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Research Article

Geometric Morphometric Description of the Body Shapes of the "Porang" Fish, *Rasbora sp*., An Endemic Fish Species in Lake Wood, Zamboanga Del Sur, Mindanao, Philippines

Mary Ann M. Ganzon[1] and Cesar G. Demayo[2,*]

[1] *Department of Biological Sciences, College of Science and Mathematics, MSU-Iligan Institute of Technology, Iligan City, Philippines*

***Corresponding author:** cgdemayo@gmail.com

Abstract. Biological descriptions of body shapes in fishes were commonly based on qualitative methods. However, with advances in imaging, geometry and statistics, descriptions of biological shapes have become more quantitative. Landmark-based geometric analysis is a new approach that has become more popular in analysing biological shapes thus was used in this study of an endemic fish species that can be found in a lake in Mindanao, Philippines. A total of 47 females and 104 male fishes were collected and digitized using 20 anatomical landmarks of the fish body. The digitized landmarks were Procrustes-fitted and were subjected to relative warp analysis (RWA). Relative warp scores were also subjected to Canonical Variate Analysis (CVA). RWA revealed within and between sex variations in body shapes. Male fish head is shorter and broader resulting to shorter length of the mouth from the snout tip to the posterior extremity of the premaxillar. Deeper body depth has also been viewed resulting to shorter standard length and longer and narrower tail region, while females have broader and elongated head regions having lengthy eye margins, extensive length between posterior insertion of anal fin and ventral points of the maximum curvature of the peduncle and mouth part are observed to have elongated distance between the snout tip and the posterior extremity of the premaxilla. These variations in shapes were observed in the two sexes, statistical analysis also has demonstrated that the shape variance between sexes in both left and right orientation of the body were significant. This means that the variations observed within sexes are sufficient to explain that the variations are associated to sex. Other characters aside from body shapes maybe are associated with sexual differences and should be further explored.

Keywords. Landmark-based geometric analysis; Endemic fish; Body shape; Relative warp scores; Canonical variate analysis

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1. Introduction

Fish morphometrics is extensively used in fishery science to study phylogeny, phenotypic plasticity, fish condition, differences among stocks or morphotypes and to determine parental species of purported hybrids [10]. Since patterns of population variations play an important role in evolutionary diversification of organisms, many insights into evolutionary processes have come from studies of within population variation over a broad geographical range of species [2]. The porang fish, *Rasbora sp*., an endemic species found in Wood Lake of Lakewood, Zamboanga del Sur, which is located in the eastern part of the central Zamboanga Peninsula, is 7 degrees, $49'60''$ north and 123 degrees, $9'0''$ south (Figure 1).

Figure 1. Photograph of the Wood lake in Lakewood, Zamboanga del Sur. (Source: `maps.google.com.ph`)

The fish is the most popular fish of the province since it can only be found in this famous lake in the province. While the economic significance of this species is not yet known, relatives of the group are very popular as aquarium fishes. This species is a small fish of the Cyprinidae family where most of the members in this group have characteristic variations in body shapes. It was theorized that within the species variability in body shapes may also be observable and quantified especially with tools in imaging, geometry and statistical analysis of shape data. *Geometric Morphometrics* (GM) have been found to be a useful tool in understanding shape variations in organisms and is applied in describing the body shape of the fish. Geometric morphometric methods provide greater power than the traditional methods since the position of the landmarks can be maintained and can be graphically reconstructed. There is then an implication that GM conserves the geometry of object studied and allocates visualization of shape differences between specimens and between group means in specimen shape [3,4,5;1].

Douglas *et al*. (2001) and Parsons *et al*. (2003) have reported that it is easier to visualize shape differences using outcomes of thin-plate spline analyses of GM. Trapani (2003) and Parsons *et al*. (2003) reported discrimination of subtler morphometric differences among groups using thin-plate splines aside from the many benefits of multivariate morphometrics and geometric morphometrics in describing and understanding the nature of shape variations [12;10]. In the current study, we describe body shape variations within and between sexes in the fish.

2. Materials and Methods

A total of one hundred fifty-one individuals (47 females and 104 males) of *Rasbora sp*. were collected. To reduce the amount of intrapopulation shape variation, only sexually mature individuals were collected. Digital images of the left and right sides of the fish were taken using Canon with 14.1 megapixels digital camera. Sexes were identified through the removal of fish gonads done after image capture.

A total of 20 anatomical landmarks located along the outline of the body of fish samples were selected to provide a summary of the morphology of fishes (Figure 2). The landmarks digitized in this study are standard points used in fish morphometrics and are said to have both evolutionary and functional significance [17]. Both the left and right side images of the samples were digitized using the TpsDig freeware 2.12 [14]. The TpsDig facilitates the statistical analysis of landmark data in morphometrics by making it easier to collect and maintain landmark data from digitized images.

The X and Y coordinate of the digitized landmark points of the left and right images of the fish contain both shape and non-shape components of variation. The study focused only on the shape differences, so the non-shape components were removed through *Generalized Procrustes Analysis* (GPA) using the TpsRelw version 1.45 [13] software. The relative warps, which are the principal components of the covariance matrix of the partial warp scores, were computed using the unit centroid size as the alignment-scaling method. Variability in body shapes was then examined through *relative warp* (RW) analysis of the set of uniform and non–uniform components of shape. The collective RW scores were subjected to different multivariate analyses, which include Discriminant Function Analysis and Kruskal-Wallis Test, using the

Paleontological Statistics (PAST) software developed by Hammer *et al*. (2009).

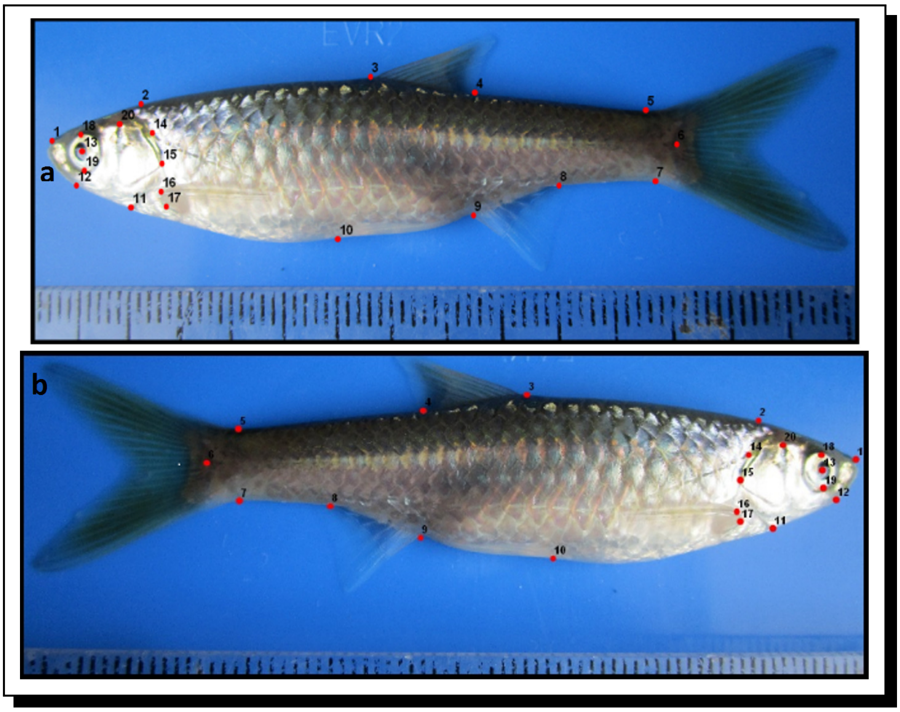

Figure 2. Digitized image ofleft and right body shape orientation of *Rasbora sp*. with the 20 landmarks as follows: (1) snout tip; (2) most posterior aspect of the neurocranium (beginning of scaled nape); (3) and (4) anterior and posterior insertion of the dorsal fin; (5) and (7) dorsal and ventral region of the caudal peduncle where there is the greatest curvature; (6) posterior most body extremity; (8) and (9) posterior and anterior insertion of the anal fin; (10) insertion of the pelvic fin; (11) insertion of the operculum on the lateral profile; (12) posterior extremity of premaxillar; (13) centre of the eye; (14) beginning of the lateral line; (15) point of maximum extension of operculum on the lateral profile; (16 and 17) superior and inferior insertion of the pectoral fin; (18 and 19) superior and inferior margin of the eye; (20) superior margin of the preoperculum.

3. Results and Discussion

Results of the MANOVA (Table 1) of the relative warp scores of the left and right sides of the fish show significant differences in body shapes of the two sexes. It can be observed also from the data that very minimal number (<10%) of individuals have been misclassified (Table 2) strengthening the idea of dimorphism and asymmetry in the fish. The result is graphically presented in the distribution of individuals along the first two canonical variate axes (Figure 3) which shows not only dimorphism but also asymmetry in body shapes. As observed in the body shape using relative warp analysis, the female fluctuate in the depth of their bodies and the contour of their abdomen, while males have longer gape length and caudal peduncle indicating different locomotion patterns during feeding and territorial behavior of males and a slenderer body outline. Occurrence of the dimorphic traits are said to be the results of the selective pressures for shape differences between the sexes. It can then be expected from both sexual selection and natural selection to operate in the secondary sex characters such as body shape.

The observed asymmetry in *Rasbora sp*could be attributed to developmental instability which maybe brought about by environmental stress as a means of adaptation of organisms [8]. The variations observed in the body shape could also reflect ecological and behavioral differences within and between the sexes, which may directly bear the important traits for fitness such as feeding efficiency, vulnerability to predators and reproductive success [9]. Studies on fishes indicate that these traits have been linked directly to locomotor performance and efficiency thus the body shape of fishes can be expected to be of particular ecological and evolutionary relevance [15].

Table 1. MANOVA test for body shape between sexes of *Rasbora sp.*

Wilks' lambda	3.32E-02
Pillai trace	1.86E+00
p(same)	8.20E-103

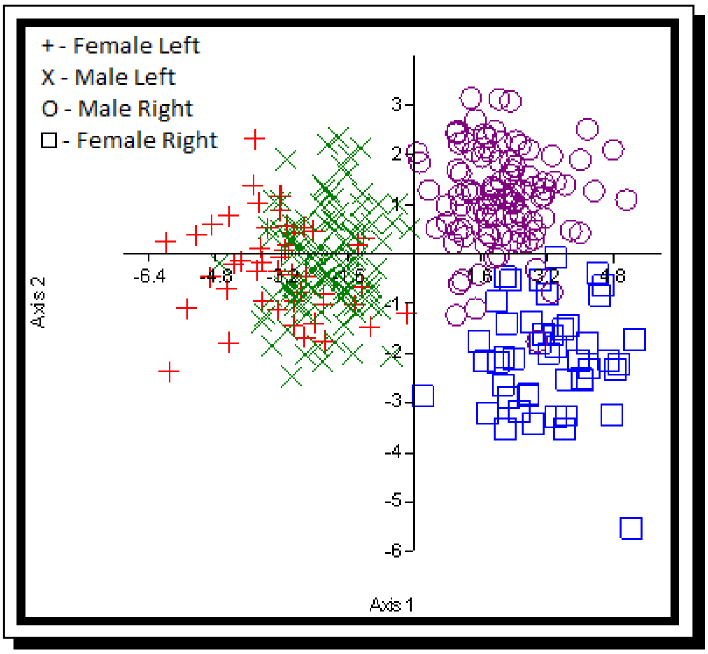

Figure 3. Scatter plot of the canonical variate analysis of RW scores between sexes of *Rasbora sp.*

Table 2. Confusion matrix between male and female *Rasbora sp.*

	Female left	Female right	Male left	Male right	Total
Female left	43 (91.5%)	0	4 (8.5%)	0	47
Female right	0	44 (93.6%)	0	3 (6.7%)	47
Male left	7	(6.7%)0	97 (93.3%)	0	104
Male right	0	5 (4.8%)	0	99 (95.2%)	104

4. Conclusion

The results of the statistical analysis of relative warp scores generated from the landmark coordinates show sexual dimorphism in the body shape of *Rasbora sp.*The variation in shape could reflect ecological and behavioral differences within and between sexes which bear on traits important for fitness such as feeding efficiency, vulnerability to predators and reproductive success.

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Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

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