Elliptic Fourier Analysis in Describing Scutes in Selected Body Regions of *Decapterus sp.*

Edgar Gary R. Vasallo, Mark Anthony J. Torres, and Cesar G. Demayo

***Abstract*—A scute is a bony type of projection often is a modified scale. Scute material from Decapterus species found in coastal waters of Macajalar Bay is presented. Geometric morphometric methods were used to determine if scute morphology can discriminate between sexes and scutes variants among different body regions. Based on the morphological characterization of scutes using SHAPE method, Paleontological Statistics (PAST) revealed a morphological variation of scutes among regions but not between male and female Decapterus sp. Scute variation often an alteration of one or more morphological, behavioral, physiological, or developmental responses. This paper will help provide more information about diversity and complexity of fish scutes as it may resolve identification problems for future fish taxonomy.**

***Index Terms*—*Decapterus* scutes, principal component analysis, elliptic fourier analysis and sexual dimorphism.**

I. Introduction

In an attempt to categorize the many fishes of the world, morphology is most often used to separate the different types of fishes. One can separate fish by body type, air bladder type, fin type, scale type, and mouth type, to list just a few possibilities. Other differences used to classify fishes fall more into functional categories, like reproductive type and mode of movement. These distinctions are then used by taxonomists to assign fishes to scientific categories like Class, Family, Genus, and Species [1]. Studies may include scale type, however, did not go into details of the structure and development of lateral scutes. In other species of fish some of the scales have become keeled and highly modified, forming scutes to protect the lateral line or into spines.

A scute is a bony type of projection (Fig. 1).

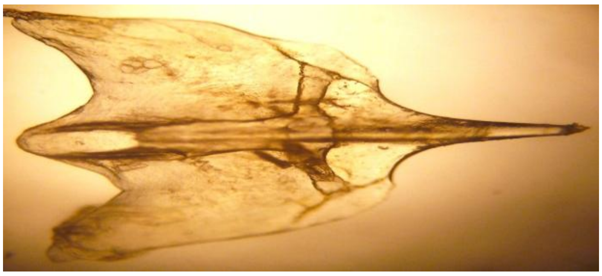

Fig. 1. Scute of *Decapterus sp.*

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Often is a modified scale [2], presence or absence, location, counts, and type of scutes is very useful in identifying certain species of fish [3]. Members of the genus *Decapterus* [4] are among the most important commercial fish in the Philippines. Being economically essential, the basic morphological characteristics of scutes of *Decapterus sp*. (Fig. *2)* were investigated [3], [5], [6].

Fig. 2. *Decapterus sp.*

Quantitative morphometrics have been made using of a variety of lengths, widths, angles, and ratios to capture information about shape. Geometric morphometric approaches to shape have focused on complete, uniform measurement of shape, retaining all geometric information throughout the analysis. This method utilizes powerful and comprehensive statistical procedures to analyse shape differences of a morphological feature [7], [8] and is considered to be the most reliable method to determine relationships among taxa [9]-[18]. In this paper, morphometric variability of scutes in *Decapterus sp*. sampled from Macajalar Bay was examined using elliptic Fourier analysis of outline data. Combination of geometric methods was expected to increase the chances of detecting the small morphometric differences in scutes at different body regions of the body of the fish.

II. Methodology

A. Collection and Processing of Scutes

Specimens of *Decapterus sp.* were collected from Macajalar Bay (Fig. 3), on June 20, 2010. This species is pelagic and it is found in large numbers in the coastal areas. A morphological descriptions and count of the total number of scutes found at the anterior-posterior horizontal stretch of the lateral line of the specimen were made following the procedures by Patterson *et al.* [3]. Scutes were removed from different regions of the fish (Fig. 4) and mounted by allowing the scutes to sit in water with a little detergent powder for a short period of time (<15 minutes).

Once they had become air-dried, the scutes were mounted between glasses. Microphotography digital image capture of the preserved fish scutes was carried out using a Stereo Microscope and a Digital Camera at generally low magnification. Dimensions of scales were measured under

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the microscope, and scale bars were then digitally added to the images. Most characters were counted and measured under a binocular dissecting microscope. For specimens too large to fit under a microscope, a magnifying glass was used. A variety of geometric morphometric approaches to curves have been used, “SHAPE” is a package of programs for evaluating biological contour shapes based on elliptic Fourier descriptors (EFDs) [19]. Data gathered using the manual curve-tracing approach was analyzed using elliptical Fourier analysis (EFA), a fairly standard approach to outline data. The software contains programs for image processing and contour recording, derivation of EFDs, principal component analysis of EFDs, and visualization of shape variations estimated by the principal components [19].

Fig. 3. Map of Macajalar Bay.

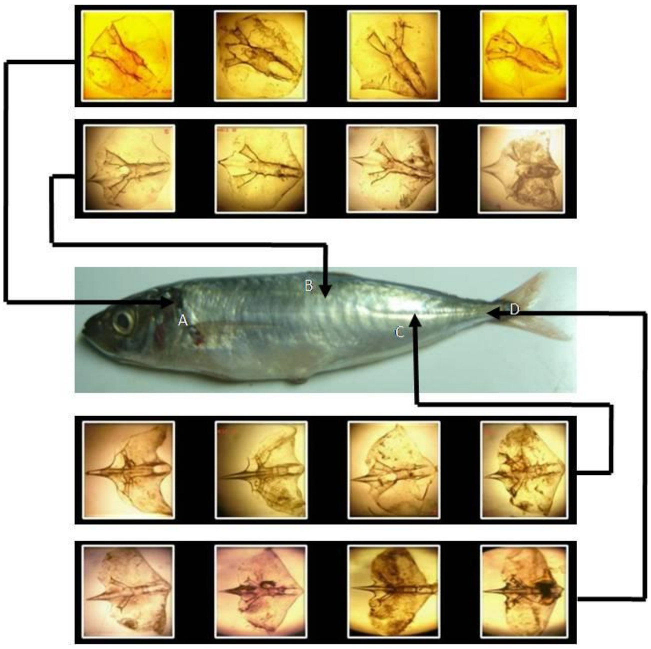

Fig. 4. Scutes at different regions.

B. Systematic Description of Scutes

Squamation patterns were recorded following Lippitsch [20]-[22]. Characters were established for scutes and squamation patterns in *Decapterus sp.* including scale shape, size and shapes of body scales from different parts of the fish body (Fig. 4). Fish scale descriptive terminology follows [21], [23].

C. Statistical Analysis of Scutes

Scutes samples were subjected to outline-based morphometric such as Elliptic Fourier Analysis (EFA) via SHAPE software [19]. Chain-code based was applied that rely on contour representation to code the shape information. This contour-based representation of the scales tracks the shape of the scales and represents each movement by a chain code symbol. The total number of chain codes per scales would vary depending on the shape and size of the structure [24]. Then, via discrete Fourier transformation of the chain codes, the coefficients of the elliptic Fourier were generated. This procedure eliminates variation related to size and orientation during scanning process. Number of harmonics was added to the function to better capture the shapes of the scale outlines. The study used 20 harmonics to effectively contain information regarding the shape of the scale outlines consisting of four coefficients. Multivariate Analysis distinctively Principal Component Analysis was employed since there are large numbers of coefficient per scales. PCA is effective in summarizing information of the variations contained in the coefficients derived after Elliptic Fourier analysis of the chain code data [24]. To validate results, Box-Plot Analysis and Kruskal-Wallis Test via PAST statistical software were used [26].

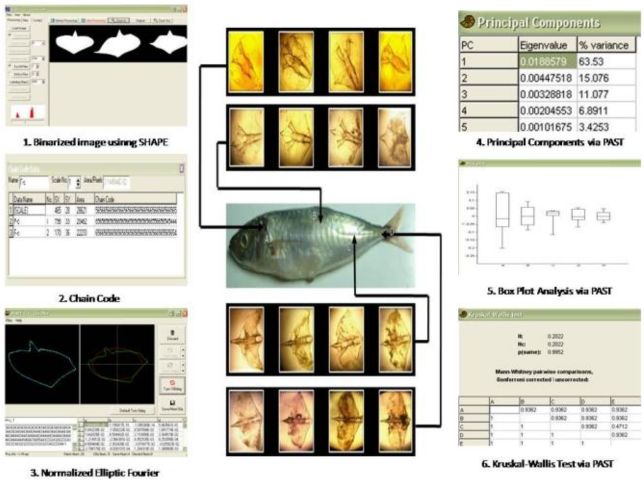

Fig. 5. Flow of the various statistical methods of analysis.

III. Results and Discussion

A. Description of Scutes

Decapterus sp: dorsal and anal fins with single detached terminal finlet; cleithrum margin with 2 papilae, the lower papillae larger; posterior end of upper jaw concave above, rounded and produced below; predorsal scaled area not reaching to middle of pupil; scutes covering posterior 3/4 of straight part of lateral line.

B. Biology

Depth: up to 550 m (usually shallower).

Habitat: sandy substrates; from near shore to deep.

Season: spawning occurs in winter month with larvae appearing in the spring and summer; spawning takes place in shallow water.

Diet: small crustaceans (e.g., amphipods, copepods), polychaetes.

Predators: fish, marine mammals, sea birds.

The relative size of scutes were small (0.8mm); position of scutes on body were 12 rows in the anterior region (A); 32 in the midline region (B); and 20 in posterior-caudal regions (C & D) of the body; posterior lateral line with heavy keeled scutes; the total number of scutes found at the anterior-posterior horizontal stretch of the lateral line was 64; overall scute shape**:** circular to w-shaped (Fig. 6).

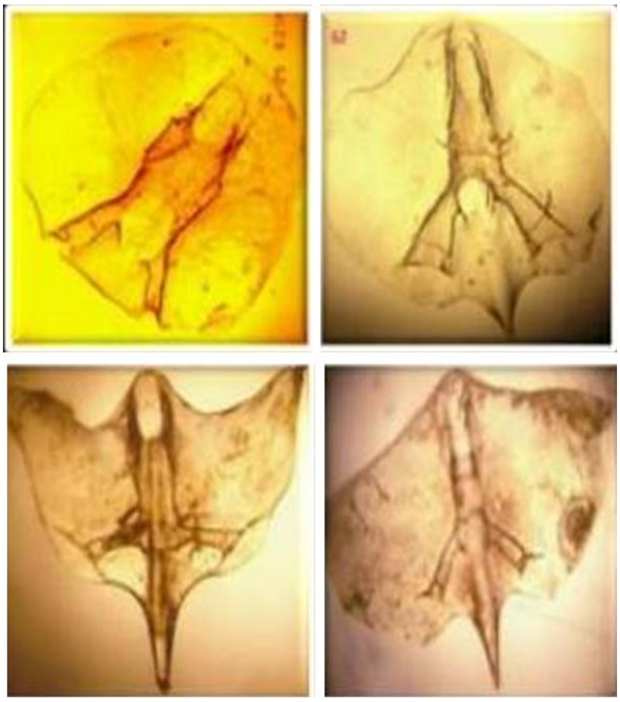

Fig. 6. Morphological variations of scutes at different regions.

There were substantial variation in size and shape, between the sampling series and regions. As to the development of each scute from the shoulder region to caudal peduncle, three stages were recognized, early, middle, and late on the basis of its structure. Scutes in A region were generally small and rounded; B region were wider with little projection; very distinctive plane-like shaped scutes with long and sharp apex and concave posterior wings were observed in C region; and D region had narrower and straight posterior wings (Fig. 4). Comparatively all scutes were provided and connected with pores or tubes (Fig. 7), region A was observed having so-called "scale-like structures".

C. Statistical Analysis of the Scutes

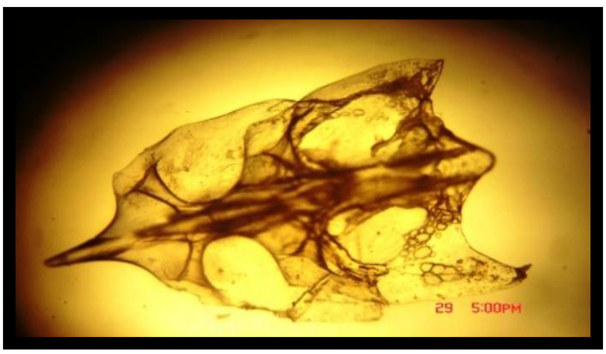

Fig. 7. Overlapping arrangement of scutes of *Decapterus sp.*

Using the Chain Coder software (Iwata and Ukai 2002), shapes of the scales were summarized and subjected to EFA to get normalized elliptic Fourier (NEF) shape descriptors or coefficients. Outline of the scutes were reconstructed and subjected to Principal Component Analysis (PCA). Shape diversity of the scutes of different regions of the two fish specimens were then analyzed and quantified using other statistical tools particularly as Box-and-whisker Plots and Discriminant Frequency.

Variation of the scute shapes among regions of male and female specimens were observed as shown in Fig. 8 and as elucidated by the significant principal components derived from chain code data . Principal component 1 (PC1) explains the great differences in the scale length-width ratio among different regions. Principal component 2 (PC2) and principal component 3 (PC3) describe the less variation in the outline of the scutes. For male specimen, PC1 has the greatest percentage of variance of 72.2% as shown in Table I. As for the female, PC 1 has the greatest percentage variance of 63.5% as depicted in Table II.

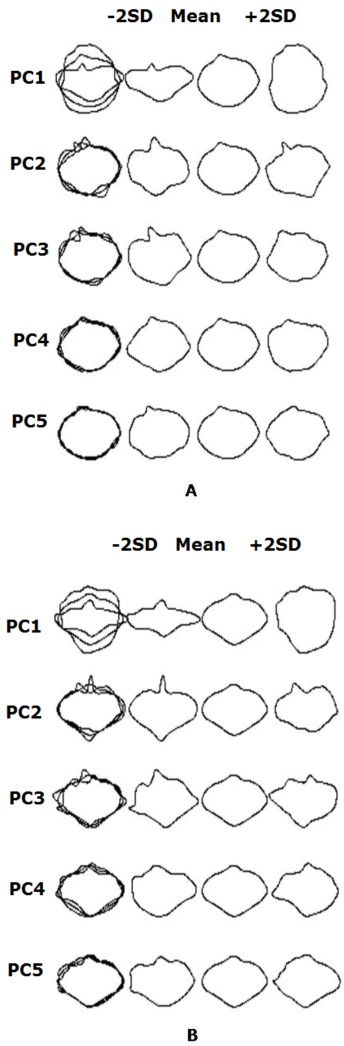

Fig. 8. Reconstructed scale outline of male (A) and female (B) specimens showing all five (5) significant principal components.

Similar result is shown in Fig. 9 for male specimen wherein distribution scores in PC1 vary deeply is more scattered than the rest of the principal component illustrated by box-and whisker plots.

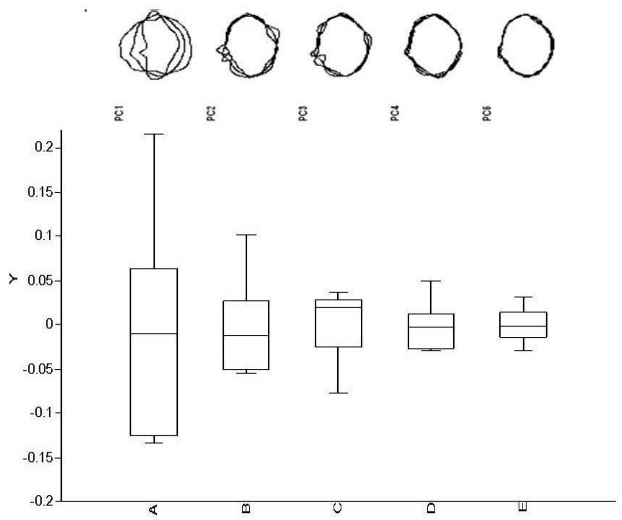

Fig. 9. Box-and-whisker plots of the five (5) principal components or significant elliptic Fourier coefficients showing variations within regions.

The distribution of the data set in PC 1 is skewed toward low values. Fig. 10 also shows that box plots of female specimen where PC1 vary greatly as the distribution of the data is more on high values as compared with the rest of principal components.

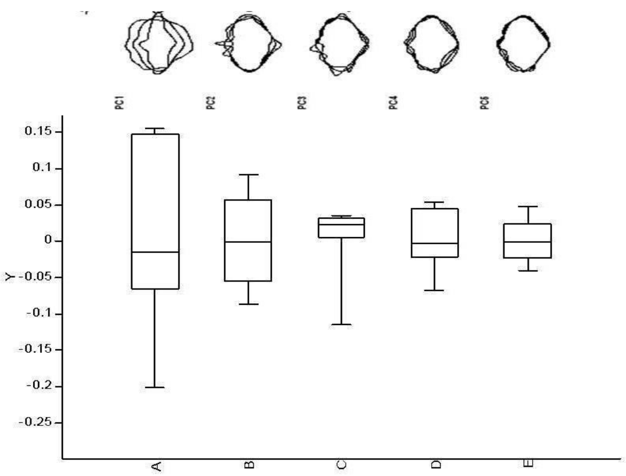

Fig. 10. Box-and-whisker plots of the five (5) principal components or significant elliptic Fourier coefficients showing variations within regions.

However, incomplete separation of the two data sets is observed in Fig. 11. There was an overlapping of the two colored bins which implies less variation in the scutes between sexes of the *Decapterus* sp. Scutes variation of *Decapterus sp***.** was quantified by means of conventional scute description and the computer-assisted approach which uses new statistical tool to measure variations of scutes.

Statistical analyses show variations of scale outline within and among regions. Observed variations are mainly seen on the length-width ratio of the scute outline and the "w"-shaped of the outline of the anterior field of the scute. However, less scute variation was observed between male and female specimens. Shapes differences of scutes may reveal adaptations to different functions and swimming characteristics, or adaptations to varying hydrodynamic conditions [1]. Moreover, morphometric characters are highly sensitive to environmental factors and show a significant defect once they became exposed to environmental stress. This changes often an alteration of one or more morphological, behavioral, physiological, or developmental responses. In many cases, responses to stresses or environmental changes entail developmental changes in morphology.

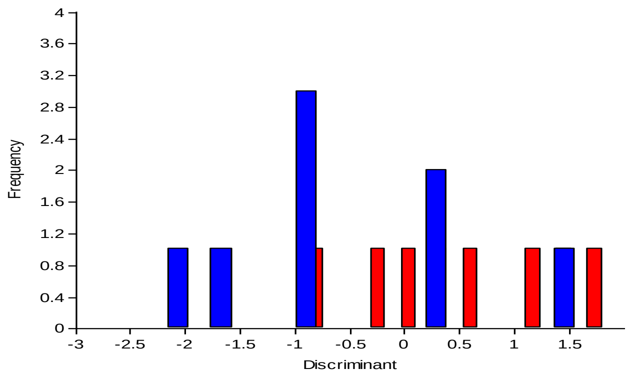

Fig. 11. Frequency histograms of the male scutes (blue bins) and female scutes (red bins) showing absence of sexual dimorphism as shown by the overlapping of the blue and red bins.

Scutes were removed from four different strategic regions of the fish sample and scanned. Scanned images were then systematically described based on several scute features. Various statistical analyses were employed using PAST software [26]. Images were digitized, gray-scaled and binarized using SHAPE softwares [19]. Chain code data were then subjected to EFA to obtain normalized elliptic Fourier shape descriptors/coefficients or principal components. These coefficients were then subjected to PCA, Box-and-Whisker Plot, and Discriminant Frequency.

There were significant scute variation in size and shape, between the sampling series and regions. Comparatively all scutes were provided and connected with pores or tubes.

TABLE I: PERCENTAGE OF VARIANCE OF PRINCIPAL COMPONENTS 1-5 OF MALE SPECIMEN

PC	Eigenvalue	% Variance
1	0.0180617	72.238
2	0.00374551	14.00
3	0.00288433	7.5364
4	0.000855745	3.4226
5	0.00045565	1.8224

TABLE II: PERCENTAGE OF VARIANCE OF PRINCIPAL COMPONENTS 1-5 OF FEMALE SPECIMEN.

PC	Eigenvalue	% Variance
1	0.0188579	63.53.15.076
2	0.00447518	15.076
3	0.00328818	11.077
4	0.00204553	6.8911
5	0.00101675	3.4253

At this stage, it is unfeasible to evaluate the level of asymmetry of those scutes characters and to determine if they are higher or lower than average or correlate with environmental pollution owing to the plasticity of phenotypes in natural environment.

IV. CONCLUSION

The results of the study show the utilization of geometric meorphometrics in a clearer understanding of shape variation in living organisms. With the aid of statistical softwares and imaging techniques, the variations in the structure can be quantitatively explained.

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