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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

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ABSTRACT: The present investigation was based on the comparative studies of some morphometric measurements and meristic counts of the mullet scales i.e., length (TLS) and width (WDS) of scale, number of ctenii arranged in horizontal (HRS) and vertical rows (VRS) on scale, total number of radii (RDS) and the vertical distance between focus and outer posterior margin of scale (Rs) among the four selected mugilid species, i.e., *Liza melinoptera, Liza macrolepis, Valamugil speigleri* and *Mugil cephalus* of the family Mugilidae were adopted in order to observe their significance in determining the phylogenetic relationship among these mullet species. As the analysis of the variations between the means of each scale parameter by test statistics (ANOVA, F-statistics) among the four mullet species of this study was found to be highly significant at 5% level ($p < 0.05$). Thus, the result of the present study had been proved that all these scale characters could be used as useful alternative tools in determining the systematic relationship among the different genera or species of these mullet fishes.

Key words: Scale length, scale width, total number of ctenii and radii, position of the focus.

INTRODUCTION

Fish scales develop from the dermis of skin that also act as an external tendon that store mechanical energy for producing efficient swimming in fishes [1]. Almost all fishes have scales found on their bodies except few fishes e.g., catfish, in which scales are absent. Tarpon and Mahsheer of India contain large sized scales ranged from 5 to 7 cm in diameter. Very small and minute scales are found in eel fish (*Anguilla anguilla*). Sometimes, scale features are unique for a particular species. Fish scales can be divided into four main types included 1. Placoid scales that are found in sharks and rays, 2. Ganoid scales that are found in gar and sturgeon fishes, 3. Cosmoid scales are found in lungfish and some fossil fishes, and 4. Leptoid scales are found in majority of bony fishes [2]. Leptoid scales are further divided into two types, i.e., cycloid and ctenoid scales. Mullets or grey mullets contain both types of leptoid scales i.e., cycloid and ctenoid scales. However, Coad [3] and Harrison and Senou [4] suggested that mullets may probably possess cycloid scales during the juvenile stage, while their adult stages contain ctenoid scales, therefore, such transition of cycloid into ctenoid scales could be seen in mullet species e.g., *Liza vaigiensis*. Also variations have been seen in the types of scales among the different mullet species, e.g., *Aldrichetta forsteri* and *Myxus sp.* contained both transforming ctenoid and cycloid scales, *Chelon sp.* have only transforming ctenoid scales, *Mugil cephalus* contained whole ctenoid scales,while *Crenimugil crenilabus* and *Neomyxus chaptalii* possessed only cycloid scales [5]. Roberts [5] further classified ctenoid type of scales into three types, which are as follows; 1. Crenate scales (e.g., *Valamugil speigleri*), 2. Spinoid scales (e.g., *Scatophagus argus*), 3. Basic ctenoid scales (e.g., *Mugil cephalus*).

As in different fish species, ctenii of ctenoid scale also shows great variations in their arrangements and shapes at the posterior margin or apex of scale, hence, on the basis of their arrangement, ctenii can be classified into three categories; (1) Transforming ctenoid scales in which ctenii are arranged into two or three alternating rows marginally and transformed into truncated ctenii sub marginally e.g., *Acanthurus lineatus*; (2) Peripheral ctenoid scales that have ctenii arranged in only one row at the posterior margin of scale e.g., *Gombiomorphus basalis*; (3) a third and rare type is called whole ctenioid scale that possessed separate spines or ctenii, arranged marginally and sub marginally at the posterior margin of scale e.g., *Mugil cephalus*. But in mullet fishes, Roberts [5] reported only two types of ctenii i.e., transforming and whole ctenii on the ctenoid scales of different mullet species and, also used them for determining their phylogenetic relationships. Lately, Ibanez *et al.* [6] had differentiated the two morphologically and genetically related mugilid species, *Mugil hopes* and *Mugil curema* based on the shapes of ctenii found on their ctenoid scales. In few cases, the character of ctenii had been found to be species specific, therefore, Hubbs [7] and Kobayasi [8] had also observed the variations in the types of ctenii among the different mugilid species and considered them as valuable taxonomic characters for correct identification.

MATERIALS AND METHODS

A. Samples collection

About 116 specimens of the four mugilid species of family Mugilidae were collected monthly from the landings at Karachi fish harbour from the period of April 2011 to December 2012. In laboratory, each specimen was identified upto the species level by using the FAO field guide of Bianchi [9] and Harrison and Senou [4]. Then each specimen was immediately preserved in 10% formaldehyde solution for about a week and later stored in 70 % ethanol for long time preservation.

B. Statistical analysis of scale data

Method used for making the permanent slides of scales in this study follow the Schneider *et al*. [10] and Hotos [11] with some modifications. In each specimen, scale samples were collected from the following four selected body regions i.e., head scales (HS); caudal scales (CS); transverse row scales (TRS) collected in transverse series from the origin of first dorsal-fin to the origin of pelvic-fin) and lateral line scales (LLS).

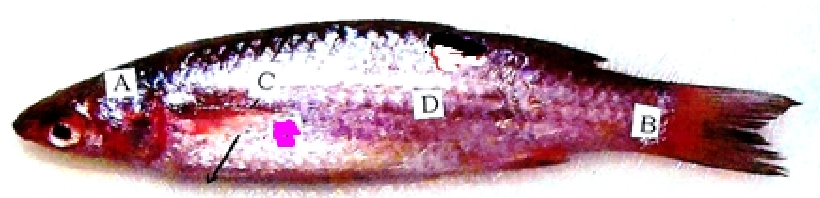

Fig. 1. Showing the four selected body regions for the collection of scale samples (A= head region; B = Caudal region; C = Transverse series of scales; D = Lateral line region).

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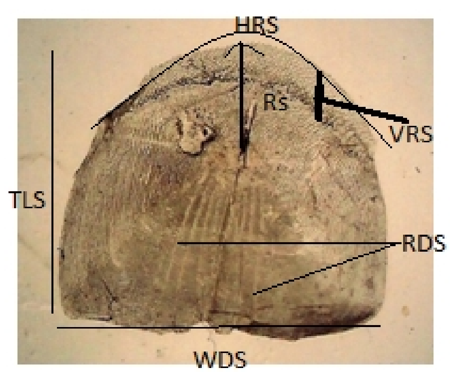

Fig. 2. Showing the measurements and counts of the morphometric and meristic characters ofmullet scale i.e., **TLS** = Scale length; **WDS** = Scale width; **HRS** = Number of ctenii arranged in horizontal row; **VRS** = Number of ctenii arranged in vertical row; **Rs** = vertical distance between focus and apex of scale.

At least 4-5 scales were taken from each body region (Fig.1). All slides were examined under the stereomicroscope (4×10) and, then measured and counts the following parameters of above mention types of scales such as, TLS = Scale length, WDS = Scale width, HRS = Number of ctenii arranged in horizontal row on scale, VRS = Number of ctenii arranged in vertical row on scale, RDS = Number of radii on scale, Rs = Scale radius or vertical distance between focus to the posterior margin of scale).

Fig. 2 shows the measurements and counts of the different parameters of ctenoid scales of mullet. All scale measurements were taken in millimeters.

F-statistics (ANOVA) at 5% significant level ($p<0.05$) was calculated by Minitab Demo 14.1 software. F-values were used to determine the variations between the means of the six selected scale parameters (TLS, WDS, HRS, VRS, RDS and Rs). The F-statistics (ANOVA) was calculated at 5% significant level ($p<0.05$) with the help of Minitab statistical software (version 14.1). F- Statistics was used for comparing the means of each selected scale parameter, in order to test the null hypothesis (Ho) that the means of each scale parameter among the four mullet species are equal against the alternate hypothesis (Ha), that is all means are not the same.

RESULTS

In the present investigations, about seven scale parameters e.g., scale length (TLS), scale width (WDS), total number of ctenii counts in horizontal row (HRS) and vertical row (VRS), total number of radii (RDS), and the vertical distance between focus and apex of scale (Rs) were statistically treated (ANOVA, $p<0.05$) in order to established the relationships among the four selected mullet species of this study.

The variations between the means of six scale parameters of each scale type (i.e., HS, CS, TRS & LLS) of four mullet species were subjected to F-Statistics (ANOVA) at $p<0.05$, as shown in the Tables 1-3. Thus, the results of the present study revealed that the mean values recorded for each scale parameter had showed the great differences among the four mullet species. In general, the variation between the means of each scale parameter (i.e., TLS, WDS, HRS, VRS, RDS and Rs) in four types of scales (head, caudal, transverse and lateral line scales) either cycloid or ctenoid type among the four mullet species was found to be statistically highly significant at 5% significant level (ANOVA, F-test: $p<0.05$) as shown in Tables 1 and 2. Therefore, the results of the statistical analysis of the different scale parameters observed in this study had providing the more valuable scale characters that could be useful in fish taxonomy. The overall result revealed that in general, the values of the total length or size (TLS) of four types of scales i.e., head, caudal, transverse and lateral line scales of the *L. macrolepis* were found to be higher than the remaining three mullet species. In general, the size (TLS) of caudal scales in each mullet species were found to be smaller than the scales obtained from the remaining other body regions. The total number of ctenii and radii in the head scales of all four mullet species were mostly lower than the scales obtained from the remaining other body regions. Furthermore, radii were most frequently absent in the scales obtained from the head region. Thus, the shape of scale surface may possibly depend on its position on the body of fish. In general, the total radii counts (RDS) for cycloid scales were found to be less as compared to the ctenoid scales.

DISCUSSIONS

A. Comparative study of the morphometric and meristic characteristics of mullet scale

In the present investigation, a detailed study about the diferent morphometric and meristic characters of the scales in four selected mullet species revealed that a certain degree of variation occurs among the different parameters of mullet scale i.e., scale size (TLS) and width (WDS), position of the focus (Rs), and the number of ctenii arranged in horizontal row (HRS) and vertical row (VRS), and total number of radii (RDS). Therefore, the main objectives of this study was to determine some useful scale characters that later could be helpful in resolving their correct identification problems and also used them in determining the exact taxonomic status of these mullet species.

Mullet scales obtained from the four different body regions were consist of the following structures such as focus, radii, and ctenii as observed by Pillay [12]. As mullet fishes are same in their external morphology, hence, it was very difficult to identify them on the basis of the morphometric and meristic characters of their body. However, various workers had used some scale characters e.g. scale shapes, number and arrangement of radii and ctenii, and the position of focus on scale in systematic classification of fishes [13-18]. Thus, the scale size (TLS) and width (WDS), the number of radii (RDS) and number of ctenii arranged in horizontal row (HRS) and verticle rows (VRS), and the position of focus (Rs) on scales obtained from the four selected body regions of these mullet species shows some variations that later could be consider as key characters in determining their exact systimatic position.

As each mullet species of this study contain both cycloid and ctenoid scales, however, variations have also been observed in the arrangement of these two types of leptoid scales among their different body regions, such as, *Mugil cephalus* have both cycloid and ctenoid scales on its whole body regions; *Liza melinoptera* and *Liza macrolepis* were found to contain ctenoid scales; whereas *Valamugil speigleri* possessed crenate type of scales. While the head region of all these mullet species contains cycloid scales along with the ctenoid scales, as compare to the remaining other body regions. Roberts [5] observed three types of ctenoid scales e.g., crenate, spinoid and basic ctenoidscalesin teleost fishes. But in mullet species of this study, only two types of ctenoid scales e.g., crenate and basic ctenoid sales were reported.

Table 1: Statistical analysis of the different parameters of ctenoid scales obtained from the head, caudal, transverse and lateral line regions of the four species of the family Mugilidae. Scale length and all other measurements are in mm. Counts for HRS, VRS and RDS are from the both sides of each scale sample. TL = Total body length in mm.

	Liza melinoptera					***Liza macrolepis***					***Valamugil speigleri***					***Mugil cephalus***						
TL range in mm.	145-180					125-290					131-194					200-378					**ANOVA**	
Scale type	**HEAD SCALES (HS)**																					
Scale parameter	**n**	**Mean**	**s.d**	**Min.**	**Max.**	**n**	**Mean**	**s.d**	**Min.**	**Max**	**n**	**Mean**	**s.d**	**Min.**	**Max.**	**n**	**Mean**	**s.d**	**Min.**	**Max**	**F**	**P**
TLS	77	5.6	1.04	3.3	8.0	69	6.3	1.37	3.0	10.5	73	5.5	0.93	4.0	8.0	31	7.7	1.93	3.0	10.0	26.0	0.0*
WDS		5.0	0.89	2.5	7.0		6.0	1.19	2.5	9.0		5.0	0.84	3.5	7.5		7.3	2.04	3.0	10.0	37.7	0.0*
HRS		34.5	25.9	2.0	126.0		57.9	34.1	10.0	147		31.5	11.3	10.0	60.0		55.2	19.6	16.0	95.0	19.0	0.0*
VRS		2.6	2.74	1.0	16.0		4.2	2.21	1.0	10.0		1.0	0.0	1.0	1.0		3.6	1.52	1.0	8.0	9.3	0.0*
RDS		1.2	2.24	0.0	9.0		1.9	2.21	0.0	8.0		3.8	3.17	0.0	14.0		5.8	3.60	0.0	15.0	26.7	0.0*
Rs		2.8	0.62	1.0	4.0		2.8	0.68	1.0	4.5		2.5	0.67	1.0	3.8		3.1	1.06	1.5	5.0	6.7	0.0*
Scale type	**CAUDAL SCALES (CS)**																					
Scale parameter	**n**	**Mean**	**s.d**	**Min.**	**Max.**	**n**	**Mean**	**s.d**	**Min.**	**Max**	**n**	**Mean**	**s.d**	**Min.**	**Max.**	**n**	**Mean**	**s.d**	**Min.**	**Max**	**F**	**P**
TLS	145	3.8	0.87	2.0	6.5	129	4.8	1.19	2.5	8.5	118	4.2	0.98	2.0	7.0	89	4.5	1.20	2.0	7.2	21.8	0.0*
WDS		3.3	0.69	1.5	5.3		4.0	1.17	1.0	6.8		3.6	1.05	2.0	7.5		4.0	1.09	1.0	7.0	14.7	0.0*
HRS		70.2	18.4	7.0	108.0		83.7	27.20	26.0	159.0		29.8	7.81	15.0	58.0		56.2	23.22	10.0	109.0	156.6	0.0*
VRS		7.1	2.60	3.0	15.0		7.4	2.59	2.0	15.0		1.0	0.00	1.0	1.0		4.3	1.91	2.0	13.0	48.1	0.0*
RDS		11.1	3.76	1.0	23.0		9.6	3.47	2.0	20.0		7.7	2.14	3.0	18.0		9.9	4.06	3.0	22.0	20.9	0.0*
Rs		1.5	0.42	1.0	3.0		1.9	0.51	1.0	3.3		1.8	0.49	1.0	3.0		1.6	0.49	0.5	3.0	16.9	0.0*
Scale type	**TRANSVERSE ROW SCALES (TRS)**																					
Scale parameter	**n**	**Mean**	**s.d**	**Min.**	**Max.**	**n**	**Mean**	**s.d**	**Min.**	**Max**	**n**	**Mean**	**s.d**	**Min.**	**Max.**	**n**	**Mean**	**s.d**	**Min.**	**Max**	**F**	**P**
TLS	132	5.7	0.74	4.0	10.0	109	8.5	2.08	5.0	14.8	107	5.8	0.98	4.0	8.0	83	7.5	1.20	5.5	11.5	116.2	0.0*
WDS		5.4	0.68	4.0	7.5		7.2	1.60	2.5	10.5		6.1	1.13	4.0	9.1		7.5	1.19	4.5	10.5	72.1	0.0*
HRS		88.6	16.3	14.0	127.0		127	30.8	66.0	222		38.8	12.00	18.0	80.0		106.4	22.55	48.0	190.0	330.7	0.0*

Table 1 contd…

VRS		7.4	2.82	3.0	20.0		10.4	3.24	4.0	20.0		1.0	0.00	1.0	1.0		5.8	2.58	2.0	16.0	61.3	0.0*
RDS		9.3	3.16	3.0	19.0		9.3	2.77	2.0	17.0		7.1	1.61	5.0	14.0		9.7	3.54	4.0	20.0	18.2	0.0*
Rs		2.2	0.44	1.5	4.0		2.9	0.69	1.5	4.5		2.4	0.52	1.5	3.5		2.6	0.80	1.3	4.5	29.2	0.0*
Scale type	**LATERAL LINE SCALES (LLS)**																					
Scale parameter	**n**	**Mean**	**s.d**	**Min.**	**Max.**	**n**	**Mean**	**s.d**	**Min.**	**Max**	**n**	**Mean**	**s.d**	**Min.**	**Max.**	**n**	**Mean**	**s.d**	**Min.**	**Max**	**F**	**P**
TLS	181	5.7	0.72	4.0	9.0	137	8.0	2.20	3.8	13.9	140	5.7	1.15	3.0	9.0	95	7.4	1.17	5.0	10.8	96.8	0.0*
WDS		4.9	1.09	2.2	8.0		6.4	2.19	2.3	12.0		5.1	1.40	1.5	9.0		6.7	1.50	2.5	10.5	44.5	0.0*
HRS		78.7	23.1	18.0	160.0		118.5	34.8	43.0	218		34.2	9.53	10.0	74.0		85.7	24.5	24.0	144	275.8	0.0*
VRS		7.7	2.87	2.0	18.0		10.0	3.90	3.0	29.0		1.0	0.00	1.0	1.0		5.7	2.60	1.0	12.0	52.5	0.0*
RDS		7.4	2.71	1.0	17.0		7.7	3.14	3.0	19.0		6.6	2.24	1.0	17.0		9.0	2.75	3.0	16.0	15.1	0.0*
Rs		2.3	0.54	1.3	4.0		3.0	0.90	1.5	6.0		2.3	0.59	1.0	4.0		2.5	0.77	1.0	4.5	40.0	0.0*

s.d = Standard deviation; * F-statistics significant at 5% level ($p \geq 0.05$). **TLS** = scale length; **WDS** = scale width; **Rs** = vertical distance between focus to the apex of scale; **HRS** = total number of ctenii arranged in horizontal row; **VRS** = total number of ctenii arranged in vertical rows; **RDS** = total number of radii.

Among the four mullet species, *Liza melinoptera*, *Liza macrolepis* and *Mugil cephalus* possessed basic ctenoid scales (Ct), while *Valamugil speigleri* contained crenate scales (Cr). Roberts [5] reported the presence of whole ctenii only in the ctenoid scales of single genus, *Mugil*. However, on the other hand, the occurrence of these whole ctenii were reported not only in the species belong to the genus *Mugil*, but also on the scales of two more species of genus *Liza* i.e., *Liza melinoptera* and *Liza macrolepis* (except *Valamugil speigleri*) in this study. This might be because Roberts [5] suggested that transforming ctenoid scales found in some mullet species show their close resemblance with whole ctenoid scales of *Mugil cephalus*.

Total number of ctenii arranged in horizontal (HRS) and vertical rows (VRS) on scales: Though the shapes of ctenii in three selected mullet species (except *V. speigleri*) of this study were found to be identical, however, variation have been observed in the number and arrangement of ctenii among the mullet species belonging to the two genera i.e., *Mugil* and *Liza.* In general, mullet scales mostly contained large numbers of ctenii arranged in both horizontal and vertical rows on the posterior field of scale. However, the total number of ctenii found in the horizontal (HRS) and vertical rows (VRS) on the ctenoid scales showed a great difference among four selected mullet species of the present study.

Table 2: Statistical analysis of the different parameters of cycloid scales obtained from the head region of the four species of the family Mugilidae. Scale length and all other measurements are in mm. Counts for RDS are from both sides of each scale sample.
TL = Total body length in mm.
Cycloid scales (Cy) from head region (HS)

	Liza melinoptera					***Liza macrolepis***					***Valamugil speigleri***					***Mugil cephalus***						
TL range in mm.	145-180					125-290					131-194					200-378					**ANOVA**	
Scale parameter	**n**	**Mean**	**s.d.**	**Min.**	**Max**	**n**	**Mean**	**s.d**	**Min.**	**Max.**	**n**	**Mean**	**s.d**	**Min.**	**Max.**	**n**	**Mean**	**s.d**	**Min.**	**Max.**	**F**	**P**
TLS	68	4.8	1.08	2.8	8.0	73	6.5	1.85	4.0	12.5	72	5.4	1.04	3.8	8.0	76	7.3	1.71	3.0	10.5	40.9	0.0*
WDS		4.8	0.87	3.0	7.0		6.2	1.29	3.8	9.0		5.1	0.87	3.0	7.0		7.2	1.68	3.0	10.3	59.1	0.0*
RDS		0.4	1.49	0.0	8.0		0.4	1.06	0.0	5.0		2.0	2.76	0.0	12.0		0.3	1.02	0.0	6.0	16.8	0.0*
Rs		2.4	0.69	1.0	4.0		2.9	0.76	1.5	5.0		2.6	0.64	1.3	4.0		3.4	1.04	1.4	5.5	22.7	0.0*

s.d. = Standard deviation; * F-statistics significant at 5% level ($p \geq 0.05$).**TLS** = scale length; **WDS** = scale width; **Rs** = vertical distance between focus to the apex of scale.

Table 3: Statistical analysis of the different parameters of cycloid scales obtained from the caudal, transverse and lateral line of *Mugil cephalus* of the family Mugilidae. Scale length and all other measurements are in mm. Total length of *Mugil cephalus* was ranged from 200 to 378 mm in TL.
Cycloid scales (Cy) from the caudal (CS), transverse (TRS) and lateral line region (LLS)

Scale types	**CAUDAL SCALES (CS)**					**TRANSVERSE SCALES (TRS)**					**LATERAL LINE SCALES (LLS)**				
Scale parameters	**n**	**Mean**	**s.d**	**Min.**	**Max.**	**n**	**Mean**	**s.d**	**Min.**	**Max**	**n**	**Mean**	**s.d**	**Min.**	**Max**
TLS	36	4.9	0.97	3.0	7.0	40	7.5	1.32	4.0	11.2	48	7.4	1.09	5.50	11.0
WDS		4.4	1.11	2.0	7.0		7.5	1.15	4.1	10.4		6.9	1.27	4.25	9.5
RDS		8.9	3.39	4.0	20.0		8.0	2.76	4.0	15.0		7.5	2.53	1.00	15.0
Rs		1.7	0.56	0.5	3.0		2.9	0.91	1.5	5.0		2.7	0.69	1.00	5.0

TLS = scale length; **WDS** = scale width; **Rs** = vertical distance between focus to the apex of scale. **s.d** = Standard deviation.
Note: cycloid scales were absent in the caudal transverse and lateral line region of three mullet species i.e., *L. melinoptera, L.macrolepis and V. speigleri.*

Such variations in the total ctenii counts within horizontal (HRS) and vertical rows (VRS) on the ctenoid scales among these mullet species may probably be because both *Liza* species *(Liza macrolepis* and *Liza melinoptera)* contained strong ctenoid scales, while *Mugil cephalus* possessed weak ctenoid scales (Table 1). This was in consistency with the observation of mullet scales by Pillay [12] and Harrison and Senou [4]. Furthermore, in general, the total numbers of ctenii arranged in horizontal and vertical rows on head scales and less frequently in some scales obtained from the other body regions possessed fewer numbers of ctenii (about 2 to 10) as shown in Table 1. This may be because the head regions in these mullet species mostly possessed weekly ctenoid scales or due to the presence of newly formed regenerated scales that represent their very early stage of development. As the scale grows, its posterior portion will also grow by the formation of new ctenii through the division of old ctenii, which then arranged into several rows [19]. Therefore, the number of ctenii will be increases in both horizontal and vertical rows on scale. However, the presence of some strong ctenoid scales was also exceptionally been observed in the head regions of these four mullet species. Moreover, it had been observed in the present study that scales from the caudal, transverse and lateral line regions were found to have large number of ctenii arranged in both horizontal and vertical rows on their posterior field, which might be due to the presence of strong ctenoid scales. Hence, strong ctenoid scales can provide better protection to fish as compared to weak ctenoid or cycloid scales. Such variations in the total number of ctenii arranged in horizontal and vertical rows on scales within the same species or among the different species might be due to the variations in the formation of ctenii. For example, earliest workers such as Baudelot [20] and Cockerell [21] reported that ctenii on ctenoid scales probably be arises from the serrae on the edges of circuli or due to the modifications and segmentations of longitudinal apical circuli present in their posterior field. Whereas, Creaser [22] and Taylor [23] had also reported that the formation of ctenial spines on the scales in fish may be related to the movements of fish body, therefore, Ganguly and Mookerjee [19] observed the absence of ctenii in the head and caudal region scales of *Sciaenacoitor*, and thus proved this view. Hence, the presence or absence of ctenii may be due to the differential movements of various body parts during swimming. Sato *et al*. [24] had described the mullets as subcarangiform swimmers, in which the amplitude of undulation was small on the anterior portion and large on the posterior portion of the fish body.

Hence, during swimming, mullet fishes can bend more their posterior half portion than the anterior portion of the body. Therefore, in the present study, scales from the caudal regions of four mullet species were found to have large number of ctenii as compared to the other selected body parts. Hence, spines or ctenii always formed on those scales that occur in the body regions which show more flexibility.

Therefore, the development of new ctenii may depend on some mechanical means (may perhaps be due to the different modes of swimming in fishes). Likewise, Sudo *et al*. [25] reported that the shapes of scale surface mostly depend on the functions and position of scales in fishes. While in contrast, Pillay [12] observed the presence of ctenoid scales on all body regions (including head and caudal regions) of four *Mugil sp.* i.e., *M. cephalus, M. corsula, M. tade, M. parsia* (except *M. speigleri*) and found no correlation between ctenoid scale formation and body movement. Furthermore, Ganguly and Mookerjee [19] reported that the number of ctenii formed in the posterior field of scales may depends on the space exists between the ends of the interrupted circuli, but no correlation was exists between the number of ctenii and the location of subsequent circuli in the posterior field of scale. However, the nature of circuli had no influence on the ctenial spine formation. Though ctenii and circuli are made up of identical substance, but in fact, they were considered as separate structures of scale. Hence, they developed independently by the deposition of the secretion of lower layer of the scale [19, 12]. Roberts [5] reported that ctenial spine growth occurs through the secretions of ctenial rather than scale osteoblasts. Thus, the results of present investigation revealed that the variations in the character of ctenii could be helpful in systematic studies of these mullet species.

Total number of radii (RDS) on scales: In the present investigation, radii were found only in the anterior part of each mullet scaleas previously observed by Pillay [12]. Although, Jawad [13] and Esmaeili *et al*. [26] classified these radii of scale into three categories i.e., primary, secondary and tertiary radii, however, only total numbers of radii were count in the present study. In addition to the number of ctenii, variations have been observed in the total number of radii (RDS) among the four mullet species. Furthermore, significant variations had been reported in the total number of radii (RDS) on the scales obtained from the four selected body regions of each mullet species, such as, head scalesof each mullet species contain 0 (zero) or less number of radii as compared to the scales collected from the other body regions (Table 1-3). This might be because during swimming, the caudal fins of fish twisted backwards, so the flow of water on the surface of caudal scales will produce numerous ridges or grooves (radii), while head scales will provide only protection to the internal organs of the fish [25]. In addition, the total radii counts were also found to be varied between the two main scale types i.e., cycloid and ctenoid scales of the four mullet species of this study. Thus, the total number of radii (RDS) that occurs on the mullet scales were also found to be varied according to the position of scale on the fish body [26]. In the present study, the total radii counts on ctenoid scales were found to be higher in comparison with cycloid scales. Such variations in the total radii counts might be due to the better nutritive conditions of fish [27-28] or because of the hydrodynamic properties of fish scales [25].

However, Johal *et al*. [28] and Dulce-Armor *et al*. [16] also reported that the formation of radii may be related to the space provided by anterior and lateral portions of the scales, as these two portions of scale was mostly overlapped by the posterior portion of proceeding scale. Furthermore, earliest worker such as Taylor [23] investigated that the origin of radii on scales mostly depends on the flexibility of those body portion from which the scales were collected. Hence, greater will be the flexibility of the body region, more will be the number of radii formed on its scales. In fact, radii was indicating the line of scale elasticity or flexibility. Therefore, the formation of radii found on the scale may have relation to its flexibility/elasticity or the space provided by the anterior and lateral portions of scale or due to different swimming modes of fish. Lippitsch [29] also observed that the occurrence of radii on a given scale was in fact a growth phenomenon. Therefore, it was not a genetic factor as observed by the above mention workers. Thus, in the present study, all these variations in the total number of radii counts among the four mullet species can provide a reliable character for their taxonomic studies. This was in agreement with Jawad and Al-Jufaili [30] who considered the number of radii as useful taxonomic character for the identification of greater lizardfish, *Sauridatumbil*.

Vertical distance from the focus to the outer posterior margin (exposed portion) of the scale: The 'Rs' values will signify the distance between the focus to of the outer posterior margin of the scale or in fact the values of Rs were representing the position of the focus on mullet scales. In the present investigation, focus was in centeral or apical portion on scales obtained from the each selected body regions of these mullet species, which was in agreement with Pillay [12] and Ibanez *et al*. [14].Variation were reported in the position of scales obtained from the different regions of the body, e.g., head scale mostly contains centrally placed focus, while caudal, transverse and lateral line scales contain focus more towards their posterior field. Further more, as the position of the focus was also found to be varied according to the type of scale and species, therefore, great variation were reported in the position of focus among the cycloid and ctenoid scales of the four selected mullet species in this study. Moreover, in case of weak ctenoid and cycloid scales, focus was located in the anterior field or more towards the central portion, which inctenoidscales, focus was mostly found in posterior field or apical portion. Such type of variations in the position of focus among the different fish species have also been reported by Jawad [13] The posterior position of focus might be related to the lateral growth of the scale rather than a mixture of anterior and posterior growths [5,13]. As significant variation have been reported in the position of the focus on the scales among the different genus or species of the family Mugilidae, therefore, it had been proved that this character could be used as useful taxonomic character for determining their exact taxonomic status, which was in agreement with Ibanez *et al*. [14] who also used this character for the identification of a mullet species i.e., *Mugil cephalus.*

Detail studies about the morphometric structure of scales in various mullet species had been proved that mullet scales could be useful for the identifications of genera, species and subspecies or geographically variants as reported by Ibanez *et al*. [14]. Cockerell [21] described the variations in scale characters such as scale shapes, length, width, position of the focus, different types and shapes of ctenii, different arrangements of radii and circuli in the scales among the different orders, suborders and families of fishes, including white mullet, *Mugil curema* (Mugilidae) from the collection at Woods Hole. Pillay [12], Chervinski [31] and Liu and Shen [32] described the importance of scale characters (such as focus, radii, circuli and ctenii) for the identifications of mugilid species from India, Israel and Taiwan. Ibanez *et al*. [14] reported that the scales of *Mugil cephalus* can easily distinguished from all other mugilid species due to the presence of a more centrally located focus.

CONCLUSION

From the results of morphometric and meristic analysis of mullet scales, it had been concluded that all selected scale characters (such as scale length and width, total number of ctenii arranged in horizontal and vertical rows on scale, total rdii counts and the position of focus) utilized in the present study would be considered as valuable taxonomic characters for determing the systematic relationships among these mullet species. Therefore, the assessment of morphometric and meristic variability of mullet scales of this study will provides a modern tool for the identification of species, population or geographical variants.

REFERENCES

Long, J.H., Knoob, T.J., Irving, K., Combie, K., Engel, V., Livingston, N., Lammert, A. and Schumacher, J. (2006). Biomimetic evolutionary analysis: testing the adaptive value of vertebrate tail stiffness in autonomous swimming robots. *Journal of Experimental Biology,* **209**(23): 4732-4746.

Vernerey, F. J. and Barthelat, F. (2010). On the mechanics of fish scale structures. *International Journal of Solids and Structure,* **47**: 2268-2275.

Coad, B.W. (1995a). Freshwater Fishes of Iran. *ActaScientiarumNaturaliumAcademiaeScientiarumBohemicae, Brno,* **29**(1): 1-64.

Harrison, I.J. and Senou, H. (1999). Mugilidae. In: *FAO identification guides for fisheries purposes.* The living marine resources of the Western Central Pacific, Vol. **4**. Bony fishes, Part 2, (Mugilidae-Carangidae), edited by Carpenter, K. and Niem. V. H. FAO. Rome.

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

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

Hubbs, C.L. (1921). Remarks on the life history and scale character of American mullets. *Trans. Amer. Micro. Soc.*,**40**: 26-27.

Kobayasi, H. (1953). 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.

Bianchi, G. (1985). *FAO species identification sheets for fishery purposes*. Field guide to the commercial marine and brackish-water species of Pakistan. Prepared with the support of PAK/77/033 and FAO (FIRM) Regular Programme. Rome, FAO, pp. 200.

Schneider, J.C., Laarman, P.W. and Gowing, H. (2000). *Age and growth methods and state averages.* Chapter 9. In: Schneider, James C. (ed.) (2000). Manual of fisheries survey methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor.

Hotos, G.N. (2003). A study on the scale and age estimation of the grey golden mullet, *Liza Aurata* (Risso, 1810), in the lagoon of Messolonghi (W. Greece). *Journal of applied Ichthology*, **19**: 220-228.

Pillay, T.V.R. *(*1951). 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.

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

Ibanez, A.L., Cowx, I.G. and O'Higgins, P. (2007). Geometric morphometric analysis of fish scales for identifying genera, species and local populations within the Mugilidae. *Can. J. Fish. Aquat. Sci.*, **64**: 1091-1100.

Ibanez, A.L., Cowx, I.G. and O'Higgins, P. (2009). Variation in elasmoid fish scale patterns is informative with regard to taxon and swimming mode. *Zoological journal of Linnean Society*, **155**(4): 834-844.

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

Garduno-Paz, M.V., Demetriou, M. and Adams, C.E. (2010). Variation in scale shape among alternative sympatric phenotypes of Arctic charr *Salvelinus alpinus* from two lakes in Scotland. *Journal of fish biology*, **76**(6): 1491-1497.

Ibáñez, A.L., and P. O'Higgins. (2011). Identifying fish scales: the influence of allometry on scale shape and classification. *Fisheries Research*,**109**: 54-60.

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

Baudelot, E. (1873). Recherchessur la structure et la development des ecailles des poisons osseux. *Arch. Zool. Exp. Gen.*, **2**: 87-244.

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

Creaser, C.W. (1926). 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.

Taylor, H.F. (1914-16). 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.

Sato, K., Yoshinaka, R., Sato, M. and Shimizu, Y. (1986). 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.

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

Esmaeili, H.R., Teimory, A. and Hojat-Ansari, T. (2007). 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.

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

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

Lippitsch, E. (1990). Scale morphology and squamation patterns in cichlids (Teleostei, Perciformes): A comparative study. *Journal of Fish Biology*, **37**: 265-291.

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

Chervinski, J.(1984). Using scales for identification of four Mugilidae species. *Aquaculture*, **38***:* 79–81.

Liu, C.H. and *S*hen, S.C. (1991). Lepidology of the mugilid fishes*. J. of the Taiw. Mus.*, **44***:* 321–357.