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Analysis of the Relationship between Water Quality Parameters and Phytoplankton Communities on the Growth of *Litopenaeus vannamei* Post-Larvae in Low Salinity Circular Ponds

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Abstract

The global demand for *Litopenaeus vannamei*, a prized shrimp commodity, has witnessed substantial growth, positioning Indonesia as a key exporter. However, the expansion of shrimp ponds has raised ecological concerns, contributing to the depletion of mangrove ecosystems. This study investigates the feasibility of transitioning *L. vannamei* cultivation to low salinity freshwater, utilizing circular ponds as a sustainable alternative on marginal lands. Over a 30-day period, the research comprehensively analyzed water quality parameters, phytoplankton communities, and the growth of *L. vannamei* post-larvae. The study observed fluctuations in essential water quality parameters, including Dissolved Oxygen (DO), temperature, light intensity, pH, and salinity, all remaining within acceptable ranges. Phytoplankton abundance, notably dominated by Cyclotella, signified conducive conditions for optimal shrimp growth. Specific Growth Rate (SGR) calculations underscored substantial growth, revealing an average daily weight gain of 3.6±11.96%. The findings underscore the pivotal role of water quality in the successful cultivation of *L. vannamei*. The adoption of low salinity freshwater in circular ponds emerges as a practical and sustainable alternative, particularly on marginal lands. This study provides valuable insights into sustainable shrimp farming practices, addressing environmental concerns associated with traditional pond expansion. Moreover, the research aligns with the imperative to meet the escalating market demand for this economically significant commodity.

1. Introduction

Litopenaeus vannamei is a superior fisheries commodity that has reached an average world shrimp export volume of 91.7 thousand metric tons per year in the last decade, with an average annual growth rate of approximately 6.75%. In Indonesia, shrimp commodities rank first in the value of fisheries exports, with a total export value of 1,302,330,215.54 USD and a volume of 147,164.7 tons. The high market demand for shrimp commodities has led to the intensive cultivation of shrimp in coastal ponds. Currently, the shrimp pond area in Indonesia has reached 300 thousand hectares, with a production of about 1 ton of shrimp per hectare (Rizky *et al.*, 2020).

The growth of shrimp ponds has been a major factor in the loss of 35% of mangrove ecosystems in the early 1990s (Ahmed *et al.*, 2018). de Lacerda *et al.* (2021) explained that extensive shrimp cultivation in coastal areas can cause serious problems, including erosion, floods, and significant mangrove forest land conversion. Marginal lands such as former mining areas, spodosol soil, land with peat layers, degraded land, and unproductive land (Saragih *et al.*, 2018) can be an alternative for shrimp pond construction. This is due to the low quality of the land for agriculture, the lack of crop yield potential, and its inability to support plant growth. However, the implementation of shrimp pond construction on marginal land often faces challenges, especially if the land is far from the sea source.

The transition of *L. vannamei* cultivation from brackish water to low salinity freshwater has the potential to be applied in Indonesia, considering that some regions in Indonesia have ponds with low salinity, approaching 0 ppt (Anisa *et al.*, 2021). Cultivating *L. vannamei* at low salinity has specific advantages, such as its ability to suppress the development of Vibrio bacteria, as these bacteria do not thrive in freshwater (Hilyana *et al.*, 2023). To support *L. vannamei* cultivation with limited land and the use of low salinity, the circular pond method can be an effective alternative solution. Savianus *et al.* (2023) explained that the circular pond model tends to be practical and does not require extensive land. This circular pond has flexibility for easy installation adjustment to land conditions, making it suitable for household-scale cultivation. Additionally, Rizky *et al*. (2022) explained that the aeration system in circular ponds is more efficient as water movement is more even without angles that can obstruct water flow. The management of these low salinity circular ponds must pay attention to water quality. Akbarurrasyid *et al*. (2022) explained that changes in water quality affect the phytoplankton community structure.

Phytoplankton abundance is an important indicator that describes water conditions and shrimp growth and can be used as a reference to measure cultivation success. Therefore, the analysis of water quality parameters and phytoplankton communities in low salinity circular ponds is crucial to understanding the growth of *L. vannamei* post-larvae. The aim of this research is to measure and analyze water quality parameters, measure and calculate the growth of Post Larvae *L. vannamei*, and calculate and identify the phytoplankton community in low salinity round ponds.

2. Material and methods

2.1 Material

The equipment includes a DO meter, pH meter, Lux meter, refractometer, microscope, beaker, centrifuge tube, hemocytometer, measuring glass, pipette, glass slide, and analytical balance. Laboratory materials consist of *L. vannamei* larvae as the researched sample, 70% alcohol for sterilizing equipment, 8% formalin for preserving phytoplankton samples, and labels for marking containers and materials.

2.2 Methods

The research method employed in this research is the descriptive analysis method. The collected data will be analyzed descriptively based on the facts as they are, without any manipulation. Water quality parameters are measured daily in the morning and afternoon, phytoplankton measurements are conducted bi-weekly, and the weight measurement of Post Larva *L. vannamei* is carried out at the initial stocking and on the 30th day.

2.3 Measurement of Water Quality Parameters

The water quality parameters measured include pH, salinity, temperature, light intensity, and dissolved oxygen (DO). These five parameters are measured using a pH meter, DO meter, Lux meter, and refractometer. Measurements are taken in the morning at 07:00 WIB and in the afternoon at 16:00 WIB. The procedures for water quality measurement and examination of *L. vannamei* adhere to SN 8037.1:2014 (Janna *et al*., 2022).

2.4 Phytoplankton Sampling

Phytoplankton sampling is conducted bi-weekly in stages on 14 days and 28 days. Water samples used to identify phytoplankton are placed in a centrifuge tube bottle, adding 5 ml of 8% formalin. The sample is labeled according to the collection date.

2.5 Calculation of Phytoplankton Density

Samples from the centrifuge bottle are taken using a dropper pipette in triplicate into a hemacytometer. The sample in the hemacytometer is covered with a cover slip and observed using a microscope to determine the density and types of phytoplankton with a magnification of 10x10 (Arifin and Arisandi, 2020). Phytoplankton calculation with a hemacytometer uses 5 fields of view divided into 4 parts. The total phytoplankton cell in the four fields of view is averaged and calculated as a part (n). The formula for the total phytoplankton density is: $n \times 10^4$ cells/ml.

2.5 Post Larva *L. vannamei* Sampling

Sampling is conducted at the beginning and end of the study to determine the growth rate of Post Larva *L. vannamei* weight. Post Larva *L. vannamei* sampling is carried out in the morning to minimize stress on shrimp due to temperature changes. Samples are taken with a scoop and weighed using an analytical balance (Usman *et al*., 2022). After measuring body weight, the Specific Growth Rate (SGR) is calculated to determine shrimp growth every day during the study period. The shrimp growth rate can be measured with the following formula:

$$SGR\ (\%) = \frac{\ln(Wt) - \ln(Wo)}{t} \times 100\%$$

Where: SGR = Daily Growth Rate (%)

Wt = Average body weight at the end of cultivation (gr)

Wo = Average body weight at the beginning of cultivation (gr)

t = Duration of cultivation.

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3. Results

3.1 Water Quality Parameter Measurements

The study presents observations on the physical and chemical parameters of *L. vannamei* pond water, encompassing temperature, salinity, pH, Dissolved Oxygen (DO), and light intensity over a 30-day period in both morning and evening sessions, illustrated in Figures 1-5.

Analyzing the data for the Dissolved Oxygen (DO) parameter in Figure 1, a notable fluctuation in DO values is evident throughout the observation period. DO levels peaked at 9.0 mg/L in the morning and 8.26 mg/L in the evening. However, following this zenith, a sharp decline occurred in the evening, reaching the lowest recorded DO value of 4.93 mg/L.

The results for water temperature exhibit significant variations during the measurement period, as shown in Figure 2. Daily water temperature tends to remain stable, with the highest morning temperature recorded at 30.4 °C and the lowest in the morning at 27.4 °C. Similarly, the highest evening temperature reached 33.2 °C, while the lowest evening temperature was 29.8 °C.

The assessment of the water quality parameter, light intensity (Figure 3), reveals variations during the measurement period. Graphical analysis suggests a higher morning light intensity compared to the evening. The peak morning light intensity recorded was 67500 lux, with the lowest intensity at 21600 lux, sharply rising to 60500 lux. Conversely, light intensity in the evening exhibited more stable variations, with the highest recorded at 28700 lux and the lowest at 1372 lux.

The pH values, examined in Figure 4, exhibit significant variations during the measurement period. Evening pH values tend to be higher than morning pH values. The peak morning and evening pH values were recorded at 8.73 and 9.17, respectively. The lowest morning pH was 7.81, while the lowest evening pH was 7.95.

Salinity, presented in Figure 5, displayed stable variations during the measurement period, with salinity measuring 5 ppt in both morning and evening and slightly reaching 6 ppt.

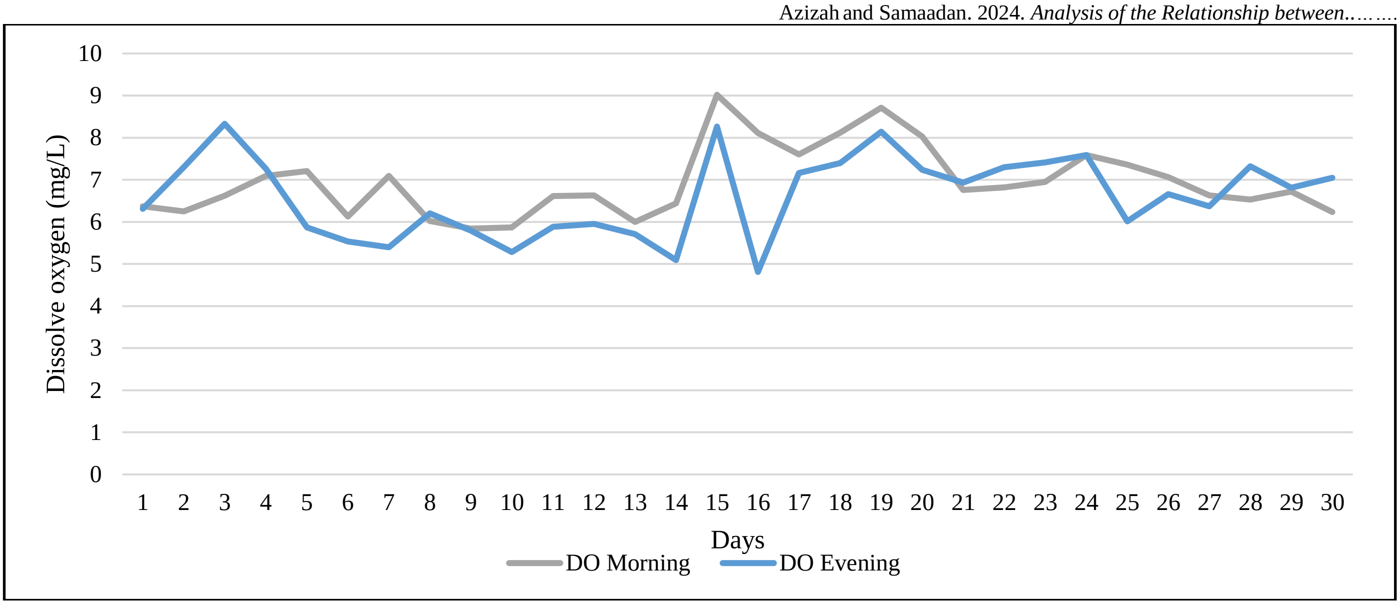

Figure 1. Dissolved Oxygen (DO) Water Quality Parameter in the Morning and Evening.

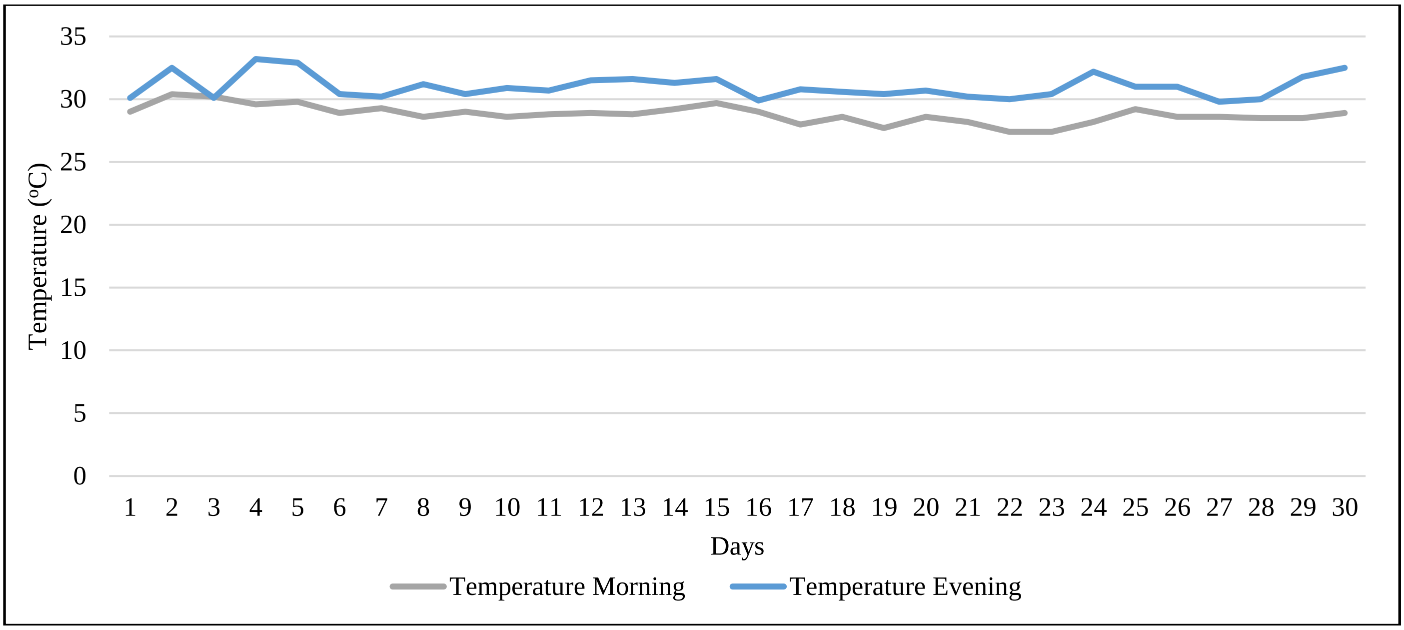

Figure 2. Temperature Parameter in the Morning and Evening.

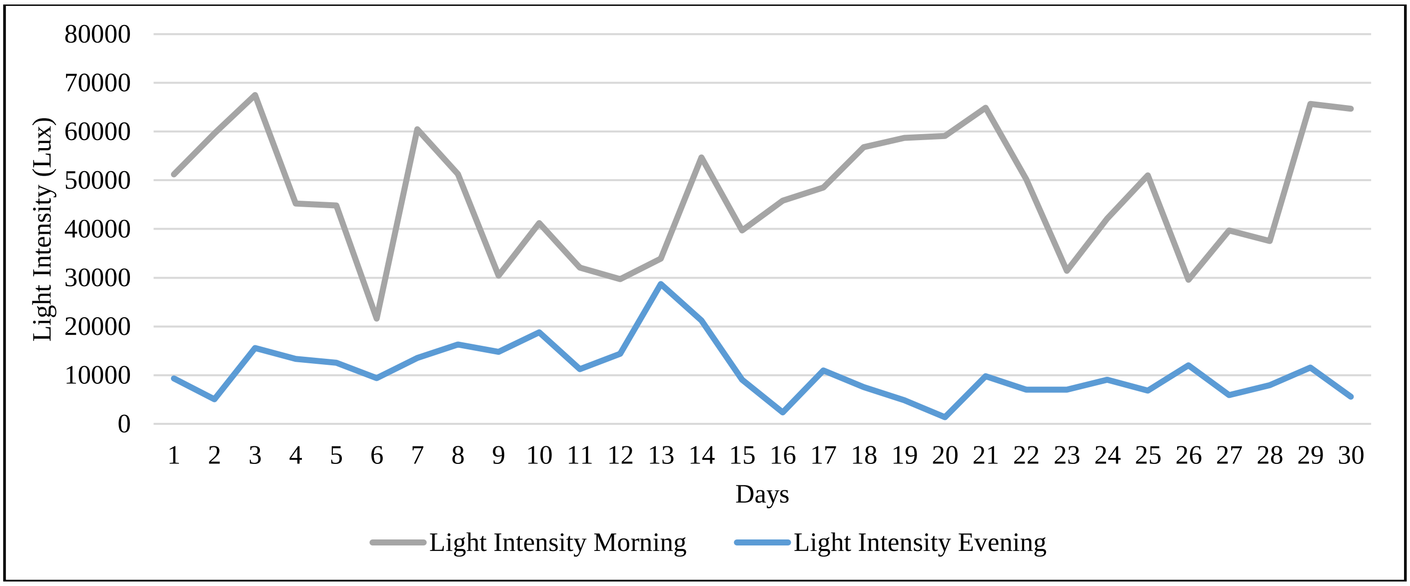

Figure 3. Light Intensity Parameter in the Morning and Evening.

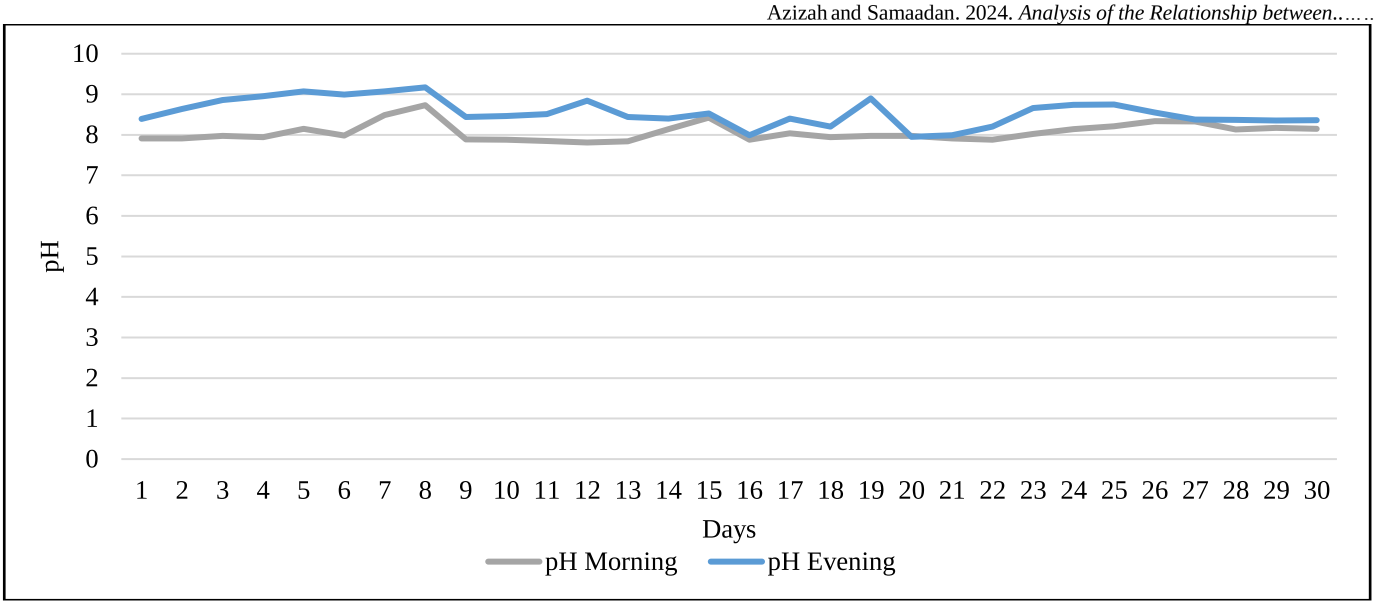

Figure 4. pH Parameter in the Morning and Evening.

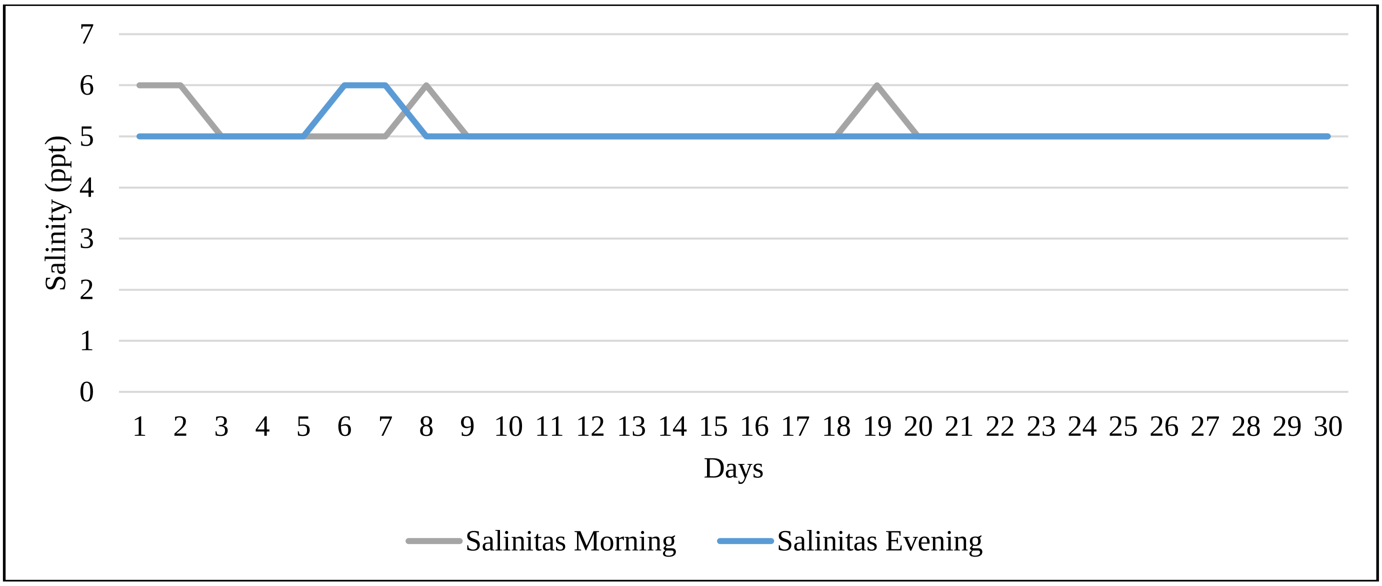

Figure 5. Salinity Parameter in the Morning and Evening.

3.2 Phytoplankton Density

Based on the calculation of phytoplankton density, the results for day 14 and day 28 with three replications are presented in Table 1. The observed phytoplankton genera include *Cyclotella* sp., *Scenedesmus* sp., *Microcytis* sp., and *Rhizosolenia* sp. After 14 days, the total abundance of phytoplankton reached 540.73 ± 61.19 x 10^4 cells/ml, where *Cyclotella* sp. dominated with an abundance of 525.92 ± 66.97 x 10^4 cells/ml, while *Scenedesmus* sp., *Microcytis* sp., and *Rhizosolenia* sp. had abundances of 0, 11.11 ± 0.00 x 10^4 cells/ml, and 11.11 ± 0.00 x 10^4 cells/ml, respectively. After 28 days, there was a significant change in the total abundance of phytoplankton to 185.18 ± 23.13 x 10^4 cells/ml. At this stage, *Cyclotella* sp. still dominated with an abundance of 140.74 ± 35.71 x 10^4 cells/ml, while *Scenedesmus* sp., *Microcytis* sp., and *Rhizosolenia* sp. had abundances of 11.11 ± 0.00 x 10^4 cells/ml each.

3.3 Specific Growth Rate (SGR) of the weight of *L. vannamei* post-larvae

The Specific Growth Rate (SGR) calculation for the weight of *L. vannamei* post-larvae over a period of 30 days indicates an average weight gain of 4.06 ± 0.47 grams and an SGR of 20.00 ± 0.40% per day (Table 2).

Table 1. Results of Phytoplankton Density

Genus	Total (x 10^4 cells/ml) 14 Days	28 Days
Cyclotella sp.	525.92 ± 66.97	140.74 ± 35.71
Scenedesmus sp.	0.00 ± 0.00	11.11 ± 0.00
Microcytis sp.	11.11 ± 0.00	0.00 ± 0.00
Rhizosolenia sp.	11.11 ± 0.00	11.11 ± 0.00
Total abundance	540.7333 ± 0.00	185.18 ± 23.13

Table 2. Specific Growth Rate (SGR) Calculation of *Litopenaeus vannamei* Post-Larvae Weight

Average initial weight (gr)	Average final weight (gr)	SGR (%)
0.01 ± 0.00	4.06 ± 0.47	20.00 ± 0.40%

4. Discussion

Quality of water plays a crucial role in the cultivation of *L. vannamei*. The optimal growth of *L. vannamei* is achievable when it is in suitable water quality conditions. Observations indicate fluctuations in the water quality of *L. vannamei* due to environmental factors and aquaculture activities. Dissolved Oxygen (DO) in pond water quality data shows values ranging from 4.93 mg/L to 9.0 mg/L. This range is considered favorable for aquatic biota growth, aligning with the recommended DO values for ponds of 3 mg/L to 10 mg/L, with an optimum range of 4 mg/L to 7 mg/L (Umami *et al*., 2018). DO levels are influenced by the photosynthesis rate generated by phytoplankton, as plankton thrive well at concentrations above 3 mg/L (Armiani and Harisanti, 2021). DO values are also linked to temperature, as a 1°C increase results in around a 10% rise in oxygen consumption, leading to reduced oxygen solubility.

Temperature fluctuations during the cultivation period exceeded the optimal water temperature for shrimp growth slightly, reaching 33.2°C in the evening. According to Supriatna *et al.* (2020), the optimal temperature range for shrimp growth is between 26°C and 32°C. Exceeding the optimum temperature can accelerate shrimp metabolism. The higher evening water temperature may be due to differences in sunlight penetration received by the water body. This disparity causes temperature values to differ based on the measurement time. Evening temperatures are relatively higher than morning temperatures, as they receive sunlight for a longer duration. Temperature is a limiting factor for phytoplankton distribution, affecting their survival rate, fecundity, development, and competition. Generally, phytoplankton photosynthesis rate increases with rising water temperature. The abundance of phytoplankton during the observation period was dominated by the genus *Cyclotella*, a diatom known to thrive in the temperature range of 20-30 °C (Akbarurrasyid *et al*., 2022).

Light intensity parameter also influences water temperature. The higher the light intensity, the higher the water temperature. Morning light intensity ranged from 21,600 lux to 67,500 lux, while evening light intensity ranged from 1,372 lux to 28,700 lux. According to Tao *et al*. (2021), sunlight intensity of 20,000-30,000 lux is effective for shrimp larvae metamorphosis in freshwater. Light intensity also affects the existing phytoplankton in the water, as light serves as an energy source for photosynthesis and influences phytoplankton distribution.

Water pH values can affect shrimp growth by influencing nutrient availability. Naturally, water pH is influenced by CO2 concentration and acidic compounds. Water pH significantly determines phytoplankton dominance, as they consume oxygen during respiration, producing CO2 at night, causing a decrease in water pH. A decrease in pH corresponds to higher CO2 levels due to increased formation of carbonic acid (H2CO3). Rising CO2 levels also coincide with decreased oxygen in the water. Conversely, pH values increase during the day due to photosynthesis. Generally, neutral pH is preferred by blue-green algae, such as *Microcytis*, which favors pH in the neutral to alkaline range and exhibits negative growth responses to acidity. Throughout the observation period, morning pH values ranged from 7.81 to 8.73, and evening pH values ranged from 7.95 to 9.17. The highest evening pH exceeded the optimum value for shrimp growth, i.e., 7.0-8.5 (Supriatna *et al*., 2020), potentially due to photosynthesis processes by phytoplankton occurring during the day.

L. vannamei cultivation is carried out using low salinity due to land limitations. Salinity results during the observation showed stable variations, dominated by 5 ppt. The use of low salinity affects species tolerance levels, growth, changes in feeding behavior, and the phytoplankton community in the pond.

Overall, four phytoplankton genera were found during the observation period: *Cyclotella*, *Mycrocitis, Scenedesmus, and Rhizosolenia*. These genera inhabit freshwater or low salinity environments and serve as a food source for shrimp. Phytoplankton density was dominated by *Cyclotella* at 1577.76 cells/ml. *Cyclotella* is a diatom that tends to thrive in freshwater with low salinity. Diatoms, including *Rhizosolenia*, have high species composition because of their ability to live in freshwater and brackish water environments. In aquatic environments, *Rhizosolenia* plays a role in increasing CO2 and producing oxygen through photosynthesis. *Scenedesmus* is a green algae phytoplankton that forms the basis of the freshwater environmental food chain. Meanwhile, the *Microcytis* genus is a blue-green algae phytoplankton. Cahyono *et al*. (2023) explain that blue-green algae can survive at a pH greater than 8.3, placing *Microcytis* within the range of cultivation pH results. However, *Microcytis* can produce various toxins, influencing water quality.

Based on the relationship between water quality parameters and phytoplankton communities, it appears to affect the growth of *L. vannamei* post-larvae. The initial weight of post-larvae was 0.01 grams, and the SGR on day 30 was 11.96% per day. This biomass increase affects the minimum oxygen requirements in the water. Dissolved oxygen will carry nutrients and distribute them throughout the shrimp's body, leading to increased growth. This is because an increase in nutrition means more energy consumed by shrimp, resulting in increased growth (Wahyuni *et al*., 2022). This condition indicates that good water quality is related to phytoplankton and can influence the growth of *L. vannamei*.

5. Conclusions

Water quality parameters show variable fluctuations, but overall, the results are within the optimal range for the growth of *L. vannamei* larvae. Post Larva *L. vannamei* experienced significant growth on day 30 with an average weight gain of 4.06 ± 0.47 grams and an SGR of 20.00 ± 0.40% per day, while the four phytoplankton communities present, namely from the genera *Cyclotella, Rhizosolenia, Mycrocitis*, and *Scenedesmus*, were dominated by the abundance of *Cyclotella*.

Ethics approval

No need permit to Post Larva *L. vannamei*.

Data availability statement

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

Credit authorship contribution statement

Kartika Nur Azizah: writing original draft preparation, visualization, project administration and data collecting. Gamal M Samaadan: Conceptualization, methodology, validation, investigation, resources, formal analysis, funding acquisition writing original draft preparation, writing review and editing, supervision, visualization. Both authors have read and agreed to the published version of the manuscript.

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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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