kn) values were highest, mean condition factor being 1.14 ± 0.07 and relative condition factor is 1.65 ± 0.009 . The premonsoon season is also characterized with high values of Condition factor (K) = 1.06 ± 0.06 and Kn = 1.21 ± 0.003 . However, sharp decrease was observed in post-monsoon season as the condition factor (0.91 ± 0.05) and Kn (1.01 ± 0.09) falls (Table 3).

During the monsoon, the condition factor (K) and relative condition factor (Kn) values were highest. This peak

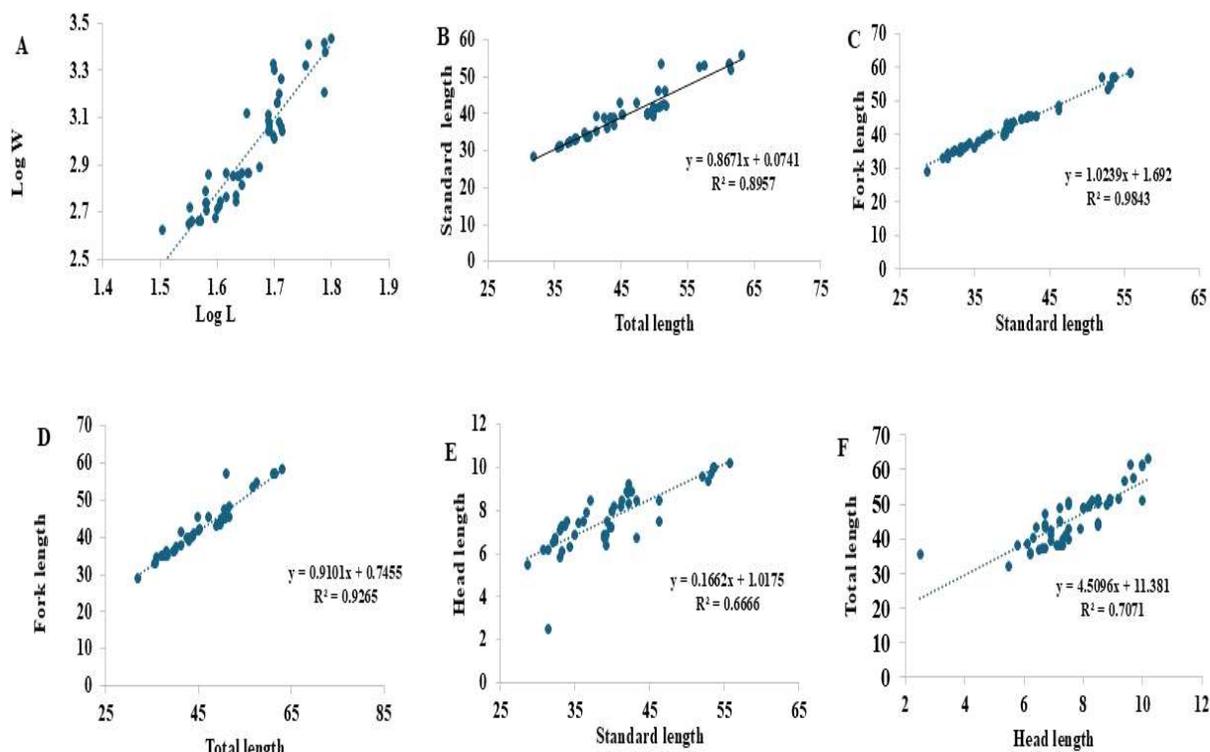


Figure 3. Length -weight and Length – length relationship (LLRs) of *T. putitora* from Gobind Sagar reservoir (a.) Log length -weight relationship (b) LLRs of total length and standard length (c). LLRs of standard length and fork length (d). LLRs of total length and fork length (e). LLRs of standard length and head length (f). LLRs of head length and total length

would correspond to increased feeding opportunities, favorable water conditions and active reproductive phases which all lead to heightened body condition (Araneda et al., 2008). The premonsoon season is also characterized with high values therefore, the preparation for spawning, the gain in energy reserve and the maintenance of good physiological status of the fish. However, sharp decrease was observed in post-monsoon season might be associated with the depletion of energy reserves after spawning, and perhaps with lower food supply or environmental stress. The winter period slightly recovers which can attribute to the lower metabolism and limited feeding activity in winter months. Altogether, this information provides evidence for *T. putitora* attaining maximum physical condition during the monsoon season, which seems to be a significant period of reproductive and growth activities, whereas post-monsoon, is a biophysically challenging period that requires carefully ecological management (Alam et al., 2014).

Seasonal changes may reveal the gonads and fatness state, whereas changes in condition factor values with length may reveal the size at the onset of maturity. o Balai et al. (2016), observed the Indian major carps (catla, rohu, and mrigal) from Jaisamand Lake were in good health, with K values ranging from 1.854 to 1.186 and Kn values between 1.005± and 1.008.

3.6. Truss Networking Analysis

In the present study, six variables with eigen values were derived from 19 morphometric measures using PCA analysis revealed that *T. putitora*, the first three principal components (PC1, PC2, and PC3) accounted for 78.377%, 18.38%, and 13.03% of the total variance, respectively. It was also observed that *T. putitora* had eigenvalues greater than one 12.83, 4.78, 3.38, 1.227, and 1.078, respectively (Table 4, Figure 4). The higher percentage of variance explained by PC1 in *T. putitora* (78.377%) exhibits a more distributed variance pattern across multiple principal components, indicating that its growth and body composition may be influenced by a combination of multiple factors such as habitat conditions, hydrodynamic forces, and trophic interactions (Nautiyal et al., 2008).

Understanding PCA results in fish species is crucial for designing effective conservation and management strategies. The high variance explained by PC1 in *T. putitora* highlights key morphological and physiological traits that should be considered for breeding, conservation, and habitat restoration programs. The significant contribution of PC2 and PC3 in *T. putitora* further emphasizes the need for maintaining river connectivity and stable hydrological conditions to support its natural migratory and reproductive behaviors. Given the ecological importance of this species in freshwater biodiversity and fisheries, long-term monitoring of their morphometric and growth patterns using PCA can

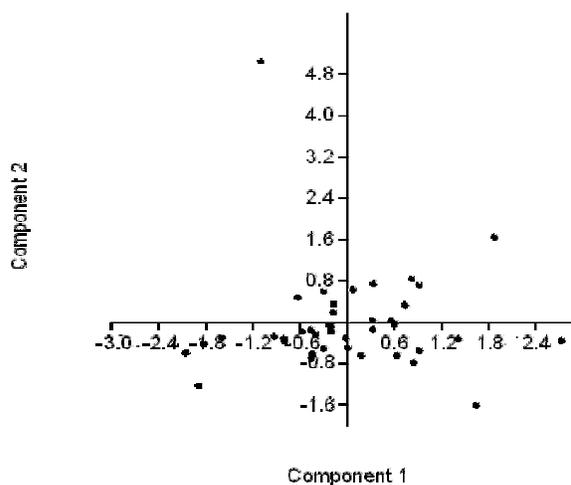


Figure 4. Principal component analysis of *T. putitora*

Table 4. Percentage of variance accounted by variables having eigen values more than 1 of within group PCA for *T. putitora* from Gobind Sagar reservoir

Principle component	<i>T. putitora</i>	
	Eigen value	% variance
1	12.83	78.37
2	4.780	18.386
3	3.388	13.032
4	1.274	4.903
5	1.078	4.146
6	0.704	2.701

Table 3. Estimation of condition factor (K) and relative condition factor (Kn) of *T. putitora*

<i>T. putitora</i>	Pre-monsoon	Monsoon	Post-monsoon	Winter
Condition factor	1.06±0.06	1.14±0.07	0.91±0.05	0.79±0.07
Relative condition factor	1.21±0.003	1.65±0.009	1.01±0.09	0.98±0.001

Values are expressed as Mean±SE

provide valuable insights for sustainable aquaculture and conservation planning. Future studies should incorporate additional environmental variables such as water quality, temperature fluctuations, and genetic diversity to refine the PCA models and better understand species-specific adaptations. Rohlf (2006) suggested that a large portion of variance can be explained by the first few principal components (PC). According to the overall results of PCA, size is the primary factor that contributes to variability in both species, followed by shape. Principal Component Analysis (PCA) is a widely used multivariate statistical technique for identifying key variables that contribute to variations within datasets, particularly in biological and ecological studies (Jolliffe and Cadima, 2016). PCA helps in reducing the dimensionality of data while retaining the maximum variability, thereby identifying patterns in species morphology, growth, and environmental interactions (Legendre and Legendre, 2012).

4. CONCLUSION

This study demonstrated that the morphometric (19) and meristic (5) traits of *T. putitora* remain consistent across different size groups, indicating a stable body plan throughout ontogeny. The dominance of pre-mature and mature individuals confirms a self-sustaining breeding stock within the Gobind Sagar Reservoir. A regression coefficient 'b' >3 highlights a positively allometric growth pattern, suggesting improved weight gain with increasing length. Principal component analysis revealed that 78.4% of the variance in PC1 is linked to a single dominant factor, likely body shape, while PC2 and PC3 reflected secondary influences such as habitat fragmentation, seasonal flow changes and ecological fluctuations typical of a migratory species. By integrating growth condition, phenotypic variability and health status, the results provide essential baseline data for stock assessment, habitat management and sustainable harvest. These findings can guide conservation policies and adaptive management strategies for safeguarding this vulnerable species within the reservoir ecosystem.

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Authors' Contributions

Supreet Kaur conducted sampling and analysed the data and wrote the manuscript. Surjya Narayan Datta helped in sampling, interpreted the results and wrote the manuscript. Prabjeet Singh conceptualized the theme, helped in sampling; and Grishma Tewari helped in sampling.

Conflict of Interest

The authors declared that they don't have any conflict of interest among them and institute for conducting the experiment.

Declaration

The authors are hereby declaring that no AI tools have been used in the writing the manuscript.

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