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The Effect of Water Quality on the Performance Growth of Vannamei Shrimp (*Litopenaeus vannamei*) at the Center for Brackish Aquaculture Fisheries

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Abstract

Vanamei shrimp is one of the leading commodities of the mariculture sector, with high production rates influenced by the rapid growth period and relatively short maintenance time, high stocking density production system, has a high appetite for food and has good resistance to disease. This study aims to assess the effect of water quality on the growth of vanamei shrimp (*Litopenaeus vannamei*) in ponds. Water quality measured includes temperature, salinity, dissolved oxygen (DO), and pH, all of which play an important role in the growth and health of shrimp. The methods used in this study included periodic measurements of water quality parameters in the morning and evening in four ponds (A5.1, A5.2, A6.1, and A6.2), observations of water cycle management used in the pond plots, and observations of Average Body Weight (ABW), Average Daily Growth (ADG), and Survival Rate (SR) of shrimp. The results showed that ponds A5.1, A5.2, and A6.1 showed an increase in SR and biomass values, while A6.2 experienced a decrease in SR and biomass values caused by the outbreak of White Feces Disease. This is influenced by temperature, salinity, and DO parameters that are not in the optimal range for shrimp growth. Fluctuations in water quality parameters can significantly affect shrimp metabolism and health. Therefore, good water quality management, including water change cycles and sterilisation, is essential to prevent health problems and improve the growth of vanamei shrimp. This study emphasises the need for attention to water quality in vanamei shrimp farming to achieve optimal results

1. Introduction

Shrimp is one of the leading commodities from the mariculture sector. As market demand increases, shrimp farming is increasingly being carried out to meet consumer needs (Ramadhani *et al*., 2024). One type of shrimp that has a high selling value is vanamei shrimp (*Litopenaeus vannamei*) which is currently widely cultivated. According to data from the Directorate General of Aquaculture, Ministry of Marine Affairs and Fisheries, vanamei shrimp production in 2021 reached 884,939 tonnes (Agustiyana *et al*., 2023). The high production rate of vanamei shrimp is influenced by the rapid growth period and relatively short rearing time as well as the production system with high stocking density (Jalil *et al.*, 2022). In addition, vanamei shrimp have a high appetite for food and have good resistance to disease (Gompi *et al*., 2023).

In conducting vanamei shrimp pond culture, one of the things that affects is water quality. Water quality has a great influence on the growth and disease susceptibility of vanamei shrimp (Listriyana *et al.*, 2023). Therefore, water quality monitoring needs to be done regularly during the implementation of vanamei shrimp pond culture, which will have an impact on the quality of the shrimp harvest obtained (Yunarty *et al.*, 2022). The application of good water management in vanamei shrimp pond culture needs to be done to maintain water quality in the pond. In addition, good water management also affects the growth of vanamei shrimp and can reduce the risk of disease in vanamei shrimp that leads to mass mortality (Saraswati *et al.*, 2023).

In monitoring water quality, there are several parameters that need to be considered. Some of these water quality parameters include temperature, salinity, dissolved oxygen (DO) and pH (Farabi and Latuconsina, 2023). The optimal temperature in vanamei shrimp pond culture ranges from 24-29 °C, because temperatures that are too low can inhibit the metabolic process and growth of vanamei shrimp, and temperatures that are too high can cause stress and susceptibility of vanamei shrimp to disease will increase

(Utami *et al.*, 2023). Optimal salinity in vanamei shrimp pond culture ranges from 25-31 ppt, because salinity levels are too low or too high can affect the osmoregulation and growth of vanamei shrimp (Jayanti *et al.*, 2022). Optimal dissolved oxygen (DO) in vanamei shrimp pond culture ranges from 3-6.2 mg/L, because dissolved oxygen levels are too low will affect the slowing growth of vanamei shrimp and increased susceptibility to disease, and if there are significant fluctuations in dissolved oxygen can cause stress in vanamei shrimp (Andriyono *et al.*, 2022). Optimal pH levels in vanamei shrimp pond culture range from 6.8-8.5, because pH levels that are too low or high can affect the disruption of the molting process and the growth of vanamei shrimp (Scabra *et al.*, 2023). Water quality is a crucial factor in the sustainability of vanamei shrimp mariculture. Therefore, this study examined the relationship between water quality factors and vanamei shrimp growth.

2. Material and methods

2.1 Material

The research conducted was an observation of vanamei shrimp ponds (*Litopenaeus vannamei*) at *Balai Besar Perikanan Budidaya Air Payau* (BBPBAP) or the Center for Brackish Aquaculture Fisheries, Jepara. Tools and materials used vanamei shrimp, chlorine, lime, digital balance, nets, DO meter, pH meter, refractometer, thermometer, distilled water, sample bottles, pipettes.

2.2 Methods

2.2.1 Water Quality Sampling

Measurement of water quality parameters was carried out in the morning at 07:00 AM and in the afternoon at 16:00 PM. Parameters measured include temperature, salinity, dissolved oxygen, and pH in vanamei shrimp ponds (*Litopenaeus vannamei*).

2.2.2 Water Turnover Cycle

Water management method carried out in vanamei shrimp farming at BBPBAP is carried out with a water change cycle goes through several stages. The source of water used in the process of cultivation of vanamei shrimp using sea water. Sea water flows into a small river and channelled to the location of the pond. Seawater in the small river is pumped and then entered to be accommodated in the reservoir. In the reservoir, sterilisation is carried out using chlorine at 20-30 ppm. Sterilisation activities are carried out before water enters the mariculture pond plots. Chlorine is stocked after the water in the reservoir is full, and then allowed to stand for about 8-12 hours in the reservoir. The use of chlorine aims to kill pathogens and contaminating microorganisms that can interfere with the health and growth of vanamei shrimp (Naban *et al.*, 2023). After sterilisation, the water in the reservoir will be flowed to each cultivation plot. Cultivation plots are divided into 4 plots namely A5.1, A5.2, A6.1 and A6.2.

In vanamei shrimp ponds, piping is done in the morning (07:00 AM) and afternoon (16:00 PM). The purpose of flushing is to reduce excess feed and debris that settles at the bottom of the pond. The wastewater is then flowed to the settling pond to settle the sediment to produce clean water. In the settling area, several types of mangrove plants are planted which act as biofilters to absorb chemicals such as nitrates, nitrites and ammonia contained in mariculture waste (Anton *et al.*, 2020). Clean water from the deposition results will then be channeled back to the sea.

2.3 Shrimp Sampling

Shrimp sampling was conducted using a net with a diameter of 2 metres, a mesh width of 3/4 inch and a thread size of 0.28 mm. The net was spread once in each pond and then pulled and the vanamei shrimp obtained were put into bags. Shrimp samples obtained were separated between those that were molting and those that were not molting. Then shrimp samples that are not molting are weighed using a digital balance. Sampling data obtained then conducted descriptive exploratory.

2.2.4 Average Body Weight (ABW)

Average Body Weight (ABW) is the average weight value per vanamei shrimp in one pond plot calculated at a certain period. ABW is calculated by random sampling data that has been done in vanamei shrimp ponds, and dividing the weight of vanamei shrimp by the number of vanamei shrimp (Pramudia *et al.*, 2022). ABW data obtained then performed exploratory descriptive.

$$\text{ABW} = \frac{Weight\ of\ all\ vaname\ shrimp\ (g)}{Number\ of\ vaname\ shrimp\ (shrimp)}$$

2.2.5 Average Daily Growth (ADG)

Average Daily Growth (ADG) is the average daily growth value of Vanamei shrimp. ADG is calculated by reducing the average weight per Vanamei shrimp in the second sampling with the average weight per Vanamei shrimp in the first sampling and divided by the number of sampling periods (Pramudia *et al.*, 2022). ADG data obtained then performed exploratory descriptive.

$$\text{ADG} = \frac{ABW\ II - ABW\ I}{t}$$

ABW I = ABW at first sampling (g)
ABW II = ABW in the second sampling (g)
t = first and second sampling periods (days)

2.2.5 Survival Rate (SR)

Survival Rate (SR) is the percentage of Vanamei shrimp survival rate during one culture cycle. SR is calculated by dividing the number of shrimp harvested by the number of initial stocking and then multiplied by 100%. The higher the SR percentage value obtained, the higher the survival rate of the Vanamei shrimp (Pramudia *et al.*, 2022). SR data obtained then performed exploratory descriptive.

$$\text{SR} = \frac{Total\ shrimp\ harvest}{Number\ of\ shrimp\ stocked} x\ 100\%$$

3. Results

3.1 Water Quality

3.1.1 Temperature

Temperature measurements were carried out for 23 days in ponds A5.1, A5.2, and A6.1, and for 7 days in pond A6.2, because total harvest had been carried out first. Temperature measurements were taken in the morning at 07:00 AM and in the afternoon at 16:00 PM, using a thermometer. Based on the observations of temperature measurements obtained in the four (ponds A5.1, A5.2, A6.1, A6.2) in the morning ranged from 24.2-27.2 °C with an average temperature of 26 °C. While the temperature measurement results in the afternoon ranged from 28.2-31.7 °C with an average temperature of 30.01 °C. The results of these measurements indicate that there is a temperature in the morning that is less than the optimal range of temperatures that support the growth and life of shrimp ranging from 27-32 °C (Farabi and Latuconsina, 2023).

3.1.2 Salinity

Salinity measurements were carried out for 23 days in ponds A5.1, A5.2, and A6.1, and for 7 days in pond A6.2, because a total harvest had been carried out first. Salinity measurements were taken in the morning at 07:00 AM and in the afternoon at 16:00 PM, using a refractometer. Based on the results of salinity measurements obtained in the four ponds in the morning ranged from 23-27 ppt with an average salinity of 25 ppt. While the results of salinity measurements in the afternoon ranged from 27-31 ppt with an average salinity of 29 ppt. The results of these measurements indicate that the number of salinity in the pond tends to exceed the optimal range of salinity that supports the growth and life of shrimp ranging from 15-25 ppt (Se *et al*., 2023).

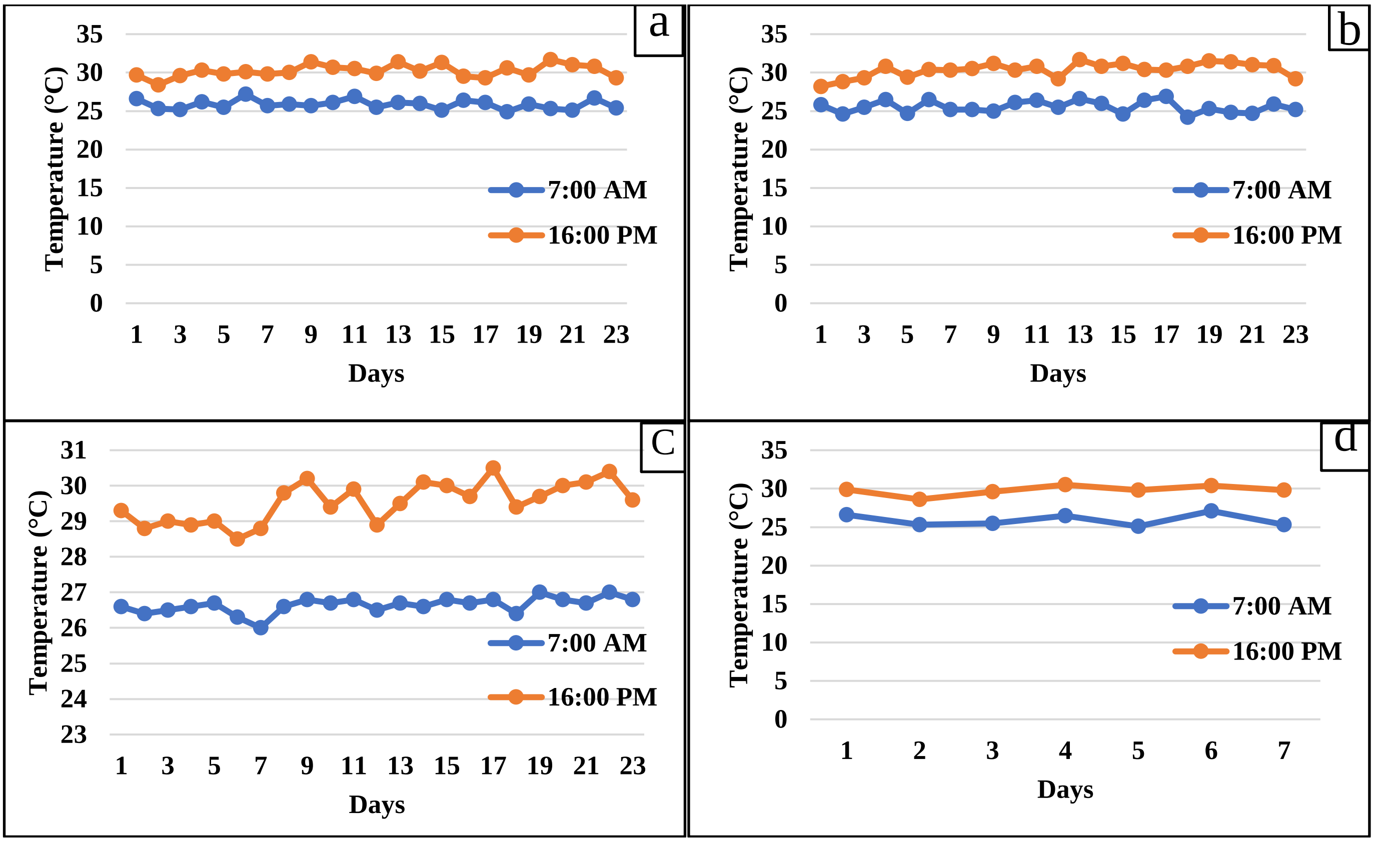

Figure 1. Graph of Temperature Dynamics at A5.1 (a), A5.2 (b), A6.1 (c), and A6.2 (d).

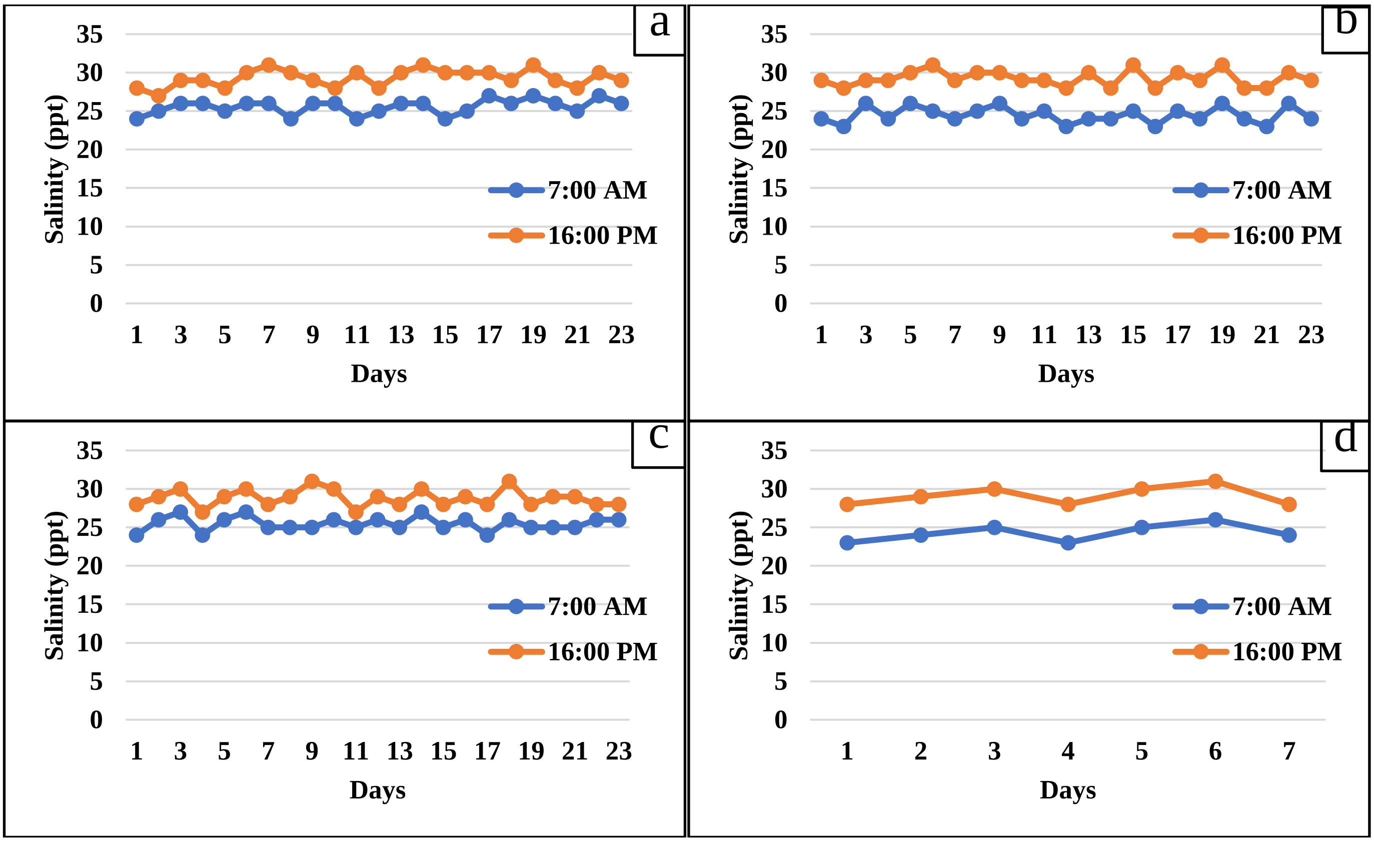

Figure 2. Graph of Salinity Dynamics at A5.1 (a), A5.2 (b), A6.1 (c), and A6.2 (d).

3.1.3 Dissolved Oxygen (DO)

Dissolved oxygen (DO) measurements were conducted for 23 days in ponds A5.1, A5.2, and A6.1, and for 7 days in pond A6.2, due to total harvesting. DO measurements were taken in the morning at 07:00 AM and in the afternoon at 16:00 PM, using a DO meter. Based on the results of DO measurements obtained, the four ponds in the morning ranged from 3.32-4.59 mg/L with an average DO of 4.07 mg/L. While the results of DO measurements in the afternoon ranged from 4.45-5.63 mg/L with an average DO of 5.08 mg/L. The measurement results show that there are DO levels in the morning that are less than the optimal range of DO that supports the growth and life of shrimp ranging from 4.5-7 mg/L (Janna *et al.*, 2022).

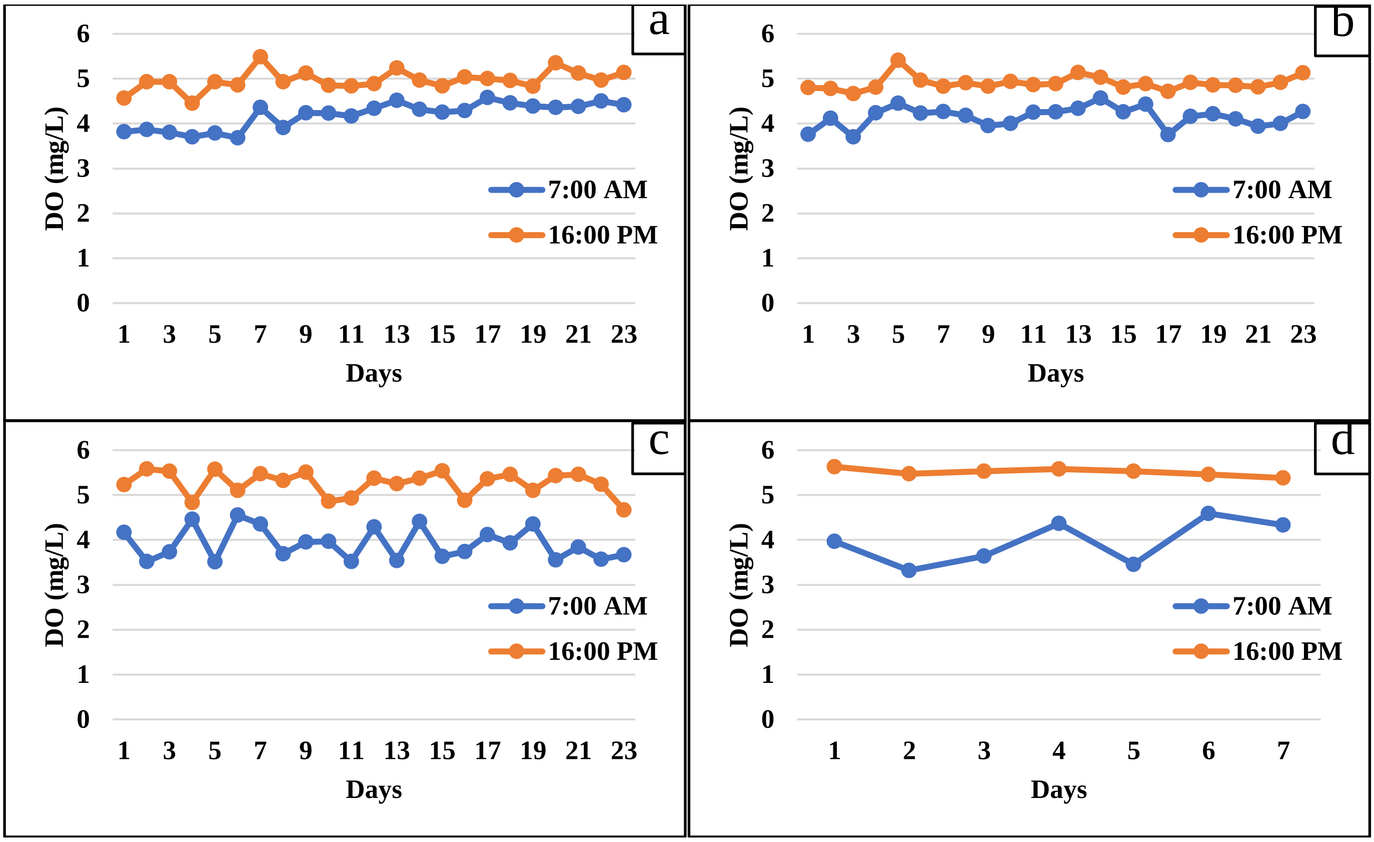

Figure 3. Graph of DO Dynamics at A5.1 (a), A5.2 (b), A6.1 (c), and A6.2 (d).

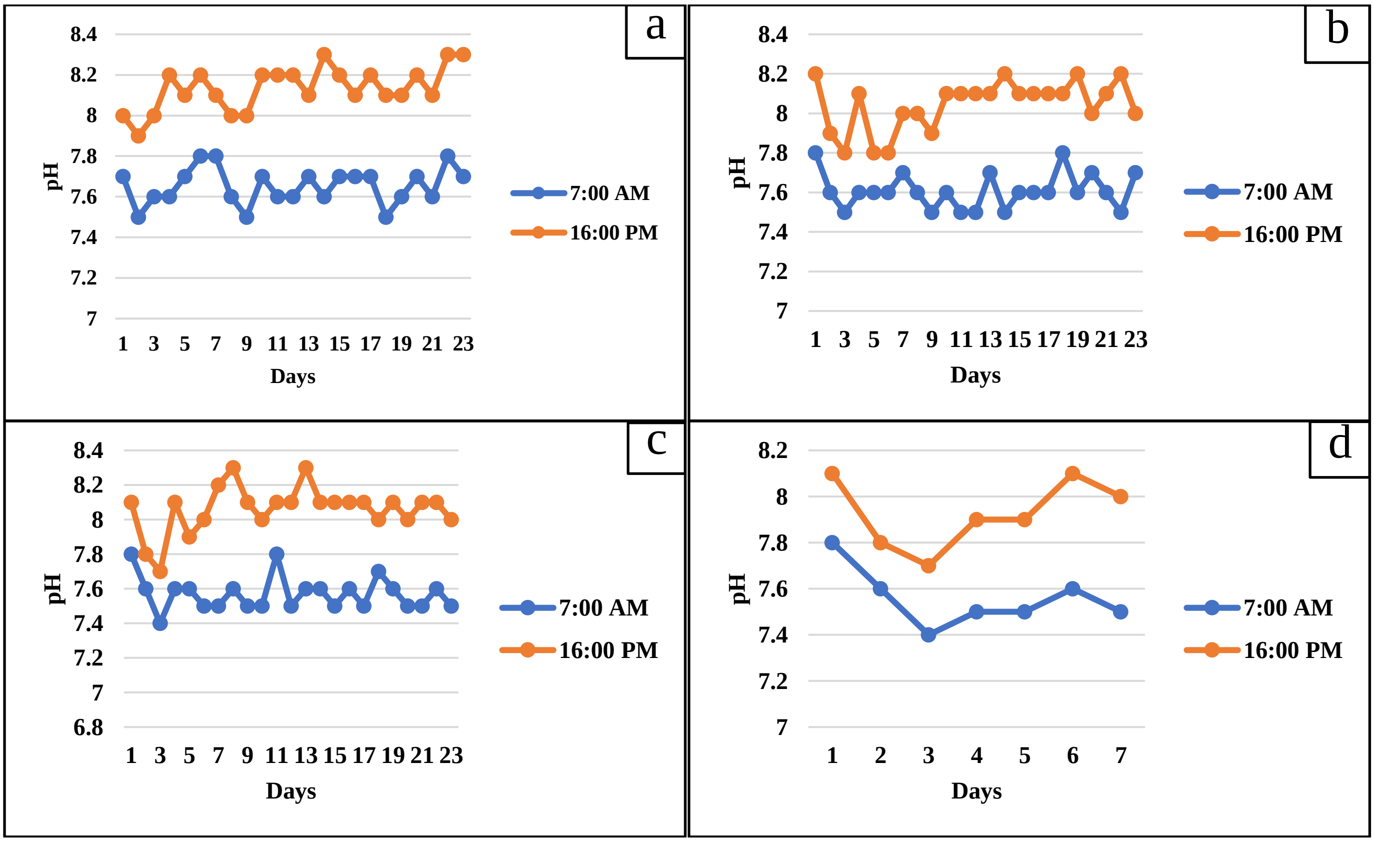

Figure 4. Graph of pH Dynamics at A5.1 (a), A5.2 (b), A6.1 (c), and A6.2 (d).

3.1.4 pH

pH measurements were carried out for 23 days in ponds A5.1, A5.2, and A6.1, and for 7 days in pond A6.2, due to total harvesting. The pH measurement was carried out in the morning at 07:00 AM and in the afternoon at 16:00 PM, using a pH meter. Based on the measurement results, the pH levels obtained by the four ponds in the morning were 7.4-7.8 with an average pH of 7.6. While the results of measuring pH levels in the afternoon ranged from 7.7-8.3 with an average pH of 8. The results of the pH numbers obtained are still in accordance with the optimal pH levels for Vanamei shrimp farming, which ranges from 7.5-8.5 (Setiyawan *et al.*, 2020).

3.2 Average Body Weight (ABW)

Based on random sampling activities that began at DOC 40 and carried out once a week in four Vanamei shrimp ponds, there was an increase in the value of Average Body Weight (ABW). In pond A5.1 there was an increase in ABW value of 15.10 gr/head during DOC 40 to DOC 106, with an average ABW value obtained is 11.06 gr/head. In pond A5.2 there was an additional ABW value of 16.93 gr/head during DOC 40 to DOC 106, with an average ABW value obtained of 11.78 gr/head. In pond A6.1 there was an increase in ABW value of 14.65 gr/head during DOC 40 to DOC 106, with an average ABW value of 10.48 gr/head. In pond A6.2 there was an increase in ABW value of 13.18 gr/head during DOC 40 to DOC 96, with an average ABW value obtained is 9.99 gr/head. Thus, of the four ponds, the highest increase in ABW value was in pond A5.2 and the lowest increase in ABW value was in pond A6.2.

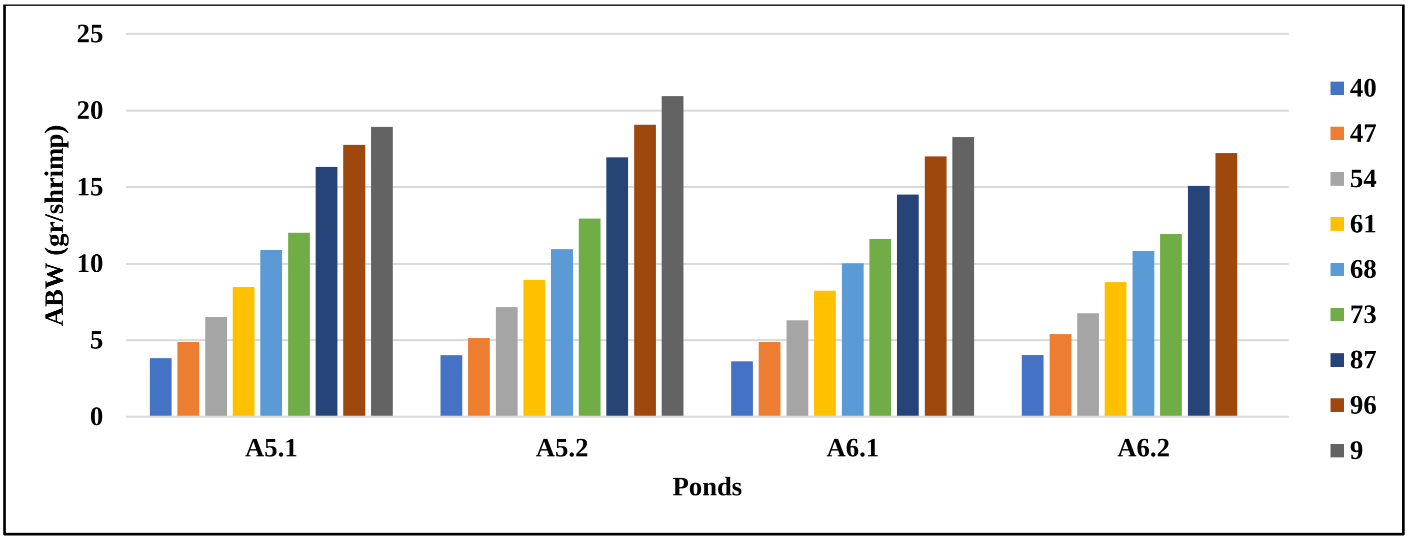

Figure 5. Comparison Chart of ABW of Shrimp Farm A5.6

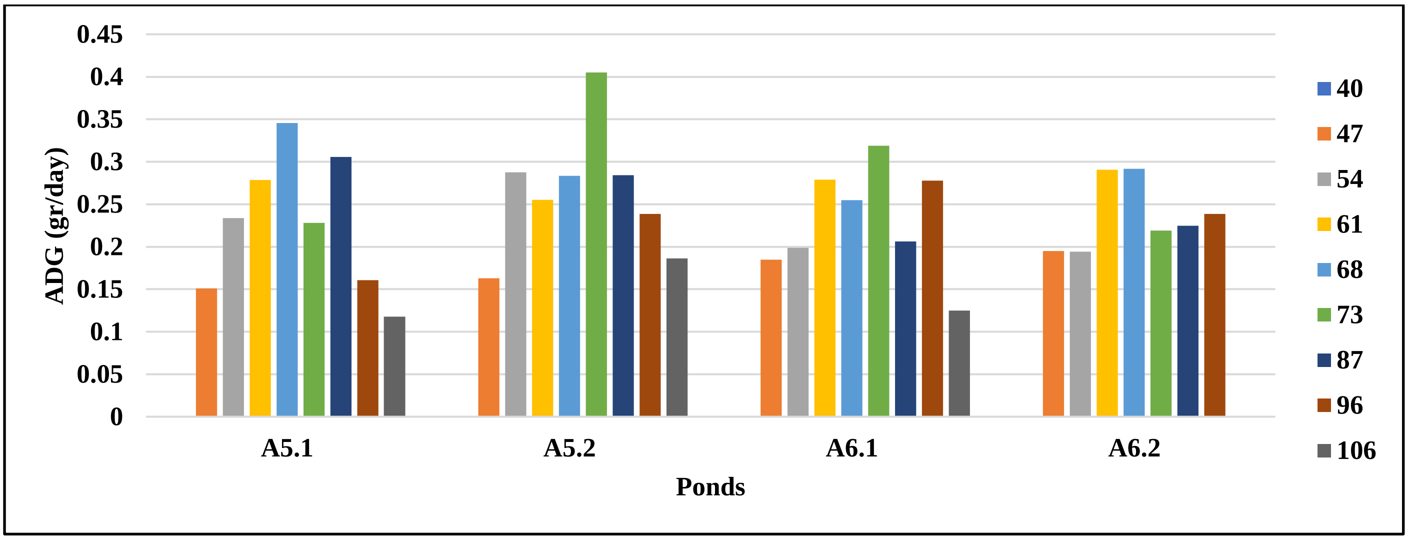

Figure 6. Comparison Chart of Shrimp Farm ADG A5.6

3.3 Average Daily Growth (ADG)

Based on random sampling activities that began at DOC 40 and carried out once a week in four Vanamei shrimp ponds, there was an increase in the value of Average Daily Growth (ADG). In pond A5.1 there was a decrease in ADG value by 0.033 gr/head during DOC 40 to DOC 106, with an average ADG value obtained is 0.22 gr/head. In pond A5.2 there was an increase in ADG value of 0.023 gr/head during DOC 40 to DOC 106, with an average ADG value obtained of 0.26 gr/head. In pond A6.1 there was a decrease in ADG value of 0.059 gr/head during DOC 40 to DOC 106, with an average ADG value obtained of 0.26 gr/head. In pond A6.2 there was an increase in ADG value of 0.043 gr/head during DOC 40 to DOC 96, with an average ADG value obtained is 0.23 gr/head. Thus, of the four ponds, the highest increase in ADG value was in pond A6.2 and the lowest increase in ADG value was in pond A6.1.

3.4 Survival Rate (SR)

The SR value obtained in pond A5.1 is 85.76%, pond A5.2 is 79.42%, pond A6.1 is 87.45%, and pond A6.2 is 72.41%. Of the four ponds, pond A5.1, pond A5.2, and pond A6.1 saw an increase especially in week 4 where there was a significant increase in SR value. While in pond A6.2 there was a decrease in SR value, which decreased by 13.02% during week 1 to week 3. Shrimp biomass in ponds A5.1, A5.2, and A.6.1 increased significantly, especially in week 4, with the largest increase in biomass found in pond A5.1 with an increase of 1682.2 kg. While in pond A6.2 there was a decrease in biomass starting from week 3 by 612.3 kg.

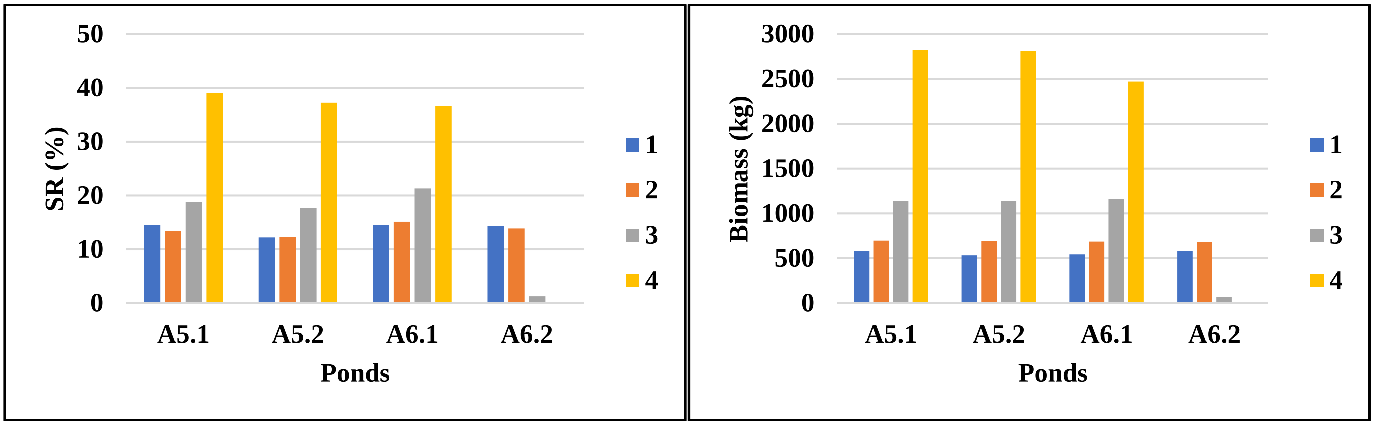

Figure 7. Comparison Chart of SR and Biomass of A5.6 Shrimp Pond per Week.

4. Discussion

4.1 Water Quality Parameters

Based on observations of the physical parameters of water quality (temperature, salinity, DO, and pH) in the four ponds, fluctuations can be seen in the resulting graph. In the temperature parameter, the highest value obtained was 31.7 °C in pond A5.2 in the afternoon water quality measurement. The temperature value almost reached the optimal limit of water quality in shrimp ponds. This is due to the penetration of sunlight to the surface faster than the deeper layers of water so that the use of pond wheels is needed so that the water temperature becomes more homogeneous (Farabi and Latuconsina, 2023). The lowest temperature value obtained was 24.2 °C in ponds A5.1 and A5.2, in the morning water quality measurement. The low temperature was caused by the release of heat during the night, and was also influenced by the cloudy conditions in the morning when measuring water quality (Sasmito *et al.*, 2021).

In the morning the measured salinity levels are lower than the salinity levels in the afternoon. The low salinity level in the morning can be influenced by checking the water during the siphoning and not yet filling the water. In the afternoon, the salinity levels of the four ponds exceeded the optimal number, reaching 31 ppt. High salinity levels in the afternoon can also be influenced by high irradiation factors during the day, which causes evaporation of seawater by sunlight which causes the concentration of salinity in pond water (Juniarti *et al.*, 2017).

The value of dissolved oxygen levels is influenced by several factors, such as the photosynthesis of plankton during the day that produces oxygen thereby increasing oxygen production in ponds (Suhendar *et al.*, 2020). Meanwhile, the decrease in oxygen levels in ponds is generally caused by algal blooms that generally occur at night due to the absence of photosynthesis processes, but the process of respiration that requires oxygen (Samadan *et al.*, 2020). The number of plankton that exceeds normal limits will cause competition for oxygen use so that DO levels will decrease. One of the efforts made in overcoming the decline in DO levels in ponds is the use of waterwheels (Baskoro *et al.*, 2020).

The optimal pH value is in the range of 7-8 (Aris *et al.*, 2022). Fluctuating pH values can cause stress to reduce growth rates and survival rates in Vanamei shrimp. High and low pH values are influenced by several factors, one of which is the concentration of CO^2 from the photosynthesis process (Imrana *et al.*, 2023). During the day, microorganisms perform photosynthesis by releasing O^2 and absorbing CO^2 so that pH values tend to be high, while at night microorganisms release CO^2 from the respiration process so that pH at night tends to be low (Supriatna *et al.*, 2020).

Through visual observation of the four ponds, there are differences in the colour of the pond water. In ponds A5.1 and A5.2, the appearance of dark green water colour is characteristic that the pond water is dominated by Chlorophyceae plankton species, while in ponds A6.1 and A6.2, the appearance of brownish turbid water colour is characteristic that the pond water is dominated by Bacillariophyceae plankton species (Aprilliani *et al.*, 2018). This is suspected because there are differences in water quality in chemical and biological parameters in the four ponds. So that observations of water quality in terms of chemical and biological parameters are also important to do.

4.2 Effect of Water Quality on Vanamei Shrimp Growth

Good water quality can produce optimal shrimp growth. Water quality parameters that were measured were temperature, salinity, DO, and pH. The pH levels obtained in the four ponds (ponds A5.1, A5.2, A6.1, A6.2) during the measurement were still in the range of normal pH levels for shrimp pond culture, namely 7.4-8.3. In all four ponds, the lowest temperature levels obtained in the morning during the measurements were lower than the optimal level of temperature in shrimp ponds, which is 24.2 °C. Low temperatures in shrimp ponds affect metabolism, such as can lead to decreased feed consumption, decreased shrimp growth, which results in decreased immunity of shrimp (Usman *et al.*, 2022). Low temperatures can cause shrimp to become less active and feed consumption becomes less which results in slowing shrimp growth. Decreased immunity in shrimp can cause shrimp to be more susceptible to disease.

Salinity levels in all four ponds were found to exceed optimal levels in the afternoon, reaching 31 ppt. Salinity values that exceed optimal levels are caused by seasonal changes. High levels of salinity in a shrimp pond that exceeds the optimal limit can cause inhibition of the molting process experienced in shrimp (Jayanti *et al.*, 2022). In all four ponds (ponds A5.1, A5.2, A6.1, A6.2), the lowest DO levels obtained in the morning during measurements were lower than the optimal level of temperature in shrimp ponds, which was 3.32 mg/L. Low DO levels in shrimp ponds can cause reduced dissolved oxygen in pond water needed by shrimp, so shrimp can experience stress. Low DO levels can also slow down the metabolic process of shrimp and shrimp growth. Low DO levels in ponds can make viruses and pathogenic bacteria to multiply and can attack shrimp.

In the descriptive analysis of ABW, ADG, and SR obtained from the four ponds, it can be seen that in ponds A5.1, A5.2, and A6.1 there was more significant growth of shrimp seen in the graph when compared to pond A6.2 which has decreased shrimp growth. This is thought to be due to the location of ponds A5.1 and A5.2 are located next to the water reservoir, so the water quality is better. The proximity of the pond to the water source reservoir can reduce the accumulation of harmful substances in the pond, which can interfere with the growth and health of shrimp. Water in reservoirs that have been sterilised with chlorine may contain fewer pathogens than contaminated water in ponds farther from the reservoir, reducing the risk of disease in shrimp (Naban *et al.*, 2023). The layout of the water pipe from the reservoir is also thought to affect water quality in shrimp ponds. The greater the distance between the pond and the water reservoir, the longer it takes for water to flow through the pipeline. In ponds that are farther from the water reservoir, as long as the water flowing through the pipeline can be contaminated by various factors such as pipe leaks, dirt, or even pathogens from the surrounding environment.

4.3 Effect of Water Quality on Vanamei Shrimp Health

Water quality has an influence on shrimp health. Pond A6.2 has decreased growth, this is caused by poor water quality in pond A6.2. The poor water conditions caused disease in Vanamei shrimp in pond A6.2, namely White Feces Disease. On direct observation of the four ponds, there was white shrimp faeces floating on the surface of the ponds that characterised White Feces Disease. In addition, there was also a decrease in appetite in pond A6.1 which was seen from the presence of quite a lot of remaining feed on the anco. White Feces Disease is a common disease in shrimp caused by *Vibrio* sp. The emergence of White Feces Disease can be caused by poor cultivation activities, poor seed quality, very high population density and lack of water management in shrimp ponds. This disease causes a decrease in appetite and discolouration of the intestine to a white colour (Ambarsari *et al.*, 2020). Decreased appetite in shrimp can have an impact on reduced growth. This was seen in random sampling in pond A6.2 where there was a decrease in shrimp biomass due to White Feces Disease. Shrimp infected by White Feces Disease can be influenced by the decline in shrimp body metabolism caused by poor water management and too high stocking density of 350,000 fish. The appearance of *Vibrio* sp. pathogenic bacteria in pond A6.2 can increase the risk of contamination in the other three ponds (A5.1, A5.2, and A6.1).

The use of chlorine is commonly used in Vanamei shrimp pond culture activities as a water steriliser to eliminate viruses or pathogenic bacteria in pond water, due to its relatively low price and ease of use (Khumaidi *et al.*, 2022). Although chlorine can be used to sterilise water, it is not fully effective in eliminating viruses or pathogenic bacteria in pond water. Through observations made during the study, there were many wild birds roaming around the pond location. The faeces of these birds can enter the ponds and water tanks and contaminate the water with viruses or pathogenic bacteria that may be present in the bird faeces. The design of the water reservoir at the study site is a rectangular open pond. This can lead to the introduction of external contamination into the water reservoir. So to prevent the influence of external contamination on the reservoir water, the reservoir design should be equipped with a cover to prevent contamination from rainwater and airborne dirt.

3 Conclusions

Through the observations that have been made, it can be concluded that water quality can affect the growth and health of vanamei shrimp, which can be seen in pond A6.2 which experienced a decrease in metabolism which resulted in the vulnerability of vaname shrimp to disease due to the influence of water quality that is not in accordance with the range of optimal levels. Good water management such as water change cycles and sterilisation and checking water quality are mandatory to prevent slowing the growth rate of shrimp.

Ethics approval

No permits were required.

Data availability statement

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

Author contributions

FA is doing research ideas, sample image collection, water quality sampling collection, FA, CRU and KFA are supervising and writing

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Declaration of competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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