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Temporal Variations in Length-Weight Relationship, Condition Factor and Biological Indices of Snow Trout, *Schizothorax labiatus* Thriving in River Sindh of Indian Himalayan Region

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ABSTRACT

Fisheries conservation and management studies require a comprehensive description of the general well-being of fish which can initially be obtained through the study of different biological parameters of snow trout, *Schizothorax labiatus* collected from river Sindh. To evaluate the condition of *S. labiatus*, the present work was carried out by studying length-weight relationship (LWR), condition factor (K), gonadosomatic index (GSI), and hepatosomatic index (HSI) with respect to sex and seasons. The results of LWR revealed that positive allometric growth was observed in both sexes of *S. labiatus* in all seasons, except summer and autumn (males) where negative allometric growth was recorded. Significantly (p<0.05) highest K and HSI values for both sexes of *S. labiatus* were recorded during autumn while the poorest value was noted in the season of spring. On the contrary, significantly (p<0.05) maximum GSI value for both sexes was noted in spring, while the minimum value was recorded during summer. Although, significant (p<0.05) differences in K, GSI, and HSI values were recorded among seasons, yet no significant (p>0.05) difference was detected between the sexes, except in spring for K and GSI. Hence, it was concluded that seasonality difference in condition indices could be accredited to gonadal changes, feeding intensity, and energy distribution.

INTRODUCTION

Length-weight relationship (LWR) of fishes is considered an indispensable tool in fish biology and fisheries management studies, aiding in the evaluation of the average weight of the fish from the given length group by setting up a mathematical relationship between them **(Razeena, 2020)**. Moreover, it gives the information about the composition of stock, life span, mortality, maturity, growth, production, biology and fisheries management **(Famoofo & Abdul, 2020; Jan & Ahmed, 2020)**. Such relationship also helps in securing the information regarding gonadal development, growth and condition of fish **(Jisr *et al.*, 2018)**. Fishes having thin elongated bodies will tend to have 'b' value less than 3, which indicates negative allometric growth, while as fishes having thicker bodies would tend to have 'b' value greater than 3, which signifies positive allometric growth and fishes having the value of 'b' equal to 3 would indicate

isometric growth **(Seiyaboh *et al*., 2016)**. The allometric growth formula was first proposed by **Huxley (1924)** in order to describe the relationship between length and weight in fishes. Later on, **Le Cren (1951)** reported that the weight of fishes would vary as cube of length and may depart significantly from this, since fishes in general do not maintain the similar shape or body outline all the way throughout their life span and in case of capture and culture fisheries, the specific gravity of the tissues might not be alike. Hence, it becomes essential to study length-weight relationship of fishes with respect to seasonal cycle.

Apart from LWR, Fulton's condition factor (K) is also used broadly in fisheries and fish biology studies, as it helps in calculating the condition, and assessing the wellbeing or fitness of fish **(Jisr *et al*., 2018)**. The fish is considered to be in a better condition, if the value of K comes greater, but contrary to this, if the value of K is lower, it signifies that the health position of fish is not better. Difference in the values of condition factor of a fish points out the age and sex of species, state of sexual maturity, and the degree of food sources availability **(Anibeze, 2000)**. The condition factor of fish is generally affected by a number of factors such as season, stress, availability of feeds, sex and other water quality parameters **(Anani & Nunoo, 2016; Laurat *et al*., 2019)**.

Gonadosomatic index (GSI) behaves as an indicator of gonadal maturity, and hence, signifies the spawning season of a fish. It is regarded as one of the vital parameter of fish biology as it acquaints the researchers well with the information regarding the health, reproduction, breeding period and maturation status of gonads of fish species **(Pandit *et al*., 2019)**. The various alterations taking place in GSI are normally carried out by determining the variations occurring in concentration of yolk during different stages of oocyte, and hence, it ascertains the information regarding maturation and seasonal patterns in the development of gonads **(Pandit *et al*., 2019)**. Hepatosomatic index (HSI) value gives precise information about the function of liver and body conditions. Besides, it has been studied that fish consisting of smaller liver have a lesser amount of energy stored in it particularly in a poor water environment **(Akhter *et al*., 2020)**. Therefore, it is mainly considered as the depot of fish's energy and also acts as an indicator of recent feeding activity. Hence, study of those indices not only provides accurate information about the well-being of fish, but also gives initial clues about the environmental condition where the fish lives.

The river Sindh is regarded as one of the chief tributary of the river Jhelum. It is about 108 kilometers in length, and flows through Ganderbal district of Kashmir valley. The river Sindh inhabits different classes of fish, primarily those belonging to family Cyprinidae. Among all the fishes, the subfamily Schizothoracine commonly called as 'snow trout' fish species is considered a group of specialized fishes which are mainly restricted to torrential mountain streams of the Himalayas and Central Asia of the region including river Sindh. The group contributes a significant proportion as food and threshold of large population who are living in colder belt of whole Himalayan region. In Kashmir valley, five species of *Schizothorax* have presently been recognized i.e, *Schizothorax plagiostomus*, *Schizothorax labiatus*, *Schizothorax*

curvifrons, *Schizothorax esocinus* and *Schizothorax niger*. Among them, *S. labiatus* locally known as 'Chush gad', is one of the most economically important fish species of Kashmir valley due to its food value and overall contribution as food of sizeable population in the region. However, the population of this species is diminishing day-by-day because of one or other reason whether natural or anthropogenic disturbances, and hence need serious reaction towards its propagation and conservation (**Bhat *et al*., 2010; Hussain *et al*., 2018; Jan & Ahmed, 2020; Jan *et al*., 2020)**. Therefore, the current work was carried out for the evaluation of health status in the habitat of *S. labiatus* for better conservation and management practices. Although, a lot of work has been carried out on LWR and biological indices of fishes inhabiting different water bodies, but to the best of the knowledge of the researchers of this work, no previous reports of seasonal variation of this fish is available so far from Kashmir valley. Hence, the present study was conducted to provide valuable baseline knowledge on LWR, condition factor and biological indices of highly demanded *S. labiatus* from river Sindh which may serve as a tool for proper conservation and management practices of the species.

MATERIALS AND METHODS

Study sites

For carrying out the present study, the lotic water body taken under consideration was river Sindh, and from this water body three sites were selected for the collection of fishes i.e., Site I Manigam **(**34º16′36.15″; 74º48′31.45″), Site II Bamloor (34º12′08.23″; 74º46′04.38″) and Site III Rabitar (34º11′01.70″; 74º40′52.15″) (Fig. 1).

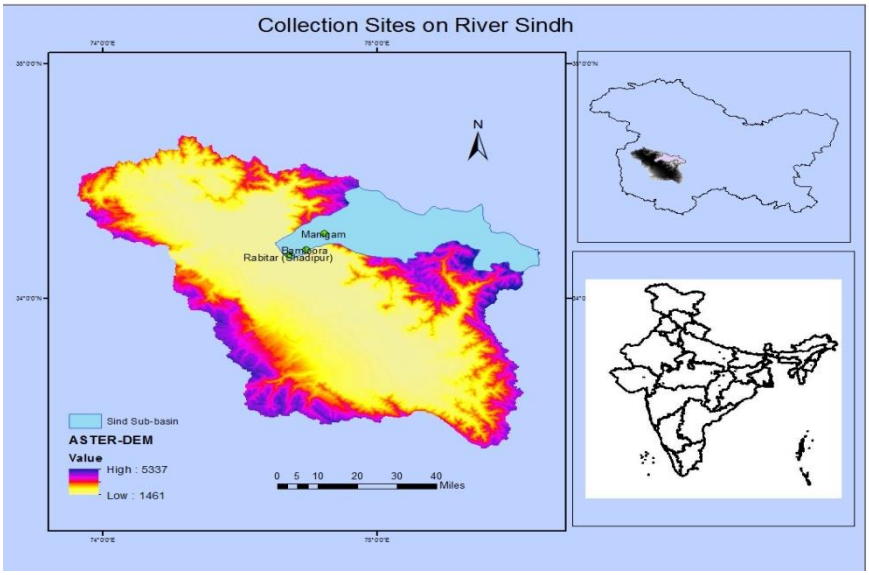

Fig. 1. A map representing different selected sites of river Sindh.

Collection and identification of fish specimens

Samples of different sizes of *S. labiatus* were collected from the three aforementioned selected sites of river Sindh during April 2017 to March 2019 with the help of various types of

fishing gears like cast nets assisted by local fisherman. Then, the fishes were recognized using standard keys reported by **Kullander *et al*. (1999)**, transferred in plastic containers containing same water and transported to wet-laboratory, Department of Zoology, University of Kashmir. A total number of 432 *S. labiatus* consisting of 216 males and 216 females was randomly selected and then measured with respect to various statistical analyses. Digital vernier calliper was used for calculation of total length (TL) which was generally taken from the tip of the snout to the extended tip of the caudal fin nearest to 0.01 cm. A digital electronic balance (Shimadzu UX320G) was used for measuring total weight (TW) with 0.01 g accuracy for each individual. From the measured TL and TW of the fishes, the length-weight relationship was determined and the statistical relationship between these measured parameters was established from the parabolic equation given by **Froese (2006)**.

$$\mathbf{W = aL^b}$$

Where,

'W' is the weight of fish in grams.

'a' is intercept (constant).

'L' is the length of fish in cm.

'b' indicates the slope of the line and is called as regression coefficient.t

The condition factor of the fish was calculated by using the equation given by **Fulton (1904)**,

$$\mathbf{K = W / L^3 \times 100}$$

Where,

K = Fulton's condition factor.

W = weight in grams.

L = length in cm.

100 is a factor to bring the value of K near unity **(Froese, 2006)**.

After estimating length-weight relationship, the fishes were dissected and liver was removed for the calculation of hepatosomatic index. Extra moisture of liver was removed using a blotting paper and then the final weight of liver was recorded in grams. The hepatosomatic index was calculated according to the equation given by **Rajaguru (1992)**.

Hepatosomatic index (HSI) = Weight of liver (g) / Body weight (g) × 100

Similarly, the gonadosomatic index of the male fish (with respect to the weight of testis) and female fish (with respect to the weight of ovaries) was calculated by using the equation described by **Afonso-Dias *et al*. (2005)**.

Gonadosomatic index (GSI) = Weight of gonads (g) / Body weight (g) × 100

Statistical analysis

The data obtained for the current study was presented in the form of mean ± SD and subjected statistically to one-way analysis of variance (ANOVA) by making use of SPSS version 22. Differences between the means was affirmed by using Duncan's multiple range test (p<0.05) **(Duncan, 1955)**.

RESULTS

During the current work, a total of 432 samples of *S. labiatus* (216 males and 216 females) were collected from river Sindh. The LWR was estimated seasonally throughout complete consecutive annual cycles in order to obtain appropriate results. Seasonal based data of length ranges, weight ranges, coefficient of determination (r^2), growth coefficient (b) for males and females of *S. labiatus* is represented in Table (1). The results revealed that length-weight relationship, condition factor and biological indices of *S. labiatus* exhibited some variation throughout the year.

For males, the mean value of parameter 'b' was estimated within the range of 2.89-3.10 and for females; the 'b' value was reported in the range from 2.95 to 3.15. The maximum 'b' value for both sexes was observed during spring season (3.10 for males and 3.15 for females) of the year, while a minimum value was noted in the summer season (2.89 for males and 2.95 for females). The value of 'r^2' for males was noted in the range from 0.85 to 0.96 and for females, it was recorded in the range from 0.81 to 0.97, respectively. The highest value of 'r^2' for both sexes was estimated in the autumn season of the year (0.96 for males and 0.97 for females), while the lowest value was noted during spring (0.85 for males and 0.81 for females).

Table 1: Total length and total weight data, regression parameter values of *S. labiatus* inhabiting the river Sindh of Kashmir Himalayan region (n = 216 males + 216 females).

Season	Sex	N	Total Length (cm)		Total Weight (g)		Regression Parameters $W = aL^b$		
			Range	(Mean ± SD)	Range	(Mean ± SD)	A	B	r^2
Spring	Male	54	31.8-39.3	34.64 ± 1.98	318.2-650.7	425.00 ± 82.10	2.19	3.10	0.85
	Female	54	34.0-39.9	35.01 ± 1.65	335.4-683.1	437.57 ± 76.23	2.28	3.15	0.81
Summer	Male	54	27.9-37.2	32.95 ± 2.10	257.5-499.1	380.68 ± 71.31	1.82	2.89	0.93
	Female	54	25.6-38.1	32.92 ± 2.77	207.4-516.5	375.12 ± 90.33	1.91	2.95	0.94
Autumn	Male	54	28.4-38.0	33.22 ± 2.01	269.1-553.2	403.62 ± 71.80	1.88	2.94	0.96
	Female	54	29.4-38.5	33.14 ± 2.02	276.2-578.9	409.18 ± 77.75	1.96	3.00	0.97
Winter	Male	54	28.3-39.4	33.94 ± 2.48	266.4-564.8	406.32 ± 95.16	2.06	3.04	0.89
	Female	54	28.7-38.8	34.36 ± 2.34	263.4-588.8	414.30 ± 90.22	2.10	3.06	0.87

SD= standard deviation; N= individuals number; a= intercept; b= slope; r^2= correlation coefficient.

The results of average value of K for both males and females exhibited the divergence throughout the seasons and the data is presented in Table (2). In case of males, the value of K

fluctuated between 0.92 g and 1.08 g while as for females; the value varied from 0.89 g to 1.11 g. Significantly, ($p < 0.05$) the highest value of K for males (1.08±0.03) was recorded in autumn season, while the lowest K value (0.92±0.06) was noted in the spring season. A similar trend was observed in the case of females where significantly ($p<0.05$) highest value of K (1.11±0.03) was noted in the autumn season, while the least value of K (0.89±0.06) was reported in the spring season (Fig. 2). Markedly, the value of K and the coefficients a, b, r^2 differed because of the variations occurring in the length classes and number of measurements available.

The seasonal variations of GSI and HSI values for males and females of *S. labiatus* were also studied and the results are presented in Table (2). In case of males, the value of GSI oscillated between 2.24 g to 11.55 g while for females, the value varied from 1.98 g to 12.67 g. Significantly, the ($p<0.05$) highest value of GSI for both sexes was recorded in the spring season being 11.55±3.16 for males and 12.67±2.42 for females, while the lowest value for both sexes was noted in the summer season being 2.24±0.99 for males and 1.98±0.77 for females (Fig. 3). Although, significant ($p<0.05$) difference in the value of K and GSI was recorded among the seasons, however no significant ($p>0.05$) difference in these values were noted in between the sexes, except spring season. Similar to males, the value of HSI ranged from 1.01 g to 4.52 g and 1.24 g to 4.70 g for females. The highest HSI value for both sexes was significantly ($p<0.05$) recorded in the autumn season being 4.52±1.12 for males and 4.70±1.22 for females, while the lowest HSI value for both sexes was recorded in the spring season being 1.01±0.63 for males and 1.24±0.57 for females (Fig. 4). In case of HSI, no significant ($p>0.05$) difference was detected between the sexes of *S. labiatus*, although among the seasons a significant ($p<0.05$) difference was noted.

Table 2: Condition factor and biological indices of *S. labiatus* inhabiting the river Sindh of Kashmir Himalayan region (n = 216 males + 216 females).

Season	Sex	*N*	K	GSI	HSI
Spring	Male	54	0.92 ± 0.06^{d}	11.55 ± 3.16^{b}	1.01 ± 0.63^{d}
	Female	54	0.89 ± 0.06^{e}	12.67 ± 2.42^{a}	1.24 ± 0.57^{d}
Summer	Male	54	1.05 ± 0.05^{b}	2.24 ± 0.99^{ef}	4.36 ± 0.96^{ab}
	Female	54	1.03 ± 0.06^{bc}	1.98 ± 0.77^{f}	3.93 ± 0.73^{b}
Autumn	Male	54	1.08 ± 0.03^{a}	2.72 ± 0.74^{de}	4.52 ± 1.12^{a}
	Female	54	1.11 ± 0.03^{a}	3.08 ± 0.72^{d}	4.70 ± 1.22^{a}
Winter	Male	54	1.02 ± 0.07^{c}	6.19 ± 1.96^{c}	2.72 ± 0.72^{c}
	Female	54	1.00 ± 0.07^{c}	5.78 ± 1.66^{c}	2.45 ± 0.90^{c}

K = Condition factor; GSI = Gonadosomatic index; HSI = Hepatosomatic index

Mean values bearing different superscript letters in a column are significantly ($p<0.05$) different

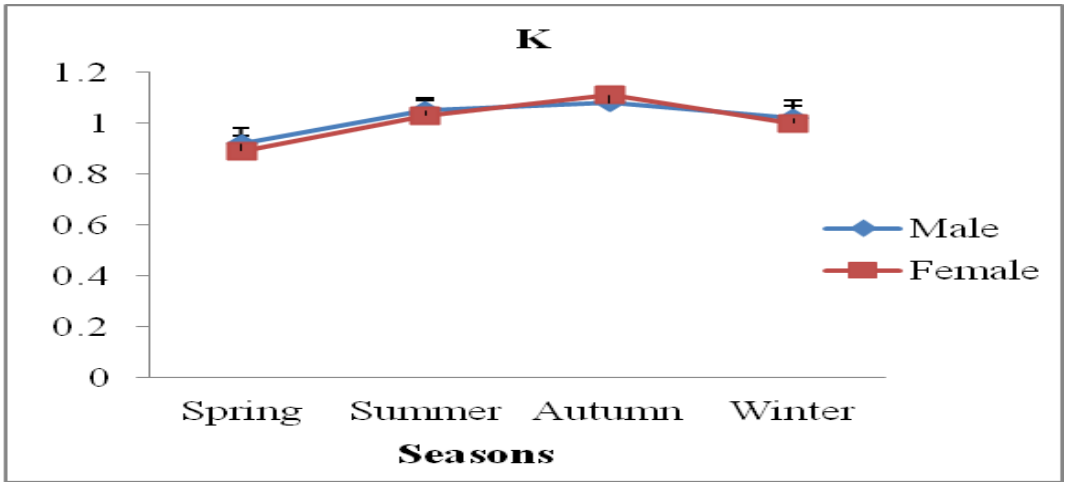

Fig. 2. Seasonal variations in condition factor (K) of *S. labiatus* habiting in river Sindh

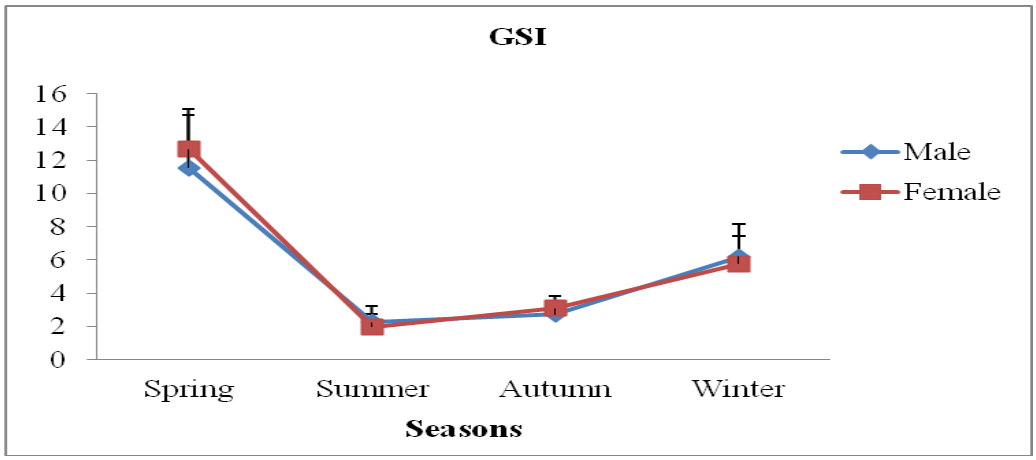

Fig. 3. Seasonal variations in gonadosomatic index (GSI) of *S. labiatus* habiting in river Sindh

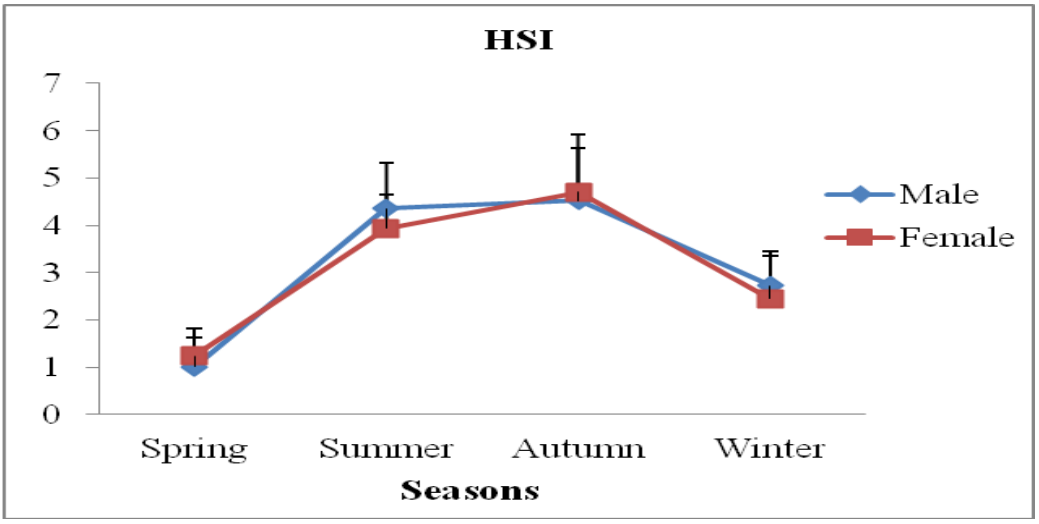

Fig. 4: Seasonal variations in hepatosomatic index (HSI) of *S. labiatus* inhabiting the river Sindh.

DISCUSSION

The studies of length-weight relationship and biological indices of fishes have got significant role in fishery management for better understanding the health status or fitness of fish population both in natural and cultured conditions. However, it has been suggested that the degree of fitness of fish can fluctuate due to various factors such as environmental, physiological and nutritional factors in any meticulous habitats. Hence, the monthly data of length-weight relationship (LWR), condition factor (K), gonadosomatic index (GSI) and hepatosomatic (HSI) of *S. labiatus* throughout its complete annual cycles was interpreted seasonally during the present study in order to obtain appropriate results. Seasonality is regarded to be significant in structuring the isometry or allometry of a fish species as LWR is chiefly varied due to seasonally oscillating natural factors such as diet, stress, habitat, reproductive activity, etc. **(Froese, 2006; Kembenya *et al*., 2014)**.

The present results showed that the mean values of parameter 'b' for both sexes of *S. labiatus* fluctuated within the range of 2.89-3.15 g which falls well within the expected reported range of **Froese and Pauly (2015)**. The current findings are in agreement with the inferences of **Ruiz Campos *et al*. (2009)** where the value of 'b' was reported in the range from a minimum of 2.863 g for reef finspot, *Paraclinus integripinnis* to 3.404 g for the fluffy sculpin, *Oligocottus snyderi*. However, there has been a continuous debate regarding the impact of seasons on LWR in fish and majority of fish biologists believe that 'b' value mainly relies on physiological growth condition such as development of gonads or availability of food **(Sheikh and Ahmed, 2018, 2019)**, biological and environmental factors **(Froese, 2006)**.

During the study, it was noted that the values of regression coefficient 'b' of *S. labiatus* showed positive allometric growth during spring season followed by winter season. **Das *et al*. (2018)** also reported somehow similar results in pre-monsoon season in which 'b' value was noted to be greater than 3 which agrees with the current study but for females, the value came < 3 which differs from recent study. The positive allometric growth pattern has also been reported in different fish species, such as *Scophthalmus maeoticus*, *Katsuwonus pelamis*, *Oreochromis niloticus*, and *Schizothorax esocinus* **(Samsun *et al*., 2007; Ahmed *et al*., 2012*;* Keyombe *et al*., 2017; Reshi & Ahmed, 2020)**. Furthermore, the 'b' value of both sexes of *S. labiatus* indicated negative allometric growth during summer and autumn season (for male only) which are in accordance with the results obtained in other fish species such as; *Epinephelus aeneus* **(Ozbek *et al*., 2013)**, *Carassius gibelio* **(De Giosa *et al*., 2014)** and *Gymnarchus niloticus* **(Falaye *et al*., 2015)**. Moreover, in the present study, the 'b' value in river Sindh was noticed to be greater in females as compared to males and similar results were obtained by other workers **(Zargar *et al*., 2012; Hossain & Sultana, 2014; Gohain & Deka, 2017)**. The greater value of 'b' in females of *S. labiatus* implies that the latter attains weight at a quicker rate in relation to its length. It has been previously reported that females are generally heavier than males of the same length most likely due to dissimilarity in fatness and gonadal development **(LeCren, 1951; Hossain & Sultana, 2014)** signifying that

the growth type of body occasionally varies as per their physiological needs.

Fulton's condition factor (K) is extensively used in fisheries and fish biological studies. It depicts the well-being status of a fish species, degree of fatness and also signifies the alterations taking place due to interactions among various recent physical and biological situations, physiological factors, feeding conditions and parasitic infections **(Famoofo and Abdul, 2020)**. In the present study, significantly, the (p<0.05) highest value of K was noticed in autumn season because of the greater deposition of fat during the preceding growing season of the fish. When the breeding season gets over, i.e., during summer, the fish usually remains in the poorer condition, as most of them get spawned. Although in summer, the water temperature is usually ambient for the optimal growth of fishes due to the heavier feeding activity **(Djurichkovic *et al.*, 2019)**, but the condition of *S. labiatus* increased during the summer season and attained its peak value during autumn season. Similar increase in the value of K has also been reported by **De Giosa *et al*. (2014)** in their study on *C. gibelio,* and **Reshi and Ahmed (2020)** in a study conducted on *S. esocinus*. On the other hand, significantly (p<0.05) lowest value of K was noted during the spring season, which may be related to the fact that fish generally get exhausted because of spawning activity. Actually, spawning is regarded as physically demanding and stressful period which leads to partial decline in condition of fish because of the release of gametes from the gonads and partly due to the consumption of energy sources for spawning activity **(De Giosa *et al.*, 2014)**. Similar decline in the value of K coincides with the findings of other workers in different fish species like *K. pelamis* **(Ahmed *et al.*, 2012)**, *Percophis brasiliensis* **(Rodrigues *et al.*, 2013)**. Fluctuations in the value of condition factor of many fishes have also been studied in relation to their stomach fullness, reproductive cycle, age, food, physico-chemical factors and physiological state of the fish **(Keyombe *et al.*, 2017; Famoofo & Abdul, 2020)**.

During the current study, the GSI and HSI values of *S. labiatus* collected from river Sindh also depicted fluctuations among the different seasons. Significantly (p<0.05) highest GSI value was recorded in spring season whereas lowest value was noted in summer season. This indicates that *S. labiatus* reaches its peak breeding period during spring season. It has been recorded that as the breeding period during pre-spawning approaches, the GSI gets increased and then declines sharply during post-spawning season which signifies that the gonads normally undergo regular seasonal cyclical changes in weight especially in females **(Nee Lakantan *et al.*, 1989; Reshi & Ahmed, 2020)**. Almost similar pattern of change in GSI has also been reported in other fish species such as *S. plagiostomus* **(Jan *et al.*, 2014)**, *Tilapia mossambica* **(Satheesh & Kulkarni, 2016)**, *S. niger* **(Ahmed & Sheikh, 2017)**, *S. niger* **(Wani *et al.*, 2018)**, *S. esocinus* **(Reshi & Ahmed, 2020)**.

Similarly, HSI also exhibited variations among various seasons and significantly (p<0.05) highest hepatic activity was noted during the beginning of preparatory phase i.e., autumn season, while the lowest hepatic activity was recorded during the spawning phase (spring

season). **Singh and Singh (1979)** also reported the coinciding outcomes in *Heteropneustus fossilis* where high HSI value was noted during preparatory and post-spawning phase and low levels were recorded during pre-spawning and spawning period of the fish. Comparable results were also recorded in *Acipenser ruthenus* **(Lenhardt *et al*., 2009)**, *Notopterus notopterus* **(Sudarshan & Kulkarni, 2013)**, *T. mossambica* **(Satheesh & Kulkarni, 2016)**, *S. niger* **(Ahmed & Sheikh, 2017)**, and *S. esocinus* **(Reshi & Ahmed, 2020)**. However, it has also been observed that HSI value exhibits inverse relation with the value of GSI by being maximum in autumn and minimum in the spring season, when the GSI value is highest which signifies that the liver undergoes weight loss during reproduction which might depict the mobilization of hepatic reserves for maturation of gonads **(Jan a& Jan, 2017)**. Similar inverse correlation of HSI and GSI has also been noted in some other fishes and suggested that hepatic tissue accumulate huge amount of nutrients during pre-spawning phase as HSI increases.

CONCLUSION

The present work revealed that length-weight relationship of *S. labiatus* showed some variation with respect to different seasons of the year. Overall, positive allometric growth was observed in both sexes of *S. labiatus*, except summer season for both sexes and autumn season in males where negative allometry was noticed. Differences in biological indices were also detected throughout the seasons. It was noticed that during summer and autumn season, the energy is mainly utilized for somatic growth of fishes while in winter and spring seasons, it is transformed in the development of gonads. Notably, no earlier work regarding seasonal variation in the length-weight relationship of Schizothorax fishes of Kashmir valley has been carried out so far, although a little information regarding biological indices of other fishes is available. Therefore, the current study would provide obligatory and baseline data on growth pattern in different seasons as well as condition of the fish, which would be valuable for proper fisheries conservation and management practices in this region.

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