Length-weight relationship, growth pattern and condition factor of four indigenous cypriniform *Schizothorax* species from Vishav Stream of Kashmir Himalaya, India

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**Abstract**
The indigenous *Schizothorax* spp. in the valley of Kashmir are facing constant threats and decline in their overall population. The current aim was to analyse the comparative length-weight relationship (LWRs) and condition factor (K) of 350 specimens belonging to four *Schizothorax* spp. (*S. plagiostomus*, *S. esocinus*, *S. labiatus* and *S. curvifrons*) from the Vishav Stream of Kashmir Himalaya, India. The fish specimens were sampled for a period of one year from April 2018 to March 2019. The results revealed that the growth coefficient ‘b’ in all the four *Schizothorax* spp. was found very close to 3, indicating an isometric growth pattern. No significant difference in the ‘b’ values of four *Schizothorax* spp. was found when compared with the isometric value (t-test: p > 0.05). The mean value of the ‘K’ for *S. plagiostomus*, *S. esocinus*, *S. curvifrons* and for *S. labiatus* were 0.81 ± 0.07, 0.80 ± 0.08, 0.85 ± 0.08 and 0.88 ± 0.12 respectively. The mean condition factor did not vary across four species (ANOVA: p > 0.05). The present findings could serve as baseline information for the management, stock assessment and future studies of indigenous capture fishery resources of the Vishav Stream and other similar habitats.

**Keywords:** Capture fishery; condition factor; growth coefficient; length-weight relationship; Vishav Stream

1 | INTRODUCTION
The study of the length-weight relationship (LWR) is of great importance in bioecological study of fish as it assists in understanding growth patterns and general wellbeing in a fish population because the LWR of the fish shows variation with respect to environmental conditions of the aquatic ecosystem. Studies on the LWR in fishes reveal important conclusions on various aspects of fish biology and establishes a mathematical relation to determine the average weight of a given fish from the length of an individual fish (Beyer 1987; Koutrakis and Tsikiras 2003); to study growth patterns in a fish population and to convert growth-in-length equations to growth-in-weight for the prediction of weight at the age (Pauly 1993) and the prediction of gonad development, maturity and condition of fish (Fulton 1904; Le Cren 1951). The condition factor (K) is an indicator of the physiological state of the fish which includes its reproductive potential, developmental phases and physical wellbeing (Ali et al. 2014). Therefore, the condition factor is extremely important in predicting the relative robustness of a fish with respect to the environment indicating that the heavier fish of a given length are...
in better condition (Goel et al. 2011). Nevertheless, study on the biological attributes of the endemic species is significant for their conservation due to their restriction in definite habitats (Almaca 1984). Though studies on the length-weight and LWR of indigenous Schizothorax spp. and other cypriniform fishes have been carried out by many workers in different water bodies of the Kashmir Himalayas (e.g. Bhat et al. 2010; Khan and Sabah 2013; Mir et al. 2014; Arafat and Bakhtiyar 2020; Sidiq et al. 2021), but information on the LWR exclusively from the Vishav Stream, the large perennial tributary contributing a major discharge to the river Jhelum of the Kashmir Himalaya, remains scanty. This very stream has tremendous potential of fish resources, especially for the local Schizothorax spp. but due to various anthropogenic influences prevailing in the stream, there is maximum possibility of negative impact on the indigenous fishery resource of this stream in future. Also, as per the literature no previous reports have been found out on LWR of Schizothorax spp. from this stream. Considering the above speculations in mind, the present study was carried out to draw important conclusions about the LWRs of Schizothorax spp. from Vishav Stream of Kashmir Himalaya, India for their future conservation and management strategies.

2 | METHODOLOGY
2.1 Fish sampling and identification
Individuals of Schizothorax spp. were sampled from April 2018 to March 2019 along the three sampling stations of Vishav Stream (Figure 1). A total of 103 specimens of S. plagiostomus, 89 specimens of S. esocinus, 59 specimens of S. curvifrons and 99 specimens of S. labiatus were collected with the help of expert fishermen using cast nets of mesh size 2 cm × 2 cm and 6 cm × 6 cm. Specimens were identified using visual differentiating features and comparing them with the standard taxonomic works of Talwar and Jhingran (1991) and Kullander et al. (1999).

2.2 Estimation of length-weight relationship (LWR) and condition factor (K)
After wiping out the moisture from fish specimens, the total length was measured from the tip of the longest jaw (snout) to the longest part of the caudal fin with the help of digital vernier caliper (Aero Space, China) accurate to 0.1 cm and for weight digital precision balance (Kerro BL50001, India) accurate to 0.1 g was used. The representative specimens of Schizothorax spp. were fixed in 10% buffered formalin solution before long term storage in 10% ethanol.

The LWR was estimated by applying the log transformation equation of $W = aL^b$ (Le Cren 1951) as Log $W = \log a + b \log L$ (Ruiz-Campos et al. 2010), Where ‘W’ represents the total weight of the fish in gram (g), ‘L’ represents the total length of the fish in centimetre (cm), ‘a’ denotes the intercept of the regression curve and ‘b’ symbolizes the regression/growth coefficient or slope of the regression curve. The fish samples were categorised into three groups viz., heavy, isometric and light. When the value of ‘b’ > 3.0 (i.e. weight gain is more than an increase in length) the fish species falls in the heavy group; when the ‘b’ value < 3.0 (i.e. increase in the length is not proportionate to the increase in weight) the fish species...
falls in the light group and when the ‘b’ value = 3.0 (i.e. that is the equal increment of both the parameters), the fish species fall in the isometric group (Ricker 1973; Salam et al. 2005).

The Correlation coefficient (r) and the coefficient of determination (r²) was calculated from the logarithmic transformed data of the total weight and the total length as per standard statistical procedure (Snedecor and Cochran 1967). The K or ponderal index was calculated according to the equation as:

\[ K = \frac{W}{L^3} \times 100 \] (Fulton 1904)

2.3 Data analysis

The data were analysed using computer package ‘Excel-2016’. Student’s t-test was used in order to test the significant difference between the calculated ‘b’ value with the isometric value (b = 3). One way ANOVA was done to determine whether the significant difference may or may not exist among the condition factors of Schizothorax spp.

| TABLE 1 Length-weight relationship and condition factor of four Schizothorax species from Vishav Stream. |
|-----------------|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Species                     | N      | TL range (cm) | TW range (g) | 95% CL of a   | b               | 95% CL of r   | r²              | K (Mean ± SD)   |
| Schizothorax plagiostomus   | 103    | 14.3–37.4     | 23.5–418.6   | 0.150          | 0.13–0.17       | 2.853          | 2.77–2.94      | 0.989 ± 0.978   | 0.81±0.07       |
| Schizothorax esocinus       | 89     | 17.5–42.5     | 44.4–734.2   | 0.127          | 0.10–0.16       | 2.975          | 2.82–3.13      | 0.970 ± 0.941   | 0.80±0.08       |
| Schizothorax curvifrons    | 59     | 14–37.8       | 27–427.3     | 0.110          | 0.09–0.14       | 3.094          | 2.94–3.25      | 0.983 ± 0.967   | 0.85±0.08       |
| Schizothorax labiatus      | 99     | 14.6–35.7     | 26.5–548.6   | 0.145          | 0.11–0.19       | 2.910          | 2.74–3.08      | 0.959 ± 0.921   | 0.88±0.12       |

N, size of sample; TL, total length; TW, total body weight; a, intercept (in antilog format); b, slope of the linear regression; CL, confidence limits; r, coefficient of correlation; r², coefficient of determination.

FIGURE 2 Graphical representation of the length-weight relationship of Schizothorax spp. from Vishav Stream.

3 | RESULTS

A total of 350 individuals representing four species of Schizothorax were collected during one year of sampling period. The comparative LWRs and K are represented in Table 1 wherein, b, r, r² and confidence intervals of ‘a’ and ‘b’ have been determined. The growth coefficient ‘b’ of the fishes was found to range from 2.853 to 3.094 and the r² value ranged from 0.921 to 0.978 with high correlation coefficient (p < 0.05). However, there was no significant difference in the ‘b’ values of all four Schizothorax spp. when compared with the isometric value (b = 3) (t-test: p > 0.05). All of the LWRs among the four Schizothorax spp. were significant (p < 0.05) as indicated by r² value which is close to 1 and indicated a good regression model (Figure 2). The mean (± SD) K for S. plagiostomus, S. esocinus, S. curvifrons and S. labiatus were 0.81 ± 0.07, 0.80 ± 0.08, 0.85 ± 0.08 and 0.88 ± 0.12 indicating the poor condition for study species in Vishav Stream.

4 | DISCUSSION

The study of LWR in fishes helps to determine the growth pattern in a particular fish species by analysing their allometric coefficient ‘b’ which can be isometric (b = 3), positive allometric (b > 3) or negative allometric (b < 3) (Jobling 2002; Morey et al. 2003). Some researchers have agreed that the expected value of ‘b’ is between 2.5 to 4 (Froese 2006), which is supported by several researchers.
around the globe (e.g. Andrade et al. 2015; Lima et al. 2017; Azevedo-Santos et al. 2018). During the isometric growth all dimensions of the fish body grow in the same proportion whereas, in case of positive allometry body becomes round in shape (i.e. width increases) with the increase in length, on the other hand in case of the negative allometry the fish body becomes slimmer, i.e. more elongated (Jobling 2002). The various parameters of LWR in fish show variation with respect to environmental condition, sex, maturity stages of gonads, health condition, habitat, stomach fullness and differences within the species (Wootton 1990; Froese 2006).

During the present study it was observed that a strong correlation existed between length and weight of *Schizothorax* spp. suggesting that relationships were linear and highly significantly. The values of b varied from 2.853 to 3.094 which were within the expected range of 2.5 to 4 (Froese 2006) and are very close to 3 therefore, it may be stated here that the *Schizothorax* spp. inhabiting the Vishav Stream maintained a constant body shape (i.e. an isometric pattern of growth). Our results are in conformity with Bhat et al. (2010) who reported the b value of various *Schizothorax* spp. from river Lidder as follows *S. plagiostomus* (2.9467), *S. esocinus* (3.0034) and *S. labiatus* (3.0997). Khan and Sabah (2013), in their study in the river Jhelum, have reported various b values for different species; *Schizothorax plagiostomus* (2.86), *S. esocinus* (3.08), *S. labiatus* (2.64) and *Schizopyge cuvierfons* (2.69). The variation in the b values of *S. cuvierfons* and *S. labiatus* from our study could be possibly attributed to the several factors like habitat type, habitat conditions, number of specimens examined and change in environmental conditions due to change in climatic pattern from year to year. Mir et al. (2014), recorded the b value in some lacustrine and lotic *Schizothorax* spp. and found following results, *S. plagiostomus* (2.60), *S. labiatus* (2.79), *S. esocinus* (2.98) and *S. cuvierfons* (2.81). The more deviation of b value of *S. cuvierfons* in the present study may be attributed to different growth patterns in lentic and lotic habitats and also due to the different range of lengths used. During the present study overall ‘b’ value was observed close to 3 depicting the overall isometric growth pattern of the *Schizothorax* spp. inhabiting Vishav Stream.

The condition factor is one of the vital parameters derived from the length-weight data which actually determines the fitness of the fish population and its environment. The fish condition factor is an index that determines the extent of wellbeing, relative fitness and is actually an interaction between abiotic and biotic factors which helps to determine the physiological condition of the fish species (Froese 2006). Various natural as well as anthropogenic factors such as dam construction, illegal fishing activity, changing water chemistry of the areas where the fishes inhabit etc. affect the abiotic and biotic configuration of the ecosystem. These factors are responsible for the change in physiology and morphology of aquatic organisms which, in turn, affect the condition factor. Fulton’s condition factor is utilised to assess the health condition and sensitivity of fish which is affected by many factors viz., season, sex, stress, availability of food and water quality (Khalfaf et al. 2003). The present study recorded the mean condition factor for *S. plagiostomus* (0.81 ± 0.07), *S. esocinus* (0.8 ± 0.08), *S. cuvierfons* (0.85 ± 0.08) and *S. labiatus* (0.88 ± 0.12). The condition factor relies on a hypothesis that heavier fish of a given length show better condition (Bagenal and Tsech 1978). A K > 1 is an indication of suitability of a particular water body and environmental conditions for fish growth (Ujjania et al. 2012; Mouloudi-Saleh and Eagedri 2019). When K ≥ 1, there is good feeding level in fish and possess appropriate environmental conditions (Ujjania et al. 2012) and as per nutritional view point, higher value of K could be due to the fat deposition (Maguire and Mace 1993). The poor condition of *Schizothorax* spp. during the present study may be attributed to the insufficient availability of food items, variation in the physicochemical parameters, recurring floods in the stream, abrupt decrease in the water level, poor habitat quality and various anthropogenic pressure that have the profound effect on the fish condition, therefore K also replicates the condition of the fish habitat. Similar to growth pattern, the K is significantly affected by sex, age, seasons, biotic as well as abiotic parameters of the environment which mark the profound effect on the condition of the fish (Barnham PSM and Baxter 1998; Anene 2005). According to our findings, the Vishav Stream is not so much conducive for the good condition of the *Schizothorax* spp. which reflects that there is a need to manage the fluctuating biotic and abiotic factors, especially anthropogenic load in the lower stretches in the form of pollution prevalence, so that the further deterioration in the body condition may be prevented. Thus, the current study can be valuable for conservation biologists and fishery managers as well as future population dynamic studies for indigenous *Schizothorax* spp.

5 | CONCLUSIONS

The *Schizothorax* spp. are the indigenous fish fauna of the Kashmir Himalayas and are mainly inhabitants of snow fed streams and rivers of the valley. The present study provides the first basic information on the length-weight relationship, growth patterns and general condition of these four *Schizothorax* species from the Vishav Stream of Kashmir Himalaya, India. Since the water bodies are under the constant threat of changing their ecological parameters due to various factors for which the indigenous *Schizothorax* species fall easy victims and as such could make them vulnerable to extinction in the near future. The Vishav Stream, which contributes the major discharge
into the famous river Jhelum, has tremendous potential to harbour the indigenous Schizothorax spp. Scanty or negligible reports are available on the bioecology of Schizothorax spp. in the Vishav Stream. The present study provides basic information on the LWR, growth patterns and general condition of four Schizothorax species which could be significant for the fishery managers to execute appropriate guidelines and principles for sustainable management and conservation of indigenous fishery resources.

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CONFLICT OF INTEREST
The authors declare no conflict of interest.

AUTHORS’ CONTRIBUTION
MYA carried out sampling in the field and analysed samples under the guidance of YB (Mentor). The manuscript was designed and finalised equally by both the authors.

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

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