FISHERIES & AQUATIC LIFE (2021) 29: 176 - 184
Archives of Polish Fisheries
DOI 10.2478/aopf-2021-0019

RESEARCH ARTICLE

Comparative study of length-weight relationships and biological indices of Himalayan snow trout, *Schizothorax labiatus*, inhabiting two lotic water bodies in the Kashmir Valley

Kousar Jan, Imtiaz Ahmed

Received – 21 November 2021/Accepted – 01 September 2021. Published online: 30 September 2021; ©Inland Fisheries Institute in Olsztyn, Poland
Citation: Jan K., Ahmed I. (2021). Comparative study of length-weight relationships and biological indices of Himalayan snow trout, *Schizothorax labiatus*, inhabiting two lotic water bodies in the Kashmir Valley. Fisheries & Aquatic Life 29: 176-184.

Abstract. The length-weight relationship (LWR) plays an important role in fishery management as it can be used to estimate the average weight of a specific length group. The results of the current study revealed that the mean values of regression coefficient *b* for both sexes of *Schizothorax labiatus* (McClelland) in the Jhelum River indicated positive allometric growth, while in the Sindh River, the *b* value for males indicated positive allometric growth and for females negative allometric growth. The value of coefficient of determination r^2 for both sexes of *S. labiatus* was equal to or greater than 0.90 in both water bodies, except for females in the Sindh River. Higher significant ($P < 0.05$) average values of Fulton's condition factor (K) and the hepatosomatic index (HSI) for both sexes of *S. labiatus* were noted in the Jhelum River than in the Sindh River. In contrast, higher significant ($P < 0.05$) values of the gonadosomatic index (GSI) were recorded in the Sindh River. The data generated during the current study provide basic information for researchers and fish biologists for the conservation and sustainable management of this commercially important food fish species in the Kashmir Valley.

Keywords: Allometric growth, Gonadosomatic index, Hepatosomatic index, Jhelum, Regression coefficient, Sindh

K. Jan, I. Ahmed [✉]
Fish Nutrition Research Laboratory, Department of Zoology, University of Kashmir, Hazratbal, Srinagar, India
E-mail: imtiazamu1@yahoo.com

Introduction

The colder zone of Kashmir Himalayan region has a number of water bodies that make unique, significant contributions to the region's large human population. Some of them, like the Jhelum and Sindh rivers, not only provide livelihoods to people but are also some of the world's most important tourist destination spots for angling and rafting. A diverse range of fishes inhabit these water bodies including both endemic and invasive species. Among them, there are a group of specialized fishes of the subfamily Schizothoracinae that are mostly confined to torrential mountain streams of the colder Himalayan and localities that have snow-fed rivers and streams, thus these fishes are commonly called snow trout. However, these fishes not only inhabit the Kashmir region but are also found in other Himalayan states of the Indian sub-continent. Schizothoracines are a key resource for subsistence and commercial fisheries. Among them, *Schizothorax labiatus* (McClelland), commonly known as Chush, is one of the most popular consumption fish species in Kashmir, and it can be found in practically all of the Kashmir Valley rivers. The fish contributes a significant share of overall fish production from the region and also

provides a source of income for the large human population, particularly those who live along the embankments of these rivers. However, due to habitat destruction, exploitation, the introduction of foreign fish species, and a variety of other natural and anthropogenic activities, the population of this species is diminishing drastically, hence understanding the basic biological parameters of *S. labiatus* is critical for conservation.

Studies of length-weight relationships and biological indices are initial markers in understanding the well-being of fish. These markers play a vital role in the proper management of fishes and also help to understand growth profiles and general fitness statuses of fish populations (Nahdi et al. 2016, Sidiq et al. 2021). The length-weight relationship (LWR) of fish provides basic information in fisheries biology and plays an important role in fishery management since these relationships are extremely useful in determining the average weight of a given length group (Karim 2020). Like any other morphometric trait, LWR can be used to classify taxonomic units, and the relationship varies with developmental events, growth, and the onset of maturity (Jan and Ahmed 2020). Huxley (1924) was the first to propose an allometric growth formula to describe the relationship between length and weight in fishes. Studies of LWRs vary temporally in water bodies depending on changes in water quality and fish stocks. In general, the weight of fishes varies as the cube of length, but it can deviate greatly from this (Le Cren 1951) because fishes do not maintain the same shape or body outline throughout their lives, and the specific gravity of tissues in catch and culture fisheries might not be the same.

Fish reproductive processes are known to be impacted by a variety of endogenous and exogenous variables (Ma et al. 2010). Values of the gonadosomatic index (GSI) and condition factor (K) are essential quantitative indices that can explain reproductive cycles and probable changes occurring in the physiological state of species over time (Braga 2005). The condition factor, or the ponderal index, is one of the most commonly used indices in fish biology, and, together with length-weight regression analysis, it provides vital information on the physiological state of fishes including health, habitat conditions, and the condition of fish populations inhabiting streams or rivers (Famoofo and Abdul 2020, Jan et al. 2021). GSI is also one of the vital parameters in fish biology as it provides information regarding the health, gonad maturation status, breeding period, and reproduction of fish species (Prasad and Nath 2020). Since the liver is considered as one of the most vital organs in gonadal development and also aids fish in manufacturing vitellogenin, which is regarded as the precursor of yolk (Lucifora et al. 2002), understanding the functioning of the hepatosomatic index (HSI) is also one of the key factors for determining the well-being of the fish. HSI is used to measure fish energy resources since it is associated with liver energy reserves and various other metabolic activities, and it also indicates recent feeding activity (Pyle et al. 2005, Jan et al. 2021). Although, there is a large body of work on the LWRs and biological indicators of different *Schizothorax* fish species, to the best of our knowledge no systematic comparative study has so far been done on these parameters in *S. labiatus* inhabiting the two lotic water bodies of the Kashmir Valley analyzed in this work. Therefore, the present study, the first of its kind, was designed to attempt to analyze fluctuations in these parameters in male and female snow trout, *S. labiatus*, and to provide a broader understanding of the impact the Jhelum and Sindh rivers, which have diverse physicochemical features, have on this species.

Materials and methods

Study area

The study area selected for the present study included two lotic water bodies, the Jhelum and Sindh rivers, in the Kashmir Valley. The Jhelum River is 725 km long with a catchment area of 33,342 km^2 and is located at an elevation of 233 m (768 ft) between 32°58’42" and 35°08’02" N and 73°23’32" and 75°35’57" E latitude. The spring at Verinag is

Table 1
Geographical attributes of the study sites of rivers Jhelum and Sindh

River	Site	Elevation	Latitude	Longitude
Jhelum	Pampore (I)	1593.49 m	34°00'38.35''	74°54'35.47''
	Chattabal (II)	1584.96 m	34°05'25.68''	74°47'03.67''
	Shadipora (III)	1584.35 m	34°10'27.70''	74°41'04.41''
Sindh	Manigam (I)	1666.95 m	34°16'36.15''	74°48'31.45''
	Bamloor (II)	1590.75 m	34°12'08.23''	74°46'04.38''
	Rabitar (III)	1582.82 m	34°11'01.70''	74°40'52.15''

located in the foothills of the Pir Panjal mountains in Anantnag and is the chief source of the the Jhelum River. It has a complicated drainage system that originates from both sides of the Pir Panjal and wider Himalayan mountains and flows from southeast to northwest Kashmir into the world famous Wular Lake. The river flows westward from Wular Lake passing through a gorge in the Pir Panjal mountain range near Kichhama Baramullah and enters Pakistan territory. From its source to its outflow, it traverses nearly the entire Kashmir Valley. The Sindh River, which is roughly 108 km long and runs from the Ganderbal region of India's Jammu and Kashmir Union Territory, is a major tributary of the Jhelum river. The Machoi Glacier, situated at an elevation of 4,800 m (15,700 ft) east of Amarnath Temple and south of Zojila Pass, between 34°12'14.860" N and 75°35'21.94" E, is the river's major source. Before reaching the town of Ganderbal, the river flows primarily westward along National Highway 1D and is nourished by numerous glacial streams. Its confluence with the Jhelum River is at Shadipora Srinagar (the summer capital of Jammu and Kashmir). For the present study, three sampling sites were selected in each river for fish and water collection. The geographical attributes of these are presented in Table 1.

Fish sample collection

S. labiatus samples were collected from the two lotic water bodies mentioned above from various locations from March 2018 to February 2020 with the help of local fishers who deployed different types of fishing gears such as cast nets.

Identification

After collection, the fish were identified with using the standard key by Kullander et al. (1999) and were then transported in plastic containers containing water to the wet laboratory at the Department of Zoology, University of Kashmir, where measurements of length, weight, gonads, livers, and other parameters were taken accordingly.

Analysis of length-weight relationships and biological indices

A total of 800 specimens of *S. labiatus* were collected and measured for various statistical analyses. Approximately 400 specimens of *S. labiatus*, comprising 200 males and 200 females, were collected from both the Jhelum and Sindh rivers. Total length (TL) was measured using a digital vernier caliper from the tip of the snout to the expanded tip of the caudal fin to the nearest 0.01 cm, and weight was determined with a digital electronic scale (Shimadzu UX320G) to the nearest 0.01 g for each specimen. The length-weight relationship was determined using the total length and total weight measurements of the fishes and the statistical relationship between the parameters measured was created using Froese's parabolic equation (2006).

$$W = a\,L^{b}$$

Table 2
Physicochemical parameters of two rivers of Kashmir Valley region

	Jhelum		Sindh	
Rivers	Range	Mean ± SD	Range	Mean ± SD
Temperature (°C)	5.4 - 22.5	13.02 ± 3.07	4.0 - 20.0	11.27 ± 3.06
Dissolved oxygen (mg l^{-1})	6.1 - 9.3	7.63 ± 0.49	7.9 - 11.4	8.63 ± 0.95
Free carbon-dioxide (mg l^{-1})	7.88 - 9.62	8.99 ± 0.76	6.6 - 8.4	7.16 ± 0.82
Total alkalinity (mg l^{-1})	96.51 - 204.9	168.44 ± 7.12	55.9 - 134.7	106.82 ± 5.61
pH	7.1 - 8.6	7.34 ± 0.29	7.2 - 8.4	7.74 ± 0.25

where, W is the weight of the fish in grams, *b* indicates the slope of the line and is called the regression coefficient, a is intercept (constant), and L is the total length of the fish in cm.

The fitness or well-being of the fish expressed as condition factor (K) was calculated with Fulton's (1904) equation.

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

where, K is the Fulton's condition factor, W is weight in grams, and L is total length in cm, and the equation is multiplied by 100 to bring the value of K to near unity (Froese 2006).

After calculating the length-weight relationship, the fish were dissected and the gonads were removed for calculations of the GSI of male fish (weight of the testis) and female fish (weight of the ovaries) with the equation by Afonso-Dias et al. (2005). GSI = 100 × gonad weight / body weight. Similarly, the HSI of the fish was determined with the equation by Rajaguru (1992). HSI = 100 × liver weight / body weight.

Physicochemical analysis

During the current investigation, random water samples from all the sampling sites in both rivers were collected monthly for physical and chemical parameter analysis. The temperature, dissolved oxygen, free carbon dioxide, total alkalinity, and pH of the water were all measured using established procedures (APHA 1998). During the present investigation, different physicochemical parameters of water samples collected from various sites of the Jhelum River and the Sindh River were also studied, and the data is presented in Table 2.

Statistical analysis

The data calculated for the present investigation was subjected statistically to regression analysis with Microsoft Excel and SPSS version 23 for Windows 10. Student's t test was used to examine the differences in the means of the condition factor (K), GSI, and HSI between the sexes of *S. labiatus* in each river. However, the Duncan multiple range test ($P < 0.05$) was used to investigate differences in the mean values of K, GSI, and HSI between the two rivers (Duncan 1955).

Results

The *S. labiatus* specimens collected from both the Jhelum and Sindh rivers in Kashmir Valley were analyzed to determine the values of the LWR, condition factor (K), GSI, and HSI. The data generated by regression analysis presented in Table 3 revealed that the minimum to maximum range of lengths for males and females of *S. labiatus* in the Jhelum River were 22.70–38.90 cm (33.59 ± 2.55) and 26.10–39.80 cm (33.19 ± 2.05), respectively, while the weight range of males and females was 128.20–542.80 g (381.71 ± 87.07) and 207.20–569.20 g (376.25 ± 73.05), respectively. Similarly in the Sindh River, the minimum to maximum length ranges for male and female *S. labiatus* were 27.00–39.70 cm (33.84 ±

Table 3
Length-weight relationships for *S. labiatus* inhabiting two lotic water bodies in the Kashmir Valley

			Total length		Body weight						
River	Sex	N	range (cm)	mean ± SD	range (g)	mean ± SD	*a*	*b*	95% CI of *a*	95% CI of *b*	r^2
Jhelum	Male	200	22.7-38.9	33.59 ± 2.55	128.2-542.8	381.71 ± 87.07	0.0060	3.14	0.0039-0.0093	3.01-3.26	0.932
	Female	200	26.1-39.8	33.19 ± 2.05	207.2-569.2	376.25 ± 73.05	0.0078	3.07	0.0048-0.0129	2.93-3.22	0.901
Sindh	Male	200	27.0-39.7	33.84 ± 2.22	211.4-583.1	400.07 ± 81.09	0.0089	3.04	0.0054-0.0145	2.90-3.18	0.911
	Female	200	28.9-40.2	33.88 ± 2.29	227.5-650.7	408.13 ± 84.54	0.0123	2.95	0.0072-0.0202	2.80-3.10	0.882

N = number of individuals; *a* = intercept; *b* = regression coefficient (slope); CI = confidence interval

2.22) and 28.90–40.20 cm (33.88 ± 2.29), respectively, while the male and female weight ranges were 211.40–583.10 g (400.07 ± 81.09) and 227.50–650.70 g (408.13 ± 84.54), respectively. To generate more precise information about the LWRs of *S. labiatus* inhabiting both water bodies, the data were analyzed statistically and the mathematical equations are as follows:

For the Jhelum River:

Males: $\log W = 2.22 + 3.14 \log L$, ($r^2 = 0.93$, $P < 0.05$)

Females: $\log W = 2.11 + 3.07 \log L$, ($r^2 = 0.90$, $P < 0.05$)

For the Sindh River:

Males: $\log W = 2.05 + 3.04 \log L$, ($r^2 = 0.91$, $P < 0.05$)

Females: $\log W = 1.91 + 2.95 \log L$, ($r^2 = 0.88$, $P < 0.05$).

During the current study, the results indicated that parameter *b* values were 3.14 for males and 3.07 for females in the Jhelum River, which indicated positive allometric growth, while for specimens from the Sindh River they were 3.04 for males and 2.95 for females. These results clearly indicated that the males exhibited positive allometric growth, but the *b* value of the females of less than 3 indicated negative allometric growth, which demonstrated that increased length did not correspond to increased weight. The findings of this investigation also revealed that the coefficient of determination r^2 value for males and females in both water bodies was equal to or above 0.90, except for the females from the Sindh River (Table 3).

The average values of K, GSI, and HSI are presented in Table 4. For both sexes of *S. labiatus*, the K value noted in the Jhelum River was significantly ($P < 0.05$) higher than that in the Sindh River. The average K values for males and females in the Jhelum River were 0.97 and 0.94, respectively, which indicated the overall well-nourished, healthy status of the fish, while in the Sindh River the K value was 0.86 for males and 0.88 for females. Variations in GSI and HSI values were also analyzed for both sexes of *S. labiatus* in these water bodies. The maximum GSI values for both male and female *S. labiatus* were recorded in the Sindh River, and these were significantly ($P < 0.05$) higher than those in the Jhelum River. The average GSI values for males was 4.17 and for females it was 4.42 in the Jhelum River, while in the Sindh River these were 5.60 for males and 5.76 for females. In

Table 4
Condition factor (K), gonadosomatic index (GSI) and hepatosomatic index of *S. labiatus* inhabiting two lotic water bodies in the Kashmir Valley. Data are mean ± SD

Rivers	Sex	N	K	GSI	HSI
Jhelum	Male	200	0.97 ± 0.20^a	4.17 ± 0.84^b	1.93 ± 0.52^a
	Female	200	0.94 ± 0.16^a	4.42 ± 0.98^b	1.98 ± 0.66^a
Sindh	Male	200	0.86 ± 0.15^b	5.60 ± 1.04^a	1.46 ± 0.40^b
	Female	200	0.88 ± 0.12^b	5.76 ± 1.12^a	1.50 ± 0.38^b

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

contrast, the HSI values in the Jhelum River were significantly ($P < 0.05$) higher compared to those in the Sindh River. The average HSI values in the Jhelum River for males and females were 1.93 and 1.98, respectively, and from the Sindh River they were 1.46 for males and 1.50 for females. However, in each water body no significant ($P > 0.05$) differences in the K, GSI, or HSI values were noted between the sexes.

Discussion

Studies of the LWRs of fish play a vital role in the comparison of morphological features of fish populations from different regions and among fish species belonging to the same taxonomic category (Famoofo and Abdul 2020). The degree of sex, diet, sexual maturity, area/seasonal impacts, stomach fullness, sample preservation techniques, number of specimens examined, and sampling time are all documented to affect LWRs (Hossain et al. 2014). In the present study, the results showed that the mean values of regression coefficient b for male and female *S. labiatus* in both water bodies were estimated within a range of 2 to 4, which falls well within expected range reported by Froese and Pauly (2021). Since *b* values are mainly associated with the general well-being of fishes, they depend largely on fatness as well as on the shape of fish species (Jisr et al. 2018). If the *b* value is less than 3, as fish increase in length they become lean, while if the value of *b* is more than 3, this indicates that as fish increase in length they gain mass (Mazumder et al. 2016). Hence, the values of *b* indicated positive allometric growth. Similar positive allometric growth is reported in different freshwater fish species such as *Labeo rohita* (Hamilton), *Tilapia mossambica* (Peters), *Heterotis nilo*ticus (Cuvier), *Raiamas senegalensis* (Steindachner), *Barbonymus gonionotus* (Bleeker), and *S. labiatus* (Mir et al. 2015, Olanrewaju et al. 2017, Mahmood et al. 2019, Sidik et al. 2020, Jan et al. 2021). In the Sindh River, the *b* value for male fish indicated positive allometric growth, but that for the females indicated negative allometric growth. Similar negative allometric growth is also reported by other researchers (Rodriguez et al. 2017, Jisr et al. 2018). In the present study, the results also showed that the value of coefficient of determination r^2 for males and females in both water bodies was equal to or exceeded 0.90, except for females in the Sindh River, thus signifying that the increased mass of the fish was attributed to the increase in body length (Komba et al. 2020).

In addition to LWRs, Fulton's condition factor (K) is vital in determining the general well-being of fishes in response to their environments. It is also useful in determining whether fishes are deep bodied and if they are robust (Datta et al. 2013). Condition factor (K) is also used as an index for monitoring fish age, growth rates, and feeding intensity and is also helpful when comparing fish nutritional condition with respect to various seasonal changes (De Giosa et al. 2014). Many fish condition parameters are known to change in response to physicochemical elements such as environment, fish age and physiological state, and feeding and reproductive cycles (Le Cren 1951, Anani and Nunoo 2016). In the present study, the average K values for both male and female *S. labiatus* in the Jhelum River were significantly ($P < 0.05$) higher than in the Sindh River. However, insignificant ($P > 0.05$) differences in K values were observed between the sexes inhabiting the same water body. The higher K values in the Jhelum River are corroborated by previous findings for *S. richardsonii* from the Jammu region (Bhagat and Sunder 1983) and *S. niger* from Dal Lake, Kashmir (Shafi and Yousuf 2012). These results demonstrated that the health condition of the fish from the Jhelum River was better compared to that in fish from the Sindh River. The difference in K values could be attributed to a number of factors such as natural food supply, fat accumulation, gonad development, maturity stage, physicochemical changes, etc. (Komba et al. 2020).

GSI values normally indicate gonad development as they increase with fish maturation and then decrease significantly thereafter (Jan et al. 2021). GSI values noted in the Sindh River were significantly ($P < 0.05$) higher than those in the Jhelum River. This could have stemmed from the lower GSI values in the Jhelum River that might have been caused by

pollutants or contamination from inland waters (Ogunola et al. 2018). Pieterse (2004) also reported that long-term fish exposure to different pollutants could cause decreased GSI values. Moreover, it was also noted that the GSI values were higher in females than in males from both of the water bodies analyzed in the Kashmir Valley. Our findings are consistent with those of other researchers who studied other fish species (Zardo and Behr 2015, Al-Deghayem et al. 2017). In addition to analyzing GSI values, HSI values were also analyzed. HSI mainly provides information about liver energy reserves and metabolic activity (Lenhardt et al. 2009), and it depicts an allocation of energy to the liver throughout the life cycle, except during reproduction when some of the energy is used for gonad maturation (Nunes et al. 2011). The present investigation determined that the overall liver weight of females was more than that of males in each water body, and the results of the current study concur with the findings of others such as Craik (1978). HSI values were significantly ($P < 0.05$) higher in the Jhelum River than in the Sindh River, and the differences in HSI noted between specimens from the two water bodies could have been caused by variations in the availability of natural food stemming from factors such as environmental changes, density or population changes etc. However, Feidantsis et al. (2020) reported liver weight decreases during reproduction, which might indicate that hepatic reserves are used in gonad maturation. Although significant ($P < 0.05$) differences in GSI and HSI values were recorded between specimens from the two water bodies, differences between the sexes were insignificant ($P > 0.05$) in the two water bodies. Therefore, the present study indicates clearly that further investigations must be conducted on the ecological conditions, the availability of the preferred food, and the biology of *S. labiatus*.

Conclusions

The differences in the climatic conditions between the Jhelum and Sindh rivers significantly affected significantly the LWRs and biological indices of *S. labiatus*. The LWR analyses of both sexes of *S. labiatus* in the Jhelum River followed the cube law, i.e., when fish length increased then fish weight increased, that indicated positive allometric growth. However, males from the Sindh River, exhibited positive allometric growth, while females exhibited negative allometric growth. While the higher K and HSI values in the Jhelum River demonstrated that the health condition of the fish in this river was superior to that of fish from the Sindh River, the reproductive growth of fish was significantly higher in the Sindh River. The information from this study is helpful in developing strategies for improving the management and conservation of this fish species, and it is recommended that further investigations be conducted on other fish species to identify which can survive in cold river environments.

Acknowledgments. The authors are grateful to the Head of the Department of Zoology for providing laboratory access and to the Department of Science and Technology (DST), Government of India, New Delhi, for providing financial assistance to Kousar Jan, one of the authors, through a DST-INSPIRE fellowship.

Author contributions. K.J. collected the materials and analyzed the data, I.A. designed the study and the concept and drafted and revised the manuscript.

ORCID iD
Imtiaz Ahmed https://orcid.org/0000-0003-4821-1707

References

Afonso-Dias, I., Reis, C., Andrade, J. P. (2005). Reproductive aspects of *Microchirus azevia* (Risso, 1810) (Pisces: Soleidae) from the south coast of Portugal. Scientia Marina, 69(2), 275-283.

Al-Deghayem, W. A., Al-Balawi, H. F., Kandeal, S. A., Suliman, E. A. M. (2017). Gonadosomatic index and some hematological parameters in African catfish *Clarias*

gariepinus (Burchell, 1822) as affected by feed type and temperature level. Brazilian Archives of Biology and Technology, 60, e160157.

Al Nahdi, A., Garcia de Leaniz, C., King, A. J. (2016). Spatio-temporal variation in length-weight relationships and condition of the ribbonfish *Trichiurus lepturus* (Linnaeus, 1758): implications for fisheries management. PloS One, 11(8), e0161989.

Anani, F. A., Nunoo, F. K. E. (2016). Length-weight relationship and condition factor of Nile tilapia, *Oreochromis niloticus* fed farm-made and commercial tilapia diet. International Journal of Fisheries and Aquatic Studies, 4, 647-650.

APHA (1998). Standard methods for the examination of water and waste water. 20th edition, American Public Health Association, Washington, DC.

Bhagat, M. J., Sunder, S. (1983). A preliminary note on the length-weight relationship and relative condition factor of *Schizothorax plagiostomus* (Heckel) from Jammu region. Journal of Inland Fisheries Society of India, 15(1-2), 73-74.

Braga, F. M. S. (2005). Feeding and condition factor of characidiin fish in Ribeirão Grande system, Southeastern Brazil. Acta Scientiarum: Biological Sciences, 271-276.

Craik, J. C. A. (1978). An annual cycle of vitellogenesis in the elasmobranch *Scyliorhinus canicula*. Journal of the Marine Biological Association of the United Kingdom, 58(3), 719-726.

Datta, S. N., Kaur, V. I., Dhawan, A., Jassal, G. (2013). Estimation of length-weight relationship and condition factor of spotted snakehead *Channa punctata* (Bloch) under different feeding regimes. SpringerPlus, 2(1), 1-5.

De Giosa, M., Czerniejewski, P., Rybczyk, A. (2014). Seasonal changes in condition factor and weight-length relationship of invasive *Carassius gibelio* (Bloch, 1782) from Leszczynskie Lakeland, Poland. Advances in Zoology, 10.1155/2014/678763.

Duncan, D. B. (1955). Multiple range and multiple F tests. Biometrics, 11(1), 1-42.

Famoofo, O. O., Abdul, W. O. (2020). Biometry, condition factors and length-weight relationships of sixteen fish species in Iwopin fresh-water ecotype of Lekki Lagoon, Ogun State, Southwest Nigeria. Heliyon, 6(1), e02957.

Feidantsis, K., Ntokou, A., Michaelidis, B. (2020). Effect of seasonality on oocyte growth, oocyte maturity stages, and reproductive capacity in the gilthead sea bream (*Sparus aurata*) in relation with depth. Acta Veterinaria Eurasia, 46(3), 87-98.

Froese, R. (2006). Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. Journal of Applied Ichthyology, 22(4), 241-253.

Froese, R., Pauly, D. (2021). FishBase. World Wide Web electronic publication. www.fishbase.org, version (06/2021).

Hossain, M. Y., Mosaddequr Rahman, M., Ahamed, F., Ahmed, Z. F., Ohtomi, J. (2014). Length-weight and length-length relationships and form factor of three threatened fishes from the Ganges River (NW Bangladesh). Journal of Applied Ichthyology, 30(1), 221-224.

Huxley, J. S. (1924). Constant differential growth-ratios and their significance. Nature, 114(2877), 895-896.

Jan, K., Ahmed, I. (2020). Morphometric and meristic characters of snow trout, *Schizothorax labiatus*, inhabiting the Jhelum River and its tributaries. Fisheries & Aquatic Life, 28(4), 216-224.

Jan, K., Ahmed, I., Dar, N. (2021). Temporal variations in length-weight relationship, condition factor and biological indices of Snow Trout, *Schizothorax labiatus* thriving in River Sindh of Indian Himalayan region. Egyptian Journal of Aquatic Biology and Fisheries, 25, 773-786.

Jisr, N., Younes, G., Sukhn, C., El-Dakdouki, M. H. (2018). Length-weight relationships and relative condition factor of fish inhabiting the marine area of the Eastern Mediterranean city, Tripoli-Lebanon. The Egyptian Journal of Aquatic Research, 44(4), 299-305.

Karim, L. R. (2020). Short communication length-weight relationship of Gold Spot Mullet-*Liza parsia* from Ashtamudi Lake, Kerala. Trends in Applied Sciences Research, 15, 54-58.

Komba, E. A., Munubi, R. N., Chenyambuga, S. W. (2020). Comparison of body length-weight relationship and condition factor for Nile tilapia (*Oreochromis niloticus*) cultured in two different climatic conditions in Tanzania. International Journal of Fisheries and Aquatic Studies, 8(3), 44-48.

Kullander, S. O., Fang, F., Delling, B., Ahlander, E. (1999). The fishes of the Kashmir Valley. In: Nyman, L. (Ed.). River Jhelum, Kashmir Valley, Impact on the aquatic environment, SWEDMAR, Sweden, Goteborg: 100-167.

Le Cren, E. D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). Journal of Animal Ecology, 201-219.

Lenhardt, M., Jaric, I., Cakic, P., Cvijanovic, G., Gacic, Z., Kolarevic, J. (2009). Seasonal changes in condition, hepatosomatic index and parasitism in sterlet (*Acipenser ruthenus* L.). Turkish Journal of Veterinary and Animal Sciences, 33(3), 209-214.

Lucifora, L. O., Menni, R. C., Escalante, A. H. (2002). Reproductive ecology and abundance of the sand tiger shark, *Carcharias taurus*, from the southwestern Atlantic. ICES Journal of Marine Science, 59(3), 553-561.

Ma, B. S., Xie, C. X., Huo, B., Yang, X. F., Huang, H. P. (2010). Age and growth of a long-lived fish *Schizothorax o'connori* in the Yarlung Tsangpo River, Tibet. Zoological Studies, 49(6), 749-759.

Mahmood, T., Mateen, A., Hadyait, M. A. (2019). Condition factor and length-weight relationship of pond reared *Labeo rohita*. PSM Biological Research, 4(2), 89-96.

Mazumder, S. K., Das, S. K., Bakar, Y., Ghaffar, M. A. (2016). Effects of temperature and diet on length-weight relationship and condition factor of the juvenile Malabar blood snapper (*Lutjanus malabaricus* Bloch & Schneider, 1801). Journal of Zhejiang University-Science B, 17(8), 580-590.

Mir, J. I., Sarkar, U. K., Gusain, O. P., Dwivedi, A. K. (2015). Length-weight relationships of the Indian Major Carp, *Labeo rohita* (Cypriniformes: Cyprinidae) from six drainages of Ganga basin, India. Cuadernos de Investigación UNED, 7(1), 71-78.

Nunes, C., Silva, A., Soares, E., Ganias, K. (2011). The use of hepatic and somatic indices and histological information to characterize the reproductive dynamics of Atlantic sardine *Sardina pilchardus* from the Portuguese coast. Marine and Coastal Fisheries, 3(1), 127-144.

Ogunola, O. S., Onada, O. A., Falaye, A. E. (2018). Preliminary evaluation of some aspects of the ecology (growth pattern, condition factor and reproductive biology) of African pike, *Hepsetus odoe* (Bloch 1794), in Lake Eleiyele, Ibadan, Nigeria. Fisheries and Aquatic Sciences, 21(1), 1-15.

Olanrewaju, A. N., Kareem, O. K., Nyaku, R. E., Tubo, M. T. (2017). Length-weight and length-length relationships of *Heterotis niloticus* (Cuvier, 1829) and *Raiamas senegalensis* (Steindachner, 1870). Journal of Aquaculture Research & Development, 11, 2-5.

Pieterse, G. M. (2004). Histopathological changes in the testis of *Oreochromis mossambicus* (Cichlidae) as a biomarker of heavy metal pollution. Doctoral thesis, Faculty of Science, Rand Afrikaans University, Johannesburg.

Prasad, S., Nath, P. (2020). Study of gonadosomatic index and maturation of an Indian major carp *Labeo rohita* (Ham) in Bihar, India. International Archives of Applied Sciences and Technology, 11, 37-41.

Pyle, G. G., Rajotte, J. W., Couture, P. (2005). Effects of industrial metals on wild fish populations along a metal contamination gradient. Ecotoxicology and Environmental Safety, 61(3), 287-312.

Rajaguru, A. (1992). Biology of two co-occurring tonguefishes, *Cynoglossus arel* and *C. lida* (Pleuronectiformes: Cynoglossidae), from Indian waters. Fishery Bulletin, 90(2), 328-367.

Rodríguez, J. M., Angón, E., González, M. A., Perea, J., Barba, C., García, A. (2017). Allometric relationship and growth models of juveniles of *Cichlasoma festae* (Perciforme: Cichlidae), a freshwater species native in Ecuador. Revista de Biología Tropical, 65(3), 1185-1193.

Shafi, S., Yousuf, A. R. (2012). Length-weight relationship and condition factor of *Schizothorax niger* (Heckel, 1838) Misra from Dal lake, Kashmir. International Journal of Scientific and Research Publications, 2(3), 1-3.

Sidik, R.A.R., Herawati, T., Sahidin, A., Herawati, H. 2020. Growth Pattern of Silver Barb, *Barbonymus gonionotus* (Bleeker, 1950) in Downstream Cimanuk River of West Java Province. Global Scientific Journal, 8: 551-558.

Sidiq, M., Ahmed, I., Bakhtiyar, Y. (2021). Length-weight relationship, morphometric characters, and meristic counts of the coldwater fish Crossocheilus diplochilus (Heckel) from Dal Lake. Fisheries & Aquatic Life, 29(1), 29-34.

Zardo, É. L., Behr, E. R. (2015). Population structure and reproductive biology of *Loricariichthys melanocheilus* Reis & Pereira, 2000 (Siluriformes: Loricariidae) in the rio Ibicuí, Brazil. Neotropical Ichthyology, 13, 371-382.