Seasonal Variation in Length-weight Relationship, Condition Factor and Biological Indices of Snow Trout, *Schizothorax esocinus* (Heckel, 1838) Inhabiting River Jhelum of Kashmir Himalaya

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Abstract

The present study encompasses studies on the seasonal variation in various biological parameters of snow trout, *Schizothorax esocinus* collected from River Jhelum. The exponent 'b' of the length-weight relationship depicted positive allometric growth type. Condition factor (K) was significantly ($P<0.05$) highest in autumn while lowest values were observed in spring and winter. Gonadosomatic Index (GSI) in both sexes was significantly ($P<0.05$) highest during the spring season (spawning phase) while the lowest value was observed during summer season (spent phase). Hepatosomatic Index (HSI) was significantly ($P<0.05$) highest in both sexes during the autumn season while as the lowest value was observed during winter season. The study provides information on health status and reproductive cycle of *S. esocinus* that could help in augmenting the production along with development of appropriate conservation and management strategies.

Keywords: *Schizothorax esocinus,* GSI, HSI

1. Introduction

The valley of Kashmir situated between 33°01'–34°08' N latitude and 74°47'–74°49' E longitude in the midst of majestic Himalayas is blessed with numerous fresh water bodies which harbor abundant fishery resources. The rich ichthyofauna of different water bodies of the valley serve as the chief food item of the human population of the region thereby serving role in providing nutrition as well as strengthening the economy of the people. The river Jhelum aptly called as 'the life line of Kashmir' is a rich repository of ichthyofaunal diversity. Various fishes belonging to genus *Schizothorax* (endemic) and other exotic carps are common in the rivers and lakes of Kashmir. Various fish species belonging to subfamily-Schizothoracinae are abundantly found in torrential mountain streams, snow-fed rivers and lakes of Himalayas and Central Asia.

These fish are believed to have actually migrated into the water bodies of Kashmir from Central Asiatic watershed, bounded by inner and southern undulation of Hindkush, Karakorum and the inner ends of the north-western Himalayan and Sulaiman ranges. The Schizothoracines serve as a major source of subsistence and commercial fisheries of not only Kashmir but other Himalayan states as well[1]. Therefore, it is imperative to have knowledge of basic biological parameters of these fishes. Among diverse fishes found in Kashmir, *Schizothorax esocinus*[2], locally known as '*Chirruh*' is one of the most popular food fish species and is found in almost all lakes and rivers of the valley. The fish contributes a significant portion of overall fish production of the valley and also provides livelihood to the considerable human population especially those living on the embankment of water bodies.

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Length-weight relationship (LWR) forms an essential aspect of fisheries and fish biology. LWRs of fish species are often studied by fishery scientists in sampling programmes as well as in managing fishery resources to obtain first hand authentic biological information about the well being of the fish as well as assessment of fish population[3]. This relationship is often used for the estimation of biomass from length observations, predicting the condition (general well being), reproductive biology of the fish, stock assessment models as well as comparing life history[4,5]. This relationship also facilitates the computation of condition indices and enables comparison of growth trajectories in species, between sexes and among different seasons and regions[6]. It also helps in establishing the biomass and converting one variable to another as is often required during regular samplings for culture operations[7].

Reproductive processes of fishes are known to be influenced by various endogenous and exogenous factors and therefore vary seasonally[8]. Contemplating seasonal patterns is known to offer imperative information on fish biology as well as their role in aquatic ecosystems[9]. Gonadosomatic Index (GSI) values and condition factor (K) are also considered as important quantitative indices which help to describe reproductive cycles and potential variations in the physiological condition of a species during its life[10,11]. Condition factor is one of the common indices used in the fish biology, which gives valuable information about the physiological state of the fish[12]. The value of K is based on the assumption that individuals of a given body length have better condition if their mass is greater and is known to depend on the coefficient of allometry 'b' of the weight-length equation, which reflects the growth pattern of a species[13–15]. The assessment of the seasonal variation of K is often used as a complementary parameter so as to depict natural cycles in reproduction, feeding ecology and growth cycle of fish[16,17].

GSI analysis provides a quantitative evaluation of reproductive cycle, the level of gonadal development, and the breeding season[18]. Its value is directly related to the development of gonads. Liver is an important organ of vitellogenin production in fish, which in turn is the yolk precursor[19]. HSI is imperative because it is a fine indicator of feeding activity and describes the stored energy in fish as well[5]. Infact, many researches study ovary maturation on the basis of both GSI and HSI[20]. Hepatosomatic Index (HSI) is often linked with energetic reserves of liver and metabolic activity[21]. Moreover, it has been established in many fishes that egg yolk and egg shell proteins exercise the liver as their key site of synthesis and then these materials are transported to the oocyte for uptake[22]. Condition indices, K and HSI are appositely used to analyze nutritional status of fish as they signify variations in energy in the different tissues and the seasonality of energy stores is strongly related to the sexual cycle, also signifying that fish store energy mostly through lipid deposition in the liver[23].

Although, studies pertaining to LWRs in different *Schizothorax* species have been studied by a number of workers in the past, nevertheless information on seasonal variation in LWR, K, GSI and HSI of *S. esocinus* have not been reported yet. Hence, this study on *S. esocinus* is first of its kind wherein an attempt has been made to investigate seasonal fluctuations in these parameters of male and female snow trout, *S. esocinus* so as to provide important knowledge of impact of seasons as well as its reproductive cycle.

2. Materials and Methods

A total of 216 specimens each of male and female *S. esocinus*[2] were collected from River Jhelum using cast nets with the help of local fishermen for the study period April 2017 to March 2019. The study was carried on seasonal basis wherein 54 specimens of each sex were collected in each season. During the transport, care was taken so that the specimens do not get damaged. The fresh specimens were transferred to the laboratory for further study. Identification of the fishes was done with the help of standard taxonomic keys[24]. All the studied samples are adults. The total length was measured with a digital calliper to the nearest 0.1 cm and body weight was determined to the nearest 0.1 g using a digital balance (Shimadzu UX320G). The statistical relationship between Total Length (TL) and Body Weight (BW) of the fishes was derived using the logarithmic transformation ($\log W = \log a + b \log TL$) of the power function $W = aL^b$ (Le Cren, 1951), where BW = body weight of fish in grams, a = intercept (constant), L = total length of fish in centimeters and b = regression coefficient (slope). Constant 'a' represents the point at which the regression line intercepts the y-axis and 'b' the slope of the regression line. Fulton's condition factor (K) was estimated from the relationship[5]:

$$K = W \times 100 / L^3,$$

Where, W= body weight, L^3 = cube of body length.

For the estimation[5] of GSI was calculated by the equation:

$$GSI = GW \times 100/BW$$

Where, GW = gonadal weight, BW= body weight, and

The Hepatosomatic Index (HSI) was determined[5] by equation:

$$HSI = LW \times 100/BW$$

Where: LW= liver weight, BW= body weight

Statistical Analysis:

The data values were treated statistically by using Microsoft Excel program and the SPSS version 20 for Windows. Differences between means were determined by Duncan multiple range test[26], ($P<0.05$).

3. Results

The results revealed that the total length of the body ranged from 29.17 – 39.5 cm while as the body weight ranged from 241.3 – 575.90 g. Mean ± SD values of the variables- length, weight and regression parameters are presented (Table 1). The statistical analysis of the data showed b value to be greater than 3 in all seasons for both the sexes. Combined equation for the pooled data for male was found as: Log W= -2.03 + 3.03log L (Figure 1). In females, the statistical analysis of the data showed the combined equation for the pooled data for female as: Log W= -2.008 + 3.02log L (Figure 2). Mean ± SD values

of condition factor and biological indices estimated on the seasonal basis Table 2. Statistical comparison of data values revealed significant ($P < 0.05$) variation in values of K, GSI as well as HSI with respect to seasons in both the sexes.

4. Discussion

The relationship between length and weight of fishes is often considered as a suitable index for understanding the survival, growth, maturity and reproduction and are used to estimate biomass when the length–frequency distribution is known[13,27,28]. The value of 'b' in LWR reflects the general well-being of fishes and it depends largely on the shape and fatness of the fish species[29]. If the value of 'b' is greater than 3, it indicates that fish will become thickset as length increases and if it is less than 3 that means fish will get lean as the length increases so if b < 2.5 there is an over-proportional increase in length than weight[28,30]. Studying LWR on seasonal basis plays a crucial role in structuring the allometry or isometry of a fish species as the LWR is mostly determined by various seasonally fluctuating natural factors such as reproductive activity, habitat, diet and stress[6]. In the current study, we observed that LWRs in the fish, *S. esocinus* tend to vary slightly on seasonal basis and the b value was noted to be greater than 3 in all seasons thereby indicating positive allometric growth pattern (Table 1). The observed value of 'b' in all seasons was within the limits of 2.5 – 3.5[28]. The determination coefficient (R^2) also displayed high values in all seasons (Table 1). The variations in LWRs in fish are known to fluctuate due to degree of sexual maturity,

Table 1. Length, weight mean data values, regression parameters for *S. esocinus* inhabiting River Jhelum on seasonal basis

Season	Sex	Total length (cm)			Total weight (g)			Regression Parameters		R²
		Minimum	Maximum	Mean ± SD	Minimum	Maximum	Mean ± SD	Intercept	Slope	
Spring	M	29.40	38.20	33.23 ± 2.23	250.00	556.30	384.72 ± 83.55	-2.20	3.13	0.90
	F	30.00	39.00	33.62 ± 2.07	268.50	574.90	392.91 ± 78.48	-2.15	3.10	0.89
Summer	M	29.20	39.50	32.67 ± 2.46	241.30	569.50	380.78 ± 91.47	-2.14	3.11	0.92
	F	29.17	37.50	33.41 ± 2.36	264.60	558.80	412.41 ± 90.86	-2.17	3.13	0.96
Autumn	M	29.27	37.40	33.08 ± 2.41	252.10	579.60	414.39 ± 95.44	-2.00	3.04	0.92
	F	29.00	37.70	32.97 ± 2.40	250.30	548.60	402.31 ± 91.50	-2.18	3.15	0.95
Winter	M	29.58	39.00	33.91 ±2.68	251.00	565.90	405.16 ± 99.63	-2.24	3.15	0.93
	F	30.10	38.30	34.38 ± 2.31	268.50	575.90	412.76 ± 90.98	-2.25	3.16	0.89

(*N*= 54 for each sex in each season)

health, gonad maturity, as well as season and habitat sex, diet, stomach fullness, sample preservation techniques, number of specimens examined, area/season effects and sampling duration[4,28,31,32].

Apart from LWR, the Fulton's condition factor of a fish is considered to be useful for comparing nutritional condition with respect to seasonal changes. The seasonality displayed in value of K is attributed to different activities like feeding, spawning, breeding and variable environmental conditions[6]. In our study, the significantly highest ($P < 0.05$) value of K in both male and female was observed during the autumn season followed by summer while as the lowest values in both sexes were recorded during the winter season (Table 2). Since spawning is a physically stressful and tough period, which affects various physiological processes of fish and this could play an important role on condition of fish as well. Variation in the values of K have been inferred as a measure of gonadal development, adaptation to the environment and histological events such a fat reservation[13]. The decrease in K values is a common phenomenon in many fish species and is often attributed to lessening somatic body reserves required for reproductive developments, gonad maturation and energy in spawned fish, subjective to reduced feeding during that period[5,33,34]. In summer and autumn season, water temperature is optimal for growing and the greatest feeding activity also starts, so the condition of *S. esocinus* improves and reaches the highest value in autumn, yet this could also be due to fat deposition during the preceding growing season for the upcoming winter season[6]. As winter approaches, temperatures in Kashmir often fall below the freezing point of water, also GSI increases; therefore, fish consumes all its stored reserves during this period. This could plausibly explain low value of condition factor in winter. In spring, *S. esocinus* undergo spawning activity; this could be a reason for low condition factor values. Moreover, the highest mean value of K was recorded in autumn season when the mean value of GSI was lowest. Similar trend was also observed in *Auchenipterichthys longimanus* and *Schizothorax zarudnyi* implying that energy expenses involved in the reproductive processes cause decrease in K values for both males and females[35,36].

GSI is one of the common indices used to gather knowledge of breeding cycle of fish[37]. GSI gives a measure of gonad size relative to body weight of the fish and presents a quantitative assessment of the degree of gonadal development, the reproductive cycle and the breeding season[18,35]. Variations in the GSI values are used to study the pattern of reproductive cycle of the fish species. Its value increases gradually as the fish matures and attains value during peak of maturity and decreases sharply as the fish becomes spent[38]. The highest value of GSI in both male and female *S. esocinus* was noted in the spring season which corresponds to the maximum gonadal growth of the fish. This was followed by a sharp decrease in summer season which represents the spent season of the reproductive cycle of fish; then the mean GSI values showed a progressive increase in autumn and winter season (Table 2). Similar trend of GSI has also been noted in *S. niger*[38]. The GSI values in the present study
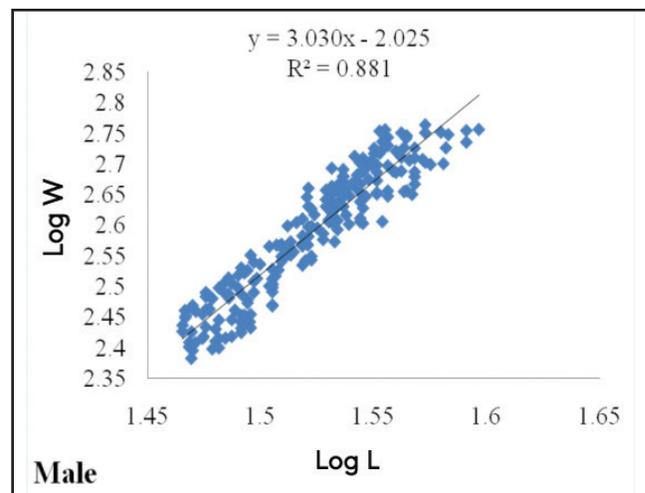

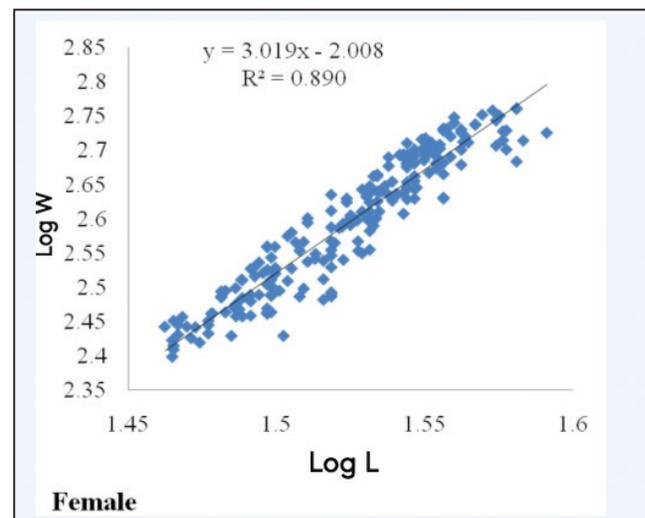**Figure 1.** Length-weight relationship of male *S. esocinus*.

Figure 2. Length-weight relationship of female *S. esocinus*

Table 2. Seasonal variation in condition factor and biological indices of *S. esocinus* inhabiting River Jhelum

Season	Sex	K	GSI	HSI
		Mean ± SD	Mean ± SD	Mean ± SD
Spring	M	1.01 ± 0.07[d]	10.75 ± 3.17[a]	1.26 ± 0.30[e]
	F	1.02 ± 0.06[d]	11.02 ± 2.89[a]	1.34 ± 0.45[e]
Summer	M	1.07 ± 0.07[c]	2.27 ± 1.14[d]	2.17 ± 0.46[b]
	F	1.09 ± 0.04b[c]	2.30 ± 1.10[d]	2.12 ± 0.48[b]
Autumn	M	1.12 ± 0.07[a]	3.46 ± 0.94[c]	3.04 ± 0.72[a]
	F	1.10 ± 0.05[ab]	3.19 ± 0.93[c]	2.90 ± 0.63[a]
Winter	M	0.99 ± 0.07[d]	7.78 ± 2.09[b]	1.76 ± 0.53[c]
	F	1.01 ± 0.07[d]	8.24 ± 2.11[b]	1.55 ± 0.48[d]

(*N*= 54 for each sex in each season; Mean ± SD values in columns with different superscripts are significantly different (*P* < 0.05)

ranged from a minimum of 2.27 in male during summer to a maximum of 11.02 in female during summer season. These values are close to the corresponding values of GSI reported in *S. plagiostomus*[39]. Moreover, synchrony in seasonal variations in mean GSI values of both male and female were observed.

The current study showed the mean values of HSI in both sexes to be significantly (*P*<0.05) lowest in spring season, then increased in summer and showed significantly (*P*<0.05) highest values in the autumn season (Table 2). The lowest values of HSI in spring could plausibly be explicated by the fact that this season corresponds the spawning season of the fish. During spawning season, there is expansion of gonads and the fish depends on food reserves accumulated in the liver for its energetic necessities and spawning activity so more energy is mobilized from liver, this explains the decreased values of HSI in the spring season[23,40].

5. Conclusion

The results obtained in this study gives information on how various parameters like length-weight relationship, condition factor, GSI and HSI fluctuate with reproductive cycle of fish. This knowledge can be used to compare these aspects of this species with other related species inhabiting the same water body or same species inhabiting other water bodies. The data generated would also be useful for fishery biologists, managers as well as researchers to develop suitable strategies for the better conservation, augmented production and management of these fish species.

6. Acknowledgements

9. References

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