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Length-weight relationship, body shape variation and asymmetry in body morphology of *Siganus guttatus* from selected areas in five Mindanao bays

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Abstract: This study was conducted to describe length-weight relationship, body shape, and asymmetry in body morphology of *S. guttatus* and their possible implication in broodstock selection and aquaculture. Shape analysis was done applying the method of geometric morphometrics. The length (L)-weight (W) relationships (LWR) were estimated using the equation, $W=aL^b$. Fluctuating asymmetry analysis was performed in each sex using landmark coordinates and six morphologic characters measured for both right and left lateral side. Results revealed variations in body shapes between sexes and populations of the fish, the LWR of female and male *S. guttatus* show positive and negative allometric growth respectively. In females, this could be attributed to the capability of rearing large number of eggs. Variations in body shapes, large body area, heavier body and longer body length were the characteristics of adult *S. guttatus* identified to be possibly the most favorable characters which could produce high quality recruits for aquaculture purposes.

Key Words: Allometry, Fluctuating aymmetry, broodstock, aquaculture

Introduction

Fish is an important food source of protein and other essential nutrients required by the body (Sikoki and Otobotekere, 1999). It is therefore important that this important resource be properly utilized and managed. It has only been in the last few years that selection of captive mature broodstock in the wild became available. Ideally, selection programs help identify best performing first generation domestic broodstock, which develops fish strain that is better suited to aquaculture conditions (Reith *et al.*, 2004). The selection of fish for broodstock are those with desirable hereditary qualities typical of improved strains such as rapid growth

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potential, higher resistance to dissolved oxygen deficiency and adverse water quality, strong appetite, omnivorous feeding regime, with well-developed sexual organs and rearing of these selected fish to produce healthy potential spawners, with dormant eggs well developed in the females. Production of good quality eggs is dependent upon the quality of the broodstock which could be reflected in its morphology such as body shape, length, and weight and body symmetry.

In aquaculture, the well-being of the fish is based upon its "condition" or "fatness". Study on carcass composition, mainly the meat and fat content of the fish is also an important trait in fish production (Romvári *et al.*, 2002). The heavier the fish of a particular length is argued to be in a better physiological condition (Bagenal, 1978; Kolher *et al.*, 1995; Petrakis and Stergiou, 1995). This length-weight (L-W) relationship is thus very important for proper exploitation and management of the population of fish species (Anene, 2005). It is used in stock assessment as index for monitoring feeding intensity, age, growth rates (Oni *et al.*, 1983; Morato *et al.*, 2001; Stergiou and Moutopoulos, 2001) and estimation of biomass from length frequency distributions (Petrakis and Stergiou, 1995; Dulćić and Kraljević., 1996). Studies reported that condition factors such as LW of different fish species are strongly influenced by both biotic and abiotic environmental conditions providing a glimpse of the status of the aquatic ecosystem in which fish live (Anene 2005; Bakare 1970; Saliu 2001 and Lizama *et al.*, 2002; Stergiou and Moutopoulos 2001).

The body shape in fishes also influences locomotion efficiency in different environments (Hood and Heins, 2000), particularly foraging and predator evasion (Nieves and Monteiro, 2003) thus could be important in aquaculture. Shape analysis is a fundamental part of much biological research and is an important character for the analysis of fish evolution especially for the analysis of spatial variation among fish populations and for theories about adaptation to local environmental conditions (Nieves and Monteiro, 2003). With advances in image analysis, computer technology, biology and statistics such as the use of geometric morphometry, the study of shape have contributed to the improvement of biometric analysis (Bookstein 1997, Adams et al 2004) thus was used in this study to describe adult *S. guttatus* collected from different coastal bays.

Other than LWR and body shape, individual and population levels of asymmetry have been shown to also relate positively to a wide range of abiotic, biotic stresses (Taylor, Reimchen, 1997; Landsberg *et al.*, 1998; Allenbach *et al.*, 1999; Leary *et al.*, 2001; Schwaiger, 2001; Franco *et al.*, 2002; Lemly, 2002; Valtonen *et al.*, 2003; Binuramesh *et al.*, 2005; Estes *et al.*, 2006). Fluctuating asymmetry, small random deviations from perfect symmetry in bilaterally paired structures was thought to reflect an organism's ability to cope with genetic and environmental stress during development (Palmer and Strobeck 1986; Møller and Swaddle, 1997; Dongen, 2006). In reared fishes for example, FA seems to increase under genetic stresses (Wilkins *et al.*, 1995; Young *et al.*, 1995; Palma *et al.*, 2001; Mazzi *et al.*, 2002; Fessehaye *et al.*, 2007). Since FA is utilized as an indicator of individual quality and as a bioindicator tool for environmental monitoring and conservation biology (Tomkins and Kotiaho, 2001), this was also used in the current study on the most economically important fish in the Phillipines, *Siganus guttatus*.

Materials and Methods

There were five collection sites established within the major bays in Mindanao. Namely, Surigao del Sur for Philippine Sea, Davao Oriental for Davao Gulf, Plaridel, Misamis Occidental for Bohol Sea I; Lopez Jaena, Misamis Occidental for Bohol Sea II, Zamboanga del Sur for Ilana Bay, and Zamboanga City for Moro Gulf as shown in Figure 1. Opportunistic sampling with a collection period of 3 to 5 days at each sampling point from fish landing ports of the five different sampling points was done. Collections of fish samples for all the areas happened from July to December 2011. Samples were placed on a Styrofoam box with ice and were processed immediately. Number of samples collected vary per sampling site since the fish samples were collected from the natural environment.

Length-weight analysis: The length-weight relationships were estimated using the equation, $W=aL^b$, Where W is total body weight (g), L the total length (cm), a and b are the coefficients of the functional regression between W and L (Ricker, 1973). Values of the exponent *b* provide information on fish growth. Parameter estimation was made through a logarithmic transformation of L-W data pairs. Analysis was done using the ordinary least- squares linear regression (Pauly, 1984):

$LogW=Loga+b \times LogL$, where the value of "b" is nearly between 2 and 4 and often close to 3 (Garcia *et al.*, 1998). When: b = 3; fish growth is isometric (length and weight increases proportionally), b>3; fish growth is in positively allometric (weight increases faster than length), b<3; fish growth is in negatively allometric (length increases faster than weight) (Morey *et al.*, 2003).

Shape Analysis: Landmark-based geometric morphometrics a technique was used to quantify body shape (Rohlf and Marcus 1993; Adams et al., 2004). Twenty-seven landmarks were identified and digitized using the TpsDig ver. 2.12 software for shape analysis (Rohlf 2008a) (Fig. 2). Unfortunately, direct analysis of the landmark coordinates will not be possible, as they contain components of both shape and

Fig. 1: Map of the Study Area (Mindanao, Philippines)

non shape variation such as position, orientation and size (Adams, 1991). To be able obtain shape variables, nonshape variation in the landmark coordinates was removed by superimposing them using a Generalized Procrustes Analysis (GPA) in TpsRelw (version 1.49) software (Rohlf, 2008b). GPA is an important procedure that consists of three steps: the translation to a common centroid at the origin of a reference coordinates system; the scaling of each element at the unitary centroid size; and the rotation that will minimize the sum of square distances between correspondent landmarks.

A TPS file generated using tpsPLS ver 1.18 (Rohlf, 2006) that contains digitized images based on selected landmarks was further analyzed using TpsRelw 1.46 (Rohlf, 2008b) loaded with corresponding links (true landmarks 1-16) and sliders (pseudolandmarks 17-26) and Images was plotted in a two-dimensional morphospace warp grid. Variations observed in the male and female population was interpreted base on relative warp grid and scores.

Variations that exceed the 5% level of significance were considered significant and results of which was interpreted based on variation in body shapes within and between sexes and populations of *Siganus guttatus*. Each relative warp scores deemed to be significant was plotted into a histogram with two-dimensional warp grid representation of each negative and positive score samples. A shape difference between populations was evaluated using Canonical Variate Analysis (CVA) (Hammer et al., 2001).

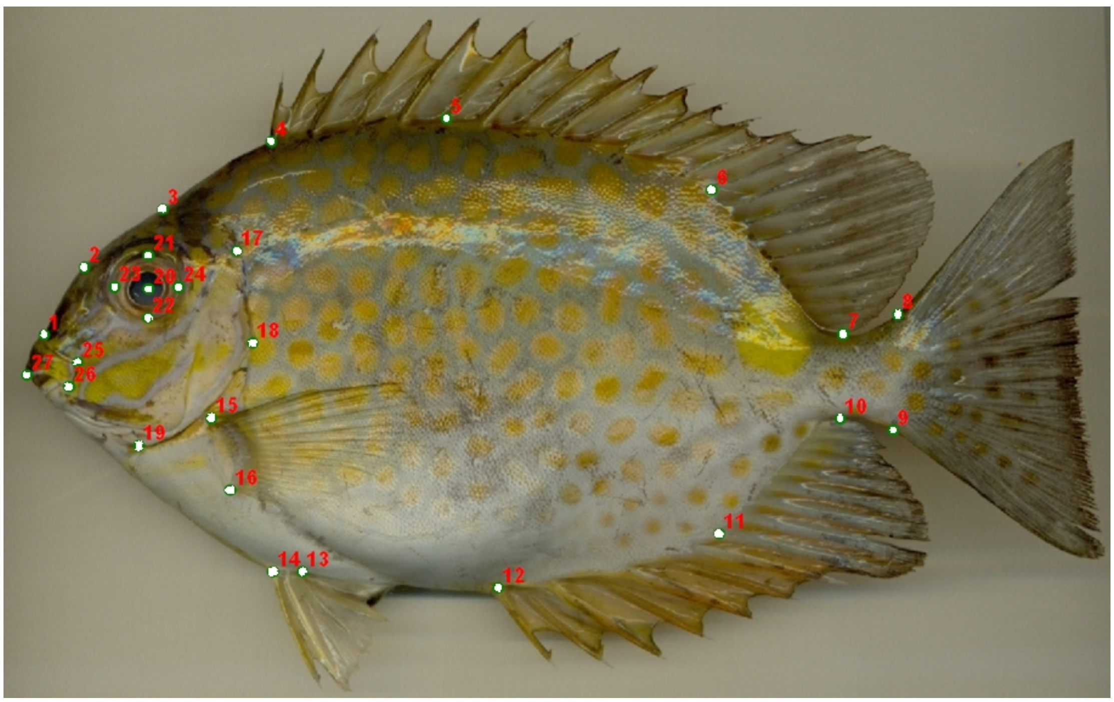

Fig. 2: Twenty-seven landmarks and morphological characters examined for shape analysis.

(1) Anteriormost tip of the snout, (2) Mid line between the upper maxilla and upperpart of the eye, (3) Deepest part of frontal lobe, (4) Origin of dorsal fin, (5) 6th dorsal spine, (6) Origin of dorsal unbranched rays, (7) Insertion of dorsal fin, (8) Superior insertion of caudal peduncle, (9) Inferior insertion of caudal peduncle, (10) Insertion of anal fin, (11) Origin of unbranched rays, (12) Origin of anal fin, (13) Insertion of pelvic fin, (14) Origin of pelvic fin, (15) Posteriormost margin of the operculum, (16) Dorso-lateral angle of the operculum, (17) Posterior margin of the operculum, (18) Origin of the pectoral fin, (19) Insertion of pectoral fin, (20) Superior margin of the orbit, (21) Inferior margin of the orbit, (22) Anterior margin of the orbit, (23) Posterior margin of the orbit, (24) Center of the eye, (25) Posterior end of the upper maxilla, (26) Junction between the posterior end of the upper maxilla, (27) Inferior margin of the upper maxilla

Asymmetry: Fluctuating asymmetry refers to small random deviations from perfect symmetry in bilaterally paired structures; it is thought to reflect an organism's ability to cope with genetic and environmental stress during development and its utility as an indicator of such stresses. Fluctuating asymmetry has been used as an indicator of individual quality in studies of natural and sexual selection and as a bioindicator tool for environmental monitoring and conservation biology (Tomkins and Kotiaho, 2001). Fluctuating asymmetry analysis was performed using symmetrical variables. These variables are a collection of biologically definable homologous landmarks along the body of the fish (landmarks 1-16) (Fig. 3). Measurements were done using PAST software (version 2.05) (Hammer et al 2001).

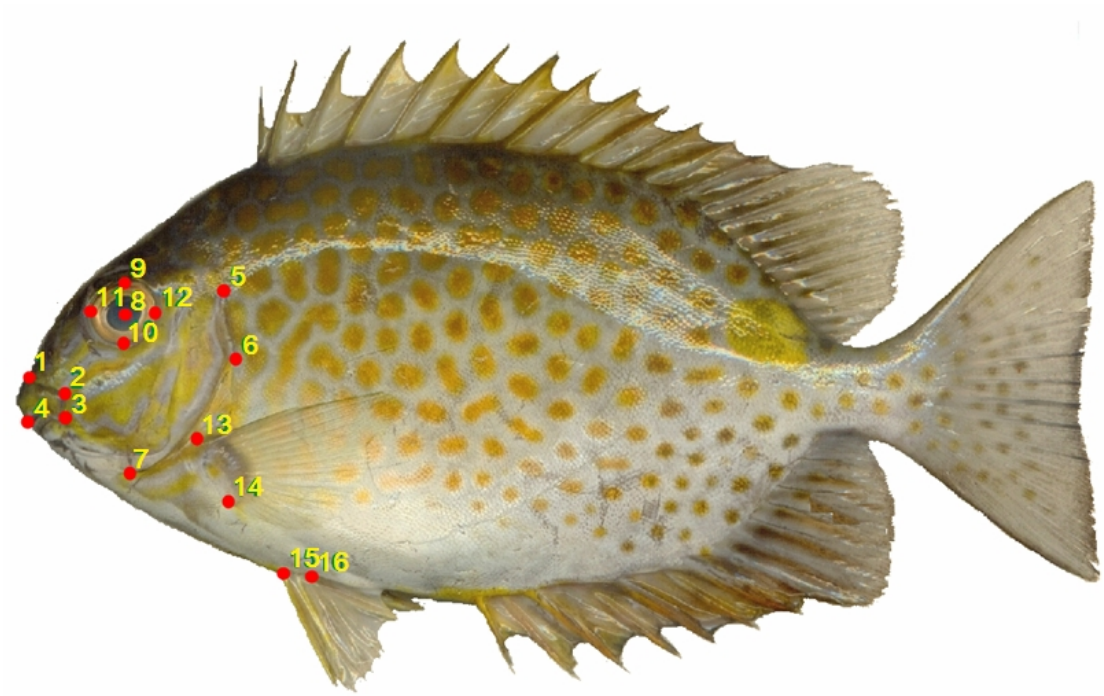

Fig. 3: Landmarks used to examined fluctuating asymmetry.

(1) Anteriormost tip of the snout, (2) Posterior end of the upper maxilla, (3) Junction between the posterior end of the upper maxilla, (4) Inferior margin of the upper maxilla, (5) Posterior margin of the operculum, (6) Origin of the pectoral fin, (7) Insertion of pectoral fin, (8) Superior margin of the orbit, (9) Inferior margin of the orbit, (10) Anterior margin of the orbit, (11) Posterior margin of the orbit, (12) Center of the eye, (13) Posteriormost margin of the operculum, (14) Dorso-lateral angle of the operculum, (15) Insertion of pelvic fin, (16) Origin of pelvic fin

Additionally, six morphologic characters for both right and left lateral side measured for each sex were also included. These are; the number of rays in the pectoral fin (PECT); the number of rays in the pelvic fin (PELV); and the distance from the posterior edge of the eye orbit to the posterior end of the operculum (BACK); Snout length (SNOUT); eye diameter (EYE) and upper lip (LIP) (Fig. 2). These characters were also used because it is present in both sides. Since these study analyzes deviations from perfect symmetry in bilaterally paired structures.

Asymmetry analysis using the coordinates of the landmark points on the digitized images and six morphologic characters used the SAGE (Symmetry and Asymmetry in Geometric Data, version 1.04) software (Marquez et al). To determine repeatability of measurements, testing for fluctuating asymmetry was measured thrice (replicates) per individual and was labeled with the same ID number.

Tab. 1: Body length, weight and area in males and female sexes of *S. guttatus.*

Population	Male				Female			
	N	Length	Weight	Area	N	Length	Weight	Area
Surigao Sur	9	18.18±3.17	153.56±79.98	41.72±7.81	28	15.56±1.57	89.86±30.3	51.81±14.57
Davao City	16	21.44±0.76	263.31±23.24	79.05±4.99	11	22.05±0.95	292.18±38.38	85.18±7.57
Plaridel	25	41.24±1.41	189.8±20.42	76.95±13.50	12	21.48±1.57	221.75±64.42	69.07±10.02
Lopez Jaena	25	38.82±1.89	109.28±16	53.78±18.25	12	17.1±2.83	138.64±85.01	47.42±11.13
Zambo Sur	35	15.33±1.48	88.46±29.10	41.91±8.30	*		-	
Zambo City	14	16.42±1.32	115.71±25.43	50.18±7.77	14	16.16±1.51	102±32.13	46.34±9.04
Total No.			124				77	

*No catch

Results and Discussion

Length and Weight Analysis: Measurements of the total length and total weight for each population (Table 1).

As shown in Table 1 and Figure 4, Davao Oriental and Misamis Occidental were found to have the longest total length among all population in both sexes. Lopez Jaena, Misamis Occidental, Zamboanga del Sur and Zamboanga City were found to have the same measurement range based on total length.

Based on the results on body weight measurements *S. guttatus* does not greatly vary between sexes in all population except for Surigao del Sur population wherein males are found heavier than females while population from Davao Oriental and Plaridel, Misamis

Occidental were opposite as females are more heavier than males. Longest measurements of total lengths are found in Davao Oriental and Plaridel, Misamis Occidental population in both sexes. Lopez Jaena, Misamis Occidental, Zamboanga del Sur and Zamboanga City have the same measurement range while fish population in Surigao del Sur differs, males are longer than females.

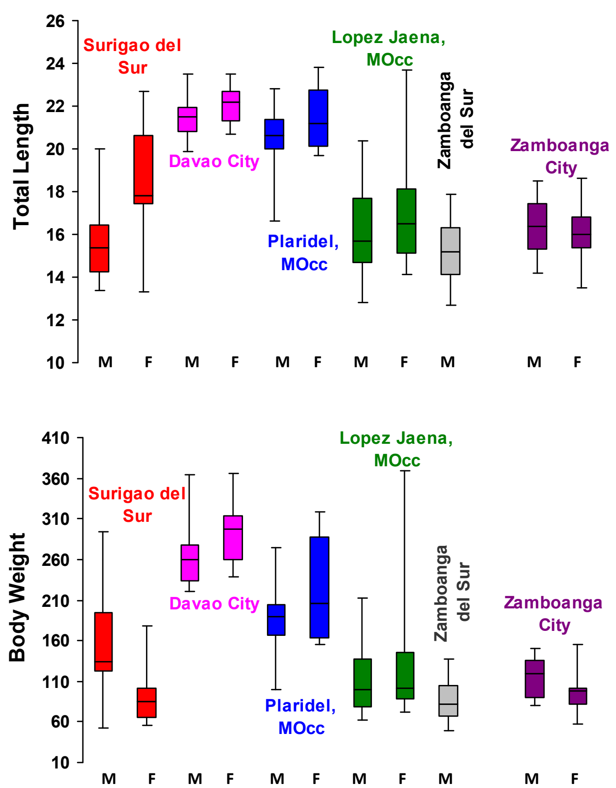

Fig. 4: Boxplot diagram of body weight and total length among populations of *S. guttatus.*

Based on samples collected measurements in body weight of *S. guttatus* does not greatly vary between sexes in all population except for Surigao del Sur population where males are found heavier than females while females in Davao Oriental and Plaridel, Misamis Occidental are heavier than males (Figure 5).

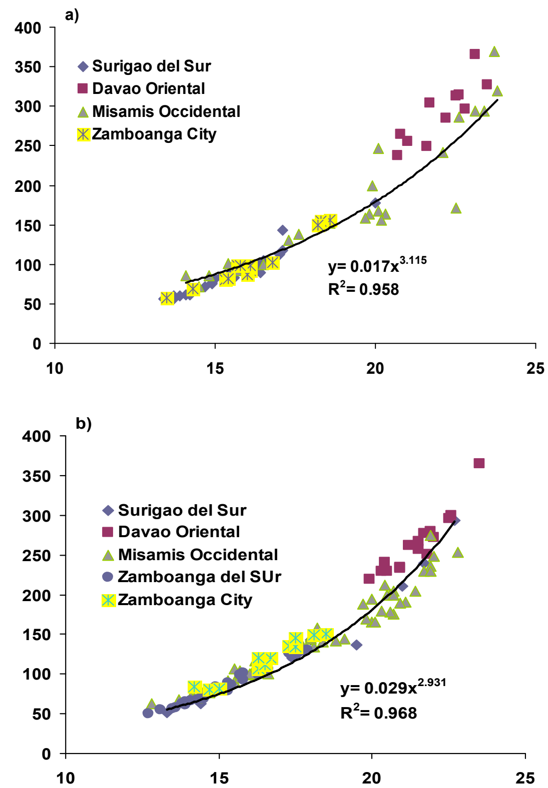

Fig. 5: Scatter plot of total length and body weight of female (a) and male (b) *Siganus guttatus.*

Based on pooled data, the length and weight of pooled individuals, intercept a, slope b values, coefficient of determination (r^2) and p value of both sexes of *S. guttatus* from a total of 199 fishes collected from the different sampling areas in Mindanao bays are summarized in Table 2.

Regression analysis shows length and

weight relationship in both female and male *S. guttatus* were highly significant. Parameter value for length-weight relationship of b = 2.944 indicated a negative allometric pattern which suggests that the length of male *S. guttatus* increases faster than its weight. In contrast, female *S. guttatus* indicates a positive allometric pattern with b = 3.115, suggesting that the weight increases faster than its length. An increase in weight may be an adaptation for increase in fecundity because of the close relation of fecundity to body weight in fish (Reidel *et al.*, 2007). This could be related to the capability of rearing large number of eggs.

Tab. 2: Length (cm) and weight (g) relationship ($W=aL^b$) in male and female sexes of *S. guttatus.*

Sex	N	Total length range	Mean Length	Body weight range	Mean Weight	a	b	r^2	*p* value
Male	77	12.7-23.5	17.79±3.2	50.0±365	17.63±2.9	0.028	2.94	0.967	5.41E-96
Female	124	13.4-23.8	149.89±89	56.0±369	143.45±70.40	0.017	3.12	0.958	6.81E-53

Shape Variation: Variation in body shape between population for both left and right image are shown in Figure 6. Thin-plate spline data from digitized images were used to analyze and examine the body shape difference of *Siganus guttatus* on each population. The Body shape variations are shown as a thin-plate spline warp grids representing consensus shape in each population. Body shape patterns between left and right images shows minimal difference.

Patterns of shape variation among population of *S. guttatus* are summarized via scatter plot diagram between centroid size and shape projections as shown in Figure 6. A deformation grid of the landmark points shows the body shape variations among all population. Fish population from Davao Gulf and Bohol Sea II have largest body size but exhibits narrower body shape compared to the rest of the population which are in small size but has broader body shape. It indicates that shape variations of *Siganus guttatus* are found to be size dependent.

Figure 6B shows thin-plate spline warp grids of consensus mean body shape (left image) in each sampling population. *Siganus guttatus* from Moro Gulf, Illana Bay and Bohol Sea II shares same pattern in body shape attested by the overlapping of population as shown in Figure 6A, having broad body depth and shorter body length. Population in Philippine Sea shows small overlapping on Bohol Sea II with the same body shape pattern except for the shorter

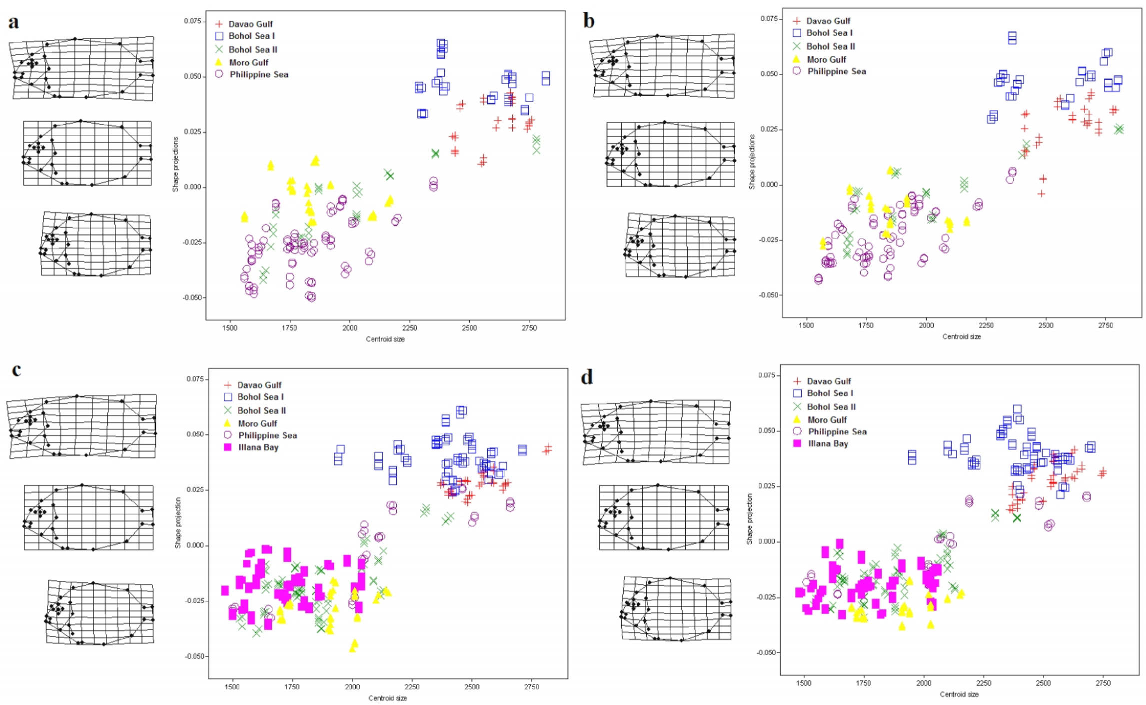

Fig. 6: Scatter plot diagram between centroid size and shape projections of female *Siganus guttatus*. (a) female left image, (b) female right image, 9c) male left image, (d) male right image) in Mindanao, Philippines along with spline plot representation of the smallest, mean and largest shape.

caudal peduncle. Davao Gulf and Bohol Sea I shares same body shape trend, having a narrower body depth and longer body length than the rest of the population.

Significant differences in body shape between populations of *Siganus guttatus* (left image) can be seen on Figure 7A by the distribution of relative warp scores along the first two canonical variate axes (Wilks' lambda = 0.05743, Pillai trace = 1.576; *p*-value = 4.562E-275).

Figure 7B shows significant differences in body shape between populations of *Siganus guttatus* (right image) based on the distribution of relative warp scores along the first canonical variate axes (Wilks' lambda = 0.05154; Pillai trace = 1.726; *p*-value = 3.63eE-273).

Thin–plate spline warp grids of consensus mean body shape (right image) and overlapping of population shown in Figure 7A have the same body pattern on the left image as presented in Figure 7B.

Fluctuating Asymmetry. Presence of Fluctuating Asymmetry were analyzed for both female and male *S. guttatus.* Table 3 provides ANOVA tables and comparison of asymmetry in *S. guttatus* between population. ANOVA shows that fluctuating asymmetry and symmetric variation was found significant in all areas

(ANOVA, p<0.05). Directional Asymmetry (Sides) found significant in almost all population except for *S. guttatus* from Plaridel, Misamis Occidental and Zamboanga City (male) which are non significant.

Tab. 3: Procrustes ANOVA, PCA and pair wise comparison of Asymmetry in female (a) and male (b) S. guttatus collected from different sampling sites.

a) Female

Population	Procrustes ANOVA					PCA
	SS	df	MS	F	p	(FA)
Surigao del Sur						76.90%
Individual (Sym)	0.1811	756	0.0002	1.7744	2.44E-15 [a]	
Sides (DA)	0.0078	28	0.0003	2.0591	0.0011 [a]	
Individual x Sides (FA)	0.1021	756	0.0001	7.9852	<0.000 [a]	
Measurement Error	0.053	3136	1.69E-05	--	--	
Davao Oriental						86.57%
Individual (Sym)	0.0544	280	0.0002	1.4531	0.0009 [a]	
Sides (DA)	0.0136	28	0.0005	3.643	1.44E-08 [a]	
Individual x Sides (FA)	0.0375	280	0.0001	4.4873	<0.000 [a]	
Measurement Error	0.0367	1232	2.98E-05	--	--	
Misamis Occidental						
Plaridel						85.08%
Individual (Sym)	0.1134	308	0.0004	1.8588	3.46E-08 [a]	
Sides (DA)	0.0086	28	0.0003	1.557	0.0392 [a]	
Individual x Sides (FA)	0.061	308	0.0002	11.3914	<0.000 [a]	
Measurement Error	0.0234	1344	1.74E-05	--	--	
Lopez Jaena						85.77%
Individual (Sym)	0.1413	280	0.0005	2.2733	6.36E-12 [a]	
Sides (DA)	0.0084	28	0.0003	1.3455	0.1199 [b]	
Individual x Sides (FA)	0.0621	280	0.0002	4.3592	<0.000 [a]	
Measurement Error	0.0627	1232	0.0001	--	--	
Zamboanga City						89.20%
Individual (Sym)	0.1154	336	0.0003	2.3454	7.11E-15 [a]	
Sides (DA)	0.0117	28	0.0004	2.8591	4.25E-06 [a]	
Individual x Sides (FA)	0.0492	336	0.0001	25.4279	<0.000 [a]	
Measurement Error	0.0084	1456	5.76E-06	--	--	

*a – significant, b – not significant

b) Male

Population	Procrustes ANOVA					PCA
	SS	df	MS	F	p	(FA)
Surigao del Sur						89.55%
Individual (Sym)	0.0966	252	0.0004	3.5618	<0.000 [a]	
Sides (DA)	0.0079	28	0.0003	2.632	3.66E-05 [a]	
Individual x Sides (FA)	0.0271	252	0.0001	5.702	<0.000 [a]	
Measurement Error	0.0211	1120	1.89E-05	--	--	
Davao Oriental						84.65%
Individual (Sym)	0.1357	420	0.0003	2.79	<0.000 [a]	
Sides (DA)	0.0122	28	0.0004	3.75	1.82E-09 [a]	
Individual x Sides (FA)	0.0486	420	0.0001	9.7719	<0.000 [a]	
Measurement Error	0.0212	1792	1.19E-05	--	--	
Misamis Occidental						
Plaridel						80.53%
Individual (Sym)	0.2179	672	0.0003	1.8828	2.22E-16 [a]	
Sides (DA)	0.0336	28	0.0012	6.9647	<0.000 [a]	
Individual x Sides (FA)	0.1157	672	0.0002	5.3919	<0.000 [a]	
Measurement Error	0.0894	2800	3.19E-05	--	--	
Lopez Jaena						79.41%
Individual (Sym)	0.2867	672	0.0004	1.2967	0.0004 [a]	
Sides (DA)	0.0107	28	0.0004	1.1572	0.2643 [b]	
Individual x Sides (FA)	0.2211	672	0.0003	13.7152	<0.000 [a]	
Measurement Error	0.0672	2800	0	--	--	
Zamboanga del Sur						76.41%
Individual (Sym)	0.2244	952	0.0002	2.9443	<0.000 [a]	
Sides (DA)	0.0046	28	0.0002	2.0605	0.001 [a]	
Individual x Sides (FA)	0.0762	952	0.0001	19.5242	<0.000 [a]	
Measurement Error	0.0161	3920	4.10E-06	--	--	
Zamboanga City						83.82%
Individual (Sym)	0.0867	364	0.0002	1.6296	1.81E-06 [a]	
Sides (DA)	0.0048	28	0.0002	1.1632	2.63E-01 [b]	
Individual x Sides (FA)	0.0532	364	0.0001	27.8338	<0.000 [a]	
Measurement Error	0.0082	1568	5.25E-06	--	--	

*a – significant, b – not significant

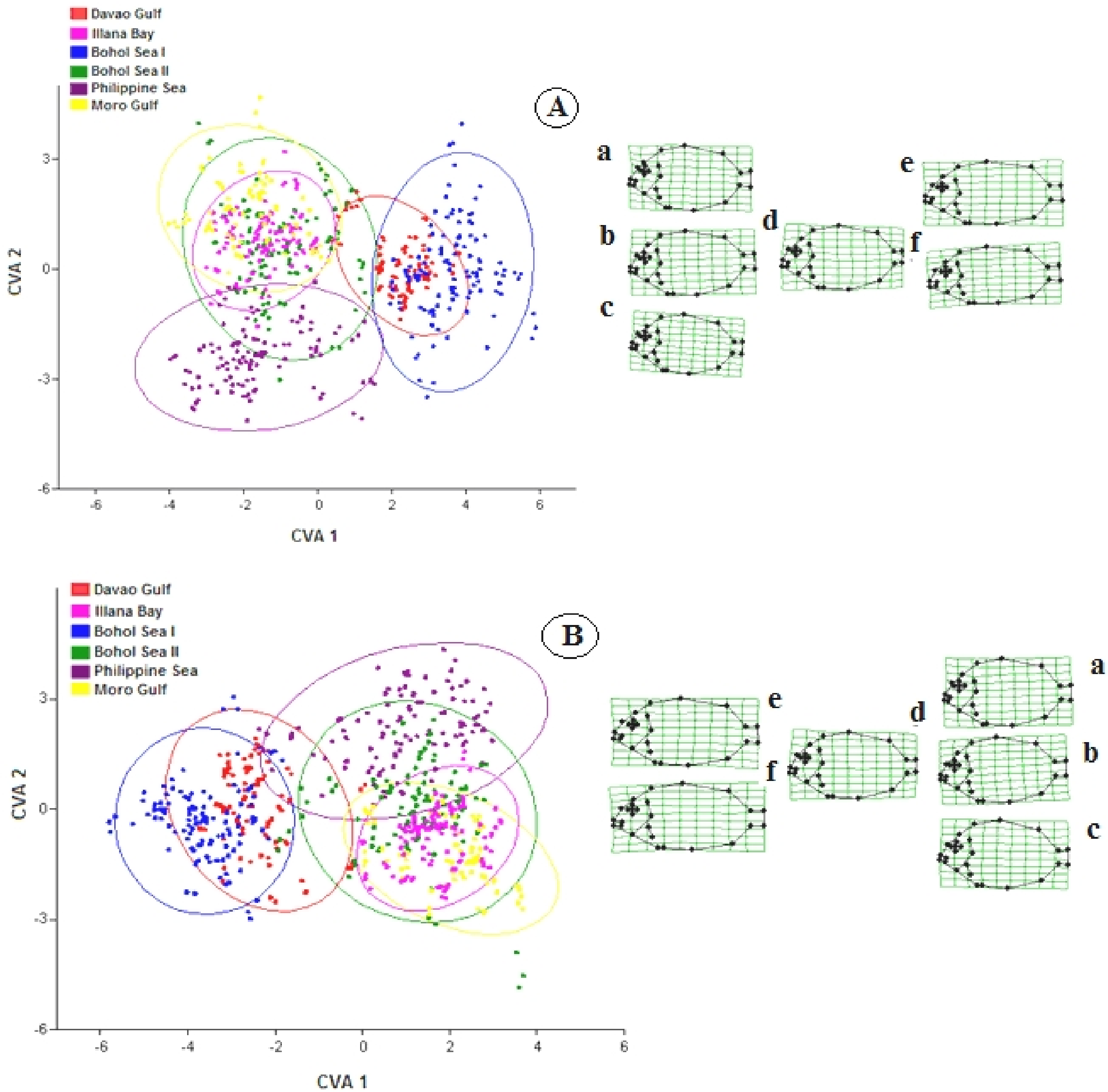

Fig. 7: Distribution relative warp scores and thin-plate splines of *Siganus guttatus*.

(A) Left image, B- Right image along the first canonical variate axes. (B) Thin-plate spline warp grids showing consensus morphology in each sampling area; a (Moro Gulf), b (Bohol Sea II), c (Illana Bay), d (Philippine Sea), e (Davao Gulf), f (Bohol Sea I).

PCA results were shown, it is plotted using deformation grids for individual variation (symmetric), sides variation (directional asymmetry) and individual x sides interaction (fluctuating asymmetry) explaining at least 5% of the total variation. In females, variations are most seen in mouth, eyes and operculum area while on males have variations in operculum and pectoral region.

Presence of fluctuating asymmetry were

analyzed for both female and male *S. guttatus* and found statistically significant in all population together with individual variation or symmetry. Directional asymmetry (Sides) found significant in almost all population except for *S. guttatus* from Lopez Jaena, Misamis Occidental and Zamboanga City (male) which are non significant.

Significant differences in FA shown In PCA results, were detected mostly mouth, eyes and operculum part in females, while on males, significant differences are present in operculum and pectoral region. Presence of asymmetry indicates environmental stress with might be cause by natural events and other factors that causes nutritional deficiences (Bengston and Hindberg, 1985). FA present in the mouth region may be caused by stress in food competition. Differences in water quality like turbidity may caused the stress in eyes and operculum area due to differences with visibility and respiration.

Comparing the results between sexes, PCA results in FA with at least 5% of the total variations show the female population has more than 85% variation. Male population has lower variations than female populations. Except for Surigao del Sur population wherein the males have the highest variation with 89.55% and female population with only 76.90%. Klingenberg (2003) said that the shape changes corresponding to the PCs can often be interpreted in the light of biological knowledge, for instance, on the development of the structure. It is important to note, however, that these are *a posteriori* interpretations applied to the PCs as descriptors of morphological variation-therefore the PCs can suggest hypotheses, but they cannot conclusively identify the underlying causal processes.

S. guttatus are highly esteemed fish in the Philippines with a high market demand and are grown on a commercial scale in polyculture systems (Pilay, 1962). A well-planned selective breeding and line crossing program should be implemented to improve desirable traits in founder stock. Based on LWA, body shape and asymmetry, a character matrix criteria was done to identify positive characteristics of adult *S. guttatus* which could be important in describing populations of the fish and for aquaculture (Table 4). Fishes from Davao Oriental and Plaridel, Misamis Occidental population exhibited large body area, heavier body weight and longer body length characteristics could be good indicators that the quality of fish from these areas are good sources of populations for aquaculture.

Since *S. guttatus* shape are found to be size dependent, selection of potential broodstock should also consider the maturity of fish, most likely, body shape characteristics usually changes as it mature. Like that of channel catfish where males are usually larger and have

Tab. 4: Character matrix criteria of female *Siganus guttatus* for broodstock selection based on shapes and measurements.

Female					
Population	**Body Shape**	**Body Area**	**Body Weight**	**Body Length**	**FA**
Surigao del Sur	broad deep-bodied	medium	light	medium	present
Davao Oriental	narrow-bodied	large	heavy	longer	present
Plaridel, Mis. Occ	narrow-bodied	large	heavy	longer	present
Lopez Jaena, Mis. Occ	broad deep-bodied	medium	light	medium	present
Zamboanga del Sur			*		
Zamboanga City	broad deep-bodied	medium	light	medium	present
Male					
Population	**Body Shape**	**Body Area**	**Body Weight**	**Total Length**	**FA**
Surigao del Sur	broad deep-bodied	medium	medium	longer	present
Davao Oriental	narrow-bodied	large	heavy	longer	present
Plaridel, Mis. Occ	narrow-bodied	large	medium	longer	present
Lopez Jaena, Mis. Occ	broad deep-bodied	medium	light	medium	present
Zamboanga del Sur	broad deep-bodied	medium	light	medium	present
Zamboanga City	broad deep-bodied	medium	light	medium	present

*No catch

broader heads than females. As spawning season approaches, males become leaner, develop even larger, muscular heads, and turn a dark bluish to black color (Chappell, 2008).

A study by Uusi-Heikkila *et al.*, (2010) of a laboratory-held wild *D. rerio* where spawning stock composed of large individuals had higher reproductive output compared to small individuals. Eggs produced by large females appeared to be of higher quality by exhibiting significantly lower mortality rates than eggs produced by small females. Also, a study on genetic influences on egg quality by Brooks *et al.*, 1997, emphasizes that there is a need to take into account the 'male factor', in which the complement of genes from the male will also affect embryo survival and egg quality. *S. guttatus* population from Davao Oriental is a good candidate for males based on the criteria.

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