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RESEARCH ARTICLE

Length–Weight Relationships and Condition Factor of Snow Trout, *Schizothorax richardsonii* (Gray, 1832) From Different Rivers of the Himalayan Region in India

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Abstract The present study describes the length–weight relationship and condition factor of a vulnerable indigenous snow trout, *Schizothorax richardsonii* (Gray, 1832) of the sub-family Schizothoracinae from different Himalayan rivers/streams of India. A total of 254 samples of *S. richardsonii* were measured from the rivers Ravi, Sahoo, Sewa (Chamba District, H.P.), Teesta (North West Bengal) and Indus (Leh, Jammu and Kashmir). The values of regression coefficient (b) ranged from 2.44 to 3.11 ($r^2 > 0.97$). The values of regression coefficient in rivers Sewa, Ravi and Sahoo were 3.03, 3.07 and 3.11, respectively (close to 3.0) indicating isometric growth; in rivers Teesta and Indus, the values of *b* were below isometric value (significantly <3.0) demonstrating negative allometric growth. The values of condition factor showed significant differences between rivers and ranged from 0.60 to 1.27. The findings of the present study could be useful to help in conservation and sustainable fisheries management of this indigenous species.

Keywords Condition factor · Himalayan rivers · Length–weight relationships · *Schizothorax richardsonii*

Introduction

Schizothorax richardsonii inhabits streams and rivers of Himalayan and sub-Himalayan regions. These streams usually have rocky substratum with fast water velocity. In the group Schizothoracid, the species is widely distributed all along the Himalayas in India, besides Pakistan, Tibet, Nepal, North West Bengal, and Afghanistan [1]. *Schizothorax richardsonii* inhabits rivers, preferring to live among rocks, near big submerged stones and shows herbivore feeding mainly on algae, aquatic plants and detritus [2]. In central Himalayas, *S. richardsonii,* locally known as 'Asela' has fishery importance and constitutes a principal component of subsistence food fishery of the region. This species is less abundant in Ladakh region of Himalayas, in comparison to other regions [3]. In the recent past, the population of this species in the Himalayan region has declined significantly due to introduction of exotics, habitat alterations, overfishing and increased human pressure [4–6], hence assessed as vulnerable [7]. The fish is highly important to aquatic biodiversity of the region and contributes significantly to the food basket and economy of hill fisherfolks. However, there is limited information available on the biological aspects of this species except for a few on breeding, biology [1, 8, 9] and length–weight relationship of *S. richardsonii* from some regions [10]. But the extensive data on length–weight relationship and condition factor of this species from various rivers of Himalayan regions for comparative study are still lacking in literature as well as in fish data base [11].

The aquatic ecology of these rivers of Himalayan region have changed considerably in last few decades due to construction of dams, illegal fishing and other natural and anthropogenic factors, which have resulted in the decreased water quantity and quality and increased the pace of species extinction. As the result these factors are also expected to have adverse effects on the physiology and morphology of the aquatic animals such as fishes. Morphometric parameters such as length–weight relationship, condition factor, growth, and mortality of fishes form the basis for

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Fig. 1 Location map of sampling sites in the rivers Ravi, Indus and Teesta in Northern Himalayan regions

fishery management decisions [12]. The mathematical relationship between length and weight of fishes is a practical index suitable to understand their growth profile and general fitness, to compare the morphology between species or the same species across different geographical regions [13]. In fish, the condition factor (*K*) reflects, through its variations and information on the physiological state of the fish in relation to its welfare and is used to indicate suitability of an environment [14]. The study of the condition factor is, thus, important for understanding the life cycle of fish species and contributes to the adequate management of the species and, thereby, to the maintenance of equilibrium in the ecosystem.

Recent studies dealing with condition factor and length–weight relationships of important species are well documented in many species of fishes, some of those by Serajuddin [15], Prasad and Ali [16] and Gupta et al. [17]. However, to date there has been no similar study available of *S. richardsonii* from rivers Indus, Ravi and Teesta and its tributaries. Therefore, the present study is aimed to provide baseline data on LWR and condition factor of this species in different rivers/streams of Himalayan regions in India. This is believed to be the first report of LWR and condition factor for this species from these rivers. The information from this study will be useful to support conservation and management of this important indigenous fish species in the rivers/streams of this region.

Material and Methods

Sampling Sites

The study area was selected in the rivers Indus, Ravi with its two tributaries and Teesta in the Himalayan regions of India (Fig. 1). Indus river originates at the sacred lake of Manassarovar in Tibet and flows through regions between the Zanksar range and the Ladakh range into Jammu and Kashmir and the rest in Pakistan. Ravi river, a major tributary of Indus river, originates from Bara Bangahal (at an elevation of 4,229 m; North latitude 32°33′N, and East longitude 76°07′E) in Chamba district of Himachal Pradesh. The river flowing through Himachal Pradesh with ~150 kms in district Chamba and Punjab state of India and traverses a total length (TL) of 720 km before finally merging into the Chenab river (a tributary of Indus) at Indo-Pak border [18]. In between Sahoo, and Sewa are small tributaries of Ravi, which contributes a lot of run-off to the Ravi in Chamba district of Himachal Pradesh before leaving it finally at Kheri. The TL of these two streams are ~50–60 km each within Chamba (H.P.). River Teesta is a tributary of Brahmaputra river in eastern Himalayan region, flowing through the state Sikkim and West Bengal [19].

The samples of *S. richardsonii* were collected randomly from 14 identified sampling locations of selected rivers during November 2008 to October 2011. Out of 14 locations,

Table 1 Total length and weight data, regression parameters, 95 % confidence interval and condition factor for *Schizothorax richardsonii* in different rivers/streams of northern Himalayan region of India

Rivers/ streams	*n*	Total length (cm)		Weight (g)		r^2	Regression Parameters				K (Mean ± SD)
		Min–max	Mean ± SD	Min–max	Mean ± SD		a	b	95 % CI of a	95 % CI of b	
Ravi	118	8.6–34.0	18.5 ± 4.5	16.0–328.0	60.0 ± 57.8	0.97	−2.216	3.07	−2.326 to −2.094	2.975–3.159	0.75 ± 0.08
Sahoo	42	12.2–35.0	19.4 ± 4.9	16.0–352.0	71.4 ± 67.0	0.98	−2.246	3.11	−2.242 to −2.069	2.972–3.250	0.79 ± 0.08
Sewa	21	15.0–39.5	23.0 ± 6.0	20.0–378.0	89.0 ± 83.5	0.98	−2.267	3.03	−2.522 to −2.014	2.846−3.221	0.60 ± 0.04
Indus	27	12.0–33.0	26.1 ± 6.2	28.0–381.0	230.7 ± 113.7	0.99	−1.291	2.55	−1.465 to −1.118	2.424–2.671	1.20 ± 0.18
Teesta	46	16.0–40.0	25.8 ± 6.1	65.0–550.0	243.6 ± 125.6	0.97	−1.121	2.44	−1.319 to −0.923	2.302–2.584	1.27 ± 0.21

N number of individuals, r^2 correlation coefficient, *a* intercept, *b* regression coefficient (slope), *K* condition factor

six were located in the river Ravi, two points in each stream, Sahoo and Sewa at Chamba district of Himachal Pradesh (32°55′N, 076°08′E, Altitude 732–2,029 m), and further two sites in each rivers Indus (33°54′N, 077°44′E, Altitude 3,195 m) and Teesta (27°17′N, 088°27′E, Altitude 747 m) at Leh in Jammu and Kashmir and Udalbadi in North West Bengal, respectively. The sampling points were located from upstream to downstream in each river and sampled randomly. All the sampling sites were selected on the basis of pre-field survey and the occurrence of fish species at particular site in the rivers. The sampling was conducted in the rivers Indus and Teesta during October 2008 to March 2010 whereas from the rivers Ravi, Sahoo and Sewa during November 2010 to October 2011. The fish were collected by cast nets of 1.25 × 1.25 cm mesh sizes with the help of local fishermen and subsequently identified using the standard keys [20]. The TL of fresh fish samples was measured on the spot with a digital caliper to the nearest 0.1 cm whilst body weight (W) was determined with a digital balance to the nearest 0.1 g.

Length–Weight Relationship and Condition Factor

A total of 254 individuals of *S. richardsinii* were collected and measured for analysis. The linear allometric model was used to estimate parameters *a* and *b* by $\log_{10}$-transformed TL and weight. The statistical relationship between TL and total body weight of the fish was derived by using the following formula [21]:

$$\log W = \log a + b \log L$$

where W is weight of fish in grams, a is intercept (constant), L is length of fish in cm and b is regression coefficient (slope).

The degree of well-being or relative robustness of the fish is expressed by 'coefficient of condition' (also known as condition factor). Variations in the coefficient of condition primarily reflects the state of sexual maturity and degree of nourishment. The condition factor *K* [22] was estimated by the following relationship:

$$K = 100W/L^3$$

where K is condition factor, W is weight (g), L is length (cm).

All the statistical analysis was performed by using SPSS version 11.5 and GraphPad Prism software version 5.0. To compare the variations in length weight data among different regions, 95 % confidence limits were used. The Tukey's multiple comparison test was also performed for statistical comparison in condition factors of fishes.

Results and Discussion

A total of 254 samples of *S. richardsonii* were examined from the rivers Ravi, Sahoo, Sewa (Chamba District, H.P.), Teesta (North West Bengal) and Indus (Leh, Jammu and Kashmir). The details of variations in the regression coefficient (b), intercept (a), correlation coefficient (r^2), and number of specimens (N) of the length-weight relationships in different rivers are shown in Table 1. In this study, the mean values of estimates of parameter *b* ranged from 2.44 to 3.11 and showed significant variations ($P < 0.01$) within species in different rivers. The values of regression coefficient (*b*) in rivers Ravi and Sahoo were 3.07 and 3.11 respectively, and exhibited isometric growth patterns (increase in body thickness or plumpness as they grow); in rivers Teesta and Indus, the values of *b* were below isometric value (b = 3.0) indicating allometric negative growth. In Sewa, the value of b was 3.03 (close to 3.0) also exhibiting isometric growth (Fig. 2). The same pattern of growth of *S. richardsonii* in Ravi and its tributaries indicated that there were no significant differences found. The similar mode of variation in regression coefficient in *S. plagiostomus* were also reported from Jammu region (tributaries of river Ravi) [10, 23] and in *Schizothorax niger* from Dal lake Kashmir [24]. The value of $b < 3.0$ indicates a decrease in condition

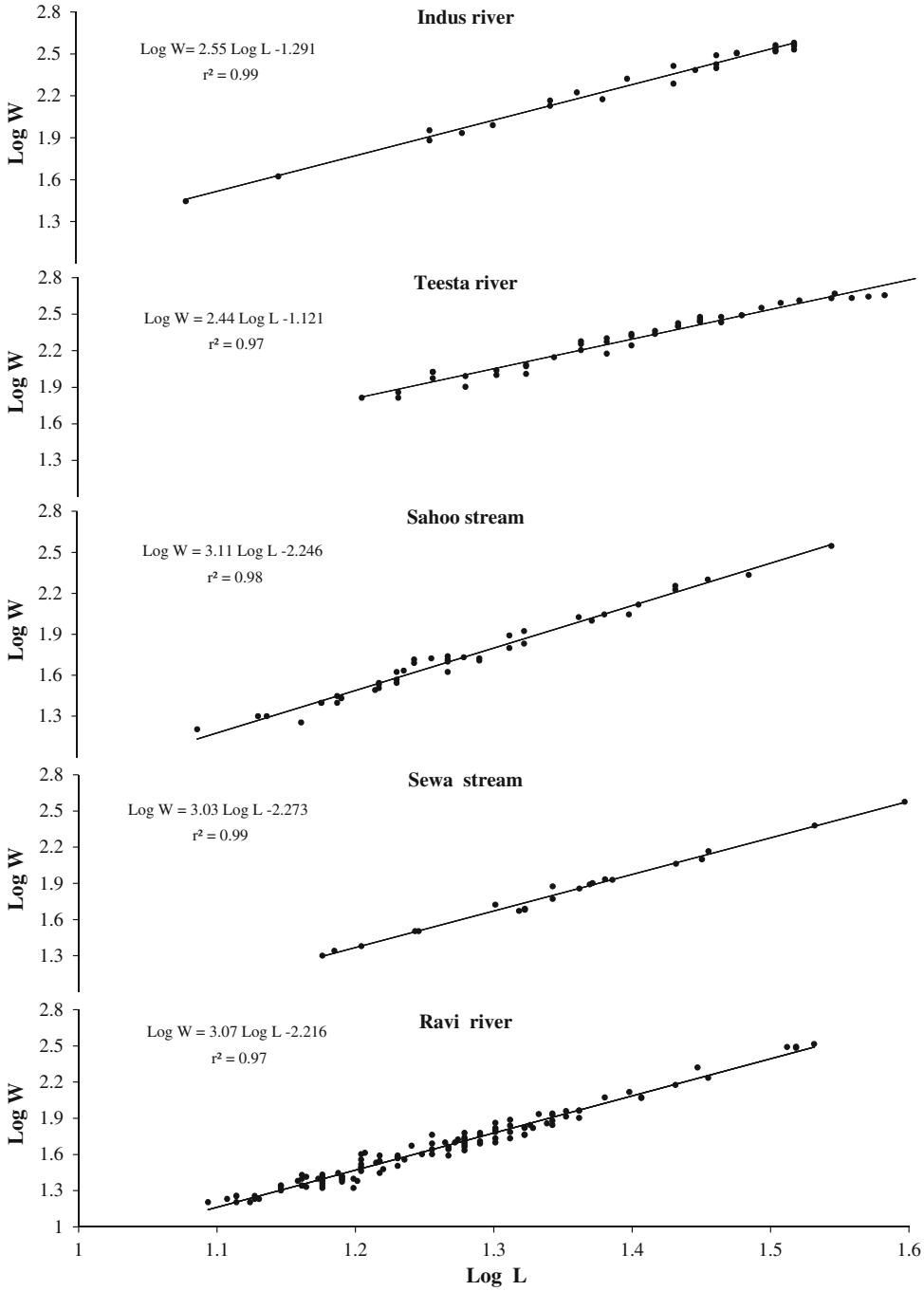

Fig. 2 Least-squares regression of $\log_{10}W \cdot \log_{10}TL$ of *S. richardsonii* in different rivers of northern Himalayan region of India

or elongation in form with increase in length, whereas b being more than 3.0 suggests an increase in condition or increase in height or width with increase in length. The larger difference from 3.0, the larger the change in condition or form [25]. The differences in the length–weight data of *S. richardsonii* between rivers Teesta, Indus with that of Ravi and its tributaries could be due to the differences in body size group, maturity condition, life stages, body health, habitat conditions and the collection time. Froese [26] also pointed out that LWR varies within species if different size groups are considered. According to Hile [25] and Martin [27] the value of *b* usually remains constant at 3.0 for an ideal fish. However, Beverton and Holt [28] suggested that the departure of the *b* value from 3.0 is rare in adult fishes.

Fluctuations in *b* values from 3.0 in the studied rivers revealed that the length-weight relationships of *S. richardsonii* followed the cube law and might be affected by the habitat conditions, life stage and type of body length measured [29, 30]. These factors are also responsible for variations in condition factor [26]. All allometric coefficients (*b*) estimated in this study were within the expected range of 2.0–4.0 and the highest correlation coefficients

(>0.97) in the present study showed that regression values were highly significant ($P < 0.001$). The intercept (a) of all the rivers was negative which indicates a perfect linear relationship between the variables. In the present study intercept *a* varies from −2.267 for Sewa stream to −1.121 for Teesta river and showed negative correlation with regression coefficient. This negative correlation showed that value of intercept for *S. richardsonii* depends primarily not on the heaviness of the fish but on the value of the exponents. Hile [25] found that large value of *b* is associated with a small value of the coefficient *a* and the reverse.

There was a noticeable difference in the size of the individuals within the sampling sites. The specimens of the rivers Ravi, Sahoo and Sewa at Chamba comprise mostly of small individuals which may be attributed to over-fishing by the natives owing to the easy accessibility to the sampling site, hence making it difficult for the species to grow to a sizeable population. However, there is a substantial increase in size in Indus and Teesta which indicates the distantly sampling location limit, higher fishing pressure and provides opportunity to fish for the increase in size.

Average value of Fulton's *K* for this species in selected rivers ranged from 0.60 to 1.27. These estimates are supported by those which are reported in case of *S. richardsonii* from Jammu region [23], and *S. niger* from Dal lake Kashmir [24]. The lowest value of condition factor in Sewa stream showed that fishes were nutritionally poor which may be due to unavailability of proper food and environmental conditions. There were significant differences ($P < 0.001$) in *K* values of *S. richardsonii* among different rivers. The higher values of *K* in rivers Teesta and Indus demonstrated that the nutritional conditions of fishes of these rivers were better in comparison to other rivers. This may be due to differences in the availability of fish food, density or population changes, developmental stages and differences in the time of sampling. Heincke [31] also realized that the condition factor is directly proportional to differences in weight and concluded that condition varies with sex, size, season and degree of gonad development. According to LeCren [21], ecological conditions of the habitat or variation in the physiology of the animal, or both, are responsible for growth rate variations in the same species from different localities. The present study clearly points out the need for a future detailed investigation on ecological conditions, especially the availability of fish food and biology of *S. richardsonii*.

Conclusion

The length–weight relationship parameters of *S. richardsonii* in the studied rivers followed the cube law (weight increases with increase in length) and fluctuated in different habitat conditions. The condition factor of the species also showed variations in different riverine ecosystems which may be due to size, sex and various physiological stages of the fish. The available literature also indicated that no previous studies dealing with LWR and condition factor for *S. richardsonii* were available from rivers Ravi, Sahoo, Sewa, Teesta and Indus. Therefore, the results of this study provide first basic information on length–weight relationship and the condition factor of *S. richardsonii* that can be useful for fishery biologists and conservation agencies to plan and implement adequate regulations for sustainable fishery management and conservation in rivers Teesta, Indus, Ravi and their tributaries, as well as, other similar rivers/streams of Himalayan.

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