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Water Quality Analysis and Relationship with Growth Performance of *L. vannamei* Ponds in Jepara, Central Java

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Abstract

This study aims to analyze water quality dynamics and their correlation with the growth performance of *L. vannamei* (*Litopenaeus vannamei*) in an intensive aquaculture system in Jepara, Central Java. The research method used an observational survey approach in 10 grow-out ponds with a stocking density of 150 individuals/m². Water quality monitoring was conducted in situ twice a day (morning and afternoon), while growth sampling was conducted every 7 days from DOC 7 to DOC 49. Data were analyzed descriptively to evaluate the relationship between environmental fluctuations and growth indicators. The results showed that the temperature (27–29°C) and pH (7.9–8.57) were within the optimal range according to PERMEN-KP No. 75/2016. However, in the final phase of cultivation (DOC 35–49), critical conditions occurred due to a decrease in dissolved oxygen (DO) to ≤ 3 mg/L and an increase in salinity that exceeded the optimal tolerance limit, reaching 38–41 ppt. Although the Average Body Weight (ABW) increased consistently to 9.59 g/individual, the Average Daily Growth (ADG) slowed significantly from 0.49 g/day to 0.40 g/day at the end of the observation period. This was accompanied by an increase in the Standard Deviation (SD) of weight to 1.35, indicating size inconsistency due to physiological stress. These findings confirm that low DO and high salinity are the main limiting factors that suppress growth efficiency in the final phase. It is recommended to strengthen the aeration system and add fresh water periodically to stabilize osmoregulation and support the sustainability of *L. vannamei* production in the region.

1. Introduction

Litopenaeus vannamei is currently the most dominant aquaculture commodity globally and nationally (Iskandar *et al.*, 2022). This popularity is driven by growing domestic and international market demand, making shrimp a major foreign exchange earner for the country. *L. vannamei* production dominates globally, with more than 80% of production coming from Asia, with Latin America as another major supplier, indicating a significant role in international trade (Easyfish, 2025).

Indonesia, as one of the major producers, recorded a total national shrimp production of around 1.09 million tons in 2023 (Ambarwati, 2023). Indonesia's shrimp export achievements are also significant, with a value of USD 1.68 billion in 2024, but Indonesia still ranks fifth among the world's largest shrimp exporters (KKP, 2025). This condition requires an increase in the efficiency and productivity of aquaculture so that Indonesia can compete with other major producing countries such as Ecuador, Vietnam, Thailand, and India (Nurtamela, 2025). The advantages of *L. vannamei* lie in their relatively fast growth rate, high tolerance to salinity fluctuations, and low feed conversion ratio, making them an ideal choice for modern farming systems. The ability of *L. vannamei* to tolerate a wide range of salinity levels is a major concern for the global shrimp farming industry (Halim *et al.*, 2025).

In order to meet the national production target of 2 million tons and increase competitiveness, *L. vannamei* farming in Indonesia is increasingly adopting intensive farming practices. The Ministry of Maritime Affairs and Fisheries is targeting an increase in shrimp production to 2 million tons to improve productivity, the exchange rate for fish farmers, and to develop modern integrated shrimp farming areas (Public Relations of the Directorate General of Aquaculture, 2021; Public Relations of the Directorate General of Aquaculture, 2022). The intensive system is characterized by very high stocking densities, which can affect growth performance (Manduca *et al.,* 2021). These stocking densities can reach hundreds of shrimp per square meter, aiming to maximize harvest per unit of land. According to the DPMPTSP of Jepara Regency, the northern coastal region of Central Java, particularly Jepara Regency, is one of the potential areas that consistently implements intensive *L. vannamei* farming. Although the intensive system offers high productivity, the key to the absolute success of high-density *L. vannamei* farming is optimal management of the aquatic environment, known as water quality. Water quality is crucial in supporting the success of aquaculture because shrimp are highly sensitive to their environment (Supono *et al.,* 2023).

According to Manullang *et al.* (2023), failure in managing intensive shrimp ponds is often caused by a drastic decline in water quality, mainly due to the accumulation of metabolic waste. In intensive aquaculture environments, feed residues and shrimp excrement can trigger an increase in toxic compounds such as ammonia and nitrite, which can cause physiological stress in shrimp. Suboptimal water quality can trigger physiological responses in the form of stress and disruption of metabolic function and the immune system in shrimp (Putra *et al.,* 2025). Stress conditions due to poor water quality can have an impact on decreased appetite and inhibit the growth, health, and immunity of shrimp (Hapsari *et al.,* 2025). Water quality parameters such as temperature, pH, DO, and salinity play an important role in determining shrimp growth performance. Fluctuations in water quality can affect shrimp metabolism and health, so water quality needs to be measured along with growth indicators (ABW, ADG) and survival rate (SR) (Apresia *et al.,* 2024).

Although the relationship between water quality and *L. vannamei* growth has been extensively studied, most previous studies have assessed each parameter separately, resulting in relatively limited information on the patterns of water quality fluctuations over time in intensive aquaculture systems. In addition, specific location data representing the conditions of intensive ponds in the northern coastal region of Central Java, particularly in Jepara Regency, is still limited.

In this context, regular water quality monitoring at weekly intervals is important to describe the dynamics of water fluctuations and the direct response of shrimp growth. Therefore, an in-depth understanding of the dynamics of water quality parameters and their specific correlation with the growth performance of *L. vannamei* in the context of intensive aquaculture is needed. Based on these issues, this study aims to analyze the water quality of *L. vannamei* ponds in Jepara, Central Java, and examine its correlation with the growth performance of intensively cultivated *L. vannamei* (*Litopenaeus vannamei*), based on the parameters of light intensity, temperature, pH, dissolved oxygen (DO), salinity, and clarity.

2. Material and methods

2.1 Tools and Materials

The facilities and infrastructure used were ponds ranging in size from 100 to 1000 m², transfer ponds, paddle wheels, blowers, water quality measuring devices, digital scales, and nets. The base of the reservoir ponds was made of soil, lined with HDPE tarpaulin, and equipped with aeration. The water quality measuring equipment consisted of a Lux meter, pH meter, Baruno JALA (temperature and DO meter), refractometer, and Secchi disk.

The shrimp postlarvae (PL 6–8) were sourced from Raja Benur. A total of 586,500 individuals were stocked at a density of 150 individuals/m². Before stocking, the postlarvae were acclimatized for 15-20 minutes until condensation appeared inside the plastic bags. In the water preparation and shrimp maintenance activities, the grow-out ponds were equipped with water wheels, which were used as circulation and oxygen supply devices in the pond water. All ponds were managed using an intensive cultivation system, with uniform stocking density, and applying uniform maintenance and feed management procedures.

2.2 Research Procedure

This study was conducted from July to September 2025, at the Telukawur *L. vannamei* farm, Tahunan District, Jepara Regency, Central Java. The stages included site surveys, field data collection, sample testing, data processing, and analysis of data obtained from 10 *L. vannamei* grow-out ponds, consisting of ponds lined with HDPE tarpaulin and concrete ponds without HDPE tarpaulin lining.

This study used a survey method with an observational approach, in which each pond was treated as an independent experimental unit to evaluate water quality dynamics and shrimp growth performance. This is in line with the research by Supriatin *et al.* (2024), where a survey method with simple random sampling technique was applied to evaluate the impact of pond type and water quality dynamics on *L. vannamei* growth performance. Data from HDPE and non-HDPE lined ponds were analyzed simultaneously because the focus of this study was the relationship between water quality fluctuations and shrimp growth response. Water quality measurements were conducted daily in situ twice a day, at 6:30 a.m. and 1:30 p.m., covering light intensity, temperature, dissolved oxygen (DO), pH, salinity, and turbidity. Shrimp growth observations were conducted periodically every 7 days, starting on the 7th Day of Culture (DOC) until the 49th DOC. At each observation time, the number of samples was adjusted according to the age of the shrimp. At DOC 7-14, approximately 15 shrimp per pond were taken; at DOC 21-28, 10 shrimp per pond were taken; while at DOC 35-49, partial biomass weighing was performed. Sampling was conducted randomly and applied consistently across all ponds.

2.3 Data Collection

Growth and water quality data were obtained from field and laboratory measurements. Water quality is measured based on light intensity, temperature, DO, pH, salinity, and clarity. Samples are measured in situ at the pond location, using measuring instruments such as a Lux meter, pH meter, Baruno JALA (temperature and DO meter), Refractometer, and Secchi disk. The measurement procedure in the morning and afternoon follows the standardization of daily water quality monitoring to observe fluctuations in environmental parameters in concrete and HDPE ponds (Suprihatin *et al.,* 2024).

Shrimp growth is measured by taking samples using sample bottles, then stored in a coolbox, taken to the laboratory to be weighed using an analytical balance. The growth performance measured includes Average Body Weight (ABW), which is the average weight per shrimp individual (grams), and Average Daily Growth (ADG), which is the weight gain over a certain period of time (grams) (Suprihatin *et al.,* 2024). This is reinforced by Pramudia *et al.*

(2022), who state that shrimp growth parameters can be measured using the following formulas: ABW = Total weight / Total population and ADG = (Final ABW - Initial ABW)/day. Sampling was conducted quickly (<30 minutes/pond) with constant aeration to minimize stress on the shrimp. Meanwhile, non-sampled shrimp were slowly returned to the water to avoid mortality.

2.4 Data Analysis

The data obtained were analyzed descriptively based on growth parameters and water quality. They were then compared with the literature to support the research results.

3. Results

3.1.1 Light Intensity

Light intensity measures the strength of light received by the pond water surface to assess plankton photosynthesis support and *L. vannamei* activity. Light intensity measurements were taken twice a day, at 6:30 a.m. and 1:30 p.m., using a lux meter. The light intensity values for *L. vannamei* cultivation are shown in Figure 1.

Based on the graph above, the light intensity (lux) data in the 10 ponds varied from moderate to quite high, with values ranging from 43,785 to 59,724 lux on DOC 7 to 49. This range of values is optimal for shrimp growth. Ponds 2A and 2B consistently obtained the highest values, while ponds 3B and 1C had the lowest lux values on several observation days.

3.1.2 Temperature

Temperature directly affects shrimp growth because it influences shrimp feeding metabolism and affects the solubility of gases, including O^2, and other chemical reactions. Temperature measurements are taken twice a day, at 6:30 a.m. and 1:30 p.m., using a Baruno JALA (temperature) device. The temperature values for *L. vannamei* farming are shown in Figure 2.

Based on the graph above, the water temperature is relatively stable with small variations, predominantly in the range of 27 to 29°C in most ponds, with ponds 1C and 1D showing slightly lower temperatures of around 26.9 to 27.5°C. Temperatures within the range of 27–32°C are very conducive to optimal metabolic activity and growth for *L. vannamei*, avoiding stress conditions due to extreme temperatures.

3.1.3 pH

pH or acidity affects the survival of shrimp, such as appetite and stress levels. pH measurements are taken twice a day, at 6:30 a.m. and 1:30 p.m., using a pH meter. The pH values for *L. vannamei* farming are shown in Figure 3.

Based on the graph above, the pH parameter in all ponds showed a high level of stability with a range of 7.9 to 8.57 from DOC 7 to 49. Ponds 2C and 3B recorded the highest pH increase, approaching a value of 8.5 at the end of the period. This pH stability is very important for maintaining the chemical balance of the water and preventing stress on the cultivated organisms.

3.1.4 DO

DO is a major factor in the survival of shrimp by meeting dissolved oxygen requirements through blowers connected to pipes and aeration hoses. DO measurements are taken twice a day, at 6:30 a.m. and 1:30 p.m., using a Baruno JALA (DO meter) device. The DO values for *L. vannamei* farming are shown in Figure 4.

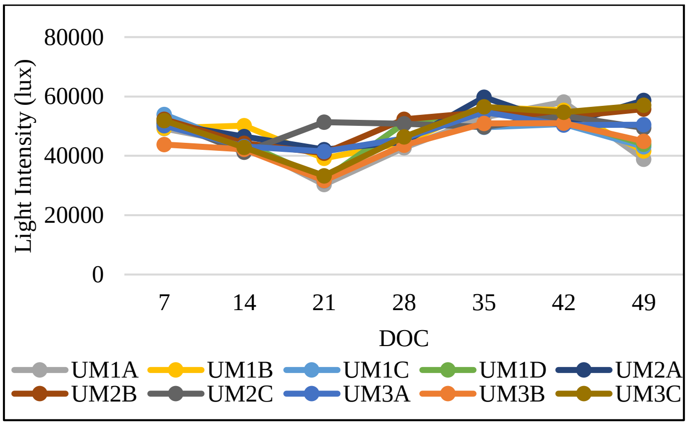

Figure 1. Light intensity in the morning (06:30) and afternoon (13:30)

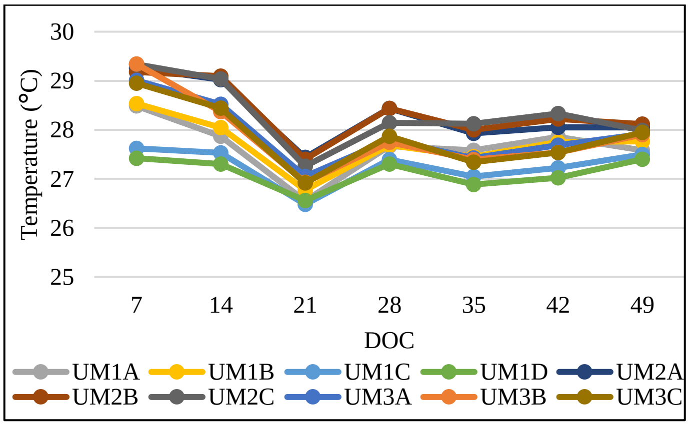

Figure 2. Temperature in the morning (06:30) and afternoon (13:30)

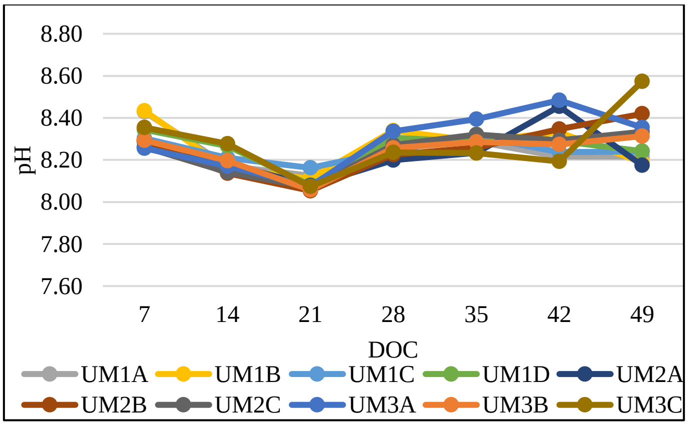

Figure 3. pH in the morning (06:30) and afternoon (13:30)

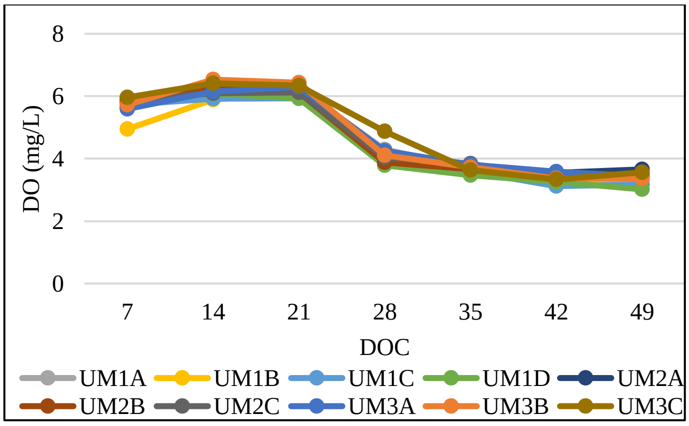

Figure 4. DO in the morning (06:30) and afternoon (13:30)

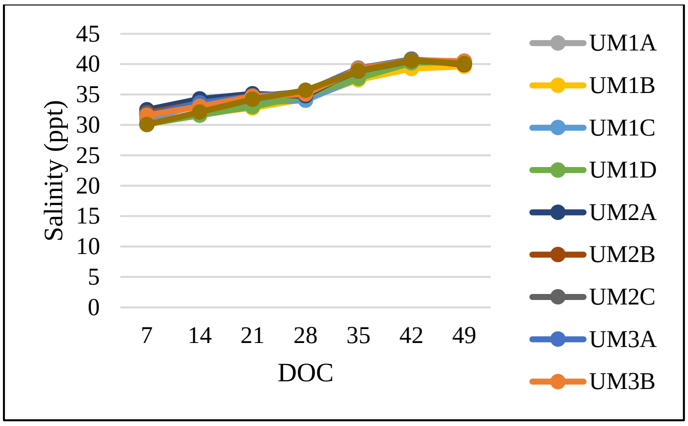

Figure 5. Salinity in the morning (06:30) and afternoon (13:30)

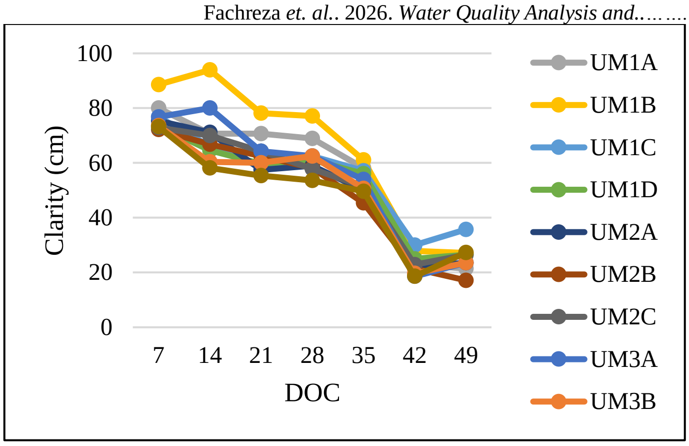

Figure 6. Clarity in the morning (06:30) and afternoon (13:30)

Based on the graph above, DO values on DOC 7 to 21 were stable in the range of 6–7 mg/L, but from DOC 28 onwards, they began to decline sharply, reaching 3–4 mg/L on DOC 35 to 49. Ponds 2B and 3C were able to maintain relatively higher DO levels (3.5–3.7 mg/L), while ponds 1A, 1C, and 2D experienced the sharpest decline to around 3.0 mg/l below the ideal value of >4 mg/L.

3.1.5 Salinity

Salinity is the total concentration of dissolved ions in water, expressed in ppt (parts per thousand). Salinity measurements are taken twice a day, at 6:30 a.m. and 1:30 p.m., using a refractometer. The salinity values for *L. vannamei* farming are shown in Figure 5.

Based on the graph above, water salinity varied from 30 to 35 ppt at the beginning of the observation on DOC 7, and gradually increased to between 38 and 41 ppt on DOC 35 to 49, with ponds 2A, 2B, and 3A showing the highest values gradually. The salinity found exceeded the tolerance limit of *L. vannamei*, which is 25–31 ppt, supporting optimal growth.

3.1.6 Water Clarity

Water clarity refers to the depth of sunlight penetration into the water pond. Clarity measurements are taken twice a day, at 6:30 AM and 1:30 PM, using a Secchi disk. The clarity values for *L. vannamei* farming are shown in Figure 6.

Based on the graph above, clarity shows significant variation, ranging from 58 to 94 cm on DOC 7, and decreasing dramatically to a range of 17 to 35 cm on DOC 49. Pond 2A maintained relatively better clarity at around 27–28 cm, while ponds 2C, 3B, and 3C experienced the sharpest decline in clarity to below 20 cm at the end of the period. Clarity values ranging from 27 to 94 cm in aquaculture ponds indicate critical conditions for shrimp growth.

Tabel 1. Growth Performance of *L. vannamei*

Day	ABW 10 ponds (g/individual)	ADG 10 ponds (g/day)
7	0.13	0.12 ± 0.02
14	0.74	0.08 ± 0.14
21	1.50	0.23 ± 0.22
28	2.66	0.41 ± 0.57
35	4.72	0.24 ± 0.98
42	7.16	0.49 ± 0.98
49	9.59	0.40 ± 1.35

3.2 Growth Conditions of *L. vannamei*

Growth observations were measured by sampling shrimp. Growth observations of *L. vannamei* (*Litopenaeus vannamei*) were conducted by sampling shrimp from ponds to determine the Average Body Weight (ABW), Average Daily Growth (ADG), and Standard Deviation (SD). The following data on shrimp growth in the observation ponds is presented in Table 1.

Performance measurements of *L. vannamei* growth were conducted periodically from DOC 7 to 49, showing a consistent and significant increase in Average Body Weight (ABW). The ABW of shrimp increased from 0.13 grams/shrimp on DOC 7 to 9.59 grams/shrimp on DOC 49. The lowest ADG was recorded in the early period, between DOC 7 and 14, with a value of only 0.08 grams/day. Conversely, the peak of rapid shrimp growth occurred between DOC 35 and 42, where ADG surged to 0.49 grams/day, indicating optimal environmental conditions, nutrition, and shrimp response during that phase.

The degree of uniformity in shrimp size, as indicated by the Standard Deviation (SD) value of shrimp weight, shows a significant upward trend as the shrimp age. The SD value shows a dramatic increase, from very low (0.02) on DOC 7, reaching 0.98 on DOC 35 and peaking at 1.35 on DOC 49.

4. Discussion

The dynamics of water physics parameters during the 49-day observation showed relatively stable conditions, despite some fluctuations. Light intensity ranged from 43,785 to 59,724 lux, which is considered optimal for maintaining a sustainable pond ecosystem balance. High light intensity supports the photosynthesis process of phytoplankton as a natural oxygen source (Hintz *et al.*, 2022; Fitrianesia *et al.*, 2024). However, a significant decrease in clarity from 90 cm to 18–30 cm indicates an increase in phytoplankton biomass and the accumulation of suspended organic matter. This condition limits light penetration and can lead to water stratification, causing high oxygen concentrations at the surface while the lower layers suffer from oxygen depletion due to decomposition and respiration (Wan *et al.*, 2022). Furthermore, high light intensity in turbid water has the potential to accelerate eutrophication. As noted by Abdillah and Armando (2025), higher surface clarity typically stimulates phytoplankton to rise for photosynthesis, but the observed turbidity during DOC 35-49 likely disrupted this balance.

Water temperature remained in the range of 26.9–29°C, meeting the optimal standards of PERMEN-KP/75/2016 (27–32°C). Stable temperatures are crucial for growth, immune response, and metabolic efficiency in *L. vannamei* (Cao *et al.,* 2024). Conversely, extreme temperatures can inhibit metabolism or increase disease susceptibility (Apresia *et al.*, 2024). The high stability of pH (7.9–8.57) reflects consistent pond management (Wyban *et al.*, 1995). The observed increase in pH during the afternoon is associated with CO_2 absorption by phytoplankton, which reduces carbonic acid concentration (Sukendar *et al.,* 2025). This pH stability is very important for maintaining the chemical balance of the water and preventing stress on the cultivated organisms. These pH conditions are indicated as a result of the chemical buffer capacity of the water and the photosynthetic activity of phytoplankton, which absorbs CO_2, reduces carbonic acid, and promotes an increase in pH. pH values in the range of 7.9-8.57 in cultivation ponds indicate optimal conditions for shrimp growth. Based on PERMEN-KP/75/2016, the optimal pH value for shrimp farming is between 7.5 and 8.5. Phytoplankton photosynthesis reduces the concentration of carbon dioxide in the water, which automatically raises the pH value of the water. The increase in carbon dioxide often observed in the afternoon can explain the daily pH dynamics in ponds (Supriatin *et al.,* 2024).

A dramatic decrease in dissolved oxygen (DO) was observed from 6–7 mg/L to 3–4 mg/L during DOC 35 to 49. This decline is directly correlated with increased shrimp biomass and organic matter accumulation, which heightens the respiration and decomposition burden (Wafi *et al.*, 2021). According to PERMEN-KP/75/2016, the optimal DO for shrimp is ≥ 4 mg/L; levels below this threshold indicate critical hypoxia that triggers pathogenic bacteria like *Vibrio* and suppresses appetite (Ariadi *et al.,* 2024). By the end of the period, DO reached 3 mg/L, a critical level that can disrupt biota and cause mortality. Consequently, continuous aeration and water circulation are mandatory interventions to maintain levels above 5 mg/L, as recommended by Xu et al. (2025). High organic content further exacerbates this by fueling microbial decomposition (Supratikno *et al.,* 2025).

Water salinity increased from 30–35 ppt to 38–41 ppt at the end of the study, exceeding the recommended limit of 25–31 ppt (Apresia *et al.*, 2024). This increase was likely caused by seasonal evaporation and reduced freshwater flow during the dry season (Nazarudin *et al.,* 2025). High salinity levels inhibit the molting process and impose chronic osmotic stress, forcing shrimp to expend more energy on osmoregulation rather than growth (Apresia *et al.,* 2024; Supono *et al.,* 2022). Long-term exposure to salinity above 35 ppt risks reducing feed efficiency, necessitating freshwater addition to stabilize the environment (Silva *et al.,* 2010).

Shrimp growth performance was assessed through ABW and ADG (Pratiwi *et al.,* 2022). While ABW increased consistently to 9.59 g, the ADG slowed from 0.49 g/day (DOC 35-42) to 0.40 g/day at DOC 49. This slowdown, alongside an increased Standard Deviation (SD 1.35), indicates high size variability and suggests that hypoxic conditions (DO ≤ 3 mg/L) became a limiting factor. As shrimp increase in size, their energy requirements for metabolic activity and maintenance rise, leaving less energy for growth (Mahendra *et al.,* 2021; Supono *et al.,* 2022). Environmental stressors, such as fluctuating salinity and low DO, further suppress appetite and daily growth rates through physiological responses (Inayah *et al.,* 2023; Duan *et al.,* 2022; Apresia *et al.*, 2024). Ultimately, proper water quality management remains the primary factor for the success of intensive shrimp farming (Anjaini *et al.,* 2024).

Overall, the results of this study highlight a critical transition in intensive vannamei culture, where the interplay between environmental degradation and physiological demand dictates the final yield. While temperature and pH remained within manageable limits, the concurrent decline in dissolved oxygen and the rise in salinity during the late grow-out phase (DOC 35-49) created a cumulative stress environment. This "environmental bottleneck" forced a metabolic trade-off, where energy was diverted from muscle growth to homeostatic maintenance and osmoregulation, as evidenced by the declining ADG and increasing size disparity (SD). These findings suggest that the traditional management approach must be adapted as biomass peaks; specifically, the intensification of aeration protocols and proactive salinity mitigation (such as freshwater dilution) are essential to bypass these limiting factors. Ultimately, maintaining environmental stability in the final phase is as crucial as the initial stocking conditions to ensure the economic sustainability and production efficiency of intensive aquaculture systems in Jepara.

5. Conclusions

This study demonstrates that while water quality in intensive vannamei ponds in Jepara remains optimal during the early stages, significant environmental shifts occur during the late grow-out phase (DOC 35–49). The decline in Dissolved Oxygen (DO ≤ 3.0 mg/L) and the surge in salinity (38–41 ppt) act as critical limiting factors that exceed the optimal tolerance of the shrimp. These fluctuations triggered physiological stress, directly correlating with a marked deceleration in Average Daily Growth (ADG) after DOC 42 and a sharp increase in size variability (SD 1.35). Consequently, to maintain uniform growth and production efficiency, it is imperative for farmers to enhance aeration systems and refine water management strategies during the final stages of the culture cycle.

Ethics approval

The study complied with Indonesian animal welfare regulations, and no specific permits were required for the sampling of marine biota. All procedures were conducted in accordance with the relevant institutional and national guidelines governing the use of aquatic organisms in research.

Data availability statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Author contributions

R.A.F.: writing-original draft, investigation, formal analysis, data curation, methodology; A.T.: resources, supervision, writing original draft preparation, writing-review and editing, validation, methodology, funding acquisition, project administration; S.S.P.: investigation, data curation, formal analysis, methodology.

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Declaration of competing Interest

None

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