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Morphometric Variation, Growth Patterns, and Interpopulation Comparisons of *Thalamita crenata* (Rüppell, 1830) in Surigao del Norte and Agusan del Norte, Philippines

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ABSTRACT

Thalamita crenata is a commercially and ecologically important crab species, yet comprehensive biological data on its populations in the Philippines remain limited. This study aimed to provide an initial assessment of *T. crenata* populations in Surigao City, Surigao del Norte and Buenavista, Agusan del Norte, Philippines. A total of 104 individuals were sampled and measured at each site. The maturity of the collected individuals was inferred from the mean values of their morphometric indices and the presence of ovigerous females. Descriptive comparisons of morphometric values between the two sites suggested potential variations in growth conditions. Mann-Whitney U tests revealed significant differences in cheliped dactylus length (CDL) between the two populations, with individuals from Buenavista exhibiting larger chelipeds (males: U = 387.5, z = 4.38, $p < 0.0001$; females: U = 639, z = -6.11, $p < 0.0001$). Strong positive Pearson's r correlations between carapace dimensions (width and length) and body weight were observed in both areas (Surigao City: r = 0.677-0.695; Buenavista: r = 0.923-0.834) highlighting the utility of carapace size measurements for monitoring growth patterns. These findings provide valuable baseline data for future assessments of mangrove health, fisheries production, and environmental suitability for *T. crenata*. Future investigations should examine environmental factors influencing growth variations and assess potential threats to these populations. Such efforts will be crucial for developing effective strategies for more proactive environmental management among related marine ecosystems.

Keywords: *Morphometrics, allometry, breeding capacity, crabs, mangrove ecosystem*

1 Introduction

Crabs are a diverse group with numerous species holding significant economic value, driving the need for comprehensive research on their biology (Noori et al. 2015). The Portunidae family, a prominent and diverse group, includes commercially important crabs like the European shore crab (*Carcinus maenas*), mud crabs (*Scylla* spp.), and swimming crabs (*Portunus* spp.)

(Davie 2021). This family comprises approximately 38 genera and over 300 recognized species, identified by a flattened dactyl on their fifth leg (Huang & Shih 2021, Koch et al. 2023). Despite this diversity, taxonomic uncertainties persist at both the family and subfamily levels within the superfamily Portunoidea (Martin et al. 2016). An economically valuable member of the Portunidae family is *Thalamita crenata* (Rüppell, 1830), also known as the crenate swimming crab or spiny rock crab. This species is a common inhabitant of mangrove communities (Muhd-Farouk et al. 2017). Typically, small in size, *T. crenata* are collected by artisanal fishers for local consumption using baby trawlers, skimming nets, or crab traps within bays and mangrove creeks (Pratiwi & Dewi Elfidasari 2020, Subang et al. 2020). Similar to mud crabs, *T. crenata* inhabits mangrove ecosystems and may even be discarded as bycatch in mud crab fisheries alongside menippid crabs and hermit crabs (Li et al. 2021).

Beyond their economic value, mangrove crabs like *T. crenata* play a crucial role as ecosystem engineers. Their burrowing activities, or bioturbation, influence sediment formation by reshaping burrows, creating ventilation outlets, constructing flow channels, and building protective walls (Al-Khayat & Giraldes 2020, Xie et al. 2022). These crabs also contribute to nutrient cycling within mangrove communities, and their abundance serves as a potential indicator of threats to the health of the mangrove ecosystem itself (Susanto & Irnawati 2014, Chen et al. 2016, Hamid et al. 2019). Such studies are particularly important in the Philippines, where the expanding fisheries sector has impacted mangrove protection, jeopardizing coastal communities' natural defense against tsunamis and storm surges (Buitreet al. 2019).

Despite its ecological and economic significance, research on freshwater and estuarine crabs in Mindanao Island, Philippines, has been limited over the last decade (Jumawan et al. 2022). The information on *T. crenata*'s biology and distribution remains scarce. Existing records of the species are limited, with Subang et al. (2020) reporting its widespread distribution in Palawan and harvesting through crab pots or fishing nets. Additionally, the species has been documented in the Santiago Dive Point (Camotes Islands) and Pacijan Island (Santiago Bay) (Marine Iconography of the Philippine Archipelago 2004).

To address this knowledge gap and contribute valuable baseline data for future assessments, this study examined the morphometric characteristics and breeding capacity of *T. crenata* populations in Surigao City, Surigao del Norte, and Buenavista, Agusan del Norte. The study also compared these populations and analyzed their morphometric relationships to explore potential growth patterns and environmental suitability. This initial assessment aims to shed light on the role of *T. crenata* in the Philippine mangrove ecosystem, paving the way for future research on their potential as a bioindicator species, and developing effective management strategies for their sustainable harvest and conservation.

2 Materials and Methods

Study Sites

The sample sites were located in Surigao City, Surigao del Norte and Buenavista, Agusan del Norte, with coordinates 9.7571° N, 125.5138° E and 8.7859° N, 125.3686° E, respectively (Figure 1). Sampling was conducted randomly and guided by resource availability, ensuring a representative population selection. Crab samples of several size ranges were kept inside the coolers and transported to the laboratory for proper storage. Identification of crab samples were done using the field guide summary from SeaLifeBase (Ng 1998). Sampling in Surigao del Norte was conducted on 11 April 2021 while sampling in Buenavista, Agusan del Norte was conducted on 21 April 2021.

Crab Species and Habitat Description

Thalamita crenata is characterized by six rounded lobes of nearly equal size along the front margin of the carapace between the eyes, as well as five sharp spines on the antero-lateral margins — key features defining the genus *Thalamita* (Figure 2). Its chelipeds, or pincers, are notably large and strong, adapted for grasping and defense. The carapace surface is smooth, with low but distinct ridges. The overall coloration ranges from dark to olive green, providing effective camouflage in its natural habitat.

The collected species were observed in shallow,

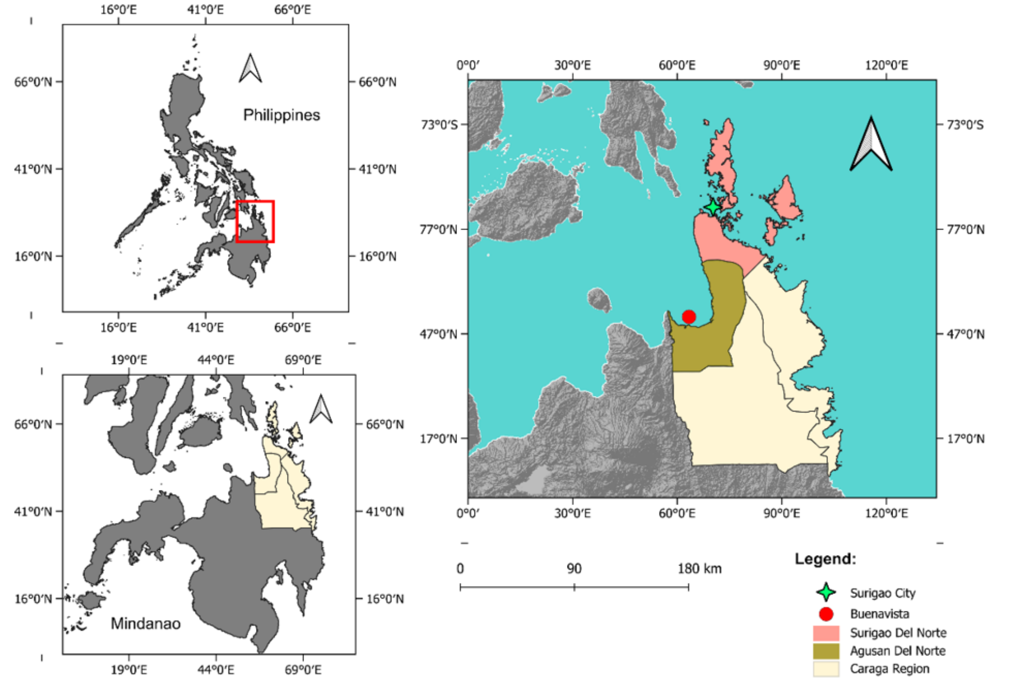

Figure 1. Map showing the sampling site for Surigao City, Surigao del Norte, and Buenavista, Agusan del Norte. Aerial view of both sites and the established coordinates were processed through QGIS v3.36.0.

non-reef habitats with soft substrates, such as intertidal mudflats, estuaries, and river mouths. It favors brackish waters and is especially common in mangrove areas, including muddy or muddy-rocky substrates on intertidal platforms. While less frequently encountered on coral reefs, it can occasionally be found in reef-associated zones. *T. crenata*, a free-living predatory carnivore, primarily preys on slow-moving invertebrates that inhabit mangrove swamps and also acts as a scavenger, helping to maintain ecosystem balance.

Morphometric Measurements

A vernier caliper and a digital weighing scale were used to measure lengths (mm) and the total weight (g) of crabs, respectively. Maximum carapace width (CW), maximum carapace length (CL), frontal width (FW), natatory leg dactylus length (NDL), natatory dactylus width (NDW), cheliped dactylus length (CDL), palm cutting edge (CE), maximum palm length (PL), and maximum palm width (PW) were measured (Figure 3) (Asaduzzaman et al. 2021, Shahdadi et al. 2018). Identification of sexes (Figure 2) were based on abdominal shape: male crabs have a V-shaped abdomen, while females have rather round-shaped (Ng 1992). Females harboring visible eggs (ovigerous) in the abdomen were also noted.

Data Analysis

Descriptive statistics of the morphometric and weight values were used to assess the developmental stages of the populations. The sex ratio of each *T. crenata* was defined as the ratio of the total number of females divided by the total number of males calculated (Wardiatno & Hamid 2015). Distribution of sex were identified through percentage of abundance in each site. Pearson's correlation coefficient (r) was used to analyze the relationships between maximum carapace width (CW), and maximum carapace length (CL) to their respective body weights (BW). Comparative analysis was done by comparing the mean values of the morphometric indices and the body weights and Mann-Whitney U was performed for comparison of Cheliped Dactylus Length (CDL). Statistical analysis was done through the software JASP version 0.14.1.0, and formulation of graphs were done through Microsoft Excel version 2016.

Figure 2. Habitus of *T. crenata*. A) Dorsal view; Ventral view, B) Male showing the distinct V-shaped abdomen; C) Female showing the distinct round-shaped abdomen.

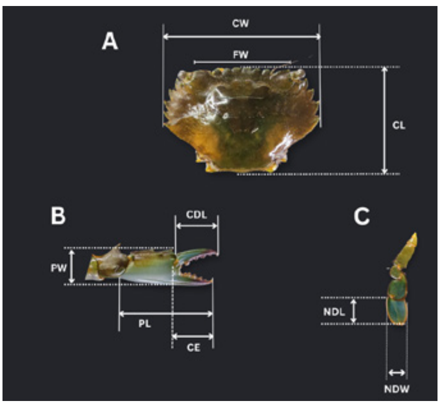

Figure 3. Morphometric indices of *T. crenata*. A) Frontal width (FW) carapace width (CW), and carapace length (CL); B) maximum palm width (PW), maximum palm length (PL), palm cutting edge (CE), and cheliped dactylus length (CDL); C) natatory leg dactylus length (NDL) and natatory leg dactylus width (NDW).

3 Results and Discussion

Proportion and Sex Ratio

A total of 104 specimens of *T. crenata* were collected and measured at each site, resulting in a balanced sex ratio (1:1) in Surigao City (n = 104, 52 males, 52 females) (Figure 4). This suggests a potentially stable population structure at this location, which could be beneficial for long-term recruitment success. Interestingly, in Buenavista (Figure 5), the collected individuals (n = 104) displayed a female-biased sex ratio (1:2.06). The dominance of females (34 males, 70 females) might indicate factors influencing sex determination or differential mortality rates between the sexes in this specific habitat (Ewers-Saucedo 2019). Notably, the observed proportion of ovigerous females was also higher in Surigao City (44%) than Buenavista (24%). This difference could be linked to the observed sex ratio disparity, with a higher proportion of females in Buenavista potentially leading to increased competition for mates, and consequently, a lower proportion of successfully reproducing females. However, statistical analysis using a chi-square test ($\chi 2$) revealed no significant difference ($p > 0.05$) between the sex ratios of *T. crenata* populations in Surigao City and Buenavista (Table 1). This suggests that despite the observed female bias in Buenavista, the overall sex ratio disparity might not be statistically robust. Hence, further investigation is needed to explore the underlying ecological drivers behind these observations.

Table 1. Proportion and sex ratio of male and female of *T. crenata* in two study sites.

Study Sites	Number (*ind.*)		Proportion (%)		Sex Ratio
	Male	Female	Male	Female	Male:Female
Surigao City, Surigao del Norte	52	52	50	50	$1{:}1^{ns}$
Buenavista, Agusan del Norte	34	70	32.69	67.31	$1{:}2.06^{ns}$

** Significant (p < 0.05); ns = not significant (p > 0.05).*

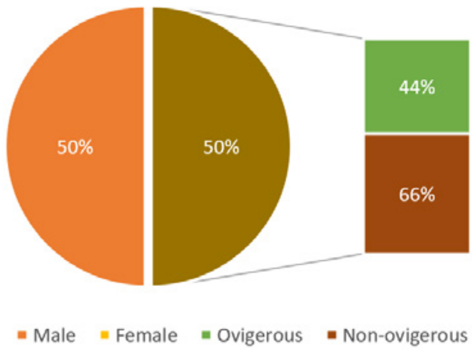

Figure 4. Percentage of sex distribution of *T. crenata* from Surigao City, Surigao del Norte with notes on ovigerous females.

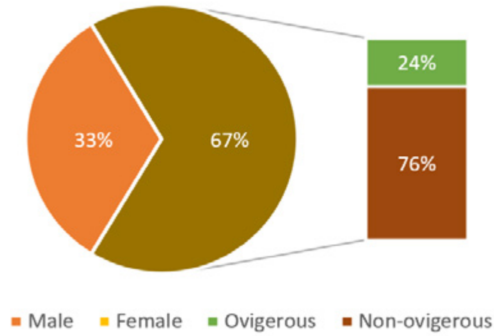

Figure 5. Percentage of sex distribution of *T. crenata* from Buenavista, Agusan del Norte with notes on ovigerous females.

The descriptive statistics for morphometric measurements and body weight in both Surigao City and Buenavista populations (Table 2) reveal a relatively homogenous distribution around the mean values within each location. This observation suggests a high degree of similarity in developmental stages among individuals within each population. The mean maximum carapace width (CW) for males in Surigao City (56.90 mm) and Buenavista (51.18 mm), with the maximum values reaching 67 mm and 70 mm. respectively. This finding aligns with the results of Muhd-Farouk et al. (2017) indicating certain size range as indicative of mature male *T. crenata*. The presence of ovigerous females in both locations strengthens the evidence that the sampled populations consisted primarily of reproductively mature individuals, as supported by Hamid et al. (2019).

While climate can influence breeding patterns, the findings suggest that *T. crenata* populations in Surigao City and Buenavista may exhibit continuous breeding throughout the year. This observation, supported by the presence of ovigerous females and the overall homogeneity of morphometric measurements, aligns with the findings of Hamid et al. (2019). This finding is similar to the observations of Sigana (2002) in Kenya, who reported year-round breeding activity for *T. crenata*. The presence of ovigerous females in Surigao City and Buenavista during April provides further support for this notion, suggesting that *T. crenata* populations in these Philippine locations might also exhibit continuous breeding patterns. The observed homogeneity in developmental stages within each population suggests successful recruitment, potentially

Table 2. Summary of descriptive statistics of identified *T. crenata* from Surigao City, Surigao del Norte and Buenavista, Agusan del Norte.

Morphometrics (mm)	Surigao City				Buenavista			
	Females		Males		Females		Males	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
n	52		52		70		34	
Body Weight (g)	30.96	7.80	37.04	9.90	22.77	9.12	29.15	15.87
PW	10.87	1.28	13.14	2.61	12.23	3.74	13.68	3.84
PL	37.85	4.06	44.96	7.49	33.89	6.41	39.59	9.28
CE	15.33	1.92	18.60	4.56	13.71	3.41	16.00	5.25
CDL	18.58	2.30	21.52	2.82	15.17	2.77	17.68	3.74
NDW	8.27	2.01	9.39	2.46	7.11	1.40	8.47	2.55
NDL	12.12	1.89	13.35	2.11	11.96	2.47	13.06	2.61
FW	32.75	3.00	34.31	4.16	30.96	5.43	31.82	6.72
CL	37.44	3.51	39.67	4.34	31.41	4.62	33.06	6.42
CW	52.92	5.69	56.90	6.10	48.24	6.50	51.18	9.38

indicating stable population structures. The presence of ovigerous females, along with parallels to findings by Sigana (2002) on year-round breeding in Kenya, point towards the possibility of continuous breeding in Surigao City and Buenavista. This information could be valuable for fisheries management strategies, particularly if continuous breeding is confirmed through further studies. However, the current analysis has limitations. Descriptive statistics alone may not definitively pinpoint maturity stages for all individuals. Future research incorporating additional maturity indicators, like gonad weight or histological examination, could provide a more robust assessment of reproductive maturity across the population. Furthermore, while Sigana (2002) reported a brief pause in breeding activity in Kenya, investigations are needed to determine if environmental variations in the Philippines might influence any temporary reproductive hiatuses for *T. crenata* populations in these locations.

Morphometric Patterns and Potential Threats

The analysis of body weight and morphometric measurements revealed notable patterns between *T. crenata* populations in Surigao City and Buenavista (Figure 6). Females and males from Surigao City exhibited larger body size and weight compared to their counterparts in Buenavista. This difference could be attributed to several factors including warmer water temperatures in Surigao City. Crustacean growth rates are positively correlated with temperature, as warmer conditions can accelerate growth by shortening molting intervals or increasing growth increments during molting (Green et al. 2014, Tropea et al. 2015, Shields 2019). Surigao City is situated on the northern coast of Mindanao, closer to the equator. This means it receives more direct sunlight and heat from the sun, leading to warmer water temperatures (Smithson et al. 2013). The smaller size of *T. crenata* in Buenavista might suggest potential suboptimal growth conditions. This could be due to cooler temperatures or other environmental factors like water quality or food availability (Rouf et al. 2021).

Interestingly, despite their overall smaller size, individuals in Buenavista exhibited larger maximum palm widths (cheliped size) compared to those in Surigao City, for both males and females. Mann-Whitney U test revealed a significant difference in cheliped size for both males ($U = 387.5$, $z = 4.38$, $p < 0.0001$) and females ($U = 639$, $z = -6.11$, $p < 0.0001$). These findings provide strong statistical support for the initial observation of larger chelipeds in Buenavista. Larger chelipeds, specifically the cheliped dactylus length, can provide advantages in several ways: increased success in capturing and consuming a wider variety of prey sizes, and enhanced dominance in competition for mates and interactions involving aggression within the species (Masunari et al. 2015, 2020). The larger cheliped size in Buenavista could be a compensatory adaptation to potentially lower food availability or quality in this habitat. Individuals with larger chelipeds might be more efficient at foraging and surviving in such conditions. Alternatively, the increased cheliped size could be result from stronger intraspecific competition for mates or resources in Buenavista, where selection might favor individuals with a competitive advantage in cheliped size.

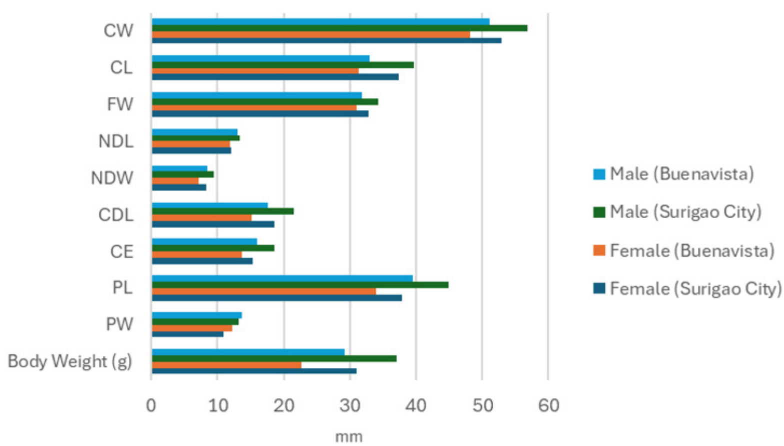

Figure 6. Graph showing the comparison of mean values of *T. crenata* between both sites.

The observed size disparity between the two populations could be further influenced by environmental contamination. Exposure to such contamination could affect oxygen consumption among crustaceans, potentially altering metabolic processes and affecting overall fitness (Capparelli et al. 2016). Aquaculture farmers in Surigao del Norte are practicing mud crab fattening methods for increasing production yield, potentially affecting the quality of other species within the mangrove communities (Sulima 2017). The province is also known to be the location of several mining corporations wherein records of metal concentration on marine sediments revealed high metal enrichment specifically in Pb and Cu (Tomaquin 2014, Capangpangan et al. 2015).

In Agusan del Norte, sediment analyses within the selected mangrove communities along the Butuan Bay area showed contaminations of Hg, Ni, and Cr at the level above the standard for sediments, and contamination of Pb in the muscles of mud clams are also above the standard level (Elvira et al. 2018). Although the current study did not directly measure heavy metal levels in *T. crenata* tissues, the documented presence of heavy metal contamination in sediments and mud clams from Buenavista raises significant concerns. As benthic scavengers and omnivores, *T. crenata* are likely exposed to these contaminants through their diet or by filtering contaminated water (Chen et al. 2016). Bioaccumulation of heavy metals can negatively impact growth, development, and reproductive success (Ebol et al. 2020). The potential for heavy metal bioaccumulation in Buenavista could contribute to the observed smaller size of *T. crenata*. While this size disparity relative to Surigao City might be linked to reduced growth rates due to heavy metal exposure, further scientific investigation is required to determine a causal relationship.

Carapace Width and Carapace Length to the Body Weight Relationship

The relationships between carapace dimensions (width and length) and body weight in *T. crenata* populations from Surigao City and Buenavista were analyzed. The findings revealed a strong positive correlation between both carapace width (CW) and carapace length (CL) with body weight (BW) in both locations (Figures 7 & 8). This positive

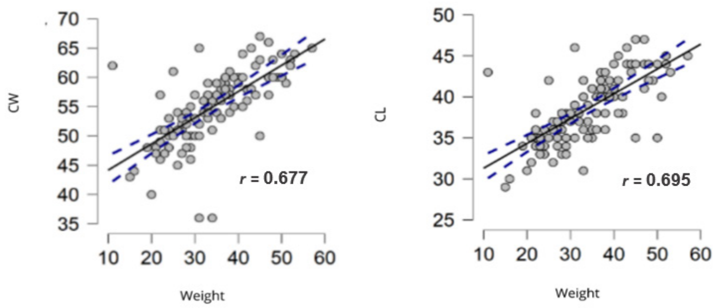

Figure 7. Scatter Plot showing the relationship of the maximum carapace width (CW) and maximum carapace length (CL) *T. crenata* to its body weight from Surigao City, Surigao del Norte, Philippines.

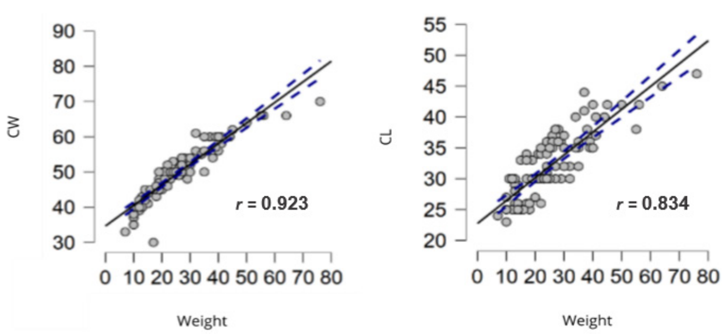

Figure 8. Scatter Plot showing the relationship of the maximum carapace width (CW) and maximum carapace length (CL) *T. crenata* to its body weight from Buenavista, Agusan del Norte, Philippines.

correlation is statistically supported by Pearson's r values, which were 0.677 and 0.695 for CW-BW and CL-BW in Surigao City, respectively. Notably, the correlations were even stronger in Buenavista, with Pearson's r values reaching 0.923 and 0.834 for CW-BW and CL-BW, respectively. The positive correlation between carapace size and body weight in *T. crenata* aligns with crustacean biology principles (Widigdo et al. 2017). As these crabs grow, they molt, requiring a larger exoskeleton.

Carapace width and length, commonly used to measure size, increase proportionally with body weight (Johnston & Yeoh 2020). This reflects the relationship between structural size and overall biomass. Larger individuals have more muscle tissue, organs, and other components, leading to greater weight. Allometry, where body parts grow at different rates, explains this connection (Bezerra Ribeiro et al. 2017). In crustaceans, carapace dimensions are isometrically related to body weight, meaning they increase proportionally to accommodate the growing body (Taylor 2018). Additionally, the growth of muscle mass, crucial for movement and feeding, significantly impacts body weight (Pescinelli et al. 2015), as does the development of internal organs as individual grows larger (Wu et al. 2020).

The strong positive correlations observed in this study offer valuable insights for understanding T. crenata populations. Carapace size measurements can be used as a non-lethal method to estimate body weight and monitor growth patterns, which is crucial for fisheries management and stock assessment (Viswanathan et al. 2016, Vermeiren et al. 2021). Furthermore, these relationships can be used to assess habitat suitability. Stronger correlations, like those seen in Buenavista, might suggest a more favorable environment with ample food resources that allow individuals to attain larger sizes. Finally, the CW-BW and CL-BW relationship data can be compared to existing studies of other crab species to identify potential differences in growth patterns or ecological adaptations among brachyurans (Bezerra Ribeiro et al. 2017, Hamid et al. 2018, Redjeki et al. 2020, Pescinelli et al. 2023).

4 Conclusion and Recommendations

This study of *T. crenata* populations in Surigao City and Buenavista revealed notable morphometric variations, potentially influenced by environmental factors such as warmer water temperatures. Further research is necessary to investigate specific factors, including food availability, water quality, and heavy metal bioaccumulation. This would help better understand population dynamics, mangrove community health and potential health risks associated with human consumption. The findings provide a valuable baseline for future studies, enabling comparisons across time and locations. Investigating environmental factors will contribute to assessments of fisheries production and environmental suitability of the species.

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Statement of Conflict of Interest

To maintain impartiality in the article's evaluation, Jess Jumawan, who serves as the member of the editorial board of JESEG refrained from involvement in the review process of this article. Also, the authors declare that there is no conflict of interest associated with the conduct of this research and the publication of this manuscript.

Author Contribution

PJB Pastor *led the research, conducting field sampling, analyzing data, and drafting the manuscript*. AB Goloran, GL Betco, and CA Salanatin *all made equal contributions to sampling and data analysis*. JH Jumawan *served as a mentor, providing the team with essential skills and shaping the study design.* Dr. Jumawan also *approved the manuscript for submission and waived the review process of this paper* due to his position as a member of the journal's editorial board.

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