

Length–Weight Relationships and Growth Characteristics of Green Mussels (*Perna viridis*) in the Waters of Tambak Lorok, Semarang

Farazila Ningtias Manurung^{1*}, Widianingsih², Ita Widowati², Retno Hartati²

¹Master Program in Marine Science, Department of Marine Science, Faculty of Fisheries and Marine Sciences, Universitas Diponegoro

²Department of Marine Science, Faculty of Fisheries and Marine Sciences, Universitas Diponegoro
Email: farazila225@gmail.com

Abstract

Green mussels (*Perna viridis*) represent a significant aquaculture commodity in tropical coastal waters, including Tambak Lorok, Semarang, which is subject to substantial anthropogenic influences from urban settlements, port activities, and land-based waste discharges. Understanding the length-weight relationship (LWR) is essential for elucidating growth patterns, physiological conditions, and population dynamics of this species. This study aimed to analyze the spatial-temporal variation of LWR in *P. viridis* from Tambak Lorok waters while considering water-quality parameters. Sampling was conducted monthly from May to September 2025 across three cultivation stations using random sampling, yielding a total of 750 individuals. Concurrent measurements of environmental parameters, including temperature, salinity, pH, and dissolved oxygen, were recorded during sampling. The logarithmic equation $W = aL^b$ was applied to determine the length-weight relationship, where W represents weight (g) and L denotes shell length (mm). The results revealed a very strong correlation coefficient ($R^2 = 0.908$). The allometric coefficient (b) ranged temporally from 2.294 to 2.580 and spatially from 2.144 to 2.562. All b values were consistently below 3, indicating a negative allometric growth pattern, wherein *P. viridis* in Tambak Lorok tends to elongate faster than it gains weight. These findings contribute valuable baseline data on the population condition and growth characteristics of green mussels in urban coastal ecosystems, supporting sustainable aquaculture management and environmental monitoring programs in the region.

Keywords: *Perna viridis*, negative allometric, spatial-temporal, growth pattern, population condition

INTRODUCTION

Green mussels (*Perna viridis*) are a bivalve species widespread in tropical and subtropical waters of the Indo-Pacific, including Indonesia's coastal areas, and is one of the important aquaculture commodities for coastal communities. This species is widely cultivated due to its relatively fast growth and ability to adapt to dynamic coastal waters, thereby making a significant economic contribution to local fisheries and livelihoods (Sukumaran *et al.*, 2024). Apart from being a food source, body parts, such as shells, also have the potential for industrial use, for example, as biomaterials and biopolymers such as chitosan (Inoue *et al.*, 2021; Morando *et al.*, 2022; Kaewprachu & Jaisan, 2023). Data from the Semarang City Fisheries Office (2024) shows that green mussels are among the marine fisheries commodities with the highest fishermen's production in Semarang City, which will reach 961,476 kg in 2024.

Ecologically, *P. viridis* is a filter feeder that filters suspended particles and nutrients from the water column, thereby contributing to maintaining the quality of coastal waters (Verma *et al.*, 2025). In addition, its ability to accumulate a wide range of pollutants, particularly heavy metals, makes this species an effective bioindicator for monitoring the environmental conditions in tropical waters (Ucros-Rodríguez *et al.*, 2025; Vysakh *et al.*, 2025; Yap & Al-Mutairi, 2023). Growth of *P. viridis* is influenced by various environmental parameters such as temperature, salinity, dissolved oxygen, and nutrient availability that can affect metabolic activity, biomineralization, and growth energy allocation in bivalves (Ma *et al.*, 2022; Cai *et al.*, 2022; Carrier-Belleau *et al.*, 2021; Batir *et al.*, 2024).

One commonly used approach to evaluate the growth dynamics of aquatic organisms is the length–weight relationship (LWR), which can provide information on growth patterns, physiological conditions, and estimate population biomass (Mehanna & Farouk, 2021). In *P. viridis*, variations in growth values can be influenced by differences in environmental conditions, both spatially and temporally (Ucros-Rodríguez *et al.*, 2025; Phaksopa *et al.*, 2022; Mi *et al.*, 2024). Although LWR studies

on green mussels have been conducted in several coastal areas of Indonesia, such as Tuban Waters, Tambak Lorok–Morosari, and Banyuurip Sea (Kristanto, 2014; Ubay *et al.*, 2021; Firdaus *et al.*, 2023), studies that integrate spatial and temporal variation in urban coastal contexts are still limited. Tambak Lorok, Semarang, is a coastal area that is influenced by anthropogenic activities, including dense settlements, port activities, and land-based waste flows, which can cause dynamic fluctuations in water quality (Wulanningrum & Jayanti, 2016; Makhfudhoh *et al.*, 2019). Therefore, this study aims to analyze the spatial and temporal variations in the length-weight relationships and growth characteristics of *P. viridis* in the waters of Tambak Lorok, while accounting for water-quality parameters.

MATERIALS AND METHODS

The material used in this study was green mussels (*P. viridis*), collected from three stations, a total of 750 individuals over five months (May-September 2025) in the waters of Tambak Lorok, Semarang (Figure 1). Three observation stations were chosen to represent the spatial variation of aquatic environmental conditions in the Tambak Lorok area. Anthropogenic activities such as urbanization, industrial waste disposal, and agricultural runoff are known to affect spatial variations in water quality parameters, including nutrients, organic matter, and microbial contamination (Hong & Giao, 2022; Kesari *et al.*, 2021). Aquatic quality parameters such as temperature, salinity, acidity (pH), and dissolved oxygen (DO) were also measured at the same time as sampling.

Green mussels were sampled using the Random Sampling method, which ensures that each population has an equal chance of being selected for the sample (Sugiyono, 2015). Samples taken by Handpicking (taken by hand), which refers to research (Muhammadar *et al.*, 2022). Then, green mussels (*P. viridis*) were measured with a caliper (0.01 mm accuracy) and weighed using digital scales. Morphometric measurements are carried out with reference to (Yaqin, 2018). The length of the shell is measured from the anterior to the posterior end (the longest part of the shell), and the shells are weighed in their whole state (including shells) to obtain the individual total weight.

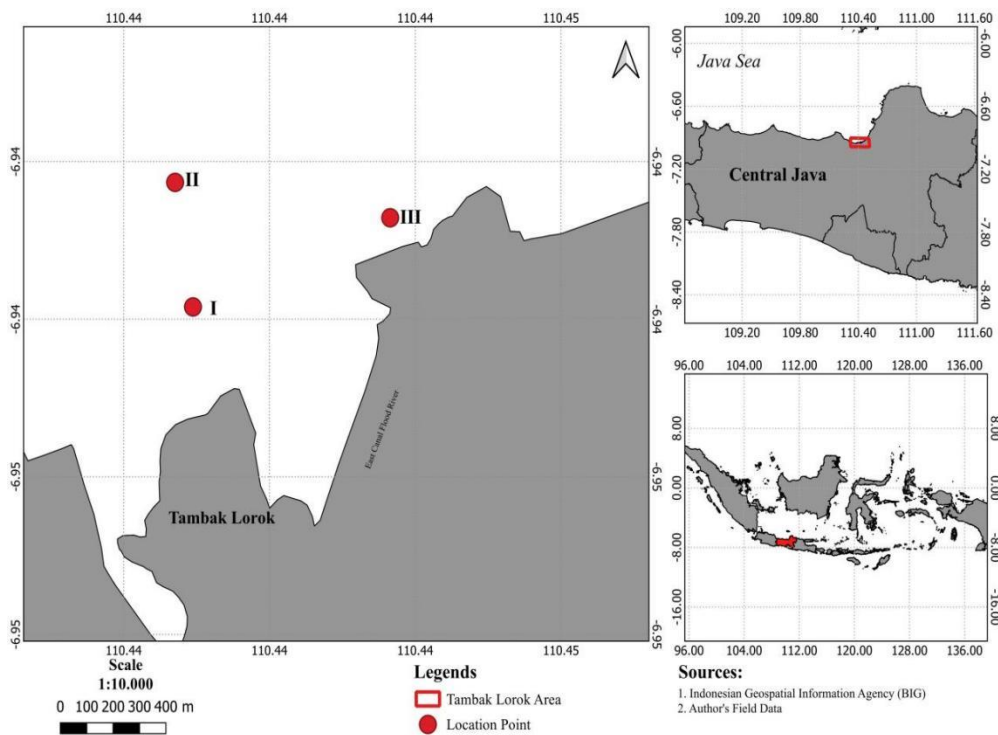


Figure 1. Sampling Location of Green Mussels in Tambak Lorok, Semarang, Central Java

Classification of green mussels by size using equations to determine the number of interval classes that correspond to the amount of data. The Sturges equation is expressed as follows:

$$K = 1 + 3,3 \log_{10}(n)$$

Description: K = number of interval classes; n = total number of samples

Once the number of classes is obtained, the data range (R) is determined from the difference between the maximum and minimum values of the shell length, then used to calculate the width of class (i) with the equation:

$$i = \frac{R}{K}$$

The classification of the length-weight relationship uses the equations of Bal & Rao (1984) and King (1995), namely:

$$W = aL^b$$

Remarks: W = Total weight of shellfish (gr); L: Shell length (mm); a: Constant, is the cut-off point of the line of the Y-axis regression equation; b: Regression coefficient (subverting the angle of the line with the axis).

Criteria for the long-term relationship of the weight (growth) of shellfish (Ubay *et al.*, 2021), namely: If $b < 3$, the increase in length is faster than the increase in weight, or called negative allometry. If $b > 3$, the weight gain increases faster than length, a pattern called positive allometry. If $b = 3$, then the increase in length and weight gain are balanced or isometric.

RESULTS AND DISCUSSION

The distribution of green mussels by length size interval class showed clear variation across observation months (Figure 2). In May, the highest number of individuals was in the 38–44 mm size class (small class), i.e., 14 individuals at Station I, while the large size class (101–104 mm) was not found at any station. During June to September, the population distribution is dominated by the middle class, with peaks of abundance varying across stations. In June, dominance occurred at Station III at intervals of 52–58 mm; in July and August, dominance shifted mainly to Station I at intervals of 59–72 mm; and in September, dominance again occurred at Station III at intervals of 52–58 mm. The absence of small classes in most of the months after May and the scarcity of large classes indicate a gradual shift in the cohort. This pattern indicates that the *Perna viridis* population is in an active growth phase, supported by relatively suitable environmental conditions.

This pattern indicates that the population is recruiting new individuals at the beginning of the life cycle. In general, the dominance of small size classes at the beginning of the growth season reflects the most recently recruited individuals, which will then shift to larger size classes over time (Lawson *et al.*, 2022). In addition, early-season environmental conditions, such as temperature and other climatic factors, can increase the survival of small individuals, leading to relatively high proportions of small individuals in this period (Gornostaev *et al.*, 2024).

The same pattern was observed in the total weight distribution (Figure 3), where the initial observations were dominated by light heavyweights, who then shifted to intermediate heavyweights in the following months. The limitations of individuals in the high weight class indicate that most of the population is still in the active growth phase. This consistency between length and weight distributions indicates progressive cohort development influenced by environmental factors such as feed availability, temperature, and salinity (Barbosa *et al.*, 2021).

In addition, reproductive dynamics and ecological pressures also affect population structure. The success of spawning and recruitment of bivalves is greatly influenced by abiotic factors such as temperature, salinity, and hydrodynamic conditions (Alter et al., 2025; Westerbom et al., 2021), while predation, harvesting activities, and habitat quality also affect population distribution and survival (Meister et al., 2023; Oróstica et al., 2022; Niino et al., 2021). Overall, environmental factors play an important role in controlling the growth and population dynamics of *Perna viridis* (Ma et al., 2022).

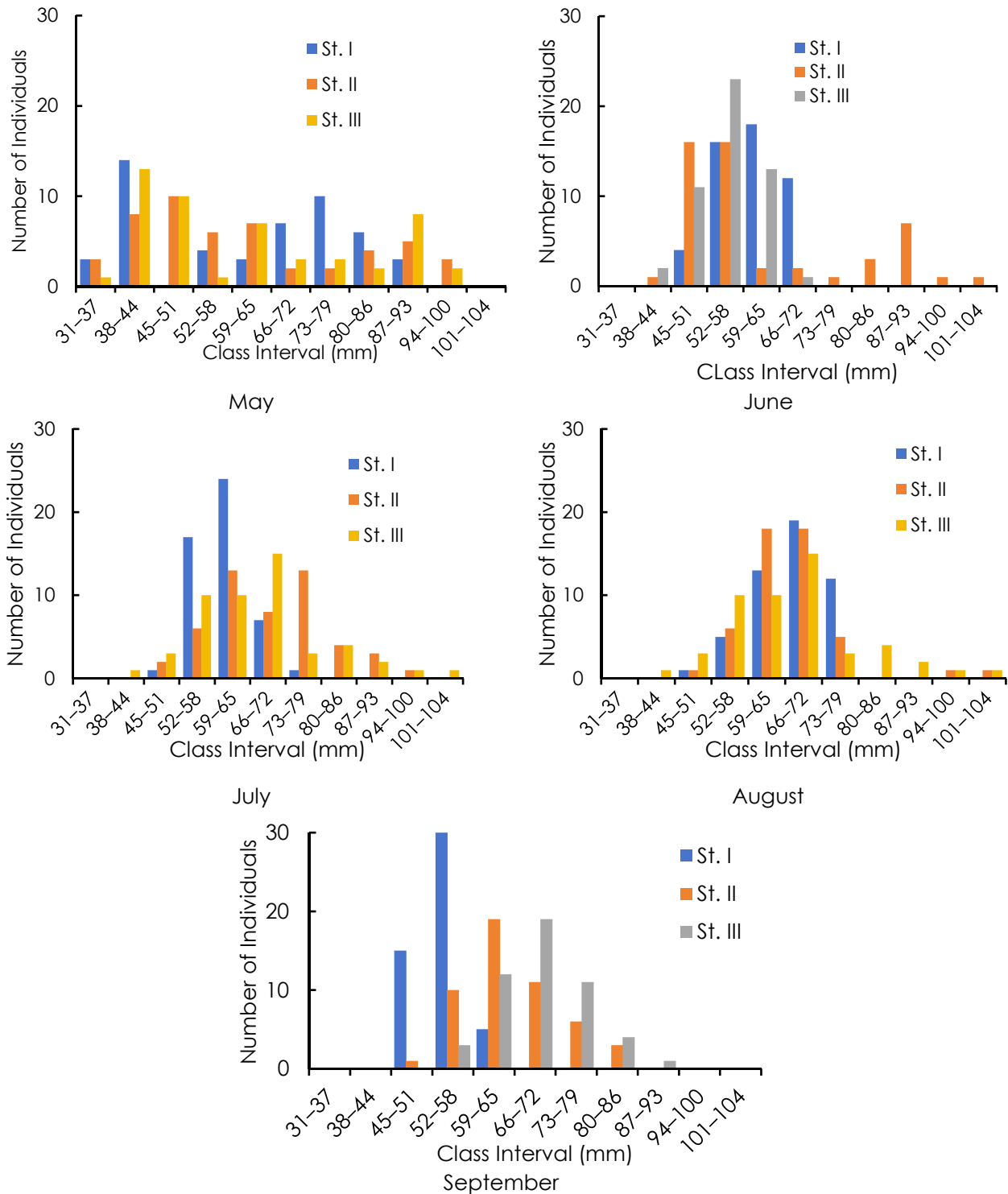


Figure 2. Distribution of green mussels by size interval class Length

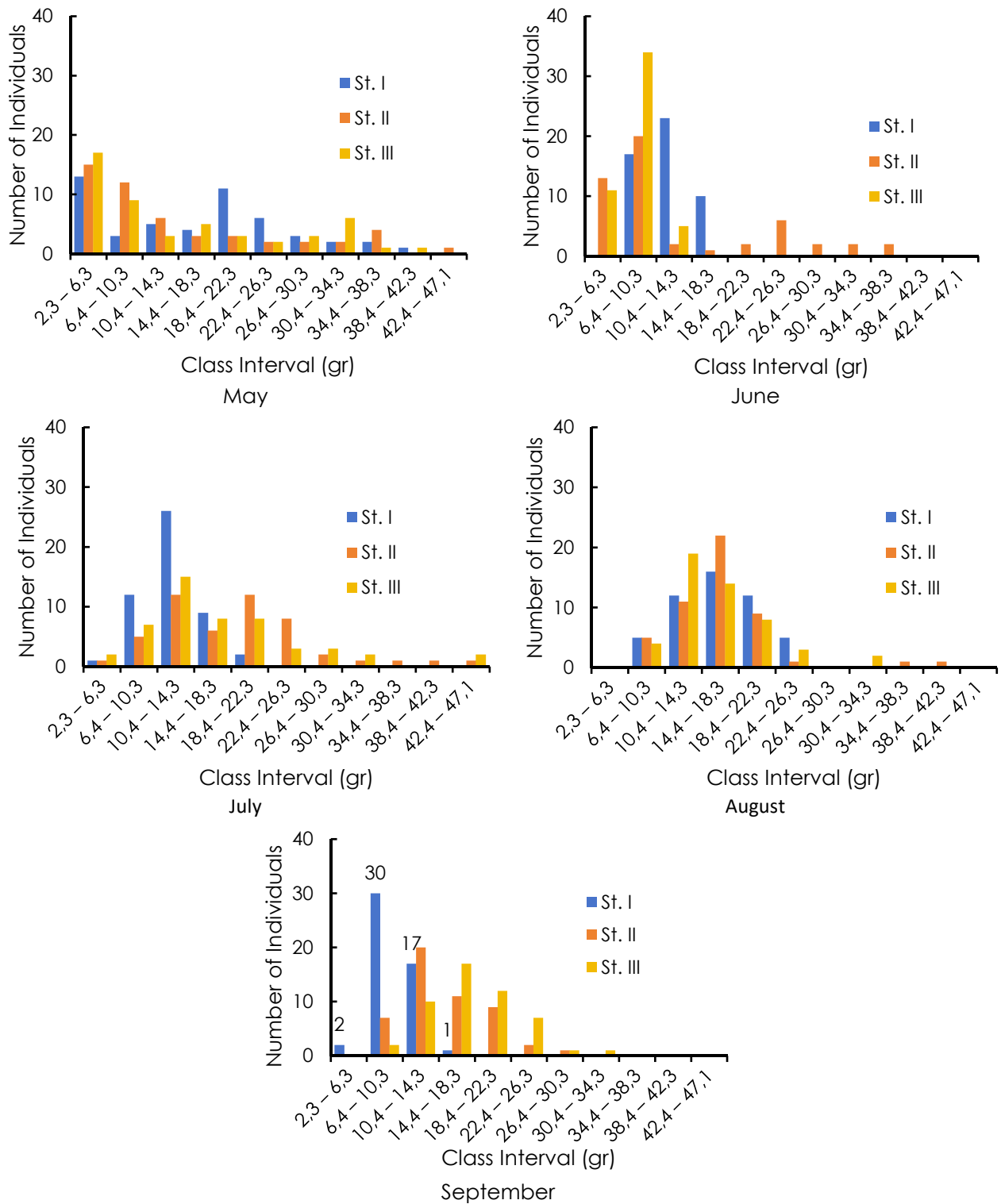


Figure 3. Distribution of green mussels by size interval class: Total Weight

The results of the regression analysis of the relationship between length and weight of green mussels totaling 750 individuals resulted in an equation of $W = 0.000605 L^{2,418}$ with a coefficient value of determination (R^2) of 0.908 and correlation (R) of 0.953, confirming that the length of the shell has

a very strong effect on the total weight *P. viridis*. Sugiyono (2015) stated that a Correlation Coefficient (R) value of 0.8-1.00 indicates a very strong correlation. *P. viridis* Overall has a negative allometric pattern where the value of $b = 2.418$ ($B < 3$), i.e., the growth of length is more dominant than the growth of weight. The value of the growth coefficient (b) of 2.418 ($b < 3$) indicates a negative allometric growth pattern, which means that the increase in length is faster than the increase in weight. The results of other studies also show the same results, such as, Ubay *et al.* (2021) green mussels in the waters of Tambak Lorok, Semarang and Morosari, Demak; in Moheskhali Channel, Cox's Bazar (Marma *et al.*, 2021); in the Java Sea, Banyuurip Village (Mazida *et al.*, 2023); and in the waters of Purworejo Village, Rembang Regency (Risma *et al.*, 2025). This pattern is commonly found in bivalves in the active growth phase or in populations dominated by juvenile to sub-adult individuals, where energy allocation is more directed towards shell growth than towards the accumulation of soft-tissue biomass. This is supported by Welton *et al.* (2024), who found that environmental stressors such as temperature changes and climate-related factors negatively impact shellfish physiology and growth, often reducing soft tissue biomass accumulation and altering allometric relationships.

Analysis of the length–weight relationship showed that the entire station had a strong correlation between shell length and the total weight of *Perna viridis* ($R^2 = 0.846–0.941$; $R = 0.920–0.970$), confirming that weight variation is largely explained by the length. This shows that, in general, the water conditions of Tambak Lorok still support the growth of green mussels. However, the variation in b-values between stations (I: 2.144; II: 2,525; III: 2,562) indicates the influence of local environmental conditions. All values of $b < 3$ show a negative allometric growth pattern, i.e., the increase in length is faster than the increase in weight.

The lowest b value at Station I, adjacent to urban areas, indicates the presence of anthropogenic stressors, such as domestic runoff and coastal activities, which can degrade water quality and suppress the accumulation of soft-tissue biomass. This statement is supported by Fernández *et al.* (2021), who report that anthropogenic stress can modulate bivalve growth by altering habitat quality. In contrast, higher b-values at Station II and especially Station III indicate relatively more favorable conditions for growth. The highest value at Station III is thought to be related to its proximity to the East Canal Flood River flow, which carries nutrient inputs from the mainland, thereby increasing water productivity and feed availability (Ma *et al.*, 2024). However, excessive nutrient inputs also trigger environmental fluctuations, such as eutrophication, which can affect growth in complex ways, as reported by Hauser-Davis and Wosnick (2022).

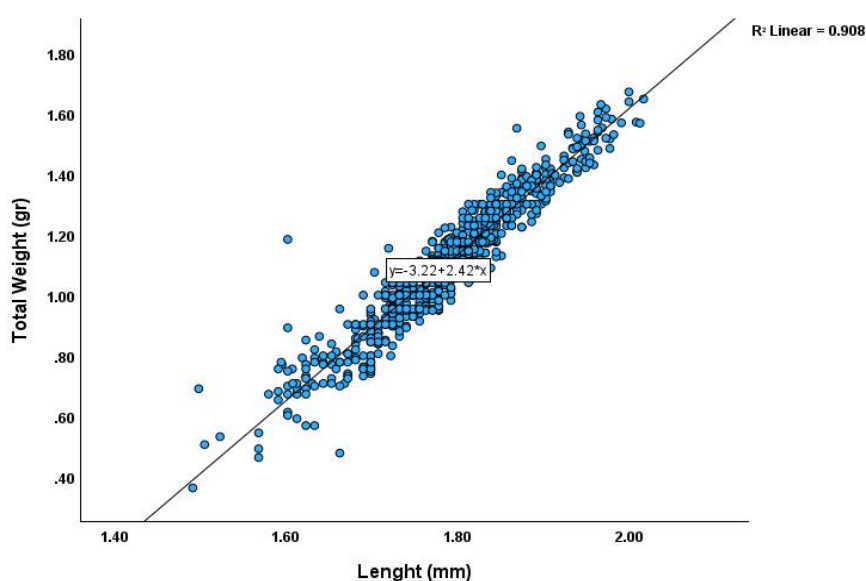


Figure 1. Relationship of Length and Total Weight of *P. viridis*

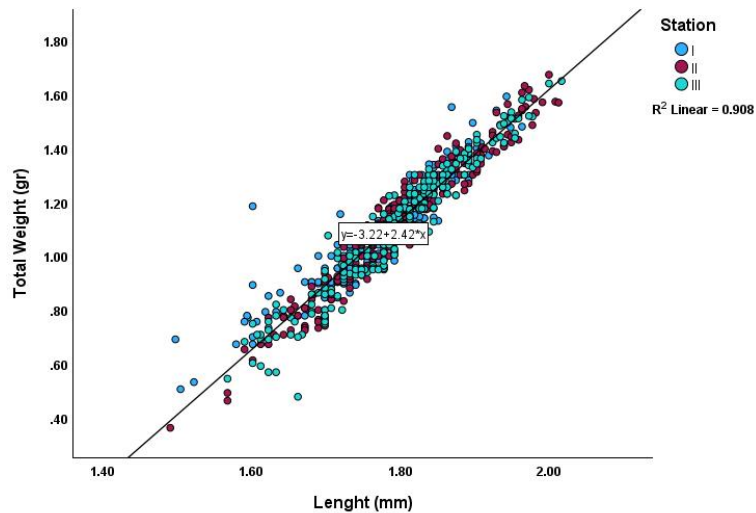


Figure 2. Spatial Relationship of *P. viridis* Length and Weight (Stations I-III)

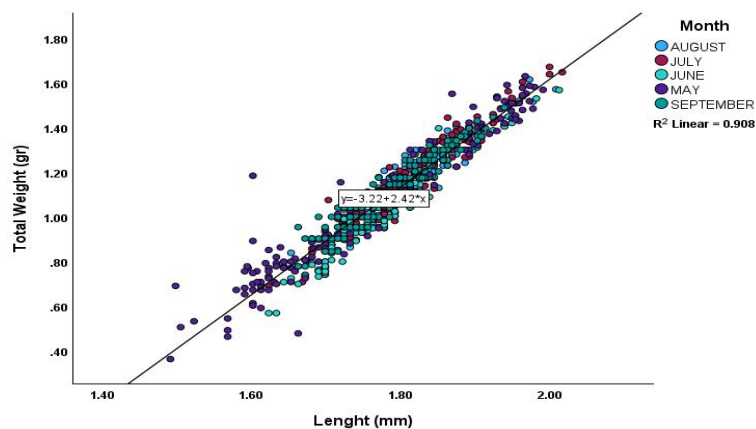


Figure 3. Temporal Relationship of *P. viridis* (May-September)

Temporal length–weight relationship analysis showed that *Perna viridis* had a strong morphometric relationship during the May–September period ($R^2 = 0.840–0.949$; $R = 0.916–0.974$). The value of the growth coefficient (b), which ranges from 2.294 to 2.580 and is entirely < 3 indicates a negative allometric growth pattern, indicating that the population is in the active growth phase and is dominated by juvenile to sub-adult individuals. The variation in b -value between months reflects the dynamics of growth influenced by temporal changes in environmental conditions.

Ecologically, seasonal fluctuations modulate metabolic energy allocation, reproductive processes, and recruitment success in bivalves, thereby influencing observed growth parameters (Ma *et al.*, 2022; Kanno *et al.*, 2022; Bazin *et al.*, 2025). Thus, the consistency of negative allometric patterns with temporal variations of b -values in *P. viridis* populations reflects an adaptive response to seasonal environmental dynamics.

The results of water parameter measurements during the observation period (May–September) at the three stations are presented in Table 1. In general, the physicochemical and nutrient parameters of the waters vary between months and stations, but most remain within the standard range of marine water quality for the growth of green mussels.

Table 1. Results of water parameter measurements

Number	Stations	Month	Parameters							
			pH	Temperature	Salinity	DO	Brightness	Nitrate	Nitrite	Phosphate
			-	°C	ppt	mg/L	m	mg/L	mg/L	mg/L
1	I	May	6	31	25	6	1	1,1	0,01	0,98
2		June	8,4	30	32	5,5	1	2,1	0,06	1,29
3		July	7,7	29,4	27	7,7	1,1	1,4	0,09	0,15
4		August.	7,2	30,1	26	6,5	1,2	0,5	0,07	0,02
5		Sep.	8,12	31,6	24	6,4	1	0,27	0,009	0,51
6	II	May	6	31,2	23	6,5	1,25	0,9	0,03	0,79
7		June	8	29,9	30	6,56	1	1,9	0,06	1,07
8		July	7,71	29,2	25	7,7	0,9	1,7	0,15	0,14
9		August.	7	30,8	25	6,5	1,2	0,3	0,03	<0,05
10		Sep.	7,95	32	23	6	1	0,24	0,006	0,69
11	III	May	6	31,4	15	6,5	0,98	0,9	0,04	2,39
12		June	8	30	28	5,77	0,9	2,25	0,07	1,83
13		July	7,7	29,2	25	7,7	0,88	1,7	0,12	0,23
14		August.	6,95	30,2	28	6,5	0,9	0,68	0,22	0,05
15		Sep.	8,04	32,1	22	6	0,8	0,24	0,006	0,72
Quality Standards			6-8,5	27-35	27-35	>5	1-3	<20	≤1	0,1-0,25
Source			a	b	a	c	b	d	d	d

Description: a. Kusuadi (2005), b. Radiarta *et al.*, (2003), c. MENLH (2004), d. Kementerian Kelautan dan Perikanan Republik Indonesia (2016).

The results of water quality parameters measurements during the study showed that, the environmental conditions in the waters of Tambak Lorok remain within the range that supports the life and growth of *Perna viridis*. Temperature values range from 29.2–32.1 °C with salinity of 15–32 ppt, pH 6–8.4, and dissolved oxygen (DO) of 5.5–7.7 mg/L, which is still within the physiological tolerance range of green mussels. The combination of temperature and salinity is known to play an important role in supporting the activity of digestive enzymes as well as the antioxidant defense system related to the growth and survival of *P. viridis* (Ma *et al.*, 2022), while the neutral to slightly alkaline pH range supports the balance of nutrient cycles in waters (Liu *et al.*, 2025). The relatively high DO value also indicates water conditions that are able to support aerobic respiration and the metabolic activity of aquatic organisms (Saravia-Arguedas *et al.*, 2021). In addition, the water column brightness ranges from 0.8 to 1.25 m, which has the potential to support phytoplankton productivity as a source of feed for filter-feeding organisms (Walker *et al.*, 2023). Concentrations of nutrients such as nitrates (0.24–2.25 mg/L), nitrites (0.006–0.22 mg/L), and phosphates (<0.05–2.39 mg/L) indicate aquatic fertility dynamics that can increase the availability of natural feed, but in high concentrations also have the potential to trigger eutrophication that can affect water quality (Grijalva-Endara *et al.*, 2024; Saravia-Arguedas *et al.*, 2021), so that the balance of nutrients controlled by microbial processes is important in maintaining the stability of coastal aquatic ecosystems (Liu *et al.*, 2025).

CONCLUSION

The distribution of green mussels was highest in the 52-58 mm length interval (medium), with a total of 30 individuals at Station I in September. The distribution of green mussels, based on the highest total weight size interval, was 6.4-10.3 g (small) with 34 individuals at Station III in June. The relationship between overall (b = 2.418), spatial (b = 2.144–2.562), and temporal (b = 2.294–2.580) weight consistently showed negative allometrics, i.e., all b values were < 3, indicating that long growth was more dominant than heavy growth.

REFERENCE

Bal, D. V., & Rao, K. V. (1984). *Marine fisheries*. Tata McGraw-Hill Publishing Company Limited, pp. 5–24.
 Batır, E., Metin, Ö., Yıldız, M., Özel, O. T., & Fidan, D. (2024). Sustainable land-based IMTA: Holistic management of finfish, mussel, and macroalgae interactions, emphasizing water quality and

- nutrient dynamics. *Journal of Environmental Management*, 372, 123411. doi: 10.1016/j.jenvman.2024.123411
- Bazin, S., Domaizon, I., Barouillet, C., Frossard, V., & Sentis, A. (2025). Seasonal variations in planktonic food web structure affect stability by shifting the distribution of energy fluxes. *Oikos*. doi: 10.1002/oik.11528
- Cai, C., He, Q., Xie, B., Xu, Z., Wang, C., Yang, C., Liao, Y., & Zheng, Z. (2022). Long non-coding RNA LncMPEG1 responds to multiple environmental stressors by affecting biomineralization in pearl oyster *Pinctada fucata martensii*. *Frontiers in Marine Science*, 9. doi: 10.3389/fmars.2022.1014810
- Carrier-Belleau, C., Drolet, D., McKindsey, C. W., & Archambault, P. (2021). Environmental stressors, complex interactions and marine benthic communities' responses. *Scientific Reports*, 11(1), 4194. doi: 10.1038/s41598-021-83533-1
- Dinas Perikanan Kota Semarang. (2024). *Perikanan dalam angka 2024*. Pemerintah Kota Semarang.
- Fernández, F. J., Muñoz, M., Ponce Oliva, R. D., Vázquez-Lavín, F., & Gelcich, S. (2021). Gaps, biases, and future directions in research on the impacts of anthropogenic land-use change on aquatic ecosystems: A topic-based bibliometric analysis. *Environmental Science and Pollution Research*, 28(32), 43173–43189. doi: 10.1007/s11356-021-15010-1
- Firdaus, Q. Y., Farikhah, F., & Safitri, N. M. (2023). Analisis pertumbuhan dan kepadatan kerang hijau (*Perna viridis*) pada tali gantung karamba apung kerang hijau di Laut Desa Banyuurip Kecamatan Ujungpangkah Kabupaten Gresik. *Jurnal Perikanan Pantura*, 6(1), 281–293.
- Gornostaev, N. G., Lyupina, Y. V., Lazebny, O. E., & Kulikov, A. M. (2024). Seasonal Dynamics of Fruit Flies (Diptera: Drosophilidae) in Natural Parks of Moscow City, Russia. *Insects*, 15(6), 398. doi: 10.3390/insects15060398
- Grijalva-Endara, A., Valenzuela-Cobos, J. D., Guevara-Viejó, F., Macías Mora, P. A., Quichimbo Moran, J. S., Ruiz-Muñoz, G., Galindo-Villardón, P., & Vicente-Galindo, P. (2024). Water quality in Estero Salado of Guayaquil using three-way multivariate methods of the STATIS family. *Water*, 16(15), 2196. doi: 10.3390/w16152196
- Hauser-Davis, R. A., & Wosnick, N. (2022). Climate change implications for metal and metalloid dynamics in aquatic ecosystems and its context within the decade of ocean sciences. *Water*, 14(15), 2415. doi: 10.3390/w14152415
- Hong, T. T. K., & Giao, N. T. (2022). Analysis of surface water quality in upstream province of Vietnamese Mekong Delta using multivariate statistics. *Water*, 14(12), 1975. doi: 10.3390/w14121975
- Inoue, K., Yoshioka, Y., Tanaka, H., Kinjo, A., Sassa, M., Ueda, I., Shinzato, C., Toyoda, A., & Itoh, T. (2021). Genomics and transcriptomics of the green mussel explain the durability of its byssus. *Scientific Reports*, 11(1), 5992. doi: 10.1038/s41598-021-84948-6
- Kaewprachu, P., & Jaisan, C. (2023). Physicochemical properties of chitosan from green mussel shells (*Perna viridis*): A comparative study. *Polymers*, 15(13), 2816. doi: 10.3390/polym15132816
- Kanno, Y., Kim, S., & Pregler, K. C. (2022). Sub-seasonal correlation between growth and survival in three sympatric aquatic ectotherms. *Oikos*, 2023(3), e09685. doi: 10.1111/oik.09685
- Kementerian Kelautan dan Perikanan Republik Indonesia. (2016). *Peraturan Menteri Kelautan dan Perikanan Republik Indonesia Nomor 75 Tahun 2016 tentang pedoman umum pengembangan kawasan budidaya laut*.
- Kesari, V., Kumar, S., Yadav, I., Chatterjee, A., Rai, S., & Pandey, S. (2021). Ganga river water quality assessment using combined approaches: Physico-chemical parameters and cyanobacterial toxicity detection with special reference to microcystins and molecular characterization of microcystin synthetase (mcy) genes carrying cyanobacteria. *Environmental Science and Pollution Research*, 29(9), 13122–13140. doi: 10.1007/s11356-021-16589-1
- King, M. (1995). *Fisheries biology, assessment and management*. Fishing News Books.
- Kristanto, D. (2014). *Pendugaan parameter biologi dan dinamika populasi kerang hijau (Perna viridis, L.) di perairan Tuban Jawa Timur* (Doctoral dissertation). Universitas Brawijaya.
- Kusuadi. (2005). *Mussel farming in state of Sarawak, Malaysia: A feasibility study* [Thesis]. The United Nation University.
- Lawson, A. J., Jodice, P. G. R., Rainwater, T. R., Dunham, K. D., Hart, M., Butfiloski, J. W., Wilkinson, P. M., McFadden, K. W., & Moore, C. T. (2022). Hidden in plain sight: Integrated population models

- to resolve partially observable latent population structure. *Ecosphere*, 13(12), 1–22. <https://doi.org/10.1002/ecs2.4321>
- Liu, Y., Yin, P., Zhou, J., Ma, Y., Lai, X., Lin, J., Peng, H., Shu, H., & Huang, W. (2025). Removal of nitrogen and phosphorus by a novel salt-tolerant strain *Pseudomonas sediminis* D4. *Water*, 17(4), 502. doi: 10.3390/w17040502
- Ma, J., Yin, X., Liu, G., & Song, J. (2024). Intensification of human land use decreases taxonomic, functional, and phylogenetic diversity of macroinvertebrate community in Weihe River Basin, China. *Diversity*, 16(9), 513. doi: 10.3390/d16090513
- Ma, Z., Fu, Z., Yang, J., & Yu, G. (2022). Combined effects of temperature and salinity affect the survival of Asian green mussel (*Perna viridis*) through digestive and antioxidant performance. *Antioxidants*, 11(10), 2009. doi: 10.3390/antiox11102009
- Makhfudhoh, D. K., Hidayat, J. W., & Muhammad, F. (2019). Struktur komunitas plankton sebagai indikator kualitas perairan budidaya di Tambak Lorok Semarang. *Bioma: Berkala Ilmiah Biologi*, 20(2), 145–153. doi: 10.14710/bioma.20.2.145-153
- Marma, M. C., Asaduzzaman, M. D., Barua, U., Akter, S., & Noor, A. R. (2021). Spat settlement and growth performance of green mussel (*Perna viridis*) in different culture systems at Moheshkhali Channel, Cox's Bazar. *Journal of Global Biosciences*, 10(1), 8243–8259.
- Mazida, A., Aminin, A., & Farikhah, F. (2023). Analisis biometri dan laju pertumbuhan kerang hijau (*Perna viridis*) yang dibudidayakan dalam karamba apung di Laut Jawa Desa Banyuurip Kecamatan Ujungpangkah. *Journal of Marine Research*, 12(2), 240–249. doi: 10.14710/jmr.v12i2.36270
- Mehanna, S. F., & Farouk, A. E. (2021). Length-weight relationship of 60 fish species from the Eastern Mediterranean Sea, Egypt (GFCM-GSA 26). *Frontiers in Marine Science*, 8, Mehanna, S. F., & Farouk, A. E. (2021). Length-weight relationship of 60 fish species from the Eastern Mediterranean Sea, Egypt (GFCM-GSA 26). *Frontiers in Marine Science*, 8, 625422. doi: 10.3389/fmars.2021.625422
- MENLH. (2004). Keputusan Menteri Lingkungan Hidup Nomor 51 Tahun 2004 tentang baku mutu air laut. Kementerian Lingkungan Hidup Republik Indonesia.
- Mi, Y., Li, S., & Wang, Z. (2024). Spatial distribution and topographic gradient effects of habitat quality in the Chang-Zhu-Tan Urban Agglomeration, China. *Scientific Reports*, 14(1), 22563. doi: 10.1038/s41598-024-73949-w
- Morando, M. A., Venturella, F., Sollazzo, M., Monaca, E., Sabbatella, R., Vetri, V., Passantino, R., Pastore, A., & Alfano, C. (2022). Solution structure of recombinant Pvpf-5β reveals insights into mussel adhesion. *Communications Biology*, 5(1), 739. doi: 10.1038/s42003-022-03699-w
- Muhammadar, A., Rusydi, I., Misqa, N., Mellisa, S., Nurfadillah, & Devira, C. N. (2022). Studi Kebiasaan Makan Kerang Hijau (*Perna viridis*) di Perairan Aleu Naga, Banda Aceh. *Jurnal Kelautan Dan Perikanan Indonesia*, 2(3), 189–200.
- Phaksopa, J., Sukhsangchan, R., Keawsang, R., Tanapivattanakul, K., Asvakittimakul, B., Thamrongnawasawat, T., & Worachananant, S. (2022). Assessment of microplastics in green mussel (*Perna viridis*) and surrounding environments around Sri Racha Bay, Thailand. *Sustainability*, 15(1), 9. doi: 10.3390/su15010009
- Radiarta, I. N., Wardoyo, S. E., Priyono, B., & Praseno, O. (2003). Aplikasi sistem informasi geografis untuk penentuan lokasi pengembangan budidaya laut di Teluk Ekas, Nusa Tenggara Barat. *Jurnal Penelitian Perikanan Indonesia*, 9(1), 67–71.
- Risma, E. A., Taufiq-Spj, N., & Suryono. (2025). Morfometri kerang hijau (*Perna viridis*) di perairan Desa Purworejo, Kecamatan Kaliori, Kabupaten Rembang. *Journal of Marine Research*, 14(2), 294–301. doi: 10.14710/jmr.v14i2.43232
- Saravia-Arguedas, A. Y., Vega-Bolaños, H., Vargas-Hernández, J. M., Suárez-Serrano, A., Sierra-Sierra, L., Tisseaux-Navarro, A., Cambronero-Solano, S., & Lugioyo-Gallardo, G. M. (2021). Surface-water quality of the Gulf of Papagayo, North Pacific, Costa Rica. *Water*, 13(17), 2324. doi: 10.3390/w13172324
- Sugiyono. (2015). *Metode penelitian kombinasi (mixed methods)*. Alfabeta.
- Sukumaran, S., Vysakh, V. G., Sebastian, W., Gopalakrishnan, A., Dharani, L. H., Pandey, A., Kumar, A., & Jena, J. K. (2024). The chromosome level genome assembly of the Asian green mussel, *Perna viridis*. *Scientific Data*, 11(1), 930. doi: 10.1038/s41597-024-03802-2

- Ubay, J., Hartati, R., & Redjeki, S. (2021). Morfometri dan hubungan panjang berat kerang hijau (*Perna viridis*) dari perairan Tambak Lorok, Semarang dan Morosari, Demak, Jawa Tengah. *Journal of Marine Research*, 10(4), 535–544.
- Ucros-Rodríguez, S., Araque-Romany, F., Montero-Mendoza, L., Sarmiento-Nater, V. C., Calvo-Carrillo, O. M., Johnson-Restrepo, B., Gallego, J. L., & Romero-Murillo, P. (2025). Analysis of pollutant accumulation in the invasive bivalve *Perna viridis*: Current status in the Colombian Caribbean 2020–2023. *Toxics*, 13(2), 77. doi: 10.3390/toxics13020077
- Verma, A. K., Rahman, A., Hussain, S., & Singh, N. S. (2025). Freshwater mussels as multifaceted ecosystem engineers: Insights into their ecological importance, bioindication, and economic contributions. *Water*, 17(11), 1629. doi: 10.3390/w17111629
- Vysakh, V. G., Sukumaran, S., & Gopalakrishnan, A. (2025). De novo transcriptome assembly of *Perna viridis*: A novel invertebrate model for ecotoxicological studies. *Scientific Data*, 12(1), 147. doi: 10.1038/s41597-025-04496-w
- Walker, C., Corrigan, S., Daniels, C., Wilding, C., Woodward, E. M. S., Widdicombe, C. E., Smale, D. A., Ashton, I. G. C., & Brown, A. R. (2023). Field assessment of the potential for small scale co-cultivation of seaweed and shellfish to regulate nutrients and plankton dynamics. *Aquaculture Reports*, 33, 101789. doi: 10.1016/j.aqrep.2023.101789
- Welton, K. R. A., Hoppit, G., Schmidt, D. N., Witts, J. D., & Moon, B. C. (2024). Reviews and syntheses: The clam before the storm – A meta-analysis showing the effect of combined climate change stressors on bivalves. *Biogeosciences*, 21(1), 223–239. doi: 10.5194/bg-21-223-2024
- Yap, C. K., & Al-Mutairi, K. A. (2023). Byssus of green-lipped mussel *Perna viridis* as a biomonitoring biopolymer for zinc pollution in coastal waters. *Biology*, 12(4), 523. doi: 10.3390/biology12040523
- Yaqin, K. (2018). Efek ukuran panjang cangkang terhadap Indeks Kondisi, dan Kandungan Logam Timbel Kerang Hijau (*Perna viridis*). *Jurnal Pengelolaan Perairan*, 1(2), 27–48.