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RESEARCH ARTICLE

Morphometric and meristic characters of snow trout, *Schizothorax labiatus,* inhabiting the Jhelum River and its tributaries

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Abstract. *Schizothorax labiatus* (McClelland) is considered to be one of the most economically important fish species among *Schizothorax* spp. A total of twenty-four morphometric and five meristic characters were examined; 18 of the morphometric characters as percentages of total length and four characters as percentages of head length were studied. It was found that the characters of standard length, fork length, pre pelvic length, pre anal length, and pre dorsal length had the highest correlations with total length, whereas dorsal fin height followed by caudal fin height had the lowest correlations. In percentages of head length post orbital length had the highest correlation whereas snout length had the lowest correlation. Overall, the results revealed that all the morphometric characters exhibited linear relationships and depicted significantly ($P < 0.05$) high degree of correlation, while the meristic characters counted were constant in all sizes of *S. labiatus*, indicating that they were independent of body size. The study provided basic information that will be useful for fish biologists and researchers in the future management and conservation of this fish species.

Keywords: external morphology, fish conservation, management, *Schizothorax labiatus*, wild population

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Introduction

The subfamily Schizothoracinae is a group of specialized fishes that prevail in the torrential mountain streams of the Himalayan region. They are limited to cold regions and especially to localities with snow-fed rivers; thus, these species are generally known as snow trout. Fourteen species of *Schizothorax* were previously identified in the Kashmir Valley, of which only five species are presently reported in the region, including *Schizothorax plagiostomus* Heckel, *Schizothorax curvifrons* Heckel, *Schizothorax esocinus* Heckel, *Schizothorax niger* (Heckel) and *Schizothorax labiatus* (McClelland). Among these five species, *S. plagiostomus*, *S. curvifrons*, *S. esocinus*, and *S. labiatus* are specialized lotic forms, and *S. niger* is found chiefly in lakes. *S. labiatus* is know locally as chush gad and is one of the most economically important Schizothoracine fish species of Kashmir. It is also the main source of livelihood of the vast population living on the banks of the Jhelum River. This species is widely distributed throughout the Himalayan foothills and is an active freshwater fish found mostly in rivers and their tributaries. It is very

sensitive and usually prefers cold, well-oxygenated waters that are free of pollutants.

Studies of morphometric and meristic characters are used mainly to describe fishes. Morphometric characters are the quantifiable characters obtained by measuring the external body parts of fish species (such as total length, standard length, fork length, head length, fin length, eye diameter or ratios among these measurements), while meristic characters are those that can be counted such as fin rays, gill rakers, scales, and so on (Talwar and Jhingran 1991). Taxonomic identification is regarded as the first step in studying a species (Nayman 1965, Langer et al. 2013). Various taxonomic methods are available to identify specimens, and morphometric and meristic techniques are considered to be the most reliable and simplest methods, and they are usually referred as morphological systematics (Nayman 1965). Morphological measurements, meristic counts, size, and shape provide data that support taxonomic identification (Brraich and Akhter 2015a, 2015b) and play important roles in determining taxonomic relationships (Chaklader et al. 2016). It is also reported that morphometric characters can be used effectively to study the evolutionary adaptation of species (Wainwright and Richard 1995). Assessing the well being of fish and determining possible variations among separate stocks of the same species can also be done by studying the morphometric relationships among various body parts (King 2007). Additionally, meristic characters are also useful in identifying species (Simon et al. 2010, Gogoi and Goswami 2015). Morphometric characters of fish species play important roles in determining whether there is any inconsistency among similar species from diverse geographic areas (Naeem et al. 2012).

Significant amounts of work on the morphological and morphometric characters of various fishes have been conducted in different parts of the world (Barlow 1961, Salam and Naeem 2004, Abowei and Hart 2009, Lawson and Whenu 2010, Naeem et al. 2012, Bhendarkar et al. 2014, Brraich and Akhter 2015a, 2015b, Hossen et al. 2016, Nawer et al. 2017, Pant et al. 2018, Kamboj and Kamboj 2019, Kaur et al. 2019). However, very fragmentary information is available on the morphometric and meristic characters of the Himalayan snowtrout species of this region (Bhat et al. 2010, 2013, Qadri et al. 2017, Arafat and Bakhtiyar 2020). Therefore, the present study was conducted to establish a first line of information on the morphometric and meristic characters of *S. labiatus* to foster better conservation and management.

Materials and Methods

Study Area

The study area selected for the present work is the famous Jhelum River of the Kashmir Valley. The Jhelum River is a river located in north-western India and eastern Pakistan. The Jhelum is an 725 km long river with a catchment of 33342 km^2. The Jhelum River lies between 32°58'42" to 35°08'02" N and 73°23'32" to 75°35'57" E. It originates from a splendid spring known as Chashma Verinag and is regarded as the main waterway of the Kashmir Valley. Three fish sample collection sites were selected in this river. Site I (Pampore) was upstream at the geographical coordinates of 34°00'38.35" N and 74°54'35.47" E; site II (Chattabal) was in the middle segment at 34°05'25.68" N and 74°47'03.67" E; and site III (Shadipora) was downstream at 34°10'27.70" N and 74°41'04.41" E. The sampling sites were selected based on the occurrence of fish species at particular sites in the river and also on a survey conducted before going out to do the field work.

Sampling

A total of 94 specimens of different sizes of *S. labiatus* ranging from 16.4 cm to 36.4 cm in total length and 34.4 g to 423.2 g in body weight were collected from the sites mentioned above on the Jhelum River (Fig. 1) from January 2018 to December 2018 with the help of local fishers who deployed fishing gears such as cast nets with mesh sizes of 2 cm × 2 cm and 6 cm × 6 cm.

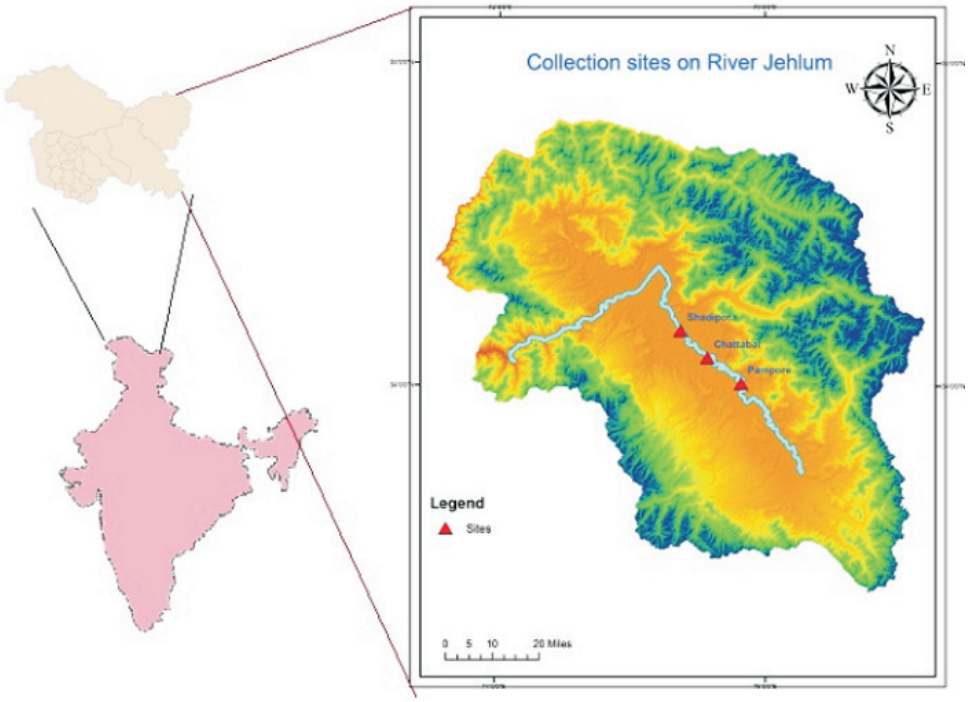

Figure 1. Sampling sites of fish collection from the Jhelum River, Kashmir, India

Identification

The specimens caught in the Jhelum River were examined and identified as *S. labiatus* following Day (1878), and Kullander et al. (1999). Then these fish were transferred to plastic containers containing water and transported live to the wet laboratory at the Department of Zoology, University of Kashmir. These fish were then stocked into a tank and anesthetized (MS-222 at 0.5 g L^{-1} of water) before measuring the morphometric and meristic characters. Dead specimens were preserved in a 10% formaldehyde solution for future reference.

Morphometric and meristic study

Twenty-four morphometric and five meristic characters were examined according to Froese and Pauly (2019). In the present study, each fish was measured to the nearest 0.01 cm with a digital vernier caliper, and total body weight was determined to the nearest 0.01g with a digital electronic balance (Shimadzu UX320G).

The morphometric characters measured were total length, standard length, fork length, pre pectoral length, pre pelvic length, pre dorsal length, pre anal length, pectoral fin length, pectoral fin height, pelvic fin length, pelvic fin height, dorsal fin length, dorsal fin height, anal fin length, anal fin height, caudal fin length, caudal fin height, head length, snout length, eye diameter, pre orbital length, post orbital length, and maximum and minimum body depth. All the body measurements were calculated in proportion to total length except snout length, eye diameter, and pre orbital and post orbital lengths, which were calculated in proportion to head length (Holden and Raitt 1974). The meristic characters studied were the dorsal fin rays, pectoral fin rays, pelvic fin rays, anal fin rays, and caudal fin rays.

Data analysis

The data generated during the current study was subjected to statistical analysis, i.e., correlation and regression analysis using Microsoft Excel 2016. Regression analysis was mainly used to generate

regression equations for each dependent variable to fit the straight linear equation (Y= a + bx), where Y is the dependent variable, a the intercept, b the slope of the regression line and x the independent variable. Scatter diagrams were also plotted between log values of various morphometric parameters, and the linear regression equation was fitted using the least square method as explained by Laevastu (1965) and Snedecor and Cochran (1967). However, the values of correlation coefficient r were tested at a 5% level of significance using the degree of freedom df = n – 1 for all relationships, where n is the number of samples. Student's t-test was used to compare differences in the various morphometric parameters with regard to total length and head length.

Results

In the present study, a total of 24 morphometric characters were studied and their statistical values are presented in Tables 1 and 2. Of the 24 morphometric characters, 18 were analyzed as percentages of total fish length, while four were analyzed with regard to head length.

Eighteen characters were analyzed as proportions of total length (Table 1). Correlation analysis indicated that all the morphometric characters varied proportionally with respect to total length. The highest correlation with regard to total length was for standard length (r = 0.99), fork length (r = 0.99), pre pelvic length (r = 0.98), pre anal length (r = 0.97), and pre dorsal length (r = 0.94), while as the lowest correlation was for dorsal fin height (r = 0.64) and caudal fin height (r = 0.77). Moreover, all the morphometric characters analyzed exhibited a linear relationship and had high degrees of correlation at $P < 0.05$ level of significance. Regression coefficient b of various variable characters (Y) of total length (X) signified that the growth rate in proportion to total length was the maximum for standard length (b = 1.140) and the minimum for pre pectoral length (b = 0.743) (Table 2).

Four characters were analyzed regarding head length (Table 1). Post orbital length (r = 0.80) had significantly ($P < 0.05$) highest correlation with head length, while snout length (r = 0.61) had the lowest correlation. Regression analysis revealed that with regard to head length, the maximum growth rate was noted for pre orbital length (b = 1.008), while the minimum growth was noted for eye diameter (b = 0.525) (Table 2).

The meristic measurements of *S. labiatus* were mainly taken by simply counting the number of fin rays of the fish examined. During the present investigation, five meristic characters were analyzed and the number of dorsal fin rays ranged from 6 to 10 with an average value of 8 ± 0.64, pectoral fin rays 10–19 (15 ± 1.74), pelvic fin rays 9–12 (10 ± 1.87), anal fin rays 5–8 (6 ± 0.77), and caudal fin rays 15–24 (19 ± 0.51) (Table 1). Although these meristic characters showed a little difference among different specimens, the range of different numbers of fin rays in various sizes of *S. labiatus* indicated that meristic counts of *S. labiatus* were not dependent on fish body size.

Discussion

Knowledge of morphometric and meristic characters of fishes is regarded as one of the most vital means of evaluating the evolutionary adaptation of a species with respect to its environment, identifying fish stocks, helping in taxonomic studies, and most importantly providing information on the precise identification of particular fish species (Pant et al. 2018). Morphometric studies are employed widely as vital, cost effective tools for identifying fish stocks, including identifying subtle variations in shape. Stock identification is considered an interdisciplinary field that involves identifying self-sustaining components within natural populations (Rawat et al. 2017). Morphometric studies also help assess the growth patterns and growth rates of species, which are important for the proper exploitation and management of populations of fish species. Growth rates are commonly determined by measuring the physiological

Table1
Minimum, maximum, range difference, mean, SD and coefficient of variation of different morphometric and meristic characters of *S. labiatus* (n = 94) inhabiting the Jhelum River

Characters	Min	Max	Range difference	Mean	SD	CV
Morphometric characters						
%of total length						
Standard length	13.6	31.4	17.8	21.53	4.15	0.19
Fork length	14.9	34.2	19.3	23.23	4.42	0.19
Pre pectoral length	3.0	6.1	3.1	4.45	0.70	0.15
Pre pelvic length	7	15.6	8.6	10.91	2.07	0.18
Pre dorsal length	6.5	15.2	8.7	10.57	2.10	0.19
Pre anal length	10.4	24.6	14.2	16.47	3.22	0.19
Pectoral fin length	0.6	1.6	1.0	0.95	0.21	0.22
Pectoral fin height	1.7	5.7	4.0	3.29	0.76	0.23
Pelvic fin length	0.6	1.5	0.9	0.98	0.21	0.21
Pelvic fin height	1.6	4.3	2.7	3.06	0.65	0.21
Dorsal fin length	1.3	3.9	2.6	2.48	0.55	0.22
Dorsal fin height	2.3	5.3	3.0	3.59	0.64	0.17
Anal fin length	0.8	2.8	2.0	1.58	0.40	0.25
Anal fin height	1.9	5.4	3.5	3.47	0.81	0.23
Caudal fin length	1.5	4	2.5	2.43	0.54	0.22
Caudal fin height	2.1	6.5	4.4	4.66	0.88	0.18
Maximum body depth	3.6	9	5.4	5.64	1.40	0.24
Minimum body depth	1.5	4	2.5	2.45	0.56	0.22
% of head length						
Snout length	0.7	1.9	1.2	1.13	0.29	0.25
Eye diameter	0.5	1	0.5	0.84	0.11	0.13
Pre orbital length	0.8	2.6	1.8	1.50	0.37	0.24
Post orbital length	0.8	3.4	2.6	2.34	0.44	0.18
Meristic characters						
Dorsal fin rays	6	10	4	8	0.64	0.08
Pectoral fin rays	10	19	9	15	1.74	0.11
Pelvic fin rays	9	12	3	10	1.87	0.18
Anal fin rays	5	8	3	6	0.77	0.12
Caudal fin rays	15	24	9	19	0.51	0.02

features of fishes (Soliman et al. 2018). During this study, it was found that various morphometric characters were highly correlated with each other, and there was a significant ($P < 0.05$) high degree of positive correlation between different morphometric parameters with respect to total length and head length. Badkur and Prashar (2015) also found positive correlations among different morphometric parameters with total length of mahseer, *Tor tor* (Hamilton) in the Narmada River. Our results are comparable with findings for red tilapia, for which standard length, body depth, pectoral fin length, pelvic fin length, anal fin length, dorsal fin length, and head length correlated highly with total length, while pre orbital length and eye diameter correlated with head length (Kohinoor et al. 1995). Similar types of inferences are also reported by other authors who also found highly positive correlations among

Table 2
Coefficient of correlation, regression equation, 95% confidence interval of different morphometric characters of *S. labiatus* (n = 94) inhabiting the Jhelum River.

Characters studied	Coefficient of correlation (r)	Coefficient of determination (r^2)	Regression equation (Y = a + bX)	95% Confidence Interval of 'a'		95% Confidence Interval of 'b'	
				Lower limit	Upper limit	Lower limit	Upper limit
Standard length	0.99	0.98	y = 1.140x - 0.286	-0.12	-0.05	0.98	1.14
Fork length	0.99	0.98	y = 1.101x - 0.235	-0.07	0.00	0.97	1.09
Pre pectoral length	0.88	0.77	y = 0.743x - 0.390	-0.50	-0.27	0.66	0.82
Pre pelvic length	0.98	0.96	y = 0.994x - 0.354	-0.40	-0.30	0.95	1.03
Pre dorsal length	0.94	0.90	y = 1.004x - 0.381	-0.47	-0.28	0.93	1.07
Pre anal length	0.97	0.95	y = 1.015x - 0.204	-0.27	-0.13	0.96	1.06
Pectoral fin length	0.81	0.66	y = 0.939x - 1.338	-1.53	-1.14	0.80	1.07
Pectoral fin height	0.82	0.67	y = 1.034x - 0.934	-1.14	-0.72	0.88	1.18
Pelvic fin length	0.79	0.62	y = 0.913x - 1.286	-1.49	-1.08	0.76	1.06
Pelvic fin height	0.86	0.74	y = 1.029x - 0.956	-1.12	-0.78	0.90	1.15
Dorsal fin length	0.87	0.76	y = 1.051x - 1.080	-1.25	-0.91	0.92	1.17
Dorsal fin height	0.64	0.52	y = 0.923x - 0.318	-0.52	-0.10	0.71	1.02
Anal fin length	0.88	0.77	y = 0.960x - 1.499	-1.68	-1.31	0.90	1.04
Anal fin height	0.88	0.78	y = 1.073x - 1.034	-1.20	-0.86	1.00	1.14
Caudal fin length	0.85	0.73	y = 0.996x - 1.011	-1.18	-0.83	0.87	1.12
Caudal fin height	0.77	0.60	y = 0.817x - 0.476	-0.66	-0.28	0.68	0.95
Maximum body depth	0.84	0.71	y = 1.068x - 0.747	-0.94	-0.55	0.92	1.20
Minimum body depth	0.84	0.71	y = 1.014x - 1.032	-1.21	-0.84	0.88	1.14
Snout length	0.61	0.37	y = 0.823x - 0.473	-0.61	-0.33	0.60	1.04
Eye diameter	0.64	0.41	y = 0.525x - 0.409	-0.48	-0.32	0.39	0.65
Pre orbital length	0.75	0.56	y = 1.008x - 0.465	-0.58	-0.34	0.82	1.19
Post orbital length	0.80	0.65	y = 0.835x - 0.160	-0.23	-0.08	0.70	0.96

various morphometric characters (Johal et al. 1994, Bhatt 1997, Negi and Negi 2010, Shah et al. 2011, Naeem et al. 2012, Langer et al. 2013, Brraich and Akhter 2015a, 2015b, Hossen et al. 2016, Qadri et al. 2017, Pant et al. 2018, Kamboj and Kamboj 2019, Kaur et al. 2019, Arafat and Bakhtiyar 2020). In the present study, the highest correlations with total length were with standard length and fork length, which concurs with findings of other authors who analyzed different fish species like *Tor putitora* (Hamilton) (Johal et al. 1994), *Mystus gulio* (Hamilton) (Begum et al. 2008), *Schizothorax* spp. (Bhat et al. 2010), *Schizothorax richardsonii* (Gray) (Negi and Negi 2010), *Onchorhynchus mykiss* (Walbaum) (Shah et al. 2011), *Rastrelliger kanagurta* (Cuvier) (Bhendarkar et al. 2014), *Botia birdi* Chaudhuri (Sharma et al. 2014), *S. curvifrons* (Qadri et al. 2017), *Hypophthalmichthys molitrix* (Val.) (Pant et al. 2018), and *S. labiatus* (Arafat and Bakhtiyar 2020). However, the lowest correlations were with dorsal and caudal fin lengths, which was similar to reports regarding fish species like *H. molitrix* (Pant et al. 2018) and *S. labiatus* (Arafat and Bakhtiyar 2020). In proportion to head length, there was a significant ($P < 0.05$), maximum correlation with post orbital length, which concurred with results reported by other authors in different fish species like *Nandus nandus* (Hamilton) (Goswami and Dasgupta 2007),

S. richardsonii (Negi and Negi 2010), *B. birdi* (Sharma et al. 2014), and *Labeo rohita* (Hamilton) (Kaur et al. 2019), while the minimum correlation was for snout length, which concurred with findings reported for *Leiognathus splendens* (Cuvier) (Gulati and Acharya 2001) and *Gonialosa manmina* (Hamilton) (Masud and Singh 2018).

During the current study, it was also noted that in proportion to total length, the maximum growth was calculated for standard length, while as the minimum growth was noted for pre pectoral length, which was revealed by regression analysis. Analogous results were noted in a similar kind of regression analysis done on *S. plagiostomus* from the Lidder River in the Kashmir Valley in which maximum growth in proportion to total length was calculated for standard length and minimum growth was noted for pre pectoral length, and in *S. esocinus* maximum growth was noted for standard length and minimum for maximum body depth (Bhat et al. 2013). Various authors (Johal et al. 2003, Alam et al. 2013, Sharma et al. 2014, Arafat and Bakhtiyar 2020) reported comparable results in equivalent types of analyses.

Meristic characters include countable, repeated structures that permit evaluating the class and species of fishes (Soliman et al. 2018). In the present study, it was found that the range of values of the meristic characters studied was well within the reported ranges of other authors who conducted research on different fish species like *B. birdi* (Sharma et al. 2014), *Crossocheilus latius* (Hamilton) (Brraich and Akhter 2015b), and *Garra gotyla* (Gray) (Brraich and Akhter 2015a). Moreover, these characters were somewhat constant in all groups of fishes from different length groups and did not vary with increases in total weight or total length. Our results from the current study are in agreement with the findings of other authors who also found that meristic characters remain independent of body size and weight (Zafar et al. 2002, De Silva and Liyanage 2010, Hazharika et al. 2011, Langer et al. 2013, Safi et al. 2014, Gogoi and Goswami 2015, Soliman et al. 2018). In contrast to these, variations in meristic characters were also reported by a number of authors analyzing different fish species (Al-Hassan 1987, Watanabe 1998, Jaiswar et al. 2004, Koshy et al. 2008, Brraich and Akhter 2015a, 2015b). Variations reported for meristic characters can be caused by many factors including temperature (Al-Hassan 1987, Sfakianakis et al. 2011), genetics (Yousefian 2011), nutrient availability, and seasonal variations.

Conclusion

The highest correlations to total length were for standard length, fork length, pre pelvic length, pre anal length, and pre dorsal length, while the lowest correlations were for dorsal fin height and caudal fin height. Post orbital length had the highest correlation with head length, while the lowest correlation was for snout length. All the morphometric characters studied exhibited linear relationships and significantly high degrees of correlation. Therefore, this suggested that most of the morphometric characters analyzed in the present study exhibited direct proportional increases to each other. Moreover, the five meristic characters analyzed showed little difference among the different specimens of fish, which indicated that the meristic counts were generally independent of fish body size. The data generated in the present study will be useful for developing strategies for establishing better management and conservation programs for this fish species.

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