SindhUniv. Res. Jour. (Sci. Ser.) Vol. 51 (03) 441-452 (2019)

http://doi.org/10.26692/sujo/2019.03.71

SINDH UNIVERSITYRESEARCH JOURNAL (SCIENCESERIES)

Phenotypic Characteristics of the Clupeid Fish *Tenualosa ilisha* (Family: Clupeidae) collected from Manjhand Vicinity, Pakistan

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Received 16th November 2018 and Revised 17th August 2019

Abstract: Thirteen body proportions of the clupeid species, *Tenualosailisha* were investigated from Manjhand locality on the Indus River, Pakistan. Negative allometricgrowths for all morphometric traits examined were attained. The highest value of 'b' coefficient obtained was at its highest level for fork length (0.8834) and its lowest value for eye diameter (0.0398). The correlation coefficient value (R^2) was at its lowest value for the relationship of the pectoral fin length-total fish length (0.46), the medium value of 0.77 and 0.80 were obtained for dorsal fin base length and anal fin base length respectively, while the highest value of 0.99 was attained for the relationship of both fork and standard lengths-total length and 0.98 for caudal peduncle length followed by 0.94 for the relationship of postorbital length-total fish length. The present report provides data to fishery biologists on body proportions of *T. ilisha* from the Indus River valley, Pakistan to support in development of management policies for this fish species.

Keywords: Morphometrics; Clupeidae; Manjhand; Indus River; Regression; spawning ground.

1. INTRODUCTION

Clupeids (Clupeidae: subfamily Alosinae) is vital group of fisheries in Asia and mainly inhabit coastal and estuarine waters. They are cosmopolitan assemblage of fishes that adventure a varied range of environments throughout the world. Certain of the species have the habit of migration and they swim upstream for breeding and some confine to the marine waters and complete their life cycle (Panhwar *et al*., 2001).

The clupeid comprises a number of species, amongst which Indian shad that showed an economic significance for the fishers and the businesspersons. In Indian sub-continent, the genus *Tenualosa* is exemplified by three species *viz. Tenualosa ilisha*, *Tenualosa toli* and *Hilsakelee* (Bhaumik, 2012). Among those species, *T. ilisha* is characterised in having upstream migration from the sea into the large rivers such as the Indus River for annual breeding. In addition to Pakistan, this species is also present in the Arabian Gulf, Bangladesh, Burma, China, India, Iran, and South Vietnam (Bhaumik *et al.,* 2013).

In most Indian sub-continent and in fisheries viewpoint, *T. ilisha* hits higher statistics than that of the joint portion of *T. Toli*and *Hilsakelee*(Jhingran, 1991). From the biological perspective, *T. ilisha* showed higher growth rate than the other two *Tenualosa* species, where its individuals reach large size of >500 mm, while those of the other two species showed to grasp 400 and 325 mm for *Tenualosa toli* and *Hilsakelee* respectively The annual catch statistics of this species have shown that Bangladesh subsidizes about 87% of the world catch of this species (2,23,177 t), followed by India (7.2%), Pakistan (3.4%), with some anecdotal catch records from Sumatra in Indonesia (Rahman, 2006).

Tenualosa ilisha is among the tremendously common food fish for the people in the Indian subcontinent and the Arabian Gulf regions. Due to its high delectableness, exceptional flavour, modest size, nice-looking body shape and worthwhile shiny look, this species became very demanding economic commodity and included in both the local and export fisheries markets of the countries living in (Panhwar *et al.*, 2001). This species will remain with high socioeconomic importance as it represents the food of the poor people and in some countries such as the southern India and Bangladesh; it comprises religious meaning throughout (Fischer and Bianchi, 1984).

The identification of a species is the first step in the conservation procedure of fishes. To achieve high level of species identification, meticulous measurements of the body morphometrics are required. Among the characters used in fish taxonomy, morphological traits considered very important (Cailliet *et al.,* 1986). Regardless of the value and handiness of genetics, physiological, behavioural and ecological data to separate species and populations, the systematic ichthyologists endure to be contingent profoundly on morphology for taxonomic characters. The morphometric traits are often prerequisite to characterize the stocks of a variety of exploited fish

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species (Turan, 2004) and they are taken as a strong means for calculating differences between species (Naeem and Salam, 2005).

Morphological characters are frequently exposed to robust natural and sexual selection because phenotypes are the boundary between an organism and their environment (Verberk, *et al.*, 2013; Bower and Piller, 2015). Choice on selecting morphological character can diverge through the variety of species, as it possible induces intraspecific morphological divergence among populations (Hankison *et al.*, 2006). Accordingly, the accumulation of divergence in the morphological traits will lead to morphological changes in the fish population due to genetic differentiation or phenotypic plasticity through natural selection (Al-Hassan 1993; Robinson and Wilson 1994; Franssen, *et al.*, 2013).The use of morphometric characters in species identification process are faster, extra applied, and fewer luxurious than genetic investigations (Ibañez, *et al.*, 2007).

In addition to the usage of body proportions in the species and race identification, mathematical illustration of the associations between diverse body dimensions ensuing from examining individuals from a specific region has a significant valuable means to investigate several aspects of the biology of the population of the fish (Jaiswar *et al.*, 2004). Thus, the array of difference among morphometric traits of fish might be valuable piece of data to outline fish population (Turan, 2004), which in turn is useful in comprehending population destruction possibilities of the species.

The information on the morphometric characters of *T. ilisha* in the Indian sub-continent in general have been mainly included within those studies that dealt with the population structure of this species, which they have been published since the early of 1950s of the last century (Rahman, *et al.*, 1997; Salini, *et al.*, 2004; Narejo, *et al.*, 2008). Outside the Indian-subcontinent, only few studies were performed on the relationships between different body proportions rising from the study of individuals from a specific area such as in the Khuzestan province, Iran (Marammzi, *et al.*, 1998) and in Shatt al-Arab River, Basrah, Iraq (Al-Daham and Al-Noor 2002; Abed *et al.*, 2012).

The study at hand provides material to researchers in fisheries science on the body proportions and their relationships of the Indian shad, *T. ilisha* collected from the vicinity of Manjhand, Pakistan. Such information will useful in the future to fishery biologists in order to assess the stocks of this species and checking the changes in the morphological traits of fishes over time since it is important due to the continuous changes in the environment.

2. MATERIALS AND METHODS

FULL TAXONOMY OF THE SPECIES *T. ILISHA*

Kingdom: Animalia
Phylum: Chordata
Class: Actinopterygii
Order: Clupeformes
Family: Clupeidae
Subfamily: Alosinae
Genus: Tenualosa
Species: T. ilisha

Study area

Indus River is one of the longest rivers in Asia and an important resource for both economic and society of Pakistan. This river originates in the Tibetan (Panhwar *et al*., 2001) Plateau in the district of Lake Manasarovar and runs through the Ladakh region of Jammu and Kashmir, to Gilgit-Baltistan and the Hindukush ranges. Indus River in its extension it passes through nearly the entire area of Pakistan before it joins the Arabian Sea at the port city of Karachi in Sindh (Yu, *et al.*,2013). The northern extremities of the river are located within the mountainous area of the Punjab, while its lower extents pass over the Sindh region where it flows in a large delta (Yu, *et al.*, 2013). Manjhand is a city situated in the Jamshoro District, Sindh, middle of Pakistan in given Latitude and Longitude (25° 51´ 30" N 68° 13´ 0" E) and on the bank of Indus River the sampling site is 70 Km away from Jamshoro Bridge (Pull) **(Fig. 1).**

Fish collection and statistical analyses

Fish individuals were collected using gill net at depth of 3 m. Fish collection was made in the period of June 2016 to May 2017. Seventy five individuals of *T. ilisha* **(Fig. 2)** were attained having size range of 55 to 226 mm TL was collected from Manjhand. Fish individuals were inspected whilst still fresh. Total length (TL), fork length (FL), standard length (SL), head length (HL), snout length (SNL), eye diameter (ED), postorbital length (POL), upper jaw length (UJL), dorsal fin base length (DFBL), pectoral fin length (PFL), prepectoral fin length (PPFL), anal fin base length (AFBL) and caudal peduncle length (CPL) were determined in mm using a digital calliper **(Fig. 3)**. To exclude scaling difficulties related with growth in morphometric characters (non-discrete, measurable), each measurement was standardized. To eliminate size influences from the data and assure that the disparity in the morphometric characters are owing only to shape of the fish body, all morphometric traits were homogenize following (Elliott *et al.*, 1995).

$$T\ adj = T\ (Ls/TL)\ b;$$

Where T is the morphometric trait, T adj is the size-accustomed extent, TL is the total length of the fish, and Ls is the mean of the TL for all fish from all samples. The factor *b* was assessed for every trait from the perceived statistics as the slope of the regression of log T on log L, using all data available.

The relationship between fish total length and body measurements was assessed by means of the following formula:

Y = a X b

Where, Y = morphological trait; X = total fish length; a, b = constants.

The kind of allometry was appraised by checking the allometric coefficient "b" (b = 1 = isometry; b>1 = negative allometry and b<1 = positive allometry). Student *TS* test was calculated to confirm whether calculated "b" was significantly dissimilar from 1 by means of the following formula:

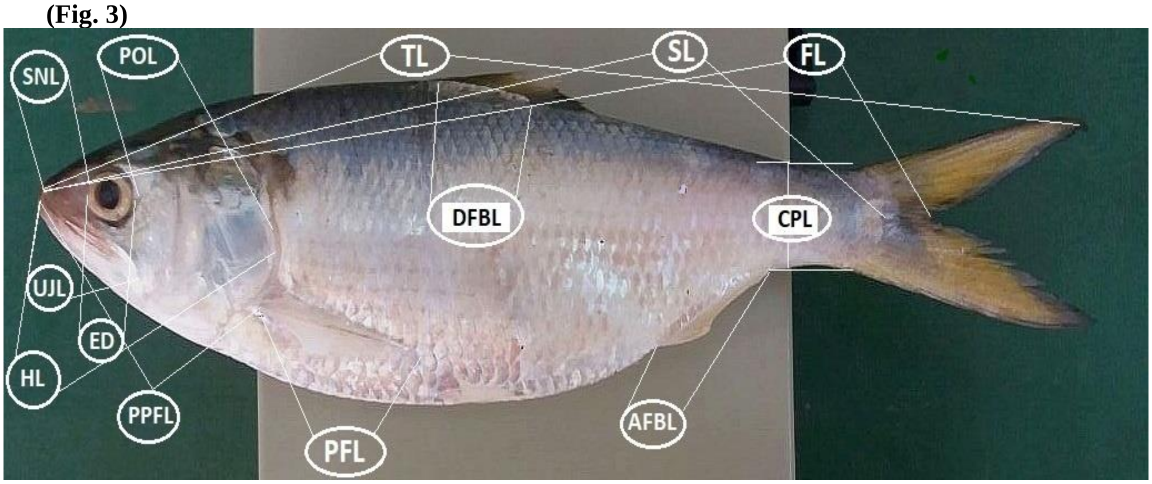
TS = *b*-1/*sb*

Where *TS* is the t-test value, *b* is the slope and *sb* is the standard error of the slope (*b*). The allometric coefficient was utilised to examine the relationship between morphological traits (Van, *et al.*, 1997).

(Fig.1)

(Fig. 2)

(Fig. 3)

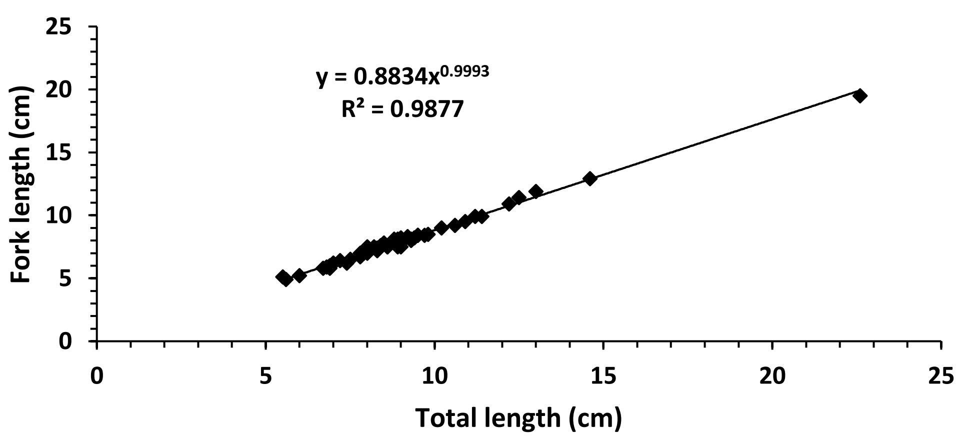


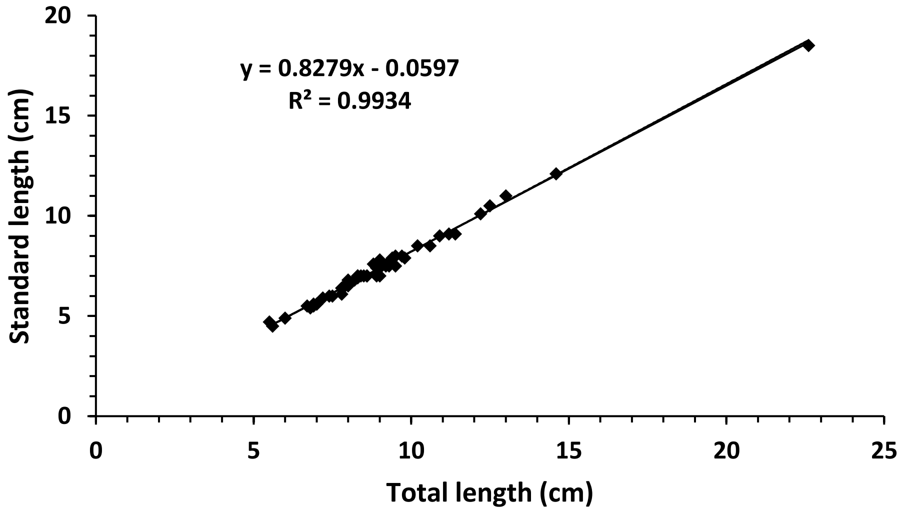
3. RESULTS

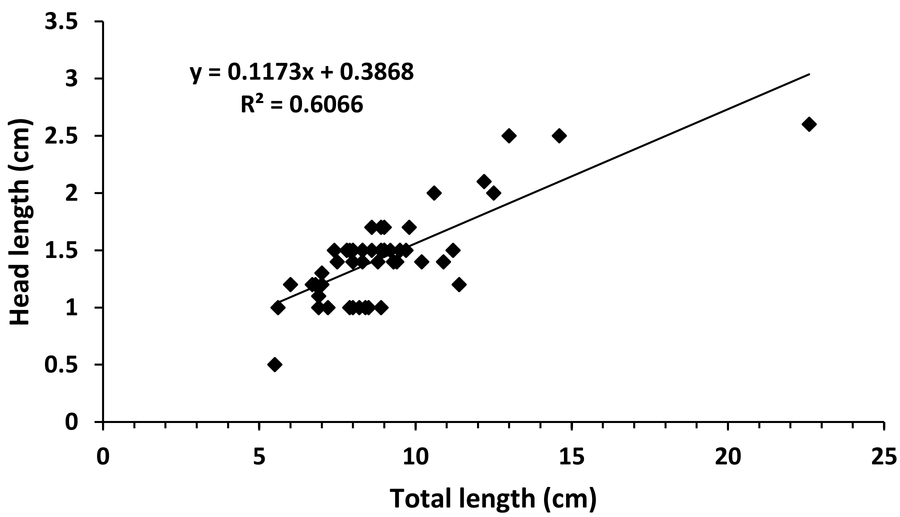
Twelve fish body proportions and their relationship with the total fish length are presented in Table 1 and (Fig's 4-14). The value of 'b' coefficient obtained for varies morphometric traits (Y) related to the total fish length (X) was at its highest level for fork length (0.8834) and its lowest value for eye diameter (0.0398) **(Table 1).** The lowest correlation coefficient value (R^2) was observed for the relationship of the pectoral fin length-total fish length (0.46), the medium value of 0.77 and 0.80 were obtained for dorsal fin base length and anal fin base length respectively, while the highest value of 0.99 was attained for the relationship of both fork and standard lengths-total length and 0.98 for caudal peduncle length followed by 0.94 for the relationship of postorbital length-total fish length. The twelve body proportions have shown to have a negative allometric growth in relation to the fish total length **(Table 1).**

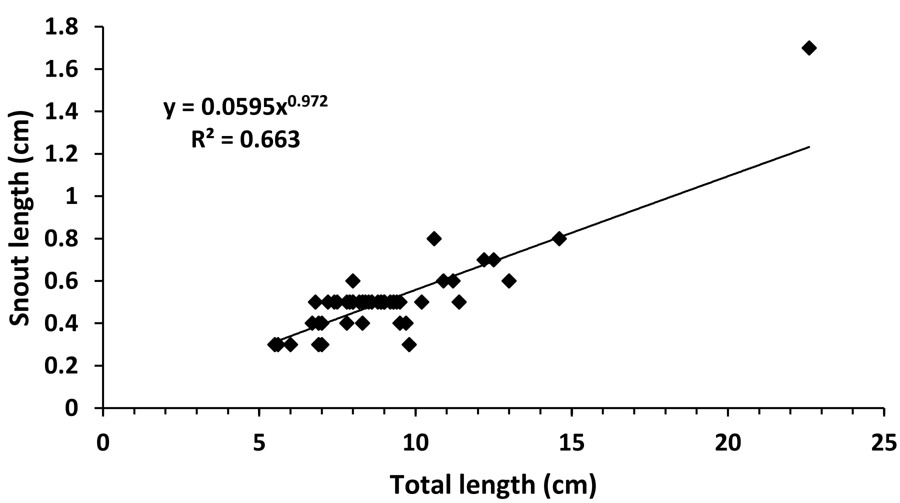
Table 1.Morphometric characters of *Tenualosa ilisha*. Min = minimum value; Max = maximum value; SD = standard deviation; R2 = correlation coefficient; TS = student test; NA = negative allometry.

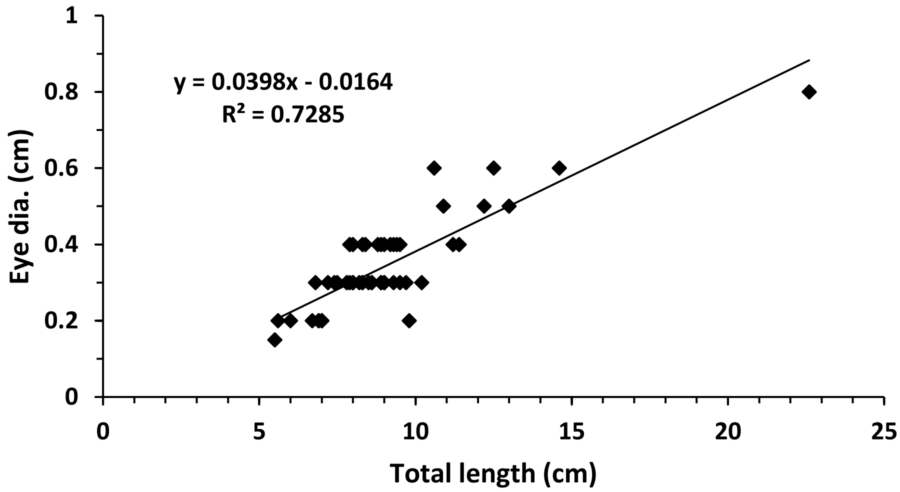
Morphometric indices	Min	Max	Mean	SD	Regression equation	R^2	TS	Relationship
Total length	55	226	139.5	1.2	-	-		
Fork length	49	195	121.6	1.1	Y = 0.8834 X0.9993	0.99	0.85	NA
Standard length	47	185	114.8	0.9	Y = 0.8279 X – 0.0597	0.99	0.91	NA
Head length	5	26	14.7	1.3	Y = 0.1173 X 0.3898	0.61	0.65	NA
Snout length	3	17	9.7	1.2	Y = 0.0595 X 0.9720	0.66	0.93	NA
Eye diameter	2	8	4.8	0.8	Y = 0.0398 X - 0.0164	0.73	0.76	NA
Postorbital length	10	70	39.6	1.1	Y = 0.3053 X - 0.2395	0.94	0.85	NA
Upper jaw length	8	27	16.5	1.2	Y = 0.1057 X 0.2659	0.57	0.92	NA
Dorsal fin bae length	7	33	19.8	1.3	Y = 0.1604 X - 0.1346	0.77	0.91	NA
Pectoral fin length	2	13	7.4	0.9	Y = 0.0683 X - 0.0204	0.46	0.87	NA
Prepectoral fin length	4	30	16.5	1.3	Y = 0.1409 X - 0.2792	0.64	0.77	NA
Anal fin base length	5	32	19.6	1.4	Y = 0.0742 X 0.3423	0.80	0.76	NA
Caudal peduncle depth	6	20	12.7	1.5	Y = 0.1287 X 0.3924	0.98	0.78	NA

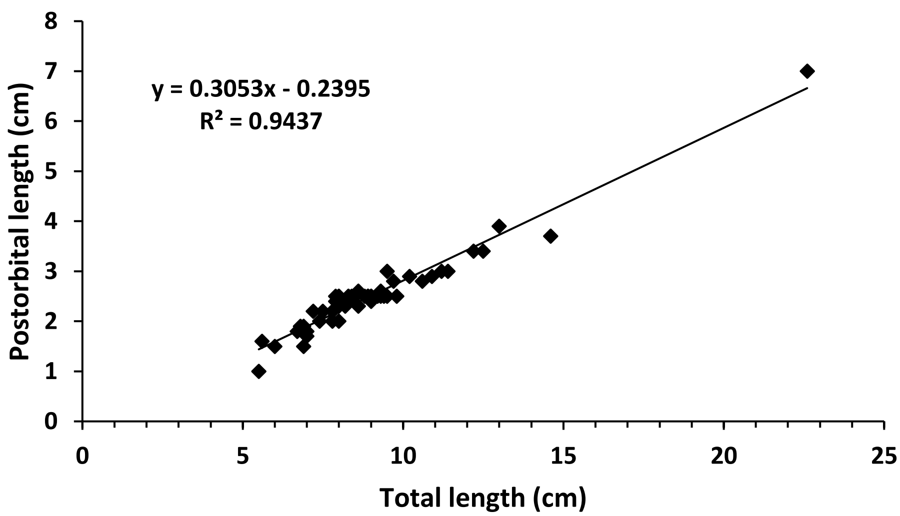


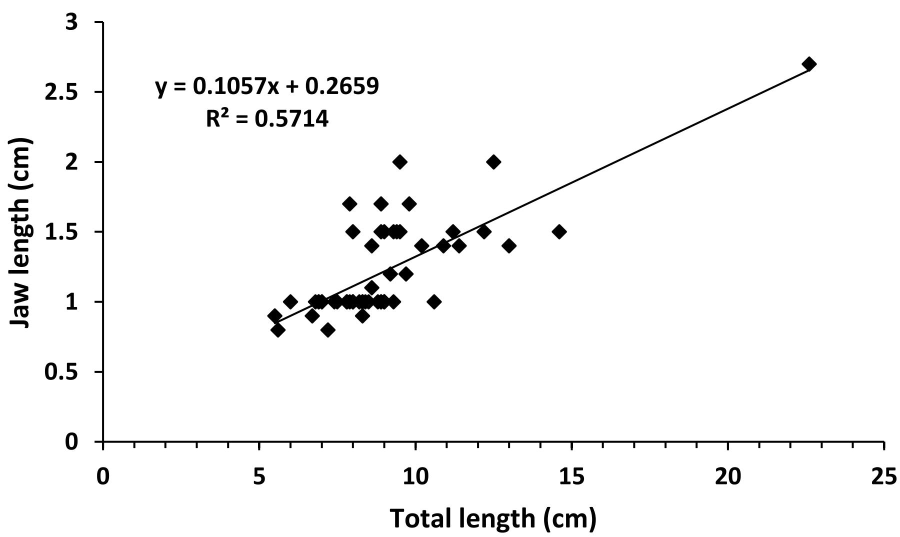

y = 0.8279x - 0.0597
R² = 0.9934
Standard length (cm)
Total length (cm)

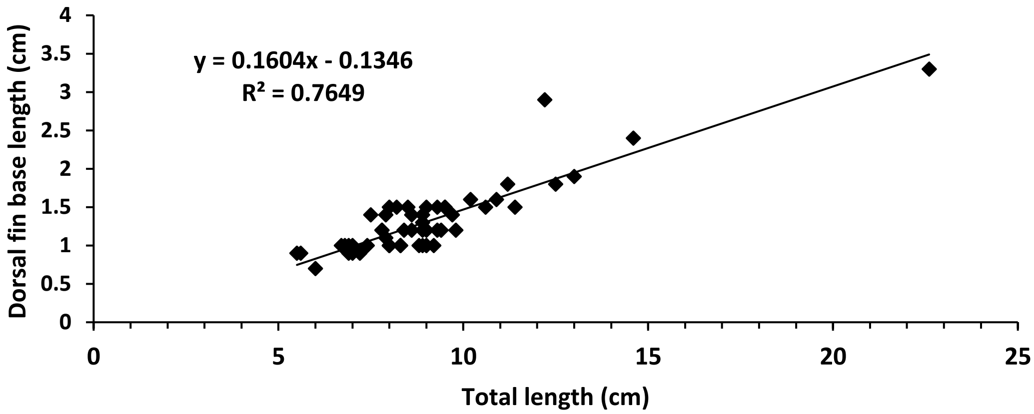

y = 0.1173x + 0.3868
R² = 0.6066
Head length (cm)
Total length (cm)

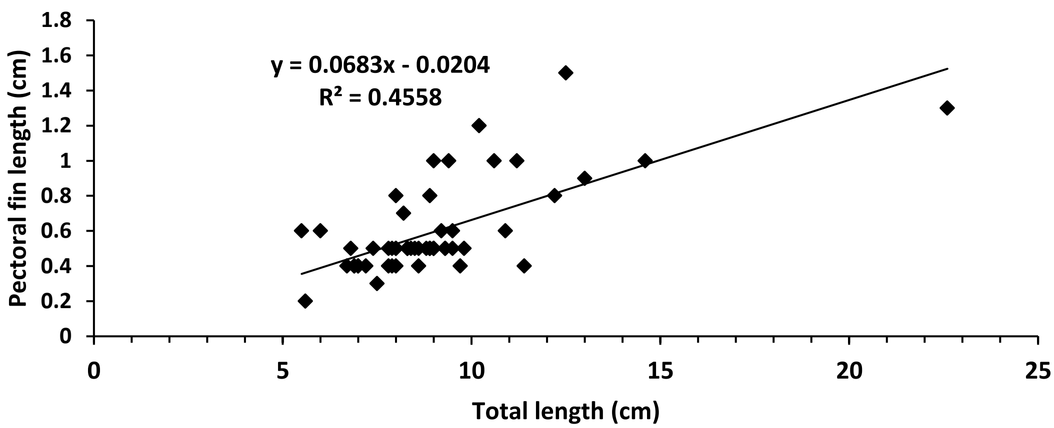

y = 0.0595x^0.972
R² = 0.663
Snout length (cm)
Total length (cm)

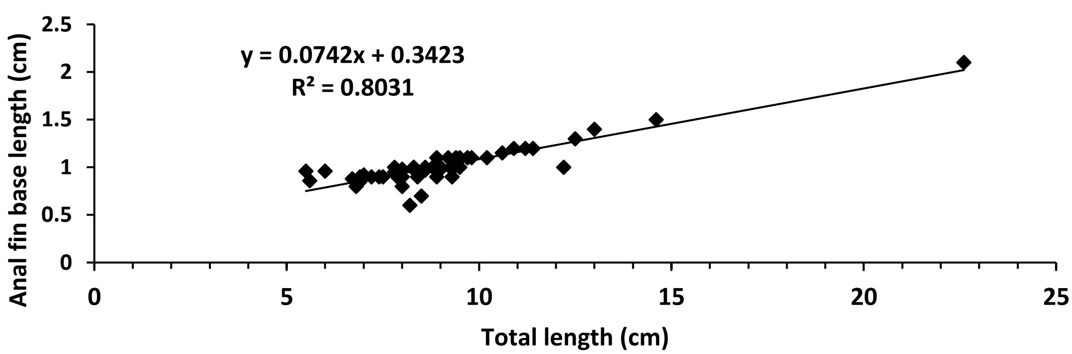

y = 0.0398x - 0.0164
R² = 0.7285
Eye dia. (cm)
Total length (cm)
0
0.2
0.4
0.6
0.8
1
0
5
10
15
20
25

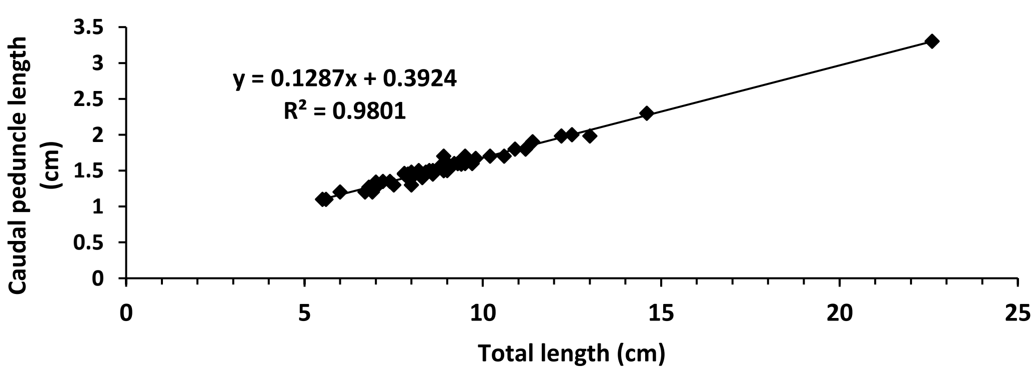

y = 0.3053x - 0.2395
R² = 0.9437
Postorbital length (cm)
Total length (cm)
0
1
2
3
4
5
6
7
8
0
5
10
15
20
25


y = 0.1057x + 0.2659
R² = 0.5714
Jaw length (cm)
Total length (cm)
0
0.5
1
1.5
2
2.5
3
0
5
10
15
20
25


y = 0.1604x - 0.1346
R² = 0.7649
Dorsal fin base length (cm)
Total length (cm)


y = 0.0683x - 0.0204
R² = 0.4558
Pectoral fin length (cm)
Total length (cm)


y = 0.0742x + 0.3423
R² = 0.8031
Anal fin base length (cm)
Total length (cm)


y = 0.1287x + 0.3924
R² = 0.9801
Caudal peduncle length (cm)
Total length (cm)

4. DISCUSSION

Body proportions or traits are vital for taxonomic studies of organisms to estimate the diversity of the species (Dean *et al.,* 2004). They are considered the main factor in the biology of fish due to their key role in taxonomic studies (Kováč *et al.,* 1999). Disparities in the shape of organism are less noticeable at the intra-specific stage, while phenotypic difference is less apparent under genetic control and more subtle to the environmental effects (Clayton, 1981). Discrepancy in the shape of fish permits adjustments to environmental modification by alteration of their physiology and behaviour to objects of environmental difference, which directs to fluctuations in morphology, reproduction and survival (Stearns, 1983; Meyer, 1987).

The 12 body proportions have shown to have a negative growth configuration of the clupeid species *T. ilisha*. The growth design of the morphometric traits could be species-specific patterns in case of T. ilisha if these body proportions are compared with those of other species of *Tenualosa*. The negative allometric patterns of the body proportions found in this report could be related with disparities in body shape in relation to the necessities of the swimming configuration that this species is used.

As a clupeid fish species that has a pelagic life, *T. ilisha* is known as a fast swimmer. To equip with this ability, the fish needs to have large median fins as what we obtained in the present study for individuals of *T. ilisha*. Maltagliati *et al.,* (2003) and Yavno *et al.,* (2013) gave an example on how swimming need may change the shape of the fish. They suggested that median fins can decrease resistance and offer for effective swimming and grab of prey. On the other hand, paired fins are responsible for manoeuvring. This suggests the larger the median fins are the better swimming. On contrary, the larger the paired fins are the better use for turning and steering swimming. Investigations on pumpkinseed fish *Lepomisgibbosus* and brook charr *Salvelinusfontinalis* have showed how morphological changes of the fins precisely related to role (Brinsmead andFox, 2002). The specimens of *T. ilisha* examined showed to have long post dorsal distance similar to those fast swimming species of fishes (Peres-NetoandMagnan, 2004). Such large postorbital distance will improve the efficiency for swimming, as given in a report on *S. Fontinalis* and *Salvelinusalpinus* (Dynes *et al.,* 1999)

There were 3 levels obtained for the correlation coefficient value (R^2). High, medium and lower values observed in the relationship of the total fish length with morphometric traits. Such variation in the value of the R^2 is an indication that the fish body proportions have different growth rate with the fish total length. (Oniye, *et al.,* 2006) and (Safi *et al.,* 2014) have reached to the same conclusion on *Protopterusannectens* and *Pomadasysstridens* (Forsskål, 1775) respectively. Recently, (Sley, *et al.* 2016a, b) on carangid species collected from the Tunisian waters and (Jawad and Al-Janabi,2016 and Jawad, *et al.,*2018) on *Silurustriostegus* from Iraqi inland water system and two cichlid species collected from Shatt al-Arab River, Basrah, Iraq.

Nikolioudakis, *et al.,* (2014) proposed that the body proportion of the fish can be affected by the environmental factors such as water temperature, where the fish that growing in. Consequently, the values of the relationship (R2 in Table 1) for the fork, standard and post orbital length were high suggesting that falling temperature encourages growing changeability in morphological variation, i.e. the alteration is small corresponding among characters. With the present of glaciers and the Himalaya in the north and hot and dry weather in the south of the extents of the Indus River (Fowler and Archer, 2005), water temperature in between these extremities has shown huge variation (Farooqi, *et al.,* 2007). In the presence of such broad changes in water temperature the body proportions are more coordinated with water temperature preferably than with other body proportions (Nikolioudakis, *et al.,* 2014). The total length of the specimens obtained falls within that given for this species (Rahman, 2006). However, this range is broad and includes very small individuals just over 50 mm TL. Body proportions were usually included in population study of *T. ilisha* along the geographical distribution of this species (Narejo*et al.,* 2008) and normally no small individuals were attained in such studies (Quddus, *et al.,* 1984; Al-Mukhtar, *et al.,* 2016) whether in neighbouring countries to Pakistan (Marammzi, *et al.,* 1998; Abed *et al.,* 2012) or in Pakistan (Panhwar, *et al.,* 2011) or from the Indus River itself (Narejo, *et al.,* 2008). Therefore, collecting young individuals as small as 55 mm TL in the present study reflects the important of this study.

From the life history of *T. ilisha*, it is known that the size of the larva of *T. ilisha* at hatching ranges between 2.3 and 3.1 mm (Motwani, *et al.,* 1957). With this small size, larvae usually seek shelter and nursery area in the lower reaches of the rivers or in the coastal waters. The juveniles with 70 mm TL start their upstream migration (Raja, 1985; Mazid and Islam, 1991). The sampling area of *T. ilisha* in the present study is 306 Km away from the Indus River estuary and the presence of individuals with 55 mm TL denotes that this area is a spawning and nursery grounds for *T. ilisha*. On the other hand, it is the first time to report for the presence of *T. ilisha* in an inland and upstream locality away from the river estuary with 306 Km. The most upstream distance reported in the Indus River was Kotri Barrage 236 Km away from the Indus River estuary (Narejo, *et al.,* 2008). Consequently, we consider the location of Manjhand is the most upstream reached by *T. ilisha*.

Sfakianakis, *et al.,* (2011) and Georgakopoulou, *et al.,* (2007) have attained that body proportions of *Daniorerio* altered with water temperature, which may impact fish metabolism via variations in dissolved oxygen (Wimberger, 1992). The present results showed that the body proportions examined were smaller than those obtained for individuals of *T. ilisha* collected from certain localities along the geographical distribution range of this species. This is considered as another evidence for the locality Manjhand with low water temperature being a spawning ground for *T. ilisha*, which individuals of this species hatching in this area showed smaller body proportions in comparison with those from other localities. The effect of lower water temperature on body morphometrics has been documented in several studies (Atkinson 1994; Haddon and Willis 1995; Emmrich, *et al.,* 2014; Jawad and Al-Janabi 2016). Other body morphometrics seem to be altered according to the decrease in temperature of water such caudal peduncle length (Georgakopoulou *et al.,* 2007; Eagderi, *et al.,* 2015). Decrease in temperature of water changes water viscosity and density. Then, fish needs to have a fusiform body shape in order to reduce the drag effect (Wimberger, 1992). Therefore, physicochemical characters of aquatic environment alter with water temperature and, consequently, fish will retort with new differences in body shape (Sfakianakis, 2011). It has been noted that the main changes in the fish body morphometrics centred on the abdominal, where greater expansion of the intestine (Elbal, *et al.,* 2004). Other investigators reported that the central part of the body expand through ontogeny (after head and tail) in the bilateral species (Osse, *et al.*, 1997; van Snik, *et al.*, 1997; Gozlan, *et al.*, 1999) later than in asymmetrical species (*Paralichthyscalifornicus*, Gisbert, *et al.*, 2002)

The shape of the anterior part of the head that includes the snout length and length of jaws has shown to be under the effect of feeding habit of the fish species (Samaee and Patzner 2010). Kind of prey size is an additional factor that may disturb the closeness of the eyes and both the preorbital and postorbital lengths (Costa *et al.,* 2003; Turan, 2004). The measurements, snout length and jaw length attained from individuals of *T. Ilisha* in the present study differ from those obtained from the other localities can be explained on the size of food items that are usually taken by those individuals in Manjhand locality studied. Such alteration supports swallowing of large and hard prey that is available in the Indus River environment (Tassaduqe, *et al.,* 2003).

The relation between fish total length and both standard length and fork length showed highly significant values ($P < 0.001$) and they were comparable to those given by Froese and Pauly (2018). The value of the coefficient “b” for the FL-TL and SL-TL is somewhat lesser than that specified by Froese and Pauly (2018) for this species. The disparities of LLRs among the values attained in the present investigation and those of Froese and Pauly (2018) may be due to the variation in the ecological circumstances of the niches or change in the metabolism of animals, or both (Le Cren, 1951). Such information about LLRs of *T. ilisha* would be valuable for decision makers in Pakistan.

The degree of turbidity in water has an effect of the size of the eye of fish species that they hatch in. The water of the Indus River is reported to have high level of turbidity owing to the muddy substrate (Harrison *et al.,* 1997; Chauhan *et al.,* 2006). With this type of habitat, the difference in eye diameter can be attributed to the developmental adaptation in fishes during their early stages inhabiting low light intensity, due to high turbidity (Matthews, 1988). Masuda and Tsokamoto (1996) suggested that some changes would happen in the development of the due to the changes in the intensity of light in water. Therefore, the disparity in eye diameter in individuals of *T. ilisha* examined in the present study from Manjhand, Pakistan can possibly be ascribed to the dissimilarity in light penetration that can be found in different geographical locations of distribution of *T. ilisha*.

Body morphometrics examined in this study could be used in emerging management policies for the study area in the future. Environmental factors could be factors for such differences, as has been shown for other fish species (Clayton, 1981; Esmaeili, *et al.,* 2011). Further investigation approving the present study on the clupeid species *T. ilisha* using molecular markers should be deemed.

ACKNOWLEDGEMENTS

The authors would like to thanks to the fishermen along the Vicinity of Manjhand Coast of Indus River for their sampling collections.

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