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Relationship between different linear dimensions of scale parameters of four species of Mugilidae from Karachi Coast, Pakistan

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ABSTRACT

The present investigation was conducted to work out linear regression relationships among six parameters scale length (TLS), scale width (WDS), number of ctenii found in horizontal (HRS) and vertical rows (VRS) on scale, total radii counts (RDS), vertical distance between focus and outer posterior edge of scale (Rs) in four commercially important mugilid species viz., *Liza melinoptera*, *Liza macrolepis*, *Valamugil speigleri* and *Mugil cephalus*) of family Mugilidae. The obtained results revealed that the most correlations between scale length (TLS) or width (WDS) with the selected scale parameters (HRS, VRS & Rs) were found to be weak ($r < 0.50$) and highly significant at 5% level (t-test; $p<0.05$). Thus, the present study adopted to focus the implication of some functional scale characters that could be used as valuable alternative tools in observing the systematic relationship between different genera or species or geographical variants of family Mugilidae.

INTRODUCTION

Fish is one of the primary sources of high-quality protein consumed by one billion people worldwide **(Ahmad *et al*., 2020; Khalid *et al*., 2020; Hussain *et al*., 2021; Hassan *et al*., 2021ab)**. Fish scales can be defined as small rigid plates that provide protection against certain diseases and predators and help in locomotion. As fish scales exhibit significant variations in their size, a number of ctenii, radii counts, and position of focus among the different species of fish, therefore, several finding including (**Zubia *et***

***al*., 2015a,b)** had used all these scale characteristics in the systematic classification of various species of fishes found in different counties of the world. Scales of fish can be categorized into four main kind's i.e., placoid scales, ganoid scales, cycloid scales, and ctenoid scales but mullets or grey mullets contain only cycloid and ctenoid scales (**Roberts, 1993).** According to **Roberts (1993),** ctenoid scales can be further categorized into three kinds, i.e., crenate, spinoid, and primary or whole type ctenoid scales. But mullet fishes possess ctenoid scales: crenate type, e.g., in *Valamugil speigleri* and primary or whole type ctenoid scales, e.g., in *Liza melinoptera, L. macrolepis* and *Mugil cephalus*, as previously reported by **Zubia *et al*. (2015a)**.

Furthermore, even great variations had been noted in the arraignment of ctenii occur at the posterior margin of ctenoid scale, thence, based on the arrangement of ctenii, ctenoid scales can also be categorized into three types including (1) Transforming ctenoid scales (2) Peripheral ctenoid scales and (3) and a sporadic third form called whole ctenoid scales. However, **Roberts (1993)** observed only transforming and whole ctenii on the ctenoid scales obtained from different mullet species. Whereas the only whole type of ctenoid scales in three mugilid species, including *Liza melinoptera, L. macrolepis*, and *Mugil cephalus* from Karachi coast of Pakistan by **Zubia and Rehana, 2011; Zubia *et al*., 2015 a&b)**. Hence, as large variations have been noted among the types of ctenoid scales and even in the agreement of ctenii on ctenoid scales between the different mugilid species, these scale characters had been considered valuable taxonomic characters that could be used in precise identifications. Moreover, the dissimilarities in length and width of scales, number of ctenii found in horizontal and vertical rows on the posterior edge of the scale, total radii counts and location of focus among the four mugilid species including *L. melinoptera, L. macrolepis, V. speigleri* and *M. cephalus* from Karachi coast by **Zubia *et al*. (2015a&b)**. Many researcher had also used the scale morphology in the identification of fish scales including i.e., **Gallardo-Cabello *et al*. (2003)** examined the structure and growth of the scales of the squeteague and the pigfish as indicative of life history; a critical study of the relation between body length and several scale measurements in the smallmouth bass, *Micropterus dolomieu Lacepede* was given by **Everhart (1950)**; **Richards and Esteves (1997)** had use of scale morphology for discriminating wild stocks of Atlantic striped bass and also by **Sudo *et al*. (2002)**; the fish scale morphology used in the identification of populations of *Leuciscus leuciscus burdigalensis* in River Viaur of South-West France at a local scale by **Poulet *et al*. (2005)**, the scale structure of a cyprinid fish *Capoeta damascina* by using scanning electron microscope (SEM) by **Esmaeili *et al*. (2007)**, the scale morphology of the Indian goatfish, *Parapeneus indicus* was analyzed by **Dapar *et al*. (2012)**, **Wainwright and Lauder (2016)** had also observed the scale morphology in bluegill sunfish, *Lepomis macrochirus* and analyzed that scale morphologically is mostly diverse among species, within species, and also in individual fish populations. Therefore, the present study was conducted to observe the relationships among all these scale characteristics of the four

mullet species on the Karachi coast. Furthermore, our study will provide helpful information regarding the various microstructures of mullet scale that later could be considered as best alternative tools for observing the phylogenetic relationships among different genera or species of the family Mugilidae in Pakistan but throughout the world.

MATERIALS AND METHODS

About 1006 fish specimens belonging to the four species, including *L. melinoptera*, *L. macrolepis*, *V. speigleri* and *M. cephalus* of Mugilidae family, were collected from April 2017 to December 2018. The collection was done on a monthly basis. Total catch contains 307, 244, 293 and 162 samples of L. melinoptera, L. macrolepis, V. speigleri and M. cephalus. In the present, four body regions were selected for the collection of the scale samples, i.e., HS = Scales obtained from the head region; CS = Scales obtained from caudal-fin base; TRS = Transverse series scales obtained from the origin of the dorsal fin to the source of pelvic fin; LLS = Scales obtained from the lateral line region in fish as shown in Figure 1.

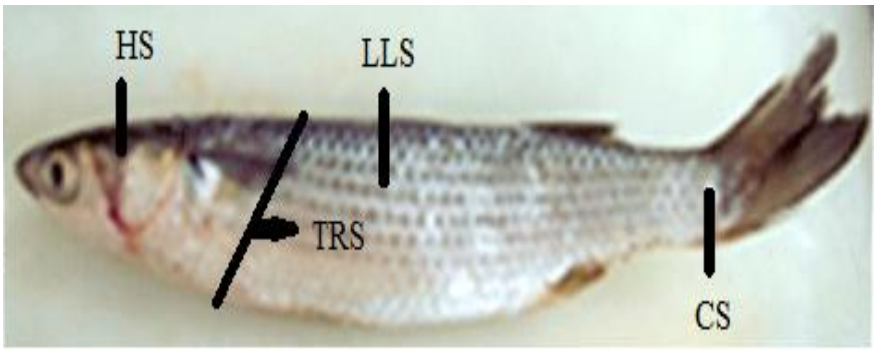

Fig .1. Four selected body regions of mullet fish for scale sampling

Scale parameters selected for the present study are as follows;

TLS = length of scale; WDS = width of scale; HRS = total ctenii counts in horizontal rows on apex of scale; VRS = total ctenii counts in vertical rows on scale ; RDS = total radii counts; Rs = Location of the focus on scale (parameters 1-6, Figure B).

The procedure utilized for the permanent slides preparations and studies of selected scale parameters under a light microscope follows the methods given by **Zubia *et al.* (2015a&b).**

Fig .2. Position of selected scale parameters.

In the present study, the linear regression relationships were observed between the scale length (TLS) versus various selected scale parameters by **Hossain *et al.* (2006&2009)** that are as follows;

TLS vs. WDS; TLS vs. HRS; TLS vs. VRS; TLS vs. RDS; TLS vs. Rs

Furthermore, relationships were also observed between widths of scale (WDS) versus various selected scale parameters, which are as follows;

WDS vs. HRS; WDS vs. VRS; WDS vs. RDS; WDS vs. Rs

Regression coefficients were calculated to determine the strength of the relationship between scale length (TLS) or scale width (WDS) versus remaining selected scale parameters (i.e., HRS, VRS, RDS, Rs) of the present study by using formula according to **Hossain *et al.* (2009)**. The level of significance of regression was subjected to the t-test analysis at $p<0.05$ to test the null hypothesis Ho that is $r = 0$ when both variables are linearly not correlated against the alternate Ha that is $r > 0$ or $r < 0$ when both variables are positively or negatively linearly correlated. All statistical analyses were done by using statistical software Minitab 17.1version.

RESULTS AND DISCUSSION

Linear regression relationship amongst the scale length (TLS) *vs.* various parameters of mullet scale

In the present surveys, about six selected parameters of scale including scale length (TLS), scale width (WDS), number of ctenii counts in a horizontal row (HRS) and vertical row (VRS) on the scale, total radii counts (RDS), and the vertical distance between focus and posterior edge of scale (Rs) for the scales collected from four body regions such as head, caudal, transverse and lateral line regions were statistically treated to assess the strength of correlations between length of scale (TLS) versus five selected parameters of scale, such as WDS, HRS, VRS, RDS, and Rs, respectively. Furthermore, the strength of correlation among the scale width (WDS) and the remaining four selected parameters i.e., HRS, VRS, RDS and Rs was also caculated. The majority of the relationships among the scale length (TLS) or width (WDS) with three selected scale

parameters, i.e., HRS, VRS& Rs were weak ($r \leq 0.50$) and highly significant (t-test; $p<0.05$) except the fewer one were moderately strong ($r = 0.51$ to 0.69) or were found to be comparatively strong ($r > 0.70$), respectively (Table 1-3). As previous literature studies on all these selected scale parameters analyzed in the present study were still scarce, their comparison with previously published work was almost intricate. However, **Zubia and Rehana (2011)** had also observed a similar linear relationship for the scale parameters of five lutjanid species of family Lutjanidae collected from the Karachi coast.

Correlation between length (TLS) *vs.* width (WDS) of the scale was

mostly highly significant ($p<0.05$) between length (TLS) and width (WDS) of the head, transverse, lateral line, and caudal scales in four mullet species. These findings were in agreement with **Gallardo-Cabello *et al*. (2003), Narejo *et al*. (2009), and Sarabia-Méndez *et al*. (2010),** who also reported a similar type of correlations for various other species, including *Anisotremus interruptus*, *Labeo calbasu* and *Lutjanus guttatus*. From the obtained results, it had been proved that the scales don,t change their basic structure and retain their shapes throughout their lifetime. As **Roberts (1993)** reported, scale growth occurred with the addition of newly formed circuli on the outer margin. **Esmaeili *et al*. (2007)** reported that the formation of these circuli occurs due to the extra secretion of calcium salts from the skin and their deposition on the scale. Thence, the distance amongst circuli is actually representing the slow and fast growth period of fish. When scale growth becomes closed during the summer season due to the abundance of food, new circuli will be formed on the outer edges of scale at a more expansive space. But, during the winter season, scales growth becomes slow due to low water temperature, and this newly formed circuli will become closer and form dark bands or annuli on the scale. Such variations in the patterns of the formation of this circuli might be related to the dissimilarity of physical and chemical parameters of oceanic currents also observed by **Sarabia-Méndez *et al*. (2010).** Thus, the growth rate of fish is proportional to the scale growth and the width of circuli or annuli on the scale.

Correlations between scale length (TLS) *vs.* number of ctenii counts arranged in horizontal (HRS) and vertical rows (VRS) on scale.

In the present study, a relationship between scale length (TLS) *vs.* total ctenii counts in horizontal row (HRS) was highly significant ($p<0.05$) for the caudal scales of *M. cephalus* and *L. macrolepis*, and transverse scales of *L. macrolepis*. Whereas, mostly insignificant relationship ($p>0.05$) was observed between scale length (TLS) versus number of ctenii arranged in vertical rows (VRS). In *V. speigleri*, weak and moderate types of correlations were recorded for scale length *vs*. total crenae counts in four types of scales selected for the present study. Furthermore, though the size of caudal scales was small, the numbers of ctenii count in horizontal and vertical rows on the apex of scale were large that might be because the formation of ctenii perhaps depends on the flexibility of fish scale or swimming modes of fish **(Sudo *et al*., 2002)**. Though the correlations between whole-body growth versus different parameters of scale including scale length and width, scale radius, and total radii counts of scale had been observed by many workers, however, previously published literature about correlations between scale

length *vs.* number of ctenii counts arranged in horizontal (HRS) and vertical rows (VRS) on the scale were still not available. However, the obtained results revealed that, in general, mostly weak ($r<0.50$) or moderate ($r = 0.51$ to 0.69) type correlations were observed between scale length (TLS) versus several ctenii arranged in horizontal (HRS) and vertical rows (VRS) for the selected mullet species (except *V. speigleri*) of the present study. As scale size in fish usually increases by adding more circuli on its outer margin, the formation of new ctenii will not always depend upon the increase in the size of the fish scale. Correlations between scale length (TLS) *vs.* number of radii (RDS)

The obtained results of the present study revealed that, in general, most correlations between scale length (TLS) versus a total number of radii (RDS) found in the anterior field of scale were weak ($r>0.50$) or negative (when $r<0.0$) and insignificant ($p>0.05$) for the head, caudal, transverse and lateral line scales of each mullet species, which was following **Esmaeili and Gholami (2011).** Furthermore, great variations were noted in the total radii counts among the head, caudal, transverse, and lateral line scales in each mullet species of the present study. For example, head scales contain very few radii, or sometimes radii were almost absent, but in contrast, scales obtained from the caudal, transverse, and lateral line region of each mullet species possess many radii. In addition, though the size of the caudal scale was small, the total radii counts were large that might be because the number of radii present on the scale is totally determined by the flexibility of scale by **Gallardo-Cabello *et al*. (2003)** or swimming modes of fish by **Sato *et al*. (1986)** or the position of scale on the body of fish by **Esmaeili *et al*. (2007).**

Correlations between scale lengths (TLS) *vs.* vertical distance between focus to the apex of scale (Rs)

The obtained results of the present study revealed that most strong ($r\geq0.70$) and highly significant relationships ($p<0.01$) was observed between scale length (TLS) and vertical distance from the focus to the posterior margin of scale (Rs) for the ctenoid type scales obtained from four selected body regions of four mullet species. According to **Pillay (1951),** focus is usually located more towards the posterior portion or near the center of scale in most mullet fishes. The present investigation reveals differences in stress position among the cycloid and ctenoid scales of mullet species; for example, in ctenoid scale, the focus is located primarily towards the apical part, while in cycloid direction mainly was found close to the center of the scale. As the position of the focus had been found to be constant throughout the life of fish **(Liu and Shen, 1991; Jawad, 2005),** therefore, Rs values will be increases or decrease only due to the growth of scale, which mostly occurs with the addition of more marginal circuli or new ctenii at the anterior and posterior fields **(Roberts, 1993).** Thence, the vertical distance between the focus and the posterior margin of scale (Rs value) seemed to be increased with increasing size of scale, particularly ctenoid scale, but in the case ofcycloid scale, such correlations were found to be moderately strong ($r = 0.51$ to 0.69), which might be because the growth of a posterior portion of cycloid scale was relatively slow as compared to its anterior portion.

Linear regression relationship between scale widths (WDS) *vs.* various scale parameters

Correlations between scale width (WDS) *vs.* the total number of ctenii found in horizontal (HRS) and vertical rows (VRS) on scale except head scales, mostly significant ($p<0.05$) and strong ($r>0.70$) or moderate type of relationships ($r = 0.51$ to 0.69) were examined between WDS and HRS in all selected types of scales of each mullet species of the present study. However, correlations between WDS and VRS were found to be weak ($r<0.50$) for HS, CS, TRS, and LLS of four selected mullet species. As no previous published data was accessible about these two kinds of correlations, comparison of our present data with previous published data was almost impossible.

Correlations between scale width (WDS) *vs.* the total number of radii (RDS) and distance between focus to the apex of scale (Rs) on scale

The obtained results revealed that most correlations between WDS and RDS of the head, caudal, transverse, and lateral line scales in each mullet species seemed to be weakly negative ($r<0.50$), except the ctenoid scales obtained from the head region of *Mugil cephalus* that shows moderately strong relationship. In addition, WDS *vs.* Rs mostly shows weak ($r<0.50$) or moderate ($r=0.51$ to 0.69) but highly significant ($p<0.05$) correlations for head, caudal, transverse and lateral line scales of each mullet species, except the caudal and transverse scales of *L. macrolepis* that showed only strong correlation ($r>0.70$). These findings were in line with the results of **Courtney *et al.* (2000)**. They also found strong correlations between non-periodic microstructures, i.e., focus, radii, and ctenii are strongly correlated with each other and the whole body growth of fish. Such variations in scales microstructures might relate to fish swimming modes or the type of habitat in which they lived, as suggested by **Sudo *et al.* (2002)** and **Zaporozhets and Zaporozhets (2000).** Moreover, even a single fish show a considerable variation in the scale structures obtained from different body regions due to the impact of specific factors, e.g., environmental pollution (oil exploration and exploitation activities) as observed by **Hassan *et al.* (2020ab). Ilkyaz *et al.* (2006)** or high fishing activity or due to the differences in temperature, food, geographical location of their habitats or nutritional levels of the study area as reported by **Bagenal and Tesch (1978), King (1984), Ibanez *et al.* (2009& 2011**) and **Wainwright and Lauder (2016).** Thus, our present study was in good agreement with the earlier findings.

CONCLUSION

From the obtained results of our present study, it was concluded that each scale character utilized in the present study could be considered valuable taxonomic characters to determine the systematic relationships among the different mullet species. Therefore, the assessment of variability in the selected parameters of mullet scales will offer a modern tool for identifying some new species or geographical variants or populations. Thence confirmed that mullet scale characters could help determine the possible differences among the different mullet species found in the various regions throughout the world.

REFERENCES

Ahmad, A.; Khan, W.; Das, S.N.; Pahanwar, W.A.; Khalid, S.; Mehmood, S.A., Ahmed, S.; Kamal, M.; Ahmed, M.S.; Hassan, U.H.; Zahoori, S. and Maqbool, A. (2020). Assessment of ecto and endo parasites of *Schizothorax plagiostomus* inhabiting river Panjkora, Khyber Pakhtunkhwa, Pakistan. Braz. J Biol., 84:1678-4375. https://doi.org/10.1590/1519-6984.222214

Bagenal, T. B. and Tesch, A. T. (1978). Conditions and growth patterns in fresh water habitats. blackwell scientific publications, oxford, london.

Courtney, D. L.; Mortensen, D. G. and Orsi, J. A. (2000). Digitized scale and *otolith microstructures* as correlates of juvenile pink salmon size. N. Pac. Anadr. Fish Comm. Bull. 2**:**337-345.

Dapar, M. L. G.; Torres, M. A. J.; Fabricante, P. K. and Demayo, C. G. (2012). Scale morphology of the Indian goatfish, *parapeneus indicus* (shaw, 1803) (perciformes: mullidae). *Adv.* Environ. Biol., 6:1426–1432.

Esmaeili, H. R.; Ansari, T. H. and Teimory, A. (2007). Scale Structure of A Cyprinid Fish Capoeta Damascina (Valenciennes In Cuvier and Valenciennes, 1842) Using Scanning Electron Microscope (Sem). Iran. J. Sci. Technol. Trans. A., 31 :255–262.

Esmaeili, H. R. and Gholami, Z. (2011). Scanning Electron Microscopy of the Scale Morphology in Cyprinid Fish, Rutilus Frisii Kutum (Kamenskii, 1901) (Actinopterygii: Cyprinidae), Iran. J. Fish. Sci., 10(1) : 155-166.

Everhart, W. H. A. (1950). Critical study of the relation between body length and several scale measurements in the smallmouth bass, *Micropterus dolomieu* Lacepede. J. Wildl. Managem., 14 :266–276.

Gallardo-Cabello, M.; Espino-Barr, E.; González-Orozco, F and Garcia-Boa, A. (2003). Age Determination Of *Anisotremus Interruptus* (Perciformes: Haemulidae) By Scale Reading, In The Coast Of Colima, Mexico, Rev. biol. Trop., 51(2) : 519-528.

Hossain, M. Y.: Ahmed, Z. F.,: Leunda, P. M.: Islam, A. K.M.R.: Jasmine, S.; Oscoz, J.: Miranda, R. and Ohtomi, J. (2006). Length-Weight and Length-Length Relationships of Some Small Indigenous Fish Species from the Mathabhanga River, Southwestern Bangladesh, J. Appl. Ichthyol., 22(4): 301-303.

Hossain, M. Y.; Jasmine, S.; Ibrahim, A. H. M.; Ahmed Z. F.; Rahman, M. M. and Ohtomi, J. (2009). Length-Weight and Length-Length Relationships of 10 Small Fish Species from the Ganges, Bangladesh, J. Appl. Ichthyol., 25(1): 117-119.

Hussain, H.; Hassan,U,H.; Siddique, M.A.M.;Mahmood, K.; M.F.A. Abdel-Aziz, M.F.A. ; Laghari, M.Y.; Abro, N.A.; Gabol, K.; Nisar, Rizwan , S. and Halima (2021). Effect of varying dietary protein levels on growth performance

and survival of milkfish *Chanos chanos* fingerlings reared in brackish water pond ecosystem, Egypt. J. Aquat. Res., https://doi.org/10.1016/j.ejar.2021.05.001

Hassan, H.U.; Ali, Q.M.; Ahmad, N.; Masood, Z.; Hossain, M.Y.; Gabol, K.; Khan, W.; Hussain, M.; Ali, A.; Attaullah, M. and Kamal, M. (2021a). Assessment of growth characteristics, the survival rate and body composition of Asian Sea bass *Lates calcarifer* (Bloch, 1790) under different feeding rates in closed aquaculture system. Saudi J. Biol. Sci., 28 (2): 1324-1330. https://doi.org/10.1016 /j.sjbs.2020. 11.056

Hassan, H.U.; Ali, Q. M.; Khan, W.; Masood, Z.; Abdel-Aziz,M.A.; Shah,M.I.A.; Gabo,K.;Wattoo, I.; Chatta, A.M.; Kamal, M., Z.; Zulfiqar,T. and Hossain, Y. (2021b). Effect of Feeding frequency as a rearing system on biological performance, survival, body chemical composition and economic efficiency of Asian seabass *Lates calcarifer* (Bloch, 1790) Reared under Controlled Environmental Conditions. Saudi J. Biol. Sci., https://doi.org/10.1016/j.sjbs.2021.08.031

Hassan, H.U.; Ali, Q.M.; Rahman, M.A.; Kamal, M.; Tanjin, S.; Farooq, U.; Mawa, Z.; Badshah, N.; Mahmood, K.; Hasan, M.R.; Gabool, K.; Rima, F.A.; Islam, M.A.; Rahman, O. and Hossain, M.Y. (2020a). Growth pattern, condition and prey-predator status of 9 fish species from the Arabian Sea (Baluchistan and Sindh), Pakistan. Egypt. J. Aquat. Biol. Fish., 24: 281-292.

Hassan, H.U.; Ali, Q.M.; Ahmad, N.; Attaullah, M.; Chatta, A.M.; Farooq, U. and Ali, A. (2020b). Study of vertebrate diversity and associated threats in selected habitats of Sindh and Baluchistan, Pakistan. Int. J. Bio.Biotech., 17 (1): 163-175, 2020.

Ibáñez, A. L. and O'higgins, P. (2011). Identifying Fish Scales: The Influence Of allometry On Scale Shape and Classification. Fish. Res., 109: 54-60.

Ibanez, A. L.; Cowx, I. G. and Higgins, P. (2009). Variation In Elasmoid Fish Scale Patterns Is Informative With Regard To Taxon and Swimming Mode. Zool. J. Linnean, Soc., 155(4):834-844.

Ilkyaz, A. T.; Firat, K.; Saka, S. and Kinacigil, H. T. (2006). Age, Growth, And Sex Ratio Of Golden Grey Mullet, *Liza Aurata* (Risso, 1810) In Homa Lagoon (Üzmir Bay, Aegean Sea), Turk.J. Zool., 30: 279-284.

Ibanez, A. L.; Gonzalez-Castro, M. and Pacheco-Almanzar, E. (2011). First Record Of *Mugil Hospes* In The Gulf Of Mexico and Its Identification From *Mugil Curema* Using Ctenii, J. Fish Biol., 78: 386-390.

Jawad, L. A. (2005). Comparative Morphology of Scales of Four Teleost Fishes from Sudan and Yemen. J. Nat. Hist., 39:2643–2660

Khalid, S.; Khanb, W.; Das, S.N.; Ahmad, A.; . Mehmood , S.A.; Pahanwar , W.A.; Ahmed, S.; Kamal, M.; Waqas, M.; Waqas, R.M.;Hassan, U.H.; Zahoor, S. and Maqbool, A. (2020). Evaluation of ecto and endo parasitic

fauna of *Schizothorax plagiostomus* inhabitants of river Swat, Khyber Pakhtun Khwa, Pakistan. Braz. J. Biol. 81: 1678-4375

King, R. P. (1984). On the biology of the Mugilidae in Bonny river (Niger Delta) with particular reference to feed ecology. M. Sc Thesis, University of port Harcourt Nigeria, pp. 198.

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

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

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.**

Poulet, N.; Reyjol, Y.; Collier, H. and Lekdoes, S. (2005). Fish scale morphology allow the identification of populations at a local scale? A case study for rostrum dace *Leuciscus leuciscus burdigalensis* in River Viaur (SW France), Aquat. Sci, 67:122–**127.**

Richards, R. A. and Esteves, C. (1997). Use of scale morphology for discriminating wild stocks of Atlantic striped bass, Trans. Am. Fish. Soc, 126 :919–925.

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

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

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, Bull. Jpn. Soc. Sci. Fish. 52 (9) :1595-1600.

Sudo, S.; Tsuyuki, K., Ito, Y. and Ikohagi, T. (2002). A study on the surface shape of fish scales. Jap. Soc. Mech. Eng., 45: 1100–1105.

Wainwright, D. K. and Lauder, G. V. (2016). Three-dimensional analysis of scale morphology in bluegill sunfish, *Lepomis macrochirus*. Zoology, 119 (3): 182-195,

Zaporozhets, O. M. and Zaporozhets, G. V. (2000). Using the coordinates of some character points of scales for differentiation of Pacific salmon stocks, N. Pac. Anadr. Fish. Comm. Bull. No. 2:325-329.

Zubia, M.; Rehana, Y.; Rehaman, F. U.; Haider, M. S.; Lakht-E-Zehra, Hossain, M. Y.; Rehman, H.U.; Asim, U.; Waqas, A. and Shah, Q. U. (2015a).

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.; Rehana, Y.; Haider, M. S.; Lakht-E-Zehra, Tarar, O.M.; Mussarat, U. A.; Rehaman, H U.; Ullah, A.;Ihsan, M. B. and Hossain, M. Y. (2015b)**.** 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.

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