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Morphometric Characteristics, Length–Weight Relationship, and Condition Factor of Kapis Clams (*Pecten maximus*, Linnaeus, 1758) in Sarang Island Coastal Waters

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Abstract

Background: *This study examined the morphometric characteristics, length–weight relationship, and condition factor of scallops belonging to the family Pectinidae in the waters of Sarang Island and Mecan Island, Belakang Padang District, Batam City. This research is important because scientific information regarding the biological characteristics and population condition of scallops in this area is still limited, while exploitation by local fishermen continues to occur.* **Methodology:** *The study was conducted from August to October 2024 using a quantitative descriptive approach. Sampling was carried out through diving surveys at three fishing stations using a sweeping technique along transects covering an area of approximately 100 m² at depths ranging from 2–6 m. Morphometric measurements included shell length, shell width, shell thickness, dorsal width, and total body weight. The length–weight relationship was analyzed using logarithmic regression, while physiological condition was evaluated using the relative condition factor (Kn).* **Findings:** *A total of 88 individuals were collected.. Water quality parameters showed suitable environmental conditions with temperature ranging from 29–31 °C, salinity 30–32 ppt, dissolved oxygen 5.2–6.4 mg/L, and pH 7.6–8.1. The growth exponent (b = 2.5877) indicates a negative allometric growth pattern, where shell length increases faster than body weight. This pattern may reflect ecological adaptation and environmental conditions in the study area.* **Contributions:** *These findings provide baseline biological information for sustainable scallop resource management.*

Keywords: *Bivalves; Length–weight relationship; Marine Biota; Morphometric characteristics; Pecten maximus*

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INTRODUCTION

The scallop *Pecten maximus* is widely distributed along the northeastern Atlantic coasts, ranging from Norway to the northwestern coast of Africa and extending into parts of the Mediterranean Sea. Previous studies reported that this species commonly inhabits sandy and gravel substrates in coastal marine environments along the European Atlantic region (Nicolle et al., 2017). The scallop *P. maximus* has significant economic and ecological value in coastal waters due to its relatively large body size, patchy distribution patterns, and its role in trophic dynamics and scallop aquaculture. Morphometric studies and length–weight relationship analyses of bivalve species such as *P. maximus* provide fundamental information on growth patterns, physiological condition, and adaptive responses to environmental factors, which are essential for effective resource management and conservation strategies (Duncan et al., 2016). Length–weight relationship (LWR) and condition factor are commonly used indicators to evaluate growth patterns, population health, and environmental influences on aquatic organisms. These parameters are also widely applied to compare populations across different locations or time periods and serve as fundamental references in fisheries and biological studies (Robinson et al., 2010).

Morphometric characteristics and length–weight relationships in marine bivalves provide important insights into population dynamics, growth patterns, and ecological responses to environmental variability (Meira et al., 2024). Biometric measurements such as shell length and body weight, combined with condition indices, are essential for assessing growth, physiological status, habitat quality, and population health in benthic mollusks (Sepúlveda et al., 2024). Recent studies show that morphometric relationships in bivalves vary across spatial and environmental gradients, highlighting the need for species-specific analyses to understand ecological adaptation and allometric growth (Cerdeira-Arias et al., 2024). Length–weight relationships and morphometric indices are essential tools in fisheries science and marine ecology for estimating biomass, analyzing growth dynamics, and supporting sustainable shellfish management (Ali et al., 2022).

Experimental studies on *P. maximus* have demonstrated that environmental factors such as temperature and water quality can influence calcification rates and condition factors, which in turn affect morphometric traits and productivity. Scallops belonging to the family Pectinidae are widely distributed in marine ecosystems worldwide, with the highest species diversity occurring in the Indo-Pacific region (Mahidol et al., 2007). Such findings underscore the importance of linking morphometric data and length–weight relationships with local environmental parameters when assessing population status (Cameron et al., 2019). In Indonesia, numerous biometric studies on mollusks and aquatic organisms have applied length–weight relationships (LWR), morphometric analyses, and condition indices to assess local growth patterns and the impacts of environmental conditions. Baseline biological information on scallops in the waters of Sarang Island, Batam City, is still limited, particularly regarding morphometric characteristics, length–weight relationships, and condition factors. Therefore, this study aims to analyze the morphometric characteristics, length–weight relationship, and condition factor of

P. maximus to provide scientific information that may support resource management and the potential development of mollusk aquaculture in the region (Diandari et al., 2024).

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 surrounding areas of Batam 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 (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).

Given the limited availability of biometric and length–weight relationship data for *P. maximus* in the Riau Islands region, particularly in the waters of Sarang Island, Batam City, and considering the ongoing changes in environmental pressures and local utilization potential, this study aims to describe the morphometric characteristics and growth patterns of the local population, estimate the length–weight relationship and condition index as indicators of population health, and analyze the relationship between morphometric variation and local environmental factors as a basis for management recommendations. The findings are expected to provide baseline biological information to support the establishment of appropriate catch size regulations and facilitate population monitoring of scallops in the waters of Sarang Island, Batam City.

MATERIALS AND METHODS

Study Area and Sampling Design

This study was conducted from August to October 2024 in the waters of Sarang Island and Mecan Island, Belakang Padang District, Batam City. Sampling activities were conducted at three observation stations selected using a purposive sampling approach, determined based on information regarding fishing areas frequently utilized by local fishermen to harvest scallops. The selection of these sites was intended to ensure that the collected samples accurately represented natural habitat conditions as well as actual scallop utilization areas in the field. Scallop sampling was conducted at three stations. Station 1 was located at coordinates 1°6′48.558″ N, 103°50′51.276″ E, approximately 60° northeast relative to the coastline of Sarang Island. Station 2 was located at 1°6′45.984″ N, 103°50′55.8″ E, approximately 352° north of the island, while Station 3 was positioned at 1°7′14.634″ N, 103°50′38.55″ E, approximately 290° west relative to the coastline.

Each station was selected to represent different aquatic environmental characteristics. Station 1 was dominated by sandy substrate, Station 2 consisted mainly of sandy-mud substrate, while Station 3 was characterized by a mixture of sand and coral rubble. These habitat differences allowed comparisons of morphometric traits and growth patterns of scallops among the study sites Sampling was carried out using a sweeping method, whereby researchers conducted underwater surveys with scuba diving equipment to collect scallops directly from the seabed. The sampling activities were conducted during daytime under relatively calm sea conditions and adjusted to the tidal cycle to facilitate safe and effective underwater observations. At each station, sampling was conducted along transects measuring 100 m in length with a sampling width of 1 m on both sides of the diving path. Three replicate transects were established at each station to ensure sampling consistency. The surveys were conducted at depths ranging from 2 to 6 m. All *Pecten maximus* individuals encountered within the designated area were collected and placed in labeled sample containers according to their respective stations for subsequent laboratory analysis.

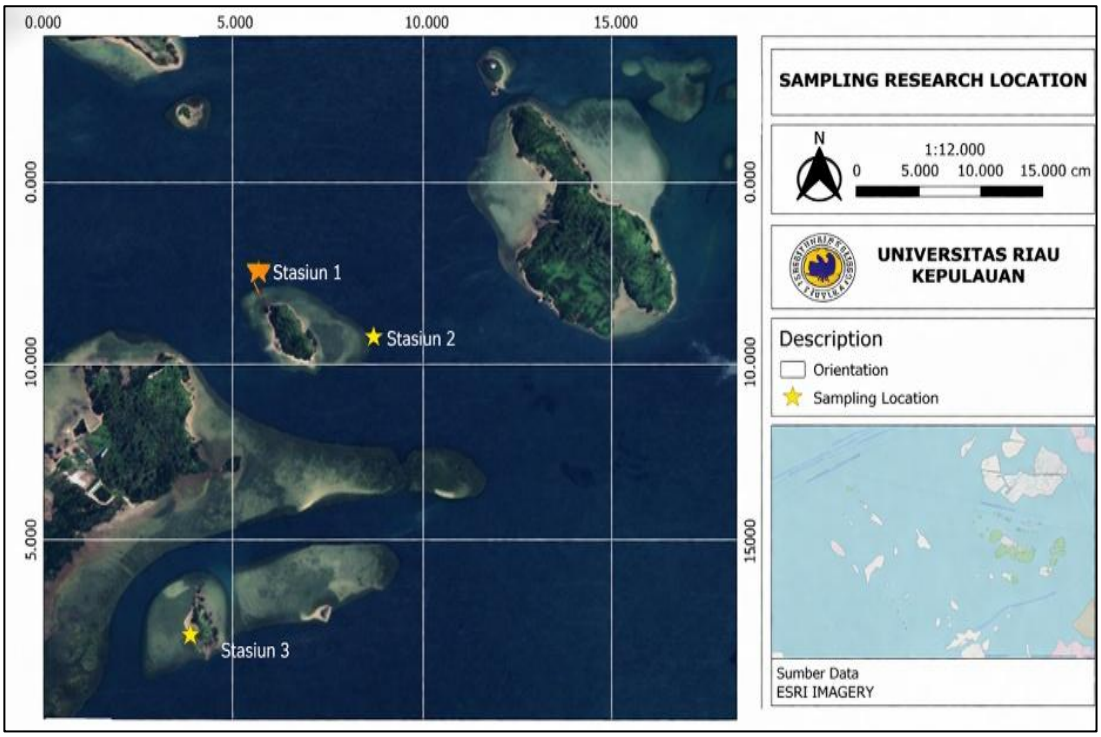

Figure 1. Research Location Map

Tools and Materials

Data collection in this study was conducted to obtain information on the morphometric characteristics of scallops (*Pecten maximus*) at three observation stations, namely Station 1 and Station 2 on Sarang Island, and Station 3 on Mecan Island. The primary equipment used included a Global Positioning System (GPS) device to determine the coordinates of each station and to establish a 100 m transect as the sampling boundary,

as well as writing tools and data recording sheets for field documentation. Scallop specimens were collected manually using sample bags to store individuals from each observation quadrat

Scallops collected from each station were placed in separate plastic containers according to their respective stations and subsequently transported to the laboratory for measurement. Morphometric analysis was conducted using a digital caliper with a precision of 0.01 mm to measure shell length from the anterior to the posterior margin. Total individual weight was determined using a digital balance with a precision of 0.01 g. Visual documentation of habitat conditions was carried out using a field camera for morphological verification and assessment of environmental conditions.

In addition to organism sampling, *in situ* measurements of water quality parameters were conducted to characterize actual habitat conditions during the study period. The instruments used included a thermometer to measure water temperature, a refractometer to assess salinity, and a Secchi disk to determine water transparency. Water depth was measured using a measuring line or an echosounder at each station to ensure the accuracy of environmental data, thereby supporting ecological interpretation and understanding the distribution of *Pecten maximus* populations at the study sites.

Water Quality Measurement

Water quality measurements were a critical component of this study, as physicochemical parameters such as temperature, salinity, pH, dissolved oxygen, and turbidity can directly influence the growth, metabolism, and physiological condition of *Pecten maximus*. In bivalve populations, deviations of these parameters from optimal ranges may suppress filtration rates, slow shell calcification processes, or induce oxidative stress, thereby affecting length–weight relationships and condition factor values. To obtain representative data, *in situ* measurements were conducted at the time of scallop sampling using instruments including a digital thermometer, refractometer, pH meter, dissolved oxygen (DO) meter, and turbidimeter. These water quality values were subsequently analyzed to examine their correlations with morphometric variations in *P. maximus*. This approach is consistent with previous coastal studies According to Suryono & Rochaddi (2017), in which water quality parameters such as DO, temperature, salinity, and pH were found to fall within ranges suitable for supporting scallops and other bivalve species.

Morphometric Measurement

Morphometric measurements were conducted to obtain quantitative information on the physical characteristics of *Pecten maximus*, reflecting growth patterns and morphological variation of the population in the waters of Sarang Island. The morphometric parameters commonly measured included shell length, shell height, shell width, and total individual weight. All measurements were performed using a digital caliper with a precision of 0.01 mm and an analytical balance to ensure data accuracy with a precision of 0.1 gram. These morphometric data served as the basis for length–weight relationship analysis and condition factor determination to assess whether growth patterns were isometric or allometric. Furthermore, morphometric variation may reflect the

influence of environmental conditions, food availability, and species adaptation to local habitats. This approach is consistent with previous studies by Rumbiak et al., (2014) indicating that morphometric parameters are key indicators for understanding growth dynamics and population health of bivalves in coastal environments.

Taxonomic Confirmation of *Pecten maximus*

Taxonomic confirmation of scallop specimens was conducted based on shell morphological characteristics following standard identification keys for the family Pectinidae. The observed diagnostic characters included shell shape, number and arrangement of radial ribs, auricle morphology near the hinge, shell symmetry, and the presence of a byssal notch. These morphological features are commonly used to distinguish species within the family Pectinidae and are considered reliable indicators for taxonomic identification in scallops (Serb, 2016). The identification process also referred to comparative morphological descriptions reported in previous taxonomic studies of pectinid bivalves, where shell characters such as rib number, auricle proportions, and hinge structures are key traits used to differentiate species and confirm taxonomic status (Slynko et al., 2020). Specimens collected during field sampling were examined visually and compared with diagnostic descriptions provided in standard taxonomic references for marine bivalves to confirm the species identity.

DATA ANALYSIS

Morphometric Measurement

Morphometric analysis was conducted to describe variations in the size and shape of *P. maximus* based on shell length, shell height, shell width, and body weight parameters. The collected data were analyzed descriptively to determine minimum, maximum, mean, and standard deviation values. This approach aimed to identify growth patterns and morphological variation within the population, which may be influenced by environmental conditions, food availability, and local adaptation. Each parameter was further examined using basic proportional relationships to assess interrelationships among size measurements. The general formula by Froese (2006) used for morphometric description was based on ratio comparisons among body parts, as follows:

$$Morphometric\ Ratio = \frac{Shell\ Length}{Shell\ Height}, \frac{Shell\ Length}{Shell\ Width}, \frac{Shell\ Height}{Shell\ Width} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

These ratios help identify dominant shell forms (e.g., more elongated, wider, or rounded) and assess phenotypic variation within a single population. Morphometric analysis is important because it can reveal growth conditions and environmental factors that influence organismal performance. Similar approaches have been widely applied in previous studies on bivalves and other aquatic organisms.

Figure 2. Morphometric Measurement of *P. maximus*

Length–Weight Relationship

Length–weight relationship (LWR) analysis is used to describe growth patterns of aquatic organisms, including bivalves. This relationship illustrates how increases in shell length are accompanied by changes in body weight. The results of LWR analysis typically determine whether bivalves exhibit isometric growth (where length and weight remain proportional) or allometric growth (where weight increases faster or slower than length). This parameter is important for assessing population health, reproductive potential, and the ecological performance of a species within a given habitat. The equation used in this analysis by Asmita & Machrizal (2023) is as follows:

$$W = aL^b \quad \text{..... (2)}$$

Where,

- W = body weight of the organism (g)
- L = shell length (mm or cm)
- a = intercept (initial condition factor)
- b = growth exponent

Condition Factors

Fulton's Condition Factor (Kn) is used to assess the physiological fitness or "plumpness" of an organism based on the relationship between its length and body weight. This index is widely applied in fisheries stock studies because it provides insight into individual health status and the quality of the habitat in which the organism lives. The formula for the condition factor by Froese (2006) is as follows:

$$Kn = \frac{W}{L} \; x \; 100 \quad \text{..... (3)}$$

Where, W represents the individual body weight (g), and L denotes body length (cm). Higher K values indicate better physiological condition, such as adequate food availability or environmental conditions that support optimal growth. Conversely, lower K values may indicate environmental stress, food competition, declining water quality, or other stress-related factors. The use of condition factor indices has been widely applied in studies of bivalves and other marine organisms. For example, growth studies on scallops have

demonstrated that *K* values can reflect organismal responses to environmental variation and nutrient availability in aquatic habitats (Froese, 2006).

RESULT AND DISCUSSION

Morphometric Measurement

Morphometric measurements of *Pecten maximus* collected from the three study stations revealed clear spatial variation in shell size and body characteristics among locations. At Station 1 on Sarang Island, the mean shell length reached 77.21 mm, with an average shell width of 68.47 mm, body weight of 71.47 g, shell thickness of 18.70 mm, and dorsal width of 32.90 mm. The relatively narrow size range (shell length 70.4–80.9 mm) indicates a homogeneous population structure and stable growth conditions.

At Station 2, morphometric variation was considerably higher, with a mean shell length of 68.42 mm (range 50.3–90.9 mm), shell width of 61.64 mm, and the lowest average body weight (51.56 g). In addition, the mean shell thickness was only 16.32 mm, with a dorsal width of 31.74 mm. The large size variability observed at this station suggests a mixture of juvenile and adult individuals, reflecting environmental conditions that differ from those at the other stations. In scallops, shell size is commonly used as an indicator of ontogenetic stage, where smaller individuals generally represent juvenile stages and larger individuals indicate mature or adult specimens (Kraak et al., 2015). At Station 3 on Mecan Island, scallop size showed a tendency toward larger dimensions, with an average shell length of 75.59 mm, shell width of 67.57 mm, body weight of 71.50 g, shell thickness of 18.17 mm, and dorsal width of 32.23 mm. The shell length range of 60.9–90.2 mm indicates a more diverse age structure, although the population remained dominated by medium- to large-sized individuals.

Length–Weight Relationship

The analysis of the length–weight relationship of *Pecten maximus* revealed a consistent growth pattern across the three observation stations. Based on logarithmic regression analysis, the obtained equation was $W = 0.000908 \times L^{\wedge 2.5877}$, with a correlation coefficient (r) of 0.89073. This value indicates a very strong relationship between shell length and body weight, whereby increases in shell length are accompanied by significant increases in body weight. The coefficient of determination (R^2) of 0.7934 suggests that 79.34 % of the variation in body weight can be explained by shell length, while the remaining variation is influenced by environmental factors or individual physiological conditions.

Table 1. Morphometric Measurement

Station	Shell Length (mm)	Shell Width (mm)	Shell Thickness (mm)	Dorsal Width (mm)	Weight (g)
Sarang Island 1	77.21 ± 4.69 (70.40 – 80.90)	68.47 ± 5.94 (60.40 – 80.80)	18.70 ± 1.32 (15 – 21)	32.90 ± 4.10 (30.40 – 40.50)	71.47 ± 10.54 (53.40 – 95.60)
Sarang Island 2	68.42 ± 11.70 (50.30 – 90.90)	61.64 ± 10.32 (40.70 – 80.60)	16.32 ± 3.13 (10 – 20)	31.74 ± 3.17 (30.20 – 40.40)	51.56 ± 24.37 (19.20 – 109.20)
Mecan Island	75.59 ± 7.63 (60.90 – 90.20)	67.57 ± 6.66 (60.20 – 81.00)	18.17 ± 2.48 (14 – 24)	32.23 ± 4.15 (29 – 43)	71.50 ± 18.69 (46.50 – 107.20)

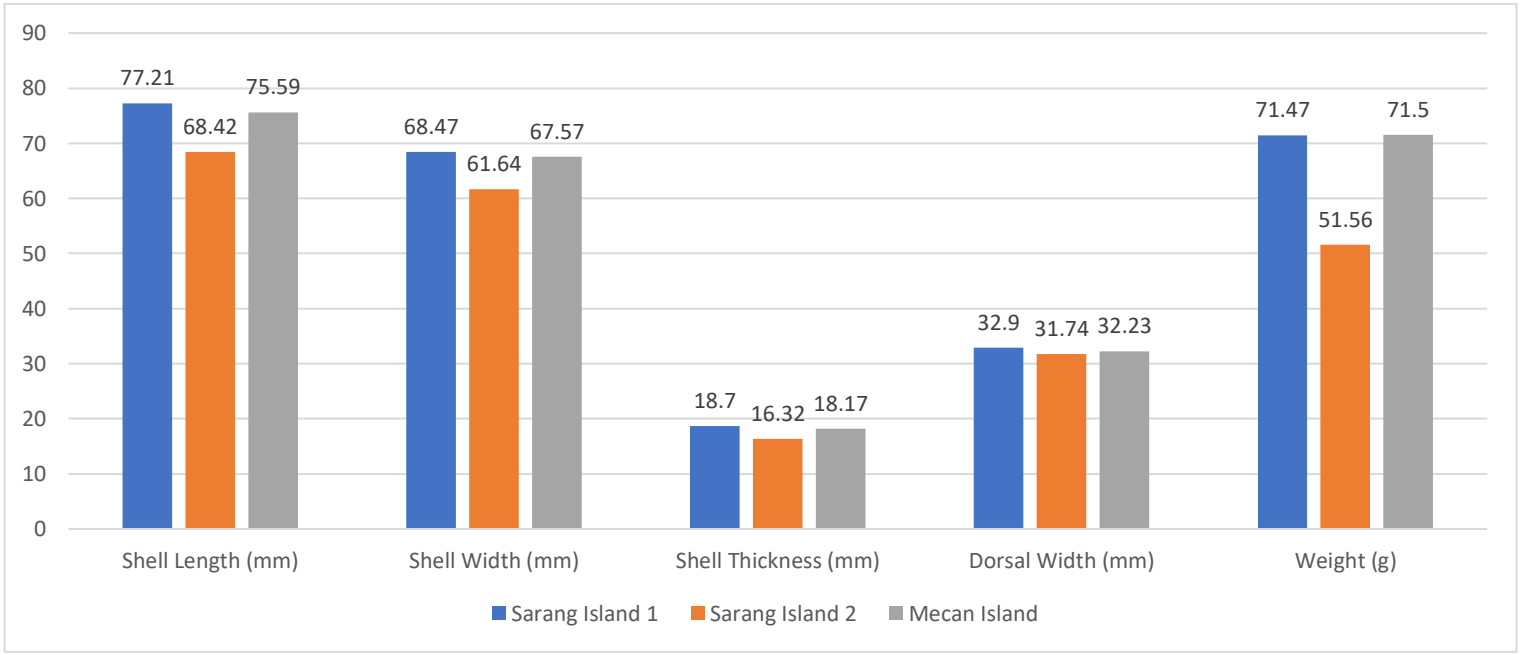

Figure 3. Morphometric Graph

Table 2. Length–Weight Relationship

No.	Parameter	Value	Description
1	a (intercept)	0,000908	Basic condition factor at zero size
2	b (growth exponent)	2.5877	Negative allometry (b < 3)
3	LWR equation	$0{,}000908 \times L^{\wedge 2{,}5877}$	Based on log-log regression
4	R^2	0,7934	79.34% of weight variation explained by length
5	r (correlation)	0.89073	Very strong relationship
6	Growth category	Negative allometry	Length increases faster than weight

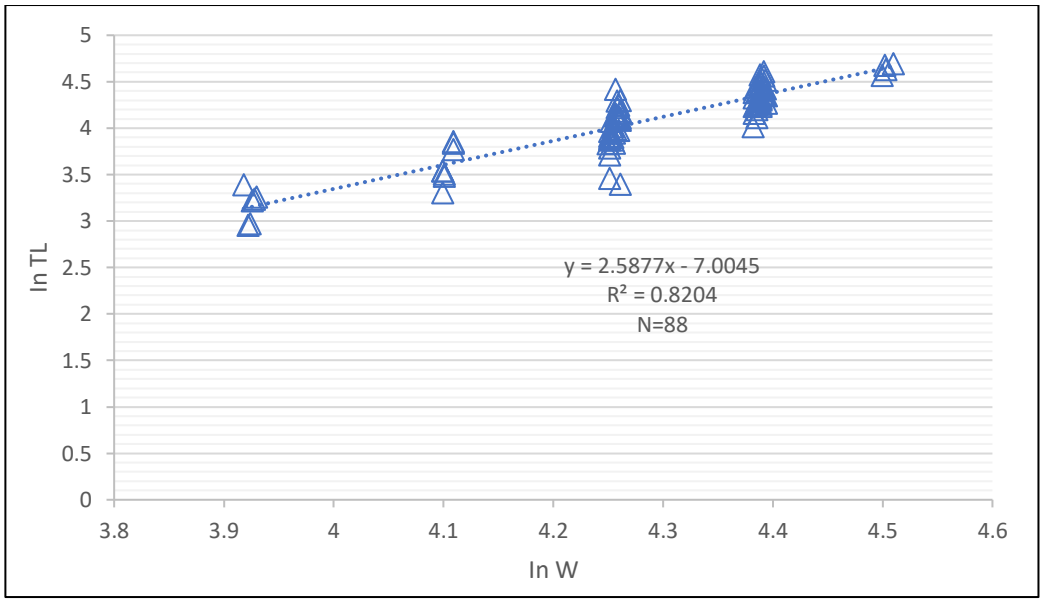

Figure 4. Length–Weight Relationship Graph

The growth exponent (*b*) value of 2.5877 indicates that the growth pattern of scallops falls within the negative allometric category, meaning that shell length increases at a faster rate than body weight. This condition is commonly observed in bivalve organisms inhabiting environments with fluctuating nutrient availability and variable water conditions. The *T*-test results yielded a calculated *T*-value of 20.59, which was substantially higher than the critical *T*-value (1.65), indicating that the length–weight relationship was statistically significant. Therefore, the derived regression model is valid for describing the growth dynamics of *Pecten maximus* in the waters of Sarang Island and Mecan Island.

Condition Factors

The analysis of the condition factor of *Pecten maximus* across the three stations indicates that, overall, the physiological condition of the population was categorized as good. Based on the calculation of relative weight (Wr), the mean condition factor was 101.47 %, indicating that the observed body weight of individuals was slightly higher than the standard weight estimated from the length–weight model. This result suggests that most scallops were in optimal physiological condition and possessed sufficient energy reserves for tissue growth.

The pattern of condition factor among stations revealed notable variation. At Station 1 and Station 3, Wr values generally ranged between 90% and 110%, reflecting stable population conditions with adequate food availability and environmental conditions conducive to growth. In contrast, Station 2 exhibited greater fluctuations, with the presence of individuals displaying low Wr values (60 – 80%) as well as very high values (120 – 186 %). This phenomenon suggests that the environment at Station 2 was more dynamic and may be subject to ecological pressures such as food competition or variability in water quality. Nevertheless, the overall condition factor values exceeding 100 % indicate that the *Pecten maximus* populations at all three locations remained in good condition.

Table 3. Condition Factors

Parameter	Value	Description
Average *Wr* (Kn %)	101.4689 %	Population status is good
Individual *Wr* range	60% – 186%	The greatest variation at Station 2
Stations with the most stable conditions	Station 1 (Kn ≈ 1.02); Station 3 (Kn ≈ 1.01)	Majority *Wr* 90–110%
Stations with the highest fluctuations	Station 2 (Kn range: 0.60–1.86)	Many low and very high *Wr* values
General interpretation	Good physiological condition	Actual weight ≈ ideal weight

Water Quality

Water quality measurements at the three observation stations indicated that most environmental parameters remained within ranges tolerable for scallops (*Pecten maximus*). 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 human activities. Water temperature ranged from 28 to 30°C across all stations, which is suitable for supporting physiological activity and growth of scallops.

Salinity values ranged from 28 - 31 ppt, reflecting relatively stable coastal conditions favorable for marine bivalves.

The pH values were recorded within neutral to slightly alkaline ranges (7.6 – 8.1), supporting metabolic processes and physiological functions of the organisms. Dissolved oxygen concentrations ranged from 5.1 - 6.4 mg/L, indicating that the waters contained sufficient oxygen to support respiration of benthic organisms, including scallops. TDS values were relatively high, ranging from 32,000 - 35,500 mg/L, reflecting elevated dissolved solids influenced by sediment input, current activity, and tidal dynamics. Water transparency was relatively low, with Secchi disk readings between 20 and 45 cm, indicating high turbidity levels. Such conditions may affect filtration processes in bivalves; however, *P. maximus* appears capable of adapting to certain levels of turbidity. Overall, water quality conditions across the three stations remained within tolerable ranges that support the growth and persistence of *Pecten maximus* in the study area.

Table 4. Water Quality

Parameter (Unit)	Station 1	Station 2	Station 3	Tolerance Range of *P. maximus* by Peake et al., (2010)
Temperature (°C)	28–30	28–30	28–30	26–30 °C
Salinity (ppt)	28–31	28–31	28–31	28–34 ppt
pH	7.6–8.1	7.6–8.1	7.6–8.1	7.5–8.5
DO (mg/L)	5.1–6.4	5.1–6.4	5.1–6.4	> 5 mg/L
TDS (mg/L)	32,000–35,500	32,000–35,500	32,000–35,500	< 40,000 mg/L (general marine waters)
Lightness (cm)	20–45	20–45	20–45	> 20 cm (depending on turbidity)

Comparison Between Stations

Comparison of morphometric measurements among the three stations revealed differences in body size distribution and physiological condition of Pecten maximus. Station 1 on Sarang Island exhibited a relatively homogeneous population characterized by stable shell length, shell width, and body weight. Individuals at this station were generally within the medium- to large-size classes, indicating relatively uniform growth conditions. Pearson correlation analysis between environmental parameters and morphometric variables indicated that water temperature and dissolved oxygen showed moderate positive correlations with shell length and body weight ($r = 0.45 – 0.62$, $p < 0.05$), while salinity exhibited a weaker relationship. These results suggest that environmental conditions may influence growth performance of *P. maximus* across the sampling stations.

Station 2 displayed the highest morphometric variability, with shell length ranging from small to very large individuals and body weight showing considerable fluctuations. The broader variation in condition factor values may reflect differences in resource

availability or environmental heterogeneity at this station. Station 3, located on Mecan Island, demonstrated relatively consistent morphometric characteristics with higher average body weight and condition factor values compared to the other stations. The relatively stable environmental parameters recorded at this location, particularly dissolved oxygen and salinity, may contribute to more favorable growth conditions. From the perspective of the length–weight relationship, the scallop population exhibited a negative allometric growth pattern (b = 2.5877), indicating that shell length increased more rapidly than body weight.

Discussion

Morphometric Measurement

The morphometric measurements of *Pecten maximus* in the waters of Sarang Island and Mecan Island revealed variations in shell length, shell width, shell thickness, and body weight among stations, reflecting differences in local habitat conditions. Relationships among morphometric dimensions in bivalves are strongly influenced by local environmental characteristics, such as substrate type, food availability, and hydrodynamic conditions. Shell length–width ratios and overall body size of bivalves often exhibit significant variation across species and locations, indicating that morphometric traits can serve as indicators of ecological adaptation and growth strategies of benthic organisms. The similarity of these patterns suggests that the morphometric variation observed in *P. maximus* in this study represents a natural response to coastal environmental heterogeneity, consistent with findings reported for bivalves in subtropical European waters (Gaspar et al., 2002).

Furthermore, the results of this study indicate that the length–weight relationship of *Pecten maximus* tends to follow a pattern of negative allometric growth, in which the increase in shell length occurs more rapidly than the gain in body weight. Morphometric analysis and length–weight relationships suggest that individuals inhabiting environments with fluctuating resource availability tend to allocate a greater proportion of energy to linear growth rather than biomass accumulation. This condition indicates that morphometric variation is influenced not only by genetic factors but also by environmental pressures and physiological adaptive strategies of the organisms. Consequently, the morphometric patterns of *P. maximus* observed in this study can be interpreted as adaptive responses to the dynamic environmental conditions of Sarang Island and Mecan Island waters, in agreement with findings reported for other marine organisms in tropical and subtropical coastal regions (Sureandiran et al., 2025).

Furthermore, the variation in morphometric size among stations observed in this study is consistent with the general principles of size–weight relationship analysis in aquatic organisms. Differences in location and habitat conditions can result in distinct growth parameters, even when the same species or similar analytical methods are applied. Previous studies have emphasized that morphometric parameters such as length and weight are important indicators for assessing growth status and population health in both fish and marine invertebrates. This finding reinforces the conclusion that the

morphometric differences of *Pecten maximus* among stations in the present study do not represent anomalies, but rather reflect local ecological variability that influences organism growth performance. Therefore, morphometric measurements in this study have strong relevance as a basis for evaluating population condition and habitat quality of *P. maximus* in the coastal waters of Batam (Mahé et al., 2023).

Length–Weight Relationship

The analysis of the length–weight relationship (LWR) of *Pecten maximus* in the waters of Sarang Island and Mecan Island revealed exponent *b* values that deviated from 3, indicating allometric growth patterns, either negative or positive depending on local conditions. These deviations reflect growth dynamics that are strongly influenced by site-specific environmental factors and organismal energy allocation strategies. Similar patterns of variation in *b* values have been consistently reported in studies of coastal fish communities along the northwest Atlantic coast, where length–weight relationships for seven fish species demonstrated *b* coefficients ranging from 2.64 to 3.17. This range indicates growth patterns spanning from negative allometry to near-isometric growth, depending on species characteristics and local ecological conditions. Such findings support the interpretation by Ruzafa & González (2024) that variability in LWR parameters is a common ecological response rather than an anomaly, reinforcing the role of environmental heterogeneity in shaping growth patterns across aquatic organisms.

Almost all analyzed species exhibited a statistically strong length–weight relationship, with coefficients of determination (R^2) exceeding 0.90. This provides robust empirical support by (Jiang et al., 2024) that the relationship between length and weight represents a consistent biological parameter, even though the *b* values may vary among species and across marine habitats ranging from tropical to subtropical regions. In addition, a study by Villanueva-Saz et al., (2022) on length–weight relationships (LWR) of 16 marine fish species in Vietnamese waters reported *b* values ranging from 2.53 to 3.28. These findings further confirm that variations in LWR parameters are influenced not only by species-specific physiological traits but also by spatial and temporal factors, as well as sexual dimorphism, all of which can significantly affect the growth dynamics of aquatic organisms.

Condition Factors

The analysis of the condition factor in this study on *Pecten maximus* indicates that the relative condition factor of this bivalve reflects its physiological status and body energy balance, which are strongly influenced by local environmental conditions. This pattern is consistent with findings reported in studies on other aquatic organisms. Although the length–weight growth pattern was predominantly characterized by negative allometric growth, the condition factor exhibited significant differences between males and females. Female individuals consistently showed better condition values throughout the sampling period, inline with Gustiarisanie et al., (2016) suggesting that variations in condition factor may reflect physiological differences and distinct energy allocation strategies among biological groups. In addition to the length–weight relationship, condition factor values

also vary among species and provide an overview of the general health status of populations. Species exhibiting higher condition factor values tend to possess better body condition and greater resilience to environmental fluctuations. This supports the interpretation by Jiang et al., (2024) that condition factor can be used as an ecological indicator to assess organismal well-being within their habitats.

The measured relative condition factor values showed only minor variation among fish size groups and remained close to 1.00, indicating that the population was generally in good condition. This finding reinforces the notion that although condition factor values may vary depending on organism type and ecological setting, values that remain around or above a certain threshold (e.g., close to 1) are commonly interpreted as indicators of adequate nutritional status and overall population well-being. This interpretation is consistent with Sartika et al., (2023) results on *Pecten maximus*, which also demonstrate condition factor values reflecting favorable physiological conditions within the studied populations.

Water Quality

Water quality in the waters of Sarang Island and Mecan Island, characterized by temperatures ranging from 28–30 °C, salinity of 28–31 ppt, neutral to slightly alkaline pH, and dissolved oxygen levels above 5 mg/L, indicates environmental conditions that remain suitable for the survival and growth of *Pecten maximus*. These conditions are consistent with studies conducted on the habitat of *Anadara granosa* in tropical coastal waters, Álvarez et al., (2016) which report that temperature and salinity within these ranges represent optimal conditions for bivalve filtration activity and metabolic processes. Such environmental parameters play a crucial role in maintaining energy balance and supporting favorable physiological conditions in bivalve species.

In addition, the relatively high dissolved oxygen (DO) levels observed in this study indicate aquatic conditions that support the respiratory requirements of benthic organisms. This finding is consistent with studies on *Perna viridis* in Southeast Asian coastal waters, which report that DO concentrations above 5 mg/L are positively correlated with shellfish growth and condition factor, whereas decreased DO levels may induce physiological stress and lead to a reduction in relative body weight. The similarity of Choi et al., (2014) findings suggests that oxygen availability is a key environmental parameter in determining the health and sustainability of bivalve populations.

The relatively low water transparency and high levels of total dissolved solids observed in this study reflect the characteristics of coastal waters with strong sediment dynamics. Similar conditions have been reported in ecological studies of bivalves in estuarine environments, which indicate that moderate turbidity can still be tolerated by bivalves through adaptive filtration mechanisms, although it may affect feeding efficiency and long-term growth rates. This finding supports the interpretation Walles et al., (2015) that, despite the relatively high turbidity levels in the waters of Sarang Island and Mecan Island, these conditions remain within the ecological tolerance limits of *P. maximus*.

Comparison Between Stations

Differences in morphometric characteristics, growth patterns, and population attributes among stations in the *Pecten maximus* study indicate that local environmental variability strongly influences bivalve population structure at each site. This finding is consistent with Noskovich & Dvoretsky (2024) studies on *Macoma calcarea* in Svalbard fjords, which reported significant differences in population parameters such as abundance, biomass, and growth rates among station groups separated by distinct local oceanographic conditions. Stations characterized by higher water temperatures and specific substrate types were associated with larger individual sizes and higher biomass compared to other stations, indicating that spatial heterogeneity in environmental conditions plays a critical role in shaping size structure and growth patterns of bivalves.

Spatial variation in physical environmental parameters and benthic history can result in differences in the distribution and density of bivalve populations among stations. The taxonomic distribution and community dynamics at each station are clearly influenced by a combination of local environmental factors, providing evidence that the inter-station differences observed in *P. maximus* also reflect coexisting ecological variability at a local scale (de Fouw et al., 2024). Species composition and population characteristics of bivalves can vary significantly among sampling stations, influenced by habitat-related factors such as substrate type, salinity, and local oceanographic conditions. Therefore, the inter-station variability observed in the present study of *P. maximus* represents a general spatial pattern that is also commonly found in other bivalve communities inhabiting coastal waters (Zhou et al., 2025).

CONCLUSION

This study revealed spatial variation in the morphometric characteristics and physiological condition of *Pecten maximus* across the three sampling stations. Stations 1 and 3 exhibited relatively stable shell length, shell width, and body weight distributions, whereas Station 2 showed the highest variability, indicating the presence of multiple size classes within the population. The length–weight relationship followed a negative allometric growth pattern (b = 2.5877), suggesting that increases in shell length occur more rapidly than increases in body weight. The average relative condition factor (Kn ≈ 1.01 or 101.47%) indicates that the overall population is in good physiological condition. These results suggest that differences in habitat characteristics among stations may influence population structure and growth performance of *P. maximus*. In particular, Station 3 demonstrated relatively favorable conditions, as indicated by higher body weight consistency and more stable condition factor values compared with the other stations. From an ecological perspective, this study provides baseline information on morphometric variation, growth patterns, and condition factors of *P. maximus* in the coastal waters of Batam, an area where biological data on this species remain limited. Methodologically, the integration of morphometric measurements, length–weight relationship analysis, and condition factor assessment offers a practical framework for evaluating population status of scallops in tropical coastal environments. The findings of this study can support future

monitoring of scallop populations and may contribute to sustainable management strategies, including the determination of appropriate harvesting sizes and the development of potential scallop aquaculture in the region.

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