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Morphological Variation in the Shell of *Strombus* (Mollusca: Gastropoda) Across Several Local Habitats in Surigao del Sur, Southern Philippines

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Abstract

Shell characters are known to vary spatially in some mesogastropods. This study was conducted to determine the morphological shell variation of the *Strombus* across the several local habitats (muddy, sandy seagrass and corals) at Ganayon, Lianga, Surigao del Sur. Seven shell characters were measured in specimens of three commercially important species of Strombus namely: *Canarium urceus*, *Canarium labiatus* and *Gibberulus gibbosus*. Multidimensional scaling (MDS) was used to detect dissimilarities of conspecifics of the three *Strombus* species. Results showed that populations of the two *Strombus* species (*C. labiatus* and *G. gibbosus*) were clustered in the same quadrant regardless of habitat types. The *C. urceus* specimens collected in the sandy and muddy seagrass beds were located differently in the two dimensional plot, suggesting bigger disparity between conspecifics. The *C. urceus* collected in the muddy seagrass were clustered together with *C. labiatus*. On the other hand, *G. gibbosus* was separately grouped in another quadrant. Correlation analysis among shell characters also showed the biggest difference in the number of significant correlation coefficient (i.e., lip thickness vs. other shell characters) between conspecifics of *C. urceus* collected at the two local habitats. The lip thickness of *C. urceus* is evident, suggesting some degree of phenotypic plasticity, but not in the other two species. This study confirms that certain shell character (i.e., lip thickness) in *C. urceus* exhibited differences between adjacent habitats (sandy seagrass vs. muddy seagrass beds).

Keywords: *C. urceus*, *C. labiatus*, conspecifics, *G. gibbosus*, phenetics, shell morphometry

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1.0 Introduction

The genus *Strombus* belongs to the group of tropical mesogastropods of the family Strombidae. In the Philippines, there are 26 species of Strombus out of 38 species for the Indo-Pacific region (Abbott, 1960). All *Strombus* species are considered commercially important in the Philippines. They are also abundant wherever they occur, and are generally associated with sandy muddy bottoms and seagrass beds (Cob et al., 2007; Erlambang and Siregar, 1995; Abbott, 1960). The ecological study of *Strombus* in the Philippines is very limited despite having an active artisanal fishery in some areas. Ciasico et al., (2006) contributed some knowledge on the stock assessment of *Strombus* in Samar (Central Philippines), including its fishery. It should be noted that the manner of extraction (harvesting) and the range of habitats occupied by several *Strombus* species could be different in other parts of the Philippines where they are abundant. Ciasico et al., (2006) contributed some knowledge on the stock assessment of *Strombus* in Samar (Central Philippines), including its fishery. It should be noted that the manner of extraction (harvesting) and the range of habitats occupied by several *Strombus* species could be different in other parts of the Philippines where they are abundant.

While *Strombus* can be normally found in seagrass beds, observations indicated that they also exist in other substrates such as mud and sand, and in adjacent habitats such as the nearby coral reefs. In Lianga, Surigao del Sur, Southern Philippines, anecdotal observations by fisherfolks indicated that there are observable morphological variations among shell characteristics of *Strombus* of the same species suggesting morphometric variability of the shell. Studying the variations of shells can provide ontogenetic information, and could eventually lead to understanding the small variations in behaviors exhibited by certain species of *Strombus* already adapted to live in adjacent habitats (Brusca and Brusca, 2003). The variations of shells may be attributed either to genetic differences or to environmental stresses acting on the genotype to influence phenotypic expression of characters (Kemp and Bertness, 1984). For example, Dewitt et al., (1999) showed that shell shapes of the gastropod depend on the presence of predators in the local populations. Crab predation on sheltered areas where gastropods occur, are more abundant leading to its variability (Boulding et al., 1999; Reimchen, 1982; Crothers, 1970). Also, the rich epifaunal communities known to subsist on macroalgae from intertidal rapids could provide these snails with abundant food, thus allowing for rapid growth (Boaden et al., 1975) and could lead to phenetic variations among shells characters.

In this study, we determined the variability of shell structures in three species of *Strombus: C. urceus*, *C. labiatus* and *G. gibbosus*, across several adjacent habitats (seagrass and corals). From the shell measurements, Multi-Dimensional Scaling (MDS) was used to detect the underlying groupings of the

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three *Strombus* species collected from several local habitats. Using this analysis, we hope to confirm the anecdotal observations of the fisherfolks that some *Strombus* species exhibited phenetic variations, thereby serving as informative models for future morphological research on mesogastropods.

2.0 Research Methodology

Collection

The study area was conducted adjacent to the Marine Protected Area (MPA) of Ganayon, Surigao del Sur, Southern Philippines (fig. 1). Collection of *Strombus* specimens was done approximately four km away from the nearest households, during the NE monsoon. At this time of the year, strong waves splashed the intertidal area. The *Strombus* specimens which included *C. labiatus*, *C. urceus* and *G. gibbosus*, were collected from the seagrass beds and coral reef as suggested by the shell collectors. The identification verification was based on the books and descriptions by Poppe (2008), Poutiers (1998) and Abbott (1960).

Figure 1. Map of the Study Area, Ganayon, Lianga, Surigao del Sur (markers: yellow:- corals; green-muddy seagrass; red- sandy seagrass).

Sample processing

After collection, the specimens were narcotized with 3.5% magnesium chloride solution (Huet et al., 1995) and placed in the refrigerator. After 24 hours, the samples were placed in 10% seawater formalin solution and kept frozen prior to analysis. The meat of the shell was extracted by pulling slowly the soft body without the need to break the shell. This technique proved to be very practical and significantly lessen mucus secretion by the organism (Cob et al., 2007).

Morphometric measurements

The various linear morphological characteristics of the shell (fig. 2) were measured to 0.01 mm using a digital Vernier caliper. The measurements include: shell length (SL), body whorl length (BW), shell width (SW), shell depth (SD), aperture length (AL), operculum width (OW) operculum length (OL) and lip thickness (LT). A total of 520 specimens were measured representing three *Strombus* species collected from two local habitats (seagrass beds vs. coral reefs) with the seagrass beds having two different substrates (muddy vs. sandy).

Data Analysis

The measured dataset was analyzed using Multidimensional Scaling (MDS) to explore and detect underlying similarities or dissimilarities of measured shell characteristics between species found in different local habitats. On the other hand, to determine which combination pair of shell parameters was significantly correlated, the entire dataset was partitioned by species and by habitat and a correlation matrix was done for each subset of data.

3.0 Results and Discussion

A small scale *Strombus* fishery involving gleaning activities was observed in the area, despite

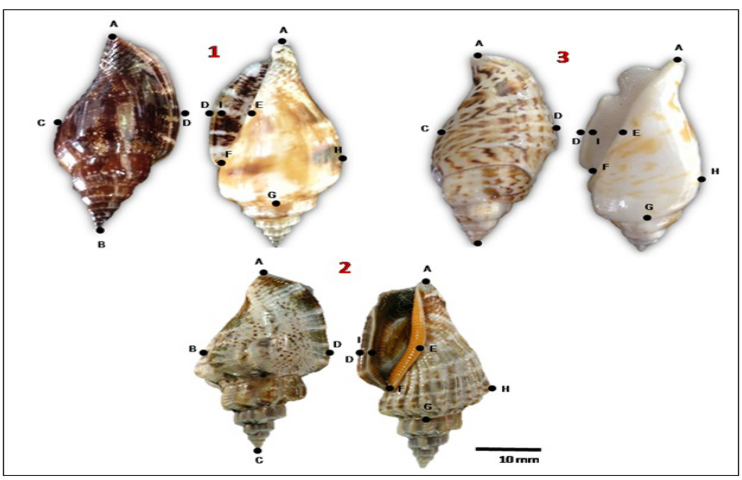

Figure 2. The shell characters of *C. urceus*; *C. labiatus*; and *G. gibbosus* (Shell Length SL (A-B); Shell Width SW (C-D); Operculum Width OW (D-E); Lip Thickness LT (D- I); Aperture Length AL (A-F); Body Whorl Length BWL (A- G); Shell Depth SD (F-H).

being proximal to the Marine Protected Area (MPA). During several visits to the area, massive collections of the evident. Anecdotal observations showed that daily shell gleaning activities last for 4-6 hours. Five gleaners reportedly collect conch at approximately 500 kgs per week particularly in the seagrass, corals and even at the outer reef habitats. The gleaners prefer for the Southwest Monsoon season because gleaning activity is easier due to small wave actions. The shell length samples (Table 1) that was randomly collected in the area was consistent with the World Register of Marine Animals (WoRM) taxonomy in terms of the common size. The SL of *C. urceus* of 35-40 mm; *C. labiatus* of 30-38 mm; and *G. gibbosus* of 40-45 mm, indicate that the degree of exploitation in the area is not intensive because majority of the samples collected were still considered as adults. A study on the stock assessment of *Strombus* is necessary to confirm this observation.

This study suggest that shell characters of *C. urceus* were somehow linked to its local habitat. The anecdotal observation by fisherfolks on the phenetic variations among shell characteristics of *C. urceus* is worth reporting here. They observed that that the lip thickness of the operculum of *C. urceus* inhabiting the muddy seagrass is very thin compared to the shells that were collected in the sandy seagrass. The observations by the fisherfolks corroborated with this measurements (Table 1) that there was a big difference in lip thickness of *C. urceus* between the two local habitats. Thus, the *C. urceus* specimens that live in muddy and sandy seagrass exhibit phenotypic shell plasticity; although a large scale sampling is necessary to confirm this.

Multidimensional Scaling Analysis

Table 1 above shows the morphometric variability of the shell characters of 3 species of *Strombus*. The 3 species of *Strombus* have different mean values due to species specific morphology of the genus *Strombus*. One of their distinctive features is the body whorl. The *G. gibbosus* specimens have BWLmeans ranging from 33-34 mm followed by *C. urceus* (29-32 mm) and *C. labiatus* (25-27 mm). The *G. gibbosus* has distinctive spires with at least five whorls, with very distinct sutures. *C. urceus* has three to five rounded spire whorls. *C. labiatus* has axial nodules consisting of five to seven whorls.

The multidimensional scaling (MDS) analysis using the 8 shell characters collected at several local habitats evidently separated the populations of 3 species of *Strombus* into 3 clusters according to different quadrants (fig. 3). The stress value is 0 suggesting that the result of MDS analysis is of high resolution. The *C. labiatus* that inhabited the sandy seagrass and corals were clustered in the first quadrant including *C. urceus* samples collected in the sandy seagrass. The *G. gibbosus* samples that both occupied in the coral and seagrass habitats were located in the second quadrant. However, only the *C. urceus* that inhabited in the sandy seagrass was located in the third quadrant. Interestingly, the *C. urceus* specimens collected from the sandy seagrass and muddy seagrass were located separately in quadrants 1 and 2, respectively.

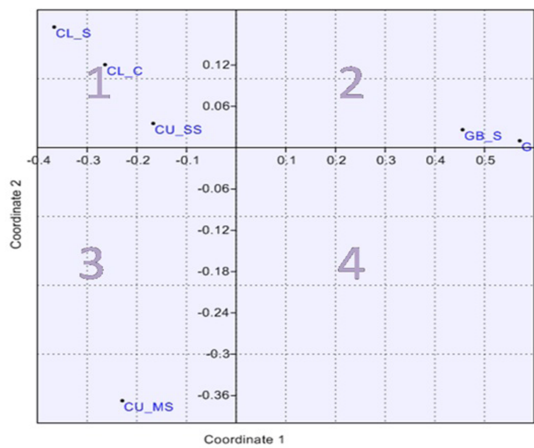

Figure 3. A 2D representation showing the proximities of 3 Strombus species collected in their local habitats (CU_SS: *C. urceus*- sandy seagrass; CU_MS: *C. urceus* - muddy seagrass; CL_ C: *C. labiatus*- corals; CL_S: *C. labiatus* - sandy; GB_C: *G. gibbosus*- corals; GB_S: *G. gibbosus* - seagrass).

Table 1. The morphometric variation (mean in mm and standard deviation) of the shell characters of three *Strombus* species collected in different local habitats (Ganayon, Surigao del Sur, Southern Philippines)

Shell Characters	*C. urceus*		*C. labiatus*		*G. gibbosus*	
	Sandy Seagrass	Muddy Seagrass	Corals	Seagrass	Corals	Seagrass
N	100	100	100	100	100	100
SL	38.21 ± 3.67	36.83 ± 2.68	37.21 ± 2.31	37.11 ± 3.02	41.31 ± 3.76	40.91 + 3.42
SW	17.72 ± 1.78	16.54 ± 1.38	16.84 ± 1.29	16.37 ± 2.00	20.06 ± 1.62	19.48 + 1.68
BWL	32.29 ± 3.02	29.33 ± 2.08	27.52 ± 1.95	26.55 ± 3.73	34.03 ± 2.93	33.18 + 2.96
AL	21.84 ± 1.69	25.54 ± 1.69	23.44 ± 2.00	23.39 ± 1.64	30.92 ± 2.63	29.84 + 2.74
OW	6.05 ± 0.51	4.36 ± 0.51	7.03 ± 0.66	6.46 ± 1.54	8.32 ± 0.99	7.95 + 1.08
SD	9.97 ± 4.81	13.55 ± 1.03	14.22 ± 1.38	13.46 ± 1.11	16.91 ± 1.69	16.79 + 1.42
LT	2.29 ± 0.32	0.79 ± 0.31	1.69 ± 0.41	13.46 ± 1.11	1.73 ± 0.27	1.61 + 0.25

Correlation Analysis

Correlation analysis of the shell characters of the three species based on where the species were collected (local habitats). The correlation analysis focused on the association of the lip thickness with other shell characters to confirm further the anecdotal observation of the fisherfolks that the lip thickness (LT) in *C. urceus* varied between muddy and sandy seagrass. Only the highly significant correlation coefficients (p<0.01) of LT vs other shell characters were presented (Table 2) instead of the entire correlation matrices.

Among the three species of conch, *C. urceus* showed a bigger disparity in terms of the number of significant correlation coefficients between their collection habitats (i.e., nothingly significant shell character combination in sandy seagrass vs. 4 highly significant shell character combinations in muddy seagrass). In contrast, *C. labiatus* and *G. gibbosus* collected in different local habitats showed the same highly significant correlation of SW, BWL, SD and AL with LT.

Table 2. Highly significant correlation coefficients between lip thickness (LT) with other shell characters of *Strombus* species across the local habitats (Ganayon, Surigao del Sur, Southern Philippines).

Species	Local Habitat	Shell Characters	r value	*p* value
C. urceus	Muddy Seagrass	* LT is not correlated with all the other shell characters		
	Sandy Seagrass	LT vs SW	0.91	< 0.01
		LT vs BWL	0.81	< 0.01
		LT vs AL	0.84	< 0.01
		LT vs SD	0.74	<0.01
C. labiatus	Seagrass	LT vs SW	0.65	< 0.01
		LT vs BWL	0.76	< 0.01
		LT vs AL	0.55	< 0.01
		LT vs SD	0.49	<0.01
	Corals	LT vs SW	0.76	< 0.01
		LT vs BWL	0.65	< 0.01
		LT vs AL	0.57	< 0.01
		LT vs SD	0.67	<0.01
G. gibbosus	Seagrass	LT vs SW	0.92	< 0.01
		LT vs BWL	0.92	< 0.01
		LT vs AL	0.93	< 0.01
		LT vs SD	0.88	<0.01
	Corals	LT vs SW	0.84	< 0.01
		LT vs BWL	0.78	< 0.01
		LT vs AL	0.89	< 0.01
		LT vs SD	0.78	<0.01

The two dimension plot (fig. 3) from the MDS analysis showed separate location of *C. urceus* in muddy and sandy seagrass. The number of highly significant correlation coefficients in lip thickness versus other shell characters between specimens collected in sandy seagrass and muddy seagrass beds also confirmed the results of the MDS analysis. The congruency on the observation of the fisherfolks and this study confirmed the plastic character of LT in *C. urceus*. On visual observation, the muddy seagrass *C. urceus* specimens were observed to distinctly harbor some epibionts. Muddy areas provide high nutrient loadings creating surface areas upon which microbial life can thrive, thus increasing the primary productivity in muddy areas (Lees et al., 1980). Also the filter-feeding clams and deposit-feeding worms convert the detritus into biomass (Sanger and Jones, 1984). Boaden et al., (1975) also showed that the epibiont species can affect the basibiont shell. Buschbaum and Reise (1999) showed that the presence of barnacles growing on the shell of *Littorina littorea* causes an increase in the snail's volume and weight and a decrease in the locomotion speed and reproductive output. Dittmann and Robles (1991) also reported that overgrown algae on the shells of mussels decreased growth rate increment, while experimental removal of epibionts led to increased growth rates. Previous studies seem to corroborate our current morphological data; the shell length of conch in the muddy area was relatively smaller compared to the conch collected in the sandy area. This observation assumes that fishing pressures is the same across local habitats. Another distinctive characteristic of the *C. urceus* collected in the muddy seagrass habitat is the lip thickness (LT). The mean lip thickness of the conch collected from the muddy habitat was 0.79 mm as against 2.29 mm from the specimens in the sandy habitat. Kitching et al., (1966) observed thicker shells in rocky shores compared to sites sheltered from wave action. Lin and Zhang (2001) showed that thickness is also affected by current strength as shells in areas of high current have a higher risk of shell injury due to dislodgement.Lip thickness in snails relies on the abundance of crabs in the area (Palmer, 1990) since the lesser shell-thickening is inresponse to decreased crab effluents by *N. lapillus*. It is possible that the lip thickness exhibited by *C. urceus* specimens in the muddy area is a possible response to less predation by crabs.The phenotypic plasticity of LT of *C. urceus* across the local habitats is evident. Bourdeau et al., (2015) define this type of character as environmentally contingent expression of phenotypes. He elaborated that the cause of this expression could be adaptive (like the developpment and behavior in response to environmental cues) and non-adaptive (for example, stressful environments or poor diets result in slow growth, low survival or low fecundity). A thorough study in phenotypic plasticity is important as it might influence species interactions; promote divergence among populations and species, and adaptive radiation (Pfennig et al., 2010). The shell characters of *C. labiatus* and *G. gibbosus* were similar across local habitats whether absolute or in relation to each shell character, suggesting no plasticity. According to Hoverman and Relyea (2016), not all species will respond plastically. Hollander et al.,

(2006) emphasized that the phenotypic plasticity is an adaptive trait that is favorable for organisms that inhabit unpredictable environments. He added that restriction to plasticity can effectively hinder the production of a favorable phenotype through plastic development, and limits to evolve plasticity might even prevent adaptation to potential environments. Nevertheless, more studies are required to identify whether lip thickness in *C. urceus* is related to local adaptation, allometry, or non-allometric plasticity.

4.0 Conclusion

The *C. urceus* specimens is different from each other across the local habitats (sandy seagrass and muddy seagrass beds) specifically on their lip thickness (LT). However, the *C. labiatus* and *G. gibbosus* were similar across local habitats whether absolute or in relation to each shell character. From these results, the next step is to study the adaptive radiation of *C. urceus* in other distant habitats and check whether LT is truly a plastic shell character.

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