

Environmental parameters and growth of cage-cultured blood cockle *Tegillarca granosa* in Aceh, Indonesia

MAWARDI^{1,2,*}, TRI MUSTIKA SARJANI¹, MUHAMMAD KHALIL^{1,2}, ANITA RASUNA SARI SIREGAR¹

¹Department of Biology Education, Faculty of Teacher Training, Universitas Samudra. Jl. Prof. Dr. Syarif Thayeb, Langsa 24416, Aceh, Indonesia. Tel./fax.: +62-852-7751-6900, *email: mawardibio@unsam.ac.id

²Department of Science Education, Faculty of Teacher Training, Universitas Samudra. Jl. Prof. Dr. Syarif Thayeb, Langsa 24416, Aceh, Indonesia

Manuscript received: 31 August 2025. Revision accepted: 6 March 2026.

Abstract. Mawardi, Sarjani TM, Khalil M, Siregar ARS. 2026. Environmental parameters and growth of cage-cultured blood cockle *Tegillarca granosa* in Aceh, Indonesia. *Biodiversitas* 27 (3): d270307. <https://doi.org/10.13057/biodiv/d270307>. This study evaluated the growth performance of cage-cultured blood cockle *Tegillarca granosa* and the environmental parameters influencing it in two mangrove-fringing coastal waters in Aceh, Indonesia. A randomized block design was used with three stocking densities (20, 40, and 60 individuals per cage) at Pusong and Lhok Banie. Water quality variables—including temperature, salinity, pH, organic matter, and sediment characteristics—were measured throughout the culture period. Growth parameters (shell length, width, and weight) and environmental factors (sediment type, salinity, and plankton abundance) were monitored for six months. Data were analyzed using Specific Growth Rate (SGR), ANOVA, and Principal Component Analysis (PCA). Results showed that growth in length ranged from 3.07-8.00 mm, width from 2.48-5.45 mm, and weight from 2.63-5.60 g. The highest growth was recorded at Pusong (P1, 20 individuals/cage), while the lowest was at Lhok Banie (LB3, 60 individuals/cage). The SGR ranged from 0.18-0.30 g. PCA indicated that sediment composition dominated by clay and clayey loam, together with salinity of 24-28‰, had the strongest positive relationship with cockle growth. Overall, the findings demonstrate that *T. granosa* grows better in areas with higher salinity and organic-rich sediments, and that a stocking density of 20 individuals per cage yields the most favorable growth performance. These results provide baseline information for improving community-based blood cockle aquaculture and support the development of sustainable mangrove-associated coastal farming systems in Aceh.

Keywords: Cage culture, environmental parameters, growth performance, specific growth rate, *Tegillarca granosa*

INTRODUCTION

The blood cockle *Tegillarca granosa* (Linnaeus, 1758) is one of the most ecologically and economically important bivalves in Southeast Asia. This species inhabits intertidal and subtidal zones, living buried in muddy and sandy sediments where it functions as a filter feeder of plankton and other suspended organic matter (Roslan et al. 2022; Mawardi et al. 2024; Hasan et al. 2024a, 2024b; Khan et al. 2025). Its ecological role includes contributing to nutrient cycling, sediment stability, and providing food for higher trophic levels (Yadav et al. 2019). Beyond its ecological significance, *T. granosa* is also highly valued as a seafood commodity, with a protein content of up to 12.41% (Cao et al. 2018; Permata et al. 2023; Hasan et al. 2024a). Its nutritional quality and wide consumer acceptance make it a staple in coastal communities and an important contributor to food security and livelihoods.

At the global scale, production of blood cockle (*T. granosa*) is concentrated in Southeast Asia, particularly Indonesia and Malaysia, as major contributors to international supply (Saif et al. 2020; Pahri et al. 2023). In Indonesia, capture production reached approximately 20,000 tons/year in 2010, with regional data from Batu Bara showing continued contributions from both capture (598.54 tons/year) and aquaculture (199.52 tons/year) (Saffian et al. 2020; Mahary et al. 2025). In Malaysia, production declined sharply from

78,024 tonnes in 2010 to around 16,866 tonnes in 2015-2016 due to environmental degradation and overexploitation (Saif et al. 2020; Pahri et al. 2023). Economically, this commodity provides significant income, with capture fisheries generating about USD 14,805 annually and aquaculture yielding USD 5,840-10,961 (Mahary et al. 2025).

Growing consumer demand has led to uncontrolled harvesting across its natural range, including in Indonesia and Malaysia (Antu et al. 2023; Pahri et al. 2023; Hasan et al. 2024b). At the same time, mangrove ecosystems that serve as primary habitats for *T. granosa* are being degraded by coastal development, aquaculture expansion, and pollution (Richards et al. 2017; Morgan et al. 2024). The loss of mangrove vegetation not only reduces habitat availability but also alters sediment composition and water quality, both of which are critical for the survival and growth of blood cockles (El-Hacen et al. 2023). Consequently, natural populations have shown signs of decline, raising concerns about the long-term sustainability of wild harvests.

Aquaculture has been proposed as a strategy to reduce harvesting pressure on wild populations while maintaining supply for local and export markets (Bogmans and van Soest 2022). Growth performance in shellfish culture is strongly influenced by stocking density, feed availability, and environmental conditions. For instance, lower stocking densities enhance growth in *Perna viridis* (Rusydi 2024),

while supplemental feeding improves the growth of *T. granosa* (Saif et al. 2020). These findings indicate that shellfish growth is context-dependent and shaped by both biotic and abiotic factors.

Although information on the biology and ecology of blood cockle is available from other regions, empirical data on growth performance under natural mangrove conditions in Aceh remain limited. Aceh hosts extensive mangrove ecosystems (~8,000 ha) that provide favorable conditions for shellfish culture, including suitable sediments, tidal dynamics, and abundant natural food sources (Shore and Douben 2021; Safuridar et al. 2022; Mawardi et al. 2023). However, no comprehensive study has evaluated how environmental parameters in these ecosystems influence the growth of cage-cultured *T. granosa*, constraining the development of sustainable aquaculture practices.

Addressing this gap is essential, as empirical growth data can inform optimal stocking density and site selection while minimizing ecological impacts, and support coastal management by balancing mangrove conservation with aquaculture development. Therefore, understanding the relationship between environmental parameters and the growth of *T. granosa* is critical for both conservation and fisheries management.

The present study was conducted to analyze the growth performance of the cage-based culture of *T. granosa* in the mangrove ecosystem of Langsa City, Aceh Province, Indonesia. Specifically, this research aimed to (i) measure

growth in terms of shell length, width, weight, and specific growth rate (SGR), (ii) examine the influence of environmental parameters on growth performance, and (iii) identify optimal cultivation conditions in natural mangrove habitats. By filling these knowledge gaps, the study provides essential scientific evidence to support sustainable aquaculture practices and contribute to the conservation of *T. granosa* populations in Aceh and beyond.

MATERIALS AND METHODS

Study area

The study was conducted from 2024 to 2025 in the coastal area of Langsa City, Aceh Province, Indonesia. Langsa City contains one of the largest mangrove ecosystems in Southeast Asia, covering approximately 8,000 ha (Safuridar et al. 2022). Research was carried out at 2 locations characterized by differences in water salinity, sediment composition, and mangrove vegetation (Figure 1). This research was conducted with official permission from the Langsa City government and supported by the coastal community. Two local community members were routinely involved throughout the entire research process, from its initiation to completion. Location was situated in the Lhok Banie and Pusong coastal area. Detailed environmental parameters for both locations are presented in Table 1.

Table 1. Locations and environmental characteristics of the study sites

Location	Coordinate	Location characteristics
Lhok Banie	4°31'55.6"N 97°59'38.0"E	Lhok Banie is a mangrove area located far from the residential areas, dominated by <i>Rhizophora stylosa</i> and <i>Sonneratia alba</i> trees. The area is frequently inundated at high tide, and the sediment is predominantly muddy sand.
Pusong	4°32'43.0"N 98°03'56.8"E	The Pusong area is a mangrove area located far from residential areas, dominated by <i>Rhizophora mangle</i> and <i>Rhizophora mucronata</i> trees. This area is close to the shoreline and is frequently inundated at high tide, with sediments dominated by muddy clay.

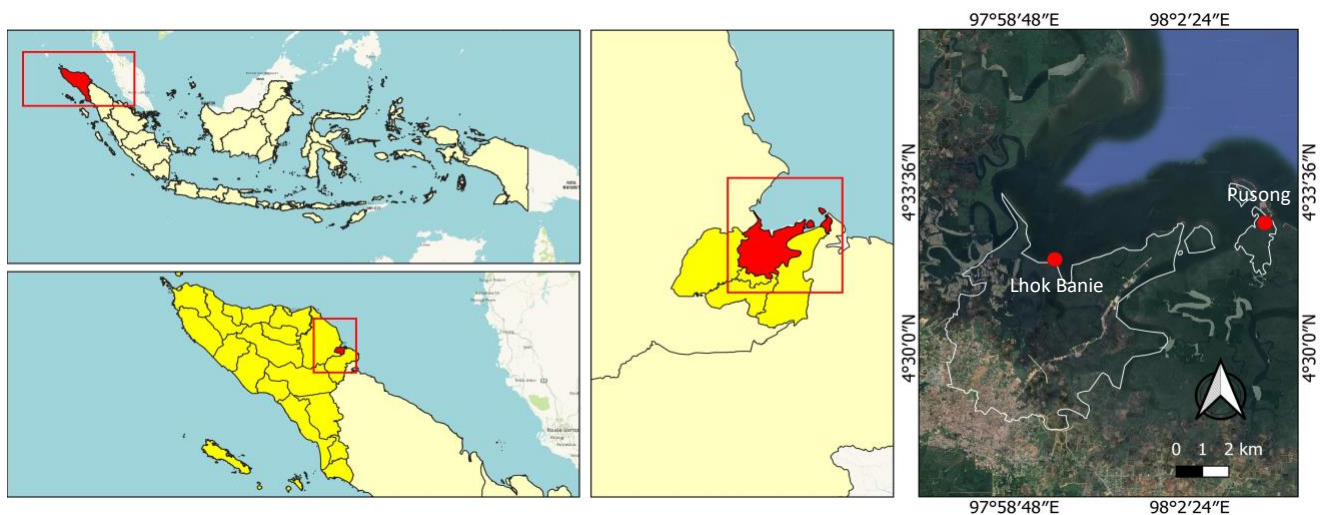


Figure 1. The research location of the coastal area of Langsa City, Aceh Province, Indonesia

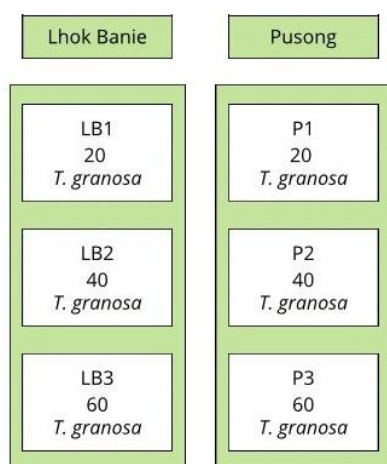


Figure 2. Research design for cage-based growth of *T. granosa*

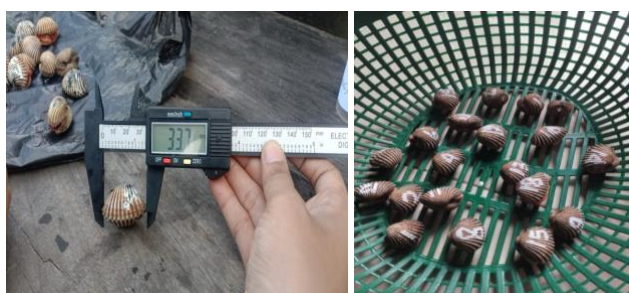


Figure 3. Representative specimens of *T. granosa* as experimental animal

Research design

The study was conducted at two locations with different salinity and sediment characteristics, namely the Lhok Banie mangrove area and the Pusong mangrove area within the Langsa City mangrove ecosystem, Aceh Province, Indonesia. These sites were selected based on previous reports indicating suitable environmental conditions and natural populations of *T. granosa*. The experimental design was developed following established methodologies in bivalve aquaculture research. A Randomized Block Design (RBD) was applied to minimize environmental variability between study sites (Gomez and Gomez 1984). Stocking density treatments were determined based on recognized density-dependent growth principles in blood cockle and other intertidal bivalve culture systems (Broom 1985; FAO 2004). The enclosure system was developed following commonly applied grow-out methods in Southeast Asian cockle farming practices. Rectangular cages (2 × 2 m; 0.5 m height) were constructed using iron posts fitted with PVC-coated iron wire with 1-inch mesh openings. The cages were stocked with varying numbers of *T. granosa*: in the Lhok Banie area, LB1: 20 individuals/cage, LB2: 40 individuals/cage, and LB3: 60 individuals/cage; in the Pusong area, P1: 20 individuals/cage, P2: 40 individuals/cage, and P3: 60 individuals/cage. A detailed schematic of the experimental design is presented in Figure 2.

Animal test

The test animals used in this study were *T. granosa*, collected from fishermen's catches in the mangrove ecosystem of Langsa City, Aceh Province, in healthy condition. *T. granosa* samples selected for this study ranged in length from 27 to 30 mm. Before being placed in the cages, the samples were acclimatized for three days. A representative image of the experimental animals, including their morphological characteristics and size range, is presented in Figure 3.

Parameters measured

To evaluate the growth of *T. granosa* across the two study sites, shell length, width, and weight were measured once a month over a six-month observation period. Environmental physicochemical parameters were measured simultaneously at both research locations, including water salinity, temperature, and pH.

Data analysis

To determine the growth rate of *T. granosa*, the Specific Growth Rate (SGR) was calculated based on the average initial and final weights. The SGR was analyzed using the following equation (Çelik et al. 2015):

$$SGR = (\ln[W_t] - \ln[W_1]) \times \frac{100}{t}$$

Where:

SGR : specific growth rate

W_t : final weight

W_1 : initial weight

t : rearing time

To determine the differences in the growth of *T. granosa* cultivated in situ in the two study sites, analysis of variance (ANOVA) was performed. The relationships between various environmental parameters—including water salinity, pH, temperature, and sediment composition—and the growth of *T. granosa* were analyzed using the Principal Component Analysis (PCA) (Mawardi et al. 2024).

RESULTS AND DISCUSSION

Growth of *Tegillarca granosa*

The growth of cage-based culture *T. granosa* in the two study sites within the mangrove coastal area of Langsa City, Aceh Province, showed variation across treatments. The highest shell length growth was recorded in the Pusong under treatment P1 (20 individuals/cage), while the lowest was observed in the Lhok Banie under treatment LB3 (60 individuals/cage). ANOVA indicated that growth in P1 was significantly different from all other treatments across both study sites. In contrast, growth LB3 did not differ significantly from LB2 but was significantly different from all other treatments (Figure 4).

In-situ growth of *T. granosa* in cage-based mangrove ecosystems in Langsa City varied significantly among treatments. The highest shell width growth was recorded in LB1 (20 individuals/cage), while the lowest was observed in LB3 (60 individuals/cage). ANOVA revealed no significant

difference between LB1 and P1, whereas LB3 differed significantly from all other treatments (Figure 5).

The weight gain of *T. granosa* in both sites with varying environmental characteristics showed significant variation among treatments. ANOVA indicated no significant difference between treatments P1 and LB1, whereas significant differences were observed among all other treatments. The lowest weight gain of *T. granosa* was recorded in the Lhok Banie mangrove ecosystem under treatment LB3 (60 individuals per cage). Detailed results of *T. granosa* weight gains are presented in Figure 6.

The length and width of *T. granosa* differed between study sites, with the highest growth observed in the Pusong mangrove ecosystem compared to the Lhok Banie mangrove ecosystem. Monthly growth data further showed that the highest growth occurred in December (the fifth month of observation, during the rainy season), while the lowest growth was recorded in August (the first month of observation, during the dry season) (Figure 7).

The weight gain of *T. granosa* varied by study site, with the Pusong mangrove ecosystem showing the highest

growth compared to the Lhok Banie mangrove ecosystem (Figure 8).

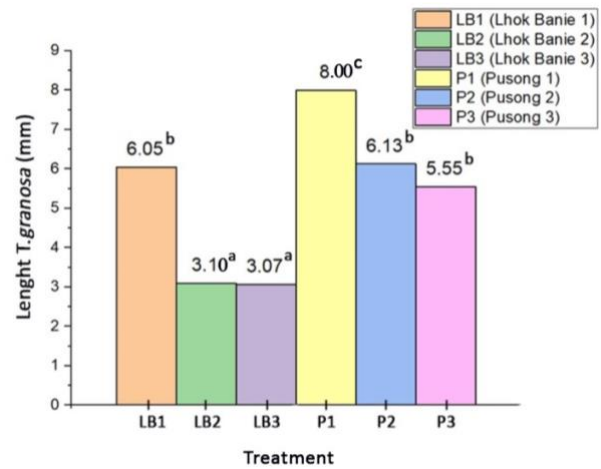


Figure 4. Shell Length of *T. granosa* in all treatments

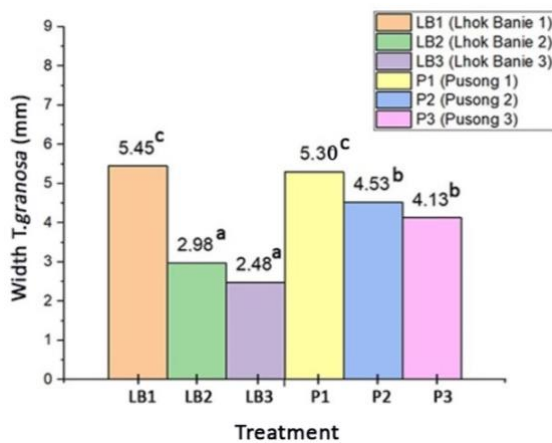


Figure 5. Shell width of *T. granosa* in all treatments recorded at study sites

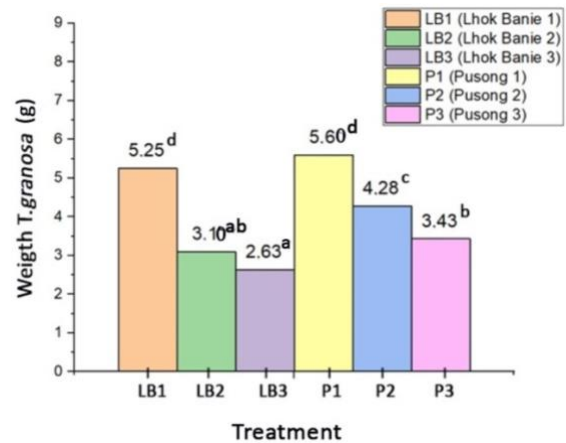


Figure 6. Weight growth of *T. granosa* across all treatments

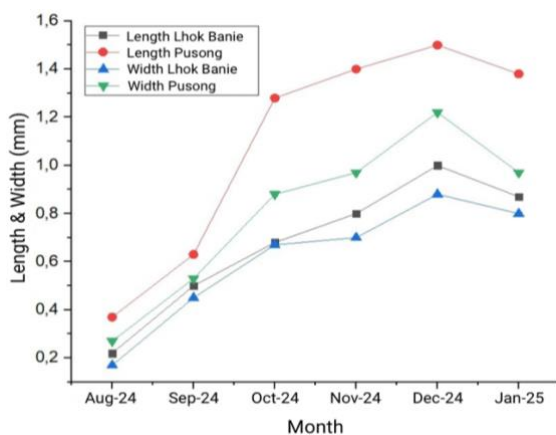


Figure 7. Shell Length and shell width of *T. granosa* on study sites

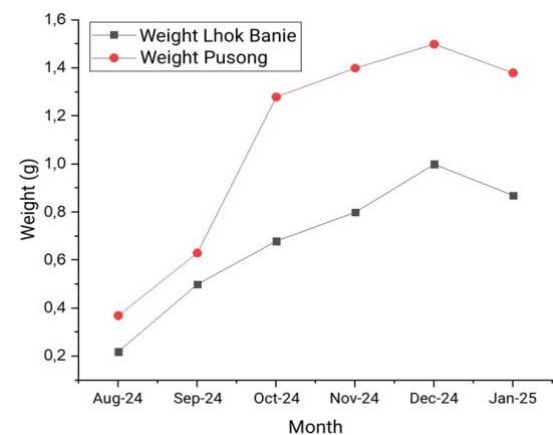


Figure 8. Weight gain of *T. granosa* based on study sites

Specific growth rate

The specific growth rates of *T. granosa* in the Pusong mangrove area under treatment P1 (20 individuals per cage, lowest density) were the highest among all treatments across both study locations. In contrast, the lowest specific growth rate was observed in the Lhok Banie mangrove area under treatment LB3 (60 individuals per cage, the highest density). ANOVA revealed a significant difference between treatment P1 and all other treatments. However, treatment LB3 did not differ significantly from LB2 but showed significant differences compared to all other treatments across both locations (Figure 9).

Water quality measurement

Water quality measurements for each treatment unit are presented in Table 2. Salinity ranged from 24-30‰ in Lhok Banie and 26-32‰ in Pusong. Water temperature was relatively uniform (29-30°C), while pH values remained stable between 6.7 and 6.9 throughout the study period, indicating that environmental conditions were within the suitable range for *T. granosa* growth.

Relationship between food sources and environmental parameters on the growth of *T. granosa*

The results of the Principal Component Analysis (PCA) showed that the main food sources of *T. granosa*, namely plankton and crustaceans, had a strong relationship with its growth. Likewise, several environmental parameters, including water salinity, water temperature, and sediment composition dominated by clay and silt, were strongly associated with the growth of *T. granosa* at the Pusong site, particularly in Pusong 1. Water salinity ranging from 26 to 32‰ also demonstrated a strong correlation with the growth of *T. granosa* at the Pusong location. In contrast, the mangrove ecosystem of Lhok Banie, which is characterized by a sediment composition dominated by sand, showed no strong relationship with the growth of *T. granosa* in the coastal area of Langsa City (Figure 10).

Growth in shell weight

The linear regression analysis of shell weight growth across the two study sites showed a very strong relationship between rearing time (months) and the increase in shell weight. The correlation coefficient (r) for all treatments ranged from 0.95 to 0.99, indicating that shell weight growth followed a consistent linear pattern throughout the observation period. At the Pusong site, the highest growth was recorded in the $n = 20$ treatment, with an r -value of 0.9625, followed by $n = 40$ (0.7188) and $n = 60$ (0.5637). This indicates that higher stocking density in the cages tended to reduce individual growth rates. The intercept values ranged between 7.23 and 7.51, suggesting that the initial shell weight was relatively uniform at the beginning of the observation period. A similar trend was observed at the Lhok Banie site, where the highest growth was also obtained at $n = 20$ (0.8893), followed by $n = 40$ (0.5313) and $n = 60$ (0.4446). The high correlation values ($r \geq 0.97$) further confirm that growth at this site was strongly influenced by rearing duration, exhibiting a linear and stable growth trend. Overall, these results demonstrate that stocking

density has a significant effect on monthly growth rate, with lower densities resulting in faster individual growth. The consistently high correlation values at both sites indicate that the growth of *T. granosa* is orderly and highly predictable over time (Figure 11; Table 3).

Table 2. Water quality parameters measured at each experimental unit in the Lhok Banie and Pusong mangrove areas

Location	Water quality		
	Salinity (‰)	Water temperature (°C)	pH
Lhok Banie 1	24-30	29-30	6.8-6.9
Lhok Banie 2	24-30	29-30	6.8-6.9
Lhok Banie 3	24-30	29-30	6.8-6.9
Pusong 1	26-32	29-31	6.7-6.8
Pusong 2	26-32	29-31	6.7-6.8
Pusong 3	26-32	29-31	6.7-6.8

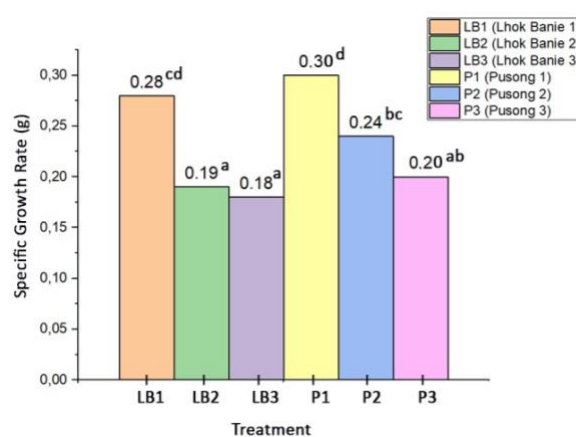


Figure 9. Specific growth rates of *T. granosa* across all treatments

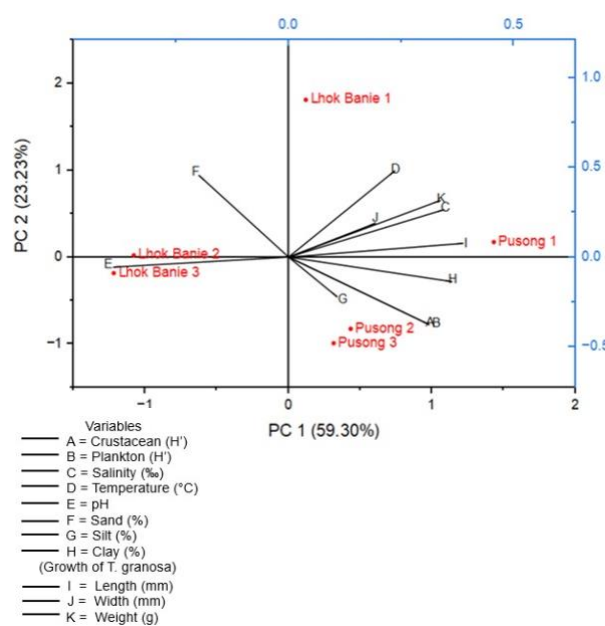


Figure 10. PCA of the relationship between several environmental parameters and the growth of *T. granosa*

Growth in shell length

The linear regression analysis of shell length growth at both study sites showed a very strong relationship between rearing time (months) and the increase in individual shell length. The correlation coefficient (r) for all treatments ranged from 0.97 to 0.99, indicating that shell length growth was linear and highly consistent over time. At the Pusong site, the highest growth was recorded at a stocking density of n = 20, with a growth rate of 1.3857 mm/month, followed by n = 40 (1.0777 mm/month) and n = 60 (0.9863 mm/month). This pattern suggests that higher stocking densities in cages tend to reduce individual shell length growth rates. The relatively uniform intercept values (approximately 27.7-27.9 mm) indicate that the initial size of the clams was fairly homogeneous at the start of the rearing period. At the Lhok Banie site, a similar growth pattern was observed. The highest growth was also found at n = 20 (1.0375 mm/month), followed by n = 40 (0.5241 mm/month) and n = 60 (0.5345 mm/month). Although the growth rates were slightly lower than those at Pusong, the very high correlation values ($r \geq 0.98$) confirm that the growth pattern at both locations remained linear and stable (Figure 12; Table 4).

Growth in shell width

The linear regression analysis of shell width, based on varying observation sample sizes (n), at both study sites demonstrated a relatively consistent pattern with very high correlation values ($r > 0.97$) across all data subsets. These correlation values indicate that the linear regression model applied has an excellent level of fit to the observed data. At the Pusong site, the slope (m) showed a decreasing trend with increasing sample size, from 0.9089 (n = 20) to 0.7381 (n = 60). This trend suggests that as the sample size increases, the estimation becomes more stable and the gradient sensitivity between variables tends to decrease. The intercept (c) also showed a slight decline from 18.13 to 17.97, reinforcing the indication that the model progressively converges toward the true population mean with larger sample sizes. A similar pattern was observed at the Lhok Banie site, although with slightly different dynamics. The slope dropped sharply from 0.9446 (n = 20) to 0.4315 (n = 60), which may be interpreted as the influence of sample heterogeneity on the linear relationship between parameters. This decrease may also be associated with environmental variations and differences in shell size at the site. The intercept ranged from 18.02 to 17.34, indicating relatively stable general shell width characteristics within the study site. Overall, the decreasing slope values with increasing sample size at both sites indicate that the relationship between variables becomes more moderate, yet remains highly consistent, as evidenced by correlation values approaching one. This confirms that the linear regression model used remains valid for describing the relationship of shell width parameters across different sample sizes, with a convergence trend toward values that more accurately represent the true population (Figure 13; Table 5).

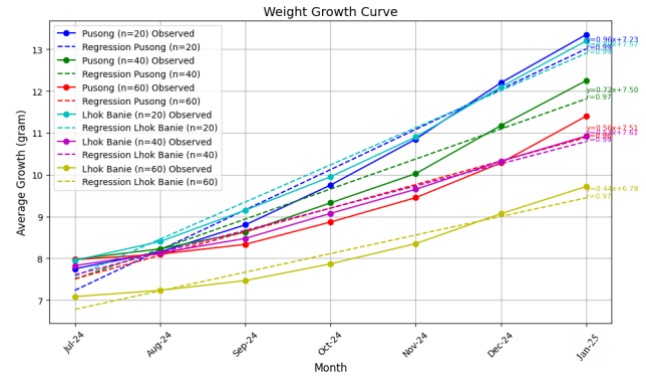


Figure 11. Linear regression of shell weight growth of *T. granosa*

Table 3. Linear regression parameters for shell weight growth of *T. granosa*

Dataset	Slope (g)	Intercept (c)	Correlation (r)
Pusong 1 (n=20)	0.962500	7.233.929	0.986221
Pusong 2 (n=40)	0.718750	7.500.893	0.974928
Pusong 3 (n=60)	0.563690	7.508.929	0.959222
Lhok Banie 1 (n=20)	0.889286	7.567.857	0.990751
Lhok Banie 2 (n=40)	0.531250	7.606.250	0.991942
Lhok Banie 3 (n=60)	0.444643	6.777.976	0.972788

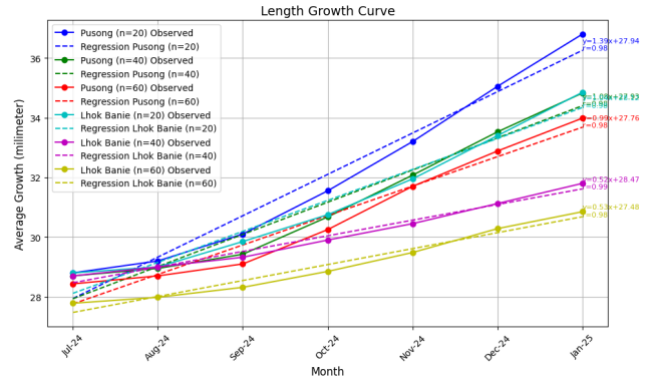


Figure 12. Linear regression of shell length growth of *T. granosa*

Table 4. Linear regression parameters for shell length growth of *T. granosa*

Dataset	Slope (mm)	Intercept (c)	Correlation (r)
Pusong (n=20)	1.385.714	27.942.857	0.983322
Pusong (n=40)	1.077.679	27.934.821	0.977354
Pusong (n=60)	0.986310	27.762.500	0.978576
Lhok Banie (n=20)	1.037.500	28.116.071	0.980591
Lhok Banie (n=40)	0.524107	28.470.536	0.989782
Lhok Banie (n=60)	0.534524	27.475.000	0.983949

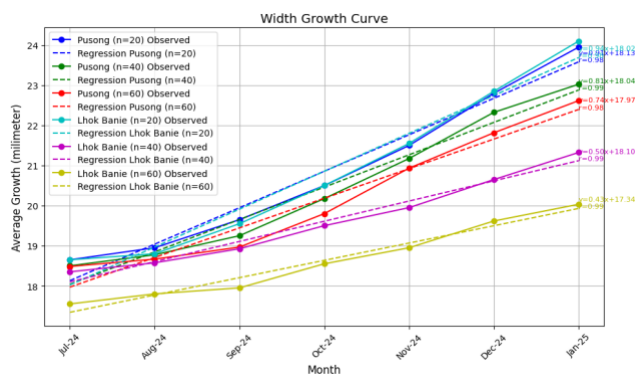


Figure 13. Linear regression of shell width growth of *T. granosa*

Table 5. Linear regression parameters for shell width growth of *T. granosa*

Dataset	Slope (mm)	Intercept (c)	Correlation (r)
Pusong (n=20)	0.908929	18.130357	0.984897
Pusong (n=40)	0.807143	18.039286	0.985168
Pusong (n=60)	0.738095	17.969048	0.977359
Lhok Banie (n=20)	0.944643	18.023214	0.982057
Lhok Banie (n=40)	0.503571	18.100000	0.987682
Lhok Banie (n=60)	0.431548	17.341071	0.985498

Discussion

The results of this study indicate that the growth of *T. granosa* in the coastal areas of Aceh Province is influenced by several factors, including favorable environmental conditions, the abundance of aquatic biota such as crustaceans and plankton as food sources, and the population density of *T. granosa* within the habitat (Mawardi et al. 2024). Potential environments, such as brackish waters with high salinity, sediment composition dominated by mud, and diverse mangrove vegetation, strongly support the growth and reproduction of this species in coastal ecosystems. Conversely, excessively high cockle population density in certain environments may negatively affect the growth of *T. granosa*, as it leads to increased competition for food through filter-feeding (Bahtiar et al. 2022). A higher number of mussels per cage resulted in less optimal growth, which was attributed to competition for food sources such as plankton, crustacean larvae, and various other aquatic microorganisms (Pradheeban et al. 2020; Doinsing et al. 2021; Mawardi et al. 2024). Competition also arises for habitat space within the sediment, as *T. granosa* inhabits the mangrove ecosystem by burrowing into the substrate (Ong et al. 2019; Lim et al. 2020; Kamal et al. 2022; Tuhumury et al. 2024).

The growth of *T. granosa* in the coastal area of Langsa City was lower than that reported in a study conducted in Johor, Malaysia, where it reached 25.36±3.00 mm over a 12-month observation period (Saif et al. 2020; Chua et al. 2022; Siregar et al. 2023). The high growth of *T. granosa* reported from cultivation in Malaysia is attributed to the use of larger ponds (up to 0.25 ha) and the provision of

regular commercial feed, where ponds specifically designed as habitats with stable physical and chemical conditions and abundant food availability provide optimal environments that promote the growth and development of shellfish (Ibrahim et al. 2021; Prasetyo et al. 2023; Rusydi et al. 2024).

Water quality parameters recorded during this study were within the ecological tolerance range of *T. granosa*, although salinity variation between locations may have influenced growth performance. Salinity ranged from 24-30‰ in Lhok Banie and 26-32‰ in Pusong, while temperature (29-31°C) and pH (6.7-6.9) remained relatively stable throughout the study period. Previous studies reported that salinity and other physicochemical parameters significantly affect population dynamics and distribution of *T. granosa* in mangrove and coastal ecosystems (Bahtiar et al. 2022; Mawardi et al. 2024). These findings suggest that the salinity differences observed between sites likely contributed to the variation in growth responses, whereas temperature and pH were relatively uniform and less variable across treatments.

The specific growth rate showed optimal growth in the Pusong mangrove ecosystem (P1), which was significantly higher than in all other treatments. Greater food availability and relatively more favorable environmental conditions make the Pusong area a more suitable habitat for *T. granosa* compared to the Lhok Banie mangrove ecosystem (Kamaruddin et al. 2020; Basri et al. 2021; Ali et al. 2022; Mawardi et al. 2024). ANOVA results indicated significantly higher growth of *T. granosa* in the Pusong mangrove ecosystem compared to Lhok Banie, likely due to smooth tidal water circulation that transports plankton and other aquatic organisms, providing essential food sources for *T. granosa* (Nguyen et al. 2021; De Winter et al. 2023).

Tegillarca granosa is a brackish-water invertebrate that inhabits coastal areas associated with mangrove vegetation. It survives by burrowing into the sediment, which provides protection against predators and human exploitation (Bahtiar et al. 2022). The habitat of *T. granosa* is generally associated with mangrove ecosystems, where the substrate is predominantly composed of clay and clayey loam. This species exhibits a high tolerance to variations in water salinity, with several studies reporting salinity levels ranging from 17 to 32‰. Research conducted in the coastal mangrove ecosystem of Langsa City indicated that the optimal salinity range for *T. granosa* habitat is 24 to 28‰ (Islam et al. 2020; Rahman et al. 2021; Pham et al. 2022; Mawardi et al. 2024).

In addition to suitable habitat conditions, the abundance of plankton, crustaceans, and other aquatic microorganisms in mangrove ecosystems serves as a crucial food source for the survival of *T. granosa*. The high diversity of crustaceans and plankton in these ecosystems, which function as habitats for shellfish, particularly *T. granosa*, significantly influences shellfish population abundance (Sari et al. 2021; Tan and Wong 2021; Bahtiar et al. 2022).

This indicates that suitable environmental conditions, supported by the abundance of aquatic organisms as food sources, significantly affect the abundance and growth of *T.*

granosa (Chatterjee et al. 2020; Tran et al. 2020; Waliullah et al. 2023). Several studies conducted in Southeast Asia, where *T. granosa* is considered a potential habitat species, have reported that high salinity in brackish areas, supported by sediment dominated by mud and sand, provides favorable conditions for the growth of this bivalve (Effendi et al. 2025). Such information can serve as a reference for shellfish farming communities in selecting appropriate cultivation areas. In determining suitable sites, several environmental parameters with potential as habitat determinants for blood cockles are considered, namely sediment characteristics, water salinity, and the abundance of plankton and crustaceans, which provide essential food sources for shellfish.

In conclusion, this study demonstrates that the growth of *T. granosa* in the coastal region of Aceh is strongly influenced by mangrove ecosystems and environmental conditions, particularly salinity, organic matter, and sediment composition. Average shell length increased by 3.07-8.00 mm, shell width by 2.48-5.45 mm, and body weight by 2.63-5.60 g. Among the stocking density treatments, 20 individuals per cage yielded the highest growth, as reflected in greater shell dimensions, weight gain, and specific growth rate. Differences between the two study sites, Pusong and Lhok Banie, were primarily associated with water quality, plankton abundance, and sediment characteristics, as supported by regression and PCA analyses. These findings provide essential baseline information for optimizing blood cockle aquaculture practices and highlight the potential for community-based aquaculture in mangrove-associated environments. However, the study was limited to two mangrove areas and lacked detailed measurements of natural food availability and sediment properties. Future research should include multi-season monitoring, expanded site coverage, quantitative evaluation of food resources, and more detailed sediment analyses, along with experiments on stocking density and cage design to support sustainable community-based blood cockle aquaculture in coastal mangrove systems.

ACKNOWLEDGEMENTS

The author extends sincere appreciation to the Institute for Research and Community Service of Universitas Samudra, Indonesia, for funding this research through Grant No. 136/UN54.6/PT.01.03/2025, and to the coastal community leaders of Langsa City, Aceh, Indonesia, for their invaluable contributions to its successful implementation.

REFERENCES

- Ali MY, Rahman MA, Hasan MR. 2022. Environmental factors influencing the growth performance of blood cockle (*Tegillarca granosa*) in tropical mangrove ecosystems. *Reg Stud Mar Sci* 53: 102502. <https://doi.org/10.1016/j.rsma.2022.102502>.
- Antu DR, Islam TT, Ahmed MR, Ahmed S, Datta SK, Ahmed MS. 2023. Diversity of bivalves and gastropods in Sonadia Island, Bangladesh. *Biores Commun* 9: 1225-1236. <https://doi.org/10.3329/brc.v9i1.63603>.
- Bahtiar B, Purnama MF, Kasim M, Ishak E. 2022. Population dynamics of blood clams *Tegillarca granosa* (Linnaeus, 1758) in Kendari Bay, Southeast Sulawesi, Indonesia. *Biodiversitas* 23: 5084-5092. <https://doi.org/10.13057/biodiv/d231015>.
- Basri NH, Arshad A, Amin SMN. 2021. Effects of water quality and sediment characteristics on the distribution and growth of blood cockles (*Tegillarca granosa*) in Peninsular Malaysia. *Ocean Coast Manag* 210: 105696. <https://doi.org/10.1016/j.ocecoaman.2021.105696>.
- Bogmans CW, van Soest D. 2022. Can global aquaculture growth help to conserve wild fish stocks? Theory and empirical analysis. *Nat Resour Model* 35: e12323. <https://doi.org/10.1111/nrm.12323>.
- Broom MJ. 1985. The biology and culture of marine bivalve molluscs of the genus *Anadara*. *WorldFish*.
- Cao L, Wang W, Yang Y, Yang C, Yuan Z, Xiong S, Diana J. 2018. Environmental impact of aquaculture and countermeasures to aquaculture pollution in China. *Environ Sci Pollut Res* 25: 16874-16884. <https://doi.org/10.1007/s11356-018-1859-4>.
- Çelik MY, Karayücel S, Karayücel İ, Eyüboğlu B, Öztürk R. 2015. The effects of environmental factors on survival, growth, and biochemical composition of transplanted oysters (*Ostrea edulis* Linnaeus, 1758) from the Aegean Sea to the southern Black Sea. *Aquac Res* 46 (4): 959-968. <https://doi.org/10.1111/are.12253>.
- Chatterjee A, Pramanik S, Banerjee K. 2020. Influence of hydrology and plankton availability on bivalve population dynamics in estuarine systems. *Estuar Coast Shelf Sci* 243: 106896. <https://doi.org/10.1016/j.ecss.2020.106896>.
- Chua EG, Tan SH, Choo PS. 2022. Growth performance and survival of the blood cockle *Tegillarca granosa* under different cultivation practices in Malaysia. *Aquac Res* 53: 2635-2646. <https://doi.org/10.1111/are.15898>.
- De Winter NJ, Van Sikkeleras S, Goudsmit-Harzevoort B, Boer W, De Nooijer L, Reichart GJ, Witbaard R. 2023. Tracing the timing of growth in cultured molluscs using strontium spiking. *Front Mar Sci* 10: 1157929. <https://doi.org/10.3389/fmars.2023.1157929>.
- Doinsing JW, Admodisastro VA, Duisan L, Ransangan J. 2021. Population dynamics and condition index of natural stock of blood cockle, *Tegillarca granosa* (Mollusca, Bivalvia, Arcidae) in the Marudu Bay, Malaysia. *Acta Oceanologica Sinica* 40 (8): 89-97. <https://doi.org/10.1007/s13131-021-1791-5>.
- Effendi I, Marpaung B, Mahary A, Ernando H, Thamrin T. 2025. Sediment composition, phytoplankton, and blood cockles (*Anadara granosa*) population. *Egypt J Aquat Biol Fish* 29 (2): p2143. <https://doi.org/10.21608/ejabf.2025.421850>.
- El-Hacen EHM, Lemrabott SYC, Meijer KJ, Piersma T, Govers LL, van Gils JA, Olf H. 2023. Growth and population structure of bloody /*cockles, *Senilia senilis*, at Banc d'Arguin and Bijagós with different environmental conditions and harvesting regimes. *Mar Ecol Prog Ser* 710: 71-83. <https://doi.org/10.3354/meps14291>.
- FAO [Food and Agriculture Organization]. 2004. Hatchery culture of bivalves: a practical manual. FAO Fisheries Technical Paper No. 471. FAO, Rome.
- Gomez KA, Gomez AA. 1984. *Statistical Procedures for Agricultural Research*. 2nd edition. John Wiley & Sons.
- Hasan MR, Rahman MA, Alam MA. 2024a. Nutritional composition and economic value of blood cockle (*Tegillarca granosa*) in Bangladesh. *J Aquat Food Prod Technol* 33: 145-158. <https://doi.org/10.1080/10498850.2024.1234567>.
- Hasan MR, Rahman MA, Alam MA, Khan S. 2024b. Status and prospects of blood cockle (*Tegillarca granosa*) aquaculture in Southeast Asia: A review. *Aquac Rep* 29: 101634. <https://doi.org/10.1016/j.aqrep.2024.101634>.
- Ibrahim N, Mohd Zain SN, Rahim SA. 2021. Influence of pond design and management practices on the growth of blood cockle (*Tegillarca granosa*) in Peninsular Malaysia. *Aquac Intl* 29: 2051-2064. <https://doi.org/10.1007/s10499-021-00725-9>.
- Islam MS, Hossain MB, Jewel MAS. 2020. Influence of water quality parameters on the growth and survival of estuarine bivalves. *Ecol Indic* 113: 106243 <https://doi.org/10.1016/j.ecolind.2020.106243>.
- Kamal AHM, Hossain MS, Chowdhury SR. 2022. Burrowing behavior and sediment preference of the blood cockle *Tegillarca granosa* in tropical intertidal mudflats. *J Sea Res* 182: 102210. <https://doi.org/10.1016/j.seares.2022.102210>.
- Kamaruddin IS, Ghazali MF, Idris MH. 2020. Influence of environmental parameters on the survival and growth of cultured blood cockle (*Tegillarca granosa*). *Aquac Rep* 18: 100520. <https://doi.org/10.1016/j.aqrep.2020.100520>.
- Khan S, Rahman MA, Hossain MS. 2025. Population status and habitat associations of blood cockle (*Tegillarca granosa*) in the coastal

- waters of Bangladesh. *Reg Stud Mar Sci* 61: 103123. <https://doi.org/10.1016/j.rsma.2025.103123>.
- Lim CS, Tan SH, Choo PS. 2020. Sediment characteristics influencing burrowing activity of blood cockle *Tegillarca granosa*. *Estuar Coast Shelf Sci* 245: 106932. <https://doi.org/10.1016/j.ecss.2020.106932>.
- Mawardi M, Sarong MA, Suhendrayatna S, Irham M. 2024. The relationship between crustacean diversity and population dynamics of blood cockle *Tegillarca granosa* in the coastal area of West Langsa, Aceh Province, Indonesia. *Biodiversitas* 25: 690-699. <https://doi.org/10.13057/biodiv/d250228>.
- Mawardi AL, Khalil M, Sarjani TM, Armanda F. 2023. Diversity and habitat characteristics of gastropods and bivalves associated with mangroves on the east coast of Aceh Province, Indonesia. *Biodiversitas* 24: 5146-5154. <https://doi.org/10.13057/biodiv/d240959>.
- Morgan L, Valentinsson D, Dahlgren TG, Hornborg S. 2024. Ecological risk assessment of invertebrates caught in Swedish west-coast fisheries. *Fish Res* 274: 106982. <https://doi.org/10.1016/j.fishres.2024.106982>.
- Nguyen TH, Vo TQ, Le AT. 2021. Environmental influences on the distribution and growth of *Tegillarca granosa* in Vietnamese mangrove ecosystems. *Aquat Living Resour* 34: 1-12. <https://doi.org/10.1051/alr/2021007>.
- Ong JE, Gong WK, Wong CH. 2019. Habitat use and burrowing ecology of blood cockle (*Tegillarca granosa*) in Malaysian mangroves. *Mar Biodivers* 49: 2249-2261. <https://doi.org/10.1007/s12526-018-0920-7>.
- Pahri SDR, Yana R, Danial MA. 2023. Sustainable management of blood cockles (*Tegillarca granosa*) industry in Malaysia from the life cycle assessment perspective: A review. *Aquac Aquarum Conserv Legislation* 16: 436-446.
- Permata YM, Liesna AT, Rangkuti FM, Insyra K, Dayanti Y. 2023. Proximate composition of *Anadara granosa* and *Paphia undulata*. *Indones J Pharm Clin Res* 6: 1-5. <https://doi.org/10.32734/ijpcr.v6i1.9196>.
- Pham HM, Tran QL, Do NT. 2022. Salinity tolerance and growth performance of blood cockle (*Tegillarca granosa*) under different mangrove estuarine conditions. *Reg Stud Mar Sci* 55: 102651. <https://doi.org/10.1016/j.rsma.2022.102651>.
- Pradheeban L, Nagarajan R, Kumar P. 2020. Zooplankton is a major natural food source for the blood cockle (*Tegillarca granosa*) in estuarine systems. *Reg Stud Mar Sci* 39: 101417. <https://doi.org/10.1016/j.rsma.2020.101417>.
- Prasetyo AP, Haryanti, Zainuddin M. 2023. Environmental stability and feed supplementation as key factors in optimizing the aquaculture of blood cockle (*Tegillarca granosa*). *Reg Stud Mar Sci* 62: 102227. <https://doi.org/10.1016/j.rsma.2023.102227>.
- Rahman MA, Ali MY, Hasan MR. 2021. Salinity tolerance and growth performance of *Tegillarca granosa* in controlled aquaculture systems. *Aquac Intl* 29: 2157-2171. <https://doi.org/10.1007/s10499-021-00772-w>.
- Richards DR, Friess DA, Faridah-Hanum I. 2017. Characterizing coastal ecosystem degradation in Southeast Asia. *Reg Environ Change* 17: 147-158. <https://doi.org/10.1007/s10113-016-1003-9>.
- Rusydi I, Nurza ISA, Dewiyanti I, Mellisa S, Maulidas S, Sharis CMU. 2024. Growth rate and survival of green shells (*Perna viridis* L.) in ponds, Alue Naga Village, Banda Aceh. *BIO Web Conf* 87: 03030. <https://doi.org/10.1051/bioconf/20248703030>.
- Roslan NS, Saffian NS, Nilamani N, Razalli N, Ilias N, Harith H, Hwai ATS. 2022. Abundance of blood cockle (*Tegillarca granosa*) at Kuala Juru River Estuary, Penang, Malaysia. *Songklanakarin J Sci Technol* 44: 137-141.
- Saif MLM, Tumin AB, Yusof F, Rani A, Apandi A, Jamari Z. 2020. Blood cockles *Tegillarca granosa* growth performance. *Intl J Fish Aquat Stud* 8: 269-276.
- Safuridar, Salman, Azhar I. 2022. Analisis the total economics value of the mangrove forest area in the development of ecotourism in Langsa City, Aceh. *Jurnal Sains Global Indonesia* 3: 8-18. <https://doi.org/10.59784/glosains.v3i1.48>.
- Saffian NS, Peng CTC, Ilias N, Hwai ATS. 2020. Overview and challenges of blood cockle culture in Malaysia. In *IOP Conf Ser: Earth Environ Sci* 414: 012020. <https://doi.org/10.1088/1755-1315/414/1/012020>.
- Sari DM, Pratama RF, Munandar H. 2021. Zooplankton and benthic organisms as key food sources in blood cockle (*Tegillarca granosa*) culture systems. *Egypt J Aquat Res* 47: 145-153. <https://doi.org/10.1016/j.ejar.2021.02.004>.
- Shore R, Douben N. 2021. Ecosystem services of mangrove habitats and implications for aquaculture. *Biodivers Conserv* 30: 3295-3314. <https://doi.org/10.1007/s10531-021-02219-4>.
- Siregar MA, Putra RD, Yuliana E. 2023. Growth comparison of blood cockle (*Tegillarca granosa*) in relation to environmental parameters in Indonesian coastal waters. *Reg Stud Mar Sci* 61: 102021. <https://doi.org/10.1016/j.rsma.2023.102021>.
- Tan SG, Wong KL. 2021. Environmental influences on the growth performance of cockles in mangrove-dominated estuaries of Southeast Asia. *J Shellfish Res* 40: 95-105. <https://doi.org/10.2983/035.040.0109>.
- Tuhumury SF, Selanno DA, Tuhumury J. 2024. Population dynamics of blood cockles (*Anadara granosa*) in the coastal waters of Letman Village, Kei Kecil District, Southeast Maluku Regency. *Mar Ecol* 45 (5): e12818. <https://doi.org/10.1111/maec.12818>.
- Tran QL, Hoang VT, Le PH. 2020. Environmental carrying capacity for blood cockle aquaculture in tropical mangrove ecosystems. *J Cleaner Prod* 262: 121321. <https://doi.org/10.1016/j.jclepro.2020.121321>.
- Waliullah ATM, Yeasmine S, Uddin MJ. 2023. Morphological variations in blood cockle *Tegillarca granosa* (L, 1758) populations collected from the southeast and south-west coasts of Bangladesh. *J Bangladesh Agric Univ* 21: 373-379. <https://doi.org/10.5455/JBAU.162927>.
- Yadav R, Malla PK, Dash D, Bhoi G, Patro S, Mohapatra A. 2019. Diversity of gastropods and bivalves in the mangrove ecosystem of Paradeep, east coast of India: A comparative study with other Indian mangrove ecosystems. *Molluscan Res* 39: 325-332. <https://doi.org/10.1080/13235818.2019>.