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Original Article

# Studies on sex ratio, condition factor and patterns of phenotypic estimation in stock identification of snow trout, *Schizothorax esocinus* Heckel, 1838 inhabiting the colder Indian Himalayan region

**Gulshan Akhter[1] • Imtiaz Ahmed[1] • Syed Mudasir Ahmad[2]**

[1] *Fish Nutrition Research Laboratory, Department of Zoology, University of Kashmir, Hazratbal, Srinagar, Jammu and Kashmir 190 006, India*

[2] *Division of Biotechnology, Faculty of Veterinary Sciences & Animal Husbandry, Sher-e-Kashmir University of Agricultural Sciences and Technology, Srinagar, Jammu and Kashmir 190 006, India*

**Correspondence**

Imtiaz Ahmed; Fish Nutrition Research Laboratory, Department of Zoology, University of Kashmir, Hazratbal, Srinagar, Jammu and Kashmir 190 006, India

imtiazamu1@yahoo.com

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**Abstract**

*Schizothorax esocinus*, a nutrient-rich food fish offered in Asian countries, is rapidly declining due to severe fishing pressure and pollution in its wild environment, requiring active conservation strategies. Our study examined 196 specimens to elucidate critical biological parameters including sex ratio, length-weight relationships (LWRs), Fulton's condition factor (*K*) and morphometric-meristic parameters. The general sex ratio was not substantially departed from the predicted value of 1 : 1, with the exception for the month of May, where $\chi^2$ = 4.15 which is greater than the calculated value of 3.84. The correlation between the length and weight was reported as Log $W$ = 0.134209 + 2.5218 log $L$ for males, Log $W$ = 0.19173 + 2.6751 log $L$ for females and Log $W$ = 0.162116 + 2.594 for combined sexes. *Schizothorax esocinus* demonstrated a negative allometric growth as indicated by the allometric parameter *b* for the LWR. The two sexes showed no significant differences in morphometric measures. So, this study included combined-sex regression analysis. These comprehensive findings highlight the critical need for conservation efforts in India and neighbouring countries to preserve this valuable fish stock for future generations.

**Keywords:** Fulton's condition factor; length-weight relationship; morpho-structure; *Schizothorax esocinus*; sex ratio

## 1 | INTRODUCTION

*Schizothorax esocinus* Heckel, 1838 is a member of subfamily Schizothoracine (Family: Cyprinidae) that comprises 15 genera and more than hundred species distributed globally (Mirza 1991). These are economically important fishes inhabiting in snow and spring fed rivers, lakes and swamps and are commonly recognised as snow trout, snow minnow and mountain barbel (Mirza 1991) or even Indian trouts (Tilak and Sinha 1975). The National Environmental Protection Agency and the Endangered Species Scientific Commission have listed these species as "Endangered" because of over exploitation and disturbance in their breeding sites (Yue and Chen 1998). In past, their taxonomic studies on this species have been done by several authors (Heckel 1838; Silas 1960; Kullander *et al.* 1999); most of these investigations used a physical and meristic enumeration approach as their foundation. However, due to intraspecific morphological similarities, precise identification of Schizothoracine fishes using physical characters is difficult and this can sometimes cause mistakes in identification of closely related species. Earlier, 14 species belong to genus *Schizothorax* were reported from Kashmir valley; currently, only five species have been found in water bodies of Kashmir. Based on physical traits such as head position and form, mouth shape, size and gill raker counts and number of scales, these five species were recognised (Kullander *et al.* 1999). Among them *S. esocinus* departs from all other *Schizothorax* species in gill raker number and have unique colour pattern, with a light ground colour and contrasting black spots on most of the samples. This fish locally known as "Churru" and it holds a significant ecological status as it is classified as "Vulnerable" by the IUCN (Akhter *et al.* 2024) and is one of the most economically beneficial food fish in the Himalayan region. In the present study during collection, we observed that whole *Schizothorax* species have suffered a dramatic decline in their number due to over-exploitation, introduction of carp fish, dirty water and rooting out of their natural breeding grounds which led to the destruction of their habitat and hampered these fishes' movement. Consequently, accurate stock recognition of fishes is of great importance in many fields and would enhance fish conservation and sustainability. The initial step for stock identification is based on morphometric and meristic parameters. This is the authentic method for specimen identification and indicates differences in general body form that showed different geographical locations and environment have significantly influence on morphometric and meristic traits. The morphological characters were also influenced by production system and indicated that big sized fishes come from farm where the availability of food was greater (Gonzalez *et al.* 2020).

So far, a large number of researches have been conducted on the length-weight relationships (LWRs), morphological and meristic aspects, for numerous fish species around the globe (e.g. Sharma *et al.* 2014; Nazir and Khan 2017; Pant *et al.* 2018). However, very discrete work had been done on the phenotypic variations of Himalayan snow trout species (Mir *et al.* 2012; Jan and Ahmed 2020; Reshi and Ahmed 2020; Arafat and Bakhtiyar 2022). The current research is the first to provide a thorough and detailed description of the sex ratio, LWRs, condition factor, morphometric measurements and meristic character counts in the Himalayan region so as to establish growth patterns of *S. esocinus* and these characters can be used to differentiate taxa of this fish, and we may use their growth patterns to enhance conservation-management plans and contribute to their long-term sustainability.

## 2 | METHODOLOGY

### 2.1 Study area

Fresh fish specimens were procured from three study sites namely Anchar Lake (34°10'22.8"N 74°51'13.1"E), Telbal Nallah (34°09′44.2″N 74°51′49.2″E) and Dal Lake (34°07′55.2″N 74°50′31.2″E) of Jammu and Kashmir, India. The Dal Lake is surrounded with the Zabarwan Mountain valley and Shankaracharaya Hills at northeast of Srinagar city. The lake covers an area of 18 km$^2$ with overall length of 7.44 km and width is about 3.5 km with catchment basin of 316 km$^2$. The availability of fish has been taken into consideration when choosing the sampling locations. The fish collection sites were displayed in the study area map (Figure 1).

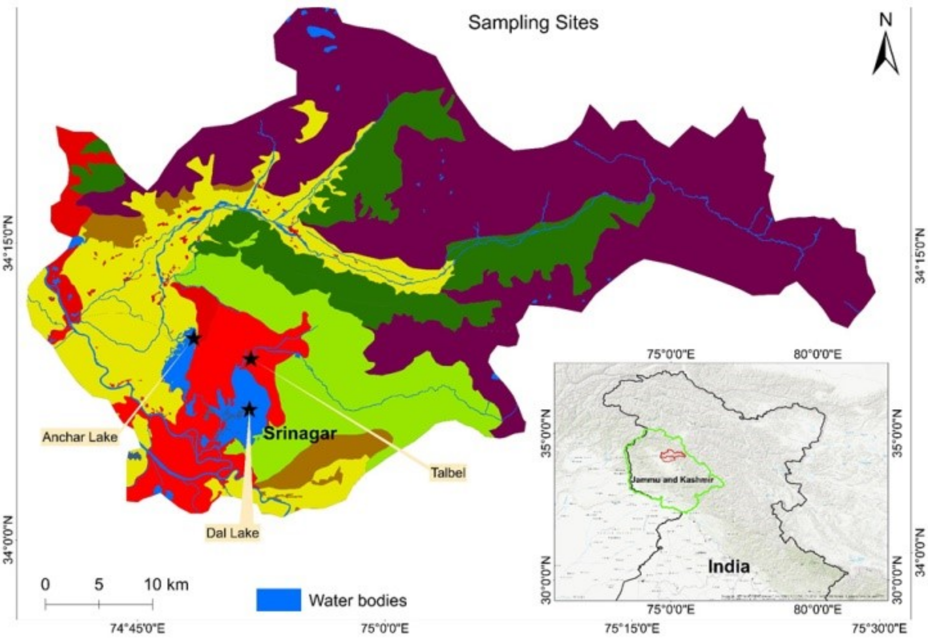


**FIGURE 1** Map showing the sampling sites of *Schizothorax esocinus* inhabiting the colder Indian Himalayan region.

### 2.2 Sampling for fish specimens

Wild fish samples were collected between September 2019 and August 2020 from different locations within the range of their actual geographic ranges. A total of 196 specimens of *S. esocinus* were used for evaluating the LWR, as well as various morphometric measurements and meristic counts. The specimens ranged in weight from 50 to 465 g, with an average weight of 186 ± 117.3 g. The total length (TL) ranged from 17.5 to 37.6 cm, with a mean (± SD) length of 26.51 ± 5.11 cm. Sampling was done by subjective sampling technique in coordination with fishermen. The fishes gathered from sampling areas were delivered immediately to the laboratory for the analysis including identification, which was done by using standard keys (Day 1878; Jayaram 1999; Kullander *et al.* 1999).

### 2.3 Data analysis

#### 2.3.1 Body measurements

Linear morphometric measurements were made in accordance with the conventional methods (Rao 1966; Dwivedi and Menezes 1974). By using a digital Vernier calliper and a digital electronic balance (model: Shimadzu UX320G, Japan) with graduations in cm and g respectively, the morphometric variables and body weight were measured. We assessed meristic counts according to the study by Froese and Pauly (2007). A total of 31 body dimensions were undertaken, including 27 morphometric and 4 meristic variables (Table S1).

#### 2.3.2 Sex ratio

Basic information for determining fish population stock size includes the sex ratio and size structure (Vazzoler 1996). Even though certain fish stocks may reveal a significant imbalance in this ratio, most aquatic species do not typically deviate from a 1 : 1 sex ratio. Such disparities could result from a variety of factors, such as temperature impacts on determination of sex (Conover and Kynard 1981), selective fatality by sex due to differential predation and divergent promiscuity, annual growth, or longevity predictions (Schultz 1996). Pearson's Chi-square ($\chi^2$) analysis was used for this investigation reveals a significant disparity in fish sex.

$$\chi^2 = \Sigma\, (O - E)^2 / E.$$

where O stands for monthly observed number of males and females, E is the monthly expected number of males and females (the hypothetical 1:1 ratio). By comparing the observed sex ratio to the theoretical 1 : 1 ratio for each month, $\chi^2$ statistics was employed to evaluate whether there was a significant difference.

#### 2.3.3 Fulton's condition factor

The condition factor of Fulton (*K*), which is related to the fish's health, was also determined. The key factor *K*, provides information about age, the proportion of food consumed, and the rate of growth. K was determined using the following equation: $K = (100 \times BW)/L^3$, where BW signifies the fish's body weight in g and L defines its overall length in cm.

#### 2.3.4 Length-weight relationship

The allometric regression analysis was employed to calculate length–weight relationship (LWR). By applying the equation of Le Cren (1951) the raw information of total length and weight were subjected to statistical analysis using the form $BW = aL^b$ was estimated, which was interpreted into logarithmic form as $\text{Log } W = \text{Log } a + b \text{ Log } L$. Where, BW symbolizes the fish's body weight in grams, L denotes its total length in centimetres, the two constants: *a* is depicted by the point where the regression line intercepts the y-axis i.e. initial growth index, and the constants *b* denoted by the slope of the regression line.

#### 2.3.5 Analysis of morphometric and meristic parameters

Microsoft Excel 2016 and the standard SPSS software (Version 26) were used for all statistical analysis. The range, mean, standard deviation (SD) and coefficient of variation (CV) for each parameter were computed. Scatter diagram for morphometric traits were plotted by applying least square approach (Laevastu 1965; Snedecor and Cochran 1967) and the linear regression model has been used to fit the data. By employing the linear regression model: $Y = b\, X + a$. The relationship between various parameters was calculated. Where, Y signifies the dependent variable, such as standard length, fork length, and so on. Constant *a* is the regression intercept the Y axis, *b* is the slope and 'X' is the value of independent variable, i.e. total length. The impact of increased total length on other body parameters in fish has been used as a biometric index and the meristic characters are those which are countable such as vertebrae, fin rays, scales. For convenience, only the fin ray counts were dealt here.

## 3 | RESULTS

### 3.1 Sex ratio

The demographic makeup in the catching region had a sex ratio of 1.2: 1.0, which did not deviate from the predicted 1 : 1 ratio (Table 2). The anticipated 1 : 1 sex ratio was often not considerably departed from during the investigation; however, males were significantly ($p < 0.05$) more than females. As given in Table 2, the computed $\chi^2$ value for the month of May is 4.15 further provides monthly catch statistics for male and female fish. At the 5% level of significance, this is greater than the calculated value of 3.84 for degree of freedom 1. Monthly capture records for male and female *S. esocinus* were also shown in Figure 2. All phases of the survey indicated almost of 1 : 1 ratio in the catch. Compared to the summer season, catches were higher during the winter season; reason might be the breeding time. At breeding time these fishes perform migration.

**TABLE 2** Chi-square test ($\chi^2$) for *Schizothorax esocinus* sex ratio comparison by months inhabiting the Indian Himalayan region.

| Month | Number | | | Sex ratio | $\chi^2$ | *p* |
|---|---|---|---|---|---|---|
| | Male | Female | Total | (M:F) | *(df=1)* | |
| Sep | 11 | 10 | 21 | 1.1:1 | 0.062 | 0.803 |
| Oct | 13 | 12 | 25 | 1.1:1 | 0.097 | 0.756 |
| Nov | 15 | 15 | 27 | 1:1 | 0.002 | 0.964 |
| Dec | 13 | 5 | 18 | 2.6:1 | 2.132 | 0.144 |
| Jan | 11 | 15 | 30 | 0.7:1 | 2.024 | 0.155 |
| Feb | 14 | 9 | 23 | 1.6:1 | 1.203 | 0.273 |
| Mar | 7 | 6 | 13 | 1.2:1 | 0.008 | 0.929 |
| Apr | 8 | 5 | 13 | 1.6:1 | 0.217 | 0.641 |
| May | 8 | 1 | 9 | 8:1 | 4.152 | **0.042** |
| Jun | 3 | 5 | 7 | 0.6:1 | 0.424 | 0.515 |
| Jul | 2 | 3 | 5 | 0.7:1 | 0.460 | 0.498 |
| Aug | 3 | 2 | 5 | 1.5:1 | 0.0484 | 0.826 |
| Overall | 108 | 88 | 196 | 1.2:1 | 12.38 | **<0.001** |

Boldface *p*-values indicate statistically significant differences.

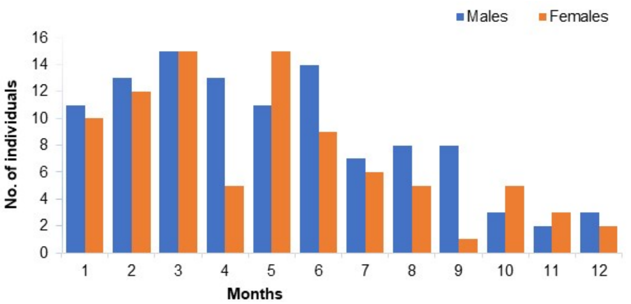


**FIGURE 2** Temporal distributions of *Schizothorax esocinus* by sex inhabiting the Indian Himalayan region.

### 3.2 Length–weight relationship (LWR)

The LWR equation was calculated individually for males, females, and combined sexes. Smooth curves were produced when empirical length values were displayed against their relative weight on an arithmetic scale (Figure 3). The correlation between length and weight was evaluated as:

Male: $W = 1.3621\ L^{2.5218}$
Log W = 0.134209 + 2.5218 log L; $r^2 = 0.941$
Female: $W = 1.555\ L^{2.6751}$
Log W = 0.19173 + 2.6751 log L; $r^2 = 0.94$
Pooled: $W = 1.4525\ L^{2.594}$
Log W = 0.162116 + 2.594 log L; $r^2 = 0.93$

It was indicated that as per the regression coefficients, there was no statistically significant difference in *b* values ($p > 0.05$) between all the length groups. As may be seen from the equations, the exponential data for males, females and pooled sexes was remarkably identical. For the regression of total length and body weight, the coefficient of determination, $r^2$ was evaluated to be 0.941, 0.94 and 0.93 for males, females and combined sexes respectively, which was highly significant ($p < 0.01$).

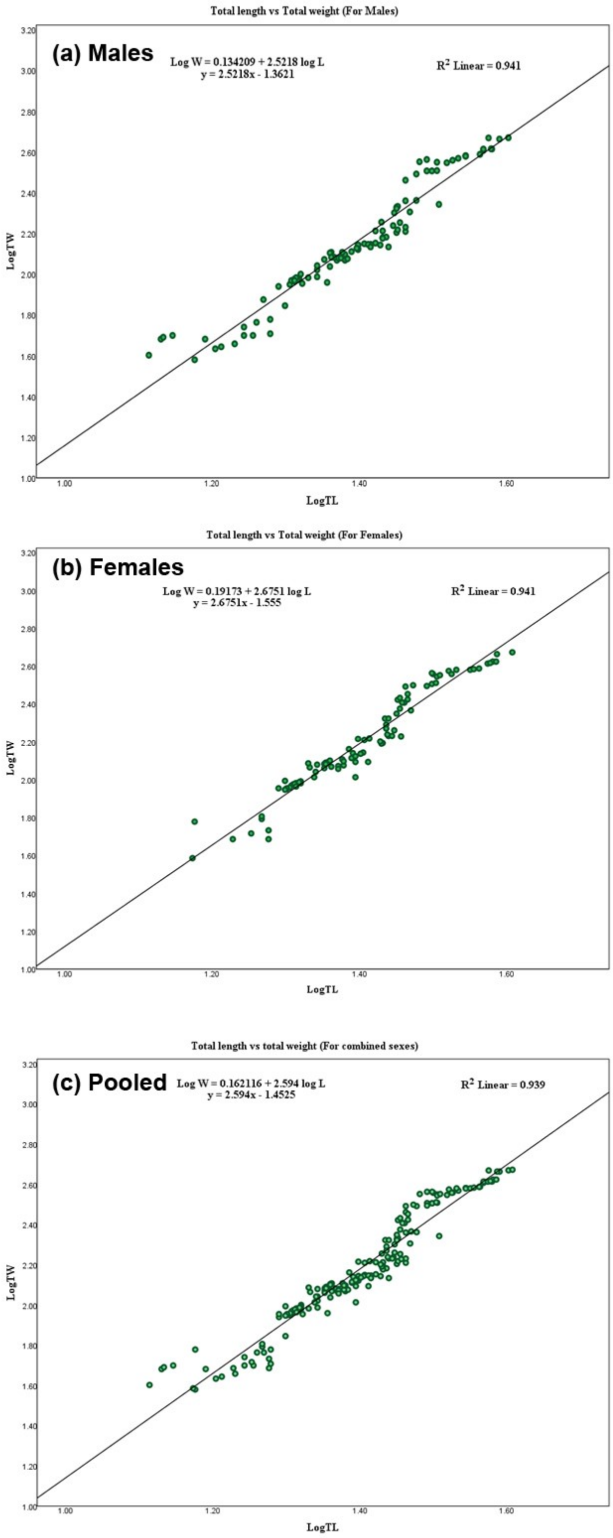


**FIGURE 3** Logarithmic relationship between total length and weight in snow trout, *Schizothorax esocinus* for the males (a), females (b) and combined sexes (c).

### 3.3 Fulton's condition factor

Form the original data set, the value of the Fulton's condition factor *K* for different sizes of *S. esocinus* was ranged from 0.671 – 0.961 in males, 0.713 – 1.193 in females and from 0.671 – 1.193 in combined sexes with the mean values of 0.841 ± 0.09, 0.915± 0.17 and 0.885 ± 0.15 respectively. Across all the size groups, the values of *K* showed minute variations (Table 3).

**TABLE 3** Mean length (± SD), mean weight (± SD), regression coefficients (*b*), coefficient of determination ($r^2$), and condition factor (*K*) for male, female and combined sex of *Schizothorax esocinus* inhabiting the Indian Himalayan region.

| Sex | *n* | Mean length (cm) | Mean weight (g) | *a* | *b* | $r^2$ | Condition factor (*K*) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Range | Mean |
| Male | 108 | 25.66 ± 6.27 | 177.77 ± 118.23 | 1.362 | 2.521 | 0.94 | 0.671 – 0.961 | 0.841 ± 0.09 |
| Female | 88 | 26.28 ± 5.81 | 196.22 ± 116.04 | 1.555 | 2.675 | 0.94 | 0.713 – 1.193 | 0.915 ± 0.17 |
| Pooled | 196 | 25.94 ± 6.06 | 186.05 ± 117.31 | 1.452 | 2.594 | 0.93 | 0.713 – 1.193 | 0.885 ± 0.15 |

### 3.4 Morphometric and meristic characters

During the present investigation on the phenotypic variations of *S. esocinus*, the statistical analysis of various morphometric parameters was done. The mean values for morphometric and meristic characters of pooled raw data (combined sexes) of *S. esocinus* from wild specimens were calculated. Among the various morphometric parameters, the most commonly used parameters were the total length (TL), standard length (SL) and head length (HL). In all, the value of TL ranged between 17.5 and 37.6 cm with a mean value of 26.51 ± 5.11 cm, SL ranged between 15.5 and 34.7 cm with a mean value of 25.06 ± 5.19 cm and HL ranged between 3.7 and 6.6 cm with a mean value of 5.28 ± 0.79 cm. The detailed mean values and range differences for other parameters have been displayed in (Table 4).

The correlation coefficient (*r*) among several morphometric parameters compared against total length was noted in the range from 0.74 – 0.99 demonstrating a good degree of relationship between the compared parameters (Table 5). Comparing of some parameters to head length also revealed high degree of *r* ranged from 0.74 to 0.92. Obtaining a high value of *r* for various morphometric characters as a function of total length and head length reveals high degree of interdependence of these compared characters. The standard length (*b* = 1.0923), fork length (*b* = 1.0758), and pre-dorsal length with *b* value 1.0134 all revealed high growth rates, whereas caudal depth (*b* = 0.7824), dorsal fin height (*b* = 0.7254) and pelvic fin base length (*b* = 0.642) all showed relatively slow growth. All the parameters that were compared against total length, the standard length (*b* = 1.0923), fork length (*b* = 1.0758) followed by pre-dorsal length with *b* value 1.0134 showed high growth rate, while for caudal depth *b* = 0.7824, dorsal fin height *b* = 0.7254 and pelvic fin base length *b* = 0.642 revealed that growth was very slow. Regression model for five characters were calculated against head length (Table 5). All the characters compared with head length showed strongly linked with head length, while interorbital distance had the lowest correlation ($r^2$ = 0.54) with head length.

**TABLE 4** Maximum, minimum, range difference, mean, standard deviation (SD) and coefficient of variation (CV) of different morphometric and meristic characters of *Schizothorax esocinus* (*n* = 196) combined sexes inhabiting in colder Indian Himalayan region.

| Characters | Max | Min | Range | Mean | SD | CV |
|---|---|---|---|---|---|---|
| **Morphometric** | | | | | | |
| TL | 37.6 | 17.5 | 20.1 | 26.51 | 5.11 | 0.19 |
| BW | 465 | 50 | 415 | 186.05 | 117.3 | 0.59 |
| FL | 36.5 | 15.5 | 21 | 25.06 | 5.19 | 0.20 |
| SL | 34.7 | 15.2 | 19.5 | 23.49 | 4.85 | 0.20 |
| BD | 7.5 | 3.6 | 3.9 | 5.47 | 1.07 | 0.19 |
| CPL | 5.2 | 2.2 | 3 | 3.45 | 0.75 | 0.21 |
| CPD | 4 | 1.4 | 2.6 | 2.25 | 0.54 | 0.24 |
| DFBL | 5 | 1.9 | 3.1 | 2.58 | 0.70 | 0.21 |
| DFH | 5.4 | 2.8 | 2.6 | 3.6 | 0.61 | 0.17 |
| PcFL | 5 | 2 | 3 | 3.23 | 0.72 | 0.21 |
| PcFBL | 1.6 | 0.6 | 1 | 1 | 0.22 | 0.22 |
| PvFL | 4.8 | 2.1 | 2.7 | 3.07 | 0.61 | 0.19 |
| PvFBL | 1.5 | 0.8 | 0.7 | 1.12 | 0.16 | 0.14 |
| AFL | 4.3 | 2.2 | 2.1 | 3.28 | 0.60 | 0.18 |
| AFBL | 2.5 | 1 | 1.5 | 1.6 | 0.30 | 0.19 |
| Pre-DL | 17.3 | 7.9 | 9.4 | 11.8 | 2.43 | 0.20 |
| Pre-PecL | 6.1 | 3 | 3.1 | 4.45 | 0.70 | 0.15 |
| Pre-PelL | 15.6 | 7 | 8.6 | 10.91 | 2.07 | 0.18 |
| Pre-AL | 29.5 | 12.5 | 17 | 20.5 | 4.20 | 0.18 |
| HL | 6.6 | 3.7 | 2.9 | 5.28 | 0.79 | 0.151 |
| HD | 4.9 | 2.7 | 2.2 | 3.74 | 0.57 | 0.154 |
| SNL | 2.6 | 1 | 1.6 | 1.78 | 0.39 | 0.222 |
| Post- Or | 3.6 | 1 | 2.6 | 2.14 | 0.80 | 0.376 |
| ED | 1.1 | 0.6 | 0.5 | 0.92 | 0.13 | 0.143 |
| IOD | 3.2 | 1.9 | 1.3 | 2.26 | 0.36 | 0.159 |
| **Meristic count** | | | | | | |
| DFR | 12 | 7 | 5 | 9.75 | 1.65 | 0.16 |
| PcFR | 18 | 8 | 10 | 14.85 | 2.03 | 0.13 |
| PvFR | 8 | 6 | 2 | 7.15 | 0.81 | 0.11 |
| AFR | 8 | 5 | 3 | 7.05 | 1.27 | 0.18 |
| CFR | 26 | 18 | 8 | 23.6 | 2.77 | 0.11 |

TL, total length; SL, standard length; FL, fork length; BD, body depth; CPL, caudal peduncle length; CPD, caudal peduncle depth; DFBL, dorsal fin base length; DFH, height of dorsal fin; PcFL, pectoral fin length; PcFBL, pectoral fin base length; PvFL, pelvic fin length; PvFBL, pelvic fin base length; AFL, anal fin length; AFBL, anal fin base length; Pre-DL, pre-dorsal length; Pre-PecL, pre-pectoral length; Pre-PelL, pre-pelvic length; Pre-AL, pre-anal length; HL, head length; HD, head depth; ED, eye diameter; SNL/PreOr, snout length / pre orbital length; Post-Or, post orbital length; IOD, inter-orbital distance; DFR, dorsal fin rays; PcFR, pectoral fin rays; PvFR, pelvic fin rays; AFR, anal fin rays; CFR, caudal fin rays.

In comparison with head length, the post orbital length showed maximum growth with *b* value of 1.9791, showing a significant ($p < 0.05$) high correlation with head length. In relation to head length, the inter-orbital distance and eye diameter showed the minimum growth. In most of the estimated variables, the coefficient of variation (CV) of samples were high (14 – 24%), and in case of body weight it was even higher. For almost all the parameters, the regression coefficient (*b*) was significant ($p < 0.05$), exhibited a linear relationship. Graphical representation for logarithmic relationship of various parameters against total length and head length were also shown (Figure 4 – 6).

The meristic characteristics were evaluated by tallying the number of fin rays of the specimen under study. Five meristic counts were analysed in this study and the meristic parameters showed average values of 9.75 ± 1.65, 14.85 ± 2.03, 7.15 ± 0.81, 7.05 ± 0.812 and 23.6 ± 0.117 for DFR, PcFR, PelFR, AFR and CFR respectively (Table 4). Even though the meristic counts differed a little between samples, but these were unaffected by size and stayed unchanged during the fish's maturation.

**TABLE 5** Regression model demonstrating relationship for various morphometric variables (Y) for combined sexes of *Schizothorax esocinus* ($n$ = 196) inhabiting the Indian Himalayan region as a function of total length and head length (x).

| Morphometric characters | Regression equation Y = bx + a | Coefficient of correlation (*r*) | Coefficient of determination ($r^2$) | 95% Confidence interval of a | | 95% Confidence interval of b | |
|---|---|---|---|---|---|---|---|
| | | | | Lower limit | Upper limit | Lower limit | Upper limit |
| **% of total length** | | | | | | | |
| TL and FL | 1.0475x – 0.095 | 0.99 | 0.98 | -0.26 | -0.14 | 1.07 | 1.15 |
| TL and SL | 1.0753x – 0.1276 | 0.99 | 0.98 | -0.17 | 0.03 | 0.92 | 1.07 |
| TL and BD | 0.9266x – 0.5818 | 0.91 | 0.83 | -0.87 | 0.29 | 0.72 | 1.13 |
| TL and CPL | 0.8974x – 0.7422 | 0.78 | 0.60 | -1.58 | -0.96 | 1.10 | 1.54 |
| TL and CPD | 0.7824x – 0.7827 | 0.86 | 0.75 | -1.62 | -1.07 | 1.01 | 1.40 |
| TL and DFBL | 0.9841x –1.0029 | 0.82 | 0.68 | -1.56 | -0.89 | 0.92 | 1.41 |
| TL and DFH | 0.7254x – 0.4762 | 0.88 | 0.78 | -0.73 | -0.21 | 0.53 | 0.91 |
| TL and PcFL | 0.987x – 0.8979 | 0.87 | 0.77 | -0.84 | -1.31 | 1.31 | 0.97 |
| TL and PcFBL | 0.8989x – 1.2828 | 0.78 | 0.61 | -2.15 | -1.45 | 1.06 | 1.55 |
| TL and PvFL | 0.8623x – 0.7406 | 0.88 | 0.78 | -1.01 | -0.61 | 0.79 | 1.06 |
| TL and PvFBL | 0.642x – 0.8621 | 0.87 | 0.76 | -1.11 | -0.61 | 0.46 | 0.81 |
| TL and AFL | 0.8632x – 0.7131 | 0.91 | 0.84 | -1.34 | -0.89 | 1.01 | 1.33 |
| TL and AFBL | 0.6963x – 0.7886 | 0.74 | 0.55 | -1.66 | -1.22 | 1.03 | 1.34 |
| TL and Pre-DL | 1.0134x – 0.3685 | 0.98 | 0.96 | -0.50 | -0.22 | 0.91 | 1.11 |
| TL and Pre-PecL | 0.6176x – 0.390 | 0.97 | 0.78 | -0.42 | -0.087 | 0.81 | 1.05 |
| TL and Pre-PelL | 0.994x – 0.354 | 0.98 | 0.96 | -1.02 | 0.04 | 0.94 | 1.08 |
| TL and Pre- AL | 1.015x – 0.204 | 0.97 | 0.95 | -1.05 | -0.68 | 0.89 | 1.04 |
| TL and HL | 0.7836x – 0.3915 | 0.93 | 0.88 | -0.59 | -0.19 | 0.64 | 0.92 |
| **% of head length** | | | | | | | |
| HL and HD | 0.8919x – 0.0724 | 0.924 | 0.855 | -0.68 | -0.36 | 0.65 | 0.88 |
| HL and SNL | 1.3299x – 0.7153 | 0.911 | 0.830 | -1.66 | -1.13 | 0.96 | 1.35 |
| HL and Post-Or | 1.9791x – 1.1212 | 0.817 | 0.669 | -1.53 | -0.89 | 0.92 | 1.41 |
| Hl and ED | 0.7469x – 0.5772 | 0.767 | 0.588 | -1.45 | -0.84 | 0.58 | 1.01 |
| HL and IOD | 0.6781x – 0.1365 | 0.741 | 0.549 | -0.85 | -0.37 | 0.51 | 0.85 |

TL, total length; SL, standard length; FL, fork length; BD, body depth; CPL, caudal peduncle length; CPD, caudal peduncle depth; DFBL, dorsal fin base length; DFH, height of dorsal fin; PcFL, pectoral fin length; PcFBL, pectoral fin base length; PvFL, pelvic fin length; PvFBL, pelvic fin base length; AFL, anal fin length; AFBL, anal fin base length; Pre-DL, pre-dorsal length; Pre-PecL, pre-pectoral length; Pre-PelL, pre-pelvic length; Pre-AL, pre-anal length; HL, head length; HD, head depth; ED, eye diameter; SNL/PreOr, snout length / pre orbital length; Post-Or, post orbital length; IOD, inter-orbital distance; DFR, dorsal fin rays; PcFR, pectoral fin rays; PvFR, pelvic fin rays; AFR, anal fin rays; CFR, caudal fin rays.

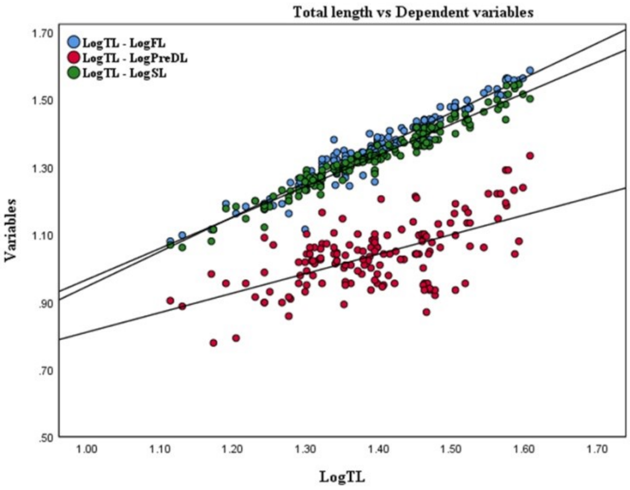


**FIGURE 4** Correlations comparing the logarithmic relationship between standard length (SL), pre-dorsal length (Pre-DL) and fork length (FL) against total length.

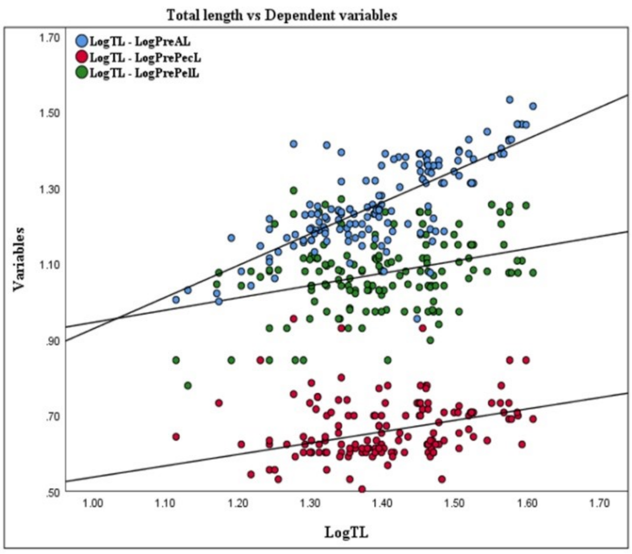


**FIGURE 5** Correlations comparing the logarithmic relationship between pre-anal length (PreAL), pre-pectoral length (Pre-PecL) and pre-pelvic length (Pre-PelL) against total length.

**4 | DISCUSSION**

In fishes, as in any animal, the rate of growth increases with the length of body. Thus, length determines growth. Computation of length-weight correlation by the designed equation $W = aL^3$ proposed by Le Cren (1951) serves two-fold purposes: to provide a mathematical association between two parameters, length and weight, and it provides an indication of general health of fishes or gonadal development i.e. condition factor. Simple linear regression slope of the *S. esocinus* for L-W was lying within the range of 2.496 and 2.755 during this study. These results corroborate with the observations made by others (e.g. Pauly 1984; Egbal *et al.* 2011) whose studies indicated that the b values for many fish species were ranged from 2.278 to 4.0. A fish is said to show isometric growth by Olurin and Aderibigbe (2006), when its length increases in proportion to its body weight and the slope for isometric growth is 3 and values greater than 3 indicate positive allometric growth, when its value is less than 3, the fish experiences a negative allometric growth (Sandon 1950). A negative allometric trend was observed for *S. esocinus* based on the estimated *t* value for the student's *t*-test at 1% level of significance. Many researchers have reported similar findings regarding Schizothoracids and other fishes inhibiting of Kashmir waters or elsewhere, the regression coefficient for *S. niger* was 2.977 from Dal Lake, Kashmir (Pandit 1987). In our observations regarding the regression coefficient was same as reported by (Mir *et al.* 2012; Khan and Sabah 2013).

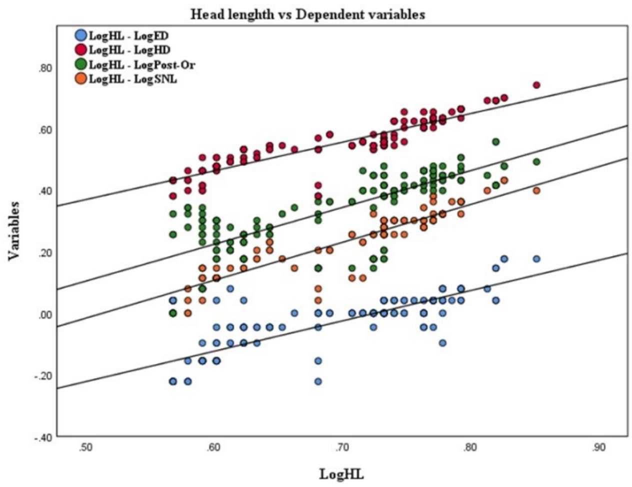


**FIGURE 6** Correlations comparing the logarithmic relationship between snout length (SNL), head depth (HD), eye diameter (ED) and post-orbital length (Post-Or) against total length.

The state of the fish's aquatic habitat can be determined using Fulton's condition factor, which is heavily influenced both by biotic and abiotic environmental exposures (Oni *et al.* 1983). In our study all the fish species sampled had condition factors equal to 1 or very close to 1, and they were all within the ranges suggested by Le Cren (1951) and Ujjania *et al.* (2012), who stated that condition factor ≥ 1 is good, indicating a proper level of feeding and good environmental condition. But in our case condition factor estimated was close to 1 or equal to 1 and this fluctuation in *K* might be due to the environmental pollution of Telbal Nallah and lakes. Both males and females had variations in *K* values, which could be attributable to differences in the quantity of food in the stomach, as reported by (Umesh *et al.* 1996; Suresh *et al.* 2007).

Analysing morphometric (continuous) and meristic counts (discrete) separately revealed that the meristic parameters remained unchanged during the growth. According to the findings of the current study, the body parameters expanded symmetrically in different length groups, and were substantially connected with total length and head length, indicating a high degree of positive correlation between them. Similar inferences were found in Mahseer (*Tor* spp.; Zafar *et al.* 2002; Badkur and Prashar 2015) and in *Triplophysa marmorata* (Bashir *et al.* 2015). In this study, the growth of the fish in relation to its overall length was measured using morphometric characteristics, which revealed a linear relationship as reported by other researcher (Saroniya *et al.* 2013; Jan and Ahmed 2020) and the highest correlation of total length with other parameters was seen in standard length and fork length, which resembles the insights of other researcher who analysed regression models for different fish genera (Goswami and Dasgupta 2007; Sharma *et al.* 2014; Pant *et al.* 2018).

During the embryonic period, meristic characters are fixed and remain constant. These characters comprise computable, repetitive structures that enable in determining the class and speciation (Soliman *et al.* 2018). It is clear from the present results that the meristic traits remained constant in every group of *S. esocinus* having different sizes, which is consistent with other findings (Gogoi and Goswami 2015; Soliman *et al.* 2018). Many researchers studying various fish species have identified variances in meristic features (Al-Hassan 1987; Koshy *et al.* 2008). Meristic variation occurred may have due to genetic factors (Yousefian 2011), temperature or nutrient availability and seasonal variations (Al- Hassan 1987; Sfakianakis *et al.* 2011).

## 5 | CONCLUSIONS

This study provides fundamental biological insights regarding sex ratio, LWR, condition factor values as well as morphometric and meristic parameters, and explicit their relationship with environmental changes. The results will not only useful for fishery sciences, but also for conservation management strategies. For the future sustainability of the stock of *S. esocinus*, separate management strategies need to be developed, such as developing guidelines for appropriate mesh size, and imposing seasons-based restrictions on fishing, which will eventually result in the resource's sustainability.

## AUTHORS' CONTRIBUTION

G. Akhter: collected the material, analysed data and writing - original draft. I. Ahmed: designed the study concept, drafted and revised the manuscript. S.M. Ahmad: manuscript review and editing.

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## CONFLICT OF INTEREST

The author declares no conflict of interest.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

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***G Akhter*** https://orcid.org/0000-0002-6255-8988
***I Ahmed*** https://orcid.org/0000-0003-4821-1707
***SM Ahmad*** https://orcid.org/0000-0001-6036-6467