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Population Density, Biomass, Secondary Productivity, and Length-Weight Relationship of Mangrove Clam *Geloina expansa* (Mousson, 1849) in a Mangrove Forest of Sto. Tomas, La Union, Philippines

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ABSTRACT

The mangrove clam (*Geloina expansa*) is the most commonly collected bivalve species in the mangrove area of Brgy. Ubagan, Sto. Tomas, La Union, Philippines, serving as both food and a source of additional income for nearby residents. This study aimed to determine the population density, biomass, secondary productivity, and length-weight relationship (LWR) of *G. expansa* to provide valuable information on the status of the clam population in the mangrove area, which can serve as a reference for conservation efforts and potential aquaculture initiatives. The results revealed that the population density of *G. expansa* in the area was 1.78±0.83 individuals per square meter. The biomass and secondary productivity of the mangrove clam were 0.115g dried weight per month and 0.0257g per square meter per month, respectively. The LWR analysis showed that *G. expansa* exhibited a positive allometric growth pattern ($b > 3$), with the LWR equation being $y = 3.3115x - 0.7804$ and an r^2 value of 0.9785. The clay substrate type and high organic matter content in the mangrove area were favorable for the growth and survival of *G. expansa*. Ongoing monitoring and management are essential to preserving both the clam population and the mangrove ecosystem, ensuring the long-term sustainability of *G. expansa* and maintaining the ecological balance of its habitat.

INTRODUCTION

Mangroves, the "rainforests of the sea," are coastal habitats with distinct flora and fauna that sustain biodiversity and provide numerous ecosystem benefits such as sources of food, medicines, timber, and housing materials **(Carugati *et al.*, 2018)**. These aquatic habitats serve as natural barriers for coastal communities, protecting against the impacts of strong waves, storm surges, coastal erosion, and typhoons. They also generate organic biomass, help reduce organic pollution, provide habitats for local and migratory birds, support mangrove flora and fauna, and act as nursery grounds and habitats for aquatic organisms such as fish, crustaceans, mollusks, and polychaetes **(Guannel *et al.,* 2016)**. However, excessive extraction from these habitats poses significant environmental risks and threatens the sustainability of aquatic resources like macroinvertebrates **(Dolorosa & Galon, 2014)**.

Macroinvertebrates are sensitive to environmental changes and serve as important indicators of ecosystem health **(Bendary *et al.,* 2022)**. They contribute to nutrient cycling and sediment stabilization, and serve as a food source for various marine species **(Alongi *et al.,* 2020; Chowdhury *et al.,* 2022)**. There are many studies on macroinvertebrates, mainly focusing on their biodiversity **(Barros *et al.,* 2014; Blanchet *et al.,* 2014; Japoshvili *et al.,* 2016; D'Alessandro *et al.,* 2018)**. *Geloina expansa* is a species of bivalve macroinvertebrate found throughout the Indo-West Pacific region, particularly in Southeast Asia, including the Philippines. Locally, it is referred to as "kaggu" in Northern Luzon, "kibao" in Palawan **(Dolorosa & Galon, 2014)**, and "imbao" in Mindanao **(Bersaldo *et al.,* 2022)**. This species is abundant in mangrove forests and is an economically and ecologically important bivalve that thrives in brackish water mangroves **(Clemente & Ingole, 2011; Argente *et al.,* 2014)**. It is a principal mollusk resource collected by artisanal fishermen for consumption and income generation **(Dolorosa & Galon, 2014; Elvira & Jumawan, 2017)**. Mangrove clam filters plankton and organic debris in brackish swamps, estuaries, and tidal flats through its burrowing behavior, which also enhances nutrient cycling and habitat diversity in mangrove ecosystems by increasing sediment turnover. Furthermore, it functions as a biofilter, facilitating the decomposition of organic waste **(Harefa *et al.,* 2024)**.

Population density provides insights on how populations interact with their environment, including resource availability, competition, and reproductive success **(Wiredufred, 2024)**. Biomass serves as an indicator of the energy available within an ecosystem. It represents the total organic matter that can be utilized by different trophic levels, influencing food webs and ecosystem productivity **(Team, 2024)**. Therefore, monitoring the density and biomass of *G. expansa* is important for maintaining ecological balance, supporting local economies, and implementing effective conservation measures in vulnerable coastal ecosystems like the mangroves **(Tarsi *et al.,* 2012; Bahtiar *et al.,* 2023)**. In addition, secondary production refers to the biomass generated by organisms during their growth and reproductive phases **(Dolbeth *et al.,* 2005)**. Mollusks and crustaceans significantly contribute to secondary production, likely benefiting from extended inundation periods in non-mangrove habitats. In contrast, increased organic matter in mangrove ecosystems may cause hypoxic sediment conditions, reducing secondary production **(Zhou & Cai, 2010)**. Thus, assessing the secondary productivity of *G. expansa* helps explain its contribution to the overall productivity of the mangrove ecosystem, which is vital for maintaining ecological balance and health **(Chahouri *et al.*, 2023)**. Similarly, information on the length-weight relationship and growth rates of *G. expansa* can inform aquaculture practices, enabling better management strategies for farming this species. Given its resilience to varying environmental conditions, *G. expansa* could be a viable candidate for aquaculture initiatives aimed at enhancing local livelihoods **(Argente & Ilano, 2021)**.

G. expansa can be found in the mangrove forest of Sto. Tomas, La Union, Philippines which serves as food and source of income to the nearby residents. However, there is no available information on the status of this important bivalve species in the area. Therefore, this study was conducted to provide baseline information on the population density, biomass, secondary productivity, and length-weight relationship of *G. expansa* on the said locality. The results of the study will serve as initial reference for future studies on *G. expansa* not only in La Union but also in the Philippines in general. In addition, the findings can contribute to policy formulation regarding mangrove conservation, resource management, and increase awareness on the importance of mangroves and their associated biodiversity. Finally, data on growth patterns and population dynamics of this species can support evidence-based decisions that align with sustainable development goals.

MATERIALS AND METHODS

1. Study area

Sto. Tomas is a coastal municipality in the southern part of La Union province, located in Region 1, the Ilocos Region, on the island of Luzon, Philippines **(PhiAtlas, 1990)**. The municipality borders the South China Sea to the west, providing access to significant marine resources and is renowned for its abundant fishing grounds and aquaculture sites. Based on the Fisherfolk Registration (FishR) system of the Department of Agriculture-Bureau of Fisheries and Aquatic Resources, there are 17,403 registered fisherfolks in La Union, with 2,226 residing in Sto. Tomas and engaged in fish and seaweeds farming, fish processing, capture fishing, and gleaning **(Philippine Fisheries Profile, 2022)**. The province has an approximately 114.70 to 155.4km coastline **(DENR, 2019)** and an estimated 152 ha of mangrove areas based on the Ecological Profile of La Union in 2020. Issues such as mangrove degradation caused by aquaculture conversion, illegal settlements, cutting, erosion, siltation, sedimentation, pest infestations, and climate change impacts have resulted to reduced mangrove areas of the province **(Provincial Government of La Union, 2020)**.

The study was conducted in the mangrove area within the vicinity of the College of Fisheries-Don Mariano Marcos Memorial State University-South La Union Campus, situated at Brgy. Ubagan, Sto. Tomas, La Union (Fig. 1). The mangrove species found in the area include *Avicennia marina*, *Sonneratia alba*, *Lumnitzera racemosa*, *Rhizophora apiculata*, *R. mucronata*, and *Bruguiera cylindrica*.

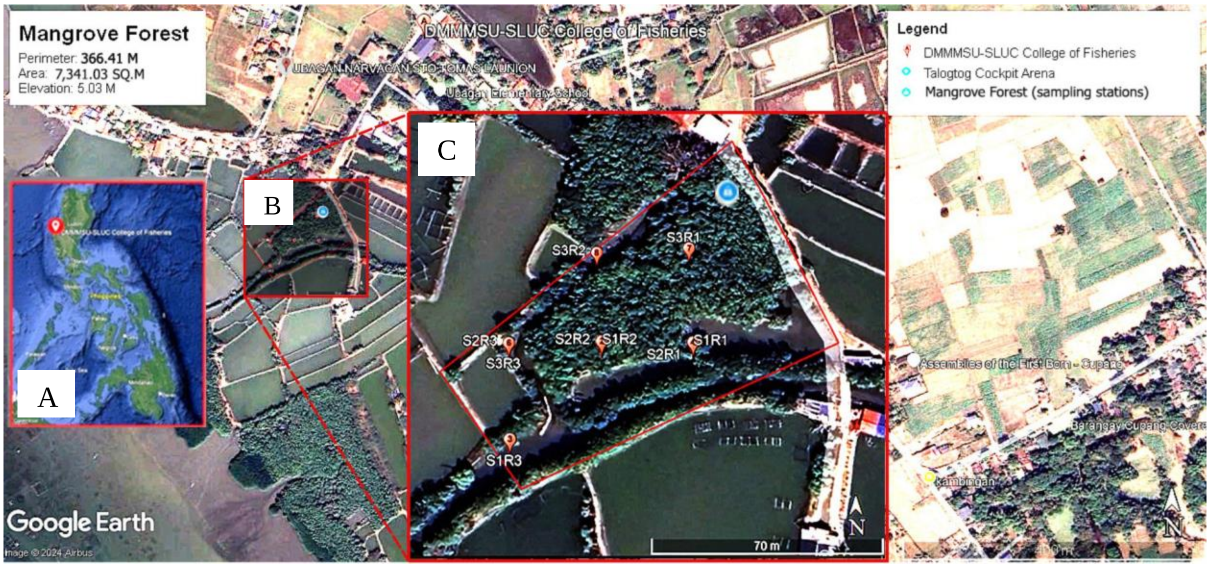

Fig. 1. Map showing the study area and sampling stations: **(A)** Location of La Union province in the Philippines; **(B)** Location of the mangrove area; **(C)** Location of the sampling sites within the mangrove area of College of Fisheries-Don Mariano Marcos Memorial State University-South La Union Campus

2. Sampling stations

Perpendicular to the shoreline, a total of three (3) sampling stations were established in the mangrove area using a transect line method. Each station has three (3) replicates. A 1m x 1m quadrant was installed after every 30m for the collection of samples. The actual coordinates and elevation of each station were obtained using Google Maps Pro (Table 1).

Table 1. Coordinates of the sampling stations

Site Codes	Elevation (m)	Latitude	Longitude
S1R1	6.76	16° 15' 54" N	120° 23' 00" E
S1R2	3.43	16° 15' 54" N	120° 22' 59" E
S1R3	3.74	16° 15' 53" N	120° 22' 58" E
S2R1	5.94	16° 15' 54" N	120° 23' 00" E
S2R2	5.06	16° 15' 54" N	120° 22' 59" E
S2R3	4.88	16° 15' 54" N	120° 22' 58" E
S3R1	5.03	16° 15' 55" N	120° 23' 00" E
S3R2	1.56	16° 15' 55" N	120° 22' 59" E
S3R3	3.35	16° 15' 54" N	120° 22' 58" E

3. Data collection

Data collection in the mangrove area was done during low tide at around 6:00 AM. Based on the tide chart for Sto Tomas, La Union during the sampling period, the first low tide occurred at 06:02h at a height of 0.64m, and the second low tide was scheduled for 15:59h at a height of 0.92m. Collection of samples was done through handpicking with the aid of a shovel. The collected samples for each sampling station were placed in a labeled zip lock then brought to the laboratory for identification and measurement. Composite soil samples were obtained and analyzed by the Department of Agriculture-Regional Soil Laboratory following the Bureau of Soil and Water Management (BSWM) Test Method manual developed in 2022.

In the laboratory, the samples were washed thoroughly before identification and measurement. Data on individual length, wet weight, weight with shell and without shell, and dry weight were recorded. A Vernier caliper with 0.01mm precision was used to measure the length, while a digital weighing scale with 0.01g sensitivity was used to measure the weight of the samples. The constant weight of the samples was obtained by drying the meat of the bivalve samples using a mechanical dryer set at 60^oC with an interval of 30 minutes.

4. Data analysis

The population density of *G. expansa* was determined using the formula used by **Syahputri *et al.* (2023)**:

$$D = \frac{Ni}{A}$$

Where:
D = Clam density (ind/m^2)
ni = Number of individuals (ind)
A = Area of sampling plot (m^2)

The secondary productivity including the biomass of the mangrove clam was calculated using the formula of **Tumbiolo and Downing (1994):**

$$P = a * B^b * W^c * 10^{dT}$$

Where:
P = secondary productivity ($gm^{-2}mo^{-1}$);
B = mean monthly biomass ($gDWm\text{-}^2$);
W = mean individual weight (gDW);
T = Temperature; and
a, b, c, and d = coefficients

The LWR was determined using the power equation: $W = aL^b$, where W represents the total weight; *a* is the intercept, indicating the initial growth; L refers to length; and *b* represents the relative growth rates of the variables and provides information on growth **(Le Cren, 1951; Froese, 2006)**. The parameters *a*, *b*, and r^2 were estimated by linear regression analysis expressed as $\text{Log } W = b \log L + \log a$ with "W" as the dependent variables for logarithm-transformed LWR expression **(Elvira & Jumawan, 2017)**. The growth pattern was determined through *b*-values. When *b* is equal to 3, growth is isometric, *i.e*. the increase in length follows an increase in weight. When *b* significantly differs from 3, growth is allometric *i.e.* increase in length may result to a decrease in weight or vice versa. A negative allometric growth pattern is exhibited if $b < 3$, while a positive allometric is assessed if $b > 3$. Descriptive and statistical analyses were done using the Microsoft Excel version 2010 and Statistical Tool for Agricultural Research (STAR) software.

RESULTS

1. Species identification

The collected samples were identified based on its morphological characteristics. *G. expansa* is considered a synonym of *Polymesoda. expansa*. This species, belonging to family Corbiculidae, has a shell shape expanded posteriorly (Fig. 2) compared to *P. erosa* with a subrhomboidal-ovate shell shape and *P. bengalensis* with subtrigonal shell shape **(Hamli *et al*., 2014)**.

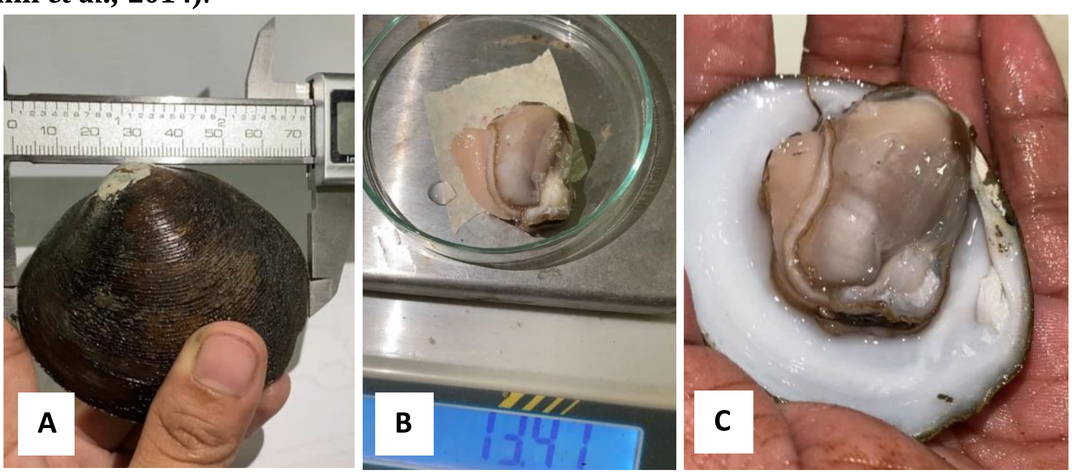

Fig. 2. A mature *Geloina expansa*: **(A)** Measuring the length of the sample using a Vernier caliper; **(B)** Weighing fresh meat of the sample; **(C)** Meat of the sample

2. Population density of *Geloina expans*

Table (2) presents the population density of *G. expansa* for each sampling station. Station 3 recorded the highest density followed by Stations 2 and 1. However, statistical analysis showed no significant difference among the stations in terms of density

(P>0.05). This implies a uniform population of *G. expansa* in the mangrove area. Overall, the population density of *G. expansa* at the study site was 1.78ind/ m^2.

Table 2. Population density of *Geloina expansa* at every sampling station

Station	Density (ind/m^2)
I	1.33±0.58
II	1.67±0.58
III	2.33±1.15
Overall	1.78±0.83

3. Biomass and secondary productivity of *Geloina expansa*

The mean individual dry weight of the samples was 1.033±0.61g (Table 3). The computed biomass of 0.115g indicates the average clam tissue per square meter of habitat over a month. Moreover, the secondary productivity means that *G. expansa* is adding approximately 0.257g of biomass per square meter each month, which reflects the efficiency of energy transfer from food sources to this organism, as well as its growth and reproduction rates.

Table 3. Secondary productivity of *Geloina expansa* in the mangrove area

Family/ Species	W (gDW)	B (gDWm^{-2})	P (g$m^{-2}$$mo^{-1}$)
Corbiculidae *G. expansa*	1.033±0.61	0.115	0.257

W = mean individual dry weight
B = mean monthly biomass
P = secondary productivity

4. Length-weight relationship of *Geloina expansa*

A total of 28 individuals of *G. expansa* were collected from the mangrove area. Total length of the mangrove clam ranged from 1.8 to 7.7cm while the weight ranged from 1.17 to 118.44g. The mean total length and mean weight were 5.84±1.42cm and 67.69±34.46g, respectively. The LWR equation is y = 3.3115x - 0.7804 with r^2 of 0.9785 (Fig. 3). Results revealed that the *G. expansa* exhibited a positive allometric growth pattern (b>3) in the mangrove area. Statistical analysis showed a significant positive relationship between length and weight of *G. expansa* (P<0.01).

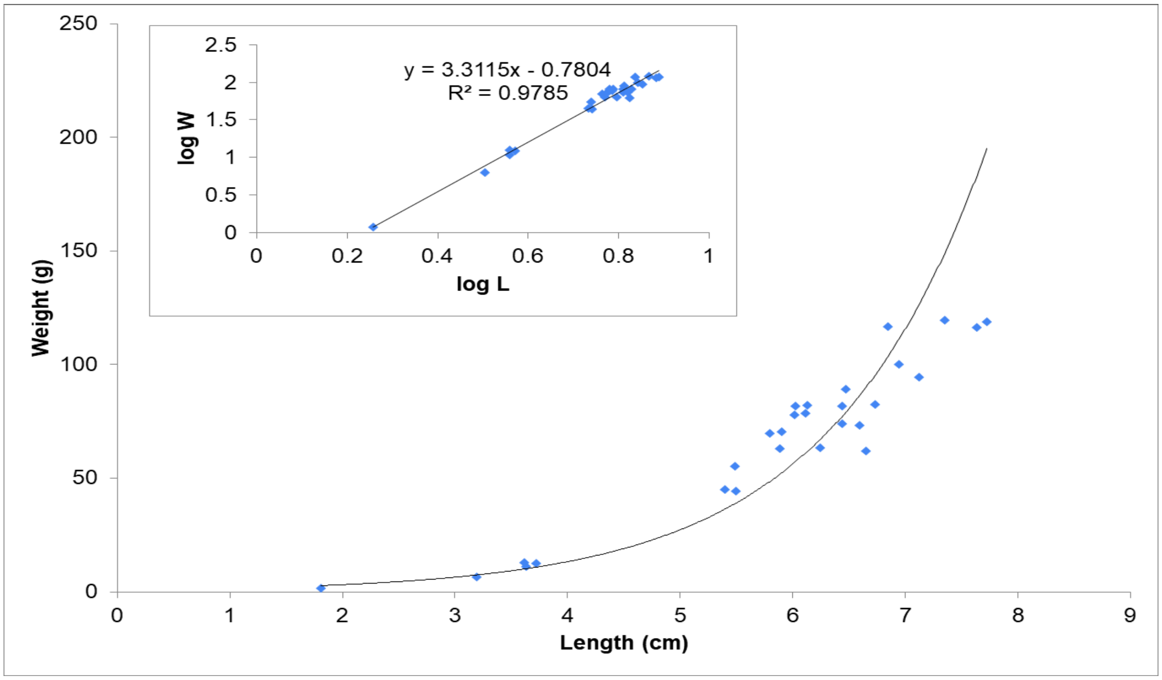

Fig. 3. Length-weight relationship of *Geloina expansa* collected from the mangrove area

5. Soil properties in the mangrove area

Table (5) presents the physico-chemical properties of the soil collected from the sampling sites. These include soil texture, percent moisture, pH, and macronutrients such as percent organic matter, phosphorus, and potassium. Based on the results, all sampling stations have a clay soil texture. Station 2 obtained the highest percent moisture followed by Station 1 and Station 3. The pH of the soil was acidic at all stations. In terms of macronutrients, Station 2 obtained the highest percent organic matter and available potassium, while Station 3 recorded the highest available phosphorus.

Table 4. Physico-chemical properties of soil collected from the sampling stations

Station	Soil texture	% Moisture	pH	Macronutrient		
				% Organic matter	Available phosphorus; P, mg/kg (ppm)	Available potassium; K, mg/kg (ppm)
S1	Clay	10.39	6.30	10.60	22.12	1830.35
S2	Clay	51.78	4.94	14.07	11.94	2169.59
S3	Clay	4.04	6.28	9.10	23.98	1820.88
Overall	Clay	22.07±25.93	5.87±0.81	11.26±2.55	19.35±6.48	1940.27±198.65

*% Organic matter is the sole Philippine Accreditation Bureau's PAB accredited parameter in the Regional Soil Laboratory of Department of Agriculture Regional Field Office No. 02. Reference Method BSWM Test Method Manual 2022 HGIC 1615.

DISCUSSION

Population density significantly influences the dynamics of ecosystems, affecting various biological processes and interactions. Understanding the factors that impact population density is crucial for comprehending how species coexist and thrive in their environments **(Edwards & Edwards, 2011)**. Findings of this study serve as a baseline for understanding the distribution of this species within the sampled mangrove ecosystem. The uniformity in population density suggests that environmental factors influencing *G. expansa* are consistent across the sampling stations. This could be due to similar sediment types, physico-chemical water quality parameters, or availability of food resources within the mangrove habitat. Thus, this study indicates a more stable population density for *G. expansa* in the examined mangrove area. According to several researchers, geographic location and climate, habitat type and conditions, fluctuations in environmental parameters including food and nutrient availability as well as predator and prey density are closely related to changes in clam density **(Davis *et al*., 2001; Gonzalez, *et al*., 2004; Compton *et al*., 2008; Clemente & Ingole, 2011; Nasution *et al*., 2021)**. In this study, it can be observed that, all the sampling stations are located in the intertidal zone with the presence of various mangrove trees favourable for the *G. expansa*. In addition, all the stations have a clay substrate type containing essential macronutrients such as organic matter, phosphorus, and potassium, increasing food availability for the mangrove clam. **Syaputri *et al.* (2023)** found that the density value of *G. expansa* in the intertidal zone (9.90 ind/m^2) of West Malangke District, North Luwu Regency, South Sulawesi Province is higher than that recorded in the subtidal zone (0.78ind/ m^2), and the clay type substrate is the determining factor for the presence of *G. expansa*. The present result is in contrast to the findings of **Bahtiar *et al.* (2023)** from Kendari Bay mangrove forest, Southeast Sulawesi Indonesia, where densities varied significantly (ranging from 23.78 to 77.44ind/ m^2) depending on seasonal changes and environmental conditions.

Moreover, understanding the biomass and productivity of *G. expansa* can provide insights into its ecological role within the mangrove ecosystem. As a filter feeder, *G. expansa* contributes to nutrient cycling and water quality improvement, which are essential functions in maintaining a healthy habitat **(Argente *et al*., 2024)**. The mean individual weight provides a baseline for evaluating the health and size of the clam population within the studied habitat **(Yahya *et al*., 2018)**. The computed biomass metric is crucial for understanding the overall productivity and ecological role of *G. expansa* in its environment while the secondary productivity reflects the growth and reproductive output of the mangrove clam **(Bahtiar *et al*., 2023)**. Accordingly, biomass ranging from 0.04 to 4.95g/ m^2 and a turnover rate (P/B) of 1.73/year reflects a healthy growth dynamic within the mangrove ecosystem **(Bahtiar *et al*., 2023)**. Hence, the values of biomass and secondary productivity obtained in the present study suggest that *G. expansa* is effectively utilizing available resources in the mangrove forest to grow and reproduce. This efficiency in energy transfer is critical for maintaining population stability and supporting the broader ecosystem, as clams often serve as a food source for various predators **(Argente *et al.*, 2021)**.

Finally, information on the growth patterns and size distribution within the *G. expansa* population can inform management strategies for this species, particularly in terms of harvesting practices and conservation efforts. Maintaining a healthy population structure is essential for sustaining its ecological functions. The present study revealed a wide range of length of *G. expansa* in the sampled habitat which may reflect differences in age, growth conditions, or environmental factors. This finding supports the study of **Bahari *et al.* (2023)** in Kerteh River, Terengganu, Malaysia, wherein the length of *G. expansa* ranged from 1.5 to 8.9cm while the height ranged from 1.7 to 8.5cm. Similarly, **Ransangan and Soon (2018)** reported that *G. expansa* at Marudu Bay have a length from 2.1 cm to 8.9cm. Meanwhile, the length of *G. expansa* ranged from 1.1 to 7.25cm in Setiu wetlands in peninsular Malaysia **(Yahya *et al.*, 2018)**. However, it can be observed that most of the samples collected during the study were considered adult reflecting the general size structure of the *G. expansa* population in the sampling site.

In addition, the positive allometric growth pattern of *G. expansa* observed in this study is ecologically significant as it suggests that larger individuals may play a crucial role in nutrient cycling and energy transfer within the mangrove ecosystem. Larger clams can filter more water, contributing to improved water quality and habitat health. Similar finding was also reported by **Mendoza *et al.* (2019)**, **Widianingsih *et al.* (2020)** and **Argente and Ilano (2021)**. This specific type of allometric growth is a characteristic of infaunal burrowing bivalves, and the resulting adult morphology can be observed in various families, including Carditidae, Crassatellidae, Veneridae, Trigoniidae and Corbiculidae **(Perez & Santelli, 2018; Argente & Ilano, 2021)**. The LWR equation computed in the present study indicates that the length of *G. expansa* proportionally increases with its weight by approximately 3.31 units. Similarly, the r^2 value signifies a very strong correlation between length and weight, indicating that the model explains approximately 97.85% of the variability in weight based on length measurements. This high value suggests that the relationship is strong and reliable for predicting the weights of mangrove clam based on their lengths. Meanwhile, a study of **Ransangan *et al.* (2019)** on *Polymesoda expansa* found an LWR equation $y = 2.24x - 0.657$ indicating a similar allometric growth pattern ($b<3$) compared to the result of the present study where weight increases with length. However, the relationship is slightly less vertical compared to the slope of the present study ($b = 3.3115$) suggesting a potentially slower growth or a different ecological adaptation **(Ransangan *et al.*, 2019)**. Additionally, **Yahya *et al.* (2018)** reported relatively the same LWR equation of *G. expansa* collected in the mangrove forest of Setiu Wetlands, Peninsular Malaysia from January to June 2017 with a slope ranging from 2.78 to 3.52 and r^2 ranging from 0.61 to 0.99. According to **Gimin *et al.* (2004)**, certain factors such as reproductive state, population density, and both physical and biological characteristics of the habitat, are known to influence bivalve growth and can alter the allometric relationship between the shell and the soft tissue. In this study, the observed growth pattern of *G. expansa* can provide insights into its adaptability to mangrove environments and its potential resilience to environmental changes or anthropogenic pressures.

CONCLUSION

The study showed a stable and uniform population density of *G. expansa* across different sampling stations within the studied mangrove area. Future studies could explore specific environmental factors influencing these densities and could assess potential impacts from human activities, such as harvesting or habitat alteration. Findings on biomass and secondary productivity highlight the efficiency of energy transfer in this species, alongside its growth and reproductive capabilities. Understanding these dynamics is essential for assessing the ecological impact of *G. expansa* within its habitat and can inform future conservation efforts aimed at preserving mangrove ecosystems and their associated biodiversity. Further research could explore seasonal variations in these parameters to provide a more comprehensive understanding of the ecological role of *G. expansa* throughout different environmental conditions.

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