COMPARATIVE SURVEY ON MORPHOMETRIC AND MERISTIC CHARACTERISTICS OF THE SCALES OF FOUR MULLET SPECIES OF FAMILY MUGILIDAE IN RELATION TO THE TOTAL BODY LENGTH

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ABSTRACT

In the present investigation, some morphometric and meristic characteristics of the scales of four mullet species (Liza melinoptera, Liza macrolepis, Valamugilspeigleri and Mugilcephalus specie) from the Karachi coast of Pakistan were used to determine their linear relationships with whole body growth (TL) and also observe their significance in fish taxonomy. Scale samples were collected from the selected body regions: head (HS), transverse row scales(TRS), lateral line (LLS) and caudal regions (CS) of each mullet specie. The results of the study revealed that the linear regression relationships between the total length (TL) versus various selected scale parameters: scale length (TLS), scale width (WDS), total number of ctenii arranged in horizontal rows (HRS) and vertical rows (VRS) on scale, radii counts (RDS) and the position of focus (Rs)were mostly found to be weak ($r < 0.50$) or moderately strong ($r = 0.51– 0.69$) and highly significant (t-test; $p<0.05$), hence, indicating that the growth of scales and its various microstructures were not always proportional to the whole body growth. Furthermore, during the analysis of linear regression relationships between total length (TL) versus each selected scale parameter, great variations were also observed for each type of scale among the four selected mullet species.Therefore, it was proved that scale characters of mullets could also be considered as useful taxonomic character in determining the possible variations among the different mullet species, and hence proved their significance in fish taxonomy.

***Keywords*:** Mullet species scales, Morphometric and meristic

No of Tables: 6; **No of Figures: 2** **No of References: 43**

INTRODUCTION

Though some workers had offered a series of external morphological characteristics that could be helpful in determining the systematic relationships among the different mugilid species (Katselis *et al.* 2006, Turan *et al.* 2011, Zubia *et al.* 2015a and Wajeeha *et al.* 2015), however, some lepidologists including Roberts (1993), Esmaeili *et al.*(2014), and Zubia *et al.* (2015b) had also provided some useful scale characteristics of various mullet species that could be helpful in determining their systematic classification. But the information regarding the morphometric measurements and meristic counts of the scales of mugilid species of family Mugilidaefrom Pakistan coast was still scarce. Recently, Zubia and Rehana (2011) and Ambareen *et al.* (2015) had examined the linear regression relationships between total length (TL) versus various scale parameters of the fishes belonging to the families Lutjanidae and Cyprinidae. More recently, Zubia *et al*. (2015a) also reported some useful morphometric and meristic characters of the scales of four mullet species from Pakistan coast that could be valuable in observing their systematic classification or taxonomy. As mullets or grey mullets contain both cycloid and ctenoid type scales, therefore, Zubia *et al*. (2015a & b) had reported some variations in the following scale characters: arrangements of cycloid and ctenoid scales among the different body regions of mullet fish, counts of ctenii and radii, and position of the focus on the scales among the different mullet species from Pakistan coast. Furthermore, great variations have also been reported in the types of ctenoid scales i.e., species like *Liza melinoptera, Liza macrolepis* and *Mugilcephalus* contain basic-type of ctenoid scales, while *Valamugilspeigleri* contain crenate-type of ctenoid scales (Zubia *et al*. 2015a&b).Therefore, present study consists of observing the strength of the relationships between whole body growth and different selected microstructures of scale of four selected mullet species from Karachi coast. Furthermore, our studies also highlighted some useful scale characters that later could be valued in the systematic classifications of these commercially important mullet species on Karachi coast and such information would be valuable for fisheries conservation and managements

MATERIALS AND METHODS

The total catch (N=1006) of the four species of family Mugilidae including *Liza melinoptera, Liza macrolepis, Mugilcephalus* and *Valamugilspeigleri* were collected monthly from the landings at Karachi fish harbour, during the period of April 2011 to December 2012. In the laboratory, scale samples (both cycloid and ctenoid scales) were collected from the four selected body regions of each mullet specie as follows:

1. Head scales (HS) collected from head region
2. Caudal scales (CS) collected from the base of caudal fin.
3. Transverse series scales (TRS) collected in series from the origin of dorsal fin to the origin of pelvic fin.
4. Lateral line scales (LLS) collected from the lateral line region of fish as shown in Figure 1.

In the present study, the linear regression relationships were observed between the total length (TL) versus various selected scale parameters, which are as follows;

1. Scale length (TLS),
2. Scale width (WDS),
3. Total number of ctenii arranged in horizontal rows (HRS),
4. Total number of ctenii arranged in vertical rows (VRS) on scale,
5. Radii counts (RDS)
6. Position of focus (Rs) as shown in Figure 2 respectively.

The methodology used for the preparation of permanent slides of scales and study of morphometric and meristic characters under light microscope was in agreement with Zubia *et al.* (2015 a&b). The counts and measurements of six selected scale parameters of the present study are presented in Figure 2. Linear regression relationship and coefficient of correlation (r) were calculated to determine the strength of relationship between total body length (TL) and all morphometric and meristic characters of scale. The values of Pearson linear coefficient of correlation 'r' were also determined by using the formula of Zubia and Rehana (2011). The significance of regression was assessed by t-test analysis at $p<0.05$ in order to test the null hypothesis Ho: $r = 0$ (both variables are linearly uncorrelated) against the alternate Ha: $r > 0$ or $r < 0$ (both variables are positively or negatively linearly correlated). All statistical analysis was calculated by Minitab Demo 14.1software.

RESULTS AND DISCUSSION

In the present study, the linear regression equation was used to observe the straight-line relationship between total length of fish and selected scale parameters. In the study, morphometric and meristic scale parameters were assumed as 'Y', while 'X' was assumed as total length of fish, 'a' was the intercept and 'b' was the regression slope, which were in accordance with Zubia and Rehana (2011). As the previous published information about the morphological characteristics of six selected scale parameters of four mullet species of this study i.e.,*Liza melinoptera, Liza macrolepis and Valamugilspeigleri* and *Mugilcephalus* was still scarce, therefore, their comparison with previous data was intricate.The results of linear regression relationship between total length versus selected parameters for ctenoid and ctenoid scales of the four mullet species from Karachi coast were presented in the

Tables 1-6, respectively. As mullet fishes contain both cycloid and ctenoid scales, but in the present study, it was observed that only *Mugilcephalus* possessed cycloid scales along with ctenoid scales in four selected body regions including head, caudal, transverse and lateral line regions, whereas the remaining three mullet species i.e., *Liza melinoptera, Liza macrolepis*and *Valamugilspeigleri* contain cycloid scales only in their head region, therefore, head scale data for cycloid scales of the four mullet species of the present study were recorded in Table 2, while caudal, transverse and lateral line scale data for the cycloid scales obtained from three selected body regions of *Mugilcephalus* were noted in Table 6, respectively.

Linear regression relationships between total length (TL) versus different scale parameters

The results of the present study revealed that the values of regression constants and correlation coefficients (r-values) obtained for the scales obtained from the selected body regions (i.e., head, caudal, transverse and lateral line regions) for four mullet species also varied significantly as shown inTables 1-6, respectively. The results of the present study revealed that the majority of relationships between total length (TL) versus different selected scale parameters were found to be weak (when r<0.50) or moderately strong (when r = 0.51 to 0.69), hence indicating that no relationship existed between the growth of scale microstructures and the whole body growth in fish. Similar type of relationships between various scale characters and total body length of various other fish species had been studied previously by several workers such as Landa (1953), Rao and Rao (1972), Wassef (1990), Courtney *et al*. (2000), Narejo *et al*. (2000), Beamish *et al*. (2001), Gallardo-Cabello *et al*. (2003) Narejo *et al*. (2009), Sarabia-Mendez *et al*. (2010), and Zubia and Rehana (2011), respectively. As it was expected that the growth of fish scale and its microstructures will be strongly correlated with whole body growth (Courtney *et al*., 2000), but in contrast, our present study revealed an unexpected results that is,not all measurements and counts of scale were always significantly proportional to the whole body growth in fish, hence, proved that the growth of all scale structures was not in relation to fish body growth. Furthermore, the analysis of t-test at 5% significant level ($p<0.05$) revealed that most relationships were between total length (TL) versus various selected scale parameters for the four types of scales in the four selected mullet species of the present study and were highly significant at 5% level (when $p<0.05$), as shown in Tables 1-6, respectively. Therefore, the analyses of these scale characters were significant for the identification of these mullet species and all such variations among the four mullet species will provide a major criterion for the identification and classification of these four mullet species.

Relationship between total length (TL) versus scale length (TLS)

According to Lagler (1952), the proportion of fish body length to its scale length was found to be constant for all body lengths of fish regardless at which body length or size when first annulus was formed, thence, the relationship between body length of fish and its scale length was determined by using the following formula as described by Joseph (1962) as follows:

$L = cS$

Where L = fish body length; S = scale length and c = constant.

Dahl (1910) had found such constant type of relationship by successful application of this formula on the scales of Norwegian salmon and trout. Whereas, Lee (1912) had found that such constant linear relationship might not always exist between body length and scale length in fish. This might be because scales formation cannot be initiated until fish attain its body size at which the first scale formed. Hence, the relationship between total body length and scale length in fish did not always remain constant, however, changing with the passage of time, which might be because in small-sized fish, scale grows more rapidly in relative to the body growth than in large-sized fish. In the present study, except *L. melinoptera*, size of head, transverse and lateral line scales of the selected mullet species were seem to increase with increasing total body length in fish, thence, the linear regression relationships were found to exist between the whole body growth of fish and its scales. This result was in agreement with the findings of some other workers such as, Landa (1953), Rao and Rao (1972), Gupta and Jhingran (1973), Courtney *et al*. (2000), Gallardo-Cabello *et al*. (2003), Narejo *et al*. (2009), Sarabia-Mendez *et al*. (2010) and Zubia and Rehana (2011). Accordingly, the analysis of marginal increments of fish scales showed a large variation in each or every month of the year. During the initial stage of life, the scale size increases more rapidly by the formation of circuli near its outer margin, but in adult stage, its size almost remains constant. Therefore, during the first year of life when fish grows more rapidly, then at that time, growth of scale mostly depends on whole body growth in fish, hence, scale size seem to increases more rapidly during the first and second years of life, but later the formation of the rest of the growth rings (circuli) on the outer margin of scale becomes progressively slow and the distance between these growth rings is small, therefore, size of scales increases very slowly at last ages of life. Beamish *et al*.(2001) reported a strong linear relationship between scale length and total length of large-sized fish that might be because of the presence of wide space between the circuli of scales in large-sized fish and in those small fish that grew more rapidly during summer season. The size of scale had also beenfound to be varied among the different fish species, which might be because it mostly depends on the swimming speed of fish or modes of life, for example, astuna and trout fishes are mostly found in fast-moving water and

swim quickly, therefore they possess small-sized scales, while carp fishes (Cyprinidae) swim slowly in slow-moving water, therefore, they contain large-sized scales (Briggs, 1994; Helfman *et al*., 1997;Sudo *et al*., 2002).

Relationship between total length (TL) versus scale width (WDS)

In the present study, weak or poor correlation (r<0.50) existed between total length versus width of head, caudal and lateral line scales (Tables 1-6). However, such correlation was found to be highly significant (t-test; p<0.05) in the head scales (ctenoid), caudal, transverse and lateral line scales (except in LLS of *L. melinoptera*), which was in agreement with the findings of several workers such as, Weisberg (1993) and Fukuwaka (1998) and Gallardo-Cabello *et al*. (2003) Zubia and Rehana (2011) who recorded significantly strong correlation between the width of scale (WDS) and total length of fish (TL) for other teleost fishes. In general, the width of scale mostly increases due to the formation of new circuli or marginal increments near the outer margin or by addition of new rows of ctenii on ctenoid scale (Ganguly and Mookerjee, 1947). The space between these circuli on scale mostly characterized the fast and slow growth rates of fish during the different season of the year (Esmaeili *et al*. 2007; Gallardo-Cabello *et al*. 2007). Gallardo-Cabello *et al*. (2007) noted that the growth rings or circuli formed on the scales periodically;for example, during spring and summer seasons, fast growth rings with wide space would appear on scales due to the higher availability of food, but during the autumn and winter season due to great reduction in food availability, slow growth rings with narrow space will be formed on scales, hence, proving that the number and width of circuli on scale were strongly correlated to the seasons of year rather than whole body growth in fish.

Relationship between total length (TL) versus number of ctenii counts in horizontal (HRS) and vertical rows (VRS) on scale

The result of the present study revealed that ctenoid scales obtained from the head, caudal, transverse and lateral line regions of selected mullet species (except *V. speigleri*) revealed the poor and weak correlation (when r<0.50) between total length versus total number of ctenii arranged in horizontal and vertical rows on scale. However, such correlations were found behighly significant (p<0.05) or insignificant (p>0.05) in the four type of scales in selected mullet species. But only transverse row scales of *L. macrolepis* showed moderately strong correlation (r= 0.51-0.69) between total body length (TL) and number of ctenii arranged in horiszontal rows. Whereas, the crenae found on the transverse scales of *V. speigleri* showed highly significant correlation (t-test; p<0.05). Though, the shape of ctenii on the ctenoid scales of mugilid species have been studied by several workers such as Jacot (1920), Pillay (1951), Kobyashi (1953), Roberts (1993), Ibanez and Gallardo- Cabello (2005) and

Ibanez *et al*. (2011), no published data was available for observing the linear relationship between total length and total ctenii counts on mullet scales. However, Zubia and Rehana (2011) recorded a strong relationship (r>0.70) between total body length versus total number of ctenii arranged in the horizontal row on lateral line scales for *Lutjanusjohnii* and *Lutjanusrusselii* (Lutjanidae). Though Courtney *et al*. (2000) observed that scale microstructures were found to be significantly correlated with each other as well as with total body length in fish, but in contrast, the results of the present study revealed that the formation of ctenii on scales was not always proportional to fish length. This might be because ctenii probably be arose from the serrae on the edges of circuli or due to the modifications and segmentations of longitudinal apical circuli present in their posterior field (Cockerell, 1913) or their formation may perhaps depends on the body movements during swimming (Creaser, 1926; Taylor, 1914-1916). Ganguly and Mookerjee (1947) also reported that the number of ctenii formed on scales may possibly depend on the space existing in between the ends of the interrupted circuli. Like radii, ctenii of ctenoid scales may also represent its flexibility or elasticity, hence ctenii always found on those scales that occurred in the body regions, i.e., caudal, lateral line and transverse scales, which showed more flexibility. According to Sato *et al*. (1986), as mullets are subcarangiform swimmers, hence, their posterior half portion of the body can bend more than the anterior portion during swimming, therefore, head scales of mullets contained less number of ctenii as compared to the other body regions in the present study.

Relationship between total length (TL) versus total radii counts (RDS) of mullet scale

The relationships between total length (TL) and total number of radii (RDS) were mostly found to be weak(when r<0.50) for scales obtained from the four selected body regions of mullet species in the present study. This may be because the formation of radii on scales mostly depends on the flexibility of scale (Ganguly and Mookerjee, 1947) or the better nutritive conditions of fish as described by Johal *et al*. (1984) and Tandon and Johal (1996) and Johal *et al*. (2006) or due to their modes of locomotion in fish (Sato *et al*., 1986) or hydrodynamic properties (Sudo *et al*., 2002). Hence, the number of radii found on scale may have some relation to its elasticity or flexibility as observed by these workers. However, such correlation had significantly strong relationships in case of ctenoid scales obtained from the head region of *M. cephalus* in the present study, which was in accord with some workers such as Jenkins and Lachner (1971), Narejo *et al*. (2009) and Zubia and Rehana (2011) who also observed the linear relationship between the number of radii and total body length for the two Lutjanid genera, i.e., *Nocomis* and *Hybopsis* (Lutjanidae), *Labeocalbasu* (Cyprinidae) and the five species of genus

Lutjanus (Lutjnidae). Our present result was also in agreement with Jawad and Al-Jufaili (2007), who reported that the numbers of radii on the scales of some teleost species such as *Mullussurmuletus* and *Mullusbarbatus* were related to the size of fish. In mullet species, radii or grooves were present only in the anterior part of scale (Pillay, 1951), so the formation of new radii may perhaps depend on the growth of the anterior portion of their scales, therefore, Johal *et al*. (2006) and Dulce-Armor *et al*. (2010) had reported that the number of radii formed on fish scale might be related to the space provided by its anterior portion, because the posterior portion of proceding scale mostly overlapped this portion.

Relationship between total length (TL) versus vertical distance between focus and apex of scale (Rs)

In the present study, the 'Rs' value represents the straight line distance measured from the focus to the outer posterior margin (exposed portion) of the scale. Hence, the value of Rs was showing the distance between the focus and the apex (posterior margin) of scale. It was observed

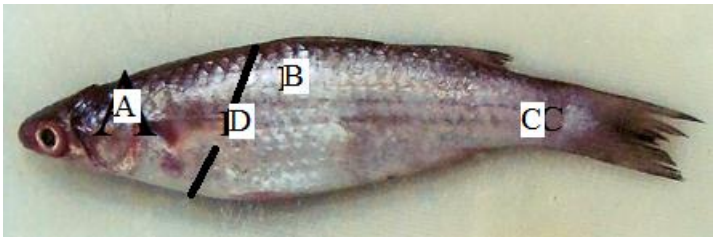

Figure 1. The four selected body regions for the collection of scale samples.

A= head region; **B**= Lateral line region **C =** Caudal region; **D**= Transverse series of scales from the origin of first dorsal fin to the origin of pelvic fin

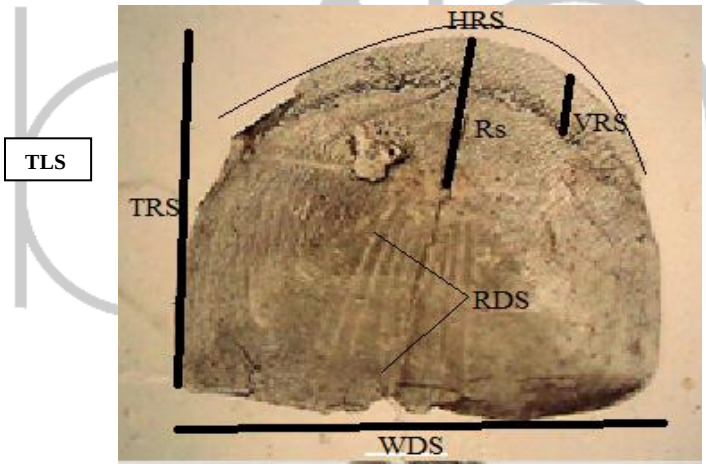

Figure 2. The measurements and counts of the different parameters of ctenoid scale

TLS= Scale length; **WDS**= Scale width; **HRS**= Number of ctenii arranged in horizontal rows; **VRS**= Number of ctenii arranged in vertical rows; **Rs**= vertical distance between focus and apex of scale, **RDS**= Counts of radii

Table 1: Regression analysis of the parameters of head scales (Ctenoid type) for the four species of the family Mugilidae.

		Liza melinoptera N= 77							*Liza macrolepis* N = 69							*Valamugilspeigleri* N = 73							*Mugilcephalus* N = 31						
		Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation			
X	Y	a	b	r	S.E(b)	t-test	P-value	CT	a	b	r	S.E(b)	t-test	P-value	CT	a	b	r	S.E(b)	t-test	P-value	CT	a	b	r	S.E(b)	t-test	P-value	CT
TL	TLS	-0.58	0.04	0.33	0.01	3.0	0.0^{a}	♠	2.79	0.0	0.53	0.00	5.06	0.0^{a}	☼	0.97	0.03	0.61	0.0	6.4	0.0^{a}	☼	-0.58	0.03	0.68	0.01	5.0	0.0^{a}	☼
TL	WDS	-0.53	0.03	0.35	0.01	3.2	0.0^{a}	♠	4.18	0.0	0.32	0.00	2.71	0.0^{a}	♠	2.73	0.01	0.34	0.0	3.0	0.0^{a}	♠	-1.80	0.03	0.72	0.01	5.5	0.0^{a}	*
TL	HRS	-102	0.84	0.29	0.32	2.6	0.0^{a}	♠	77.2	-0.1	-0.12	0.12	-0.7	0.4^{NS}	–	-9.64	0.26	0.45	0.1	4.2	0.0^{a}	♠	-5.90	0.23	0.50	0.07	3.1	0.0^{a}	♠
TL	VRS	-3.19	0.04	0.12	0.04	1.0	0.3^{NS}	♠	4.89	-0.0	-0.06	0.01	-0.3	0.7^{NS}	–	0.00	0.00	0.00	0.0	0.0	0.0^{a}	0	2.45	0.00	0.12	0.01	0.6	0.5^{NS}	♠
TL	RDS	-9.79	0.07	0.27	0.03	2.4	0.0^{a}	♠	5.25	-0.0	-0.31	0.01	-2.6	0.0^{a}	–	10.6	-0.0	-0.2	0.0	-2.3	0.0^{a}	–	-12.4	0.07	0.81	0.01	7.4	0.0^{a}	*
TL	Rs	-0.78	0.02	0.32	0.01	2.9	0.0^{a}	♠	1.54	0.0	0.37	0.00	3.24	0.0^{a}	♠	0.44	0.01	0.37	0.0	3.4	0.0^{a}	♠	0.03	0.01	0.47	0.00	2.8	0.0^{a}	♠

Note: All measurements were in mm. TL = Total length of fish; TLS = scale length; WDS = scale width; HRS = ctenii counts in horizontal series; VRS = ctenii counts in vertical series on scale; RDS = radii counts; Rs = distance between focus and apex of scale; N= number of scale samples examined; CT = correlation type; S.E = Standard Error; a: represents relationship significant at 5% level (when $p<0.05$); NS: non-significant relationship (when $p>0.05$); * shows the strong correlation (when $r \geq 0.70$), ☼ shows moderate correlation (when r = 0.51-0.69), ♠ represent weak correlation (when $r \leq 50$), – shows negative correlation.

Table 2: Regression analysis of the parameters of head scales (Cycloid type) for the four species of the family Mugilidae.

		Liza melinoptera N = 68							*Liza macrolepis* N = 68							*Valamugilspeigleri* N = 72							*Mugilcephalus* N = 76						
		Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation			
X	Y	a	b	r	S.E(b)	t-test	P-value	CT	a	b	r	S.E(b)	t-test	P-value	CT	a	b	r	S.E(b)	t-test	P-value	CT	a	B	r	S.E(b)	t-test	P-value	CT
TL	TLS	5.93	-0.01	-0.08	0.01	-0.6	0.5^{NS}	–	1.1	0.03	0.61	0.00	6.51	0.0^{a}	☼	0.1	0.0	0.63	0.00	6.87	0.0^{a}	☼	0.7	0.0	0.74	0.0	9.4	0.0^{a}	*
TL	WDS	4.68	0.00	0.01	0.01	0.1	0.9^{NS}	♠	3.2	0.02	0.49	0.00	4.78	0.0^{a}	♠	1.5	0.0	0.49	0.00	4.79	0.0^{a}	♠	2.0	0.0	0.60	0.0	6.3	0.0^{a}	☼
TL	RDS	1.57	-0.01	-0.06	0.02	-0.5	0.6^{NS}	–	0.2	0.00	0.03	0.00	0.28	0.7^{NS}	♠	2.1	-0.0	-0.0	0.02	-0.03	0.9^{NS}	–	0.4	-0.0	-0.0	0.0	-0.2	0.7^{NS}	–
TL	Rs	2.27	0.00	0.01	0.01	0.1	0.9^{NS}	♠	1.1	0.01	0.48	0.00	4.66	0.0^{a}	♠	0.2	0.0	0.44	0.00	4.14	0.0^{a}	♠	1.8	0.0	0.30	0.0	2.6	0.0^{a}	♠

Note: All measurements were in mm. TL = Total length of fish; TLS = scale length; WDS = scale width; RDS = radii counts; Rs = distance between focus and apex of scale; N= number of scale samples examined; CT = correlation type; S.E = Standard Error; a: represents relationship significant at 5% level (when $p<0.05$); NS: non-significant relationship (when $p>0.05$); * shows the strong correlation (when $r \geq 0.70$), ☼ shows moderate correlation (when r = 0.51-0.69), ♠ represent weak correlation (when $r \leq 50$), – shows negative correlation.

Table 3: Regression analysis of the parameters of caudal scales (Ctenoid type) for the four species of the family Mugilidae.

		Liza melinoptera N= 145							*Liza macrolepis* N = 129							*Valamugilspeigleri* N = 118							*Mugilcephalus* N = 89						
		Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation			
X	Y	a	b	r	S.E(b)	t-test	P-value	CT	a	b	r	S.E(b)	t-test	P-value	CT	a	b	r	S.E(b)	t-test	P-value	CT	a	B	r	S.E(b)	t-test	P-value	CT
TL	TLS	1.1	0.02	0.19	0.01	2.3	0.0^{a}	♠	3.1	0.0	0.30	0.0	3.59	0.0^{a}	♠	-0.4	0.03	0.57	0.0	7.4	0.0^{a}	☼	2.68	0.01	0.24	0.0	2.3	0.0^{a}	♠
TL	WDS	0.7	0.02	0.23	0.01	2.8	0.0^{a}	♠	1.7	0.0	0.40	0.0	4.86	0.0^{a}	♠	1.4	0.01	0.26	0.0	2.9	0.0^{a}	♠	1.64	0.01	0.34	0.0	3.4	0.0^{a}	♠
TL	HRS	92.3	-0.14	-0.07	0.16	-0.8	0.4^{NS}	–	50.5	0.2	0.25	0.1	2.93	0.0^{NS}	♠	0.0	0.19	0.46	0.0	5.6	0.0^{a}	♠	23.9	0.12	0.22	0.1	2.1	0.0^{a}	♠
TL	VRS	13.4	-0.04	-0.15	0.02	-1.8	0.1^{NS}	–	9.3	-0.0	-0.15	0.0	-1.7	0.1^{NS}	–	0.0	0.00	0.00	0.0	0.0	0.0^{a}	0	2.87	0.01	0.12	0.0	1.1	0.3^{NS}	♠
TL	RDS	2.5	0.05	0.14	0.03	1.7	0.1^{NS}	♠	6.9	0.0	0.16	0.0	1.76	0.1^{NS}	♠	0.8	0.04	0.39	0.0	4.5	0.0^{a}	♠	15.5	-0.02	-0.21	0.0	-2.1	0.0^{a}	–
TL	Rs	0.6	0.01	0.14	0.00	1.7	0.1^{NS}	♠	1.0	0.0	0.36	0.0	4.30	0.0^{a}	♠	0.2	0.01	0.40	0.0	4.7	0.0^{a}	♠	1.67	0.00	-0.03	0.0	-0.3	0.7^{NS}	–

Note: All measurements were in mm. TL = Total length of fish; TLS = scale length; WDS = scale width; HRS = ctenii counts in horizontal series; VRS = ctenii counts in vertical series on scale; RDS = radii counts; Rs = distance between focus and apex of scale; N= number of scale samples examined; CT = correlation type; S.E = Standard Error; a: represents relationship significant at 5% level (when $p<0.05$); NS: non-significant relationship (when $p>0.05$); * shows the strong correlation (when $r \geq 0.70$), ☼ shows moderate correlation (when r = 0.51-0.69), ♠ represent weak correlation (when $r \leq 50$), – shows negative correlation.

Table 4: Regression analysis of the parameters of transverse row scales (Ctenoid type) for the four species of the family Mugilidae.

		Liza melinoptera N= 132							*Liza macrolepis* N = 109							*Valamugilspeigleri* N = 107							*Mugilcephalus* N = 83						
		Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation			
X	Y	a	b	r	S.E(b)	t-test	P-value	CT	a	b	r	S.E(b)	t-test	P-value	CT	a	b	r	S.E(b)	t-test	P-value	CT	a	b	r	S.E(b)	t-test	P-value	CT
TL	TLS	3.05	0.02	0.23	0.01	2.6	0.01^{a}	♠	0.50	0.1	0.80	0.0	13.5	0.0^{a}	*	-0.2	0.04	0.74	0.0	11.4	0.0^{a}	*	2.1	0.0	0.71	0.0	9.2	0.0^{a}	*
TL	WDS	1.45	0.02	0.63	0.01	4.4	0.0^{a}	☼	1.38	0.0	0.75	0.0	11.7	0.0^{a}	*	-1.6	0.05	0.83	0.0	15.4	0.0^{a}	*	3.87	0.0	0.48	0.0	4.9	0.0^{a}	♠
TL	HRS	89.8	-0.01	-0.01	0.14	-0.1	0.9^{NS}	–	42.7	0.5	0.57	0.1	7.11	0.0^{a}	☼	-30.0	0.43	0.70	0.0	10.1	0.0^{a}	*	50.5	0.2	0.40	0.1	3.8	0.0^{a}	♠
TL	VRS	3.54	0.02	0.09	0.02	0.9	0.3^{NS}	♠	5.90	0.0	0.29	0.0	3.1	0.0^{a}	♠	0.0	0.00	0.00	0.0	0.0	0.0^{a}	0	1.4	0.0	0.28	0.0	2.6	0.0^{a}	♠
TL	RDS	-7.66	0.11	0.34	0.03	4.1	0.0^{a}	♠	8.83	0.0	0.04	0.0	0.4	0.7^{NS}	♠	4.3	0.02	0.21	0.0	2.2	0.03^{a}	♠	10.5	0.0	-0.04	0.0	-0.3	0.7^{NS}	–
TL	Rs	0.61	0.01	0.22	0.00	2.6	0.01^{a}	♠	0.88	0.0	0.61	0.0	7.9	0.0^{a}	☼	0.1	0.01	0.53	0.0	6.4	0.0^{a}	☼	0.8	0.0	0.35	0.0	3.3	0.0^{a}	♠

Note: All measurements were in mm. TL = Total length of fish; TLS = scale length; WDS = scale width; HRS = ctenii counts in horizontal series; VRS = ctenii counts in vertical series on scale; RDS = radii counts; Rs = distance between focus and apex of scale; N= number of scale samples examined; CT = correlation type; S.E = Standard Error; a: represents relationship significant at 5% level (when $p<0.05$); NS: non-significant relationship (when $p>0.05$); * shows the strong correlation (when $r \geq 0.70$), ☼ shows moderate correlation (when r = 0.51-0.69), ♠ represent weak correlation (when $r \leq 50$), – shows negative correlation.

Table 5: Regression analysis of the parameters of lateral line scales (Ctenoid type) for the four species of the family Mugilidae.

		Liza melinoptera N= 181							*Liza macrolepis* N = 137							*Valamugilspeigleri* N = 140							*Mugilcephalus* N = 95						
		Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation			
X	Y	a	B	r	S.E(b)	t-test	P-value	CT	a	b	r	S.E(b)	t-test	P-value	CT	a	b	r	S.E(b)	t-test	P-value	CT	a	b	r	S.E(b)	t-test	P-value	CT
TL	TLS	5.48	0.00	0.02	0.01	0.28	0.7^{NS}	♠	-0.1	0.1	0.71	0.0	11.7	0.0^{a}	*	-0.5	0.04	0.66	0.0	10.5	0.0^{a}	☼	3.7	0.0	0.51	0.00	5.6	0.0^{a}	☼
TL	WDS	6.72	-0.01	-0.09	0.01	-1.3	0.2^{NS}	–	-0.1	0.0	0.59	0.0	8.42	0.0^{a}	☼	0.4	0.03	0.42	0.0	5.38	0.0^{a}	♠	2.6	0.0	0.45	0.00	4.9	0.0^{a}	♠
TL	HRS	50.9	0.17	0.07	0.18	0.9	0.3^{NS}	♠	31.1	0.5	0.49	0.1	6.56	0.0^{a}	♠	-2.9	0.23	0.48	0.0	6.34	0.0^{a}	♠	45.9	0.1	0.26	0.06	2.6	0.01^{a}	♠
TL	VRS	5.13	0.02	0.05	0.02	0.7	0.5^{NS}	♠	4.5	0.0	0.27	0.0	3.27	0.0^{a}	♠	0.0	0.00	0.00	0.0	0.0	0.0^{a}	0	6.2	-0.0	-0.04	0.01	-0.3	0.71^{NS}	–
TL	RDS	-3.28	0.07	0.24	0.02	3.2	0.0^{a}	♠	0.1	0.0	0.47	0.0	6.23	0.0^{a}	♠	4.9	0.01	0.09	0.0	1.03	0.3^{NS}	♠	5.0	0.0	0.23	0.01	2.3	0.02^{a}	♠
TL	Rs	-0.16	0.01	0.26	0.00	3.6	0.0^{a}	♠	0.3	0.0	0.58	0.0	8.36	0.0^{a}	☼	0.0	0.01	0.46	0.0	6.11	0.0^{a}	♠	1.5	0.0	0.22	0.00	2.1	0.04^{a}	♠

Note: All measurements were in mm. TL = Total length of fish; TLS = scale length; WDS = scale width; HRS = ctenii counts in horizontal series; VRS = ctenii counts in vertical series on scale; RDS = radii counts; Rs = distance between focus and apex of scale; N= number of scale samples examined; CT = correlation type; S.E = Standard Error; a: represents relationship significant at 5% level (when $p<0.05$); NS: non-significant relationship (when $p>0.05$); * shows the strong correlation (when $r \geq 0.70$), ☼ shows moderate correlation (when r = 0.51-0.69), ♠ represent weak correlation (when $r \leq 50$), – shows negative correlation.

Table 6: Regression analysis of the parameters of caudal, transverse and lateral line scales (Cycloid type) of *Mugilcephalus*.

		Caudal scales N = 36							Transverse scales N = 40							Lateral line scales N = 48						
		Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation				Regression coefficients			Significance of correlation			
X	Y	a	b	r	S.E(b)	t-test	P-value	CT	a	b	r	S.E(b)	t-test	P-value	CT	a	b	r	S.E(b)	t-test	P-value	CT
TL	TLS	3.8	0.0	0.26	0.00	1.4	0.1^{NS}	♠	4.0	0.01	0.55	0.00	4.08	0.0^{a}	☼	4.3	0.01	0.62	0.00	5.41	0.0^{a}	☼
TL	WDS	2.6	0.0	0.35	0.00	2.2	0.0^{a}	♠	5.0	0.01	0.45	0.00	3.10	0.0^{a}	♠	3.6	0.01	0.57	0.00	4.64	0.0^{a}	☼
TL	RDS	9.9	-0.0	-0.06	0.01	-0.4	0.7^{NS}	–	4.3	0.01	0.28	0.01	1.83	0.1^{NS}	♠	2.4	0.02	0.45	20.1	3.40	0.0^{a}	♠
TL	Rs	1.0	0.0	0.27	0.00	1.7	0.1^{NS}	♠	2.7	0.01	0.04	0.00	0.25	0.8^{NS}	♠	2.4	0.00	0.09	0.9	0.63	0.5^{NS}	♠

Note: All measurements were in mm. TL = Total length of fish; TLS = scale length; WDS = scale width; RDS = radii counts; Rs = distance between focus and apex of scale; N= number of scale samples examined; CT = correlation type; S.E = Standard Error; a: represents relationship significant at 5% level (when $p<0.05$); NS: non-significant relationship (when $p>0.05$); * shows the strong correlation (when $r \geq 0.70$), ☼ shows moderate correlation (when r = 0.51-0.69), ♠ represent weak correlation (when $r \leq 50$), – shows negative correlation.

focus was located in the center or more towards the apical portion on mullet scale obtained from the selected body regions. In general, correlations between total length (TL) versus position of focus (Rs) were found to be highly significant (when $p<0.05$) for four types of scales except the caudal scales in *L. Melinoptera* and *M. cephalus* that showed insignificant relationship ($p>0.05$) as shown in Table 3, respectively. Lateral line scales of *M. cephalus* also showed significant relationship ($p<0.05$). Except the transverse scales of *V. speigleri* and *L. macrolepis* and lateral line scales of *L. macrolepis,* mostly poor correlations (when $r<0.50$) were observed between total length of fish versus position of focus (Rs) that might be because the position of the focus depends on the growth of the portions of scale, i.e., anterior, posterior and two lateral portions as described previously by Pillay (1951), Roberts (1993), Jawad (2005) and Gallardo-Cabello *et al*. (2003). Hence, position of focus (Rs values) depends on the size of scale (TLS) because the growth of scale depends on the formation of circuli. According to the Pillay (1951), during the earlier stage of the development, scales were smallest in size and their focus usually located nearer the base (anterior portion) than the apex (posterior portion) of scale. So its distance from the apex was more than from the base of scale. But as the fish grow, its scales also grow and become more elongated, then its focus was shifted more towards the apical portion or posterior portion of scale, hence, in large size scale, the distance between the focus and the apex of scale was found to decrease. Therefore, in small scales, focus mostly located in the centre, while in large scale, it is located more towards the apical or posterior portion of scale.

CONCLUSIONS

From the results of the present study, it was concluded that great variations were observed in the scale types, its size and width, total number of ctenii and radii counts and the position of focus in the posterior field of scales obtained from the four different body regions of individuals belong to same species or different mugilid species. Hence, all these changes in scale measurements and counts could be considered as useful taxonomic characters for the identifications and classifications of morphologically similar mullet species, which was in agreement with Batts (1964) and Coburn and Gaglione (1992), who also used various morphological and meristic characteristics of scales for the identification and phylogenetic relationship of various flatfish species (Pleuronectiformes) and several percid species (Percidae).

REFERENCES

Ambareen, K., Tehmina, Z., Zubia, M., Rehman, H. U., Asim U., Ramazanand, S. and Nelofer, J. Linear regression relationships between different scale parameters and body size of *Labeorohita* (family Cyprinidae)

collected from Baran Dam of Bannu district, Khyber Pakhtunkhuwa province, *Pakistan. World Journal of Zoology*.10 (**2**): 78-82, 2015

Batts, B.S. Lepidology of the adult Pleuronectiformes fishes of Pugnet Sound, *Washington. Copeia,* 4: 666-673, 1964

Beamish, R.J., Poier, K.L and Mahnken, C. Evidence of the validity of the critical size and critical period hypothesis. (NPAFC Doc. 564). Fisheries and Oceans Canada, Science Branch - Pacific Region, Pacific Biological Station, Nanaimo, BC, Canada, V9R 5K6 National Marine Fisheries Service, Port Orchard, WA, USA, 98366, 2001

Briggs, J. C. Encyclopedia of fishes. In: Paxon, J. R. and W. N. Sydney. New South Wales University Press: San Diego, Academic Press. [1995] 240 pp., 1994

Coburn, M. M. and Gaglione, J. I. A comparative study of percid scales (teleostei: Perciformes). *Copeia*. 1992(**4**): 986-1001, 1992

Cockerell, T.D.A. Observations on fish scales. *Bull. U.S. Bur. Fish*. 32: 117-174, 1913

Courtney, D.L., Mortensen, D.G. and Orsi, J.A. Digitized scale and otolith microstructures as correlates of juvenile pink salmon size. *N. Pac. Anadr. Fish Comm*. Bull. No. 2: 337-345, 2000

Creaser, C. W. The structure and growth of the scales of fishes in relation to the interpretation of their life history with special reference to the Sunfish Eruponotisgibbosus. *Misc. Publ. Mus. Zool. Univ. Mich*. 17: 3-76, 1926

Dahl, K. The age and growth of salmon and trout in Norway as shown by their scales. The Salmon and Trout Assoc. (1911), London, 141 pp., 1910

Dulce-Amor, P. M., Torres, M. A. J., Tabugo, S. R. M. and Demayo, C. G. Describing variations in scales between sexes of the yellow striped goatfish, *Upeneusvittatus* (Forskål, 1775) (Perciformes: Mullidae). Egypt. *Acad. J. Biolog. Sci*. 2 (1): 37-50, 2010

Esmaeili, H. R. and Gholami, Z. Scanning Electron Microscopy of the scale morphology in Cyprinid fish, *Rutilusfrisiikutum*(Kamenskii, 1901) (Actinopterygii: Cyprinidae). *Iranian Journal of Fisheries Sciences,* 10(1): 155-166,2011

Esmaeili, H. R., Khaefi, R., Sayyadzadeh, G., Tahami M.S., Parsi, B. Gholamifard,A. Scale Surface Microstructure and Scale Size in Three Mugilid Fishes Teleostei, *Mugilidae* of Iran from three Different Habitats. Istanbul *University Faculty of Science Journal of Biology*, 731: 31-42, 2014

Esmaeili, H. R., Teimory, A. and Hojat-Ansari, T. Scale structure of cyprinid fish *Capoetadamascina*(Valenciennes in Cuvier and Valenciennes, 1842) using scanning electron microscope (SEM). *Iranian Journal of Science and Technology*. 31(A3): 255-262, 2007

Fukuwaka, M. Scale and otolith patterns prove history of Pacific salmon. *N. Pac. Anadr. Fish. Comm*. Bull. No. 1: 190-198, 1998

Gallardo-Cabello, M., Espino-Barr, E., García-Boa, A., Cabral-Solís, E. G.and Puente-Gómez, M. Study of the growth of the green jack *Caranxcaballus* Günther 1868, in the coast of Colima, México. *Journal of Fisheries and Aquatic Science*. 2 (**2**): 131-139,

Gallardo-Cabello, M., Espino-Barr, E., González-Orozco, F. and Garcia-Boa, A. Age determination of *Anisotremusinterruptus* (Perciformes: Haemulidae) by scale reading, in the coast of Colima, Mexico. *Revista de Biología Tropical*. 51(**2**): 519-528,

Ganguly, D. N. and Mookerjee, S. On the structure and development of ctenoid scales in certain Indian fishes. *Proc. Nat. Inst. Sci. India*. 13:331-337, 1947

Gupta, S.D. and Jhingran, A. Aging *Labeocalbasu* (Hamilton) through its scales. *J. Inland. Fish. Soc. India*. (5):126-128, 1973

Helfman, G. S., Collette, B. B. and Facey, D. E. The diversity of fishes. Blackwell Sciences. 528pp, 1997

Ibanez, A. L., Gonzalez-Castro, M. and Pacheco-Almanzar, E. First record of *Mugilhospes* in the Gulf of Mexico and its identification from *Mugilcurema* using ctenii. *Journal of Fish Biology*, 78, 386-390, 2011

Ibanez, A.L. and Gallardo-Cabello, M. Identification of two Mugilidae species, *Mugilcephalus*and *Mugilcurema* (Pices: Mugilidae) using ctenii of their scales. *Bull. Mar. Sci.,* 77: 305-308,

Jacot, A.P. Age, growth, and scale characters of the mullets, *Mugilcephalus* and *Mugilcurema*. *Trans.* Amer. Fish. Soc. 39(3):199-229, 1920

Jawad, L. A. Comparative morphology of scales of four teleost fishes from Sudan and Yemen. *Journal of Natural History*, 39(**28**): 2643–2660 2005

Jawad, L. A. and AL-Jufaili, S. M. Scale morphology of grater lizardfish *Sauridatumbil* (Bloch, 1795) (Pisces: Synodontidae). *Journal of Fish Biology*. 70: 1185-1212, 2007

Jenkins, R. E. and Lachner, E. A. Crieteria for analysis and interpretation of the American fish genera *Nicomis* Gizard and *Hybopsis* Agassiz. *Smithsonian Contribution to Zoology*, 90: 15 pp, 1971

Johal, M. S., Esmaeili, H. R. and Sharma, M. L. Scale structure of a cobitid fish, *Cobitislinea* (Heckel, 1849) using different modes of SEM. *Current Science*. 91(**11**): 1464-1466, 2006

Johal, M. S., Novak, J. and Oliva, O. Noteson the growth of the common carp *Cyprinius carpio* In Northern India and middle Europe. *Vestnik Ceskoslovenske Spolecnosti Zoologike*. 48: 24-38, 1984

Joseph, D. C. Growth characteristics of two Sothern California Sunfishes, the California Corbina and Spotfin Croaker, Family Sciaenidae. The resources Agency of

California Department of Fish and Game Fish Bulletin, No. 119. Pp. 1-55, 1962

Katselis, G., Hotos, G., Minos, G. and Kosmas, V. Phenotypic affinities on fry of four Mediterranean grey mullet species. Turkish *Journal of Fisheries and Aquatic Sciences.* 6: 49-55, 2006

Kobayasi, H. Comparative studies of the scales in Japanese freshwater fishes, with special reference to the phylogeny and evolution. III. General lepidology of freshwater fishes. *Jap. J. Ichthyol.,* 2: 246-260, 1953

Lagler, K. F. Freshwater fishery biology. W. C. Brown Company, Dubuque, Iowa, 360pp., 1952

Landa, A. The relationship between body length and scale length in five Year-Classes of the Pacific Pilchard or Sardine, *Sardinopscaerulea* (Girard, 1854).*Pacific Science*. 7: 169-174, 1953

Lee, R. M. An investigation into the methods of growth determination in fishes. Publ. Circon. No. 63, Nov, 1912. Cons. Perm. Int. Expl. Mer, 35pp, 1912

Narejo, N. T., Jafri, S. I. H. and Sheikh, S. A. Studies on the age and growth of *Gudusiachapra*(Clupiedae: Teleosteii) from the Keenjhar lake (Distt. Thatta) Sindh. *Pakistan J. Zool*., 32(**4**): 307-312, 2000

Narejo, N.T., Mastoi, A. M., Lashari, P. K., Abid, M., Laghari, M. Y. and Mahesar, H. Age determination of a carp, *Labeocalbasu* (Hamilton) from Keenjhar Lake (District: Thatta), Sindh, Pakistan. *Sindh Univ. Res. Jour. (Sci. Ser.),* 41 (**1**) 83-86, 2009

Pillay, T. V. R. Structure and development of the scales of five species of grey mullet of Bengal. *Proceedings of the Notational Institute of Science, India*.17: 413–424, 1951

Rao, M. G. and Rao, L. H.. On the biology of *Labeocalbasu* (Ham.Buch) from the River Godavari. *J. Inland. Fish. Soc. India*, 5: 74-86, 1972

Roberts, C. D. Comparative morphology of spined scales and their phylogenetic significance in the Teleostei. *Bull. of Mar. Sci*., 52: 60–113, 1993

Sarabia-Méndez, M., Gallardo-Cabello, M., Espino-Barr, E. and Anislado-Tolentino, V. Characteristics of population dynamics of *Lutjanusguttatus* (Pisces: Lutjanidae) in Bufadero Bay, Michoacan, Mexico. *Hidrobiológica.* 20(**2**): 147-157, 2010

Sato, K., Yoshinaka, R., Sato, M. and Shimizu, Y. Collagen content in the muscle of fishes in association with their swimming movement and meat texture. *Bulletin of the Japanese Society of Scientific Fisheries [Nihon Suisan Gakkai-shi]*, 52 (**9**): 1595-1600, 1986

Sudo, S., Tsuyuki, K., Ito, Y. and Ikohagi, T. A study on the surface shape of scales.*JSME* fish *International Journal Series C-Mechanical Systems Machine Elements and Manufacturing,* 45(**4**): 1100-1105, 2002

Tandon, K. K. and Johal, M. S. *Age and Growth in Indian Freshwater Fishes*. New Delhi, Narendra Publishing House. 232pp., 1996

Taylor, H. F. The structure and growth of scales of the Squeteague and the Pig fish as indicative of life history. *Bull. U. S. Bur. Fish*., 34: 285-330, 1914-1916

Turan,C., Mevlüt-Gürlek, Deniz-Ergüden, Deniz-Yağhoğlu and Bayram-Öztürk. Systematic Status of Nine Mullet Species (Mugilidae) in the Mediterranean Sea. Turkish *Journal of Fisheries and Aquatic Sciences* 11: 315-321, 2011

Wajeeha, R., Farhat, I., Zubia, M., Masooma, K. Study of some morphometric and meristic characters of a Parassi mullet, *Mugilincilis*(Mugilidae: Mugiliformes) from the Indus river at Sukkur district of province Sindh, *Pakistan. Biological Forum-An International Journal*.7(**1**):767-772, 2015

Wassef, E. A. Growth rate of Gilthead Bream *Sparusaurata*. J.K.A.U. Mar. Sci., 1: 55-65, 1990

Weisberg, S. Using hard-part increment data to estimate age and environmental effects.*Can. J. Fish.Aquat. Sci.*, 50: 1229-1237, 1993

Zubia, M., Rehana, Y.F., Rehaman, F. U. Haider, M. S. Lakht-e-Zehra and M. Y. Hossain, Rehman, H.U. Asim U., WaqasA. and Shah,Q.U. Comparative studies on some morphometric and meristic characteristics of the scales in four mugilid species of the family Mugilidae for identifying their significance in taxonomy.*Biological Forum-An international journal*.**7**(**1**): 176-184.

Zubia, M. and Rehana, Y. F. Comparative study of different parameters of ctenoid scales in five species of genus *Lutjanus* (Perciformes: Lutjanidae) collected from Karachi fish harbor, Karachi, Pakistan. *International Journal of Biology and Biotechnology*. 8(**1**): 41-46, 2011

Zubia, M., Y. Rehana, M. S. Haider,Lakht-e-Zehra, Tarar, O. M. Mussarat, U.A. Rehaman, Asim-Ullah, H. U. Ihsan, U. H. Bilal M and Hossain, M. Y. Comparative studies of the scale characters in four Mugilid species (Family Mugilidae: Order Mugiliformes) from Karachi Coast, Pakistan. *Biological Forum-An International Journal*. 7(**1**): 410-418, 2015b