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RESEARCH ARTICLE

Length-weight relationship and morphometric and meristic variation in Dinnawah snowtrout, *Schizothorax progastus*, inhabiting the Suru River and its tributaries of Kargil, Ladakh Region

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Abstract. Morphometric variations across fish stocks have long been acknowledged as useful for determining population structure and identifying stocks. *Schizothorax progastus* (McClelland) is a common, dominant fish in most cold-water rivers and is considered a good sport fish and also delicious in taste. For the people of Ladakh, this fish is a significant source of nutrition. A total of 70 specimens were collected for this study. A total of 24 morphometric and six meristic characters were studied, with 18 morphometric characters assessed as percentages of total length and four characters analyzed as percentages of head length. Standard length and fork length had the strongest correlations with total length at 0.98 and 0.99, respectively. Overall, the findings demonstrated that all morphometric features had linear correlations and exhibited a high degree of association ($P < 0.05$). The meristic counts examined in this study were consistent among all fish of various sizes, suggesting that body size had no effect on them. The biological information generated from this study serves as an essential guideline for future management and conservation of *S. progastus*, an important food source in the Ladakh, Trans Himalayan region.

Keywords: conservation management, length-weight relationship, *Schizothorax progastus*, stock identification, wild population

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Introduction

One of the most important components of the Trans-Himalayan region is its unique animal biodiversity, which includes fishes. The water bodies of Ladakh are comprised of very few streams and rivers fed by Himalayan glaciers. Kargil is the second largest town in Ladakh and one of the two districts in the region. The Suru River runs through Kargil. The river's source is in the Himalayan mountain ranges of northern India, specifically in the Nun-Kun and Zanskar mountain ranges. The Suru River is unique in that it is largely turbid throughout the summer and has a frozen surface layer during the winter. This river is the major source of water for irrigation purposes. The flow of the river fluctuates over time. The river is a catchment region for all of the local natural valleys and drains, such as the Wakha stream and other nallahs. Fisheries are major sources of food and income for the people of the mountains. Due to its high altitude, Ladakh fish fauna is dominated by high-altitude fishes, the majority of which are snowtrout and loaches. *Schizothorax progastus*, popularly known as the Dinnawah snowtrout, is a Cyprinidae fish that inhabits cold streams and rivers. The International Union for the Conservation of Nature (IUCN) red list of threatened species classifies it as of least concern (Jha and Rayamajhi 2010). This is a common hill stream fish that is important in maintaining the stream's biological equilibrium, hence research on its conservation and management is critical.

The length-weight relationship (LWR) is used extensively in fisheries to estimate the weight for a given length of fish and additionally to calculate the biomass once the length-frequency distribution is understood (Froese 2006, Froese et al. 2011, Akhtar et al. 2021). Biometric studies, which provide information on fish species enabling an estimated evaluation of their biomass, are currently considered a keystone tool for studying the well-being of fishes and their successful conservation (Zargar et al. 2012). In biometric research, it is critical to assess fish growth parameters, such as weight and length, and also overall health, which is influenced by a variety of biological and environmental factors (Morato et al. 2001). It is essential to know about the general fitness of a fish in a given environment, thus it is an important component for the management of fishes both in natural ecosystems and in aquaculture systems because it is useful to know the average weight of a specific length group of fish specimens to determine the health status of a stock (Beyer 1991). The LWR is one of the most frequently used strategies for obtaining accurate biological data, and it is critical in fishery assessments. This type of study is considered very important in fish biology because the length of a fish determines its weight. Further, LWR studies are conducted to gather data on fish growth and condition, and to gain an understanding of fish growth patterns (Le Cren 1951, Tesch 1968, Reshi and Ahmed 2020). Additionally, knowledge of LWRs is also helpful in determining how long fishes will live, how fast they will grow, and how fit they are in general (Sheikh and Ahmed 2019, Reshi and Ahmed 2020, Sidiq et al. 2021). Several factors affect fish LWRs, including the length range of the specimens collected, habitat, sex, number, seasonality, food, and stomach fullness (Karachle and Stergiou 2008, Froese et al. 2011, Sharma et al. 2015, Sidiq et al. 2021). In addition to LWRs, morphometric and meristic counts are used as reliable methods for species identification (Jan and Ahmed 2020). Fish morphological variation may be a reliable indicator of population structure over short periods. It is frequently induced by the environment in aquatic ecosystems, and both abiotic and biotic habitat characteristics can show significant geographical or temporal fluctuations (Langerhans et al. 2007). Several studies show that standard morphometric features can be used to distinguish stocks (Quilang et al. 2007, Bektas and Belduz 2009, Jan and Ahmed 2020). For the taxonomic study of fishes, morphometric measurements and their statistical relationships are regarded as essential (Tandon et al. 1993).

The genus *Schizothorax*, commonly known as snowtrout, is abundant in Himalayan and central Asian streams and rivers (Mir et al. 2012). *S. progastus*, the Dinnawah snowtrout, is a ray-finned fish found primarily in India and Nepal, particularly in highland streams and deep run backwaters. It breeds in the upper reaches of rivers and descends after spawning. Although LWRs of many fishes have already been investigated widely all around the world (Oscoz et al. 2005, Verreycken et al. 2011, Mir et al. 2012, Sarkar et al. 2013, Jabeen et al. 2017, Reshi and Ahmed 2020, Sidiq et al. 2021), no research on the biology of *S. progastus* from the Ladakh Trans-Himalayan region has been done yet, despite the fact that only a few studies on the morphometric and meristic traits of *S. progastus* have been conducted worldwide (Dastagir et al. 2014, Akhtar et al. 2021, Regmi et al. 2021). The purpose of this study is to obtain a fundamental understanding of the biology of the species inhabiting the Suru River of Kargil, Ladakh region. This study will provide baseline information regarding the growth of *S. progastus*, and this information can be used for future research work. The current study may also be able to determine the species pattern of development, general state, and morphometrics in the native environment for effective conservation and management.

Materials and methods

Study Area

The Ladakh region is mainly known as the initial source of the Indus River system fed by various tributaries like the Zanskar, the Nubra, the Suru, etc. The Suru River lies between Lat: 33.832917°N to Long: 76.21861°E in Kargil, Ladakh. It is fed by the Panzella glacier, which is located near the Drang Drung Glacier of Pensi La and covers a distance of about 185 km before its confluence with the Indus River. The Suru River travels through the Kargil district for the most part and finally it joins the Indus River in Nurla.

Three different locations along the river were chosen as fish sampling sites mainly on the basis of various ecological, biological, and microbiological factors including physico-chemical properties, availability of fish and its food, and the quality and density of plankton. These sites represent the upper, middle, and lower reaches of the river. The upstream site was located at 34°0355 N and 76°1018 E; the middle site was located at 34°1720 N and 75°5754 E; and the downstream site was located at 34°3521 N and 75°5959 E as shown in the study area map that was created using ArcGIS Version 10.7.

Sampling

From May to October 2021, 70 specimens of *S. progastus* of various sizes ranging from 16.4 to 30.5 cm total length and 83 to 484 g body weight were caught with the assistance of local fishers. Thirty specimens were caught in the upper stream and 20 specimens each from middle and lower streams mentioned above of the Suru River (Fig. 1). The fish were caught using a variety of fishing gears like gill nets, cast nets, etc. during the sampling period. After collection, these specimens were temporarily stored in ice-filled cooling boxes before being brought to the research laboratory Department of Zoology, University of Kashmir. Using the standard taxonomic keys, the specimens were first systematically identified (Talwar and Jhingran 1991, Jayaram 1999). A digital vernier caliper was used for the different morphometric measurements in cm (to the nearest 0.01 cm) while a digital electronic

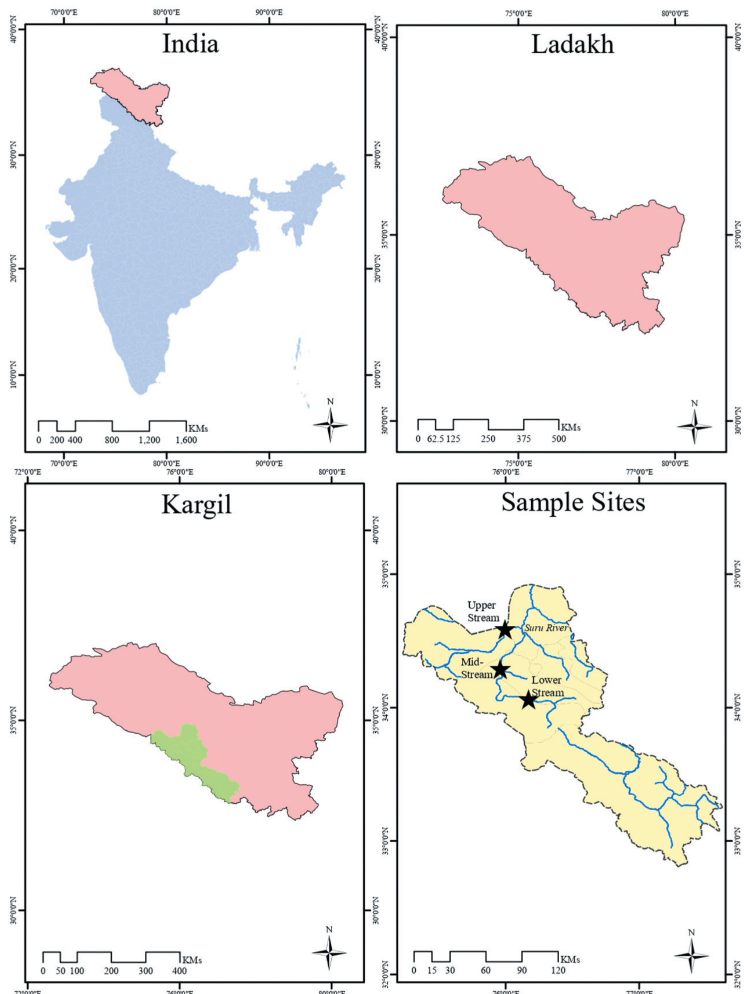

Figure 1. Map showing the collection sites of *Schizothorax progastus* from Suru River, Kargil, Ladakh Region.

balance (Shimadzu UX320G) having was used to obtain total body weight (TW) in grams (to the nearest 0.01 g). A total of 24 morphometric features and six meristic counts were considered, and statistical analysis was performed to determine averages, standard deviations, % of TL and HL, correlation coefficients, ranges, range differences, 95% confidence intervals, and regression equations. LWRs were computed using data on *S. progastus* length and weight measurements. The LWRs were calculated using the following formula (Le Cren 1951):

$$W = aL^b$$

where, W = weight of the samples in g, L = length of the sample in cm, a = constant (intercept), b = constant (slope of regression line).

Statistical analysis

Regression analysis was used to compare the growth rates of various body parts to total length (TL) and head length (HL), using the following formula:

$$Y = a + b\,X$$

where, X denotes total length (an independent variable); Y represents morphometric variables (dependent variables) including fork length, standard length, pre-dorsal length, and so on; a is the regression line intercept, and b is the regression line slope.

Other statistical calculations such as mean, standard deviation, regression equation, and correlation coefficient (r) between TL, HL, and the rest of the body parameters were calculated during the current study using SPSS Version 26.0.

Results

The LWRs and other morphological features of *S. progastus* specimens (n = 70) were considered for the analysis, and the results are presented in Table 1. TL was between 16.4 and 30.5 cm, while TW was noted in the range of 83 – 484 g. The LWR equation was written as:

$$Log\ W = 0.139 + 3.152 logL$$

The results of the correlation study showed that all morphometric variables altered proportionately with TL (Table 2). Parameters with the highest correlation in relation to TL were standard length and fork length, whereas pelvic fin length and dorsal fin height showed the lowest correlation (Table 2). In terms of head length, four characters were examined (Table 1). Post orbital length had the most significant ($P < 0.05$) correlation with head length, whereas the eye diameter had the least correlation (Table 2). Table 3 illustrates the meristic counts, including the number of lateral line scales, pectoral, pelvic, dorsal,

Table 1
Mean, maximum, minimum, range difference, standard deviation, and %TL of the various morphometric characters of *Schizothorax progastus* (n = 70)

Characters studied	Min	Max	Mean	SD	% TL
Total length (TL)	16.4	30.5	23.76	4.26	
Standard length (SL)	14.5	29.5	22.22	4.28	93.51
Fork length (FL)	15.5	30	23.03	4.30	96.92
Pre pectoral length	2.5	4.8	3.65	0.69	15.36
Pre pelvic length	9.4	17.5	13.22	2.74	55.63
Pre dorsal length	8.2	15	11.63	2.31	48.94
Pre anal length	13.5	21.5	17.55	2.73	73.86
Pectoral fin length	1	1.8	1.24	0.26	5.21
Pectoral fin height	2.2	3	2.48	0.28	10.43
Pelvic fin length	1	1.5	1.20	0.22	5.05
Pelvic fin height	2	3	2.44	0.32	10.26
Dorsal fin length	1	2	1.55	0.27	6.52
Dorsal fin height	2	3.5	2.55	0.41	10.73
Anal fin length	1	1.6	1.36	0.22	5.72
Anal fin height	2	3.5	2.66	0.46	11.19
Caudal fin length	2	3.5	2.66	0.46	11.19
Caudal fin height	3	3.8	3.47	0.24	14.60
Maximum body depth	4.2	5.8	4.93	0.52	20.74
Minimum body depth	1	2	1.47	0.30	6.18
Characters studied	**Min**	**Max**	**Mean**	**SD**	**% HL**
Head length (HL)	2	4.5	3.57	0.61	
Snout length	0.6	1.10	1.12	0.32	31.37
Pre-orbital length	1	1.6	1.31	0.21	36.69
Post orbital length	1.5	2.8	2.18	0.35	61.06
Eye diameter	0.5	1	0.84	0.11	23.52

Table 2
Regression equation, coefficient of determination, and 95% confidence intervals for various morphometric traits of *Schizothorax progastus* (n = 70)

Characters studied	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
% of total length						
Standard length (SL)	0.98	Y = 1.076X - 0.135	–0.22	–0.16	1.09	1.14
Fork length (FL)	0.99	Y = 1.041X - 0.070	–0.12	–0.07	1.04	1.08
Pre pectoral length	0.87	Y = 0.949X - 0.745	–0.83	–0.61	0.84	1.00
Pre pelvic length	0.92	Y = 1.068X - 0.350	–0.46	–0.26	1.02	1.16
Pre dorsal length	0.91	Y = 1.021X - 0.341	–0.59	–0.36	1.05	1.22
Pre anal length	0.90	Y = 0.798X + 0.146	–0.32	–0.19	1.04	1.14
Pectoral fin length	0.75	Y = 0.933X - 1.192	–2.22	–1.61	1.16	1.60
Pectoral fin height	0.71	Y = 0.498X - 0.289	–1.43	–1.12	1.14	1.37
Pelvic fin length	0.68	Y = 0.822X - 1.052	–2.89	–2.02	1.51	2.14
Pelvic fin height	0.89	Y = 0.665X - 0.526	–1.96	–1.57	1.41	1.69
Dorsal fin length	0.81	Y = 0.922X - 1.078	–1.95	–1.58	1.41	1.68
Dorsal fin height	0.68	Y = 0.676X - 0.523	–1.37	–1.03	1.07	1.33
Anal fin length	0.87	Y = 0.868X - 1.060	–2.78	–2.30	1.85	2.21
Anal fin height	0.80	Y = 0.824X - 0.709	–2.00	–1.50	1.35	1.72
Caudal fin length	0.80	Y = 0.824X - 0.709	–2.00	–1.50	1.35	1.72
Caudal fin height	0.73	Y = 0.331X + 0.086	–0.74	–0.45	0.75	0.96
Maximum body depth	0.70	Y = 0.469X + 0.048	–0.32	0.04	0.43	0.70
Minimum body depth	0.79	Y = 1.007X - 1.219	–0.79	–0.19	0.27	0.71
% of head length						
Snout length	0.87	Y = 0.854X - 0.473	–0.46	–0.12	0.27	0.89
Pre-orbital length	0.68	Y = 1.308X - 0.654	–0.33	0.03	0.14	0.82
Post orbital length	0.88	Y = 1.536X - 0.568	–0.20	0.02	0.61	1.02
Eye diameter	0.46	Y = 0.575X - 0.611	–0.37	–0.31	0.03	0.14

Table 3
Meristic characters of *Schizothorax progastus* (n = 70)

Meristic characters	Mean (cm)	Median	Mode
No. of lateral line scales	102.60	102.0	103.0
Pectoral fin rays	14.10	14.0	15.0
Pelvic fin rays	9.60	10.0	10.0
Dorsal fin rays	9.50	10.0	10.0
Anal fin rays	6.80	7.0	7.0
Caudal fin rays	19.9	20.0	20.0

anal, and caudal-fin rays. The meristic features varied little among the different fish specimens in this investigation, indicating that the meristic counts were unaffected by the body size of the fish.

Discussion

Fish are extremely perceptive to their surroundings, and it is generally recognized that morphological properties alter in relation to a range of environmental factors like temperature and food availability (Allendorf and Phelps 1980, Wimberger 1992, Jan and Ahmed 2020, Sidiq et al. 2021). Many factors influence fish length-weight connections, including the length range of individuals studied, populations, environments, seasons, sex, diet, and gut contents (Karachle and Stergiou 2008, Sharma et al. 2015). The LWR is crucial in fisheries biology and population dynamics, as many stock assessment approaches use it (Froese 2006). The value of variable b in the LWR is determined by the body shape and weight of the fish species (Gubiani et al. 2009). Despite considerable differences in fish morphologies among species, a value of *b* near 3 suggests that fish growth is isometric, while values markedly different from 3.0 indicate allometric fish growth (Tesch 1971, Zar 2010, Reshi and Ahmed 2020). According to Pauly (1984), a value of b of less than 3 indicates thinness as a fish increases in length, whereas a value greater than 3 indicates plumpness.

The current study's *b* value was 3.152, which indicated positive allometric growth. During the current study, all of the fish specimens collected were typical dwellers of a flowing habitat in their distributional range. The value of *b* in *S. progastus* was found to be 2.50 by Akhtar et al. (2021) from the Neelum and Jhelum rivers in Azad Kashmir, Pakistan. However, Dastagir et al. (2014) reported the *b* value in the same fish as 2.508 from the Zhob River (Baluchistan). Variations in *b* value seen in this study compared to other studies might be attributed to changes occurring in environmental factors such as temperature, environment type, access to food in their native habitat, and fish performance in various environments (Al Nahdi et al. 2016, Sheikh and Ahmed 2019).

Swain and Foote (1999) stated that environmental factors can also influence phenotypic variation in morphological features or meristic counts. Throughout this study, various morphometric variables were found to be substantially associated with one another, with a remarkably high degree of positive association between diverse morphometric features in terms of total length and head length. The morphometric parameters showed a proportional positive increase with increasing fish length. Our findings are comparable to those of red tilapia, in which total length was strongly correlated with standard length, pectoral fin length, pelvic fin length, dorsal fin length, anal fin length, and body depth, while preorbital length and eye diameter were both correlated with head length (Jan and Ahmed 2020, Sidiq et al. 2021). Many authors have reported similar types of inferences, as well as highly positive correlations among various morphometric characters (Shah et al. 2011, Langer et al. 2013, Pant et al. 2018, Kaur et al. 2019, Arafat and Bakhtiyar 2020). In this study, the standard length and fork length showed the strongest relationship with overall length, which supports the findings of other authors who studied other fish like *Schizothorax richardsonii* (Gray) (Negi and Negi 2010), *Oncorhynchus mykiss* (Walbaum) (Shah et al. 2011), *Rastrelliger kanagurta* (Cuvier) (Bhendarkar et al. 2014), *Botia birdi* (Chaudhuri) (Sharma et al. 2014), *Schizothorax curvifrons* (Heckel) (Qadri et al. 2017), *Hypophthalmichthys molitrix* (Valenciennes) (Pant et al. 2018), *Schizothorax labiatus* (McClelland) (Jan and Ahmed 2020), *S. progastus* (Akhtar et al. 2021), and *Crossocheilus diplochilus* (Heckel) (Sidiq et al. 2021).

Meristic characteristics are countable, repeating structures that allow fish to be classified and assigned to species (Langer et al. 2013, Jan and Ahmed 2020). The range of values for the meristic features assessed in this study was observed to be well within the stated ranges of previous authors who investigated various fish species, such as *Garra gotyla* (Gray) (Brraich and Akhter 2015), *S. labiatus* (Jan and Ahmed 2020), and *C. diplochilus* (Sidiq et al. 2021). The meristic counts were nearly consistent across all length groups of fish with varying body lengths, implying that the body length had no effect on meristic counts (Zafar et al. 2002, Jan and Ahmed 2020). Our findings are consistent with those of other researchers who claim that meristic traits are unaffected by body size or weight (Talwar and Jhingram 1991, Gogoi and Goswami 2015, Soliman et al. 2018, Jan and Ahmed 2020, Sidiq et al. 2021). Contrary to this, many authors reported variations in meristic characters of various fish species (Watanabe 1998, Koshy et al. 2008, Brraich and Akhter 2015).

Conclusions

Information on morphometric and meristic characters for *S. progastus* in the Suru River of the UT Ladakh is lacking, despite the fact that only a few studies on morphometric and meristic traits of *S. progastus* have been conducted worldwide. As a result, this is the first comprehensive and useful study to provide baseline biological information on the morphometrics, meristic, and LWRs of *S. progastus* that can be used to determine the stock structure of the species. These findings will aid in the development of appropriate regulations to regulate *S. progastus* fisheries in this region.

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Author contributions. A.Z. collected the materials and analyzed the data, I.A. and S.M. Ahmad designed the study and concept and drafted and revised the manuscript.

Ethical statement. This study's data collection did not necessitate the use of experimental animals, and all fishing activities were carried out in conformity with national laws and regulations.

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