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Comparison of Water Conditions and Growth Performance of Vannamei Shrimp (*Litopenaeus vannamei*) under Different Pond Management Systems (Superintensive, Intensive, and Traditional Culture Systems)

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Abstract: Vannamei shrimp (*Litopenaeus vannamei*) is one of the high-value aquaculture commodities in the global market, known for its excellent adaptability to various environmental conditions, rapid growth, and high survival rates. This study aims to compare water conditions and the growth performance of vannamei shrimp under three different pond management systems: supra-intensive, intensive, and traditional. The analysis was conducted by measuring water quality parameters such as temperature, salinity, pH, dissolved oxygen, ammonia, and nitrate concentrations. Growth performance was evaluated through observations of Average Daily Gain (ADG) and Mean Body Weight (MBW). At 50 days of cultivation, the supraintensive system produced an average body weight of 11.85 grams with a daily growth rate of 0.2219 grams/shrimp/day. The intensive system resulted in slightly lower growth, with an average body weight of 8.6 grams and a daily growth rate of 0.1547 grams/shrimp/day. The traditional system showed the lowest growth performance, with an average weight of 6.66 grams and an ADG of 0.0265 grams/shrimp/day. The different pond management systems influence the dynamic risks of water quality changes based on input loads from feed waste and feces. The traditional system exhibits a slower rate of water quality changes compared to the intensive and supraintensive systems.

Keywords: Growth performance; Intensive; *Litopenaeus vannamei*; Supraintensive; Traditional; Water quality

Introduction

Whiteleg shrimp (*Litopenaeus vannamei*) was first introduced in Indonesia in the early 2000s and has since become a major commodity in fisheries exports. Liao & Chien (2011) stated that this type of shrimp is one of the leading commodities in the aquaculture sector, especially because it has rapid growth, resistance to disease, and high market demand (Utojo et al., 2012). Whiteleg shrimp cultivation in Indonesia is growing rapidly with various pond management approaches, ranging from traditional, intensive, to supra-intensive systems. Differences in these management approaches include aspects of pond environmental management, technology utilization, and production intensity levels, which directly affect water quality and shrimp growth performance (FAO, 2010).

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Traditional, intensive, and supraintensive pond cultivation systems have different characteristics. Supraintensive systems utilize advanced technology and controlled management to produce high productivity, but require large investments and complex management. Intensive systems combine the use of technology with conventional cultivation techniques, producing fairly high productivity at more moderate operational costs. In contrast, traditional systems rely on natural resources with minimal human intervention, so they tend to produce lower productivity but at more affordable costs (Pariakan & Rahim, 2021).

Widigdo & Wardianto (2013) stated that cultivation systems with different characteristics will certainly contribute different results to water quality and the growth of vaname shrimp. Boyd & Tucker (1998) and Farionita et al., (2018) stated that traditional ponds tend to utilize natural ecosystems to support shrimp growth, but are less effective in controlling water quality. This is different from intensive and supra-intensive systems that integrate more modern and sophisticated technology (Krisandini, 2023). Aprilia et al. (2020) stated that technologies commonly used in intensive and supraintensive ponds such as aerators, biofilters, and water circulation systems to optimize production. However, the weakness of both ponds is that they require better waste management (Katili et al. (2017) to reduce environmental impacts (Avnimelech, 2009).

The success and development of shrimp cultivation technology are greatly influenced by aquatic environmental factors (Mustafa et al., 2024), especially the quality of pond waters. Water quality parameters in shrimp cultivation ponds that crucially affect the survival and growth of shrimp include temperature, pH, dissolved oxygen (Supriatin et al., 2024), salinity, nitrate, nitrite, ammonia, phosphate, total suspended solids, and total organic matter (Mustafa et al., 2022). Water quality parameters that fluctuate dynamically during intensive shrimp cultivation include dissolved oxygen, nitrite, Total Organic Matter (Ariadi et al., 2023), pH, salinity, and abundance of Vibrio bacteria. Dynamic fluctuations in the abundance of Vibrio bacteria can trigger the emergence of Acute Hepatopancreatic Necrosis Disease infection which is the cause of death in farmed shrimp (Suryana et al., 2021). Apart from that, differences in different shrimp cultivation systems can also affect the water quality values of shrimp ponds (Arsad et al., 2017).

Based on the results of previous research, shows that the optimal range of pond water quality values for successful shrimp cultivation is temperature 27–32 °C, salinity 15–25 ppt and 16-32 ppt, dissolved oxygen > 5 mg/L, and ammonia levels < 0.1 mg/L (Farabi & Latuconsina, 2023). The importance of monitoring pond water quality needs to be carried out periodically because every pond tends to experience significant changes in water quality at any time. Information on the relationship between the pond management system and water quality and shrimp growth performance is very important to provide appropriate recommendations for farmers, especially in the Java area. This research aims to analyze differences in water conditions and growth performance of shrimp in super intensive, intensive, and traditional cultivation systems, as well as provide insights to increase the efficiency and sustainability of shrimp cultivation. This information can be used as a consideration for shrimp cultivators to decide which cultivation system to apply because the shrimp cultivation system can significantly influence the level of growth performance of the shrimp produced (Nguyen et al., 2019).

Method

This research was conducted from June to September 2024, lasting approximately 16 weeks, with field data collection taking around 6 weeks and laboratory testing taking about 10 weeks. Field data collection took place at a vannamei shrimp pond located in Kandangsemangkon, Paciran District, Lamongan Regency, East Java, using a purposive sampling method (Figure 1). This method involves selecting samples based on specific considerations aligned with the research objectives. Data were collected from three types of ponds with different management systems (super-intensive, intensive, and traditional). Sampling was conducted at three designated sampling stations, with three repetitions at each station to ensure accuracy. Samples were taken in situ (measured directly in the field) for parameters such as pH, temperature, transparency, light intensity, and dissolved oxygen (DO), and ex situ (laboratory testing) by collecting water samples for nitrate, phosphate, and plankton analysis in the morning, afternoon, and evening. The ex-situ water samples were stored in bottles and placed in a cool box before further analysis in the laboratory. This approach aims to observe differences in fertility status and water quality across ponds with different management systems.

Average Daily Gain (ADG)

Measurement of the average weight gain of shrimp per day. This measurement provides an overview of the shrimp's daily weight growth during the monitoring period. The formula for calculating ADG, according to Akbarurrasyid et al. (2024), is as follows.

$$\mathrm{ADG} = \frac{\mathrm{W_t} - \mathrm{W_0}}{\mathrm{t}} \tag{1}$$

Explanation:
ADG = average daily weight gain (grams/day)
W_t = weight of shrimp at the end of the period (grams)
W_0 = weight of shrimp at the beginning of the period (grams)
t = time period measured (days)

Figure 1. Research location map

Mean Body Weight (MBW)

Measurement of the average weight of shrimp in a population at a specific time. This is crucial for monitoring the overall growth of the shrimp group and determining the optimal harvest time. The formula for calculating MBW, according to Akbarurrasyid et al. (2024), is as follows.

$$MBW = \frac{\sum W}{N} \tag{2}$$

Explanation:
MBW = average body weight of shrimp in the population (grams)
ΣW = total weight of all shrimp measured (grams)
N = total number of shrimps measured

Data Analysis

The results of water quality measurements, both in-situ and ex-situ, as well as shrimp body weight measurements, will be tabulated, and the ADG and MBW values will be calculated using Microsoft Excel. For statistical analysis of the relationship between water quality parameters and ADG and MBW parameters, a Tukey HSD (Honestly Significant Difference) test will be conducted using the PATH application. The statistical results will be described by comparing them with other references.

Result and Discussion

Lamongan Regency is one of the highest-producing centers for shrimp cultivation commodities in East Java. Shrimp cultivation production in this district has decreased quite drastically over the last 10 years due to a decline in water quality due to the rise of industrial development in the area (Hermawan et al., 2024). Water quality measurements in shrimp ponds are carried out to ensure adequate carrying capacity of pond water for shrimp growth. The research findings on water quality measurements at DOC 20, 35, and 50 are presented in Table 1.

Based on the results of the calculation of the average standard deviation of 12 water qualities that have been measured and evaluated in three different pond management systems, it is known that the levels of phosphate, pH and brightness of pond waters between management systems show significant differences (p-value < 0.01), namely supra-intensive management has the highest phosphate levels (0.408 ± 0.063 mg/L, a), intensive (0.202 ± 0.099 mg/L, b), the lowest is traditional (0.043 ± 0.009 mg/L, c).

The high levels of phosphate in supra-intensive ponds (0.408 mg/L) compared to intensive and traditional according to the results of research by Capetillo-Contreras et al. (2024) that this reflects the level of use of additional feed and fertilizers that are intensive in the supra-intensive system, so that it tends to increase organic waste compared to traditional ponds which are more towards natural processes in the aquatic ecosystem. Food that is not consumed by shrimp will generally accumulate at the bottom of the pond (Iber & Kasan et al., 2021) and will be decomposed by microorganisms in the pond water. Apart from feed, fertilizer containing nitrogen and phosphorus given as a treatment during shrimp cultivation has the potential to increase primary productivity and phosphate accumulation in shrimp ponds (Hlordzi et al., 2020). Differences in pond management between traditional, intensive, and supra-intensive cultivation systems can affect the growth of vaname shrimp. The results of measuring the growth of shrimp weight in a certain population and time (DOC 20, 35, and 50) are shown in Figure 2.

Table 1. Average (± standard deviation) water quality in shrimp ponds with different management, different letters indicate significant differences based on the results of the Tukey HSD (Honestly Significant Difference) test

Parameters	Intensive	Supraintensive	Traditional	p-value
Nitrate (mg/L)	0.061 ± 0.046a	0.168 ± 0.105a	0.189 ± 0.197a	0.228
Phosphate (mg/L)	0.202 ± 0.099b	0.408 ± 0.063a	0.043 ± 0.009c	0.000**
Ammonia (mg/L)	0.052 ± 0.101a	0.153 ± 0.126a	0.106 ± 0.112a	0.121
Temperature (°C)	29.817 ± 1.141a	29.583 ± 1.677a	31.567 ± 1.912a	0.098
pH	8.49 ± 0.08a	8.198 ± 0.195b	8.462 ± 0.24ab	0.028*
Salinity (ppt)	22.167 ± 1.835a	26.167 ± 1.169a	27.667 ± 7.474a	0.125
DO (mg/L)	9.85 ± 0.802a	8.883 ± 1.091a	8.967 ± 0.393a	0.107
Clarity (cm)	36.833 ± 5.307b	25 ± 4.472c	45 ± 5.477a	0.000**
TOM	1.517 ± 0.515a	1.35 ± 0.706a	1.25 ± 0.476a	0.72
TSS	14.851 ± 4.038a	15.067 ± 1.662a	15.417 ± 6.996a	0.979
Intensity	4631.917 ± 2946.733a	1588.417 ± 378.345a	4170.333 ± 2469.027a	0.0674
Nitrite (mg/L)	0.038 ± 0.009a	0.041 ± 0.014a	0.03 ± 0.012a	0.265

$p < 0.05$; ** $p < 0.01$ Different letters in the same row indicate significant differences.

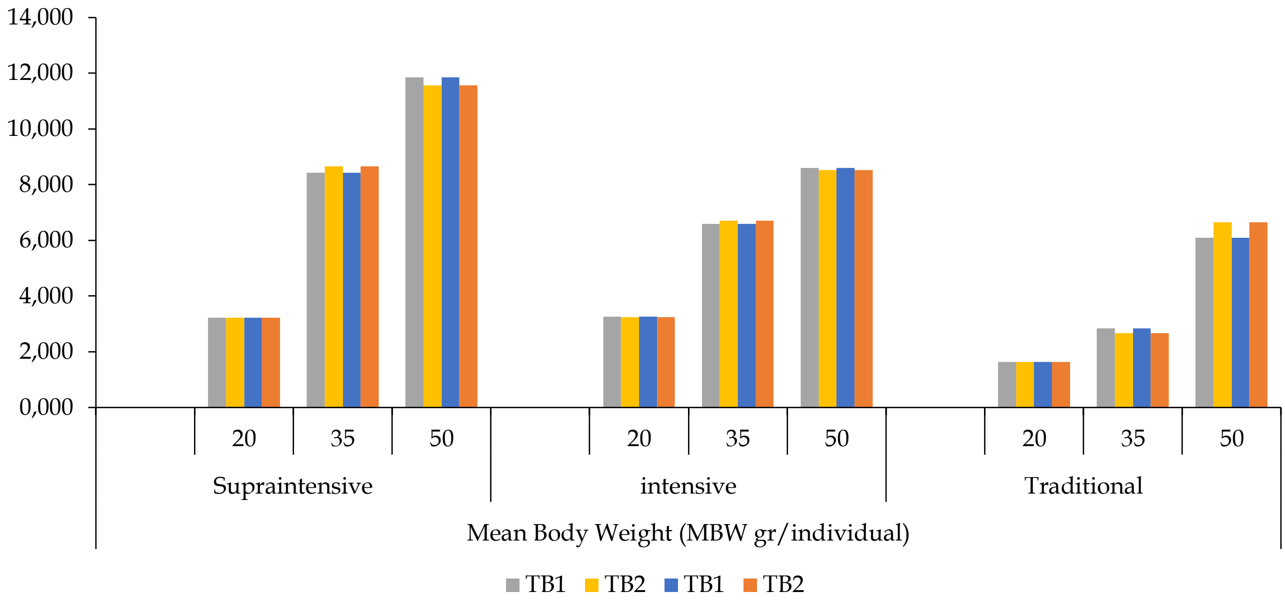

Figure 2. Mean Body Weight (MBW) of vannamei shrimp in different pond management systems

The average body weight of shrimp in the supraintensive system showed a consistent increase from 1.4 grams at 1 day of age to 11.85 grams at 50 days of age. The average body weight in this sample was 11.85 grams, with body weight fluctuations that were not too significant between samples (the average body weight at 50 days of age was between 8.43 and 12.0 grams).

The consistent increase in the average weight of superintensive cultured shrimp in this study has achieved optimal growth during maintenance. According to Pratiwi et al. (2022), the average body weight at 50 days of age in the superintensive system is < 11.0 grams with a stocking density of 250 individuals/m². Differences in shrimp stocking density also influence the ADG value of shrimp. A shrimp stocking density of 100 individuals/m² can produce an ADG value of 0.33g/head (Suriawan et al., 2019).

In the intensive system, the body weight of shrimp also increased from 1.1 grams at 1 day of age to 8.6 grams at 50 days of age. The average body weight in this sample was 8.6 grams. Overall, the body weight of shrimp in the intensive system was slightly lower than that in the supraintensive system, but still showed good growth, with fairly stable variations (the average body weight at 50 days of age ranged from 6.6 to 9.1 grams). The low weight of shrimp in the intensive system is caused by several factors, including the number of shrimp populations in the pond, limited space for shrimp to move to get food and the amount of oxygen in the pond (Purnamasari et al., 2017).

In the traditional cultivation system, the body weight of shrimp tends to be lower than the other two systems. The average body weight at 50 days of age was 6.66 grams, with values ranging from 5.8 to 7.1 grams. Although there were some samples showing slightly higher body weights (such as 7.1 grams at 50 days of age), in general the growth performance was lower compared to the supraintensive and intensive systems. The low average body weight of shrimp in traditional shrimp cultivation systems is influenced by the cultivation media used and the influence of water quality during the cultivation period (Aprilia et al., 2024).

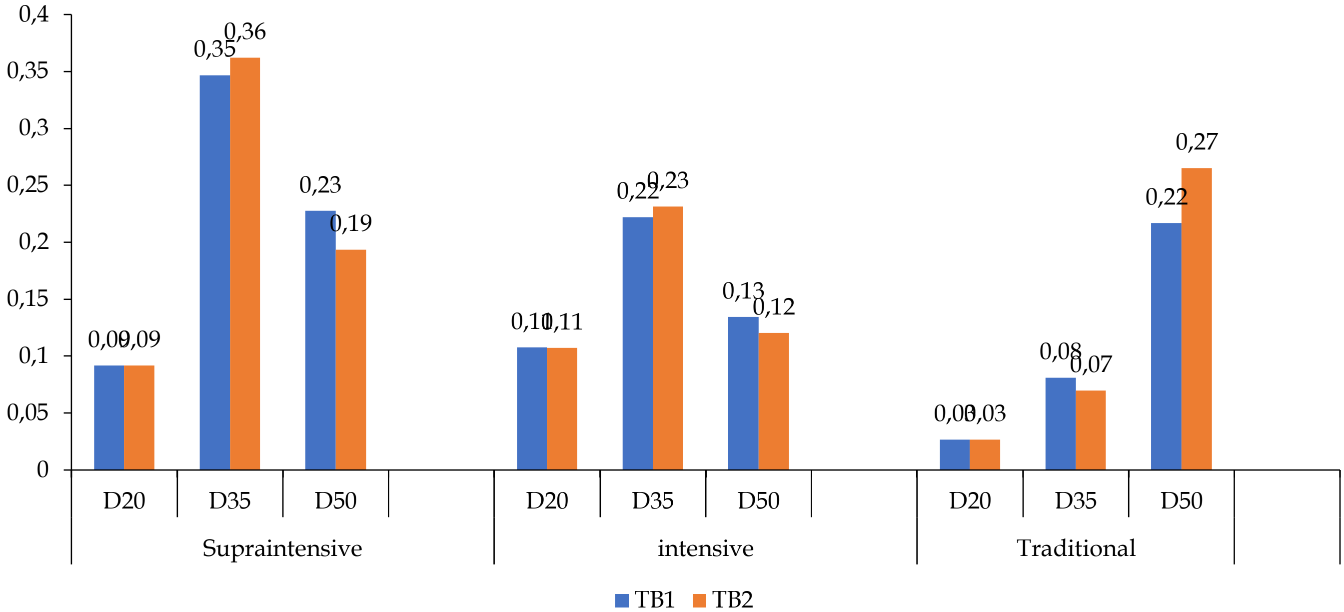

Figure 3. Average daily gain (ADG) results for vaname shrimp in different pond management systems

The growth rate in supra-intensive DOC 20 is known to have an average daily growth rate of 0.09 grams/head/day. This value indicates relatively good growth at the beginning of the cultivation period. In DOC 35, the daily growth rate increased to 0.36 grams/head/day. This increase indicates that shrimp experience a faster growth phase at an older age. While in DOC 50, the daily growth rate tends to decrease slightly to 0.19 grams/head/day. Although decreasing, this value still shows quite good growth in the final stage of cultivation.

The growth rate in intensive ponds is known to have an average in DOC 20 of around 0.11 grams/head/day. This value is slightly higher than the traditional system, but lower than the supra-intensive system. DOC 35 daily growth increased to 0.23 grams/head/day, indicating a faster growth phase, at D-50 the daily growth rate was 0.1203 grams/head/day, which was lower than D35, but still showed a fairly good growth rate.

The growth rate in the traditional system at DOC 20 age was 0.0266 grams/head/day, which was much lower than the other two systems. Then at DOC 35 age, the daily growth rate increased to 0.0698 grams/head/day, but remained relatively low and at DOC 50 age, the daily growth rate increased slightly to 0.2653 grams/head/day, indicating an increase in the final phase of cultivation.

Water Conditions in Each Different Cultivation System Management

Water conditions are an important factor in determining the success of vaname shrimp cultivation, because good water quality can support the growth and health of shrimp. Based on the results of the calculation of the average and standard deviation of water quality in three different pond management systems (supraintensive, intensive, and traditional), there are significant differences in several water quality parameters, such as phosphate, pH, and brightness as seen from the p-value < 0.05.

Phosphate is a nutrient in water from rock weathering and decomposition of organic matter that is beneficial for phytoplankton growth (Rizqina et al., 2017). Phosphate levels in supraintensive ponds (0.408 ± 0.063 mg/L) are much higher than intensive ponds (0.202 ± 0.099 mg/L) and traditional ponds (0.043 ± 0.009 mg/L). This shows that the supra-intensive system, which uses intensive feed and fertilizer, produces more organic waste, which has the potential to increase phosphate concentrations in the water. Meanwhile, traditional pond systems show the lowest phosphate values, because they still use natural feed and fertilizers. High phosphate can affect the balance of aquatic ecosystems, because phosphate is the main limiter of water productivity and can stimulate algae growth, leading to decreased water quality. Research by Capetillo-Contreras et al. (2024) revealed that intensive and supra-intensive cultivation systems with high feed inputs tend to increase phosphate concentrations, which have an impact on water quality and shrimp health.

Differences also appear in the pH value that can be seen in intensive ponds (8.49 ± 0.08) indicating a higher pH compared to traditional ponds (8.462 ± 0.24) and supra-intensive (8.198 ± 0.195). This difference indicates that the intensive system is able to maintain better pH stability, this is due to more controlled aeration and feeding management, which can affect the chemical balance of the water. Conversely, the lower pH in supra-intensive ponds can be caused by the accumulation of organic compounds during the decomposition process, states that the intensive system has better aeration management, which helps maintain pH stability.

Water clarity showed significant differences between the three pond management systems, with traditional ponds having the highest clarity (45 ± 5.477 cm), followed by intensive ponds (36.833 ± 5.307 cm), and supra-intensive ponds with the lowest clarity (25 ± 4.472 cm). Higher clarity in traditional ponds reflects clearer water, which may be due to fewer dissolved organic particles and waste compared to intensive and supra-intensive systems that use intensive supplementary feed. Zhang & Wang (2021) explained that intensive and supra-intensive systems produce more organic particles and suspended solids due to more intense feed use and biological processes.

Other parameters did not show significant differences in the three shrimp pond cultivation systems, for example in nitrate. Nitrate levels (0.228 mg/L) did not show significant differences between the three management systems, indicating that differences in management do not have a significant effect on nitrate levels in the water. Research by Noor (2023) stated that nitrate levels in ponds tend to be stable due to the efficient nitrification process, which is produced by nitrifying bacteria in the water column. Likewise, ammonia levels remained stable (p-value = 0.121 > 0.05) in all three systems. This shows that with good aeration management, ammonia levels can be well controlled (Jongjaraunsuk et al., 2024).

The temperature in traditional ponds (31.567 ± 1.912 °C) appeared higher compared to intensive ponds (29.817 ± 1.141°C) and supraintensive ponds (29.583 ± 1.677 °C), although there was no significant difference. Smith & Hall (2022) study showed that higher temperature fluctuations in traditional ponds were due to the lack of temperature control technology in the ponds. Higher temperatures in traditional ponds can affect the health of whiteleg shrimp, although the optimal temperature range for whiteleg shrimp is 27–32 °C.

Based on the results of the water quality evaluation, the pond management system has a significant influence on water quality, the fluctuations of which have an impact on the health and growth of whiteleg shrimp. The supraintensive system showed higher phosphate levels and lower pH, reflecting increased organic waste, while the traditional system showed clearer water with the highest transparency. Although temperature and nitrate and ammonia levels did not show significant differences, it is important to consider how each management system affects water conditions to achieve optimal culture results.

Growth Performance of Whiteleg Shrimp in Different Management Systems

The growth performance of whiteleg shrimp is greatly influenced by the water conditions in the pond, which are reflected in the water quality and management of the cultivation environment. In this study, an evaluation of the growth performance of whiteleg shrimp was conducted in three different pond management systems, namely the supra-intensive, intensive, and traditional systems. This growth performance evaluation involved measuring the daily body weight of whiteleg shrimp (grams/tail) in each system during the observation period.

The growth performance of whiteleg shrimp is greatly influenced by the pond management system applied, which includes feed management, water quality, and shrimp population density. In this study, three cultivation systems, namely supra-intensive, intensive, and traditional, were compared to determine the differences in the growth rate of whiteleg shrimp based on the Average Daily Gain (ADG) on various observation days (DOC).

In the supraintensive cultivation system, the growth of whiteleg shrimp experienced a significant increase, especially in DOC 35, where ADG reached 0.36 grams/day, which was much higher than the growth in DOC 20, which only reached 0.097 grams/day. The high increase in ADG in DOC 35 was due to better feed quality management, sufficient dissolved oxygen levels, and more stable temperature and pH control. According to Nguyen (2023), feed quality that is rich in protein (more than 35%) greatly affects shrimp metabolism and growth, which supports these results. However, in DOC 50, although the supraintensive system supports faster growth, high shrimp density can cause stress due to competition for feed and space. This is consistent with the findings of Su (2022) which stated that high density can increase stress in shrimp and inhibit their growth.

In the intensive system, the growth of whiteleg shrimp also showed positive results, although not as fast as the supra-intensive system. In DOC 35, ADG reached 0.23 grams/day, which was higher than DOC 20 which only reached 0.107 grams/day. Although not as high as in the supra-intensive system, the intensive system was still able to provide quite good growth thanks to better management in terms of feed, dissolved oxygen, and stability of pH and water temperature. Nguyen (2023) also emphasized the importance of optimal environmental management to support shrimp metabolism in the intensive system. However, as in the supra-intensive system, increasing density in DOC 50 can trigger stress that slows shrimp growth, due to competition for feed and space. The activity of fighting over food between individual shrimp is closely related to the frequency of feeding because shrimp food needs to be supported by sufficient natural food and artificial food in the right quantity to achieve survival, optimal shrimp growth and the right feed conversion ratio (Van et al., 2017). One type of natural shrimp food that can significantly support shrimp growth is spirulina microalgae (Li et al., 2022).

The traditional system shows a different growth pattern. Despite its slower growth rate, the traditional system recorded an ADG of 0.028 grams/day at DOC 20, which increased to 0.082 grams/day at DOC 35 and reached 0.267 grams/day at DOC 50. The increase in ADG at DOC 50 in the traditional system indicates that whiteleg shrimp in this system can adapt well to a more natural and less intensive environment. Despite its slower growth, the traditional system can support shrimp health thanks to the more stable water quality, as explained in the study by Lee et al. (2021), which stated that stable water quality is very important to support shrimp metabolism.

Comparison of Growth Performance

Overall, supra-intensive showed superior growth at the fastest DOC 35, but had potential problems related to stress due to high density at DOC 50. The intensive system also supported good growth, although slightly slower than supra-intensive, with better water quality stability. Meanwhile, the traditional system, although slower in terms of growth rate, showed advantages in terms of environmental stability and shrimp adaptation to natural conditions.

Environmental Factors Affecting Growth

Shrimp growth in all three systems was influenced by several main environmental factors, including feed quality, dissolved oxygen, water pH, salinity, and temperature. In both supra-intensive and intensive systems, good feed management, adequate aeration, and water temperature and pH stability played important roles in supporting optimal growth. However, in the traditional system, although feed quality and technology use were more limited, better water quality stability and natural environmental conditions could support shrimp growth in the long term, although at a slower rate. The intensity and amount of feeding that is appropriate to the abundance of shrimp in the cultivation pond can be the main factor in increasing shrimp growth (Reis et al., 2021).

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Environmental Factors Affecting Growth

Several cases that have been studied previously showed that shrimp growth performance was influenced by the nutritional content of feed and feed washing (Ullman et al., 2019). The results of the study showed that shrimp growth in the three systems was influenced by several main environmental factors, including feed quality, dissolved oxygen, water pH, salinity, and temperature. In supra-intensive and intensive systems, good feed management, sufficient aeration, and water temperature and pH stability played an important role in supporting optimal growth. However, in the traditional system, although feed quality and technological inputs were more limited, better water quality stability and natural environmental conditions could support shrimp growth in the long term, although at a slower rate.

The average shrimp weight gain (MBW) in various pond management systems showed a significant increase in each DOC (20, 35, and 50). In the supra-intensive system, weight gain ranged from 3,178 to 5,433 grams/head, influenced by high-protein feeding and intensive water quality management, which increased the efficiency of shrimp metabolism (Nguyen, 2023). In the intensive system, weight gain ranged from 1,888 to 3,342 grams/head, while in the traditional system it ranged from 1,218 to 3,422 grams/head. Frequency of monitoring the amount of food, feeding schedule, and monitoring water quality is needed for the sustainability of shrimp aquaculture (Bardera et al., 2018).

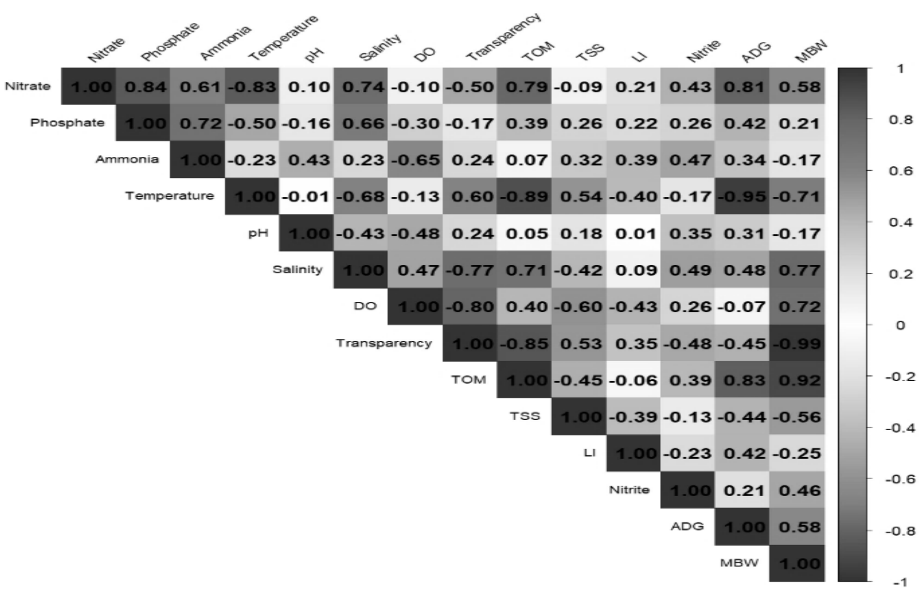

Figure 4. Correlation of water quality with ADG and MBW in supra-intensive systems

The results of statistical analysis showed a significant relationship between various water quality parameters and shrimp growth. Temperature was positively correlated (0.71) with MBW growth, indicating that the optimal temperature (28–32°C) supports shrimp metabolism, while temperatures outside this range were negatively correlated (-0.95), which can cause stress and inhibit growth. Temperature plays a role in maintaining immune stability and shrimp metabolism to fight pathogenic microorganisms during the growth phase (Ren et al., 2021). One type of pathogenic and resistant microorganism that threatens shrimp growth is *Vibrio parahaemolyticus* bacteria (Rohmatika et al., 2023), *Escherichia coli* and *Vibrio harveyi* bacteria (Asih et al., 2024b). These three types of bacteria belong to a group of bacteria that are able to adapt well to waters and are difficult to inhibit their growth (Asih et al., 2024a). Other parameters show, Salinity was positively correlated (0.77) with MBW, where stable salinity (15–25 ppt) supports osmoregulation and feed efficiency. Low DO was negatively correlated (-0.07) with ADG, while high DO was positively correlated (0.72) with MBW, indicating that oxygen was sufficient to support growth. TOM (Total Organic Matter) was positively correlated (0.83-0.92) with ADG and MBW, increasing nutrient cycling and supporting the ponasihd ecosystem. Salinity was also positively correlated with nitrate and phosphate (0.66-0.74), while TOM, nitrate, and salinity were positively correlated (0.71-0.79), supporting nitrate formation and increasing pond ecosystem productivity.

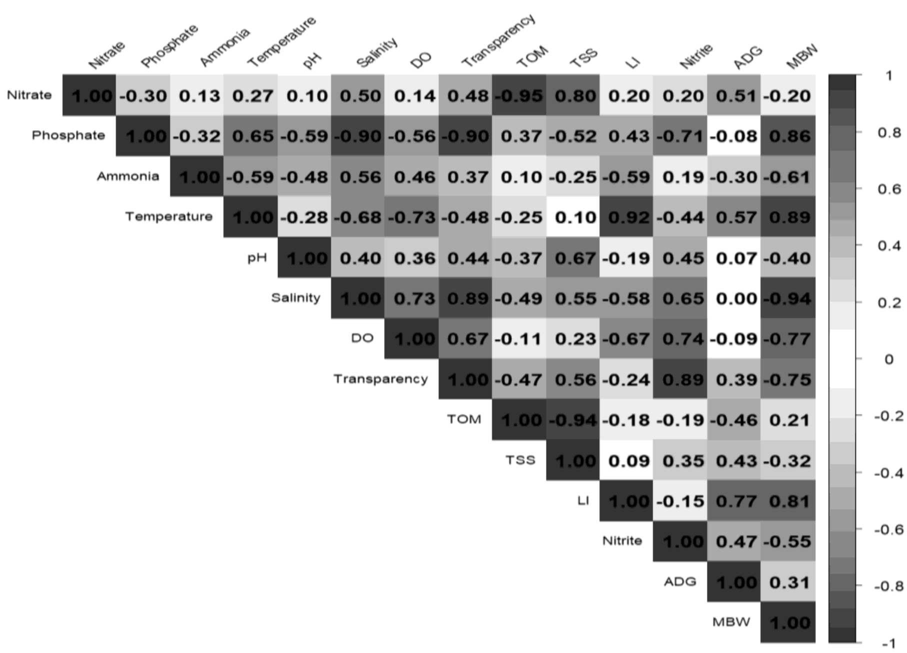

Figure 5. Correlation of Water Quality with Shrimp Growth (ADG and MBW) in Intensive Systems (Study Results)

The results of the correlation of water quality with shrimp growth in intensive ponds showed that light intensity was positively correlated with Average Daily Growth (ADG) (0.77) and Mean Body Weight (MBW) (0.81), which supported phytoplankton growth and increased the availability of dissolved oxygen for shrimp. Phosphate and temperature also showed a positive correlation with MBW (0.86-0.89). Conversely, DO and brightness were negatively correlated with MBW (-0.75 to -0.77), with high brightness being able to reduce pond productivity because it triggered temperature fluctuations and increased the risk of phytoplankton blooms.

The correlation between water quality parameters showed that brightness was positively correlated with salinity (0.89), indicating that clearer water supports osmotic stability. TSS, pH, and nitrate (0.67-0.80) were positively correlated, supporting the biological cycle and activity of microorganisms in decomposing organic matter. Organic matter accumulated in water bodies has a very strong and significant relationship to the abundance of pathogenic bacteria, one of which is Escherichia coli (Asih et al., 2024c). Light intensity and temperature (0.92) showed a synergistic relationship, mutually supporting pond productivity. Nitrite, salinity, DO, and brightness (0.65-0.89) showed a positive correlation, but high nitrite levels should be watched out for because they are potentially toxic to shrimp.

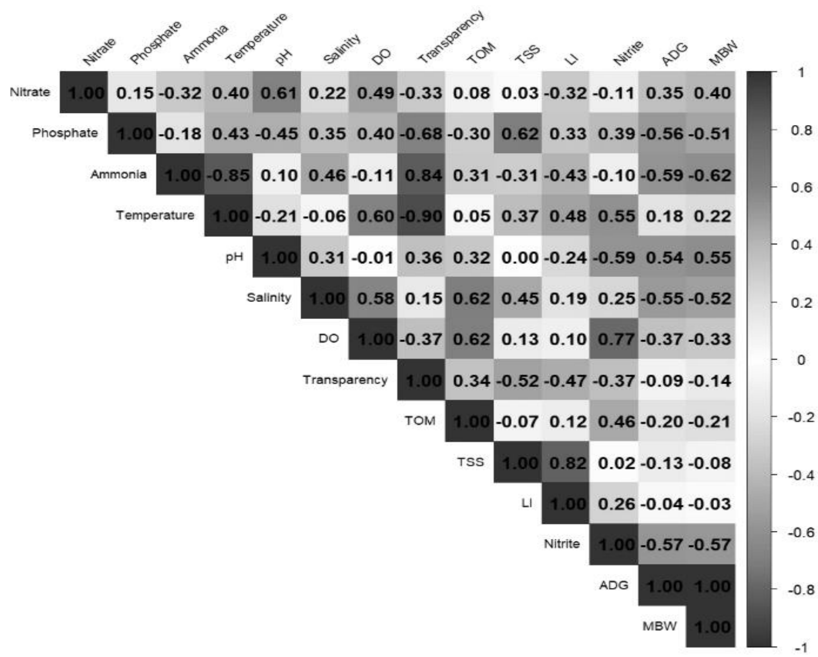

Figure 6. Correlation of water quality with shrimp growth (ADG and MBW) in traditional systems (study results)

The results of the correlation of water quality parameters with the growth of whiteleg shrimp showed that pH was positively correlated with ADG and MBW (0.54-0.55), while salinity, phosphate, and ammonia were negatively correlated with ADG (-0.55; -0.56; -0.59) and MBW (-0.51; -0.62). High levels of phosphate and ammonia can inhibit shrimp growth, with phosphate causing phytoplankton blooms and excessive ammonia being toxic.

The correlation between water quality parameters showed that nitrite was positively correlated with DO (0.77), indicating that good aeration supports nitrification. TSS was positively correlated with phosphate (0.62), indicating that an increase in suspended matter is often accompanied by an increase in nutrients such as phosphate, which generally occurs in ponds with low sediment maintenance. TOM was positively correlated with salinity and DO, and brightness was positively correlated with ammonia. The high level of ammonia identified in shrimp ponds is thought to indicate intensive decomposition activities of organic material by microorganisms (Zafar et al., 2015).

Overall, stable water quality, including optimal pH and sufficient dissolved oxygen. This is very important to support shrimp growth. On the other hand, fluctuations in salinity, phosphate and ammonia can have a negative impact on its growth.

Effectiveness and Sustainability of Pond Management Systems

In shrimp farming, the choice of pond management system has a major impact on the effectiveness of shrimp growth and the sustainability of aquatic ecosystems. The three main systems that are often used are supra-intensive, intensive, and traditional systems. Each system has advantages and challenges that need to be considered in achieving optimal production goals.

The supra-intensive system has been proven to provide the most optimal shrimp growth with an average body weight of 11.85 grams at 50 days of age and the highest daily growth rate. This system allows for large-scale and rapid production, but requires very strict water quality management. The main drawback of this system is the increase in phosphate levels that can damage water quality, as well as a decrease in water clarity that can be risky for shrimp health. Therefore, efficient management of nutrients and water quality is essential for this system to remain sustainable. Providing nutrition in this shrimp farming system requires using live food, especially when the shrimp are still in the post-larval stage (Fricke et al., 2023). Post larval shrimp require a higher nutritional intake than adult shrimp (Wanna et al., 2023) which is used for metabolic processes and increasing the amount of oxygen consumed (Xue et al., 2021).

The intensive system provides good results with stable growth (average weight of 8.6 grams at 50 days), although slightly lower than the supra-intensive system. This system is easier to control and has lower risks related to water quality, but still requires attention to nutrient balance and waste management. The advantage of the intensive system is its ability to optimize space and resources, suitable for areas with limited land. However, if not managed properly, negative impacts on the environment can still occur, such as increased waste accumulation.

The traditional system showed lower growth (6.66 grams at 50 days of age), but was more friendly to the aquatic ecosystem because of the clearer water quality. Its main advantages are sustainability and lower environmental impact, because it does not require excessive use of feed and chemical drugs. However, growth is slower, and lower production results may not be enough to meet high market demand. Therefore, the traditional system is more suitable for small scales or for ecosystem conservation.

Sustainability in pond management must consider environmental, economic, and social factors. Supra-intensive and intensive systems, although they can produce products quickly, must be equipped with efficient waste management and water quality treatment technology so as not to damage the ecosystem. Traditional systems, with their lower environmental impact, are more sustainable in the long term although they require more careful management of land use and natural resources. Innovative technologies such as biofilter systems, use of organic feed, and real-time monitoring of water quality can help improve the sustainability of intensive and supraintensive systems, making them more environmentally friendly.

Conclusion

This study can be concluded that different pond management systems have significantly different water quality and growth performance. Water quality in ponds with supra-intensive and intensive systems has a better value than the traditional system. This can be seen from the results of several parameters such as pH, DO, temperature, salinity, brightness, nitrate and phosphate. Shrimp growth also differs between shrimp pond cultivation systems. The Supra-Intensive System provides the best growth with an average body weight of 11.85 grams at the age of 50 days and a daily growth rate of 0.2219 grams/head/day. The Intensive System also shows good growth, although slightly lower, with an average body weight of 8.6 grams and a daily growth rate of 0.1547 grams/head/day. The Traditional System has the lowest growth (6.66 grams). And the best shrimp growth can be seen from the results of ADG and MBW measurements which show a high increase in shrimp growth in ponds with a supra-intensive system with an average increase in growth rate of 1.4 grams.

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Author Contributions

Conceptualization, methodology, software, preparation of original writing draft, formal analysis, investigation, resource, S.A.; project administration, data curation, supervision, writing-review and editing, visualization, S.A. and A.M.S.H.

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Conflicts of Interest

All author declares that there is no conflict of interest.

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