Morphometric analysis using fluctuating asymmetry and length-weight relationship in Japanese parrotfish, *Calotomus japonicus* (Valenciennes, 1840)

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Abstract. Fluctuating asymmetry (FA) has received increasing attention in the last decade, yet studies on FA in fish communities remain limited in the regional seas of the Philippines. To address this, a mini-study was conducted in the waters of Surigao City, specifically Brgy. Danawan, to assess whether fishes exhibit increased FA in morphological traits under prevailing habitat conditions. *Calotomus japonicus*, a reef-associated marine species, was selected as the study sample. A total of 45 adult individuals were captured using fish nets and spearguns by local fishermen. Geometric morphometrics was applied to analyze FA, while length-weight ratio (LWR), and Fulton's condition factor (K) were used for fish growth analysis. FA was assessed using SAGE and PAST software, assisted by TPS series for landmark digitization, while LWR and K were calculated in Excel. Results showed body asymmetries across landmark points and sexes, with cumulative FA scores of 78.24% and 76.17% for adult males and females, respectively, indicating environmental stress. Growth analysis revealed a slightly negative allometric pattern ($b = 2.9138$, ≈ 3; $R^2 = 0.878$), while individual fish were in good condition (weighted mean $K = 2.10$). These findings suggest that *C. japonicus* may have been exposed to environmental perturbations during development; however, the high individual condition factors ($K = 2.11$) and near-isometric growth indicate that the fish remained plumper as they increased in length. Considering the observed high FA, a bioindicator of environmental stress, these results highlight the need for enhanced management and monitoring of the sampling site to maintain a healthy habitat and ensure sustainable abundance and biomass of *C. japonicus*.

Key Words: developmental instability, fluctuating asymmetry, Fulton's K condition factor, length-weight ratio, morphometric analysis.

Introduction. Organisms in natural habitats face diverse stressors, and their ability to buffer these influences shapes their fitness within populations. Under environmental changes and anthropogenic stresses, organisms experience impaired developmental homeostasis, leading to increased fluctuating asymmetry (FA) (Zakharov 1992; Palmer 1994; Bergstrom & Reimchen 2005).

FA is an ecological concept that phenotypically reflects random deviations from bilaterally symmetrical patterns of anatomical sides of organisms (Van Valen 1962). These deviations indicate changes in growth and condition and may negatively impact the performance of species, such as aquatic organisms (Barton et al 2002). FA of species may increase due to unfavorable conditions, including chemical contamination, temperature changes, population densities, and many other factors (Clarke 1998; Benítez et al 2008). Notably, FA is a biomarker of developmental instability (Clarke 1993; Rasmuson 2002), hence elevated levels of FA are typically associated with decreased developmental stability (Sopinka et al 2016). Morphologically, an organism may be unable to maintain perfect bilateral symmetry during development. Consequently, FA levels are often positively correlated with the intensity of environmental pressures (Palmer & Strobeck 1986; Clarke 1993; Rasmuson 2002). Internal factors influencing the developmental process, such as inbreeding activity, can also contribute to increased FA (Bergstrom & Reimchen 2002; Iguchi et al 2005; Daloso 2014; Jumawan et al 2016). Furthermore, the extent of FA has been also closely linked to individual fitness, as it can reflect a species' capacity for adaptation and survival (Palmer 1994; Oxnevad et al 2002; Palmer & Strobeck 2003; Sopinka et al 2016), and even susceptibility to mortality and diseases (Reimchen & Nosil 2001; Fréchette et al 2003; Møller 2006; Muallil et al 2014; Jumawan et al 2016).

There have been many studies confirming FA as a biomarker for developmental instability and environmental stress, particularly in aquatic species such as fishes. One such study by Lutterschmidt et al (2016) investigated the redbreast sunfish (*Lepomis auritus*) and bluegill (*Lepomis macrochirus*) as biological indicators of urbanization and environmental stress within the middle Chattahoochee watershed. Findings observed significant differences in FA among creeks, with the highest FA levels recorded in the most urbanized creek, suggesting a potential link between urban stress and developmental instability. On the other hand, Joseph et al (2016) reported high FA levels in *Glossogobius giuris* populations, with 69.27% in females and 63.92% in males where the majority of the landmark points were affected in both sexes except for anterior insertion of second dorsal fin and superior margin of the preoperculum. Additionally, Lajus et al (2003) found that FA in certain traits of eelpout, *Zoarces viviparus*, correlated with environmental conditions such as salinity and temperature, while *Barbodes binotatus* from Java, Bali, Sumatra, and Nusa Tenggara reported a higher percentage of FA possibly influenced by internal and external factors, such as environmental pressure caused by river pollution and differences in habitat conditions (Astuti et al 2022).

Considering the growing attention on fishes for FA measurements, this study focuses on the parrotfish, specifically *Calotomus japonicus* (Valenciennes, 1840), due to its commercial and ecological value in the Philippines. Commonly known in Surigaonon as "*Molmol*", *C. japonicus* is a native species in the Philippines and is generally distributed in the Northwest Pacific: southern Japan, and at least as far as Tokyo, and the adjacent Asian mainland. This species is abundant in marine, reef-associated waters and is apparently confined to coastal waters in rocky areas with seaweeds (Froese & Pauly 2025). Parrotfishes comprise approximately 95 species under the family-level taxon Scaridae. In the Philippines, 45 species of parrotfish have been documented, with 24 species across various genera recorded exclusively in Danajon Bank, located in the Bohol Sea and Cebu Strait (Abrenica et al 2021). There is currently no official nationwide ban on the harvesting or sale of parrotfish, despite circulating misinformation. However, Lavides et al (2016) reported a significant decline in bumphead parrotfish, *Bolbometopon muricatum* populations, leading to its classification as Vulnerable on the IUCN Red List. In contrast, parrotfish species such as *C. japonicus* remain listed as Least Concern, although further research on their distribution and population status is necessary to guide effective management and conservation strategies as posited by Maybelle Fortaleza, a University Research Associate at the Coral Reef Resiliency and Ecology Studies Laboratory, University of the Philippines Mindanao (MindaNews 2024).

Given the economic significance of parrotfish to both local livelihoods and the tourism industry, particularly through their role in sustaining reef health and marine balance, pressures such as overfishing and marine habitat degradation pose serious ecological concerns. Overfishing, particularly due to the flock of unregulated fishers as reported by local communities, may significantly compromise parrotfish populations. Moreover, the potential encroachment of illegal fishing activities, poses a threat to essential habitats, including shelter and foraging grounds critical for the species' survival. Furthermore, with the dearth of research ventures on FA in the seawaters of Surigao City, specifically for parrotfishes in Brgy. Danawan, Surigao City, this study aims to assess the morphological patterns and variations between male and female adult *C. japonicus* populations using the FA tool. Additionally, the length-weight relationship (LWR) and condition factor (k_c) status of these fishes across sexes are also evaluated, capturing growth patterns and enabling morphometric comparisons among species, populations, and across different geographic regions (Pauly 1983; Petrakis & Stergiou

1995; Haimovici & Velasco 2000; Morato et al 2001; Ozaydin et al 2007), also providing data that reflect the overall health and environmental conditions of the population.

Material and Method

Sampling site, fish collection and processing. Fish samples of *C. japonicus* were caught using fish net and speargun methods in the open-sea waters of Barangay Danawan, Surigao City, Surigao del Norte, Philippines, during the month of May 2025. Geographically, Barangay Danawan is positioned at approximately 9°55'35" N, 125°30' 03" E, with an elevation of 5.0 meters (16.4 feet) above mean sea level (Figure 1).

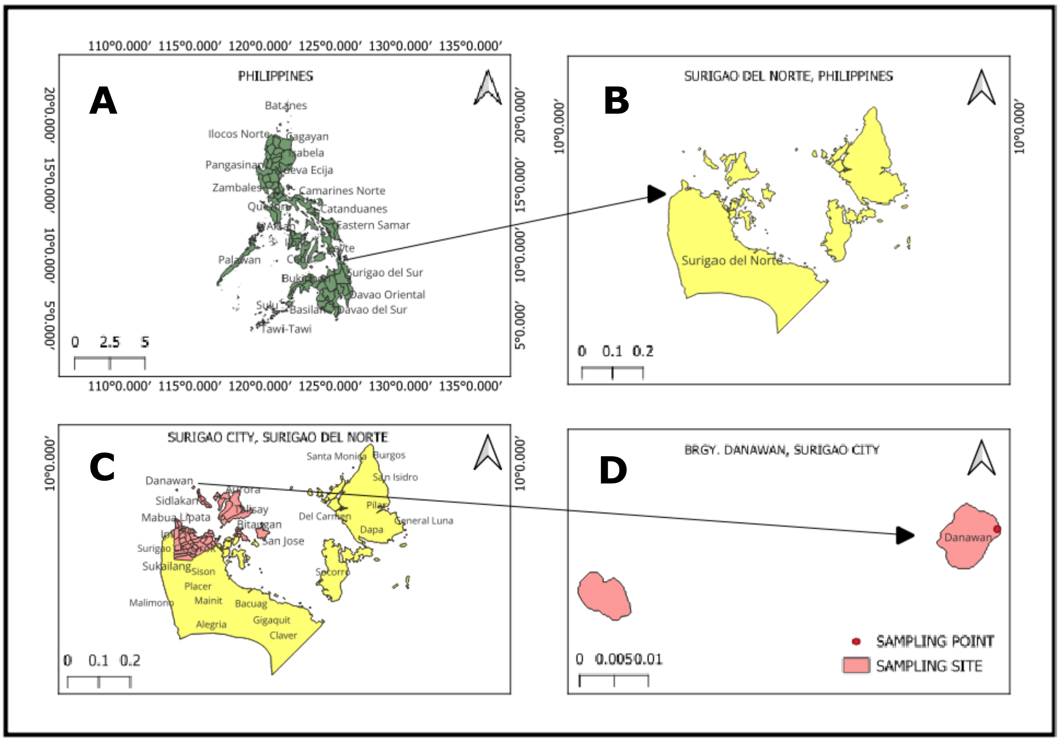


Figure 1. Map of the sampling area showing the Philippines (A), Surigao Del Norte (B), Surigao City and its Barangays (C) and Brgy. Danawan, Surigao City (D).

Specimens were promptly transferred to insulated storage containers and preserved on ice to maintain post-harvest condition prior to further analyses. Each fish was wiped dry using a tissue before subsequent assessments. A total of 45 fish samples collected from the sampling area, of which 25 females and 20 males were identified for morphometric measurements to assess for FA and LWR. Standard length and body weight were measured first, using a ruler with 1 mm and a digital balance, respectively. Following LWR and FA measurements, sex determination was conducted through gonadal inspection. According to Natividad et al (2015), male specimens were identified by the presence of whitish, soft-textured gonads, while females exhibited yellowish, coarsely textured gonads, often containing visible eggs.

Landmark selection and digitization. All fish samples were individually positioned on a 1.22 m x 2.44 m styrofoam board, with the fins and caudal regions carefully pinned to ensure proper anatomical alignment and minimize distortion. A 100 mL solution of diluted formalin was applied to the pinned areas and the fish body parts to maintain tissue integrity during imaging. Each specimen was then photographed thrice from both the left and right lateral perspectives by the same individual using a CANON DSLR camera under standardized lighting conditions to address inter-rater digitization error. The digital images were subsequently processed and landmarked using the software tpsDig2 (version 2.31; Rohlf 2017) for geometric morphometric analysis. A thin-plate spline (TPS) series was used, and landmark digitization was performed to generate outline views for

FA analysis. A total of 16 landmarks, as shown in Table 1, were used for FA assessment, corresponding to 16 X and 16 Y Cartesian coordinates (Chakrabarty et al 2008).

Table 1
Landmark points for FA indices in the body shapes of *Calotomus japonicus* adopted from Chakrabarty et al (2008)

Number	*Description*
1	Rostral tip of premaxillae
2	Posterior end of nuchal spine
3	Anterior insertion of dorsal fin
4	Posterior insertion of dorsal fin
5	Dorsal insertion of caudal fin
6	Midpoint of caudal border of hypural plate
7	Ventral insertion of caudal fin
8	Posterior insertion of anal fin
9	Anterior insertion of anal fin
10	Dorsal base of pelvic fin
11	Ventral end of lower jaw articulation
12	Posterior end of maxilla
13	Anterior margin through midline of orbit
14	Posterior margin through midline of orbit
15	Dorsal end of operculum
16	Dorsal base of pectoral fin

***Shape analysis**.* Figure 2 shows the landmark points of the fish.

Figure 2. Landmark points of male (top) and female (bottom) *C. japonicus*.

The TPS landmark configurations of the left and right sides of *C. japonicus* were then analyzed via Symmetry and Asymmetry in Geometric Data (SAGE) software (version 1.04; Marquez 2007) to evaluate patterns of bilateral symmetry and asymmetry based on principal component (PC) scores. The visualization of specific landmarks could contribute to shape variation within the specimens. Meanwhile, a Procrustes Analysis of Variance (ANOVA) was run to evaluate for significant effects of individual symmetry, side (left vs. right), and their interaction (individual x sides). Body shapes of *C. japonicus* across sex were also evaluated within these tools. A threshold of $p < 0.05$ for the statistical significance was also assessed. Additionally, the application of PAST (Paleontological Statistics; Hammer et al 2001) analysis ascertained the intraspecific sexual dimorphism in shape variation among the samples, with histogram data of symmetry metrics illustrating the differences between male and female specimens.

Length-weight relationship and Fulton's condition factor (K). Length and weight measurements of the specimens were obtained using a ruler and a digital balance. The LWR was applied to estimate standing stock biomass and to compare the ontogenetic development of fish populations (Ayoade & Ikulala 2007). Generally, the relationship between weight (W) and length (L) in fishes is typically expressed as: $W = aL^b$, where W is the total body weight (g), L is the total length (cm), and a and b are the coefficients of the functional regression between weight and length (Beckman 1948; Ricker 1973). The constants a and b were estimated using least-squares linear regression on log-transformed values of length and weight, following the equation: $\log W = \log a + b \log L$ (Zar 1984; Sivashanthini et al 2009). Additionally, the LWR provides a basis for calculating the Fulton condition factor (K), which reflects the overall health and well-being of the fish. Seasonal variations in the K can indicate biological and physiological changes (Kuriakose 2014). K is calculated using the formula: $K = 100 \times W / L^3$, where W is the total weight (g) and L is the total length (cm) of the fish. A condition factor $K \geq 1$ suggests the fish is in good growth condition, whereas $K < 1$ indicates poor growth condition (Ragheb 2023).

Results and Discussions. In this study, the results for Procustes ANOVA for the shape variation of *C. japonicus* from Danawan, Surigao City, Philippines are shown in Table 2. The left and right sides were analyzed to compare the FA. Three factors were analyzed for FA including the individuals, sides, and individuals x sides. For both males and females, the "Sides" and "Individual × Sides" interaction effects were found to be highly significant ($p < 0.0001$), indicating the presence of FA in the species. This suggests that there are small but consistent differences between the left and right sides of the fish, reflecting developmental instability potentially caused by environmental stressors.

Table 2

Procrustes ANOVA for the body shape of *C. japonicus* fish in terms of sexes

Factors	*Sum of squares*	*Degree of freedom*	*Mean square*	*F value*	*P value*
		Male			
Individuals	0.1154	532	0.0002	0.9826	0.5804^{ns}
Sides	0.0164	28	0.0006	2.6592	0.0001**
Individual x sides	0.1174	532	0.0002	22.8704	0.0001**
Measurement error	0.0216	2240	0	---	---
		Female			
Individuals	0.1326	672	0.0002	1.0878	0.1378^{ns}
Sides	0.0192	28	0.0007	3.7759	0.0001**
Individual x sides	0.1219	672	0.0002	21.838	0.0001**
Measurement error	0.0233	2800	0	---	---

Note: ** indicates significant difference ($p < 0.05$).

For *C. japonicus* male, the non-significant p-value for the "Individuals" factor (p = 0.5804) implies that there is no strong variation in body shape between different male individuals. However, the significant "Sides" (p = 0.0001) and "Individual × Sides" (p = 0.0001) factors indicate that asymmetry exists across individuals, and that the degree of asymmetry varies from fish to fish. This is a common pattern observed in fish under environmental stress (Lajus et al 2019), where developmental noise due to habitat degradation or pollutants affects individuals differently. Similarly, female parrotfish also showed non-significant variation among individuals (p = 0.1378), but had highly significant asymmetry between sides (p = 0.0001) and among individuals for asymmetry (p = 0.0001). This difference was in opposite to the findings of Muallil et al (2014) where strains of genetically improved Nile tilapia (GINT) had no significant differences in FA levels between the male and female individuals for all characters. However, previous studies suggested that FA is not usually sex-dependent but rather just a result of shared environmental pressures during development (Palmer & Strobeck 2003). Research has also shown that FA in fish is a sensitive biomarker for environmental quality, especially in areas affected by human activity (Leary & Allendorf 1989). Furthermore, the differences in FA levels among the three GINT strains indicate that FA is highly sensitive in detecting stressors affecting the normal development of GINT species (Muallil et al 2014). Since FA represents small deviations from perfect symmetry due to genetic and environmental stress during development, its detection here may indicate reduced habitat quality, potentially related to the reported habitat disturbance through overfishing and encroachment of illegal fishing activities, such as "boso" (use of compressor for fishing) and "fish poisoning" in the sampling area as reported by the local fisherfolks. Close proximity to human habitation (e.g. pollution) may also cause fish developmental instability and phenotypic change (Mohd et al 2023).

The principal component analysis (PCA) of *C. japonicus* body shape presented in Table 3 further revealed significant patterns of symmetry and asymmetry in both male and female specimens. In males, the first five principal components accounted for 78.63% of the total shape variance, with PC1 alone revealing 27.08%. This component showed 100% directional asymmetry (DA), suggesting consistent left-right differences possibly linked to inherent biological features or chronic environmental exposure. More importantly, FA, which reflects random developmental instability often caused by environmental stress, was evident across PC1 to PC3, each showing a high 36.35% FA and involving all 16 anatomical landmarks. This indicates that male fish may be experiencing substantial stress affecting their entire morphology, possibly due to habitat degradation or pollution.

Table 3

Principal component scores showing the value of symmetry and asymmetry scores with the summary of the affected landmarks

PCA	*Individual symmetry (SA)*	*Sides (directional asymmetry)*	*Interaction (fluctuating asymmetry)*	*Affected landmarks*
			Male	
PC 1	27.0768%	100%	36.3455%	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16
PC 2	20.3336%		36.3455%	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16
PC 3	12.1311%		36.3455%	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16
PC 4	9.9269%		8.5717%	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16
PC 5	9.1597%		5.8755%	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16
	78.6281%		123.4837%	
			Female	
PC 1	46.2468%	100%	34.0542%	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16
PC 2	14.6506%		16.2781%	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16
PC 3	7.9065%		10.7966%	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16
PC 4	7.2467%		8.7079%	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16
PC 5	5.9828%		6.3315%	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16
	82.0334%		76.1683%	

Similarly, in females, the first five PCs explained 82.03% of the variance, with PC1 contributing a dominant 46.25% and also showing 100% DA. However, FA in females peaked at 34.05% in PC1 and gradually decreased in subsequent components. The slightly lower FA values in females may suggest that males are more sensitive to environmental changes, or that sex-specific developmental patterns influence how stress manifests morphologically. All 16 landmarks were consistently affected in both sexes, confirming that the impacts of the environmental pressures to the fish are not localized, rather affecting its entire body shape. These findings are consistent with previous studies, which recognize FA as a reliable indicator of sub-lethal stress in fish caused by factors such as pollution, habitat alteration, and water quality degradation (Palmer & Strobeck 2003; Klingenberg 2015; Lajus et al 2019). The results underscore the potential impact of local stressors in Barangay Danawan, suggesting that *C. japonicus* may be experiencing widespread morphological changes due to environmental disturbance.

Figures 3, 4, 5, and 6 visualize the data using PCA-based deformation grids derived from PC scores (PC 1-5). Red dots highlight the landmark points affected by asymmetries. The plots show warping in different regions, and when magnified with vectors and deformation exaggeration, the landmark points of the fish body shapes become more apparent, allowing observation of both the degree of FA and the direction of morphological change.

In Figure 3, it can be observed that the PC scores for individual symmetry follow a decreasing trend (PC1 > PC2 > PC3 > PC4 > PC5). Correspondingly, the warping of the plots is more pronounced in PC1-PC3, indicating higher deviations from the perfect bilateral symmetry of the individual *C. japonicus* in both the left and right perspectives, however, diminishes in PC4 and PC5. In these plots, the highly affected regions of the fish with more developmental noise or stress include the head and caudal regions of the male fish.

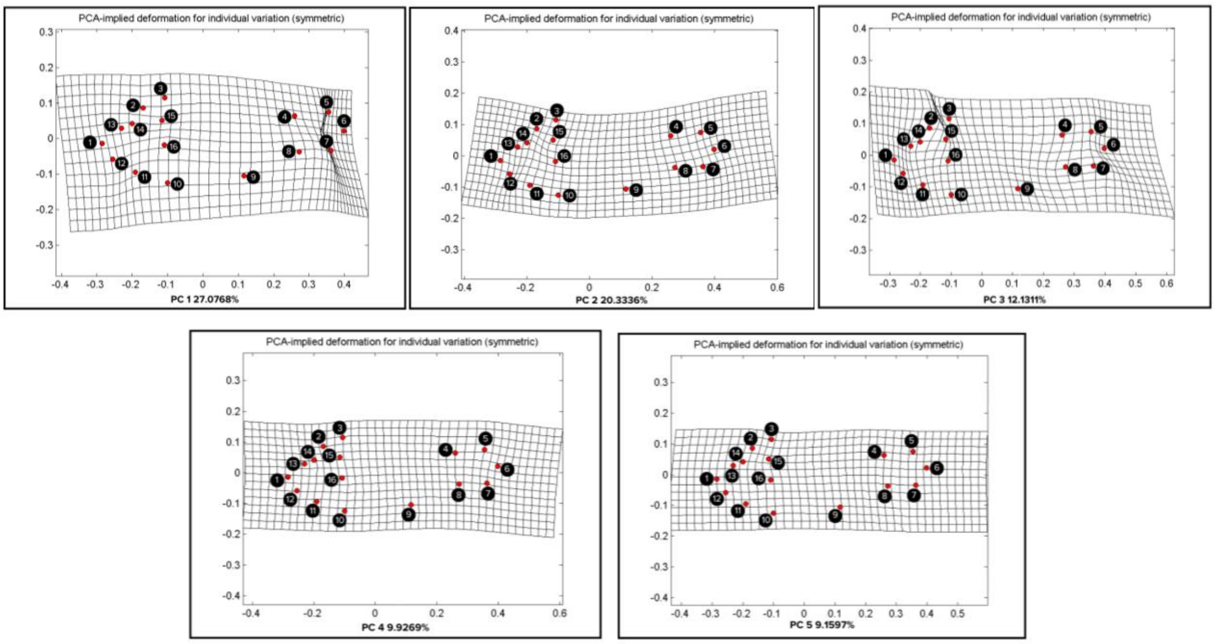


Figure 3. Principal components (PC) implied deformation grid and a histogram of individual (symmetric) in *C. japonicus* female individuals.

Figure 4 illustrates the individual variation of adult female *C. japonicus* based on deformation associated with individual symmetry. Each fish exhibited deviations of body parts from the midline, reflecting bilateral asymmetry. A similar trend to that observed in males was noted, with PC scores following PC1 > PC2 > PC3 > PC4 > PC5. A slight difference in total individual symmetry between males and females was also observed.

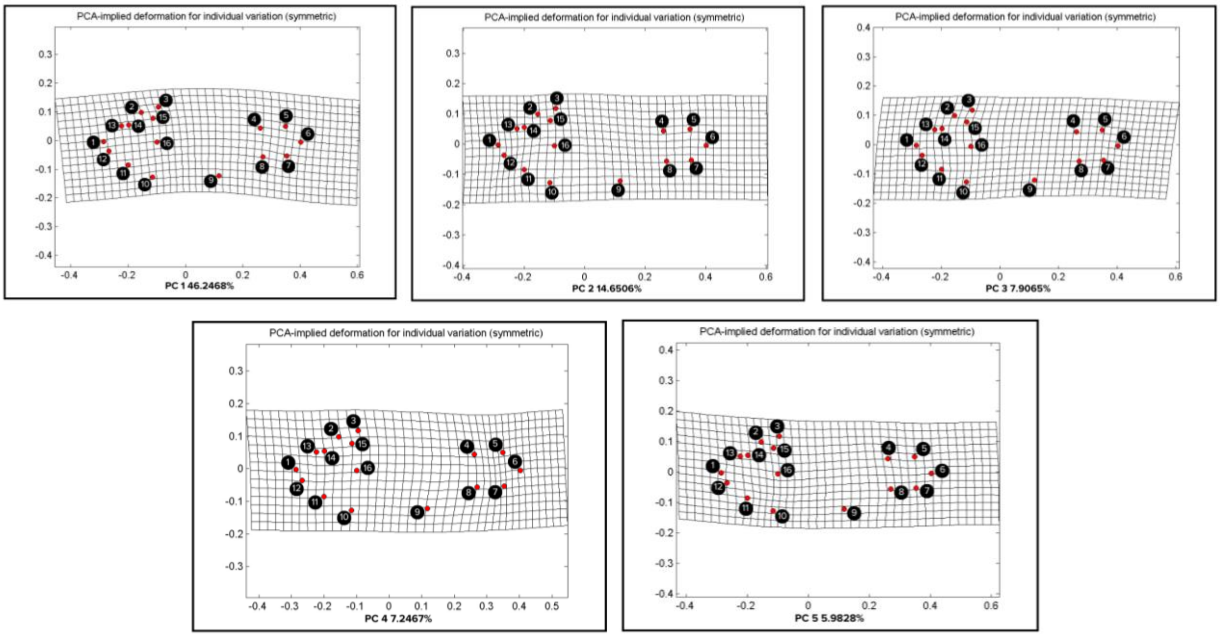
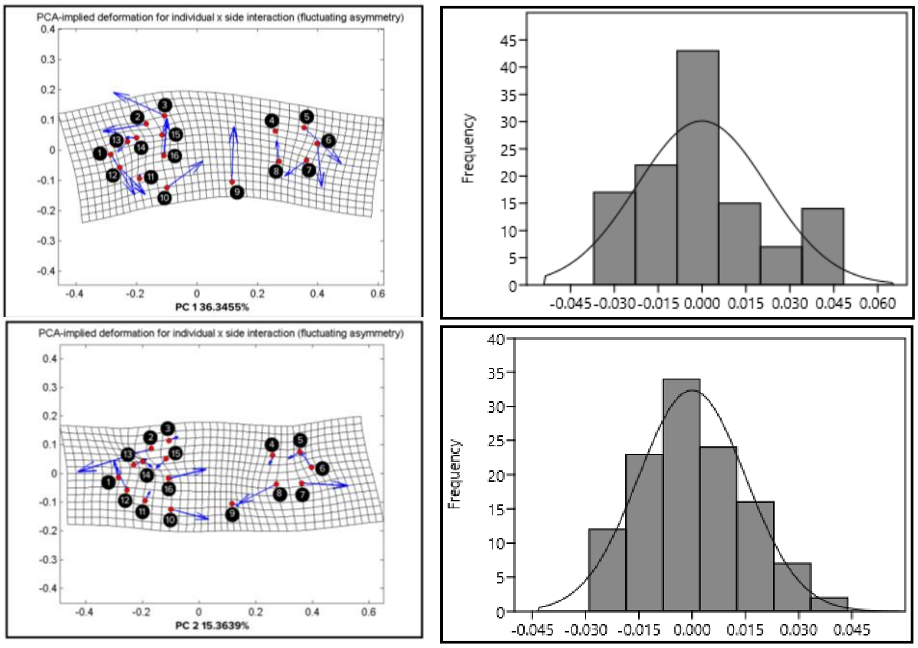


Figure 4. Principal components (PC) implied deformation grid and a histogram of individual (symmetric) in *C. japonicus* female individuals.

Figures 5 and 6 present fluctuating asymmetry data derived from PCA-based deformation analysis of the individual × side interaction, along with the corresponding histogram distribution. Deformation vectors are magnified to facilitate visualization of the magnitude and direction of shape deviations. Figure 5 illustrates the degree of deformation derived from PC 1-5 scores, where a large deformation was observed in PC 1 (FA = 36.3455%) and decreased across PC 2-5. Similar deviations were detected in specific fish regions, namely the head (snout area) and caudal regions, with minimal effects observed in the pelvic and anal fins. This pattern is consistent with the findings of Jumawan et al (2016), who reported that male fish *Cheilopogon pinnatibarbatus* commonly exhibit FA at the snout tip, posterior end of the nuchal spine, anterior and posterior insertion of the dorsal spine, anterior and posterior insertion of the anal fin, and dorsal base of the pelvic fin. Histogram analysis further confirmed that fluctuating asymmetry is present across samples, as the distribution of PC scores was approximately normal (bell-shaped).



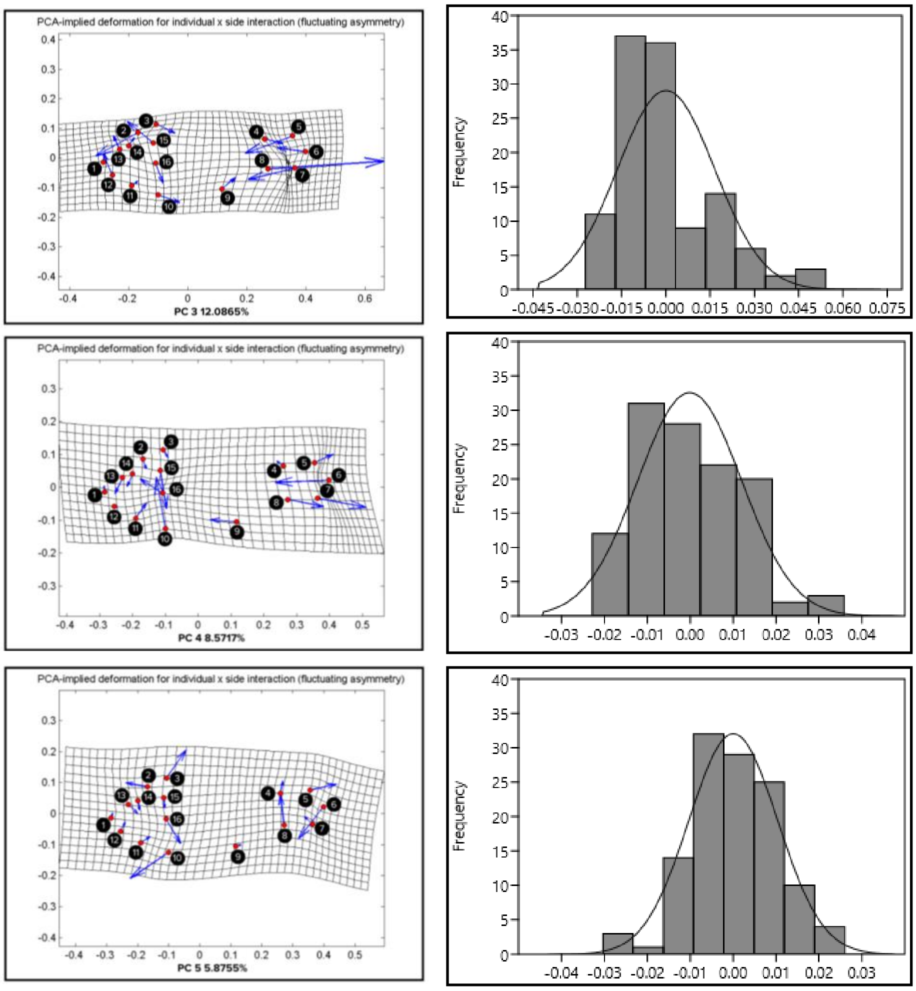
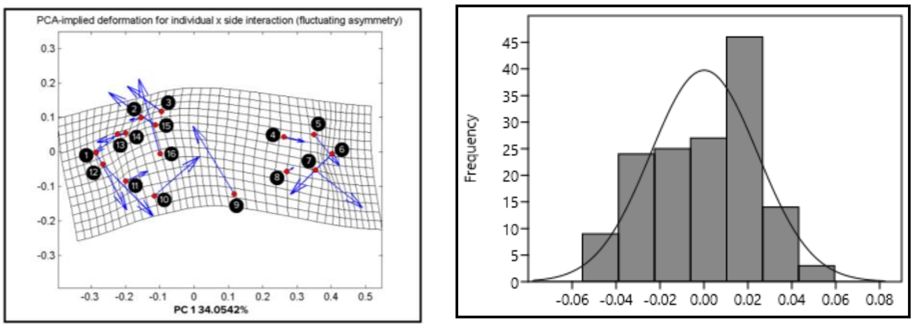


Figure 5. PCA-implied deformation grid and a histogram of fluctuating asymmetry (interaction) in *C. japonicus* male individuals (continued).

Figure 6 illustrates the degree of shape deformation derived from PC1-PC5 scores. The largest deformation was observed in PC1 (FA = 34.0542%), with progressively decreasing contributions from PC2 to PC5. The assessment of FA further indicated that phenotypic variation in the fish samples was primarily concentrated in the cephalic region, particularly in the snout and nuchal spine, as well as at the posterior end of the maxilla. Other deviations were detected in the pelvic region, while minimal asymmetry was observed in the tail region. Overall, Figures 5 and 6 demonstrate relatively elevated FA in the cephalic region, tail, and base of the pelvic area.



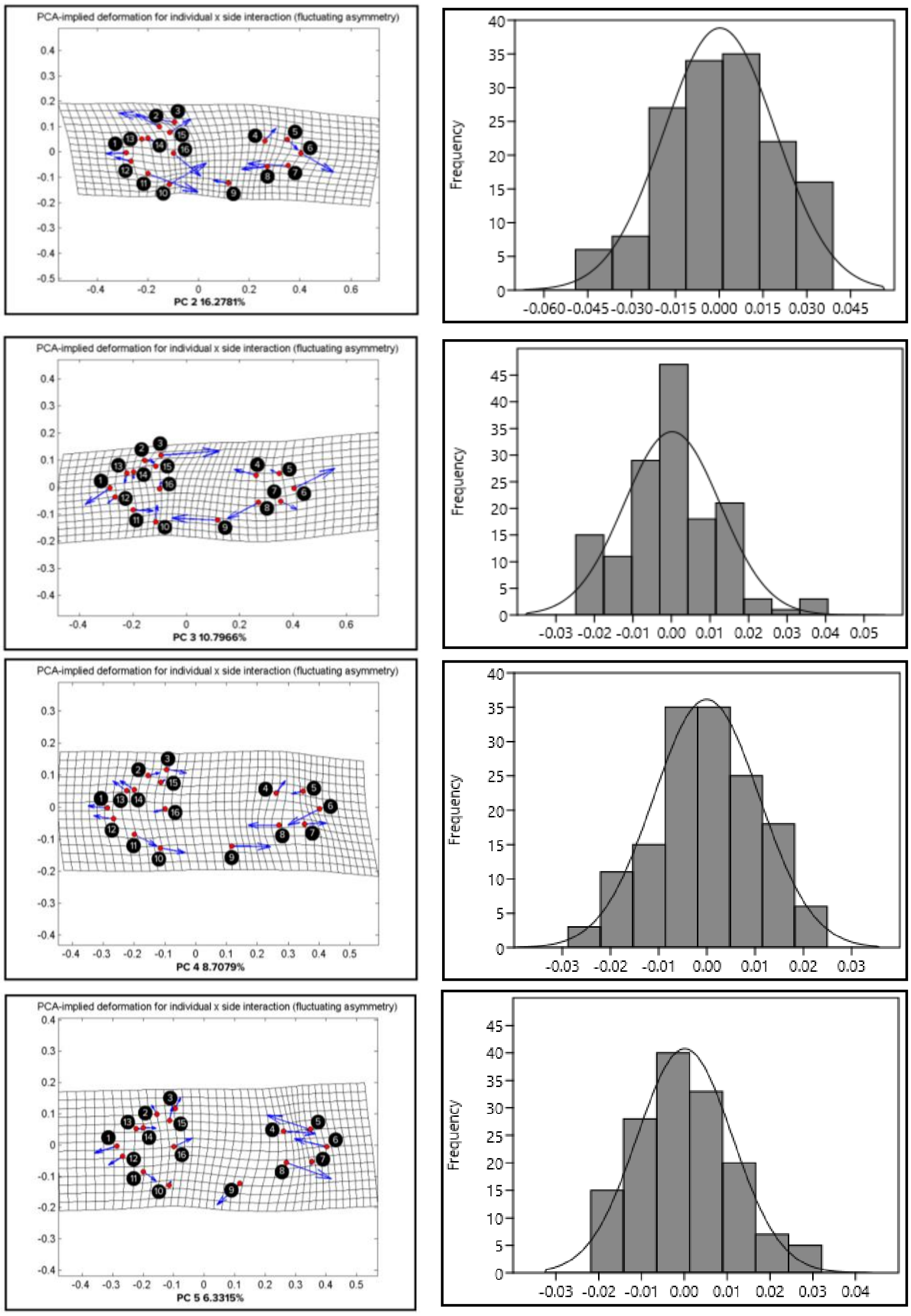


Figure 6. PCA-implied deformation grid and a histogram of fluctuating asymmetry (interaction) in *C. japonicus* female individuals.

Figure 7 shows the scatter plots for the length-weight relationship, while Table 4 presents the K of *C. japonicus* in the sampled area. The estimated allometric parameters of the length-weight relationship were a = 0.02696 and b = 2.9138, with a coefficient of determination (R^2 = 0.878), indicating a significant relationship between length and weight. Across sexes, the value of b suggests a near-isometric growth pattern, as it is close to 3. This indicates that body weight increases slightly proportional than length in both sexes. However, males (b = 2.8239) exhibit a higher growth coefficient than females (b = 2.7629), suggesting that males gain weight at a relatively faster rate in relation to length compared to females. When combined, a b-value reaches 0.878 (negative allometric pattern). This tells only that despite near-isometric condition, the deviation of the b value from 3 may suggest minor environmental pressures. Such disturbances could contribute to developmental instability, as reflected by the observed FA of the fish body parts.

Furthermore, such condition may also reflect from food limitations or altered feeding activity, as suggested by Weatherley (1972), Omogoriola et al (2011), and Fafioye & Ayodele (2018). While, other contributing factors may include reproductive cycles, nutritional stress, and various environmental and habitat-related pressures (Morato et al 2001).

In contrast, K indicated that both male and female *C. japonicus* are in better condition, with mean K values of 2.16 and 2.04, respectively. Males exhibited slightly higher condition than females, consistent with the observed differences in growth patterns. When combined, the overall K value of 2.10 suggests that the population is generally healthy and robust, reflecting favorable environmental conditions. Despite the generally good health of the fish, environmental stressors such as pollution and other human-induced factors may still compromise developmental stability in fish, resulting in increased FA, as observed in the samples.

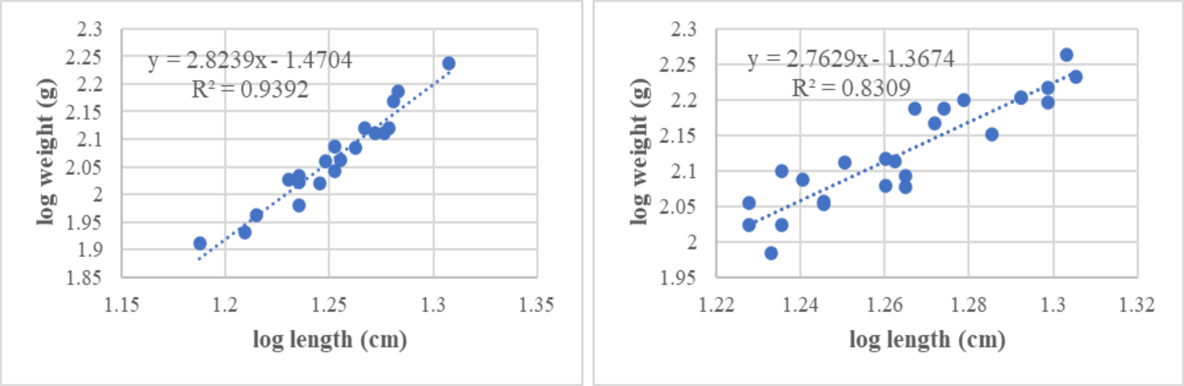


Figure 7. Length-weight relationship results in a scatter plot of male (left) and female (right) *C. japonicus*.

Table 4

Length-weight relationship and Fulton's condition factor of *C. japonicus*

Sex	*Average length (cm)*	*Average weight (g)*	*a*	*b*	*R^2*	*Allometric growth classification*	*Fulton's condition factor (K)*
Male	17.885	117.945	0.0339	2.8239	0.9392	Negative	K = 2.16**
Female	18.432	136.004	0.0429	2.7629	0.8309	Negative	K = 2.04**
Both sexes	18.16	126.97	0.02696	2.9138	0.878	Negative	K = 2.10**

Legend: *b* = 3 (isometric); *b* < 3 (negative allometry); *b* > 3 (positive allometry); * indicates poor condition (< 1); ** indicates good condition (> 1).

Conclusions. Morphological analysis of *Calotomus japonicus* revealed fluctuating asymmetry (FA) across the body, as assessed at 16 landmark points. Both sexes exhibited detectable FA, with males showing slightly higher values than females, particularly in principal components (PCs) 1-3. The overall FA score was 78.24% for males and 76.17% for females. This suggests that *C. japonicus* has been exposed to environmental disturbances, likely resulting from illegal fishing activities and pollution in the open-coast waters of Brgy. Danawan, Surigao City, as reported by local fishermen.

Despite these asymmetrical deviations, the species exhibited a near-isometric growth pattern. Whereas, condition assessment further showed that *C. japonicus* is generally in good condition, likely due to adequate food availability in the habitat.

Overall, *C. japonicus* and other aquatic organisms remain vulnerable to both genetic and environmental stressors. While their fitness allows them to thrive under current conditions, increasing pollution, climate change, and other anthropogenic activities pose significant risks, particularly to aquatic mammals. This mini-study provides valuable insights for enhancing marine protection and management and may help inform authorities in developing policy-based actions to safeguard aquatic ecosystems.

This study acknowledges limitations due to the small sample size of *C. japonicus* and seasonal variations in fish availability. Additionally, physicochemical characteristics of the seawater were not measured, which is why observations from local fisherfolk were used to assess potential environmental pressures in the area. In this regard, the researchers recommend increasing the sample size in future studies and considering additional field sites and data analyses for a more comprehensive investigation.

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Conflict of interest. The authors declare that there is no conflict of interest.

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