Journal of Informatics and Mathematical Sciences
Vol. 9, No. 4, pp. 1041–1046, 2017
ISSN 0975-5748 (online); 0974-875X (print)
Published by RGN Publications

DOI: 10.26713/jims.v9i4.1022

http://www.rgnpublications.com

Research Article

Describing the Body Shape of Rainbow Sardine (*Dussumieria Acuta*) Using Landmark-Based Geometric Morphometric Analysis

Aprille Joy M. Luceño and Cesar G. Demayo*

Department of Biological Sciences, MSU-IIT, Iligan City, Philippines
***Corresponding author:** cgdemayo@gmail.com

Abstract. This study utilized geometric morphometric analysis of the body shape between sexes of *Dussumieria acuta*. *Canonical Variate Analysis* (CVA) and *Discriminant Function Analysis* (DFA) of the relative warp scores show significant differences in the body shape between males and females. Females exhibit body shapes that are geared to support larger number of eggs as shown by the distension of their belly region and a broader body compared to the males which possess a slender body shape. Variations observed within sexes can be attributed to selection pressures present in the environment. It is concluded that landmark-based geometric morphometric analysis is a useful tool in describing variations within and between sexes of *D. acuta*.

Keywords. Geometric morphometrics; multivariate methods; canonical variate; discriminant

MSC. 92C37; 92C40

Received: November 1, 2016 **Accepted:** January 20, 2017

1. Introduction

Shape analysis using landmark data (i.e., anatomical points inferred to be homologous between specimens) is a method that has been increasingly exploited during the past decade to explore systematic, developmental, ecological, or pathological variances between individuals or populations [1]. In addition, landmark-based method poses no limitation on the direction of variation and localization of shape fluctuations, and are much more effective in taking information about the form of an organism [2]. This method, combined with multivariate statistical procedures, offer a powerful tool for testing and graphically displaying differences in shape [3, 4]. Another essential aspect of geometric morphometric analysis is that results can be presented visually in terms of the 2-D or 3-D space of the organism which makes it easier to deduce since they are constructed as shapes within a coordinate system [5]. Thus, at different spatial scales, they provide analytical and graphical means to examine phenotypic variation [5]. In fishes, the application of geometric morphometric analysis has been found to be useful in stock identification of fresh water and marine fish species [6–10]. Since body shape is an important aspect of an organism's phenotype, and bears directly on traits such as feeding efficiency, locomotor performance, vulnerability to predators, reproductive success, differentiation of populations, influence of predation, salinity, temperature, food availability, and all other factors, geometric morphometric analysis can be helpful in quantitatively assessing the relationship of the variations observed in the body shape with these factors. In this current study, sexual dimorphism in body shape of *D. acuta,* a sardinella species was conducted.

2. Methodology

Image acquisition of 30 mature males and 30 females of *D. acuta* was done using a DSLR (Nikon D5100) camera mounted on a tripod for stability and uniform focus. Standard positioning was followed so as to show their natural position when swimming (Figure 1). Landmark-based geometric morphometric analysis involves the processing of the captured image using the freeware Tps Dig ver. 2.12 [11]. This image analysis and processing software facilitates the processing of the landmark data statistically [11]. Figure 1 shows the 18 homologous plotted anatomical landmarks on the fish's body regions used in the analysis of the variations in the body shape of *D. acuta* [12]. Changes and variations were based on positions of homologous anatomical landmarks of the body [3]. This is to have a graphical and visual presentation of results as it compares shape variations based on measured angles, distances, and ratios.

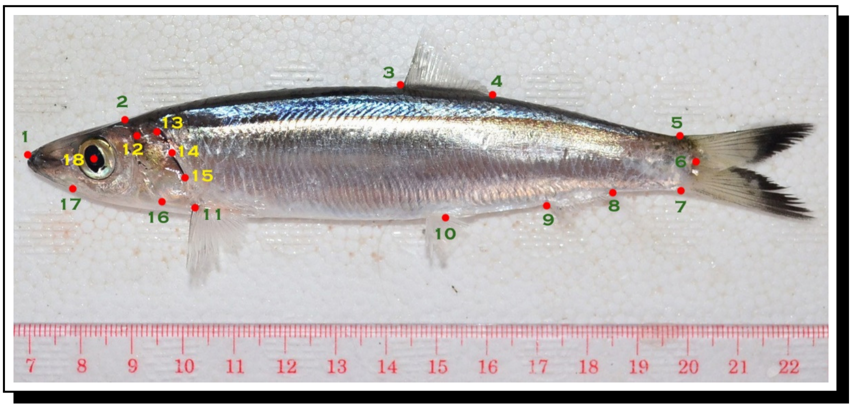

Figure 1. The 18 landmark locations for analyzing fish body shape (red dots). 1) anterior tip of snout at upper jaw, 2) most posterior aspect of neurocranium (beginning of scales nape), 3) origin of dorsal fin, 4) insertion of dorsal fin, 5) anterior attachment of dorsal membrane from caudal fin, 6) posterior end of vertebrae column, 7) anterior attachment of ventral membrane from caudal fin, 8) insertion of anal fin, 9) origin of anal fin, 10) insertion of pelvic fin, 11) origin of pectoral fin, 12) – 16) contour of the gill cover, 17) posteriormost portion of maxillary, 18) center of the eye.

From their digitized landmarks, the geometric conformations composed of x and y coordinates were converted first into shape variables before subjecting it to statistical analyses of shape variation. Applying the TpsRelw software, *Generalized Procrustes Analysis* (GPA) was utilized [13] since shape and non-shape variables are within the images which came from orientation and positional differences. Generated relative warps were used to determine the different body shape variations between sexes in *D. acuta*. Relative warp scores were subjected to *Discriminant Function Analysis* (DFA) and *Canonical Variate Analysis* (CVA) [14] to further analyse the differences existing between male and female *D. acuta* from Butuan Bay.

3. Results and Discussion

Canonical variate (Wilk's lambda=0.3641, P=2.499E-19; Pillai trace=0.6359, P=2.499E-19) and discriminant analysis (F=8.0217, P=2.449E-19) of relative warp scores as shape variables show significant variations in shape between sexes of the fish body shapes (Table 1). Correct classification of the samples shows a 77.22% discrimination indicating the amount of differences between the sexes (Table 1). The variations are graphically presented in Figure 2.

Table 1. CVA and confusion matrix results based from the RW scores as shape variables

CVA analysis				Confusion Matrix			
Wilk's lambda	0.3641	Pillai trace	0.6359		Male	Female	Total
df1	32	df1	32	Male	82	8	90
df2	147	df2	147	Female	8	82	90
F	8.022	F	8.022	Total	90	90	180
p(same)	2.50E-19	p(same)	2.50E-19	Correctly classified = 77.22%			

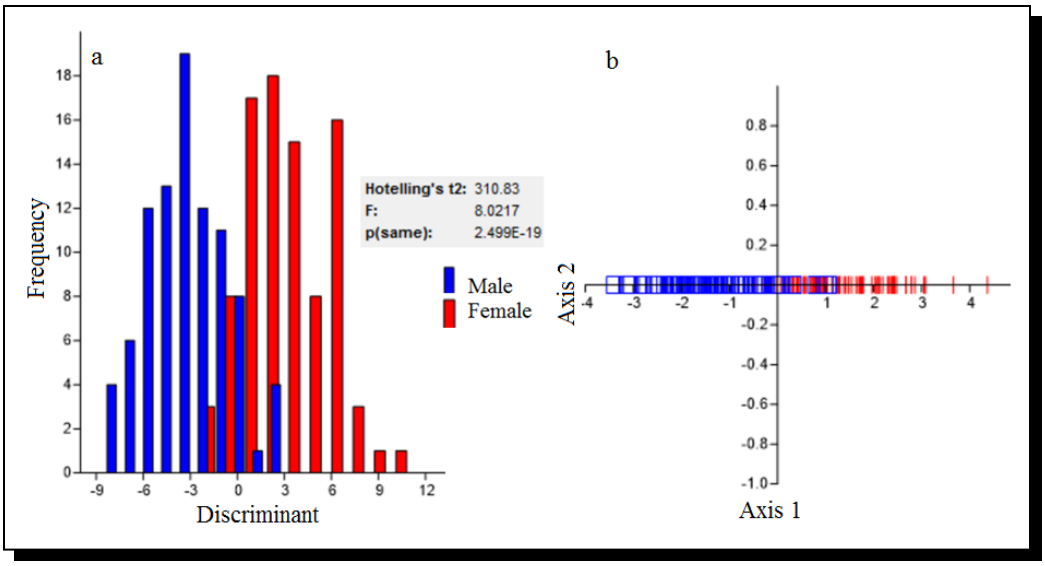

Figure 2. Graphical presentation of the distribution of individuals as a result of (a) Discriminant and (b) CVA

The descriptions of the variations based from the significant relative warps are presented in Table 2 and graphically presented in Figure 3. The extent of body shape variations within sexes of *D. acuta* are described by the boxplots. The description of the variations for each of the significant RWs for each sexes with their corresponding variances are also shown in Figure 3.

As shown by the RWs, females and males differ in terms of the curvature of the body. The female population exhibits body curvature that is in a downward direction as opposed to the male population. While females have a mid-section that is distended, males possess a compressed belly region. The female population tends to have an overall body shape that is broader compared to the males. Additionally, males have a smaller head compared to the females.

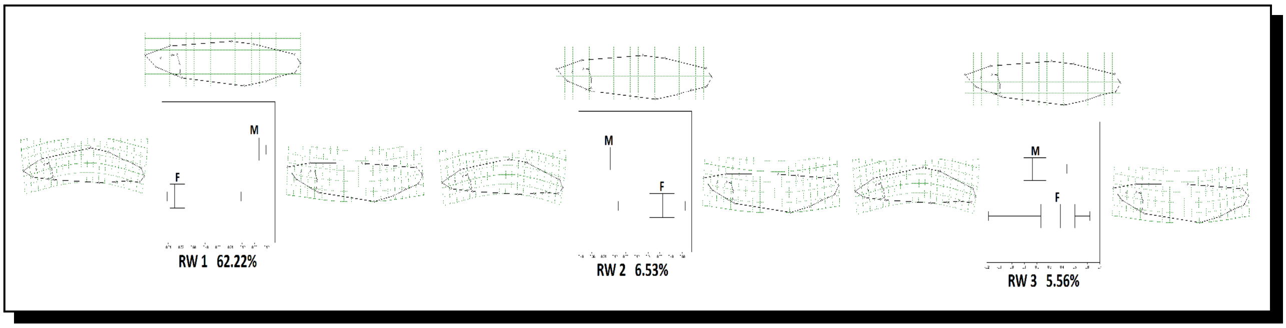

Figure 3. Summary of landmark based geometric morphometric analysis showing the boxplot and variation of the body shapes between sexes of *D. acuta* females and males from Butuan bay as explained by each of the significant relative warps

Table 2. Variation in the body shapes of *D. acuta* populations as explained by each of the significant relative warp and its corresponding percentage variance

RW	Female	Male
1 **62.22%**	Variation in the curvature of the body. Female population body curvature bends downward leaning towards the negative extreme.	Male population body curvature leans toward the positive extreme exhibiting an upward curve. Head and tail portion slightly bends upward.
2 **6.53%**	Body curvature leans toward the positive extreme exhibiting a slightly upward curve. There is slight distension of the belly.	Male population body curvature bends downward leaning towards the negative extreme. Mid-section is compressed.
3 **5.56%**	Slightly distended belly. Head is slightly larger. Body shape approaching consensus. Longer distance from pectoral fin to anal fin.	Body curves slightly upward. Change in the position of the gill cover. Slightly smaller head. Compressed belly region.

Results of the analysis show the main variations between sexes of *D. acuta* is focused in the curvature of the body, distension in the belly region, broadness of the body, and size of the head. Females possess a belly region that is argued to be designed to support a huge amount of eggs which is very essential for reproduction. Males' body "shape is slenderer compared to the females which are broader. It was Darwin [15] who first postulated that sexual selection can explain sexual dimorphism. He emphasized that variations in the roles in reproduction between sexes may influence patterns of selection and could lead to sex differences in morphological attributes such as the shape of the body [16].

4. Acknowledgment

The senior author would like to acknowledge the Philippine Department of Science and Technology - Accelerated Science and Technology Human Resource Development Program (DOST-ASTHRD) for the research scholarship grant.

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.

References

[1] K. Manimegalai, M. Arunachalam and R. Udayakumari, Morphometric geometric study of wing shape in *Culex quinquefasciatus* Say (Diptera: Culicidae) from Tamil Nadu, India, *Journal of Threatened Taxa* **1**, 5 (2009).

[2] M.J. Cavalcanti, L.R. Monteiro and P.R.D. Lopes, Landmark-based Morphometric Analysis in Selected Species of Serranid Fishes (Perciformes: Teleostei), *Zoological Studies* **38**, 3 (1999).

[3] F.J. Rohlf and L.F. Marcus, "A revolution in morphometrics," Trends in Ecology & Evolution 8, 4 (1993).

[4] F.J. Rohlf, A. Loy and M. Corti, Morphometric Analysis of Old World Talpidae (Mammalia, Insectivora) using partial warp scores, *Syst. Biol.* **45** (1996).

[5] M.E. Douglas, M.R. Douglas, J.M. Lynch and D.M. McElroy, Use of Geometric Morphometrics to Differentiate Gila (Cyprinidae) within the Upper Colorado River Basin, *Copeia* **2001**, 2 (2001).

[6] Z. Mamuris, P. Apostolidis, P. Panagiotaki, A.J. Theodorou and C. Triantaphyllidisdir, Morphological variation between red mullet populations in Greece, *Journal of Fish biology* **52**, 1 (1998).

[7] S.X. Cadrin, Advances in morphometric identification of fishery stocks, *Reviews in fish Biology and Fisheries* **10**, 1 (2000).

[8] A. Murta, Morphological variation of horse mackerel (*Trachurus trachurus*) in the Iberian and North African Atlantic: Implications for stock identification, *ICES Journal of Marine Sciences* 57, 4 (2000).

[9] S. Pakkasmaa and J. Piironen, Morphological differentiation among local trout (*Salmo trutta*) populations, *Biological Journal of the Linnean Society* **72** (2001).

[10] H. Cabral, J.F. Marques, A.L. Rego, A. Catarino, J. Figueiredo and J. Projecto-Garcia, A Genetic and morphological variation of *Synaptura lusitanica* Capello, 1868, along the Portuguese coast, *Journal of Sea Research* **50**, 2-3 (2003).

[11] F.J. Rohlf, *NTSYSpc: Numerical Taxonomy System*, ver. 2.20, Exeter Publishing, Setauket, NY (2008).

[12] A.J.M. Luceño, M.A.J. Torres, S.R. Tabugo and C.G. Demayo, Describing the Body Shapes of three populations of *Sardinella lemuru* (Bleeker, 1853) from Mindanao Island, Philippines Using Relative Warp Analysis, *Int. Res. J. Biological Sci.* **3**, 6 (2014).

[13] F.J. Rohlf and D.E. Slice, Extensions of the Procrustes method for the optimal superimposition of landmarks, *Syst. Zool.* **39** (1990).

[14] O. Hammer, D.A.T. Harper and P. Ryan, PAST: Paleontological Statistics Software Package for Education and Data Analysis, *Paleontologia Electronica* **4**, 1 (2001).

[15] C.R. Darwin, *The Descent of Man, and Selection in Relation to Sex*, London: Murray (1871).

[16] S.J. Casselman and A.I. Schulte-Hostedde, Reproductive roles predict sexual dimorphism in internal and external morphology of lake whitefish, *Coregonus clupeaformis*, *Ecology of Freshwater Fish* **13** (2004).