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Growth Pattern Analysis of Whiteleg Shrimp (*Litopenaeus vannamei*) in an Intensive Aquaculture System at the Busmetik Pond, Sorong City, Southwest Papua

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Abstract

Whiteleg shrimp (*Litopenaeus vannamei*) is a major aquaculture commodity that continues to be developed through intensive culture systems. This study aims to evaluate the growth patterns and survival rates of *L. vannamei* reared in an intensive aquaculture system at the Busmetik pond of the Sorong Marine and Fisheries Polytechnic during the 2021–2024 period. Observed parameters included average daily growth (ADG), average body weight (ABW), survival rate (SR), feed management practices, and water quality indicators. Data were analyzed using ANOVA and Kruskal-Wallis tests to identify interannual differences. Results revealed a consistent increase in SR, from 78.05% in 2021 to 91.7% in 2024, along with a steady improvement in shrimp length and weight, although the differences were not statistically significant ($p > 0.05$). Factors such as feed quality, feeding frequency, water pH and dissolved oxygen (DO), as well as disease control measures, were shown to influence culture performance. These findings suggest that integrated and adaptive management practices play a critical role in enhancing the growth efficiency and survival of *L. vannamei* in intensive aquaculture systems.

Keywords: *Litopenaeus vannamei*, intensive culture, growth performance, survival rate, water quality

INTRODUCTION

The introduction should The whiteleg shrimp (*Litopenaeus vannamei*) is a major global aquaculture commodity with high economic value in both domestic and international markets. In Indonesia, this species is a central focus of aquaculture development, with national targets aiming for a 250% increase in shrimp production and export value by 2024 (Mustafa et al., 2023). The growth and productivity of *L. vannamei* are highly dependent on the availability of land with suitable water quality that is free from biological and non-biological pollutants. Increases in shrimp biomass are influenced by both environmental carrying capacity and growth performance, which often exhibit inconsistent trends across production cycles (Alauddin & Putra, 2023; Hatje et al., 2016).

To enhance production efficiency and sustainability, intensive and super-intensive culture systems have been developed. These systems apply strict biosecurity measures, including the use of lined ponds with High-Density Polyethylene (HDPE) to prevent erosion and disease transmission, along with controlled water input. Biofloc technology is also employed, utilizing heterotrophic bacteria to convert organic waste into nutritious microbial biomass. This approach has been shown to support shrimp growth, enhance immune response, and maintain water quality throughout the culture period (Li et al., 2024; McKay et al., 2023; Mirzaei et al., 2019).

Previous studies have reported that *L. vannamei* cultured under intensive systems exhibited an average daily growth (ADG) of 0.17 ± 0.01 g/day with feed conversion ratios (FCR) ranging from 1.36 to 1.55 (Syah et al., 2017). Other findings indicate that higher stocking densities, such as 170–175 shrimp/m², can yield improved growth performance and survival. A density of 170 shrimp/m² resulted in an average weight of 29.23

g/shrimp and a survival rate of 86.70%, while 175 shrimp/m^2 produced an average weight of 29.18 g/shrimp and a survival rate of 82.35% (Purnamasari et al., 2017). The primary objective of this study is to analyze the growth patterns of *L. vannamei* cultured under intensive pond systems at the Busmetik facility of the Marine and Fisheries Polytechnic of Sorong over the period of 2021 to 2024.

MATERIALS AND METHODS

Location and time of research

This study was conducted at the Busmetik shrimp pond facility of the Marine and Fisheries Polytechnic of Sorong, located in Sorong City, Southwest Papua Province, Indonesia. The pond was constructed on red clay soil and lined with 0.5 mm thick high-density polyethylene (HDPE). The pond dimensions are 50 m × 34 m, with a total surface area of 1,700 m^2 and a water volume capacity of 2,550 m^3. Data were collected from *Litopenaeus vannamei* grow-out activities conducted over four consecutive years (2021–2024). The number of post-larvae (PL) stocked each year was as follows: 130,000 (2021), 100,000 (2022), 150,000 (2023), and 150,000 (2024), with uniform initial rearing conditions across all cycles.

Observed Parameters

The study observed both technical culture parameters and environmental water quality indicators. Technical parameters included feed management practices, specific growth rate (SGR), survival rate (SR), average body weight (ABW), and total body length. Water quality variables monitored consisted of temperature, salinity, pH, dissolved oxygen (DO), nitrite (NO_2^-), nitrate (NO_3^-), and phosphate (PO_4^{3-}). Measurements were taken every 10 days from the start of the grow-out cycle up to day 80 to track shrimp growth dynamics and environmental stability throughout the production period.

Data analysis

Statistical analyses were conducted to evaluate shrimp growth performance and culture conditions during the 2021–2024 period. The Shapiro-Wilk test was used to assess the normality of data distribution, while homogeneity of variance was tested as a prerequisite for parametric analysis. For normally distributed and homogenous data, one-way analysis of variance (ANOVA) was applied to assess interannual differences. For non-parametric data, the Kruskal-Wallis test was used. Post hoc comparisons were conducted using Tukey's Honest Significant Difference (HSD) test to determine specific differences between years.

consciousness marked by a response when given stimulation, and the fish were already swimming actively. When the fish is unconscious until the fish is conscious, record the time to enter the gouramy consciousness.

RESULTS AND DISCUSSION

Results

Feed Management

Feed management in *Litopenaeus vannamei* culture at the Busmetik Pond, Marine and Fisheries Polytechnic of Sorong, was adjusted according to shrimp growth phases. During the initial stage (days 1–11), feed was administered three times daily. This frequency increased to four times daily during the intermediate phase (days 12–60), and to five times daily in the final phase (days 61–90), at scheduled times: 07.00, 11.00, 15.00, 19.00, and 23.00 WIT. Feeding was performed manually by evenly distributing feed throughout the pond to minimize competition, improve feed efficiency, and support uniform growth and overall shrimp health.

Feed consumption trends across years displayed consistent age-related increases. In 2021 and 2022, consumption rose steadily, with notable surges between days 60 and 80, peaking on day 80—higher in 2021. The year 2023 recorded the highest overall consumption, especially between days 30–60, followed by a gradual decline. In contrast, 2024 showed similar early-stage trends but lower consumption increases after day 40 and a sharper decrease post-day 70, suggesting reduced feed demand in late stages. The most rapid increases occurred between days 20 and 60 across all years (Figure 1), likely influenced by variations in feeding strategy and environmental conditions.

Table 1. The Concentration of infused

Concentration of infused (ppm)	Sample	Mortality (%) 24 h	48 h
1000	6	0	0
2500	6	0	0
5000	6	0	0
7500	6	100	100

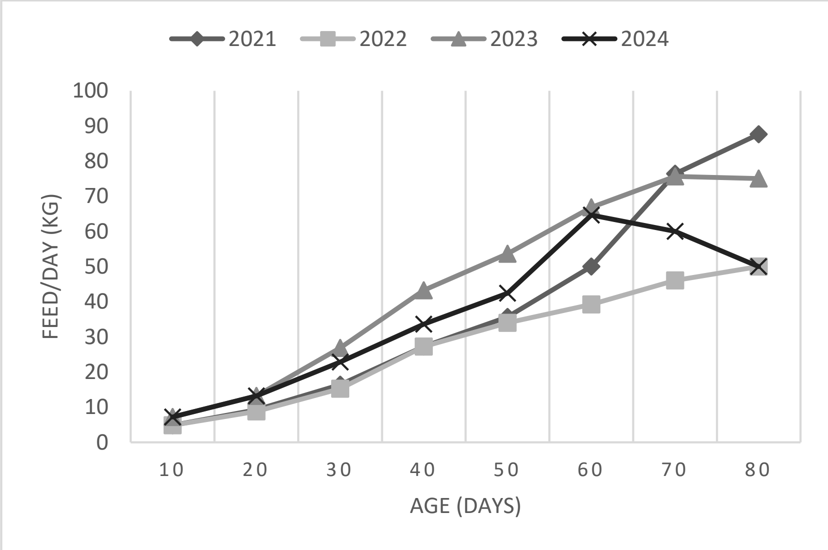

Figure 1. Daily Feed Comparison in *L. vannamei* Culture (2021–2024)

The Shapiro-Wilk normality test indicated that the daily feed amount data from 2021 to 2024 followed a normal distribution, satisfying the assumptions required for parametric analysis. Homogeneity of variances across groups was also confirmed. The one-way ANOVA results showed no significant differences in feed quantity among the years ($p = 0.591$), and the post hoc Tukey HSD test further confirmed that interannual variations in feeding were not statistically significant ($p > 0.05$).

Growth Pattern of *L. vannamei*

The growth trends of *L. vannamei* from 2021 to 2024 are illustrated in Figure 2. Panel A displays carapace length progression between days 20 and 80. Overall, carapace length increased consistently with age, showing relatively stable trends each year. The highest average length was recorded in 2024, while 2022 showed slightly lower growth, particularly during the early phase (days 20–50). A slowdown in growth between days 70–80 suggests that shrimp approached their maximum carapace length. These differences imply a gradual improvement in culture management over time.

Panel B of Figure 2 presents body weight development over the same age range. Significant weight gains were observed after day 50, peaking at day 80. Higher average weights were recorded in 2021 and 2023, especially during the later stages, compared to 2022. Although 2024 exhibited strong early-stage growth, weight gain appeared to slow between days 70–80. The relatively lower performance in 2022 may be attributed to suboptimal environmental conditions, feeding strategies, or nutritional quality.

Collectively, these findings demonstrate annual variability in growth performance, likely reflecting the effectiveness of specific management interventions. Such insights are valuable for refining and optimizing *L. vannamei* culture practices in intensive aquaculture systems.

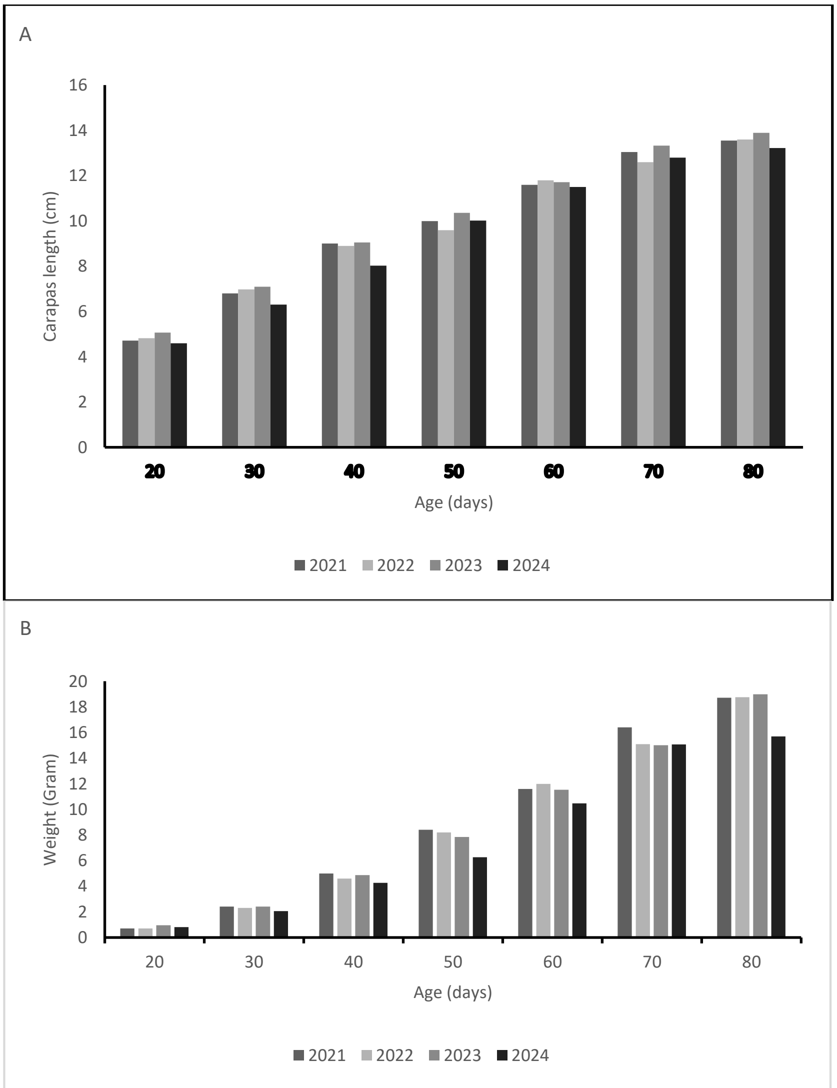

Figure 2. Average growth of *Litopenaeus vannamei* during the cultivation period. (A) Mean carapace length growth from day 20 to day 80. (B) Mean body weight growth from day 20 to day 80

Analysis of Growth Performance (ABW and ADG)

The analysis of average body weight (ABW) and average daily growth (ADG) of *L. vannamei* during the 2021–2024 period revealed interannual variations in culture performance, as shown in Table 2. The highest ABW was recorded in 2023 at 18.98 g with a corresponding ADG of 0.237 g/day, while the lowest values were observed in 2024 with an ABW of 15.69 g and ADG of 0.196 g/day. In contrast, 2021 and 2022 exhibited relatively stable outcomes, with ABW around 18.7 g and ADG of 0.234 g/day. The decline in growth observed in 2024 may be attributed to suboptimal environmental or technical factors affecting culture conditions.

Table 2. *Average body weight (ABW) and calculated average daily growth (ADG) of Litopenaeus vannamei during the cultivation period (2021–2024)*

Years	ABW (gram)	ADG (gram/day)
2021	18.72	0.234
2022	18.75	0.234
2023	18.98	0.237
2024	15.69	0.196

The Shapiro-Wilk normality test confirmed that the data on shrimp body weight and length from 2021 to 2024 followed a normal distribution, satisfying the assumptions for parametric testing. The homogeneity of variance test also indicated that the data met the assumption of homoscedasticity. One-way ANOVA revealed no statistically significant differences in shrimp length across the years (p-value = 0.990; F = 0.038). This result was further supported by Tukey's HSD post hoc test, which showed no significant pairwise differences ($p > 0.05$), indicating that the mean length and body weight of *L. vannamei* remained consistent across production cycles.

Water Quality Conditions

The intensive culture of *L. vannamei* is known to require specific water quality parameters to support optimal growth and survival. Reported standards include pH levels between 7.134–7.32 salinity ranging from 22–34 ppt, temperature between 26–33°C, dissolved oxygen (DO) levels of 3–6.2 mg/L, nitrite concentrations between 0–0.5 mg/L, nitrate concentration ranging from 0–0.12 mg/L, and phospat level between 0.1-0.375 mg/L (Table 3).

Table 3. *Water quality parameters during the cultivation period*

Parameters	Years			
	2021	2022	2023	2024
Temperature °C	26-32	28-32	28-33	27-33
Salinity (ppt)	22-32	24-34	23-35	23-34
pH	7.134	7.268	7.32	7.249
DO (ppm)	4,375	4,875	4,125	4
nitrite (ppm)	0	0	0.5	0.5
nitrate (ppm)	0	0	0.5	1
Phospat (ppm)	0.1	0.256	0.375	0.119

Water Quality Dynamics and Its Implications on Shrimp Growth

Water temperature within the range of 26–33°C plays a critical role in regulating the metabolic processes of aquatic organisms. This range supports optimal enzymatic activity, influencing shrimp growth, movement, and reproduction. Temperatures below the optimal range may suppress metabolism, while those above may accelerate metabolic rates but increase thermal stress, reduce dissolved oxygen (DO), and disrupt ecological balance. Temperature data from 2021–2024 showed relatively stable trends, with slight increases observed in 2023 and 2024. Although elevated temperatures may promote growth, levels exceeding 32°C may adversely affect shrimp health, underscoring the importance of continuous temperature monitoring to maintain ecological stability and optimize productivity.

Water transparency, measured using a Secchi disk, ranged between 45–65 cm at pond depths of 1.5 meters. Ideal turbidity for shrimp culture is between 30–40% of total water depth (approximately 45–60 cm), facilitating photosynthesis for plankton growth, which provides both oxygen and natural feed. Excessive turbidity or clarity may signal poor water quality due to suspended solids or insufficient plankton density. Statistical analysis using the Kruskal-Wallis test indicated no significant difference in temperature between years ($H = 2.518$, $df = 3$, $p = 0.472$), suggesting relative thermal stability across production cycles.

Salinity ranged from 22–35 ppt, with minor interannual fluctuations. Although changes in salinity did not significantly affect shrimp survival or body mass, they may influence disease resistance and growth uniformity. Salinity trends peaked in 2023 but remained within acceptable ranges. The Kruskal-Wallis test showed no significant difference in salinity across years ($H = 1.238$, $df = 3$, $p = 0.744$), reflecting stable osmotic conditions.

The pH of pond water remained within the optimal range (7.1–7.3) across all years, conducive to shrimp health and enzymatic function. However, ANOVA results indicated a significant difference in pH values across years ($p = 0.016$), suggesting sensitivity to environmental variation. Along with pH, DO showed annual variability, with the highest levels recorded in 2022 and a decline to 4.0 mg/L in 2024. Low DO concentrations can cause physiological stress in shrimp. DO also exhibited a statistically significant difference between years ($p = 0.024$), reflecting environmental impacts on oxygen availability.

Nitrite and nitrate levels remained within the safe range (0–1 ppm), indicating effective waste management. However, phosphate levels showed fluctuating trends, with a peak in 2023 possibly due to nutrient runoff, which poses a eutrophication risk. Statistical tests revealed no significant differences in nitrite ($p = 0.462$) or phosphate ($p = 0.238$) levels, indicating relative consistency in these parameters.

In intensive shrimp aquaculture, external factors such as water quality (including pH, salinity, temperature), nutrition, and stocking density directly influence growth rates. Suboptimal conditions may impair growth or elevate disease risk. Therefore, integrated and intensive monitoring of both shrimp condition and environmental parameters is essential. Effective aquaculture management encompassing water quality regulation, optimized feeding strategies, and disease prevention—is key to ensuring maximum growth potential and sustainable production outcomes.

Pests, Diseases, and Survival Performance of *Litopenaeus vannamei*

During the cultivation period at the Busmetik shrimp pond of the Sorong Polytechnic of Marine and Fisheries, several competitor pests were identified, such as sea hares and small fish. Among pathogenic threats, *Vibrio* spp. were the most frequently encountered bacteria in the shrimp culture environment. These opportunistic pathogens are known to cause significant mortality in *Litopenaeus vannamei*, particularly under suboptimal environmental conditions. Therefore, implementing a comprehensive risk management approach is essential to maintaining system stability and survival in shrimp farming. The observed increase in survival rate (SR) from 2021 to 2024 reflects improvements in pond management practices, including enhanced water quality control, optimized feeding strategies, and external hazard mitigation. These findings underscore the significance of adopting technological innovations and integrated management strategies to maximize survival, thereby contributing to the overall success and sustainability of shrimp production.

Harvest and Survival Rate (SR)

Survival rate (SR) is a key performance indicator in shrimp aquaculture, directly reflecting the effectiveness of cultivation practices. The results of this study showed a consistent upward trend in SR over the 2021–2024 period, with values of 78.05%, 84.2%, 89%, and 91.7%, respectively. This progression indicates substantial improvements in production efficiency, environmental control, feeding practices, and disease prevention protocols. The peak SR recorded in 2024 demonstrates the successful implementation of adaptive and optimized cultivation techniques. Despite the observed increase in SR, Kruskal-Wallis analysis of FCR, ADG, SR, and ABW from 2021 to 2024 yielded a non-significant result ($p = 0.392$), indicating no statistically significant differences in performance among years. This suggests relative stability in the culture system, though further multivariate analyses may be necessary to identify additional variables that could influence shrimp growth and survival more specifically.

Discussion

Feed is the dominant component of production costs in intensive shrimp farming, accounting for approximately 70% of total expenditure. The type and pellet size were adjusted to shrimp developmental stages and mouth size to optimize consumption efficiency. The formulated feed contained 32% protein, 6% lipid, 3.5% fiber, 13% ash, and 11% moisture, which falls within the optimal nutritional range for *L. vannamei* in intensive systems (Strebel et al., 2023). Prior to application, feed underwent fermentation to improve nutrient absorption, enhance protein digestibility, and facilitate the breakdown of fiber, while also suppressing *Vibrio* populations and promoting biofloc formation (Mathan Muthu et al., 2024). The addition of probiotic bacteria such as *Lactobacillus* spp. has also been shown to enhance nutrient uptake and growth performance (Syadillah et al., 2020; Wahyudi et al., 2022). Improper feed management can degrade water quality, negatively impacting survival, growth, and biomass yield (Budiardi et al., 2004). Conversely, appropriate probiotic supplementation has been reported to improve average daily growth (ADG), feed conversion ratio (FCR), and survival rate (SR) (Li *et al*., 2024). Inadequate nutrition may also directly or indirectly trigger disease outbreaks, mass mortality, and production losses (Rosyida, 2019). As reported, optimizing feed efficiency simplifies control, thereby reducing operational costs in *Litopenaeus vannamei* farming (Putra et al., 2023).

Previous studies have reported that, under intensive systems, *L. vannamei* reached an ABW of 21.98 g at day 105 (DOC 105), with ADG ranging from 0.14 to 0.35 g/day and survival rates (SR) averaging 88.41% (Yunarty et al., 2022). High stocking density has been identified as a limiting factor that negatively affects shrimp growth performance (Yuan et al., 2023), and can also reduce final harvest size and body weight (Tinh et al., 2023). In the context of precision aquaculture and Industry 4.0, modeling growth performance has become essential for estimating harvest size, waste output, and feed/nutrient requirements, thereby enhancing data-driven decision-making in aquaculture production systems (Zarzar et al., 2023)

Previous findings suggest that the concentrations of nitrogenous waste compounds, particularly nitrite (NO_2^-) and ammonia (NH_3), tend to increase with shrimp age due to the accumulation of organic matter during the production cycle (Wulandari et al., 2015). The water quality parameters in this study, including pH, temperature, salinity, dissolved oxygen (DO), and nitrogenous compounds, align with the optimal ranges recommended for shrimp culture (Linayati et al., 2023).

The presence of organic waste and nutrient loading can affect microbial activity and influence the abundance of opportunistic pathogens such as *Vibrio* spp. Studies have shown that *Vibrio* populations in shrimp ponds tend to fluctuate dynamically in response to metabolic activity and environmental conditions. Over extended culture periods, these bacteria may become more virulent and pose a greater risk of infection (Ariadi & Mujtahidah, 2022). The abundance of *Vibrio* spp. tends to fluctuate dynamically, following the metabolic activity of the bacterial population and surrounding environmental factors, which may increase infection rates over extended cultivation periods (Syah et al., 2017). Common viral diseases affecting *L. vannamei* and *Penaeus monodon* include White Spot Syndrome Virus (WSSV) and Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV) (Supriatna et al., 2014). However, no disease outbreaks were observed during the grow-out phase in this study, suggesting that health management strategies were effective. Despite *L. vannamei*'s inherent resilience to disease, unfavorable environmental conditions can still lead to significant mortality. In shrimp aquaculture, health challenges arise from both infectious and non-infectious causes, highlighting the importance of integrated disease management. Disease control is a critical component of intensive aquaculture systems. Pathogens, including bacteria, viruses, and parasites, can drastically reduce shrimp survival rates if not properly managed. Previous studies have demonstrated that shrimp health can be improved through vaccination programs and the administration of probiotics, which enhance immune responses and support better survival outcomes (Azhdari et al., 2023; Gadhiya et al., 2025). Additionally, the use of plant-based extracts, such as those derived from medicinal leaves, has been shown to improve disease resistance in shrimp (Manguntungi et al., 2016).

Survival in shrimp culture is influenced by a complex interplay of environmental factors, including water quality, stocking density, and overall shrimp health. Proper water quality management is key to improving the survival rate (SR) (Ariadi et al., 2019). In addition, optimal nutrition plays a critical role, as feed that meets the metabolic requirements of shrimp supports healthy growth and enhances disease resistance (Tacon et al., 2022). For instance, a study conducted at PT Indokor revealed that effective water quality management in intensive systems significantly enhanced shrimp growth rates, water parameters, and SR in *L. vannamei* cultivation (Fuady et al., 2013).

Conclusion

The growth pattern of *Litopenaeus vannamei* under intensive aquaculture systems demonstrated stable performance and adaptive responses to environmental and feeding management. These findings affirm that integrated culture management significantly contributes to production efficiency and overall success. To enhance sustainable aquaculture practices, the development of real-time water quality monitoring technologies and growth-phase-based feeding optimization is highly recommended.

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References

Alauddin, M. H. R., & Putra, A. (2023). Kajian Daya Dukung Lingkungan Dalam Budidaya Udang Vaname. *Jurnal Kelautan Dan Perikanan Terapan (JKPT)*, *1*, 103. https://doi.org/10.15578/jkpt.v1i0.12214

Ariadi, H., Fadjar, M., Mahmudi, M., & Supriatna. (2019). The relationships between water quality parameters and the growth rate of white shrimp (Litopenaeus vannamei) in intensive ponds. *AACL Bioflux*, *12*(6), 2103–2116. http://www.bioflux.com.ro/aacl

Ariadi, H., & Mujtahidah, T. (2022). Analisis Pemodelan Dinamis Kelimpahan Bakteri Vibrio sp. pada Budidaya Udang Vaname, Litopenaeus vannamei. *Jurnal Riset Akuakultur*, *16*(4), 255. https://doi.org/10.15578/jra.16.4.2021.255-262

Azhdari, S. M. H., Kazemzadeh Pournaki, S., Tavabe, K. R., Hosseni, S. V., Bagheri, D., Javanmardi, S., Azhdari, A., & Frinsko, M. (2023). Effects of Bacillus subtilis and Lactobacillus plantarum probiotics on the Litopenaeus vannamei growth performance, hemolymph factors, and physicochemical parameters. *Aquaculture Reports*, *33*(November), 101873. https://doi.org/10.1016/j.aqrep.2023.101873

Budiardi, T., Muluk, C., Widigdo, B., Praptokardiyo, K., & Soedharma, D. (2004). Tinkat Pemanfaatan pakan dan Kelayakan Kualitas Air serta Estimasi Pertumbuhan dan Produksi (Litopenaeus vannamei , Boone 1931) pada Sistem Intensif. *Ilmu-Ilmu Perairan Dan Perikanan Indonesia*, *15*(2), 109–116.

Gadhiya, A., Katariya, S., Khapandi, K., & Chhatrodiya, D. (2025). Probiotics as a sustainable alternative to antibiotics in aquaculture: a review of the current state of knowledge. *Microbe (Netherlands)*, *8*(June). https://doi.org/10.1016/j.microb.2025.100426

Hatje, V., de Souza, M. M., Ribeiro, L. F., Eça, G. F., & Barros, F. (2016). Detection of environmental impacts of shrimp farming through multiple lines of evidence. *Environmental Pollution*, *219*, 672–684. https://doi.org/10.1016/j.envpol.2016.06.056

Li, Z., Ju, C., Jiao, T., Liu, H., & Li, Q. (2024). Effects of biofloc on growth performance and survival of Pacific white shrimp (Litopenaeus vannamei) through C/N ratio manipulation, probiotic supplementation, and cocultivation time: A meta-analysis. *Aquaculture*, *587*(20).

https://doi.org/10.1016/j.aquaculture.2024.740837

Linayati, L.-, Nugroho, L. B., Mardiana, T. Y., Soeprapto, H., & Yahya, M. Z. (2023). The Effect of Avicennia marina Leaf Extract Addition To the Artificial Feed On the Growth of Litopenaeus vannamei. *Sains Akuakultur Tropis : Indonesian Journal of Tropical Aquaculture*, *7*(1), 88–94. https://doi.org/10.14710/sat.v7i1.16447

Manguntungi, B., Budhi Kusuma, A., & Yunianti, D. (2016). *Pengaruh Kombinasi Ekstrak Kirinyuh (Chromolaena odorata) dan Sirih (Piper betle L) dalam Pengendalian Penyakit Vibriosis pada Udang The Influence of Kirinyuh (Chromolaena odorata) and Betel (Piper betle L) Leaf Extract Combination in Controlling Vibriosi*. *1*(3), 138–144. https://doi.org/10.24002/biota.v1i3.1231

Mathan Muthu, C. M., Vickram, A. S., Bhavani Sowndharya, B., Saravanan, A., Kamalesh, R., & Dinakarkumar, Y. (2024). A comprehensive review on the utilization of probiotics in aquaculture towards sustainable shrimp farming. *Fish and Shellfish Immunology*, *147*(February), 109459. https://doi.org/10.1016/j.fsi.2024.109459

McKay, H., McAuliffe, W., & Waldhorn, D. R. (2023). *Welfare considerations for farmed shrimp*. *December*, 1–72. https://doi.org/10.17605/OSF.IO/YAFQV

Mirzaei, F. S., Ghorbani, R., Hosseini, S. A., Haghighi, F. P., & Saravi, H. N. (2019). Associations between shrimp farming and nitrogen dynamic: A model in the Caspian Sea. *Aquaculture*. https://doi.org/10.1016/j.aquaculture.2019.05.070

Mustafa, A., Syah, R., Paena, M., Sugama, K., Kontara, E. K., Muliawan, I., Suwoyo, H. S., Asaad, A. I. J., Asaf, R., Ratnawati, E., Athirah, A., Makmur, Suwardi, & Taukhid, I. (2023). Strategy for Developing Whiteleg Shrimp (Litopenaeus vannamei) Culture Using Intensive/Super-Intensive Technology in Indonesia. *Sustainability (Switzerland)*, *15*(3). https://doi.org/10.3390/su15031753

Purnamasari, I., Purnama, D., & Utami, M. A. F. (2017). Pertumbuhan Udang Vaname (Litopenaeus vannamei) di Tambak Intensif. *Jurnal Enggano*, *2*(1), 58–67. https://ejournal.unib.ac.id/jurnalenggano/article/view/1359/1134

Putra, A., Ilham, Rukmono, D., Aini, S., Larasati, R. F., Suriadin, H., & Aulia, D. (2023). Increasing Productivity of Intensive Vaname Shrimp Farming Through Kaizen Approach. *Jurnal Sains Akuakultur Tropis*, *7*, 153–174. https://doi.org/https://doi.org/10.14710/sat.v7i2.17044

Rosyida, E. (2019). Kebutuhan Protein/Asam Amino dan Karbohidrat Bagi Udang-Udang Penaeid: Suatu Studi Literatur. *Biota : Jurnal Ilmiah Ilmu-Ilmu Hayati*, *12*(1), 17–22. https://doi.org/10.24002/biota.v12i1.2531

Strebel, L. M., Nguyen, K., Araujo, A., Corby, T., Rhodes, M., Beck, B. H., Roy, L. A., & Davis, D. A. (2023). On demand feeding and the response of Pacific white shrimp (Litopenaeus vannamei) to varying dietary protein levels in semi-intensive pond production. *Aquaculture*, *574*(May), 739698. https://doi.org/10.1016/j.aquaculture.2023.739698

Supriatna, I., Yustiati, A., & Iskandar. (2014). Sekuen Asam Amino Anti White Spot Syndrome Virus (WSSV) pada Udang Windu (Penaeus monodon). *Bionatura*, *16*(1), 40–46. https://www.neliti.com/publications/218045/sekuen-asam-amino-anti-white-spot-syndrome-virus-wssv-pada-udang-windu-penaeus-m

Syadillah, A., Hilyana, S., & Marzuki, M. (2020). Pengaruh Penambahan Bakteri (Lactobacillus sp.) dengan Konsentrasi Berbeda terhadap Pertumbuhan Udang Vannamei (Litopenaeus vannamei). *Jurnal Perikanan Unram*, *10*(1), 8–19. https://doi.org/10.29303/jp.v10i1.146

Syah, R., Makmur, M., & Fahrur, M. (2017). Cultivation of vaname shrimp with high distribution intensity. *Media Akuakultur*, *12*(1), 19–26. http://ejournal-balitbang.kkp.go.id/index.php/ma

Tacon, A. G. J., Metian, M., & McNevin, A. A. (2022). Future Feeds: Suggested Guidelines for Sustainable Development. *Reviews in Fisheries Science and Aquaculture*, *30*(2), 135–142. https://doi.org/10.1080/23308249.2020.1860474

Tinh, T. H., Kokou, F., Hai, T. N., Verreth, J. A. J., & Verdegem, M. C. J. (2023). Effects of feed, carbohydrate addition and stocking density on Pacific white shrimp (Litopenaeus vannamei) production. *Aquacultural Engineering*, *101*(September 2022), 102325. https://doi.org/10.1016/j.aquaeng.2023.102325

Wahyudi, P. D., Marantika, A. K., & Yudasmara, G. A. (2022). Efek Pemberian Pakan Fermentasi Dan Campuran Probiotik Terhadap Pertumbuhan Dan Kelulushidupan Udang Vaname (Litopenaeus vannamei). *Pena Akuatika : Jurnal Ilmiah Perikanan Dan Kelautan*, *21*(2), 61. https://doi.org/10.31941/penaakuatika.v21i2.2191

Wulandari, T., Widyorini, N., & P, P. W. (2015). Hubungan Pengelolaan Kualitas Air dengan Kandungan Bahan Organik, NO2 dan NH3 pada Budidaya Udang Vannamei (Litopenaeus vannamei) di Desa Keburuhan Purworejo. *DIPONEGORO JOURNAL OF MAQUARES MANAGEMENT OF AQUATIC RESOURCES*, *4*(2), 42–48. http://ejournal-s1.undip.ac.id/index.php/maquares

Yuan, H., Xie, M., Hu, N., Zheng, Y., Hou, C., Tan, B., Shi, L., & Zhang, S. (2023). Growth, immunity and transcriptome response to different stocking densities in Litopenaeus vannamei. *Fish and Shellfish Immunology*, *139*(May), 108924. https://doi.org/10.1016/j.fsi.2023.108924

Yunarty, Y., Kurniaji, A., Budiyati, B., Renitasari, D. P., & Resa, M. (2022). Karakteristik Kualitas Air dan Performa Pertumbuhan Budidaya Udang Vaname (Litopenaeus vannamei) secara Intensif. *Pena Akuatika : Jurnal Ilmiah Perikanan Dan Kelautan*, *21*(1), 71. https://doi.org/10.31941/penaakuatika.v21i1.1871

Zarzar, C. A., Fernandes, T. J., & Cardoso de Oliveira, I. R. (2023). Modeling the growth of Pacific white shrimp (Litopenaeus vannamei) using the new Bayesian hierarchical approach based on correcting bias caused by incomplete or limited data. *Ecological Informatics*, *77*(August). https://doi.org/10.1016/j.ecoinf.2023.102271