

Density, Morphometrics, Length–Weight Relationship, and Condition Factors of Manila Clams (*Ruditapes philippinarum*) in Waters Batam City

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Abstract

Background: The Manila clam *Ruditapes philippinarum* is an economically important marine bivalve and a key component of coastal ecosystems. Environmental factors such as sedimentation, salinity fluctuations, and human activities may influence its abundance, growth, and physiological condition. This study aimed to assess the abundance, morphometric characteristics, length–weight relationship, and condition factor of *R. philippinarum* in the waters surrounding Sarang Island, Batam Plot. **Methodology:** Sampling was conducted at three intertidal stations—Tempayang Island, Piring Island, and Layang Island—using purposive manual collection within 3 plot observation. Shell length, height, and thickness were measured using digital calipers, and total weight was recorded with a digital balance. Growth patterns were analyzed using log–log regression, while condition factors (*K* and *WR*) were used to evaluate physiological status. **Findings:** 87 individuals of *R. philippinarum* were recorded at Station 1, 118 at Station 2, and 117 at Station 3. The shell length of *Ruditapes philippinarum* ranged from 15.2 to 42.6 mm across all sampling stations. The length–weight relationship showed a weak correlation ($r = 0.145$) with a low coefficient of determination ($R^2 = 0.21\%$) and a negative allometric growth pattern ($b = -0.3419$). The *WR* value (121.81) indicated generally good physiological condition. Water quality parameters were generally within tolerance limits; however, stations with higher total dissolved solids and lower water transparency indicated increased turbidity, which was associated with relatively smaller shell sizes of *R. philippinarum* compared to stations with better water clarity. Overall, variations in abundance and size among stations were influenced by environmental differences, while the *R. philippinarum* population remained relatively healthy. **Contributions:** These findings provide baseline ecological information that can support future monitoring and sustainable management strategies for *R. philippinarum* resources in intertidal coastal ecosystems.

Keywords: Bivalves; Intertidal Ecosystem; Manila Clams; Population Structure; Water Quality



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INTRODUCTION

Bivalve fisheries resources play an important role in supporting food security, coastal economies, and the balance of marine ecosystems. One bivalve species with high economic and ecological value is *Ruditapes philippinarum*, commonly known as the Manila clam. This species is widely distributed throughout the Indo-Pacific region and has become a high-value fisheries commodity in many Asian countries, including Indonesia. However, bivalve populations worldwide are increasingly facing ecological challenges such as climate change, coastal pollution, habitat degradation, and overexploitation, which may affect their distribution, growth, and population sustainability. In addition to its use as a food resource, *R. philippinarum* also serves as a bioindicator of coastal environmental quality due to its ability to adapt to varying aquatic conditions and to accumulate environmental contaminants within its tissues (Çolakoğlu & Palaz, 2014). Bivalve molluscs, including *Ruditapes philippinarum*, are widely recognized as effective bioindicators of coastal environmental quality due to their sessile lifestyle, sediment-dwelling behavior, and filter-feeding mechanisms that facilitate the accumulation and integration of physical, chemical, and biological stressors from surrounding waters and sediments (Chahouri et al., 2023).

In the context of aquatic ecology, the abundance and distribution of bivalves are generally influenced by environmental factors such as temperature, salinity, turbidity, sediment texture, and the availability of organic matter. The composition and distribution of bivalve communities along Datok Island Beach are strongly affected by substrate characteristics and overall water quality (Savaria et al., 2025). The relationships between these environmental factors and the biological characteristics of bivalves, such as shell morphometrics, body weight, and condition indices, provide an essential basis for understanding population dynamics and production potential. Shell morphometric parameters, including length, width, and height, are commonly used to analyze variations in shape and growth among individuals and populations inhabiting different environmental conditions. Morphometric plasticity in bivalves is widely recognized as a response to environmental stressors such as changes in temperature, salinity, food availability, and sediment characteristics, which may influence shell growth and morphology (Nerlovic et al., 2016). Through such analyses, researchers can evaluate the degree of morphological adaptation to local environmental conditions. Previous studies have shown that habitat characteristics strongly influence shell morphology and population structure in bivalves. For instance, individuals inhabiting mangrove ecosystems often exhibit differences in shell size and shape compared with those found in seagrass beds due to variations in sediment composition, organic matter availability, and hydrodynamic conditions (Srimariana et al., 2025).

Similarly, other studies have reported that environmental gradients such as substrate type, water circulation, and food availability can lead to significant spatial variation in bivalve morphology and distribution. However, despite these findings, studies comparing morphometric responses of *Ruditapes philippinarum* across different coastal habitats, particularly between mangrove and seagrass ecosystems in tropical intertidal

environments, remain limited. Therefore, further investigation is needed to understand how habitat differences influence morphological variation and spatial distribution of bivalve populations in these ecosystems.

Furthermore, the relationship between shell length and body weight in bivalves is a commonly used biometric parameter to describe organismal growth patterns. Length–weight relationships and condition indices are widely applied in bivalve ecological studies as integrative biological indicators for evaluating population health, growth strategies, and habitat suitability under varying environmental pressures (Fassatoui et al., 2024). This relationship indicates whether a population exhibits isometric growth, characterized by proportional increases in length and weight, or allometric growth, in which growth is non-proportional. Meanwhile, the condition factor or condition index is applied to evaluate individual well-being and physiological status. This index reflects the balance between body weight and shell size and is influenced by food availability, temperature, and habitat quality. Exposure to unstable environmental conditions, such as fluctuations in temperature and salinity, may reduce the condition factor of *Ruditapes philippinarum* and subsequently affect its growth rate (Yin et al., 2017).

Although numerous studies on the morphometric characteristics and condition factors of *Ruditapes philippinarum* have been conducted in other regions, similar research in Indonesia, particularly in the Batam area, remains limited. Sarang Island, located in Batam Plot, is a coastal region with considerable marine ecosystem potential but is increasingly subjected to anthropogenic pressures, including overexploitation, sedimentation, and changes in water quality resulting from port activities and surrounding industrial development. These conditions may influence the growth, abundance, and physiological condition of Manila clam populations inhabiting these waters. Therefore, the collection of accurate baseline data on the biological and ecological aspects of *Ruditapes philippinarum* in this area is crucial to support sustainable coastal resource management.

In the context of Indonesian small-island waters, morphometric characteristics, length–weight relationships, and condition factors have been shown to be effective biological indicators for assessing population status and environmental suitability of marine mollusks. Studies conducted in the waters of Sarang Island and other surrounding areas of Batam have reported that mollusk populations generally exhibit allometric growth patterns, with condition factor values indicating that local environmental conditions remain supportive of normal growth and physiological stability. However, most previous studies have primarily focused on general population characteristics without examining how different coastal habitats influence morphometric variation and ecological responses of bivalve species.

In particular, comparative studies between mangrove and seagrass ecosystems in the intertidal zones of Kelapa Dua Island remain limited. Therefore, this study aims to provide new insights into the morphometric characteristics, length–weight relationship, and ecological responses of *Ruditapes philippinarum* across different habitat types in the intertidal ecosystem of Kelapa Dua Island, Batam (Dinata et al., 2025). Similar findings from Batam coastal waters further confirm that variations in morphometric traits and

length–weight relationships are closely associated with habitat quality, substrate type, and water physicochemical parameters, providing essential baseline data for sustainable management and conservation planning (Hasibuan et al., 2025). In addition, biometric studies in Indonesian coastal ecosystems emphasize that integrating morphometric data, length–weight relationships, and condition indices is crucial for evaluating population health and supporting fisheries and aquaculture development strategies in small-island environments (Ramses et al., 2019).

Based on this background This study aims to examine the abundance, morphometric characteristics, length–weight relationship, and condition factor of the Manila clam (*R. philippinarum*) in the waters of Sarang Island, Batam. It is hypothesized that variations in environmental conditions and habitat characteristics influence the abundance, morphometric variation, and growth patterns of *R. philippinarum*, with more favorable habitats supporting larger individuals and better physiological condition. The findings are expected to provide comprehensive scientific insight into the population status and ecological potential of this species in local waters and to serve as a foundation for the sustainable management and conservation of bivalve resources in the coastal areas of Batam.

METHOD

This study was conducted from August to October 2024 in the coastal waters of Batam Plot, with sampling of *Ruditapes philippinarum* carried out at three observation stations representing different habitat characteristics. Station 1 was located on Tempayang Island, Station 2 on Piring Island, and Station 3 on Selayang Island. The stations were selected purposively based on substrate conditions, degree of water exposure, and the potential presence of Manila clam populations. Station 1 was characterized by a sandy–mud substrate with relatively moderate water exposure, Station 2 consisted predominantly of muddy sediment associated with mangrove vegetation, while Station 3 was dominated by sandy substrate with higher water circulation and greater exposure during low tide. In ecological surveys of bivalves refers to Greeve et al., (2023), representative sampling designs typically involve the systematic or randomized collection of specimens across multiple habitat types to capture spatial variability in abundance and community composition, with standardized sample units ensuring comparability between sites and conditions.

At each station, four observation plots of 1 m × 1 m were established along a transect line in the intertidal zone. The plots were arranged systematically with an approximate distance of 5 m between plots to ensure representative sampling of the habitat. All clam individuals within each plot were manually collected during low tide. Therefore, the total sampling area at each station was 4 m². The collected specimens were placed into labeled containers and subsequently transported to the laboratory for further analysis. Sampling was performed using a transect–plot method with a plot size of 50 × 50 cm.

Field sampling was conducted during low tide to facilitate the collection of clam individuals in the intertidal zone. The sampling activities were carried out in the morning

between 08.00 and 11.00 A.M to ensure consistent environmental conditions during observation. The geographical coordinates of the sampling locations are presented in Figure 1. Station I on Tempayang Island was located at $1^{\circ}7'31.206''$ N and $103^{\circ}50'39.612''$ E, Station II on Piring Island at $1^{\circ}7'3.204''$ N and $103^{\circ}50'29.508''$ E, and Station III on Selayang Island at $1^{\circ}7'59.772''$ N and $103^{\circ}51'0.666''$ E.

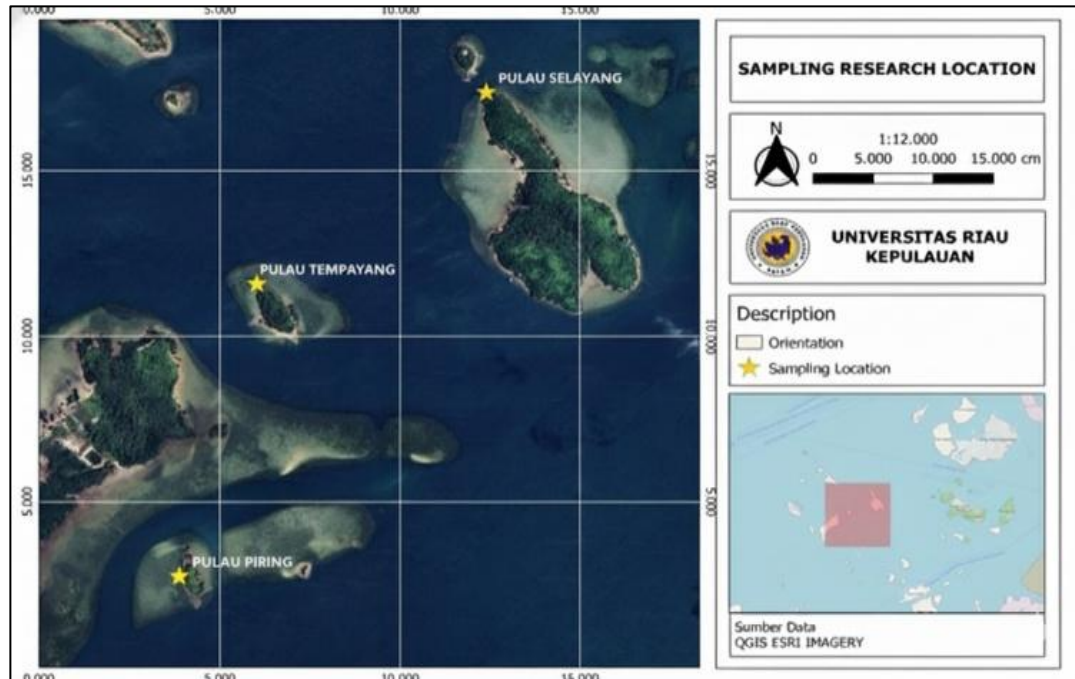


Figure 1. Research Location Map

Materials and Equipment

The equipment used in this study included a GPS device to determine the coordinates of the observation stations, a measuring tape to establish sampling area boundaries, and a digital caliper with an accuracy of 0.01 mm to measure shell length, shell height, and ligament length. Total body weight was measured using a digital balance with a precision of 0.01 g. Additional instruments included a multimeter, a digital dissolved oxygen (DO) meter (MH01 model, accuracy 0.01), a camera for visual documentation, stationery, and sample containers for storing collected specimens. Detailed documentation of all materials and equipment used in bivalve ecological research, encompassing field collection tools, laboratory measurement instruments, and analytical reagents, ensures reproducibility and data integrity across sampling events and analytical procedures (Ding et al., 2022). Water quality parameters were measured in situ, including temperature, salinity, dissolved oxygen (DO), total dissolved solids (TDS), water transparency, and current velocity. Each parameter was measured in triplicate at each sampling location to ensure data accuracy and representativeness of water quality conditions.

Data Analysis

Abundance

The abundance analysis of *Ruditapes philippinarum* in this study was conducted using a relative abundance approach, as information on the exact area of each sampling plot was not available. Relative abundance was calculated to determine the proportion of individuals at each station relative to the total population recorded across all sampling locations. The calculation was performed using the following formula 1 by [Muhammad et al., \(2023\)](#):

$$KR = \frac{ni}{N} \times 100\% \dots\dots\dots (1)$$

Where:

KR = Relative Abundance (%)

ni = represents the number of individuals at the i-th station, and

N = denotes the total number of individuals recorded across all sampling stations.

Multivariate statistical approaches, including cluster analysis, non-metric multidimensional scaling (nMDS), and similarity percentage analysis (SIMPER), have been shown to effectively differentiate spatial heterogeneity in bivalve abundance and community composition across multiple sampling sites, enhancing interpretation of environmental impacts on population structure ([Syahrial et al., 2025](#)). This approach is effective when the sampling area is not explicitly defined, enabling population dominance to be assessed based on each station's relative contribution. The relative abundance results were subsequently compared among stations to evaluate spatial variations in distribution and abundance of *Ruditapes philippinarum* within the studied coastal area. Recent studies on intertidal bivalve populations demonstrate that spatial variation in environmental conditions such as sediment characteristics and water quality can significantly influence bivalve abundance patterns, emphasizing the necessity of incorporating environmental gradients in abundance analyses ([Cerdeira-Arias et al., 2024](#)).

Morphometric Measurements

Morphometric measurements were conducted on all *Ruditapes philippinarum* specimens collected from each plot at the three sampling stations. Prior to measurement, each individual was cleaned to remove adhering sediment and debris from the shell surface to ensure measurement accuracy. The morphometric parameters observed included shell length (anterior–posterior), shell height (dorsal–ventral), ligament length, and shell thickness ([Acarli, et al., 2023](#)). Morphometric relationships and relative growth analyses involving dimensions such as shell length, height, width, and total weight are widely used to distinguish allometric patterns and characterize morphological diversity within bivalve populations, informing both ecological interpretations and comparative growth assessments ([Dąbrowski et al., 2023](#)). All parameters were measured using a digital caliper with an accuracy of 0.01 mm. Total body weight was determined using a digital balance with a precision of 0.01 g after excess surface water had been removed from the shell. Measurements were performed consistently across all specimens to minimize

observational error and to obtain representative morphometric data Morphometric relationships derived from shell dimension measurements are effective proxies for assessing growth patterns and reproductive maturity in bivalve species, as variations in the slopes of these relationships often reflect key ontogenetic and environmental influences (Oliveira et al., 2025). The resulting data were subsequently used to analyze the length–weight relationship and morphometric variation among stations, and to calculate condition factors as indicators of the Manila clam's health status and body condition at each study site.

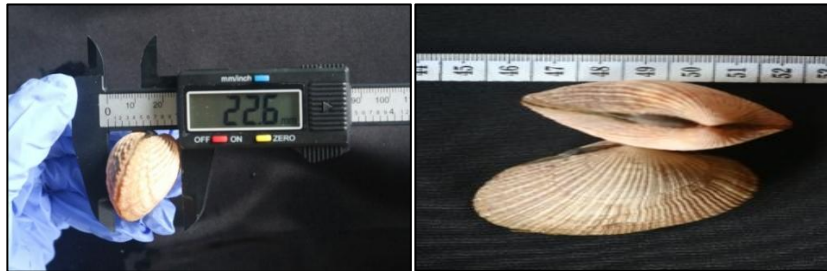


Figure 2. Morphometric Measurements

Length–Weight Relationship

The length–weight relationship of *Ruditapes philippinarum* in this study was analyzed using a biometric equation where individual body weight was expressed as a function of shell length. To estimate the constant a and the growth exponent b , length and weight data were first transformed into logarithmic form and subsequently analyzed using linear regression $\ln W = \ln a + b \ln L$, thus, growth patterns were classified as isometric when $b = 3$ or allometric when $b \neq 3$ (Autor et al., 2025). In addition, the condition factor was analyzed using Fulton's formula to assess body condition and physiological well-being of the Manila clam as indicators of habitat suitability and nutrient availability. This analytical approach is widely applied in bivalve studies because it effectively describes the relationship between growth performance and environmental quality in a comprehensive manner (Çolakoğlu & Palaz, 2014).

Condition Factor

The condition factor of total clam was analyzed using Fulton's condition factor (K) and the relative weight condition factor (Wr), with the standard weight (Ws) predicted from the combined length–weight regression of all sampling locations. Relative weight (Wr) was calculated based on the equation 2 proposed by Rypel & Richter (2008),

$$Wr = (W \times Ws) \times 100 \dots\dots\dots (2)$$

Where

- Wr = represents the relative weight,
- W = the actual body weight of the clam (g), and
- Ws = the standard weight (g)

Ws is the standard weight (g) estimated from the length–weight regression equation calculated separately for each sampling station, expressed by the following equation 3,

$$W = a L^b \dots\dots\dots (3)$$

The condition factor reflects the health status or overall fitness of the clam (Ramses et al., 2019). Fulton’s condition factor was calculated refers to Hariyadi et al., (2024) using the following formula 4,

$$KR = \frac{W}{L^3} \times 100 \dots\dots\dots (4)$$

Where

- K = Fulton’s condition factor,
- W = represents body weight (g),
- L = body length (mm)
- Exponent 3 = The standardize the index so that K approaches unity.

Water Quality Measurement

Water quality measurements were conducted at each sampling station to assess environmental conditions that may influence the presence and biological variation of *Ruditapes philippinarum*. The physical and chemical parameters measured included temperature, salinity, pH, water transparency, and total dissolved solids (TDS). Water temperature was measured using a digital thermometer placed directly in the water column to obtain representative values. Salinity was determined using a refractometer that was calibrated prior to measurement. pH values were recorded using a standardized portable pH meter, while water transparency was measured by lowering a Secchi disk until it was no longer visible to the observer. TDS levels were measured using a TDS meter to determine the concentration of dissolved solids in the water. Previous studies conducted in the Marina Beach area of Batam have demonstrated that the presence of macrozoobenthos is closely associated with water quality parameters and can serve as a bioindicator of aquatic environmental conditions (Arta et al., 2023).

Accurate measurement of key water quality parameters such as pH, salinity, temperature, dissolved oxygen, and turbidity is fundamental in coastal ecological assessments, as these variables strongly affect bivalve physiology, distribution, and community dynamics (Lu et al., 2020). Water quality measurements were conducted in triplicate at each sampling station, coinciding with clam collection, to ensure that the recorded data accurately represented the environmental conditions at the study sites. The three measurements were then averaged to obtain representative values for each station. Standardized methodologies for measuring physicochemical water quality parameters have been emphasized in ecological monitoring studies to ensure comparability of data across sites and temporal scales, particularly where biological responses such as bivalve growth and community structure are linked to environmental gradients (Comeros-Raynal et al., 2021).

Table 1. Water Quality Measurement

No.	Parameters	Equipment	Unit
1	pH	pH Meter	–
2	Temperature	Thermometer	°C
3	Dissolved Oxygen	DO Meter	mg/L
4	Salinity	Refractometer	ppm
5	Turbidity	Turbidity Meter	NTU
6	Brightness	Secchi Disk	m
7	Current Speed	Flow Meter	m/s

RESULT AND DISCUSSION

Abundance

The abundance of *Ruditapes philippinarum* across the three sampling stations showed notable variation among locations. Calculations indicated that Station 2 had the highest number of individuals, with 118 clams (36.65%), followed by Station 3 with 117 individuals (36.34%). Station 1 had the lowest abundance, with 87 individuals (27.02%). This variation reflects differences in habitat characteristics among sites, which influence the distribution and abundance of Manila clams. These results suggest that Stations 2 and 3 provide more favorable conditions for *R. philippinarum* than Station 1.

Table 2. Abundance Measurements

No	Location	Amount of Individuals	Relative Abundance (%)
1	Station 1 (Tempayang Island)	87	27.02
2	Station 2 (Piring Island)	118	36.65
3	Station 3 (Selayang Island)	117	36.34
Total		322	100

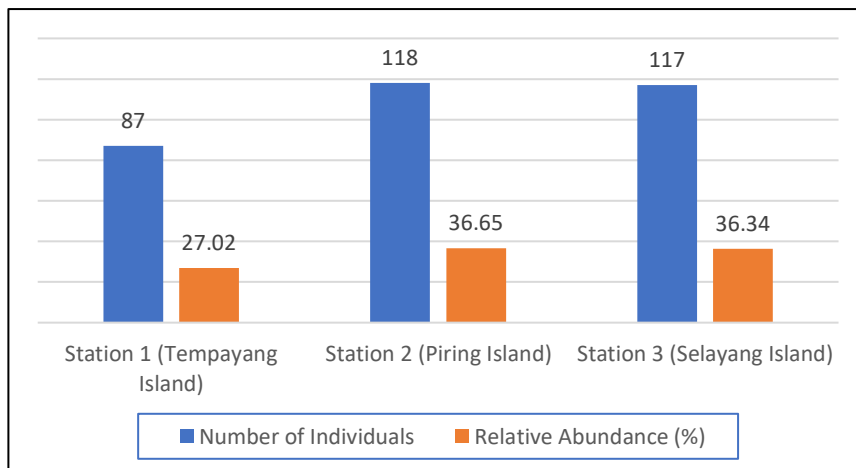


Figure 3. Abundance Measurements Graph

Morphometric

The morphometric analysis of the Manila clam (*Ruditapes philippinarum*) based on the latest data revealed variations in shell length and individual weight across the three sampling stations. Overall, shell length ranged from 5.2 to 62.9 mm, while individual body weight ranged from 0.9 to 53.0 g. This wide size range indicates that the Manila clam population at the study sites consists of multiple size and age classes, from juvenile to adult individuals. Based on mean values, Station 1 had the largest individuals, with an average shell length of 46.50 mm and an average weight of 21.37 g, followed by Station 2 with an average shell length of 44.34 mm and weight of 18.31 g, and Station 3 with an average shell length of 40.99 mm and weight of 18.44 g. These differences in mean values reflect variations in local environmental conditions among stations, particularly regarding food availability and habitat characteristics.

Although Station 3 had lower average shell length and weight, the size distribution at this station was the widest, indicating high population dynamics and ongoing recruitment processes. In contrast, the dominance of medium to large individuals at Station 1 suggests that habitat conditions there are more favorable for shell growth and biomass accumulation. The relatively high variation in size and weight at Station 2 reflects heterogeneous habitat conditions, resulting in non-uniform growth among individuals. In general, these morphometric results indicate that the growth of Manila clams across the three stations is influenced by local environmental factors. Differences in the range and mean values of shell length and weight among stations reflect the clams' adaptation to the dynamic intertidal environment. Overall, however, the population exhibits normal morphometric characteristics, supporting the species' continued survival at the study sites.

Table 1. Morphometric Measurements

Station	Shell Length (mm) Min–Max	Average TL (mm)	Weight (g) Min–Max	Average Weight (g)
Station 1	26.7 – 62.9	46.50 ± 7.85	3.1 – 53.0	21.37 ± 9.42
Station 2	16.0 – 57.3	44.34 ± 8.21	2.5 – 35.2	18.31 ± 7.63
Station 3	5.2 – 61.5	40.99 ± 10.34	0.9 – 46.2	18.44 ± 9.15

Length–Weight Relationship

The analysis of the length–weight relationship of the Manila clam (*Ruditapes philippinarum*) based on the latest data showed that the growth pattern at all three sampling stations followed a negative allometric trend, with growth coefficient (b) values less than 3. This indicates that shell length increases at a faster rate than body weight. The length–weight relationship derived from logarithmic data demonstrated that although weight increases with shell length, the increase is not proportional. This pattern reflects that growth energy in *R. philippinarum* is predominantly allocated to shell dimension development rather than soft tissue biomass accumulation. The coefficient of determination (R^2) and correlation values across the three stations indicated a weak to moderate relationship between shell length and weight. Considerable variation in weight

was observed among individuals of similar shell length, particularly in smaller and larger size classes. Variation in body weight was observed among individuals with similar shell lengths, particularly in both smaller and larger size classes. Such variation has been reported in bivalve populations and may be related to differences in physiological condition or growth dynamics among individuals (Gosling, 2008).

At Station 1, the length–weight relationship appeared relatively stable, indicating a consistent growth pattern of *Ruditapes philippinarum* within this habitat. Stations 2 and 3 exhibited higher residual variation, reflecting heterogeneous environmental conditions and differences in physiological responses among individuals. Nevertheless, no extreme systematic bias was observed, indicating that the derived length–weight model remains representative of the population’s growth pattern.

Table 2. Length–Weight Relationship

Station	Length–Weight Equation ($W = aL^b$)	Value of a	Value of b	Growth Pattern
Station 1	$69.48 L^{-0.34}$	69.48	0.34	Negative allometry
Station 2	$6.02 L^{0.27}$	6.02	0.27	Negative allometry
Station 3	$1.03 L^{0.76}$	1.03	0.76	Negative allometry

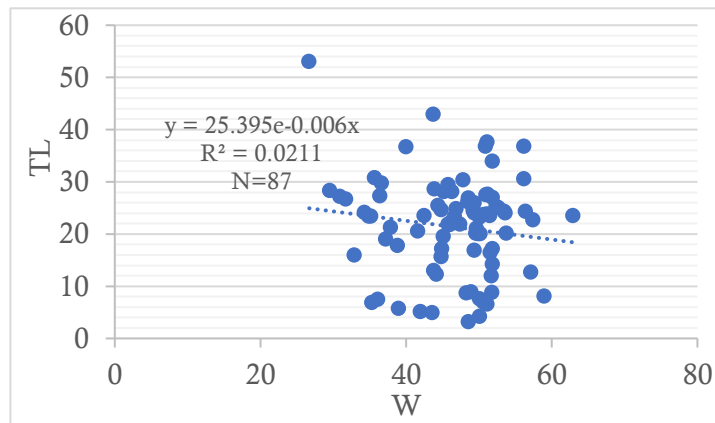


Figure 2. Station 1

The length–weight relationship of the Manila clam (*Ruditapes philippinarum*) at Station 1 exhibited a negative allometric growth pattern, with a growth coefficient (b) less than 3. The resulting regression equation indicated that increases in shell length were not accompanied by proportional increases in body weight. The coefficient of determination ($R^2 = 0.0211$) showed that only a small portion of the variation in body weight could be explained by shell length. The relatively dispersed data distribution suggests considerable variation in weight among individuals with similar shell lengths. This indicates that environmental factors, such as food availability and water dynamics, play a more significant role in influencing body weight than shell length alone. Nevertheless, individuals at this station tended to have relatively large body sizes, suggesting that habitat conditions are sufficiently stable to support shell growth.

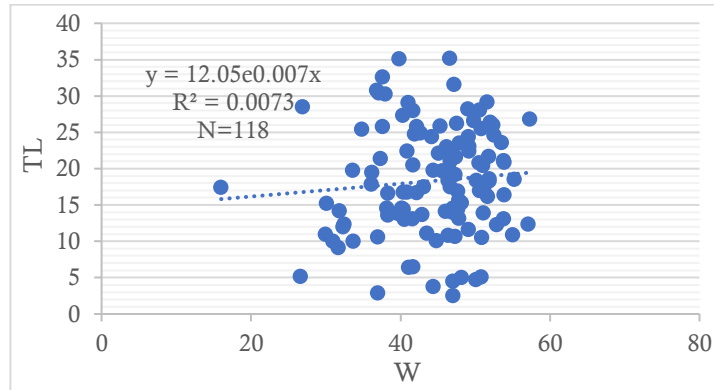


Figure 3. Station 2

At Station 2, the length–weight relationship also exhibited a negative allometric growth pattern, characterized by a low growth coefficient. The very small R^2 value ($R^2 = 0.0073$) indicates that the relationship between shell length and body weight is extremely weak. This suggests that variations in the body weight of Manila clams at this station are scarcely influenced by increases in shell length. The dense distribution of data points without a clearly defined linear pattern reflects high environmental heterogeneity and suggests the presence of inter-individual competition due to high population density. The muddy–sandy substrate conditions and fluctuations in water quality are presumed to cause energy allocation to be more strongly directed toward physiological maintenance rather than biomass accumulation, resulting in inconsistent body weight growth.

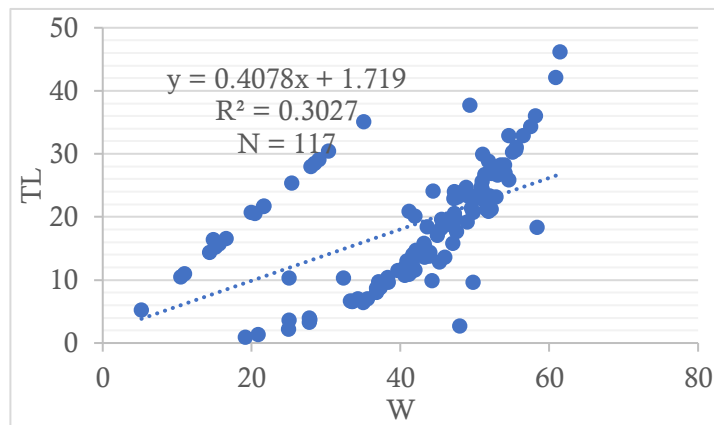


Figure 4. Station 3

In contrast to the previous two stations, the length–weight relationship at Station 3 exhibited a relatively stronger association, although it was still classified as negative allometric. The higher coefficient of determination ($R^2 = 0.3027$) indicated that variations in shell length accounted for approximately 30.27% of the variation in body weight. The data distribution pattern showed an increase in weight with increasing shell length, although the relationship remained non-proportional. This suggests that some individuals at this station were able to convert shell length increment into biomass more efficiently

compared to those at other stations. However, the relatively wide data spread indicates that environmental factors, such as high turbidity and fluctuations in dissolved solids, continue to influence the body weight growth of *Ruditapes philippinarum* at this location.

Condition Factor

The analysis of the condition factor of the Manila clam (*Ruditapes philippinarum*) based on the latest data indicated that, overall, individuals at all three sampling stations were in good physiological condition. Condition assessment was conducted using Fulton's Condition Factor (K) and Relative Weight (WR), which reflect the balance between shell length and body weight. The Fulton's K values across all stations showed variation among individuals but remained within a range indicative of normal growth. The relatively uniform K values suggest that the relationship between shell length and weight is still proportional, despite the negative allometric growth pattern. This indicates that although weight gain does not keep pace with shell length increase, the clams' body condition remains well-maintained.

Based on Relative Weight (WR) values, most individuals had $WR \geq 100$, indicating that their actual weight was equal to or greater than the standard weight for the same shell length. Station 1 had an average WR of 121.81, suggesting relatively stable individual condition and a habitat conducive to biomass accumulation. Station 2 exhibited an average WR of 118.42 with considerable variation, indicating environmental heterogeneity and differences in individuals' ability to utilize available resources. Station 3 showed the highest average WR at 135.91, albeit with a very wide distribution. This suggests that some individuals had body weights far exceeding the standard for their shell length, particularly at certain size classes. The high variation in WR at this station indicates that, although the environment tends to be productive, fluctuating water conditions result in non-uniform growth responses among individuals.

Table 3. Condition Factor

Station	Fulton Condition Factor (K)	Average Relative Weight (WR)	Condition Interpretation
Station 1	Relatively stable	121.81	Good
Station 2	Variable	118.42	Fairly good, heterogeneous
Station 3	Highly variable	135.91	Very good

Water Quality

The water quality measurements at the three sampling stations indicated that most environmental parameters were still within the tolerance range for the Manila clam (*Ruditapes philippinarum*). The measured parameters included temperature, salinity, pH, dissolved oxygen (DO), total dissolved solids (TDS), and water transparency. Variations among stations were influenced by differences in vegetation cover, tidal dynamics, and the intensity of surrounding anthropogenic activities. Temperature at all stations ranged from

28 to 30°C, which is within the normal range for clam growth. Salinity remained relatively stable, ranging from 28 to 31 ppm, consistent with the physiological requirements of estuarine bivalves. pH values were slightly alkaline to neutral, ranging from 7.6 to 8.1, supporting metabolic processes in clams.

Dissolved oxygen levels were adequate, ranging from 5.1 to 6.4 mg/L, indicating conditions that support benthic organism respiration. However, TDS values were relatively high at all three stations, ranging from 32,000 to 35,500 mg/L, reflecting elevated dissolved solids due to sediment dynamics and tidal flow. In addition, water transparency was low (20–45 cm), which may affect the filtration activity of Manila clams, as low light intensity is often associated with high turbidity. Nevertheless, overall water quality conditions remained within tolerable ranges to support the presence and growth of *Ruditapes philippinarum* in the study area.

Table 4. Water Quality

Parameter	Station 1	Station 2	Station 3	Optimal Range Manila Clam (Nam et al., 2018)
Temperature (°C)	29	28	30	25–32
Salinity (ppt)	31	30	28	25–34
pH	8.1	7.9	7.6	7.5–8.5
DO (mg/L)	6.4	5.8	5.1	>5
TDS (mg/L)	35.5	34.1	32.8	<40.000
Lightness (cm)	45	30	20	— (low tolerance bivalves)

DISCUSSION

Abundance

The abundance of the Manila clam (*Ruditapes philippinarum*) at the three sampling stations showed variation influenced by environmental conditions and habitat characteristics at each location. Based on the latest data, Station 2 had the highest abundance with 118 individuals (36.65%), followed by Station 3 with 117 individuals (36.34%), while Station 1 recorded the lowest abundance at 87 individuals (27.02%). This pattern indicates that the distribution of *R. philippinarum* in the study area is uneven, with higher concentrations at Stations 2 and 3. This uneven distribution may be attributed to a combination of factors, including substrate structure, availability of suspended food, tidal dynamics, and the level of anthropogenic disturbance.

Stations 2 and 3 featured muddy sand substrates that were relatively more stable and suitable for the filtration activities of Manila clams. The finer substrate allowed clams to burrow and filter feed optimally, supporting their higher abundance. Additionally, dissolved oxygen (DO) levels at both stations ranged from 5.1 to 5.8 mg/L, which is well within the tolerance limits for benthic organisms. These conditions facilitate clam respiration and maintain metabolic stability, thereby influencing population abundance.

In contrast, Station 1 exhibited lower abundance compared to the other two stations. Although temperature, salinity, and pH were still within optimal ranges, this area had higher water transparency, indicating lower turbidity. Manila clams generally prefer moderate turbidity because it carries more suspended organic material as food. Furthermore, physical stressors, such as stronger tidal currents at Station 1, may increase sediment mobility, affecting clam settlement. Variations in sediment composition and water flow can reduce habitat stability and hinder the ability of clams to establish themselves. The observed variation in abundance and bivalve dominance in the waters of Desa Pasir, Kabupaten Mempawah, highlights distinct distribution patterns among the sampling stations (Utami et al., 2019).

The high abundance observed at Stations 2 and 3 may also be related to lower competition among benthic organisms and the presence of areas that are relatively protected from anthropogenic disturbances. The combination of optimal substrate conditions, availability of suspended food, and stable physical water conditions makes these two stations more favorable habitats. Overall, these results indicate that the abundance of Manila clams is strongly influenced by microhabitat conditions, with the presence of muddy sand substrates, adequate dissolved oxygen, and suitable turbidity levels being critical factors for population development.

Morphometric

The morphometric analysis of the Manila clam (*Ruditapes philippinarum*) across the three sampling stations revealed size variations influenced by environmental conditions and local habitat characteristics. The latest data indicated that Station 1 had the largest average sizes, with shell lengths ranging from 26.7 to 62.9 mm and weights from 3.1 to 53.0 g. Morphological differences and shell size in bivalves, such as Manila clams, are strongly influenced by external environmental factors, including substrate type, food availability, and oceanographic conditions (Utami et al., 2022). The larger individual sizes observed at this station indicate that habitat conditions are relatively stable and conducive to the growth of body structures. Under low population density, intraspecific competition for food resources and living space is reduced (Nahak et al., 2023). The denser substrate and sufficient food availability likely play a role in supporting biomass growth and shell elongation. Substrate conditions and the presence of organic matter also influence shell size characteristics (Haqiqi et al., 2023). In contrast to Station 1, Station 2 exhibited a more heterogeneous size distribution, with shell lengths ranging from 16.0 to 57.3 mm and weights from 2.5 to 35.2 g. The wider size range indicates that the population at this station consists of multiple age classes, including both juveniles and adults. The high number of individuals (118) may also suggest competition for resources, which could contribute to slightly smaller average body sizes compared to Station 1. This size variation also reflects the muddy sand substrate at Station 2, which supports filtration activities but remains dynamic due to tidal influences.

Station 3 exhibited the widest size range, with shell lengths of 5.2–61.5 mm and weights of 0.9–46.2 g, indicating active recruitment at this site. The presence of many

small-sized individuals suggests that Station 3 serves as a suitable area for the early development of Manila clams. However, the occurrence of extreme weight values indicates considerable variability in environmental conditions. Factors such as low water transparency and high TDS may affect clam filtration efficiency, thereby influencing biomass growth. Nevertheless, the diversity of individual sizes reflects that the habitat at Station 3 is still capable of supporting growth across different developmental stages. Overall, the morphometric analysis demonstrates that the body size of *Ruditapes philippinarum* is strongly influenced by microhabitat conditions, particularly substrate type, tidal currents, and food availability. Station 1, with its more stable environment, produced the largest body sizes, whereas Stations 2 and 3 showed more complex population dynamics. These differences highlight that morphometric characteristics not only reflect the physiological condition of the organisms but also serve as indicators of ecological conditions and environmental pressures affecting Manila clam populations in the study area

Length–Weight Relationship

The analysis of the length–weight relationship of Manila clams (*Ruditapes philippinarum*) across the three stations showed a negative allometric growth pattern, indicating that shell length increases more prominently than body weight. At Station 1, the growth coefficient (b) was -0.3419 , and the coefficient of determination (R^2) was 0.021 , indicating that shell length only explained 2.1% of the variation in body weight. This suggests that biomass growth in the clams was relatively low despite increases in shell length, resulting in more elongated bodies. In contrast, under certain environmental conditions, the length–weight relationship exhibited positive allometric growth, indicating that body weight increased more rapidly than shell length (Efriyeldi et al., 2022). The length–weight relationship reflects a specific growth pattern that indicates the physical adaptive response of Manila clams to local environmental conditions (Alburhana et al., 2023).

A similar phenomenon was observed at Stations 2 and 3. Although these stations had wide size ranges and high individual abundance, the length–weight relationship remained weak. The presence of extreme weight values, particularly among medium- to large-sized individuals, resulted in an unstable relationship between length and weight. The low correlation values indicate that environmental factors, rather than body length, have a greater influence on the variation in clam weight. Conditions such as high turbidity, fluctuating TDS, and variable sediment composition at these stations likely impose physiological stress, which in turn affects the clams' weight growth.

Overall, the weak length–weight relationship in the Manila clam populations across all stations indicates that increases in shell length were not accompanied by proportional increases in body weight. This pattern may occur when food availability is unstable, causing energy to be allocated primarily to maintaining basic metabolic functions rather than increasing biomass. In addition, dynamic tropical habitat characteristics, such as changes in currents, sediment composition, and turbidity, also affect the clams' filtration

efficiency. Thus, the observed negative allometric growth reflects that the environmental conditions in the study area favor shell elongation over body weight accumulation.

Condition Factor

The analysis of the condition factor of Manila clams (*Ruditapes philippinarum*) across the three study stations indicated that the populations were in relatively stable physiological condition. The condition factor was assessed using Relative Weight (WR), which compares the actual weight of individuals to the standard weight predicted from the length–weight equation. At Station 1, the mean WR was 121.81, indicating that clams had actual weights exceeding their standard weights. This suggests that individuals at this site were healthy, with adequate food availability and habitat conditions supporting biomass growth. WR values greater than 100 generally indicate optimal metabolic processes and energy storage, allowing clams to maintain sufficient energy reserves. At Stations 2 and 3, WR values were generally around 100, indicating that clams were in stable or normal condition. Despite the wide variation in size and weight at these stations, WR values close to 100 suggest that body weight remained proportional to shell length. This indicates that, even under environmental pressures such as high turbidity and elevated total dissolved solids (TDS), clams were able to maintain physiological balance. The moderate variation in WR also suggests that filtration processes were still effective, even though water quality at these stations was more dynamic.

The differences in WR values among the stations indicate that the condition factor is strongly influenced by a combination of environmental factors, such as suspended food availability, substrate stability, and water quality. Station 1, which exhibited the highest WR, likely benefits from environmental conditions that support biomass accumulation, such as more stable food concentrations and lower levels of anthropogenic disturbance. Meanwhile, Stations 2 and 3 showed relatively good condition despite being in more fluctuating environments. Overall, the WR values across all stations indicate that the Manila clam populations in the study area are physiologically healthy and capable of adapting to local aquatic conditions.

Environmental Quality Parameters

Environmental quality parameters play a crucial role in influencing the distribution, abundance, growth, and physiological condition of Manila clams (*Ruditapes philippinarum*). Water quality measurements at the three stations indicated that most parameters remained within tolerable ranges for Manila clams, although some environmental parameters showed notable variability. Water temperature ranged from 28 to 30°C, which is optimal for supporting the metabolic activity of filter feeders. This temperature range falls within the ideal limits for *R. philippinarum* (25–32 °C) and does not impose significant thermal stress on the population. Salinity values ranged from 28 to 31 ppt, indicating relatively stable estuarine conditions suitable for bivalves. Stable salinity supports osmoregulation and promotes feeding activity and biomass growth.

The pH values across all stations ranged from neutral to slightly alkaline (7.6–8.1), which is ideal for maintaining physiological processes, including respiration and enzymatic performance in benthic organisms. Variations in physicochemical parameters were observed across the sampling stations. Differences in salinity and pH may influence the distribution and density of macrozoobenthic organisms, although the present study did not perform a statistical correlation analysis to quantify these relationships. Overall, these findings suggest that the environmental conditions in the study area are generally conducive to sustaining Manila clam populations, although dynamic changes in certain parameters may influence local distribution and physiological responses (Pramika et al., 2021). Physicochemical parameters such as dissolved oxygen (DO), pH, and salinity have a significant relationship with the macrozoobenthic diversity index, indicating that higher values of these parameters are associated with greater benthic community diversity (Mutia et al., 2025).

Dissolved oxygen (DO) ranged from 5.1 to 6.4 mg/L, remaining above the minimum respiratory requirement for clams (DO > 5 mg/L). Adequate DO values indicate that water circulation is sufficient to meet the oxygen demands of benthic organisms. However, high Total Dissolved Solids (TDS) values ranging from 32,800 to 35,500 mg/L suggest elevated dissolved material concentrations in the water, typically associated with strong tidal dynamics, sediment mobility, and high turbidity. Low water transparency, measured at 20–45 cm, further indicates substantial turbidity. Increased turbidity can affect clams' filtration efficiency, as excessive suspended particles may clog siphons or reduce feeding efficiency. At Station 3, which exhibited the lowest transparency (~20 cm), high turbidity likely explains the presence of many small-sized individuals and the wide variation in body weight. This suggests that although clams can survive and grow, dynamic environmental conditions directly influence biomass accumulation. Conversely, Station 1, with higher water transparency, showed larger average clam sizes, reflecting a more stable environment conducive to growth.

CONCLUSION

This study demonstrated spatial variation in the abundance and morphometric characteristics of the Manila clam (*Ruditapes philippinarum*) across three sampling stations in the waters of Sarang Island, Batam. Stations 2 and 3 exhibited higher abundance, while Station 1 showed lower abundance but larger average shell size. The length–weight relationship indicated a negative allometric growth pattern, suggesting that shell length increased faster than body weight. The relative weight (WR) values generally indicated good physiological condition of the clam populations across the study area. This study provides new baseline ecological information on the population characteristics, growth patterns, and condition status of *R. philippinarum* in intertidal habitats of Batam, particularly in relation to habitat differences among sampling stations. The findings contribute to improving the ecological understanding of Manila clam populations and may serve as a reference for future monitoring and sustainable management of bivalve resources in coastal ecosystems.

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