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Scale Morphology of the Indian goatfish, *Parupeneus indicus* (Shaw, 1803) (Perciformes: Mullidae)

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ABSTRACT

Scales have numerous hidden details in their structures that contribute effectively to fish identification and classification. A traditional approach has been made to study the scale morphology of the Indian goatfish *Parupeneus indicus* using a stereomicroscope in tandem with a 12.2 megapixel Samsung ST500 digital camera in which digitized images were processed using Adobe Photoshop CS4 Extended software. Two specimens of fish sample of both sexes were described qualitatively and observed quantitatively. Thirty scales in every region were obtained for description and comparison. In describing the scales, several distinguishable characteristics were considered such as the type of the scale, overall scale shape, scale size, the shape of the posterior margin group of ctenii square, the position of the focus, circuli appearance, and the type of radii. Results of the study revealed that there are significant variations of shapes observed between male and female species. The presence of disrupted circuli, the same type of radii existing in each body regions in both sexes of the fish cannot be used to establish sexual dimorphism in *P. indicus* due to their similarities. The existence of an oblong scale shape is unique to males and that of a cycloid shape unique to females. Also, the variation of other scale shapes in region G where male has rectangular while female has triangular shapes but both have square scale shape and in region J where male has rectangular shape while female has square shape but both have triangular shape. Thus, these are significant indicator of sexual dimorphism between the sexes of *P. indicus.*

Key words: Squamatology, comparative scale morphology, principal component, scale variation, sexual dimorphism

Introduction

There have been numerous researches existed regarding the studies of fish scales which served as the dermal derivatives of the fish body. Most of these studies are concerned with ecological importance, systematics and fish economics.

Studies on the detailed structure of fish scale are very important in the nomenclature, classification and identification of fish to major groups [30,45,35] and species levels [3,6,31], phylogeny [27,28], sexual dimorphism [22], age determination [10,44,19,21], past environment experienced by fish scale due to water pollution of the water body [12,13,16], and for growth studies [5,43,21,16,4,37,38,32,14].

Scales have numerous hidden details in their sculptural design that contributes effectively to fish identification and classification. Circuli, radii, ctenii, lateral line canal and other structures associated with scales have been used authentically for classification [26,7,24,25]. The use of scale size, shapes and number can be traced back to the first half of the 19th century when Agassiz [1] used it in fish taxonomy for the first time [40,9] and even some fishery biologists also used scale in determining the age of fish [23]. Other past numerous scale studies on the commercial fish scale structures [5,43,21,16] have been conducted around the globe and its breakthrough on the scientific research has been positively used in growth studies [4,37,38,32,14], the calculation of minimum harvestable size in order to prescribe the legal fishable size [18], for the determination of old age in commercial fish [44], and the pollution status of the water body [12,13,16,17]. Due to some subjective reasons, most of the lepidological studies in the past are on commercial fishes.

Of those commercial fishes, the goatfish family (Mullidea) is commercially important demersal fish group throughout their distribution around the world [42]. It constitutes of 15 genera, of which

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Parupeneus is the most important inhabiting the vicinity of its origin Indo-Pacific including the Philippines [39]. One study of goatfish has been limited on one species, the yellowstriped goatfish, *Upeneus vittatus* which demonstrated that scale characteristics can provide useful taxonomic information on the morphological differences between sexes of *U. vittatus* [34].

Keeping in mind the above facts, this study was conducted to morphologically and qualitatively provide descriptions on the scales of male and female Indian goatfish *P. indicus* known for its greenish-white overall with a yellow blotch on each side and a black spot in front of the tail. The coloration may darken to reddish-brown along the back of the fish (see Fig. 1). This commercially demersal species are mostly located in the reef-associated, brackish, marine, depth range 10 - 30 m environment [39].

The morphological qualitative descriptions of the fish scale were patterned after Lippitsch [32] and Kuusipalo [29] using stereoscope in order to investigate the variations of scales within and among the regions/areas of the Indian goatfish *P. indicus* (Shaw, 1803) using the traditional approach, the systematic scale description.

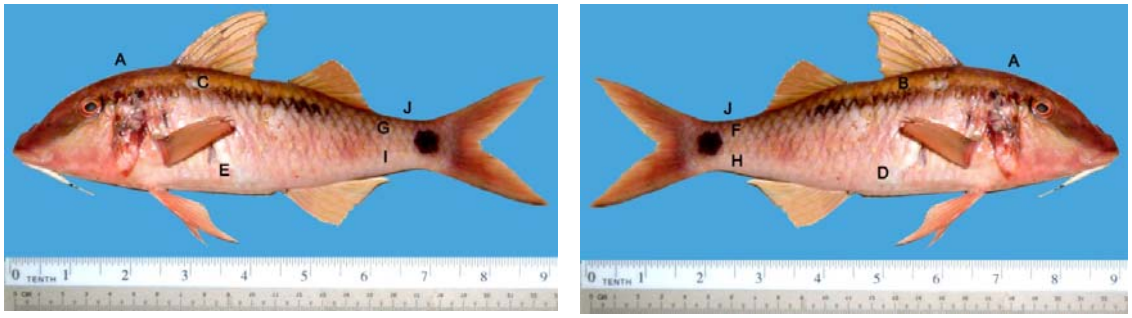
The significance of this study would provide baseline information on the comprehensive systematic understanding of the biological basis of the observed variation in the scales which are essential in the proper and effective conservation of the species.

Ii. Materials and methods:

Collecting and Processing of Scales:

Two adult fish samples weighing 250g each of both sexes and has a length of 9 in and 8 in, male and female respectively were obtained from Pala-o Wet Market, Iligan City and prepared in the laboratory for fish scale removal. Before the scales were removed, the fish sample were systematically identified and classified accordingly up to the species level, thus revealing the species scientific name as *P. indicus* (Shaw, 1803) (Perciformes: Scaridae), commonly known as Indian goatfish (see Fig. 1).

Male Specimen (weight: 250g, length: 9 inches or 22.86 centimeters)



Female Specimen (weight: 250g, length: 8 inches or 20.32 centimeters)

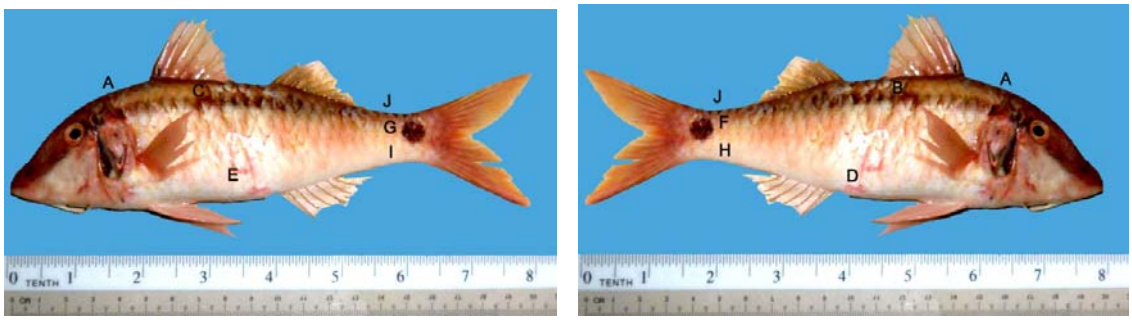


Fig. 1: Pictures of *P. indicus* showing different scale regions. (A) antero dorsal (upper head to dorsal fin region), (B-C) scale region above and on the lateral line canal, (D-E) antero-ventral scale region (before pectoral fins), (F-G) postero-dorsal region (above the peduncle), (H-I) postero-dorsal region (below the peduncle), and (J) postero-dorsal region (after the dorsal fin).

The scales were removed from each six (6) regions from both left and right side of the fish as illustrated in the Atlas of Common Squamatological Material in Coastal British Columbia and an Assessment of the Utility of Various Scale Types in Paleofisheries Reconstruction [36,2] with the use of a flat end forceps. soaked them to the corresponding 12 vials (6 vials for each specimen) with Joy

dishwashing liquid solution for 24 hours in order to completely clear up the impurities making the scales clean and clear enough to be observed in the microscope. Once the scales had become flexible and clear enough, the scales were then mounted between (1" x 3") glass slides. Each slide contains 5-8 scales depending upon the size. The Armak invisible tape was then used to seal the edges of the slides so as to keep the slides together.

Photography of Mounted Fish Scales:

The detailed structures of the scales were viewed in the stereoscope at its lowest magnification (2X) and the digital images of the scales were captured using Samsung ST500 digital camera with a 12.2 megapixels. The scales were also uniformly scanned at 600 dpi using Canon Pixma MP258 scanner to easily visualize the overall shapes and the common type of the scales of the specimens. However, some scales usually the large ones may overlap in the field of view of the microscope making it not visible in its overall shape. The Leica STL microscope was used to examine and visualize these large scales in its overall shape making it totally visible when captured in the digicam.

Systematic Description of Scales:

The squamatological and structural scale observations using light microscopy were made. To facilitate the study of variation in the shape and size of the scales, the fish was divided into six regions (see Fig. 1). In describing the scales, several distinguishable characteristics were considered such as the type of the scale, overall scale shape, scale size, the shape of the posterior margin group of ctenii square, the position of the focus, circuli appearance, and the type of radii.

Results And Discussions

General Morphological Description of the Scales:

The study revealed that all the scales found in the different regions of the fish body have a focus, a radius, a circuli, a lateral field, a posterior field, an anterior field and a ctenii found at the posterior field of the scale (see Fig. 2). This is also true for both sexes of fish.

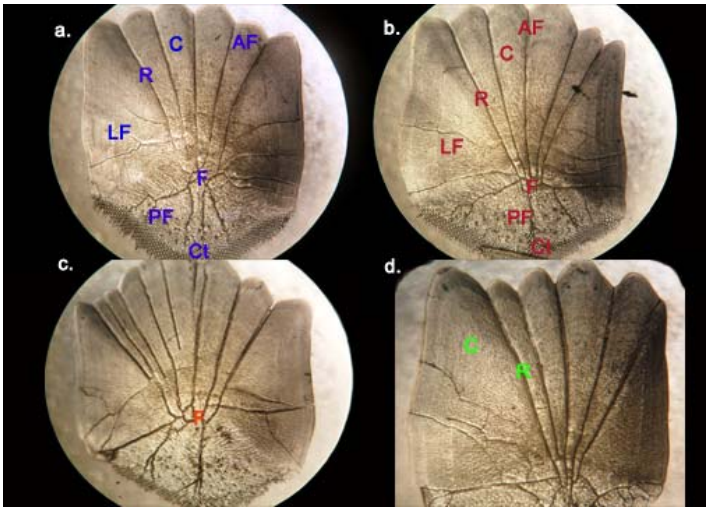


Fig. 2: A macrophotograph of a ctenoid scale of *P. indicus* showing anterior field (AF), posterior field (PF), lateral field (LF), ctenii (Ct), radius (R), focus (F), circuli (C) of (a) male (image dimensions 625 x 599 pixels); a female (b) (image dimensions 615 x 610 pixels; (c) a fish scale showing its focus (image dimensions 692 x 656 pixels); more details in (c) (image dimensions 665 x 644 pixels) and (d) (image dimensions 725 x 699 pixels).

The two specimens of both male and female have varying scale shapes ass illustrated in this figure.

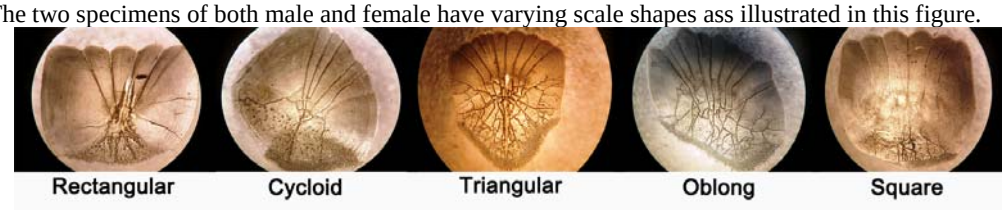


Fig. 3: Fish scale shapes commonly found in male and female *P. indicus* (image resolution: 400 dpi).

Jawad [8] stated that there are several types of scale shapes such as elliptic, oblong, pentagonal, rectangular, square, triangular and cycloid but in the case of *P. indicus*, only five types were observed. These types of scales are only cycloid, oblong, square, triangular and rectangular shapes. Variation in scale shapes do occur within body regions in some species of fish [8] and this was also observed in both sexes of *P. indicus*.

Table 1: Variation in the type of scales, scale shape, scale size, and shape of the posterior margin of male and female Indian goatfish, *P. indicus.*

Body Regions	Type of Scale	Scale Shape	Scale Size	Shape of the Posterior Margin Group of Ctenii
Male Fish				
Region A	ctenoid	square and oblong	small	triangular, tongue-like, square, lower lateral line scale
Region C	ctenoid	square and triangular	small-moderate	tongue-like, square
Region E	ctenoid	rectangular	moderate	tongue-like, square
Region G	ctenoid	square and rectangular	small-moderate	tongue-like, square
Region I	ctenoid	square and triangular	moderate	tongue-like, square, triangular
Region J	ctenoid	triangular and rectangular	small-moderate	tongue-like, square
Female Fish				
Region A	ctenoid	square and cycloid	small	triangular, tongue-like, square, lower lateral line scale
Region C	ctenoid	square and triangular	small-moderate	triangular, tongue-like, square
Region E	ctenoid	rectangular	moderate	triangular, tongue-like
Region G	ctenoid	square and triangular	small-moderate	triangular, tongue-like, square, lower lateral line scale
Region I	ctenoid	square and triangular	small-moderate	triangular, tongue-like, square
Region J	ctenoid	square and triangular	small	triangular, tongue-like

The body regions of the fish were observed to have square and cycloid shapes in the head of both male and female. Both sexes also have triangular and square shapes in scale above the lateral line in region C. Both also have uniformed rectangular scale shapes in region E but variations in shape in region G for both sexes were observed. Both have common shape in region G of square shape but rectangular shape was observed in male while triangular shape in female. In region I, both sexes were also have common scale shapes which are square and triangular but in region J, both have triangular shapes but variations of some shapes were also observed, as male has rectangular shape while female has square shape. Oblong scale shape is only present among the males while cycloid scale is in females. This can be considered as a key point in the differentiation of the two sexes of *P. indicus*.

The scales also showed variation in the shape of the posterior margin group of ctenii in both sexes of *P. indicus*. Variations are shown in Fig. (4) (image resolution is 200 dpi).

Fig. 4: Ctenoid scales of *P. indicus*. showing variations in the posterior margin of the scale where ctenii are grouped.

Table 2: Variation in focus position, type of radii, number of radii and circuli appearance of male and female Indian goatfish, *P. indicus.*

Body Regions	Focus Position	Type of Radii	Circuli Appearance
Male Fish			
Region A	28 center, 2 posterior	27 primary, 3 secondary	18 distinct, 12 disrupted
Region C	25 center; 5 posterior	23 primary, 7 secondary	19 distinct, 11 disrupted
Region E	26 center; 4 posterior	22 primary, 8 secondary	22 distinct, 8 disrupted
Region G	24 center; 6 posterior	24 primary, 6 secondary	18 distinct, 12 disrupted
Region I	23 center; 7 posterior	25 primary, 5 secondary	20 distinct, 10 disrupted
Region J	12 center; 18 posterior	28 primary, 2 secondary	21 distinct, 9 disrupted
Female Fish			
Region A	29 center; 1 posterior	28 primary, 2 secondary	19 distinct, 11 disrupted
Region C	26 center; 4 posterior	25 primary, 5 secondary	17 distinct, 13 disrupted
Region E	25 center; 5 posterior	26 primary, 4 secondary	16 distinct, 14 disrupted
Region G	24 center; 6 posterior	24 primary, 6 secondary	18 distinct, 12 disrupted
Region I	23 center; 7 posterior	27 primary, 3 secondary	17 distinct, 13 disrupted
Region J	13 center; 17 posterior	29 primary, 1 secondary	20 distinct, 10 disrupted

The scale of both male and female species of *P. indicus* obtained from the different regions showed that most of its scales have centrally located focus. Most of the focus arrangements were observed between regions follows a pattern. From the head to the focus of the scale are observed to have a mixture of centrally located focus with few of them located at the posterior field. The positions of the focus for both sexes of the fish in every region are observed to be the same having mostly primary. Posterior location of the focus is due probably to lateral scale growth rather than a combination of anterior and posterior scale growth [8,41]. No apparent differences exist between sexes in terms of focus position. It is argued that the position of the focus on the scale remains the same throughout the life of the individual species [8,33].

The lines of growth from the focus started to appear and develop into ridges. These lines of growth are known as Circuli. These are numerous on the anterior part of the scale for both sexes. The circuli of *P. indicus* when examined closely using a stereomicroscope and photographed with a with a 12.2 megapixels Samsung ST500 digital cam and digitized using Adobe Photoshop CS4 Extended software showed that the circuli in the scales of both male and female species of *P. indicus* are disrupted. These disruptions may be due to the exposure of the fish to some environmental and biological factors such as spawning, stunted growth or abundance of food. The condition of circuli on the surface of the scale in between radii is also a morphological point of comparison. However, both sexes of the fish demonstrated the same type of circuli. The circuli observed here are those above the focus only and did not reach the first ridge. A close observation on the circuli of both sexes of *P. indicus* species have disrupted circuli (Fig. 5).

Fig. 5: A disrupted circuli in *U. vittatus* in between radii.

Summary:

Traditional identification of scale structures revealed the presence of focus, circuli, lateral line canals, radii, lateral fields, posterior fields, anterior fields. The shape of the scale, position of the focus, type of circuli, type of radii and shapes of the lateral line were considered here for the analysis for these characters may constitute as criteria for differentiating sexes of *P. indicus.* The presence of disrupted circuli, the same type of radii existing in each body regions in both sexes of the fish cannot be used to establish sexual dimorphism in *P. indicus* due to their similarities. Differences were observed with an oblong scale shape unique to males and a cycloid shape unique to females. Also, in region G the male has rectangular shape while the female has triangular shapes. In region J, the male fish has rectangular shape while the female has square shapes. These variations may be used as significant indicator of sexual dimorphism between the sexes of *P. indicus.*

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