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Length-Weight Relationships, Condition Factor and Morphometric Characteristics of Schizothoracinae from Neelum and Jhelum Rivers of Azad Jammu and Kashmir, Pakistan

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ABSTRACT

The morphometrics, length-weight relationships and condition factor are presented for commercially important Schizothoracinae from Neelum and Jhelum rivers during 2015-2016. In the present study, four species of *Schizothorax* had been found, in which three species were already reported (*S. esocinus, S. plagiostomus* and *S. progastus*) and one new species (*S. niger*) was found first time in AJK. One hundred and fifty-nine specimens of *S. plagiostomus*, 74 specimens of S. esocinus, 21 specimens of *S. progastus* and 8 specimens of *S. niger* were taken for the study. The maximum snout length, eye diameter, length of lateral line, head length, dead depth and pre anal length were observed in *S. niger* followed by *S. esocinus* and two other species. Overall value of "b' fluctuated from 1.183 to 2.711 which did not follow the cube law (b=3) and indicated the negative allometric (b<3) growth pattern. Studies on condition factor (K) of Schizothorax species revealed the lowest values. High pollution load and environmental stress on these species seems to be very high and not led to the ideal growth pattern. It is concluded that, the fish is under the physiological stress and it is very essential for fishery managers to impose adequate regulations for sustainable fishery management and conservation in this state of Pakistan, in which most of population depend upon fish resources. No information regarding LWRs and morphometric measurements of *S. progastus* and *S. niger* was available in Fish Base.

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Authors' Contribution
TA and GA designed the experiments, analyzed the data and wrote the manuscript. TA conducted the experiments. NS helped in sample collection.

Key words
Co-efficient of correlation, LWR, Morphometrics, Schizothoracinae, Wellbeing of fish

INTRODUCTION

Many freshwater fish species are currently threatened by direct and indirect influence of human activities, such as habitat destruction and fragmentation (Mir *et al*., 2013). Construction of dams across rivers in particular affects fish movements, which may restrict the gene flow and lead to differentiation of populations (Meldgaard *et al*., 2003). The anthropogenic disturbances are likely to alter the genetic diversity within populations and genetic differentiation between populations (Yamamoto *et al*., 2004). The long-term isolation of populations and interbreeding can lead to morphometric variations between populations, and this morphometric variation can provide a basis for population differentiation. Morphometric differences among stocks of a species are recognized as an important tool for evaluating the population structure and as a basis for identifying stocks (Turan, 1999).

Morphological characters useful in identification include shape of head, position and shape of the mouth, size and number of scales and gill rakers (Jhingran, 1991). Morphological variation in fishes may provide a good record of short-term population structuring. It is often environmentally induced for aquatic environments can exhibit great spatial or temporal variability in both abiotic and biotic habitat parameters (Langerhans *et al*., 2003; Langerhans *et al*., 2007). There are many well documented studies that provide evidence for stock discrimination based on traditional morphometric characters (Quilang *et al*., 2007; Więcaszek *et al*., 2007; Bektas and Belduz, 2009). However, a new system of morphometric measurements called the truss network system, constructed with the help of landmark points, has been increasingly used for stock identification (Mir *et al*., 2013).

Like the other morphological characteristics, the LWR could be used for the taxonomic differentiation and different developmental events such as onset of maturity, metamorphosis and growth (Thomas *et al*., 2003). It can also be used to create an equation to quantify the total fish landed and compare the different population in a specific area (Singh *et al*., 2011). LWR is helpful in fish biology in numerous ways: to calculate the total fish weight from its length, to estimate the condition factor, life history and morphometric characters of different populations (Sani *et*

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al., 2010) and to study the allometric changes (Teixeira de Mello *et al*., 2006).

Moreover, the weight-length relationship improves the information about the history of commercially valuable fishes, thus enhance the knowledge of conservation and management. Fulton's condition factor (Kn) is generally used in fisheries science to describe the condition of fish by calculating the weight-length relationship (Froese, 2006). The state of sexual maturity, age, sex, and the availability of food sources in fish species were indicated by different values in K (Anibeze, 2000). The LWR is also very essential component of Fish Base (Froese and Pauly, 2012). Additionally, it also provides useful information of environmental and climate changes, and variation in practices of human survival. A lot of LWR data is available for European and North American freshwater fishes, but are lacking for most tropical and sub-tropical fish species (Dubey *et al*., 2012; Mir *et al*., 2012).

Family Cyprinidae, genus Schizothorax locally known as snow trout is abundant in the Rivers and streams of the Himalaya and Central Asia (Mir *et al*., 2012). Schizothorax species are the endemic carps of Neelum and Jhelum Rivers of Azad Jammu and Kashmir, Pakistan. Genus Schizothorax in these rivers was represented by four species i.e., *S. plagiostomus*, *S. esocinus*, *S. niger* and *S. progastus*. It is highly preferred by the local masses because of its food value and taste that fetches high market price (Akhtar *et al*., 2016).

LWR have been extensively studied across the world (Bhat *et al*., 2010; Drouineau *et al*., 2010; Shadi *et al*., 2011; Dar *et al*., 2012; Sarkar *et al*., 2012; Mir *et al*., 2012). In Azad Jammu and Kashmir, there is inadequate study on LWRs and condition factor of snow trouts fishes a recent contribution of Akhtar *et al*. (2016) is available on LWR, condition factor and sex ratio of only *S. plagiostomus* from River Neelum and Jhelum of Kashmir. Moreover, there is no information about morphometrics, LWR and wellbeing of other Schizothorax species from River Neelum and Jhelum of AJK therefore, taking into consideration of above facts, the current study was conducted to establish the growth pattern, general condition and morphometrics of these species from natural habitat for conservation and assessment.

MATERIALS AND METHODS

Ethical statement

All animal experimental procedures were conducted in accordance with local and international regulations. The international regulation is the Wet op de dierproeven (Article 9) of Dutch Law (International).

Sample collection

Current study estimates the weight-length relationship, condition factor and morphometric characteristics of four endemic Schizothorax species from river Neelum and Jhelum of AJK, Pakistan during 2015 to 2016. The fish samples were randomly collected by local fisherman from River Jhelum and Neelum, Muzaffarabad (from Ghori to Kohala) with GPS coordinates viz. river Neelum (Ghori, 34°26'47.1"N 73°30'38.9"E; Challah Bandi, 34°23'03.0"N 73°27'53.8"E) and river Jhelum (Airport, 34°19'46.3"N 73°30'44.8"E; Garhi Dupatta, 34°14'05.7"N 73°36'31.6"E; Domail, 34°21'14.6"N 73°28'03.8"E; Chatter, 34°20'13.8"N 73°27'10.8"E; Ambore, 34°19'50.3"N 73°27'57.1"E; Chatter Kalass, 34°12'25.1"N 73°29'50.8"E; Kohala, 34°05'48.2"N 73°29'52.0"E) from 2014 to 2015.

The collection points in the study were not part of any reserve forests, protected area, and national park. All the fish samples were carefully handled to avoid the damages during studies. The Board of Advanced Studies and Research, University of Azad Jammu and Kashmir, Muzaffarabad permit to conduct this study in Jhelum and Neelum Rivers of Muzaffarabad city. No specific permission was required for collection sites and the collected fish samples were anesthetized by immersion in 1% benzocaine in water and euthanized by benzocaine excess. The labeled samples were packed in polyethylene bags and brought back to the Laboratory of Molecular Genetics, University of Azad Jammu and Kashmir for further research analysis. After analysis, voucher specimens were kept in 70% ethanol and stored in Zoological museum hall of the University of Azad Jammu and Kashmir, Pakistan. The collected voucher specimen were recognized according to Jayaram (1999) identification key. The *S. plagiostomus* has a suctorial mouth and the body is uniformaly silvery without any black spot. The dorsal fin of *S. plagiostomus* is inserted nearer to the tip of snout than caudle fin base. The phenotypic characters of *S. progastus* are similar to *S. plagiostomus* but, the dorsal fin is inserted midway between the tip of snout and caudle fin base. The *S. niger,* has a mouth horse-shoe shaped. Its lips are rounded and fleshy and the body is much darker in color. In *S. esocinus*, the mouth is not sectorial while, the lips are soft and pointed. The cleft of mouth is deep while, the side and back of the body have the small irregular spots. These species were also identified by Akhtar and Ali (2016) through molecular DNA barcoding, and barcode of life data system search engine (BOLD). After removing the excess water on the specimens by pressing with blotting paper, the weight and length measurements were taken at the site using measuring scale (accuracy of 0.1cm) and digital weighing balance (accuracy of 0.01g), respectively.

Table I. Estimated parameters of the length-weight relationships for *Schizothorax* species in Neelum and Jhelum Rivers of Azad Jammu and Kashmir.

Species name	Number	Length (cm)		Weight (g)	
		Min-Max	Mean± SD	Min-Max	Mean± SD
S. plagiostomus	159	17-39	28.35±4.83	50.5-542	245.59±103.29
S. esocinus	74	13-36	27.29±4.84	50-554	258.03±89.66
S. progastus	21	24-39	30.85±3.93	163-534	274.26±74.49
S. niger	8	23-38	29.37±4.72	175-520	257.12±113.83

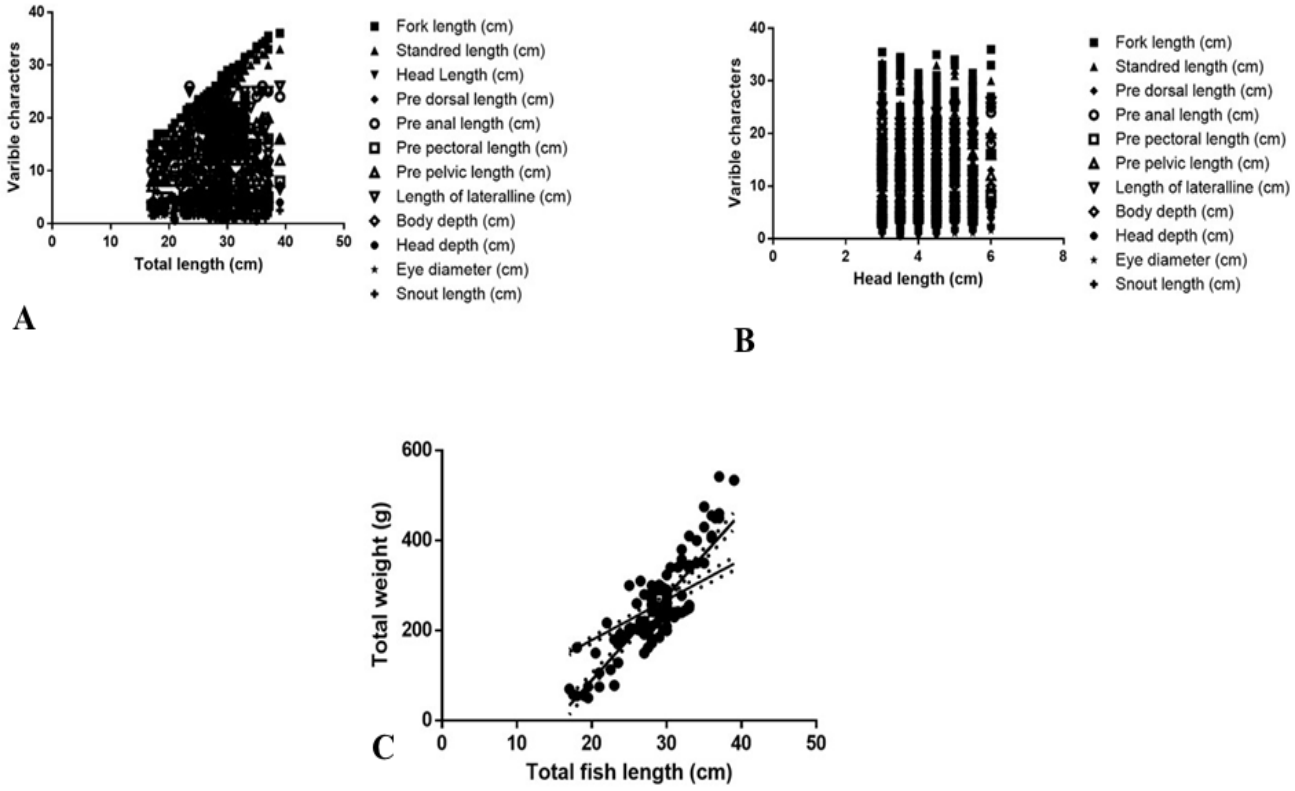

Fig. 1. Relationship of various morphometric measurements compared with total length (A) head length (B) and weight length relationship (C) of *S. plagiostomus*.

Length-weight relationship of four fish species was examined by evaluating weight and length of fish specimens collected from River Neelum and Jhelum Muzaffarabad. The correlation between these parameters were assembled by following the equation of Froese (2006). $W = a L^b$ Where, W= weight of fish (g), L=length of fish (cm), a= constant and b= an exponent. This equation was converted into logarithmic form gives a straight line relationship graphically. Log W= Log a + b Log L Through condition factor, the fitness and general wellbeing of fish was calculated based on the statement that heavier fish of a given length are in better condition (Mir *et al*., 2012). The condition factor was calculated by following Fulton (1904) equation.

$K = W*100/L^3$ Where, W= weight (g), L= length (cm) and 100 is a factor to bring the value of K near unity. The morphometric correlation coefficient (r), regression coefficients (a and b) between TL, HL with rest of the body parameters was calculated using Graph Pad Prism for Windows (version 5.03) and also used to plot graphs.

Table II. The significant correlation of various morphometric parameters with TL and HL in the four Schizothorax species.

Independent variable	Dependent variable	P values			
		S. plagiostomus	***S. esocinus***	***S. niger***	***S. progastus***
Total length (TL)	Fork length	< 0.0001(****)	< 0.0001(****)	< 0.0001(****)	< 0.0001(****)
	Standard length	< 0.0001(****)	< 0.0001(****)	< 0.0001(****)	< 0.0001(****)
	Head length	< 0.0001(****)	0.2187(ns)	0.6578(ns)	0.1732(ns)
	Max. body depth	< 0.0001(****)	0.4353(ns)	0.8952(ns)	0.5616(ns)
	Pre dorsal length	< 0.0001(****)	0.0917(ns)	0.7582(ns)	0.7381(ns)
	Pre pectoral length	< 0.0001(****)	0.0049(**)	0.8971(ns)	0.7230(ns)
	Pre pelvic length	< 0.0001(****)	0.0010(**)	0.8269(ns)	0.5613(ns)
	Pre anal length	< 0.0001(****)	< 0.0001(****)	0.7758(ns)	0.6346(ns)
	Snout length	0.8823(ns)	0.6914(ns)	0.2185(ns)	0.0121(*)
	Eye diameter	0.4952(ns)	0.3067(ns)	0.5589(ns)	0.6224(ns)
	Length of lateral line	< 0.0001(****)	< 0.0001(****)	0.7048(ns)	0.6606(ns)
	Head depth	< 0.0001(****)	0.5774(ns)	0.5264(ns)	0.3295(ns)
Head length (HL)	Fork length	< 0.0001(****)	0.2671(ns)	0.6565(ns)	0.1574(ns)
	Standard length	< 0.0001(****)	0.2671(ns)	0.5800(ns)	0.1574(ns)
	Max. body depth	< 0.0001(****)	0.2671(ns)	0.0185(*)	0.1942(ns)
	Pre dorsal length	< 0.0001(****)	0.2671(ns)	0.2085(ns)	0.0743(ns)
	Pre pectoral length	0.0474(*)	0.2671(ns)	0.2938(ns)	0.5264(ns)
	Pre pelvic length	0.0416(*)	0.2671(ns)	0.3485(ns)	0.4003(ns)
	Pre anal length	< 0.0001(****)	0.2671(ns)	0.3011(ns)	0.1217(ns)
	Snout length	0.0002(***)	0.2671(ns)	0.8374(ns)	0.4800(ns)
	Eye diameter	0.1035 (ns)	0.2671(ns)	0.9457(ns)	0.9999(ns)
	Length of lateral line	< 0.0001(****)	0.2671(ns)	0.2805(ns)	0.0167(*)
	Head depth	< 0.0001(****)	0.2671(ns)	0.0240(*)	0.0086(**)

Significant (alpha = 0.05); ns: non-significant.

RESULTS

Overall, 262 length-weight relationships, condition factor and morphometric characteristics referring to four Schizothorax fish species from rivers of Azad Jammu and Kashmir, Muzaffarabad. *S. plagiostomus* was the most dominant fish in the Rivers Neelum and Jhelum, followed by *S. esocinus* and *S. progastus* while, we received the low catch of the *S. niger* from the study area during our whole collection.

A total of 159 specimens of *S. plagiostomus* were collected randomly from these rivers which ranged in total length from 17 to 39 cm and in total weight from 50.5 to 542 g (Table I). The total length was 1.08 times the fork length, 1.18 times the standard length, 2.19 times the pre-dorsal length, 1.55 times the pre-anal length, 2.99 times the pre-pectoral length, 2.15 times the pre-pelvic length, 1.52 times the length of lateral line, 5.22 times the total body depth, 6.80 times the head length, 7.31 times the head depth, 14.83 times the eye diameter and 15.44 times the snout length. All these parameters recorded significant positive relationship ($P < 0.001$) with the total length except the eye diameter and snout length. These two parameters show non-significant relationship with the total length (Table II; Fig. 1A).

The head length was 0.15 times the fork length, 0.17 times the standard length, 0.32 times the pre-dorsal length, 0.22 times the pre-anal length, 0.43 times the pre-pectoral length, 0.31 times the pre-pelvic length, 0.22 times the length of lateral line, 0.76 times the total body depth, 1.07 times the head depth, 2.17 times the eye diameter and 2.27 times the snout length. All these parameters recorded significant positive relationship with the head length while, the eye diameter show non-significant relationship with

Table III. Correlation coefficient (r) and regression coefficients (a & b) of various morphometric parameters with TL and HL in the four Schizothorax spp.

Independent variable	Dependent variable	*S. plagiostomus*			*S. esocinus*			*S. niger*			*S. progastus*		
		a	b	r	a	b	r	a	b	r	a	b	r
Total length (TL)	Fork length	-1.86	0.987	0.994	-1.277	0.965	0.994	-1.151	0.972	0.996	-1.603	0.982	0.995
	Standard length	-3.59	0.972	0.989	-3.062	0.960	0.993	-3.39	0.972	0.994	-3.603	0.982	0.994
	Head length	2.58	0.056	0.350	3.446	0.021	0.144	5.240	0.031	0.186	2.171	0.064	0.333
	Max. body depth	1.23	0.148	0.387	4.635	0.033	0.092	7.255	0.023	0.056	6.273	0.061	0.148
	Pre dorsal length	4.30	0.305	0.510	10.20	0.110	0.197	11.82	0.065	0.130	12.27	0.049	0.073
	Pre pectoral length	-0.359	0.347	0.401	2.211	0.275	0.323	9.210	0.047	0.054	9.376	0.077	0.072
	Pre pelvic length	3.34	0.346	0.394	4.312	0.309	0.373	13.73	0.088	0.092	14.88	0.139	0.135
	Pre anal length	5.38	0.455	0.594	7.496	0.380	0.502	18.33	0.073	0.120	13.49	0.101	0.095
	Snout length	1.88	-0.001	0.011	1.647	0.006	0.120	4.574	0.066	0.048	3.206	0.045	0.532
	Eye diameter	1.67	0.008	0.053	1.367	0.021	0.046	4.388	0.059	0.244	1.433	0.016	0.138
	Length of lateral line	3.48	0.531	0.645	8.716	0.352	0.448	18.99	0.099	0.160	12.73	0.122	0.106
	Head depth	2.21	0.400	0.340	3.593	0.011	0.065	1.992	0.074	0.264	5.371	0.057	0.263
Head length (HL)	Fork length	17.62	2.041	0.327	21.56	0.873	0.130	32.11	0.084	0.187	21.93	1.629	0.319
	Standard length	15.79	1.964	0.318	19.30	0.959	0.144	31.13	0.350	0.232	19.93	1.629	0.318
	Max. body depth	-0.124	1.332	0.554	5.793	0.057	0.022	-1.972	1.979	0.794	7.000	0.628	0.295
	Pre dorsal length	6.321	1.585	0.424	13.88	0.167	0.043	7.357	1.483	0.498	16.48	1.379	0.397
	Pre pectoral length	5.905	0.853	0.157	10.16	0.106	0.018	-1.566	2.175	0.425	10.34	0.807	0.146
	Pre pelvic length	9.441	0.887	0.161	13.25	0.121	0.021	1.776	2.168	0.383	14.86	1.029	0.193
	Pre anal length	10.01	1.979	0.413	15.10	0.688	0.137	13.99	1.510	0.419	24.54	1.900	0.348
	Snout length	0.841	0.238	0.289	2.033	0.048	0.047	2.927	0.069	0.873	2.107	0.071	0.163
	Eye diameter	1.373	0.129	0.129	1.826	0.029	0.024	2.444	0.041	0.280	1.929	0.091	0.012
	Length of lateral line	10.31	1.972	0.382	18.43	0.021	0.003	14.19	1.608	0.435	29.32	0.071	0.515
	Head depth	2.210	0.399	0.339	4.100	0.044	0.035	-1.392	1.294	0.774	6.214	0.628	0.557

the head length (Table III) (Fig. 1B). The length-weight relationship in the fish was represented by the equation; Log W = -3.08 + 1.301 Log L (Fig. 1C)

The condition factor (Kn) of *S. plagiostomus* was also calculated as 0.87 in current study. Seventy four specimens of *S. esocinus* having total length from 13 to 36 cm and total weight from 50 to 454.5 g were collected during current study. The total length was 1.09 times the fork length, 1.19 times the standard length, 2.06 times the pre-dorsal length, 1.52 times the pre-anal length, 2.8 times the pre-pectoral length, 2.13 times the pre-pelvic length, 1.48 times the length of lateral line, 4.71 times the total body depth, 6.78 times the head length, 8.39 times the head depth, 14.06 times the eye diameter and 14.9 times the snout length. Fork length, standard length, pre pectoral length, pre pelvic length, pre anal length and length of lateral line show the significant positive relationship while, the rest of parameters show the non-significant relationship with total length (Fig. 2A).

Head length was 0.16 times the fork length, 0.17 times the standard length, 0.30 times the pre-dorsal length, 0.22 times the pre-anal length, 0.41 times the pre-pectoral length, 0.31 times the pre-pelvic length, 0.21 times the length of lateral line, 0.79 times the total body depth, 1.23 times the head depth, 2.05 times the eye diameter and 2.19 times the snout length. All these parameters recorded non-significant relationship with the head length (Fig. 2B). The length-weight relationship in *S. esocinus* was represented by the equation

Log W = -1.661+1.183 Log L (Fig. 2C). While, condition factor (Kn) of *S. esocinus* was 0.839

S. progastus was represented by 21 specimens which ranged in length from 24–39 cm and in weight from 163 to 534 g. Statistical analysis of the data revealed that the total length was 1.07 times the fork length, 1.15 times the standard length, 2.87 times the pre-dorsal length, 1.85

times the pre-anal length, 2.42 times the pre-pectoral length, 2.91 times the pre-pelvic length, 1.86 times the length of lateral line, 4.07 times the total body depth, 7.40 times the head length, 8.59 times the head depth, 16.60 times the eye diameter and 16.23 times the snout length. Fork length, standard length, and snout length show the significant positive relationship while, the rest of all the parameters show the non-significant relationship with total length (Fig. 3A).

Similarly, head length was 0.14 times the fork length, 0.15 times the standard length, 0.38 times the pre-dorsal length, 0.25 times the pre-anal length, 0.59 times the pre-pectoral length, 0.39 times the pre-pelvic length, 0.25 times the length of lateral line, 0.95 times the total body depth, 1.16 times the head depth, 2.16 times the eye diameter and 2.19 times the snout length. The length of lateral line and head depth show the significant positive relationship while, rest of all the parameters show the non-significant relationship with head length. (Fig. 3B). The length-weight relationship in *S. progastus* was represented by the equation Log W = -2.081+2.50 Log L (Fig. 3C). The condition factor of *S. progastus* was 0.826.

Eight specimens of *S. niger* having total length from 23 to 38 cm and total weight from 175 to 520 g were collected during current study. The total length of *S. niger* was 1.07 times the fork length, 1.16 times the standard length, 2.13 times the pre-dorsal length, 1.43 times the pre-anal length, 3.76 times the pre-pectoral length, 2.64 times the pre-pelvic length, 1.39 times the length of lateral line, 4.47 times the total body depth, 7.02 times the head depth, 11.10 times the eye diameter and 11.20 times the snout length. Fork length and standard length show the significant positive correlation while, the rest of all the variables show the non-significant relationship with total length (Fig. 4A).

Head length was 0.15 times the fork length, 0.17 times the standard length, 0.31 times the pre-dorsal length, 0.21 times the pre-anal length, 0.55 times the pre-pectoral length, 0.38 times the pre-pelvic length, 0.20 times the length of lateral line, 0.65 times the total body depth, 1.03 times the head depth, 1.64 times the eye diameter and 1.63 times the snout length. Head length show the significant relationship with body depth and head depth while, rest of all the parameters show the non-significant correlation with head length (Table II; Fig. 4B). The length-weight relationship in *S. niger* was represented by the equation Log W = -3.51+2.711 Log L (Fig. 4C) and the condition factor of *S. niger* was 0.859. *S. plagiostomus* and *S. esocinus* shows that weight of fish is not growing in accordance with the length of fish and significantly deviate from the isometric growth (b=3).

DISCUSSION

The morphometric measurements have been widely used for fish identification (Yousuf *et al*., 2003). *S. progastus* showed the shortest head length, body depth, head depth, snout length, eye diameter and pre pectoral length as compared to other three species. The maximum snout length, eye diameter, length of lateral line, head length, dead depth and pre anal length were observed in *S. niger* followed by *S. esocinus* and two others. Bhat *et al*. (2010) also reported the similar type of study and concluded that *S. esocinus* showed maximum growth in head length, pre-dorsal length, pre-pectoral length and eye diameter, while *S. plagiostomus* ranked second in pre-dorsal length while, maximum caudal fin length and pre-anal length was observed in *S. plagiostomus*.

The variations in various morphometric parameters of these species were statistically significant and thus can be regarded as different species (Yousuf *et al*., 2001; Bhat *et al*., 2010). Values of b for *S. progastus* and *S. niger* were within the normal range of 2.5–3.5, as suggested by Froese (2006), while the *S. plagiostomus* and *S. esocinus* showed the negative allometric growth pattern which indicates that, these fish species are not growing in accordance with the increase in their total length. The divergences between expected and calculated values may be due to habitat, low number of specimens examined, size range covered, seasonal variation, extent of stomach fullness, sex, sexual maturity, and the health condition of fishes (Froese, 2006; Jamali *et al*., 2014; Khan and Sabah, 2013), lack of covering all size-classes, or over-representing juveniles that were not considered in the present study.

Previous findings on the WLR of cyprinid fishes revealed that, most of them rigorously follow the cue law (b=3) while, the other showed the positive allometry (b>3) or negative allometry (b<3). Qadri and Mir (1980) reported the value of "b" as 2.448 for *S. plagiostomus* from the peripheral water bodies of Dal Lake, while Bhagat and Sunder (1983) reported it to be 2.928 for the same fish from the Jammu water bodies. Similarly, from Lidder Lake, the value of "b" for this fish was calculated as 2.9467 (Bhat *et al*., 2010); however, Khan and Sabah (2013) reported the "b" value of same fish as 2.86 from Kashmir valley while, Akhtar *et al*. (2016) recorded the value of same fish as 1.672 from Neelum and Jhelum rivers, Azad Kashmir. The previous findings of Akhtar *et al*. (2016) verify the present findings on the value of "b" as 1.301 for *S. plagiostomus*. *S. plagiostomus* also shows that, the weight of fish is not growing in accordance with the length of fish and significantly deviate from the isometric growth.

Isometric growth pattern has been reported in case of *S. esocinus "b"* as 3.0180 from the Dal Lake

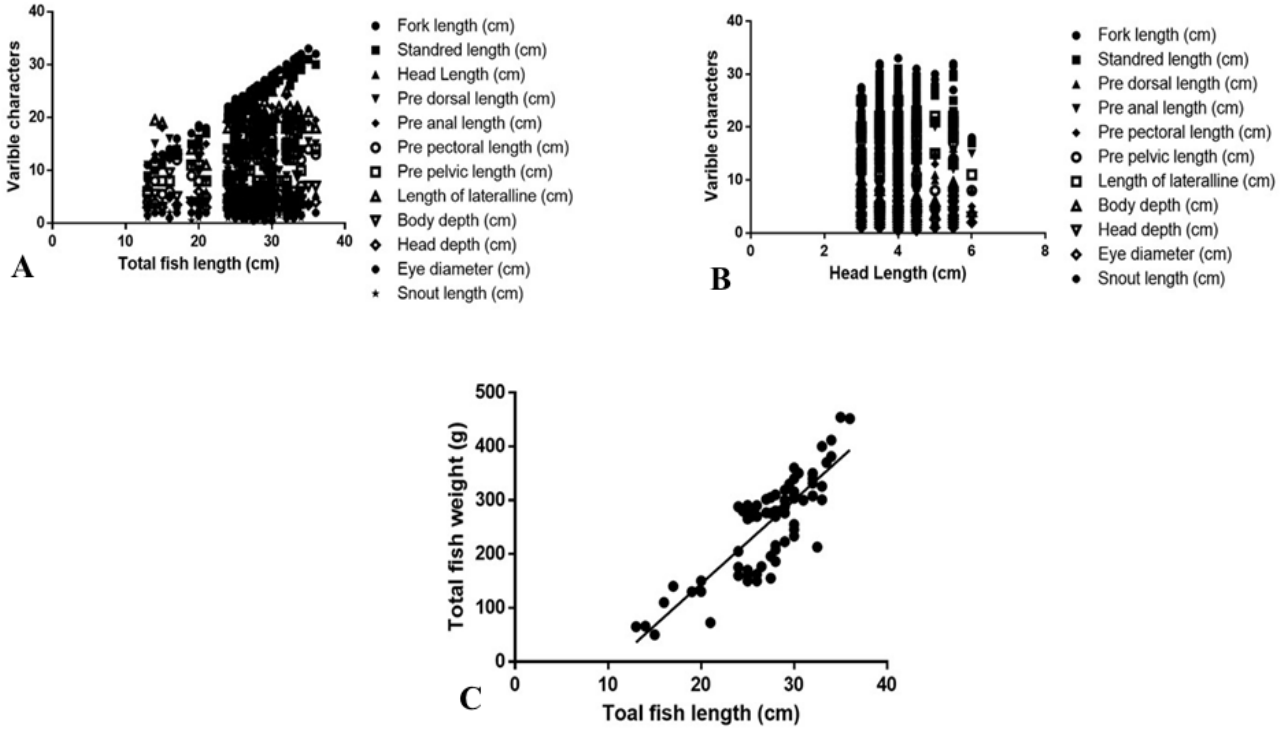

Fig. 2. Relationship of various morphometric measurements compared with total length (A) head length (B) and weight length relationship (C) of *S. esocinus*.

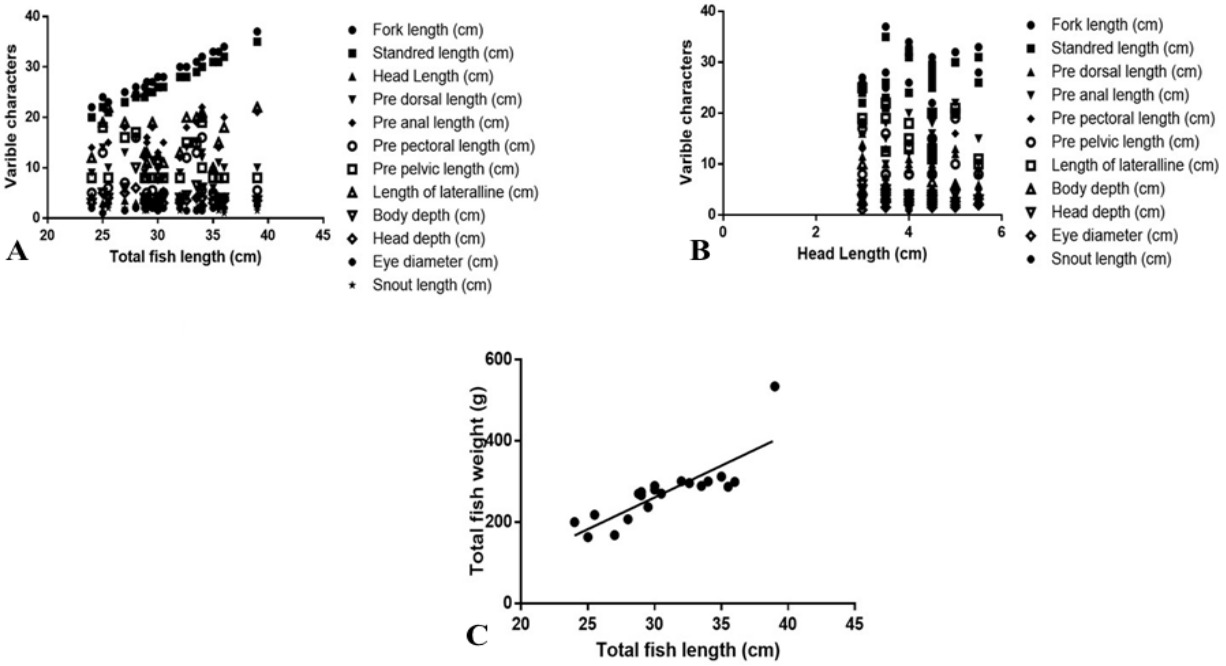

Fig. 3. Relationship of various morphometric measurements compared with total length (A) head length (B) and weight length relationship (C) of *S. progastus.*

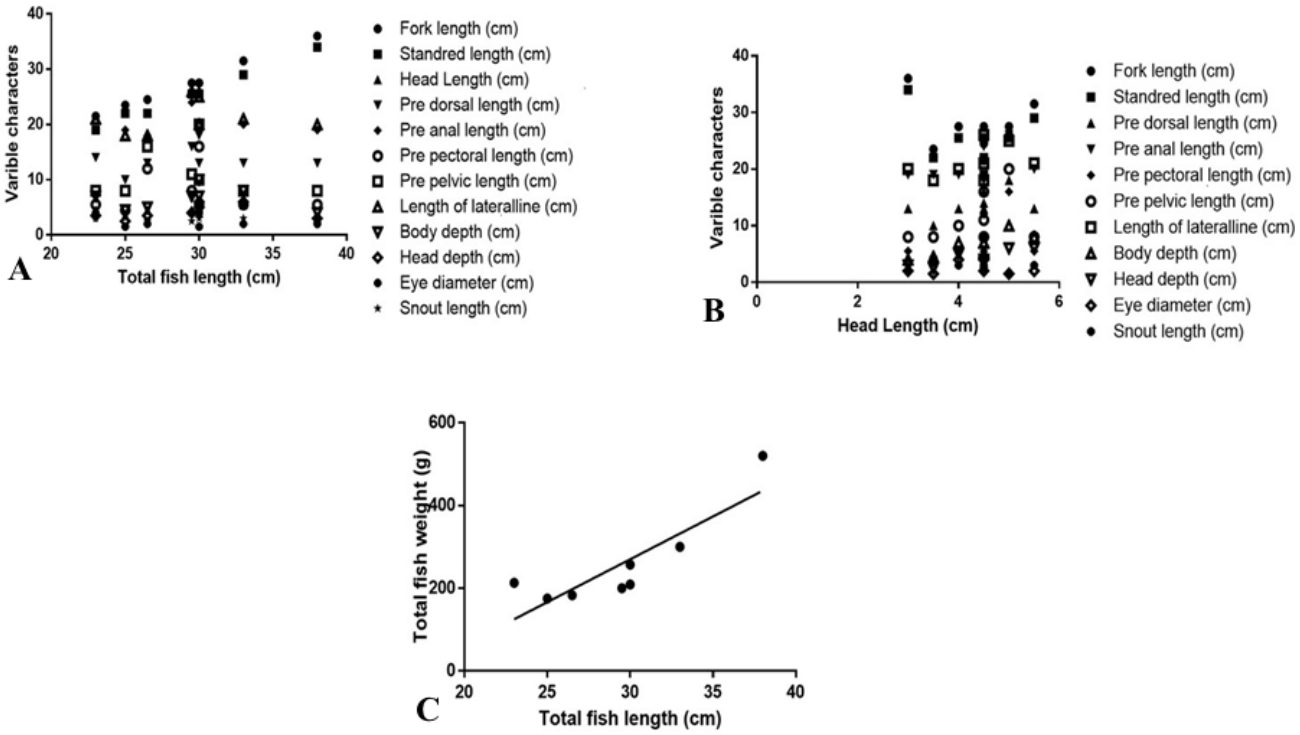

Fig. 4. Relationship of various morphometric measurements compared with total length (A) head length (B) and weight length relationship (C) of *S. niger*.

(Bhagat and Sunder, 1983), while, Bhat *et al*. (2010) reported it to be 3.00 from River Lidder of Kashmir. However, Khan and Sabah (2013) recorded the value in the same fish as 3.08 from Kashmir valley, while, Dar *et al*. (2012) reported it to be 2.86 from river Jhelum Kashmir and Mir *et al*. (2014) reported the value of this fish as 2.98 from Kashmir valley India. In *S. esocinus*, the value of "b" in the present study was found as 1.183 which, show the deviation from isometric growth pattern.

The value of "b" of *S. progastus* was calculated as 2.442 in current study. No previous findings were reported for the "b" value of *S. progastus*. Shafi and Yousuf (2012) observed that the value of "b" as 3.07 in *S. niger* from Dal lake, while, Khan and Sabah (2013) reported the value of "b" of same fish as 2.66 from Kashmir valley. However, the value of "b" of same fish was observed as 2.711 in current study.

The value of b calculated from present study is different from the previous findings, which is possibly due to several factors such as the habitat, number of specimens examined and length ranges and length types used. Among these fishes *S. esocinus* and *S. plagiostomus* deviated more from the value of "b" as compared to *S. niger* and *S. progastus*. As suggested by Petrakis and Stergiou (1995), use of LWRs should be strictly limited to the observed length ranges applied in the estimation of the linear regression parameters. Study of WLR has the great importance in fisheries conservation and its management, as it supports to understand the general wellbeing and growth patterns (isometric and allometric) of fish population and is influenced by many environmental factors like pH, temperature, salinity, dissolved oxygen, ammonia and heavy metal concentration. Yousuf and Firdous (1992) and Yousuf *et al*. (2001) observed that environmental factors are responsible for the deviation from the ideal state to a great extent. All the fish species under Schizothoracinae, reported in the Rivers of Azad Kashmir during the present study are typical inhabitants of running habitats in their distributional range. It can be determined that in Schizothorax species gain weight at slower rate in relation to its length.

Le Cren (1951) reported that the condition factor higher than one directed to the good health of fish whereas, its value lower than one indicated that fish is not healthy. The current study revealed that all the species were found to be not in good condition and recorded a "Kn" value lesser than one which ranged from 0.826 to 0.874. A change in Kn value of different fish species were due to change in their spawning cycle (Narejo *et al*., 2002; Mir *et al*., 2012), feeding

rhythms or change in environmental factors (Doddamani and Shanbouge, 2001) and also by pollution (Devi *et al*., 2008). According to Jan and Ahmed (2016) and Dar *et al*. (2012), the fluctuations in condition factor in *Schizothorax species* could be credited to the reproductive cycles and food concentration. The result of this study shows negative allometric growth pattern and it is a bit difficult to say that, environment is supportive of the growth, reproduction and survival of Schizothorax species. Current findings provide the baseline and useful information about morphometrics, weight-length relationship and general health of four commercially important Schizothorax species of river Neelum and Jhelum Muzaffarabad AJK. This study could be valuable to enforce suitable systems for sustainability of fish conservation and management of these selected rivers as well as for other rivers of the Azad Jammu and Kashmir Pakistan, to prevent their complete extinction. This study also provide valuable information for the online Fish Base database as well as contribute to fishery research and its management in wild condition.

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Novelty statement

In current study, one new species (*Schizothorax niger*) was found first time in AJK, Pakistan. This is the first study regarding length weigh relationship and morphometric measurements of *S. progastus* and *S. niger* because, no information is available for these species in Fish Base.

Statement of conflict of interest

The authors declare there is no conflict of interest.

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