



Morphometric Analysis and Growth Patterns of Blood Cockle (*Tegillarca granosa*) in Langsa Mangrove Ecosystems, Indonesia

Mawardi Mawardi^{1,2}, M. Ali Sarong^{3*}, Suhendrayatna Suhendrayatna^{4,5} and Muhammad Irham^{6,7}

¹Graduate School of Mathematics and Applied Sciences, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia; ²Department of Biology Education, Faculty of Teacher Training, Samudra University, Langsa City 24416, Aceh, Indonesia; ³Department of Biology Education, Faculty of Teacher Training, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia; ⁴Department of Chemical Engineering, Faculty of Engineering, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia; ⁵Biochar and Forest Conservation Research Center, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia; ⁶Department of Marine Science, Faculty of Marine Science and Fisheries, Universitas Syiah Kuala, 23111 Banda Aceh, Indonesia; ⁷Geographical Information Systems Laboratory, Faculty of Marine and Fisheries, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia

* Correspondence: alisarong@fkip.unsyiah.ac.id

Article History

Received
18 August 2024

Accepted
15 October 2024

Available Online
24 October 2024

Keywords

Coastal biota
Macroinvertebrates
Shell morphology
Environmental quality
Coastal areas

Abstract

The mangrove area is a nutrient-rich zone that serves as a food source for various aquatic organisms and as a spawning and nursery ground for species such as fish, crabs, and clams. The aim of this study is to investigate the morphometrics and growth pattern of blood cockle (*Tegillarca granosa*) in the mangrove area of Langsa City. Data collection for *T. granosa* was conducted using purposive sampling at three designated research locations with varying environmental conditions. Transects were established from the shoreline towards the mangrove vegetation at each research location. Within each transect, 1 meter x 1 meter plots were established for *T. granosa* sampling. The blood cockles found at the research sites were measured for shell length, shell width, and total weight. The research collected 98 individuals of *T. granosa* at the study location, with morphological variations including length, width, total weight, and sex. The size of the blood cockles ranged from 3 cm to 6.76 cm, the shell width ranged from *T. granosa* 2.50 cm to 5.52 cm, while the total weight of *T. granosa* ranged from 12 grams to 122 grams. Based on morphometric analysis, the growth pattern of *T. granosa* in the mangrove area of Langsa City is characterized by $b = 2.5085$, falling into the negative allometric category. This growth pattern indicates that the length of *T. granosa* grows faster compared to its total weight. Location 1 (Lhok Banie) showed the best growth pattern for *T. granosa*, the least favorable growth was found at Location 3 (Kuala Langsa). In conclusion, the morphometrics of *T. granosa* at the study site showed significant variation in length, width, and total weight. Morphometric analysis indicates that *T. granosa* exhibits a negative allometric growth pattern.

Introduction

The mangrove ecosystem of Langsa City, located in Aceh Province, Indonesia, plays an important role in maintaining environmental balance, both physically and ecologically [1]. Ecologically, mangroves serve as an ideal habitat for various animals, especially fish, crabs, shrimp, and clams. The mangrove ecosystem plays a crucial role for various coastal organisms, particularly as a spawning ground, nursery, and feeding area [2–4]. Mangrove areas serve as important food sources for clams, as fallen leaves and branches provide food for plankton, which is the main diet of clams [5]. Mangrove roots also play a role in protecting clams from predators and strong currents [6,7].

Tegillarca granosa is one of the clam species that inhabit the mangrove ecosystem of Langsa City. It possesses a pair of shells that function to protect its soft body organs from environmental

changes and predation by other animals [8]. Currently, the distribution of this clam population is limited to Asian regions, including Indonesia, Malaysia, Myanmar, and India [9]. This species thrives in mangrove areas with stable water circulation, including tidal zones and estuaries [10]. The dominant population of *T. granosa* is found in mangrove areas characterized by sandy and muddy sediments with smooth water circulation [11]. The composition of sandy and muddy sediments facilitates their ability to avoid predation by burying themselves in the substrate [12]. Sediments and water currents in coastal areas play a crucial role in the survival and food requirements of coastal biota [13–15].

Several studies have been conducted on the population dynamics of *T. granosa* in the Kendari Bay area, indicating that the population of this clam has started to decline due to ecological pressures and exploitation regularly conducted by the community [16]. Climate change and coastal community activities have disrupted the habitat of coastal biota. The management efforts for *T. granosa* in the coastal areas of Malaysia are being carried out due to the drastic decline in the population of this clam. There has been a significant decrease in the adult clam population due to exploitation by the community, climate change, and pollution [17]. These issues undoubtedly pose a threat to the survival of *T. granosa* in its natural habitat.

The importance of conducting research on the growth patterns of *T. granosa* in the mangrove area of Langsa City is to study the growth patterns of these clams, which are correlated with habitat conditions and food availability, as part of efforts to ensure the survival of this species [18]. The lack of research on the population of this species in the coastal areas of Langsa City has resulted in very limited information on the condition of this coastal biota population. The aim of this research is to analyze the morphometrics and growth patterns of *T. granosa* in the mangrove area of Langsa City, Aceh Province, to determine whether the morphometric conditions and growth patterns of *T. granosa* are isometric or allometric. This research can serve as valuable information regarding the condition of *T. granosa* in the coastal areas of Langsa City and can be used as a reference for sustainable and environmentally friendly management of blood cockles in coastal regions.

Materials and Methods

Study Area

This research was conducted in the mangrove ecosystem of Langsa City, Aceh Province, Indonesia. The study site is located in the coastal area in the eastern part of Aceh Province, directly adjacent to the Strait of Malacca. The sediment conditions at the research site are dominated by sand, clay, and very little silt. A stable circulation of seawater is one of the indicators of an ideal habitat for *T. granosa*. The water salinity at the research site ranges from 25‰ to 32‰. The survey and collection of *T. granosa* were conducted in May 2023 using the transect method at three research locations (Figure 1).

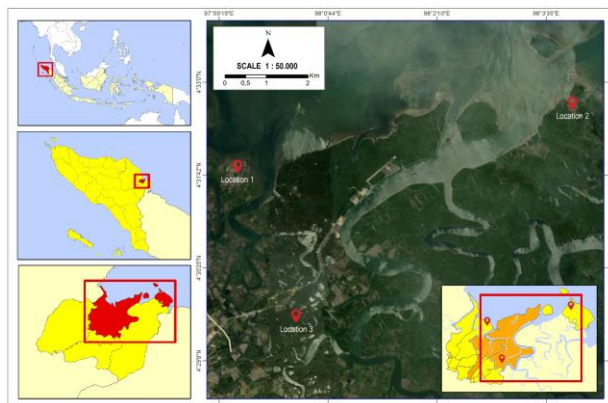


Figure 1. Research location map in the coastal area of Langsa City, Aceh Province.

Data Collection

The data collection technique for *T. granosa* was performed through purposive sampling at three research locations, which were selected based on varying environmental conditions based on water salinity and sediment composition in the *T. granosa* habitat. At each research location, transects were established from the coastline towards the mangrove vegetation. Within each transect, plots measuring 5 meters x 5 meters were designated for collecting *T. granosa* within the plot. Each *T. granosa* found in the plots, based on variations in size and gender, was placed in sample bottles for identification in the biology laboratory. Shell length and shell width were measured using a digital caliper (accuracy of 0.1 mm). The total weight of the clams was measured using a digital scale (accuracy of 0.1 gram). The identification of *T. granosa* species and sex was analyzed using an Olympus Trinocular Microscope (Olympus CX 43). Sex identification was based on the color of the gonads. Male *T. granosa* had a grayish-cream gonad color, while females had a brick-red or orange gonad color [19] (Figures 2 and 3). The identification activities were carried out at the Biology Laboratory of Samudra University. The measurement of environmental physicochemical data was conducted simultaneously with the collection of *T. granosa*.



Figure 2. Morphometrics of *T. granosa*.



Figure 3. Gonad of *T. granosa*: (a) Male, (b) Female.

Data Analysis

The morphometrics of *T. granosa* were analyzed based on the data of shell length and shell width relationship. For the analysis of the growth pattern of *T. granosa* based on the data of shell length and total weight relationship and measure the growth pattern of *T. granosa* based on gender found in the mangrove area of Langsa City, the following formula was used the growth relationship of *T. granosa* follows the equation $W = aL^b$, where W is the total weight (grams) and L is the shell length (centimeters). This formula helps analyze the species growth patterns [20].

If the growth of total weight in *Tegillarga granosa* is balanced with the growth of shell length, it is considered isometric ($b = 3$). However, if the value of b is greater or smaller than 3, the growth is considered allometric. Assuming that if the value of $b < 3$ (negative allometry), the growth of shell length in *T. granosa* is faster compared to the growth of total weight. On the other hand, if the value of $b > 3$ (positive allometry), it means that the growth of total weight is faster than the growth of shell length in *T. granosa* [21,22].

Results and Discussion

Morphometrics of *T. granosa*

A total of 98 individuals of *T. granosa* were found at three research locations, exhibiting variations in length, width, and total weight across different locations. The highest number of blood cockles was found at location 1 (Lhok Banie) with 53 individuals, while the lowest number was found at location 3 (Kuala Langsa) with 20 individuals. The shell length ranged from 3 cm to 6.76 cm, the shell width ranged from 2.50 cm to 5.52 cm, and the total weight of *T. granosa* varied between 12 grams and 122 grams (Table 1).

The average shell length at location 1 was higher than the overall average length, but lower than the overall average at location 2 and location 3 (Figure 4a). The same trend was observed for shell width and total weight, where the average values were higher at location 1 but lower at location 2 and location 3 (Figure 3b and Figure 3c).

Table 1. Morphometric Measurements of *T. granosa* in the Coastal Area of Langsa City, Aceh Province. (N=98 Individuals).

Research Locations	Coordinates	LCC (cm)	CCW (cm)	Weight (gram)
Location 1	4°31'55.6"N 97°59'38.0"E	3.00 – 6.76	2.50 – 5.52	12 – 122
Location 2	4°32'43.0"N 98°03'56.8"E	3.12 – 5.73	2.60 – 4.58	15 – 70
Location 3	4°30'41.4"N 98°00'34.6"E	3.60 – 4.50	2.90 – 3.72	26 – 36
Mean		4.38	3.68	41.26

Explanation: LCC: Length of Shell; CCW: Shell Width.

Based on Table 1, it can be observed that location 1 (Lhok Banie) has the best population of *T. granosa* in terms of the number of individuals, shell length, and the total weight of the blood cockles. On the other hand, location 3 (Pusong) exhibits a less favorable population of blood cockles.

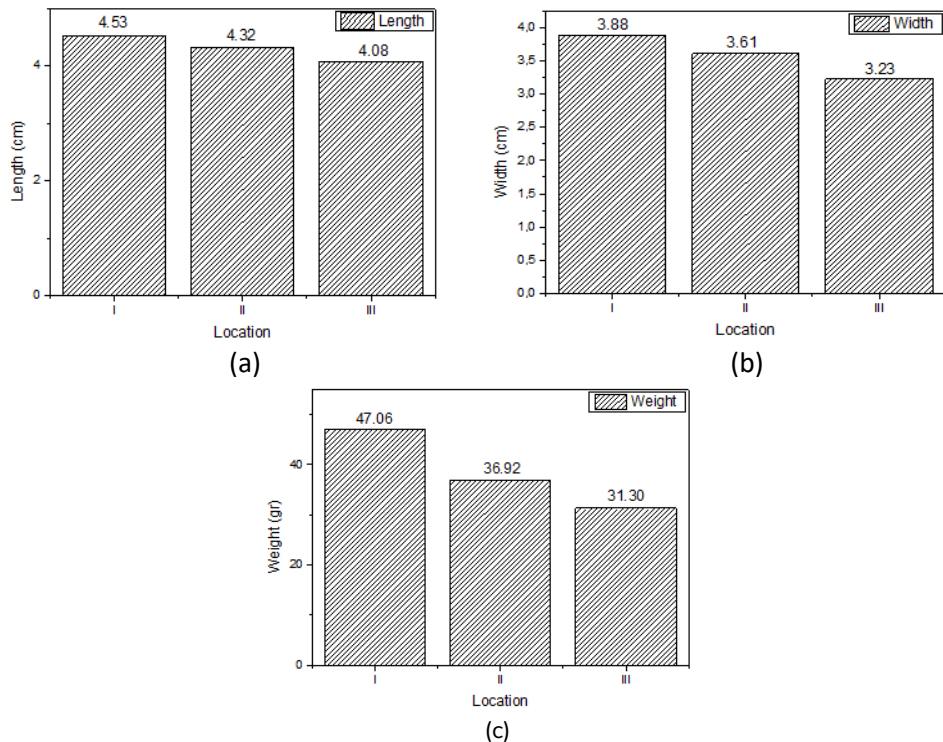


Figure 3. Morphometric measurements of *T. granosa* (a) shell length, (b) shell width, (c) total weight.

If we observe the gender of the blood cockles, it can be seen that the male blood cockles have more dominant sizes compared to the females in terms of shell length, width, and total weight. The most significant difference can be observed in the total weight of the blood cockles (Figure 4).

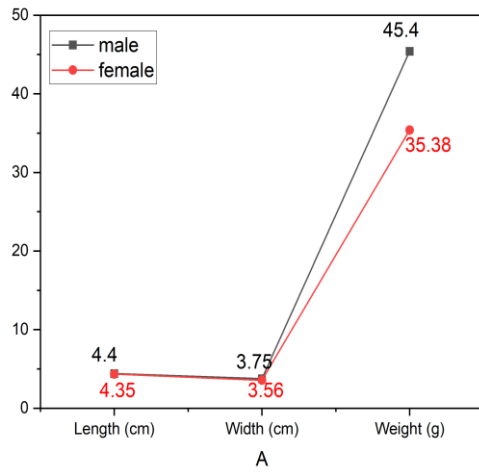


Figure 4. Morphometric measurements of male and female *T. granosa*.

The Relationship between Shell Length, Shell Width, and Total Weight of T. granosa

The analysis results indicate a strong relationship between the increase in shell length of the blood cockles and the increase in total weight. Similarly, a positive relationship is observed between shell width and total weight of the cockles (Figure 5a & Figure 5b). There is also a positive relationship between shell length and shell width of the blood cockles (Figure 5c).

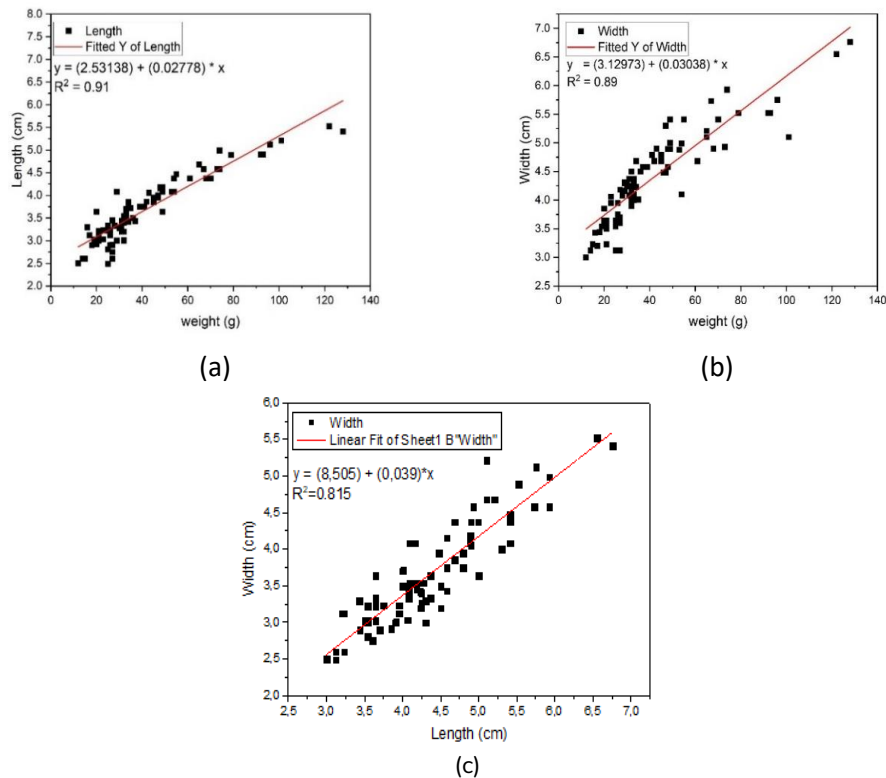


Figure 5. Relationship Analysis (a) shell length - total weight; (b) shell width - total weight; (c) shell length - shell width.

The Growth Pattern of T. granosa

The growth pattern of *T. granosa* in the research locations generally exhibits negative allometry ($b = 2.5085$), indicating suboptimal growth of the clam species, as the increase in shell length occurs at a faster rate compared to the increase in total weight of the clams (Table 2). Negative allometric growth suggests that the coastal area of Langsa City as a habitat is becoming disrupted for the survival of coastal biota, both in terms of habitat characteristics and food availability.

Table 2. Growth pattern of *T. granosa* in the coastal area of Langsa City, Aceh Province.

Equation for the relationship between length and total weight	R ²	A	B	Growth pattern
$1.0497L^{2.5085}$	0.8503	1.0497	2.5085	Allometric. (-)

The analysis results of the growth pattern of *T. granosa* based on the research locations indicate that location 1 exhibits a better growth pattern compared to locations 2 and 3, although all locations fall under the same category of positive allometry (Figure 6). This is supported by the environmental conditions at location 1, where the presence of well-preserved mangrove vegetation indicates a smooth and stable circulation of seawater. The less favorable growth pattern of the blood cockles at location 3 is due to its distance from the sea, resulting in an unstable circulation of seawater. The disturbed environmental conditions caused by the use of the area as a waterway for local community boats contribute to the less ideal growth pattern of the blood cockles in that location.

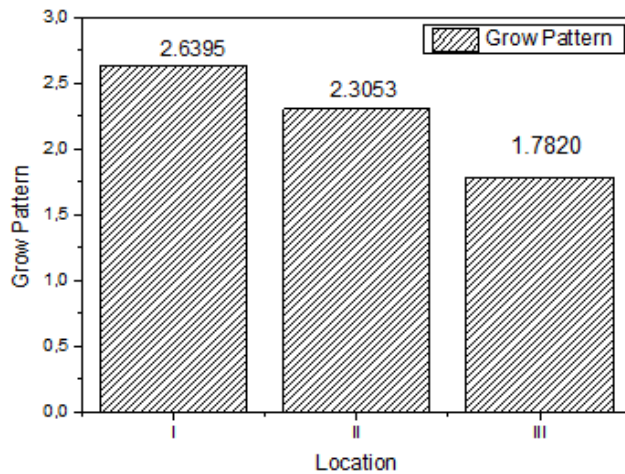


Figure 6. Growth pattern of *T. granosa* based on research locations.

A total of 98 individuals of *T. granosa* were found at three research locations in the coastal area of Langsa City, Aceh Province, with varying sizes and genders at each research location. Morphometrically, the highest shell length and shell width of the clams were found at location 1 (Lhoh Banie), while the lowest measurements were found at location 3 (Kuala Langsa). Environmental factors play an important role in the distribution of various aquatic biota species, including the distribution of blood cockles based on size and age in their habitat [23]. Lhoh Banie is a research location with well-preserved mangrove vegetation and stable water circulation, which leads to a more dominant clam population. In contrast, location 3 (Kuala Langsa), which is close to residential areas and far from the coastline, experiences human activities and unstable water circulation, resulting in a lower population of blood cockles in this area. The limited number of blood cockle individuals found at the research locations indicates a decline in their population in their natural habitat in the coastal area [24]. Blood cockles are one of the bivalve species that inhabit mangrove areas with stable water circulation and are generally suitable for

sandy and muddy substrates [13]. The population of these animals in their habitat is currently highly concerning due to ecological habitat degradation and uncontrolled exploitation by communities for consumption and commercial purposes, driven by the high market demand for blood cockles [25]. Their high nutritional content and delicious taste make them popular for consumption by many people at any time.

The blood cockles found exhibited a wide variation in size, including length, width, and total weight. The length of the blood cockles ranged from 3.00 cm to 6.76 cm, while the width ranged from 2.50 cm to 5.52 cm. The sizes of the blood cockles found at the research locations indicated they were mostly adults and older individuals. The majority of individuals found were adults, accounting for 90.82%, while only 9.18% were classified as older individuals. Male blood cockles were more dominant compared to females at the research locations. Distinguishing between male and female cockles morphometrically is challenging due to their similar morphology. The distribution of shell length and width in male and female cockles was almost the same, but a significant difference could be observed in the total weight. Male *T. granosa* had a higher total weight compared to females. The occurrence of morphometric variations based on shell length and width indicated that the distribution based on shell size was still good and heterogeneous. The increasing heterogeneity of animal distribution in an environment indicates the population's good condition in its habitat [26,27].

In general, the growth pattern of *T. granosa* with a value of $b = 2.5085$ falls under the criteria of negative allometry, indicating that the length of the blood cockles grows faster than their total weight. This is influenced by environmental factors in their habitat, including mangrove vegetation, sediment composition, and water salinity [23]. Mangrove vegetation plays an important role for *T. granosa* as a nursery habitat, protection against currents and predators, and a source of food for various coastal biota species. The better the mangrove vegetation at a location, the richer the available sources of nutrients in that environment [28]. The high activities of ships and fishing boats in this coastal area are one of the causes of habitat degradation for various coastal biota in ecological terms. Oil spills and pollution resulting from the activities of ships and fishing boats contribute to water pollution, which affects the declining quality of the cockle habitat [29].

Based on the research locations, the best growth pattern of *T. granosa* was found at location 1 (Lhok Banie Village) with a value of $b = 2.6395$, approaching the isometric criterion ($b = 3$). On the other hand, a less favorable growth pattern was observed at location 3 in Pusong Village with a value of $b = 1.7820$. Location 1, situated in Lhok Banie Village, has a very stable water circulation due to its proximity to the coast and the good environmental conditions, as evidenced by the presence of mangrove vegetation. These conditions contribute to the good growth of blood cockles in the area as the tidal currents bring abundant food sources such as plankton and various microorganisms from the ocean and land [30]. An ideal habitat and abundant food supply are among the main factors influencing the growth and development of a species [31].

Uncontrolled exploitation by shellfish gatherers for commercial purposes, without selective mechanisms based on size or age, has led to the increasing rarity of these animals in their habitat [32]. The continuous degradation of habitat due to illegal logging of mangrove vegetation for charcoal production by the local community is also a factor endangering the survival of *T. granosa* [33]. It is crucial to implement sustainable coastal management efforts to preserve the habitat of various animal species living in mangrove areas. Conserving the environment as a habitat for shelter, spawning, nurturing, and foraging for aquatic species is essential for the stability of their populations [32].

This research illustrates the degraded condition of the coastal area of Langsa City due to the activities of ships and fishing boats, as well as the logging of mangrove vegetation by the local community, resulting in the decline of various coastal biota populations. *T. granosa*, as one of

the *Bivalvia* species, serves as a suitable indicator of environmental conditions based on its population. The decline in the clam population indicates the need for collective attention from the government and the community to protect and manage the environment, ensuring the sustainability of various coastal biota in their natural habitat as a source of nutrition for the community [34]. This research can also serve as a reference for stakeholders, including the government and private institutions, in managing vulnerable coastal areas that are susceptible to pollution from both land and sea sources.

Conclusions

Variations in the morphometrics of *T. granosa*, including length, width, total weight, and sex, were found at all study locations. Morphometric analysis indicated that the growth pattern of *T. granosa* in the mangrove area of Langsa City showed a value of $b=2.5085b = 2.5085b=2.5085$, which falls under the negative allometric category. This growth pattern suggests that the length of *T. granosa* increases at a faster rate than its total weight. This growth pattern of *T. granosa* indicates that the clam's habitat in the mangrove area of Langsa City has begun to experience ecological degradation, necessitating sustainable management efforts and the conservation of *T. granosa* to ensure the survival of various biota in the coastal region. The high mobility of boats and fishing vessels in the mangrove area, along with illegal mangrove logging, are among the causes of habitat degradation in this coastal region. This study was only conducted during the dry season. To obtain more comprehensive data, it is recommended that researchers conduct studies during the rainy season to gather more complete data.

Funding: This study does not receive external funding.

Ethical Clearance: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data used in this study are available upon request from the corresponding author in accordance with applicable data protection and privacy regulations.

Conflicts of Interest: The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

References

- [1] Abd Rahman MA, Asmawi MZ. Mangrove Degradation: Issue and Awareness. *Asian Journal of Quality of Life* 2018;3:89–96. <https://doi.org/10.21834/ajqol.v3i10.104>.
- [2] Akpogheli JO, Ugbuku UA, Esemadefe UJ. A Review of Oil Spill Pollution and Air Quality in the Niger Delta: Causes, Effects and Control. *Journal of Chemical Society of Nigeria* 2021;46. <https://doi.org/10.46602/jcsn.v46i5.660>.
- [3] Alhejoj I, Bandel K, Salameh E. Aquatic Mollusks: Occurrences, Identification and Their Use as Bioindicators of Environmental Conditions (Salinity, Trace Elements and Pollution Parameters) in Jordan, 2017, p. 295–318. https://doi.org/10.1007/978-3-319-51856-5_17.
- [4] Indriaty I, Ginting B, Hasballah K, Djufri D. A Comparative Study of Total Tannin Contents and Antimicrobial Activities in Methanol Extracts of Rhizophoraceae Species. *Heca Journal of Applied Sciences* 2023;1:62–70. <https://doi.org/10.60084/hjas.v1i2.89>.
- [5] Atlanta V, Ambarwati R, Rahayu DA, Mujiono N. Diversity of Bivalves on the North Coast of Lamongan, East Java, Indonesia. *Biodiversitas Journal of Biological Diversity* 2022;23. <https://doi.org/10.13057/biodiv/d230850>.
- [6] Azmi F, Mawardi AL, Nurdin MS, Febri SP, Sinaga S, Haser TF. Population Dynamics of *Anadara antiquata* of East Coast of Aceh, Indonesia. *Biodiversitas Journal of Biological Diversity* 2022;23. <https://doi.org/10.13057/biodiv/d230145>.
- [7] Bahtiar B, Purnama MF, Kasim M, Ishak E. Population Dynamics of Blood Clams *Tegillarca granosa* in Kendari Bay, Southeast Sulawesi, Indonesia. *Biodiversitas Journal of Biological Diversity* 2022;23. <https://doi.org/10.13057/biodiv/d231015>.

- [8] Biandolino F, Di Leo A, Parlapiano I, Papa L, Giandomenico S, Spada L, et al. Nutritional Quality of Edible Marine Bivalves from the Southern Coast of Italy, Mediterranean Sea. *Polish Journal of Food and Nutrition Sciences* 2019;69:71–81. <https://doi.org/10.31883/pjfn-2019-0001>.
- [9] Callier MD, Byron CJ, Bengtson DA, Cranford PJ, Cross SF, Focken U, et al. Attraction and Repulsion of Mobile Wild Organisms to Finfish and Shellfish Aquaculture: A Review. *Reviews in Aquaculture* 2018;10:924–49. <https://doi.org/10.1111/raq.12208>.
- [10] Cannicci S, Lee SY, Bravo H, Cantera-Kintz JR, Dahdouh-Guebas F, Fratini S, et al. A Functional Analysis Reveals Extremely Low Redundancy in Global Mangrove Invertebrate Fauna. *Proceedings of the National Academy of Sciences* 2021;118. <https://doi.org/10.1073/pnas.2016913118>.
- [11] Dinulislam A, Sulistiono, Lumbanbatu DTF, Affandi R. Heavy Metals (Pb, Hg) in Blood Cockle (*Anadara granosa*) in Cengklok Waters, Banten Bay, Indonesia. *IOP Conference Series: Earth and Environmental Science* 2021;744:012012. <https://doi.org/10.1088/1755-1315/744/1/012012>.
- [12] Diring B, Pretell K, Avellan R, Chanta C, Cedeño V, Gentile G. Genetic Structure, Phylogeography, and Demography of *Anadara tuberculosa* (Bivalvia) from East Pacific As Revealed by mtDNA: Implications to Conservation. *Ecology and Evolution* 2019;9:4392–402. <https://doi.org/10.1002/ece3.4937>.
- [13] Doinsing JW, Admodisastro VA, Duisan L, Ransangan J. Population Dynamics and Condition Index of Natural Stock of Blood Cockle, *Tegillarca granosa* (Mollusca, Bivalvia, Arcidae) in the Marudu Bay, Malaysia. *Acta Oceanologica Sinica* 2021;40:89–97. <https://doi.org/10.1007/s13131-021-1791-5>.
- [14] Fretwell SD. Populations in a Seasonal Environment. (MPB-5). Princeton University Press; 2020.
- [15] Hamli H, Rahim AA, Idris MH, Kamal AHM, King WS. Morphometric Variation among Three Local Mangrove Clam Species of Corbiculidae. *Songklanakarin Journal of Science and Technology* 2015;37:15–20.
- [16] Kim J-H, Lee H-M, Cho Y-G, Shin J-S, Yoo J-W, Hong H-K, et al. Effects of Spawning Stress on the Immune Capacity of Blood Cockle *Tegillarca granosa* Occurring on the South Coast of Korea. *Fish & Shellfish Immunology* 2022;120:15–22. <https://doi.org/10.1016/j.fsi.2021.11.013>.
- [17] Kritsanapuntu S, Chaitanawisuti N. Distribution and Diversity of Benthic Macroinvertebrate Fauna in Three Repeated Operating Ages of the Blood Cockle *Anadara granosa* Cultivation in Bandon Bay, Suratthani Province, Southern Thailand. *Aquaculture Research* 2019;50:3539–48. <https://doi.org/10.1111/are.14308>.
- [18] López-Alonso R, Sánchez O, Fernández-Rodríguez I, Arias A. Diversity and Distribution of Bivalve Molluscs in the Central Cantabrian Sea and the Avilés Canyons System (Bay of Biscay). *Estuarine, Coastal and Shelf Science* 2022;273:107907. <https://doi.org/10.1016/j.ecss.2022.107907>.
- [19] López-Rocha JA, Melo FJF-R, Gastélum-Nava E, Larios-Castro E, Romo-Piñera A. Morphometric Relationship, Growth Parameters, and Natural Mortality as Estimated Primary Inputs for Fishery Management in Newfishing Areas for Bivalve Molluscs (Bivalvia: Veneridae). *Journal of Shellfish Research* 2018;37:591–600. <https://doi.org/10.2983/035.037.0312>.
- [20] Mawardi M, Sarong MA, Suhendrayatna S, Irham M. The Relationship between Crustacean Diversity and Population Dynamics of Blood Cockle *Tegillarca granosa* in the Coastal Area of West Langsa, Aceh Province, Indonesia. *Biodiversitas Journal of Biological Diversity* 2024;25. <https://doi.org/10.13057/biodiv/d250228>.
- [21] Mawardi AL, Atmaja THW, Sarjani TM, Khalil M, Sarong MA, Yusriono Y. Growth Patterns of Captive Painted Terrapins *Batagur borneoensis* in the Aceh Province, Indonesia. *Biodiversitas Journal of Biological Diversity* 2022;23. <https://doi.org/10.13057/biodiv/d230956>.
- [22] Pandian TJ. Reproduction and Development in Mollusca. CRC Press; 2018.
- [23] Pahri SDR, Yana R, Danial MA. Sustainable Management of Blood Cockles (*Tegillarca granosa*) Industry in Malaysia from the Life Cycle Assessment Perspective: A Review. *Aquaculture, Aquarium, Conservation & Legislation* 2023;16:436–46.
- [24] Rand GM, Wells PG, McCarty LS. Introduction to Aquatic Toxicology. Fundam. Aquat. Toxicol., CRC Press; 2020, p. 3–67.
- [25] Saputra RF, Masithah ED, Wulansari PD. The Analysis of Cockle (*Anadara inaequalis*) Gonad Maturity Level in the Estuary of Banjar Kemuning River, Sedati, Sidoarjo. *IOP Conference Series: Earth and Environmental Science* 2019;236:012061. <https://doi.org/10.1088/1755-1315/236/1/012061>.
- [26] Schoch. Ocean Biodiversity Information System 2020.
- [27] Spalding MD, Ruffo S, Lacambra C, Meliane I, Hale LZ, Shepard CC, et al. The Role of Ecosystems in Coastal Protection: Adapting to Climate Change and Coastal Hazards. *Ocean & Coastal Management* 2014;90:50–7. <https://doi.org/10.1016/j.ocecoaman.2013.09.007>.
- [28] Srisunont C, Nobpakhun Y, Yamalee C, Srisunont T. Influence of Seasonal Variation and Anthropogenic Stress on Blood Cockle (*Tegillarca granosa*) Production Potential. *Journal of Fisheries & Environment* 2020;44.

- [29] Talukdar A, Panda A, Srivastav A, Hussain SA, Malik PK, Nigam P. Growth Patterns of Critically Endangered, Head-Started Three-Striped Roofed Turtle, *Batagur dhongoka* (Gray, 1834). *Biologia* 2021;76:3705–10. <https://doi.org/10.1007/s11756-021-00858-y>.
- [30] Yadav R, Malla PK, Dash D, Bhoi G, Patro S, Mohapatra A. Diversity of Gastropods and Bivalves in the Mangrove Ecosystem of Paradeep, East Coast of India: A Comparative Study with Other Indian Mangrove Ecosystems. *Molluscan Research* 2019;39:325–32. <https://doi.org/10.1080/13235818.2019.1644701>.
- [31] Young MJ, Feyrer F, Stumpner PR, Larwood V, Patton O, Brown LR. Hydrodynamics Drive Pelagic Communities and Food Web Structure in a Tidal Environment. *International Review of Hydrobiology* 2021;106:69–85. <https://doi.org/10.1002/iroh.202002063>.
- [32] Mawardi AL, Khalil M, Sarjani TM, Armanda F. Diversity and Habitat Characteristics of Gastropods and Bivalves Associated with Mangroves on the East Coast of Aceh Province, Indonesia. *Biodiversitas Journal of Biological Diversity* 2023;24. <https://doi.org/10.13057/biodiv/d240959>.
- [33] Yusup DS, Rayi Arimurti A, Kusumayuni LPE, Proborini MW. The Response of Juvenile Olive Turtle, *Lepidochelys olivacea* : The Inclusion of Dried Seaweed and Seagrass in Fish Based-Formulated Feed. *IOP Conference Series: Earth and Environmental Science* 2021;709:012060. <https://doi.org/10.1088/1755-1315/709/1/012060>.
- [34] Zgouridou A, Tripidaki E, Giantsis IA, Theodorou JA, Kalaitzidou M, Raitzos DE, et al. The Current Situation and Potential Effects of Climate Change on the Microbial Load of Marine Bivalves of the Greek Coastlines: An Integrative Review. *Environmental Microbiology* 2022;24:1012–34. <https://doi.org/10.1111/1462-2920.15765>.