FLUCTUATING ASYMMETRY IN THE BODY SHAPE OF THE MOTTLED SPINEFOOT FISH, *SIGANUS FUSCESCENS* (HOUTTUYN, 1782) COLLECTED FROM DIFFERENT BAYS IN MINDANAO ISLAND, PHILIPPINES

[1,2]Zarine M. Hermita, [2]Jessie G. Gorospe, [3]Mark Anthony J. Torres, [2]Gil J. Lumasag, [3*]Cesar G. Demayo

[1]Ateneo de Davao University, Davao City, Philippines
[2]School of Graduate Studies- Mindanao State University at Naawan, Naawan Misamis Oriental, Philippines; [3]Department of Biological Sciences, MSU-Iligan Institute of Technology, Iligan City, Philippines; *Corresponding author: C.G. Demayo, cgdemayo@gmail.com

ABSTRACT: *Variations in the patterns of fluctuating asymmetry in a total of sixteen bilateral traits of the Mottled spinefoot fish Siganus fuscescens from five populations in Mindanao, Philippines were determined using the method of landmark-based geometric morphometrics. The spinefoot fish S. fuscescens is an important commercial fish in the country and an evaluation of the extent of asymmetry among its traits can be used to identify valuable sources of fish stocks for aquaculture purposes as trait asymmetry is believed to be an indicator of developmental noise and is a tell-tale sign of the quality of fish populations. To do this, a total of sixteen landmark points were collected from digitized images of 194 fishes. Fluctuating asymmetries in the traits were analyzed using Procrustes ANOVA. The results of this study showed differences in the patterns of asymmetry between sexes of the fishes. Generally, all the populations exhibited significant levels of trait FA. However, looking at the number of localized trait FA, the fishes from Davao City showed the most number of asymmetrical traits (10/16 in males; 7/16 in females) whilst the Pagadian (6/16 in males; 5/16 in females) and Misamis Occidental (5/16 in males; 6/16 in females) populations had the lowest number of asymmetrical traits. Thus, these two populations which showed the least trait asymmetries are believed to have experienced lesser stress or noise during their development and can be potential sources of quality fish stocks for commercial purposes.*

INTRODUCTION:

The Mottled spinefoot fish *Siganus fuscescens* is an important commercial fish in the Philippines and is considered to have higher market value to the widely cultured fish *Chanos chanos* (Woodland 1990). Commercial production of this species requires extensive knowledge about available healthy fish stocks from natural populations. There are many ways to evaluate the quality of fish stocks from natural sources. One way is to search for populations of fishes that show minimal levels of fluctuating asymmetry (FA) in bilateral traits.

Fluctuating asymmetry, defined as subtle differences between the left and right sides of bilateral traits, is believed to be an indicator of the fitness of populations of fishes and consequently the quality of fish stocks [1]. Generally, high trait FA is associated with perturbations and stresses during the development of an individual fish. Also, individual fishes with random left-right departures from bilateral symmetry are predicted to have reduced fitness. In a study conducted on fishes with higher trait FA, results showed lower survival rates in test conditions when compared to those that show minimal FA [2]. Trait FA is also high in populations that develop in stressful and or marginal environments.

Increased FA is a reflection of poor developmental homeostasis at the molecular, chromosomal and epigenetic levels [3]. To simplify matters, the relationships between homeostasis and FA can be further described as follows: high FA results from poor developmental homeostasis; and poorer developmental homeostasis results from high developmental instability. Developmental instability, in this case, is defined as a suite of processes that tend to disrupt the precise development of bilateral traits in organisms [4] and is believed to stem from various exogenous and endogenous stresses collectively referred to as developmental noise or perturbations [5].

There are many ways of computing for trait FA. It is usually calculated using the difference in the measurements of bilateral traits [5, 8]. There are also several means of determining and presenting FA data and this is summarized by Palmer [4]. Whilst there are many available methods to determine trait FA using traditional linear distance measures, advances in digital imaging has made it possible to describe developmental instability using the landmark-based method of geometric morphometrics or GM. Geometric Morphometrics is a library of tools that can be used to separate the three components of body form, which are size, shape and symmetry. Thus, this tool was used in this study to quantify deviations from bilateral symmetry and determine levels of FA in a total of sixteen traits in several populations of *S. fuscescens* from Mindanao, Philippines [9]. The objective of which is to evaluate the quality of the five fish stocks based on the levels of trait FA exhibited by the five populations.

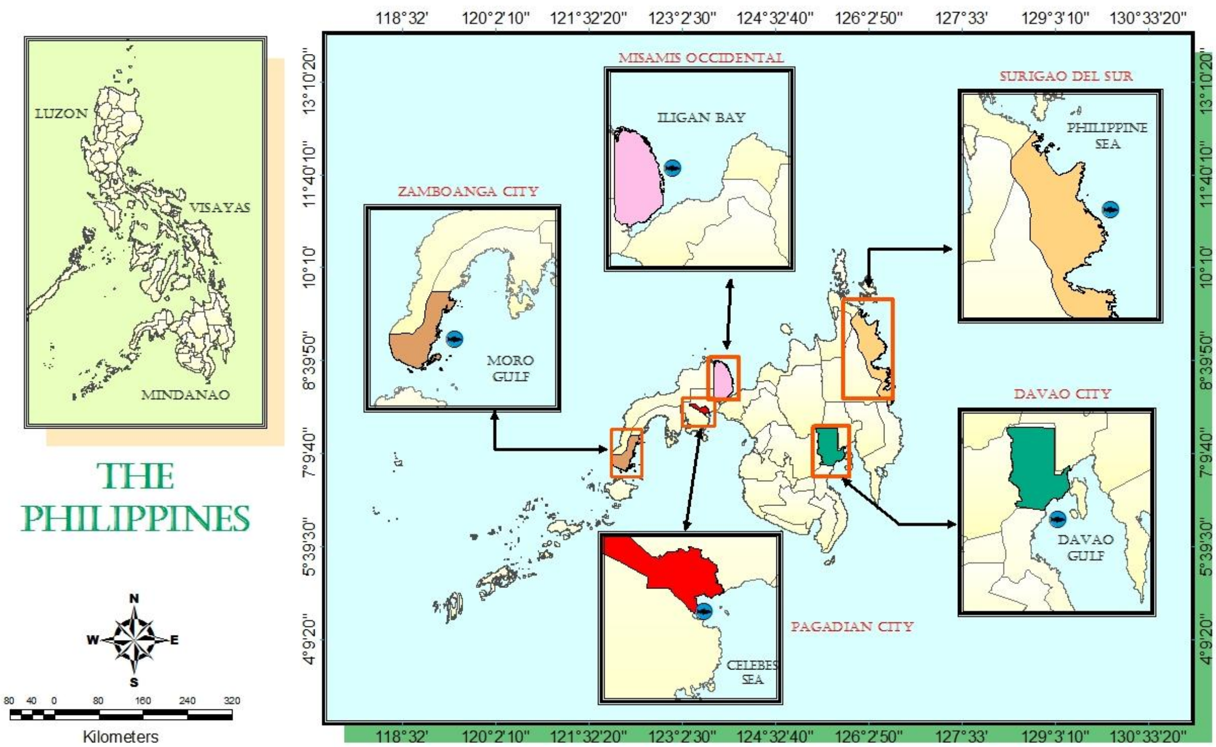

Figure 1. Geographic location of the study sites in Mindanao, Philippines.

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Figure 2. The locations of the landmarks used for the FA analyses. (1) Lower anterior of the premaxilla (2) Lower posterior of the premaxilla (3) Upper posterior of the premaxilla (4) Upper anterior of the premaxilla (5) Center of eye (6) Anterior margin through the midline of the eye (7) Posterior margin through the midline of the eye (8) Superior margin of the eye (9) Inferior margin through the midline of the eye (10) Dorso-lateral angle of the operculum (11) Posterior margin of the operculum (12) Isthmus (13) Origin of pectoral fin (14) Insertion of pectoral fin (15) Origin of pelvic fin (16) Mid-superior margin of the upper lip.

MATERIALS AND METHODS:

Study area: The study was conducted in selected areas of Mindanao namely Surigao del Sur, Davao City, Misamis Occidental, Pagadian City and Zamboanga City (Figure 1).

Fish sample collection and digital imaging preparation. The fish samples were collected from the five sites mentioned above. The fins of the samples were stiffened by applying 10% percent formalin-seawater solution using the method used by Love and Chase [10, 11]. Two-dimensional images of the fishes were generated using an HP G2410 flatbed scanner at 1,200 DPI.

Landmark selection and digitization of sample images. A total of sixteen landmarks were digitized using the tpsDig version 2.12 [12]. The location of the landmarks and the anatomical descriptions of each are presented in Figure 2

FA Analyses. Overall- and localized fluctuating asymmetries were determined by subjecting the paired landmark coordinates to Procrustes ANOVA following the method of Klingenberg [14] and using the SAGE software version 1.0 [15].

RESULTS AND DISCUSSIONS

Looking at the overall body shapes of the fishes, the results of the analyses showed that all populations exhibited significant levels of fluctuating asymmetry (Tables 1 & 2). However, when all sixteen bilateral traits were examined separately, the results identified the Davao population particularly the males to exhibit the most trait FA with 10 out 0f 16 characters with significant FA levels (Table 3). The female fishes from this population also exhibited FA in 7 out of 16 traits.

Almost all populations except for the Zamboanga female samples showed FA in the lower anterior of the premaxilla. The male samples from Davao differed from the other samples in manifesting FA in the superior margins of the eyes and the inferior margins through the midline of the eyes. Both sexes from this population also exhibited FA in the lower posterior of the premaxilla. These samples are similar to the Pagadian fishes in manifesting FA in the upper posterior of the maxilla. Differences between sexes can be observed in this population. For example, only the male samples showed FA in the following traits: upper anterior of the premaxilla, superior margins of the eyes, inferior margins through the midlines of the eyes, dorso-lateral angle of the operculum, insertion of the pectoral fins, and the origin of the pelvic fins.

Sex differences were evident in the populations of fishes examined. For example, only the female fishes from Misamis Occidental showed FA in the upper anterior of the premaxilla; only the male fishes from Zamboanga had FA in the dorso-lateral angle of the operculum; and only the female Pagadian samples showed FA in the mid-superior margin of the upper lip. The observed differences in the patterns of trait FA between sexes might mean that there might exist differences in the levels of developmental homeostasis between males and females.

The results of this study is similar to the findings of other studies in that not all characters examined in the fish populations exhibited FA [1,16,17]. These differences in the levels of FA among characters in that the trait differs in their ability to buffer developmental noise and achieve homeostasis [17, 18].

Based on the results of the study, the *S. fuscescens* from Misamis Occidental and Pagadian manifested the lowest number of trait FA out of the sixteen characters examined. This results might imply that the fishes from these populations experienced lesser developmental perturbations and stresses [19]. Hence, these populations could be good sources of quality fish stocks that can be cultured. The other populations especially those from Davao which showed the highest number of trait FA which might have resulted from enumerable sources of stress both exogenous and endogenous. Endogenous type of stresses include the occurrence of inbreeding depression because of small population sizes or because the population is comprised of founders. Gilligan *et al.* [20] found increased levels of asymmetry in populations of organisms with low levels of genetic heterozygosity because of inbreeding. Inbreeding has been linked to reduced health of populations of organisms and can pose critical effects on the survival of new fish recruits, and consequently on body shapes [17, 21, 22]. On the other hand, high levels of genetic heterozygosity increases the chance that a population develop normal despite of the existence of environmental perturbations [23, 24].

Table 1. Results of the Procrustes ANOVA for all female samples of the Mottled Spinefoot fish *Siganus fuscescens*.

SITE	*SS*	*df*	*MS*	*F*	*P*
Surigao del Sur	0.0732	588	0.0001	19.0128	0.0099
Davao City	0.0573	252	0.0002	39.1009	<0.000
Misamis Occidental	0.0108	392	0.0003	57.4745	<0.000
Pagadian City	0.0096	112	0.0001	20.0549	<0.000
Zamboanga City	0.0096	28	0.0003	77.1398	<0.000

Table 2. Results of the Procrustes ANOVA for all male samples of the Mottled Spinefoot fish *Siganus fuscescens.*

SITE	*SS*	*df*	*MS*	*F*	*p*
Surigao del Sur	0.2053	1512	0.0001	22.5618	0.0099
Davao City	0.1269	532	0.0002	9.1649	0.0099
Misamis Occidental	0.0535	280	0.0002	34.3105	0.0099
Pagadian City	0.092	840	0.0001	23.3881	0.0099
Zamboanga City	0.083	616	0.0001	30.159	<0.0000

Table 3. Presence of localized trait asymmetry in the populations of the Mottled Spinefoot fish *Siganus fuscescens*.

	Surigao		Davao		Mis. Occidental		Pagadian		Zamboanga	
CHARACTER	M	F	M	F	M	F	M	F	M	F
Lower anterior of the premaxilla	**	**	*	*	*	*	*	*	*	
Lower posterior of the premaxilla			*	*						
Upper posterior of the premaxilla			*	*			*	*		
Upper anterior of the premaxilla	*	**	*			**		*	*	
Center of eye										
Anterior margin through the midline of the eye										
Posterior margin through the midline of the eye										
Superior margin of the eye			*							
Inferior margin through the midline of the eye			*							
Dorso-lateral angle of the operculum	*	*	***		**	**	*		**	
Posterior margin of the operculum			***	*	*	*			*	*
Isthmus	*	*	**	*		*	*		**	*
Origin of pectoral fin			**	*	*		*		*	*
Insertion of pectoral fin	*		**						*	
Origin of pelvic fin	*	*	**		**		*	*		*
Mid-superior margin of the upper lip	**	***	*	*		*		**		
Total	7	6	10	7	5	6	6	5	7	4

SUMMARY AND CONCLUSION:

The results of this study showed differences in the patterns of trait FA among populations and between sexes of the mottled spinefoot fish *Siganus fuscescens*. The Davao samples showed the highest number of trait FA whilst the Pagadian and Misamis Occidental populations showed the least number of trait FA. There are a number of factors that might explain high trait FA in the Davao samples. This population might have experience developmental perturbations/noise early in life which resulted to the observed deviations from bilateral symmetry in many of the traits examined. Possible sources of developmental noise include exogenous and endogenous stresses such as low habitat quality to low genetic heterozygosity among others. On the other hand, the fishes from Pagadian and Misamis Occidental might possess mechanisms that buffer developmental noise that made it capable of maintaining homeostasis. This means that these two populations could be regarded as good sources of quality fish stocks that can be utilized for breeding purposes.

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