Bangladesh J. Fish. (2019) **31**(1) : 01-16

Squamatological variations in five inland fishes of Bangladesh

MD. ASHRAFUL ISLAM, JOBAYDA SIFAT, H.M. AL KABID RAFIN AND MOSTAFA ALI REZA HOSSAIN*
Department of Fisheries Biology and Genetics, Bangladesh Agricultural University
Mymensingh 2202, Bangladesh
*Email: marhossain@bau.edu.bd

Abstract. Fish scales have numerous hidden information in their structures that contribute in fish identification and classification. In the present study, scales were collected and examined from twelve body regions including lateral line of five fish species belonging to five Families and five Orders of inland fishes of Bangladesh. A wide spectrum of variations in the scales of five fish was recorded concerning the surface morphology, shape of the circuli, grooves, pattern of the different fields and the shape of ctenii. The morphological descriptions were based on the scale's type, shape, features of the anterior, posterior and lateral fields, radii types, and circuli distribution. The microstructures included focus position and shape, shape of first circuli, number of radii and tubercle size and shape. Results of the study reveals that scales of the studied fishes were either cycloid or ctenoid types with notable variation in scale shape, circuli distribution, focus position and shape, shape of first circuli, radii types and tubercle size and shape. Considerable variation in lateral line scales were also observed and two types of lateral line scales observed with three sub-types. Morphometric indices were calculated from scale of the anterior dorsal flank area of each species and represented a valuable tool for species separation. The outcomes of the present study, first of its kind in Bangladesh, would assist in resolving identification problems for future fish taxonomists and fisheries-oriented researchers.
Keywords: Scales, Morphology, Microstructure, Lateral line, Inland fish

Introduction

Like other animals, fish body consists of different internal and external organs. External organs of fish are eyes, fins, gills, scales, lateral line, photophores, spines and rays. Fish have either scales as a body covering or they are scale-less with a naked body. Fish scales are ossified plates. Scales are the most exterior part of majority of fish's body and are used for protection, coloration and as sensory receptors. Dermal derivatives of fish body consist of hard and flattened skeletal element that proclaim a vast range of morphological diversity. Teleost scales consist of a layer of acellular bone which enshroud a plate of promiscuously equipped collagen fibers (Grande and Bemis 1998, Sire and Akimenko 2004). Scales are arrayed in imbricating manners where every single scales overlaps each other but remains opened posteriorly (Wainwright and Lauder 2016). These are the most exterior part of fish body usage for protection, coloration as well as sensory receptors (Barazona *et al*. 2012). Various types of scales are found in fishes like plate-like placoid, diamond shaped ganoid, smooth disc-like cycloid and ctenoid scales having small projection towards the posterior margin (Casteel 1976, Patterson *et al*. 2002).

Scales are made of calcium carbonate and collagen embedded within the fish epidermis and often very useful in the identification of fish species. The analysis of scale morphology appeared to be promising as it is relatively easy to apply, fast, cheap and does not require animal to be killed and dissected (Renjith *et al*. 2014). Since the early 1900s, fish identification based on the scales have been used as a common method (Ibanez and O'Higgins 2011). Scale shape and number have been applied in taxonomical researches since the first half of the 19th century when

Agassiz (1883-1884) used this for the first time in fish taxonomy. During the late 19th century and first half of 20th century, scale morphology studies have progressed dramatically in the field of taxonomy (Cockerell 1910, Lagler 1947, McCully 1961).Scales can be a useful tool in various scientific fields, like systematics, phylogeny, palaeontology, life history, ecology and toxicology. Scale morphology and microstructures have been applied in systematics that reflected a vivid taxonomic status as well as a well-founded phylogenic tree of various groups of fishes along with the functional and systematic approaches (Alkaladi *et al*. 2013, Renjith *et al*. 201, Masood *et al*. 2015), determination of age (Jhingran 1957, Gholami *et al*. 2013), past environmental history of fish, differentiating hatchery reared and wild populations, migration, pathology and pollution of the water body (Johal and Dua 1995, Johal and Sawhney 1997, Esmaeili 2001), for the growth studies (Johal *et al*. 1984, Lippitsch 1990, Johal *et al*. 2001), in the palaeontological analysis (Esmaeili 2001) and genetic studies (Kumar *et al*. 2007). Moreover, variations in scale size and J-indices were proved to be an effective taxonomic tool for the discrimination of fish species (Gholami *et al*. 2013, Esmaeili *et al*. 2014).

According to the Red List, 64 indigenous riverine fishes of Bangladesh are threatened – vulnerable (VU), endangered (EN) and critically endangered (CR) (IUCN-Bangladesh 2015). Correct identification of fish species is necessary to formulate management and conservation measures for threatened fish species. As identification of fish scales helps to identify certain Genera even Species, and is prerequisite to study sexual dimorphism, age determination, phylogeny and other systematics studies, it is indispensable to study the fish scale. Though the study of fish scale has received great attention in developed countries, so far, researches on fish scale in Bangladesh have received no attention in the past. Therefore, a proper study on scale of indigenous fishes of Bangladesh is the need of time. The present work aimed to screening and documenting the diversity of scale characteristics of five indigenous fish from the water bodies of Bangladesh in an attempt to determine the valid scale characters for identification of the studied species and to give an interpretation for the surface scale morphology. Also the study has been designed to describe the microstructures of the studied scales, inter-specific variability of scale shapes, and to describe the lateral line scales, present in the five fish.

Materials and methods

Collection sites and selected fish: Fish sample were collected from the local markets of Mohonganj, Netrokona, Mymensingh Sadar and Khulna Sadar, respectively. Scales were sampled from 5 fish Species, belonging to 5 Families and 5 Orders of common inland fishes in Bangladesh (Table I).

Table I. List of the sampled fishes

Order	Family	Scientific name	Common name	Local name
Clupeiformes	Clupeidae	*Tenualosa ilisha*	Hilsha Shad	Ilish
Cypriniformes	Cyprinidae	*Amblypharyngodon mola*	Mola Carplet	Mola
Osteoglossiformes	Notopteridae	*Notopterus notopterus*	Grey Featherback	Foli
Perciformes	Nandidae	*Nandus nandus*	Mud Perch	Bheda
Mugiliformes	Mugilidae	*Sicamugil cascasia*	Yellowtail mullet	Kachki Bata

Preparation of scales: Before removing the scale, every single fish specimen was rinsed out with freshwater. Scales were taken from twelve areas of the selected fish (Fig. 1). Maximum

effort were given to remove as much tissue as possible while taking fish scales using forceps without damaging the scales. In case of some species, it was not possible to take scales from each of the selected twelve body areas as sufficient number of scales were not present.

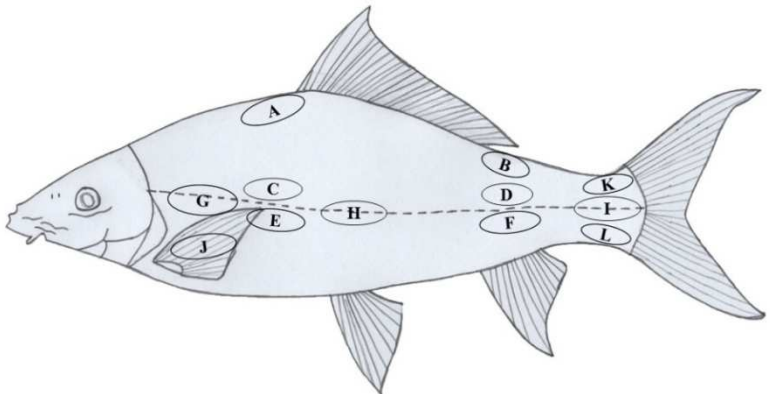

Fig. 1. Schematic drawing of sampling region of fishes: anterior, dorsal, rostral to dorsal fin (A); posterior, dorsal, caudal to dorsal fin (B); anterior, dorsal, above lateral line (C); posterior, dorsal, above lateral line (D); anterior, ventral, below lateral line (E); posterior, ventral, below lateral line (F); anterior, lateral line (G); mid, lateral line (H); posterior, lateral line (I); below pectoral fin (J); upper caudal peduncle (K); lower caudal peduncle (L).

Scale materials were sonicated in 70% ethanol and brushed gently to remove the reaming tissue and staining was done using 0.05% Alizarin Red S solution for 45 minutes. Before mounting, the scales were kept in absolute ethanol after that on distilled water for 15 minutes to avoid curling. When scales became flexible, they mounted between the glass slides. For ensuring the moistness of scales, care was taken to impede curling.

Photography of preserved fish scale: Microphotography digital imaging was performed using Delta IPOS-810 Stereo Zoom-Microscope (Budapest Telescope Centre, Budapest, Hungary) and Amscope microscope digital camera (Amscope USA) at lower magnification. For describing the microstructure of scales, Micros-Austria, Daffodil MCX100 Binocular Microscope (Micros, Austria) was used. Appropriate scale bars were added digitally using imaging software (Image J). Digital imageries were rendered on a computer using Adobe Photoshop CC 2015.

Scale types and characteristics: The scales are defined following Roberts (1993) with some modifications and differentiated two main scale types as follows – i. *Cycloid scales*- no additional isolated ossifications, marginal indentations might happen. Two sub- types - scale without spine-like projections or marginal increments is known as true cycloid and scale with increased marginal site is termed as crenate scale. ii. *Ctenoid scale* – with additional isolate ossification forming distinct spines known as cteni. The isolate ossifications ascend as complete spines in two or more alternating row marginally. When isolate ossifications transmute into truncated spines sub-marginally, the cteni is known as transforming cteni. Scale characteristics that are used in this study are defined by Lagler (1947) and maintained uniformness of benchmarks used in preceding works by other researchers (Patterson *et al*. 2002, Brager and Moritz 2016, Gholami *et al*. 2013) are given follows (Fig. 2).

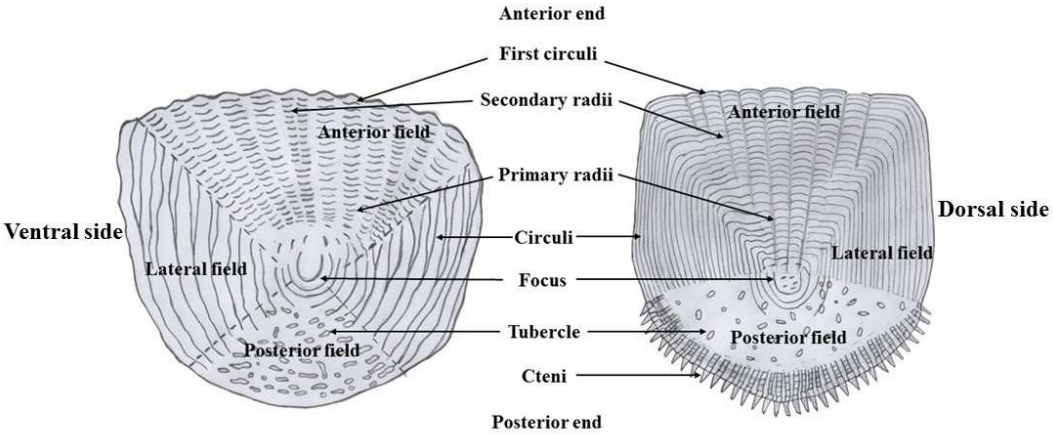

Fig. 2. Schematic drawing of cycloid scale (left) and ctenoid scale (right) including the terms used in this study. 'Focus'- the nucleus, first part of scale in ontogeny, geometrically central but often placed anterior and posterior and surrounded by circuli; 'Fields'- the outer surface area of the scale, either real or implicit. The fields of scales can be differentiated as anterior, posterior, dorsal and ventral, where lateral two are similar and called as lateral fields; 'Anterior field' - bounded by imaginary lines connecting the anterolateral corners or their equivalent points on rounded scales; 'Posterior field' - bounded by imaginary lines connecting the posterolateral corners with the focus; 'Circuli' - elevated markings on the surface generally rising as lines which pursue the outline of the scale, are usually incessant lines but often interrupted by grooves; 'Radii' - grooves that radiate from the focus to the scale margin; 'Primary radii' - radii that extend from the focus to the margin, 'Secondary radii' - begin from the margin but end afterwards short distance and cannot reach to the focus; 'Tertiary radii'- located between focus and scale margin; and 'Cteni' are tooth like additional structure found in the posterior margin. In the posterior margin it seems marginally or sub-marginally; 'Tubercles' - pigmented granules and its concentration relies on the position of the scale in fish body.

Scale shape, morphometric and microstructures: Scales show a high level of diversity in their shapes with considerable inter and intra-specific variation. Shape variability of fish scales are described in accordance with the number of different scale shapes that found within a specimen: uniform – 1 scale shape; low – 2 scale shapes; moderate – 3 scale shapes; high – 4 or more scale shapes.

Different morphometric and microstructure characters and discriminative features of a scale are the important tools that measure inter and intra-specific variation of specimens. Morphometric structures of scales in our study included scale type, shape, field, cteni, circuli etc. while microstructure deals with shape of first circuli, focus position, tubercles and radii. The discriminative features of the morphometric structures of scalesare given in Table II.

Table II. Summary of morphological and microstructures characters and discriminative features used in scale identification including lateral line scales

Characters	Discriminative Properties
Type	Cycloid: true cycloid / crenate
	Ctenoid: transforming cteni
Shape	Circular/oval/oblong/square/round square/pentagonal/round pentagonal/ irregular
Shape variation	Uniform /low/ moderate / high
Anterior field	Convex/flattened
Anterior margin	Smooth/waved / scalloped
Posterior field	Rounded/tapered
Posterior margin	Smooth/crenulated /ctenous
Lateral field	Convex/flattened
Extension	Extended in dorso-ventral axis/
	Elongated in antero-posterior axis
Focus position	Antero-central/central/postero-central
Focus shape	Rounded/oblong/rectangular/ oval
Radii	Primary/secondary/ tertiary other grooves
Cteni	Transforming cteni
Circuli	Continuous/discontinuous
Shape of first circuli	Convex/concave/straight
Tubercle	Few/absent
Tubercle size	Small
Tubercle shape	Rounded
Lateral line canal	Present/absent

For describing morphometric parameters, scales were sampled from body area C (anterior, dorsal, above lateral line) from every specimen. Morphometric parameters were measured as follows (Fig. 3).

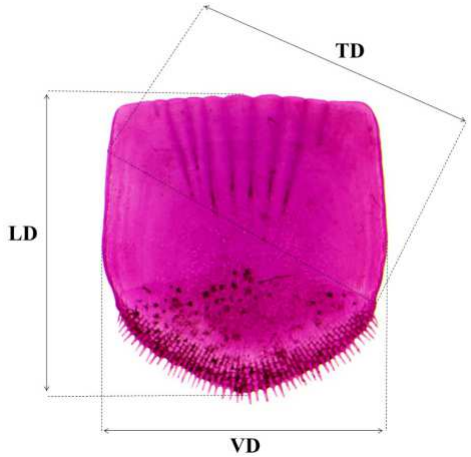

Fig. 3. Scale morphometric parameters used in this study (*Nandus nandus*).

Longitudinal diameter (LD)-The maximum longitudinal diameter of the scale in antero-posterior axis; Vertical diameter (VD)- The maximum vertical diameter of the scale in dorso-ventral axis; Transverse diameter (TD)-The maximum transverse diameter of the scale; Shape index (Si) has calculated for describing shape of scales after Burdak (1979), as follows: Si = TD / LD. The relative scale sizes (J-indices) for the scale length (Jsl) and scale width (Jsw) were calculated following Esmaeili (2001): Jsl (Jsw) = length (width) of scale / fish standard length (SL) × 100. Shape index, J-indices, focal index, and scale type for each species are abridged in Table II.

Results

Morphometric and microstructure descriptions: The photographs of the scales collected from twelve locations (A to L) of each of the species are given in the Figs. 4 - 8.

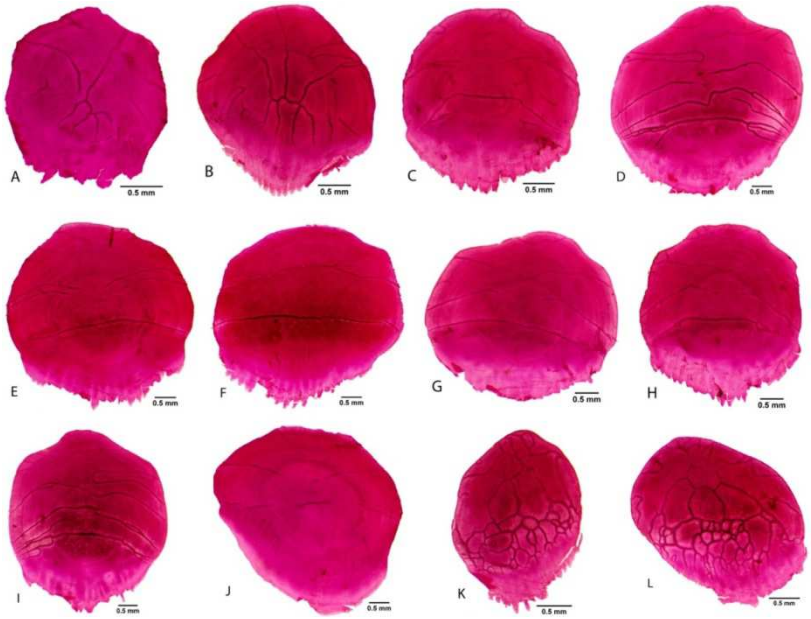

Fig. 4. Scales of Hilsha shad (*Tenualosa ilisha*); 133 mm SL; Scale bar = 0.5 mm.

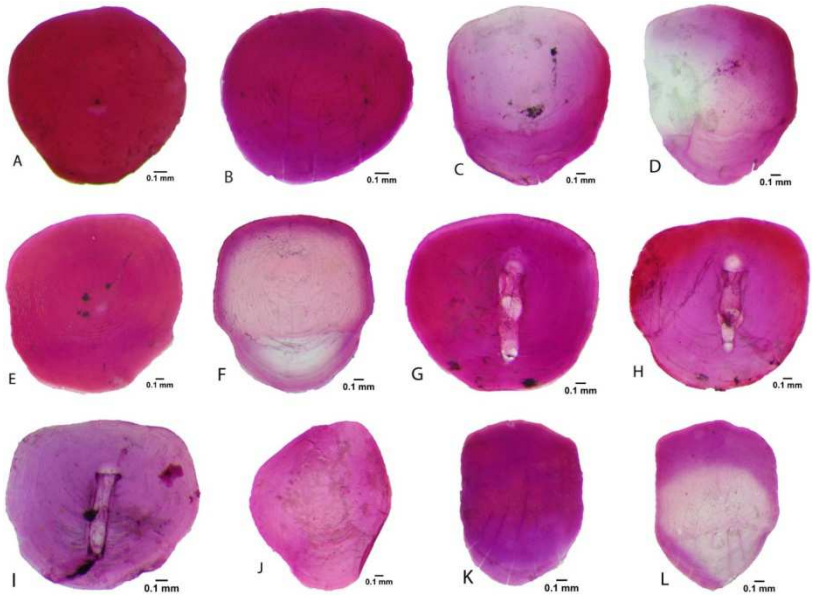

Fig. 5. Scales of Mola carplet (*Amblypharyngodon mola*); 81 mm SL; Scale bar = 0.1 mm.

Fig. 6. Scales of Grey featherback (*Notopterus notopterus*); 208 mm SL; Scale bar = A-J = 0.5 mm, K-L = 0.1 mm.

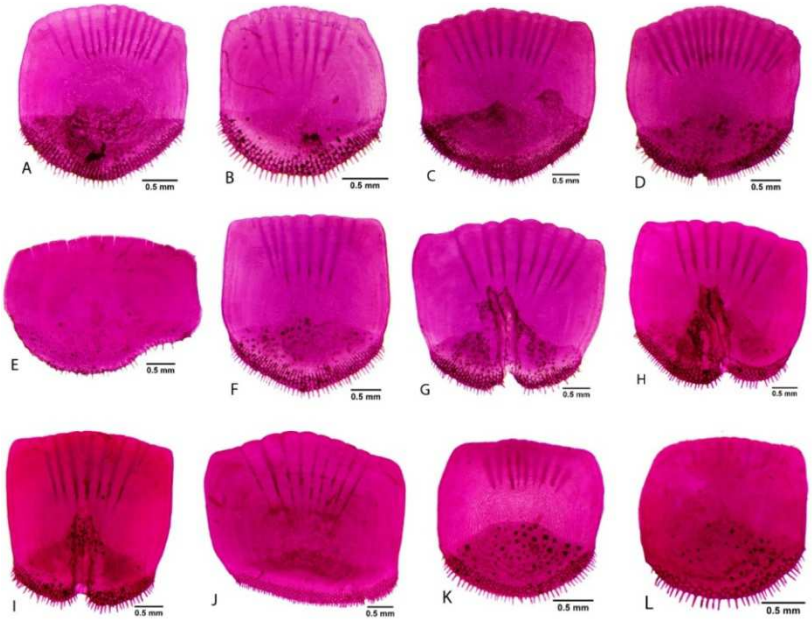

Fig. 7. Scales of Mud perch (*Nandus nandus*); 134 mm SL; Scale bar = 0.5 mm.

Fig. 8. Scales of Yellowtail mullet (*Sicamugil cascasia*); 54 mm SL; Scale bar = A-J = 0.5 mm, K-L = 0.1 mm.

The type, shape and shape variation of the scales of five fishes are described in the Table III. Cycloid – crenate scale was found only in one studies fish – ilish, mola and foli are with true cycloid scale. Ctenoid scale with transforming cteni is present in bheda and kachki bata. Kachki bata, however, has two different types of scales where true cycloid is present only in the body area A and ctenoid scale is found in the rest of the body parts.

Table III. Type, shape and shape variation of the scales in five fish

Fish	Ilish	Mola	Foli	Bheda	Kachki Bata
Type	Cycloid - Crenate	Cycloid - True cycloid	Cycloid - True cycloid	Ctenoid: Transforming cteni	Cycloid -True cycloid in body area A and Ctenoid - Transforming cteni in areas B, C, D, E, F, G, H, I, J, K and L.
Shape	Circular	circular to oval to pentagonal	Oblong to square	Square to round square to round pentagonal to irregular shape	Round square to round pentagonal
Shape variation	Uniform	Moderate	Low	High	Low

Table IV described the three fields(anterior, posterior and lateral) of the scales of five fish. The anterior field of the scales of ilish, mola foli and bheda are convex with different patterns of

marginal appearance, whereas, the anterior field of the scale of kachki bata is flattened. Ilish with tapered end, however, differs in posterior field of the scale from four other studies fish with rounded posterior field. The lateral field of the scale is convex in ilish, foli and bheda and flattened in mola and kachki bata.

Table IV. Anterior, posterior and lateral field of the studies scales

Fish	Anterior field	Posterior field	Lateral field
Ilish	Convex with conical tip and smooth margin	Tapered end with crenulated margin, subjected to splitting	Convex to flattened and extended in dorso-ventral axis
Mola	Convex with smooth margin	Rounded end with smooth margin	Flattened to convex and extended in dorso-ventral axis
Foli	Convex with waved margin	Rounded and slightly tapered end with smooth margin	Convex to flattened and elongated in antero-posterior axis
Bheda	Convex to flattened with slightly scalloped margin	Rounded end with ctenous margin	Convex to flattened and extended in dorso-ventral axis
Kachki Bata	Flattened with scalloped margin	Rounded end with ctenous margin	Flattened to convex and extended in both axes

Position and shape of the focus of scales of five fish is illustrated in Table V. The position of scale focus is at the center in ilish, bheda and kachki bata but antero-central and postero-central, respectively, in mol and foli. The shape of the scale focus is round in mola and foli, rounded to oblong, rounded – rectangular and – oblong, respectively, in ilish and kachki bata and oval to rectangular in bheda.

Table V. Position and shape of the focus of scales of five fish

Fish	Ilish	Mola	Foli	Bheda	Kachki bata
Focus position	Central	Antero-central	Postero-central	Central	Central
Focus shape	Rounded to rectangular	Rounded	Rounded	Oval to rectangular	Rounded to oblong

The number and pattern of radii in the scales of five fishes is presented in the Table VI. The radii is countable in all the fishes except in ilish where only transverse grooves are present. The number of radii in the scales of four fishes vary between 3 and 17. In the scales of two relatively smaller fish – mola and kachki bata, respectively, only 3-5 and 3-7 radii are present and in the scales of two larger fish - foli and bheda, higher number of radii – 9-11 and 9-16 are present, respectively. The tertiary radii are only present in the scale of bheda.

Table VI. The number and type of radii present in the scales of five fish

Fish	Radii
Ilish	Transverse grooves exist in the anterior and lateral field; longitudinal groves can also be observed in some cases
Mola	Total radii 3-5,present in the posterior field
Foli	Total radii 9-11, primary and secondary radii present in anterior and lateral fields
Bheda	Total radii 9-16, primary, secondary and tertiary radii present in the anterior field
Kachki Bata	Total radii 3-7; primary and secondary radii present in the anterior field

The circuli are distinct in the scale of all five fishes (Table VII). They are, however, continuous in anterior field of scale of only mola, discontinuous in the lateral field of scales of only ilishand indistinct in the posterior field of scale of ilish, bheda and kachki bata.

Table VII. The circuli appearance and distinctions in different fields of scale of five fishes

Fish	Circuli appearance	Distinction in three field		
		Anterior	Lateral	Posterior
Ilish	Distinct	Discontinuous	Discontinuous	Indistinct
Mola	Distinct	Continuous	Continuous	Discontinuous
Foli	Distinct	Discontinuous	Continuous	Continuous
Bheda	Distinct	Discontinuous	Continuous	Indistinct
Kachki bata	Distinct	Discontinuous	Continuous	Indistinct

The shape of first circuli of the scales are convex in ilish and mola, straight in foli and bheda, and concave in kachki bata. The scale tubercles are absent in ilish andmola. A few small sized round tubercles are present in the scales of foli, bheda and kachki bata. Scales present in the lateral line and their canals are detailed in Table VIII. The shape of the scales present in the lateral line are circular or square to round square. Round pentagonal lateral line scales are found in kachki bata. Two studied species – ilish and kachki bata do not have canals in their lateral line scales. Other three species – mola, foli and bheda, however, are with long and straight to curved canals in their lateral line scales. In mola and foli, both anterior and posterior opening of the canal of the lateral line scales are 'C' shaped. In bheda, though the posterior opening of the canal of the lateral line scales is 'C' shaped, the anterior opening is 'V' shaped.

Table VIII. Lateral line scales and their canals in five fishes

Fish	Lateral line scale	Canal in lateral line scale	Anterior opening of canal	Posterior opening of canal
Ilish	Circular	No existence of canal	-	-
Mola	Circular	Long and straight canal along with tubule	C shaped	C shaped
Foli	Square	Long and curved canal along with tubule	C shaped	C shaped
Bheda	Square to round square	Long and straight to curved canal with the presence of ctenous margin	V shaped	C shaped
Kachki Bata	Round square to round pentagonal	No existence of canal	-	-

***Relative scale sizes (J-indices)*:** J-indices is a useful tool for describing scale size and shape as well as species discrimination even in closely related species. Calculating shape index (Si), relative scale sizes (Jsl and Jsw) and focal index (Fi) used as a valuable tool for species differentiation (Table IX).

Table IX. Scale types of fishes under different Orders and Families with exemplary morphometric indices of scales derived from body area C (i.e., anterior part of the flank above lateral line)

Fish	Scale Type	Si	Jsl	Jsw	Fi
Ilish	Cr	0.99	2.16	2.08	0.47
Mola	Cy	0.96	2.39	2.13	0.25
Foli	Cy	0.72	1.07	0.62	0.65
Bheda	Tr	1.10	2.36	2.40	0.58
Kachki Bata	Cy/Tr	0.93	3.78	3.08	0.52

N.B. Scale type abbreviations based on Roberts (1993): **Cy** – true cycloid scale; **Cr** – crenate scale; **Tr** – ctenoid scale with transforming cteni. Scale shape index after Burdak (1979): **Si** = TD/LD, where TD – maximal transverse diameter of the scale; LD – maximal longitudinal diameter of the scale. The relative scale sizes (J-indices) for the scale length (**Jsl**) and scale width (**Jsw**) were calculated following Esmaeili (2001): Jsl (Jsw) = length (width) of scale (in mm) / fish standard length (in mm) × 100. Focal index (**Fi**) is given as the distance (in mm) from the outermost edge of the anterior field to the focus / the distance (in mm) from the outermost edge of the anterior field to the outermost edge of the posterior field.

Types of lateral line scale (LL): Two main types of lateral line scales with three sub-types are identified in five fishes on the basis of the relationship between the tube (ossified canal segment) and scale plate (Fig. 9). They are Tubular-scalar (Unmodified tubular scalar I, Unmodified tubular scalar II, Unmodified tubular scalar III) and Non-tubular. Several features are considered in the categorization of LL scales within these types: scale plate, tube, free posterior margin of scale plate, position of posterior opening of tube, projections or extra-development of tube and scale pocket.

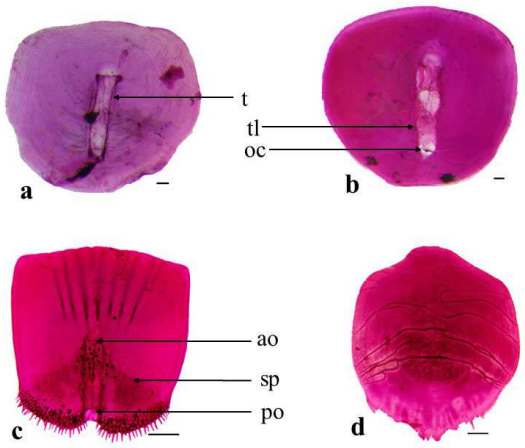

Fig. 9. Types of Lateral line scales. **A.** Unmodified tubular scaler I (Mola); **B.** Unmodified tubular scaler II (Mola); **C.** Unmodified tubular scaler III (Bheda); **D.** Non-tubular lateral line scale (Ilish). ao: Anterior opening, po: Posterior opening, oc: Opening for canaliculus, SP: Scale plate, T: Tubule. Scale bar =a, b = 0.1 mm; c, d = 0.5 mm.

Tubular-scalar lateral line scales: This LL scale type has a developed and externally differentiable scale plate and tube. A scale pocket and a free posterior margin are generally present. The ossification of the trunk canal wall lying over the scale canal makes a tube discrete from the scale plate. Formation of canal wall causes disarrangement of radii, circuli and cteni, formation of furrows and openings and modification of posterior margin of the scale plate. In present study, three types of tubular-scalar LL scales are present depending on whether or not the posterior margin of scale plate is involved in the formation of the posterior opening of the tube, and on the position of that opening (Fig. 9). Unmodified tubular-scalar I lateral line scales are recorded in mola that have an unmodified posterior margin, a complete tube with a posterior opening on the inner side of scale plate which is distant from the posterior margin (Fig. 9A). Unmodified tubular-scalar II lateral line scales have an unmodified posterior margin, and a complete tube with a posterior opening on inner side of scale plate that is close to posterior margin and joined with the opening for the canaliculus (Fig. 9B). This structural scale type was observed in foli and mola. Unmodified tubular-scalar III lateral line scales are observed in bheda which have an unmodified posterior margin, a tube with a posterior opening on the posterior margin and outer side of scale plate (Fig. 9C).

***Non-tubular Lateral line scales*:** In these LL scales, the scale plate is present, but a tube is absent. Non-tubular LL scales are found in ilish and kachki bata with the trunk canal absent (Fig. 9D).

Discussion

The scales from five fish species in this study are described based on morphologies, morphometric characteristic and the range of ratios relating to different lengths within a scale. Scale types vary considerably among fishes (Roberts 1993, Khemiri *et al*. 2001) based on the shapes and related characters (Patterson *et al*. 2002, Jawad 2005, Gholami *et al*. 2013).The general classification includes cosmoid, ganoid, placoid, cycloid and ctenoid found in the modern teleost fishes (Ikoma *et al*. 2003). In the present study, we considered crenate scales as sub-types of cycloid scales, and considered ctenoid scales only those possessed isolate ossifications from the main scale body in agreement with Brager and Moritz (2016).Besides these easily definable scale types, special types of scales were found in some taxonomic groups which makes the scale classification, rather complex. In the present study, ilish, *Tenualosa ilisha* is form such complex taxon. The scales of ilish are quite thin and relatively large and are more or less circular having multitudinous grooves as well as irregular crack marks, andpossess a crenulated posterior margin. We labeled the observed grooves in the anterior and lateral fields as “transverse grooves” and within the posterior field as “longitudinal or irregular grooves” in accordance with the orientation of the groove (Fig. 4). Brager and Moritz (2016) also recorded similar grooves in studying Clupeoid fish scales.

In the current study, more than one types of scales were observed in a single fish species, kachki bata, *Sicamugil cascasia* which contain both cycloid and ctenoid scales. Brager and Moritz (2016) also had found more than one type of scales (cycloid and ctenoid) in fish species - *Epinephelus aeneus* and *Eutrigla gurnardus*. Different scale shapes- circular, oval, oblong, square, round square, pentagonal, and round pentagonal- are observed in the present study as recorded earlier by Gholami *et al*. (2013), Brager and Moritz (2016), Jawad (2005), and Patterson *et al*. (2002).

The radiiformation on the fish scale is considered to be linked with the accommodation power of the large surface area of the anterior and lateral parts of the scale in the lesser space as these two parts of the scale are overlapped by the posterior part of the preceding scale (Esmaeili *et al*. 2012).Radii are generally present in the different fields of a fish scale such as, only anterior, as in pickerels (*Esox*); only posterior, as in shiners (*Notropis*); anterior and posterior, as in suckers (Catostomidae); or even in all four fields, as in barbs (*Barbus*) (Helfman *et al.* 2009). In the present study, radii present in anterior and lateral field in ilish, only posterior in mola, anterior and lateral in foli, and only anterior in bheda and kachki bata. Number of radii vary as well. There is no significant relationship between the number of radii and scale size, since the numbers of radii depend on the position of the scale on the fish body (Esmaeili *et al*. 2012). The number of radii may correlate with the flexibility of body of fish (Jawad and Al-Jufaili 2007) and the presence of higher number of radii correlate to the better nutritive conditions of the fish (Esmaeili *et al*. 2007).The relative number of primary and secondary radii in this study, is found to be more than the tertiary radii as observed in a few other past studies (Esmaeili *et al*. 2007, Jawad and Al- Jufaili2008).

Fish scales are bony structures and gradually become larger as fish grow in size. As fish grow, so do the scales. The scales produce characteristic circuli at the scale margin and once a circulus is deposited on the scale, it remains unchanged along the entire life span of the fish (Sire and Akimenko2004). Scales circuli can play a significant role to deliver a counteraction against the frictional forces through mechanical anchoring (Mahmoud *et al*. 2005 Mekkawy *et al*. 2011). Circuli arrangement were observed distinct and continuous to discontinuous in the anterior, lateral and posterior field in the agreement ofPatterson *et al.* (2002), Jawad (2005), Gholami *et al.* (2013), and Brager and Moritz (2016).

There was noticeable variation in the shapes of the anterior, posterior lateral fields of the scales observed in this study. Anterior field was convex and flattened whether in case of posterior fields it was rounded or tapered and in lateral field it varied from convex to flattened. Similar results were also observed by Barazona *et al*. (2012) and Brager and Moritz (2016) in their study. J-indices are found to be a trustworthy tool for species discrimination, even in case of closely related species (Esmaeili *et al*. 2014). In the current study, in assessing for scale shapes, a set of morphometric parameters was used - shape index (Si), relative scale sizes (Jsl, Jsw) and focal index (Fi) assist as used by Esmaeili (2001) and Brager and Moritz (2016) as valuable tools in fish species differentiation.

Scale focus forms foremost during ontogenesis (Esmaeili *et al*. 2009) and its shape remains constant throughout the whole lifespan of individual species (Ganzon *et al*. 2012). In the present study, focus shapes were recorded oval, rounded, oblong and rectangular. Different focus shapes were also observed in a single species. The findings of the current study show similarities with the study of Jawad and Al-Jufaili (2007) and Esmaeili *et al.* (2012).

The current research reveals that, shape of first circulus was convex, concave or straight - supported by a number of earlier studies (Jawad2005;Esmaeili *et al*.2007; Gholami *et al*. 2013). Such variations of characteristic features are species specific (Lippitsch 1993; Mahmoud *et al*. 2005 and Mekkawy *et al*. 2011) but in some cases external factors seems to modify these characteristics (Lippitsch 1990).

Tubercles on the fish scales are formed by the aggregation of the epithelial layer of the skin which covers the posterior part of the scale. The scale tubercles impart specific color to fish body as they contain chromatophores in the outer surface (Esmaeili *et al.* 2012).The present study, scale tubercles are absent in ilish and mola. Round shape and small tubercles were

observed infoli, bheda and kachki bata. Different shape of tubercles such as rounded, oblong, oval shape were observed by Gholami *et al*. (2013) and Esmaeili *et al*. (2007,2012).

Scales on the lateral line have been used by several researchers in fish classification and taxonomy (DeLamater and Courtenay 1973, Kaur and Dua 2004). The lateral line acts as a unique mechanosensory system in fish and amphibians (Watanabe *et al*.2010). The system usually detects water vibration and has an important role in schooling (Partridge and Pitcher 1980), food searching (New 2002), and mating (Satou *et al*.1994).The lateral line scale is one of the major characteristics of true fishes. In a number of fishes, the lateral line system is retained in the lateral line canal and conspicuous along the sides of the body and head of fish. The number, position of canal, and its alignment (straight oroblique, perforations, i.e. anterior, posterior or lateral) are important features that have been given substantial relevance for fish classification (Kaur and Dua 2004).The wide range of structural variation of lateral line canal has been documented in different teleost species by many authors (Mahmoud *et al*. 2005 and Mekkawy *et al*. 2011). The position of canal, its alignment are significant features that have been given substantial relevance for classification of fish (Kaur and Dua 2004). In the present study, lateral line scales canal shapes were different like long and straight, long and curved, short and straight to curved canals were present which show similarities with the findings of Jawad (2005). The current study also reveals that two main types of LL scales were present with three sub-types. LL scales were tubular-scaler and non-tubular scales. Voronina and Hughes (2017) recorded four main types of LL scales including tubular-scaler and non-tubular cycloid scales which support the findings of the current research. In case of *A. mola* two structural types of lateral line scales were recorded while Voronina and Hughes (2017) recorded two types of lateral line scales in case of clupeiformes, anguilliformes and some other orders.

General shape, size and the architectural specifications such as focus, circuli, radii, tubercles, cteni and so on of the fish scales - observed using microscopy have long been effectively used as versatile research material in various ichthyological researches such asphylogeny, sexual dimorphism, past environment experienced by fish, discrimination between hatchery reared and wild populations, determined times of migration, periods of food scarcity, illness, the pathology of a fish scale due to water pollution, growth studies and pollution status of the ecosystems of which fishes are a part (Esmaeili *et al*. 2012). The results of the present work revealed that the characters of the scales of the five indigenous fishes exhibited species-specific valuable taxonomic characters and indicated that such scale characters are fixed and stable. The present analysis of scale morphology of five fish may be used in combination with other morphological and molecular data in a synergic approach to the phylogenetic and systematic study of the fishes of Bangladesh.

Literature Cited

Alkaladi, A., A.S.A. Harabawy, and I.A.A. Mekkawy, 2013. Scale Characteristics of Two Fish Species, *Acanthopagrus bifasciatus* (Forsskål, 1775) and *Rhabdosargus sarba* (Forsskål, 1775) from the Red Sea at Jeddah, Saudi Arabia. *Pak. J.Biol. Sci.*,16: 362-371.

Barazona, C.A., M.A.J. Torres, J.J. Gorospe and C.G. Demayo, 2012. Describing Squamatological Variation between Sexes of *Mesopristes Cancellatus* (Cuvier, 1989). *Intl. Proc. Chem., Biol. Environ. Engg.*,44: 85-90.

Bräger Z. and T. Moritz,2016. A scale atlas for common Mediterranean teleost fishes. *Verte. Zool.*, 66: 275-388.

Burdak, V.D., 1979. Functional morphology of fish scale cover. Naukova Dumka, Kiev, 163 p.

Casteel, R.W., 1976. The scales of the native freshwater fish families of Washington. *Northwest Sci.*,47: 230-238.

Cockerell, T.D.A., 1910. The scales of the African characinid fishes. *Smith. Misc. Coll.*,56: 1–10.

DeLamater, E.D. and W.R. Courtenay, 1973. Variations in structure of the lateral line canal on the scales of Teleostean fishes. *Z. Morphol. Tiere.*, 75: 259-266.

Esmaeili, H.R., 2001. Biology of an exotic fish, silver carp, *Hypophthalmichthys molitrix* (Val., 1844) from Gobindsagar Reservoir, Himachal Pradesh, India. Ph.D. Thesis. Panjab University, Chandigarh, India.

Esmaeili, H.R., S. Baghbani, H. Zareian and F. Shahryari, 2009. Scale Morphology of Tank Goby *Glossogobius giuris* (Hamilton-Buchanan, 1822) (Perciformes: Gobiidae) using Scanning Electron Microscope. *J. Biol. Sci.*, 9: 899-903.

Esmaeili, H.R., A. Gholamifard, N. Zarei and A. Arshadi, 2012. Scale structure of a cyprinid fish, *Garra Rossica* (Nikol'skii, 1900) using scanning electron microscope (SEM). *Iran. J. Sci. Tech. (Sci.)*, 36: 487-492.

Esmaeili, H.R., A.T. Hojat and A. Teimory, 2007. Scale structure of a cyprinid fish, *Capoeta damascina* (Valenciennes in Cuvier and Valenciennes, 1842) using scanning electron microscope (SEM). *Iran. J. Sci. Tech. (Sci.)*, 31: 255-262.

Esmaeili, H.R., R. Khaefi, G. Sayyadzadeh, M.S. Tahami, B. Parsi and A. Gholamifard, 2014. Scale surface microstructure and scale size in three mugilid fishes (Teleostei, Mugilidae) of Iran from three different habitats. *IUFS J. Biol.*, 73: 31-42.

Ganzon, M.A.M., M.A.J. Torres, J.J. Gorospe and C.G. Demayo, 2012. Variations in scale morphology between sexes of the spotted barb, *Puntius binotatus* (Valenciennes, 1842) (Actinopterygii: Cyprinidae). *Proc. 2nd Intl. Conf. Environ. Biosci. (IPCBEE)*. 44: 80-84.

Gholami, Z., A. Teimori, H.R. Esmaeili, T. Schulz-Mirbach and B. Reichenbacher, 2013. Scale surface microstructure and scale size in the tooth-carp genus *Aphanius* (Teleostei, Cyprinodontidae) from endorheic basins in Southwest Iran. *Zootaxa*, 3619: 467-490.

Grande, L. and W.E. Bemis, 1998. A comprehensive phylogenetic study of amiid fishes (Amiidae) based on comparative skeletal anatomy. An empirical search for inter connected patterns of natural history. *J. Vert. Paleont.*,18: 1-696.

Helfman, G.S., B.B. Collette, D.E. Facey, and B.W. Bowen, 2009. The diversity of fishes: Biology, Evolution and Ecology. John Wiley & Sons, Ltd., Publication, 720 p.

Ibanez, A.L. and P. O. Higgins, 2011. Identifying fish scales: The influence of allometry on scale shape and classification. *Fish. Res.*,109: 54-60.

Ikoma, T., H. Kobayashi, J. Tanaka, D. Walsh and S. Mann, 2003. Microstructure, mechanical and biomimetic properties of fish scales from *Pagrus major*. *J. Struct. Biol.*,142: 327-333.

IUCN Bangladesh, 2015. Red List of Bangladesh. Freshwater Fishes. International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh. 5: 29 p.

Jawad, L.A. and S.M. Al-Jufaili, 2007. Scale morphology of greater lizardfish *Saurida tumbil* (Bloch, 1795) (Pisces: Synodontidae). *J. Fish Biol.*, 70: 1185-1212.

Jawad, L.A., 2005. Comparative morphology of scales of four teleost fishes from Sudan and Yemen. *J. Nat. Hist.*,39(28): 2643-2660.

Jhingran, V.G., 1957. Age determination of the Indian major carp, *Cirrhinus mirgala* (Ham, 1822) by means of scales. *Nature,* London,179: 468-469.

Johal, M.S., J. Novak and O. Oliva, 1984. Notes on the growth of the common carp *Cyprinius carpio*. in northern India and middle Europe. *Vest. Cesk. Spol. Zool.*,48: 24-38.

Johal, M.S. and A. Dua, 1995. Elemental lepidological and toxicological studies in *Channa punctatus* (Bloch) upon exposure to an organochlorine pesticide, Endosulfan. *Bull. Environ. Cont. Toxic.*, 55: 916-921.

Johal, M.S. and A.K. Sawhney, 1997. Lepidontal alterations of the circuli on the scales of freshwater snakehead, *Channa punctatus* (Bloch) upon exposure to Malathion. *Curr. Sci.*, 72: 367-369.

Johal, M.S., H.R. Esmaeili and K.K. Tandon, 2001. A comparison of back-calculated lengths of silver carp derived from bony structures. *J. Fish Biol.*, 59: 1483-1493.

Kaur, N. and A. Dua, 2004. Species specificity as evidenced by scanning electron microscopy of fish scales. *Curr.Sci.*,87: 692-696.

Khemiri, S., F.J. Meunier, M. Laurin and L. Zylberberg, 2001. Morphology and structure of the scales in the Gadiformes (Actinopterygii: Teleostei: Paracanthopterygii) and a comparison to the elasmoid scales of other Teleostei. *Cah. Biol. Mar.*, 42: 345-362.

Kumar, R., P.J. Singh, N.S. Nagpure, B. Kushwaha, S.K. Srivastava and W.S. Lakra. 2007. A non-invasive technique for rapid extraction of DNA from fish scales. *Ind. J. Exp. Biol.*,45: 992-997.

Lagler, K.F., 1947. Lepidological studies 1. Scale characters of the families of Great Lakes fishes. *Trans. Am. Micros. Soc.*, 66: 149-171.

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

Lippitsch, E., 1993. A phyletic study on lacustrine haplochromine fishes (Perciformes, Cichlidae) of East Africa, based on scale and squamation characters. *J. Fish Biol.*, 42: 903-946.

Mahmoud, U.M., I.A.A. Mekkawy and A.S.A. Harabawy, 2005. Scale characteristics of seven species of genus *Lethrinus* (Family Lethrinidae) from the Red Sea, *Egyp. J. Zool.*, 44: 545-580.

Masood, Z., R. Yasmeen, F. Ur-Rehaman, M.S. Haider, L. Zehra, M.Y. Hossain, H. Ur-Rehman, Asim-Ullah, W. Ahmed and Q. Shah, 2015. 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. *Biol. Forum*,7: 176-184.

McCully, H., 1961. Amputation and replacement of marginal spines in ctenoid percoid scales. *Proc. Calif. Aca. Sci.*, 38: 411–414.

Mekkawy, I.A., E.T. Wassif and A.A. Basmidi, 2011. Scale characteristics of three *Lutjanus* species (Family: Lutjanidae) from the Red Sea, Egypt. *J. Fish.Aquat. Sci.*,6: 506-522.

New, J.G., 2002. Multimodal integration in the feeding behaviors of predatory teleost fishes. *Brain. Behav. Evol.*, 59: 177-189.

Partridge, B.L. and T.J. Pitcher, 1980. The sensory basis of fish schools: Relative roles of lateral line and vision. *J. Comp. Physiol. A*,135:315-325.

Patterson, R.T., C. Wright, A.S. Chang, L.A. Taylor, P.D. Lyons, A. Dallimore and A. Kumar, 2002. Atlas of common squamatological (fish scale) material in coastal British Columbia and an assessment of the utility of various scale types in paleo fisheries reconstruction. *Palaeont. Electron.*, 4: 1-88.

Renjith, R.K., A.K. Jaiswar, S.K Chakraborty, S. Jahageerdar and G.B. Sreekanth, 2014. Application of scale shape variation in fish systematics- an illustration using six species of the family Nemipteridae (Teleostei: Perciformes). *Ind. J. Fish.*, 61: 88-92.

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

Satou, M., H.A. Takeuchi, J. Nishii, M. Tanabe, S. Kitamura, N. Okumoto and M. Iwata, 1994 Behavioral and electrophysiological evidences that the lateral line is involved in the inter-sexual vibrational communication of the hime salmon (landlocked red salmon, *Oncorhynchus nerka*). *J. Comp. Physiol. A*,174: 539-549.

Sire, J.Y. and M.A. Akimenko, 2004. Scale development in fish: a review, with description of sonic hedgehog (SHH) expression in the zebrafish (*Danio rerio*). *Intl. J. Develop. Biol.*, 48: 233-247.

Voronina, E.P. and D.R. Hughes, 2017. Lateral line scale types and review of their taxonomic distribution. *Acta Zool.*,99:65–86.

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

Watanabe, K., K.Anraku, H.M. Monteclaro and R.P. Babaran, 2010. Morphological characteristics of lateral line in three species of fish. *Aqua. Sci.*,58:25-35.

(Manuscript received 10 December 2018)