

Dynamics of Phytoplankton Abundance on the Growth of Pacific whiteleg shrimp *Penaeus vannamei*

Asmi Al Husnyah Rukmana¹⁾, Wiyoto Wiyoto^{1*)}, Sigid Ary Santoso²⁾, Dian Eka Ramadhani¹⁾, Mohamed Elsayed Megahed³⁾



Abstract

Fluctuations in pond water quality parameters can result in low survival rates and suboptimal shrimp growth, ultimately affecting production targets. One key factor influencing water quality is the presence of phytoplankton. This study aimed to analyze the dynamics of phytoplankton abundance and composition and their potential impact on the specific growth rate of Pacific whiteleg shrimp. The methodology involved water sampling, identification and quantification of phytoplankton abundance, water quality measurement, and shrimp growth assessments. In the B5 pond, phytoplankton abundance ranged from $4.78 \pm 4.35 \times 10^5 \text{ mL}^{-1}$ cells. Similarly, the B6 pond showed an abundance of approximately $4.14 \pm 2.14 \times 10^5 \text{ mL}^{-1}$ cells while the B7 pond ranged from $5.05 \pm 3.57 \times 10^5 \text{ mL}^{-1}$ cells. Phytoplankton abundance fluctuated across all ponds, with their composition was in accordance with standard requirements. However, results from the Pearson correlation test indicated no direct relationship between phytoplankton abundance and the specific growth rate of the shrimp.

Keywords: abundance, pacific whiteleg shrimp, phytoplankton, specific growth rate.

¹⁾ Technology and Management of Applied Aquaculture Study Program, College of Vocational Studies, IPB University, Bogor 16128

²⁾ PT. Hasil Sukses, Situbondo, Indonesia 68353

³⁾ National Institute of Oceanography & Fisheries (NIOF), Cairo, Egypt 4262110

^{*} Correspondence author
Email:
wiyoto@apps.ipb.ac.id
Kumbang St. No.14, Bogor City, Indonesia 16128

Received: 06 Sept 2024

Revised: 10 Oct 2024

Accepted: 10 Oct 2024

<https://doi.org/10.29244/java.v1i1.59424>

I. INTRODUCTION

Shrimp is a key export commodity for Indonesia, with major export destinations including the United States, the European Union, Japan, and several Asian countries (Rosyidah *et al.*, 2020). Among the various species cultivated, the Pacific whiteleg shrimp (*Penaeus vannamei*) is widely farmed in Indonesia. Indonesia ranked as the fourth-largest shrimp exporter globally, following India, Ecuador, and Vietnam. Shrimp production reached 881,599 tons in 2020 and increased slightly to 884,939 tons in 2021 (DJPB, 2021). Global shrimp market competition is becoming increasingly intense, necessitating efficient and competitive domestic production to maintain Indonesia's market share. The increase in Pacific whiteleg shrimp production

is supported by the advantages of Pacific whiteleg shrimp including high economic value (Dahlan *et al.*, 2019), which ranges from Rp 43,000–Rp 70,000 kg⁻¹ for size 50–70 in the East Java area, depending on the size (Rosyidah *et al.*, 2020), fast growth rate, low feed conversion ratio, high stocking density (Syaifullah, 2018), and nonborrowing habit (Wiyoto *et al.*, 2022).

Several factors influence shrimp growth, including feed management (Ritonga *et al.*, 2021), water quality (Akbarurrasyid *et al.*, 2022), sediment quality (Wiyoto *et al.*, 2016), and stocking density (Rakhfid *et al.*, 2018). Water quality is a factor that affects the growth of Pacific whiteleg shrimp, because

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fluctuations in various water quality parameters in the water of shrimp growth can lead to low survival, suboptimal shrimp growth and ultimately, failure to meet production targets (Supriatna *et al.*, 2020).

Water quality is a crucial factor in Pacific whiteleg shrimp farming (Akbarurrasyid *et al.*, 2022). Key water quality parameters that significantly impact shrimp growth include temperature and dissolved oxygen levels. Stable temperatures with minimal fluctuations positively influence shrimp growth by enhancing their appetite (Ilham *et al.*, 2021). Another water quality parameter is dissolved oxygen which is required for respiration, metabolism and provides energy for growth and reproduction (Wahyuni *et al.*, 2022).

Dissolved oxygen levels in pond water are influenced by the presence of phytoplankton, which generate oxygen through photosynthesis (Liwutang *et al.*, 2013). Monitoring the abundance and composition of phytoplankton is essential in Pacific whiteleg shrimp farming to prevent harmful algal blooms caused by certain phytoplankton species.

Phytoplankton abundance is affected by several factors including phytoplankton composition, organic matter, and water salinity. The study aimed to analyze the dynamics of phytoplankton abundance and composition and their impact on the specific growth rate of Pacific whiteleg shrimp.

II. MATERIALS AND METHODS

2.1 Phytoplankton Sampling

Data collection in this study involved three Pacific whiteleg shrimp ponds with with sampling conducted at three specific points in each pond: the inlet, the anco bridge, and the outlet. Water sampling was performed twice daily at 05.00 and 13.30 WIB. during periods of low or high dissolved oxygen levels to analyze the dynamics of plankton abundance (Masithah *et al.*, 2018). The sampling method involved securing a bottle to a Secchi disk and lowering it vertically into the pond to collect water samples.

Water samples were collected at a depth of 50 cm below the water surface (Akbarurrasyid *et al.*, 2022). A 250 mL water sample was placed in a sample bottle for laboratory observation and identification. To preserve the sample, 5 drops (0.25 mL) of 1% Lugol solution were added (Winarsih and Susanto, 2023), and the mixture was then homogenized.

2.2 Identification and Calculation of Phytoplankton

Abundance

The identification of phytoplankton species and the calculation of phytoplankton abundance were conducted using an Olympus CX-22 microscope. Preserved samples (1 mL) were extracted using a dropper pipette, and a single drop (0.05 mL) was placed onto a Neubauer Improved hemocytometer. A 30 mm × 30 mm glass cover slip was then applied. Observations were made under a microscope using a 10× ocular lens and a 40× objective lens. Phytoplankton species were identified based on a reference guidebook for genus identification and the Web Culture Collection of Algae and Protozoa (CCAP).

Phytoplankton abundance was calculated using the sweep method (Apriadi *et al.*, 2021), which involves counting all areas using the hemocytometer. Identification of phytoplankton species was conducted simultaneously during the abundance calculation process using the same tool. The abundance of phytoplankton was expressed in cells mL⁻¹ using the following formula:

$$N = n \times 10^4$$

N : phytoplankton abundance (cells mL⁻¹)

n : phytoplankton cells number observed (cells)

2.3 Shrimp Growth Sampling

SShrimp growth was sampled every five days, with sampling activities conducted at 05:00 WIB. Sampling was performed at two points in each pond, one on each side facing the designated areas. The sampling method involved using cast nets followed by weighing with buckets and digital scales. The number of shrimps was then counted to calculate the specific growth rate (SGR), average daily growth (ADG), and average body weight (ABW). The data sampling results were recorded in a notebook and calculated using a calculator. The formula for the specific growth rate parameters (Zokaeifar *et al.*, 2012) Average Daily Growth, and Average Body Weight (Alfizar *et al.*, 2021) are as follows:

$$SGR = \frac{\ln W_t - \ln W_0}{t} \times 100$$

Description:

SGR : specific growth rate (% day⁻¹)

W_t : average weight at time t (g shrimp⁻¹)

W₀ : average weight at time 0 (g shrimp⁻¹)

t : observation period (days)

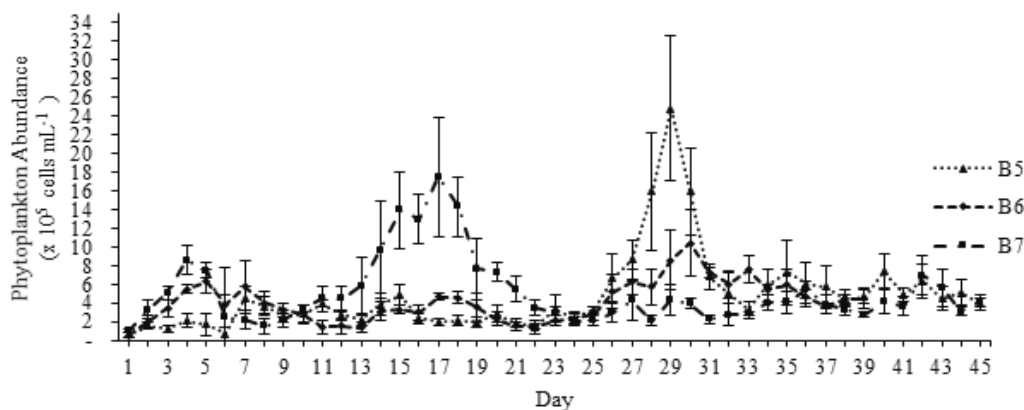


Figure 1. Phytoplankton abundance during the 45-day rearing period in Pacific whiteleg shrimp *Penaeus vannamei* ponds

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

Description:

- ADG : average daily growth (g day⁻¹)
- ABW II : average body weight at the time of second sampling (g shrimp⁻¹)
- ABW I : average body weight at the time of first sampling (g shrimp⁻¹)
- t : Observation period (day)

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

2.4 Water Quality

Daily water quality parameters were observed in situ, including temperature using an Hg thermometer, water transparency using a Secchi disk, dissolved oxygen using a DO Meter (YSI 550A), water color, water level, and weather conditions, all recorded visually during water sampling. Ex situ measurements included pH, which was measured using a pH meter (Hanna Instrument HI98107) with a range of 0–14, and salinity, which was measured using a refractometer (Trans Instrument) with a range of 0–100 g L⁻¹. The water quality parameters observed weekly included nitrite, nitrate (measured using a test kit, Salifert, with a range of 0–1 mg L⁻¹), phosphate (measured using a test kit, Salifert, with a range of 0–3 mg L⁻¹), ammonia (measured using a test kit, Monitor), alkalinity, and total organic matter (TOM), which was measured using the titrimetric method (SNI, 2004).

2.5 Data Analysis

Data were processed using Microsoft Excel 2016. The relationship between phytoplankton abundance and the specific growth rate of Pacific whiteleg shrimp was tested for normality, followed by a Pearson correlation

test using SPSS version 27.0. Water quality parameters were analyzed descriptively.

III. RESULT

3.1. Phytoplankton Abundance and Composition

Daily phytoplankton abundance fluctuated in all ponds. Daily phytoplankton abundance in pond B5 was $4.78 \pm 4.35 \times 10^5$ cells mL⁻¹. Phytoplankton abundance on day 29 reached the highest value of 2.47×10^6 cells mL⁻¹. The phytoplankton abundance on the 30th day began to decline and tended to stabilize until the observation day was completed on the 45th day. Phytoplankton abundance in pond B6 was $4.14 \pm 2.14 \times 10^5$ cells mL⁻¹, and on the 30th day phytoplankton abundance reached the highest value of 1.04×10^6 cells mL⁻¹. Pond B7 has a phytoplankton abundance value of $5.05 \pm 3.57 \times 10^5$ cells mL⁻¹. Phytoplankton abundance on day 17 reached the highest value of 1.74×10^6 cells mL⁻¹ and began to stabilize until day 45. The daily phytoplankton abundance data for 45 days are presented in graphically in Figure 1.

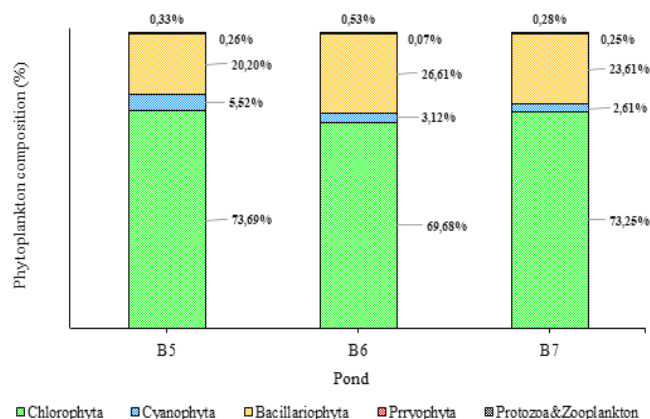


Figure 2. Phytoplankton composition during the 45-day rearing period in the Pacific whiteleg shrimp *Penaeus vannamei* pond

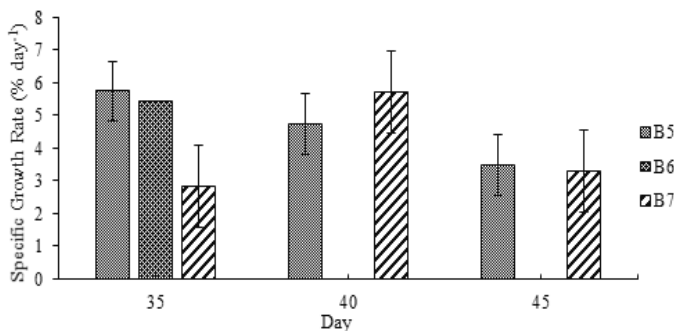


Figure 3. Specific growth rate of Pacific whiteleg shrimp *Penaeus vannamei* during the 45-day rearing period in the pond

During the 45-day observation period, the highest phytoplankton composition in pond B5 belonged to the Chlorophyta phytoplankton, comprising 73.69%. The Cyanophyta also had its highest percentage in pond B5. In pond B6, the Bacillariophyta (diatom) reached its highest proportion at 26.61%, while the highest percentage of Dinoflagellates (Pyrrophyta) was recorded in pond B5 at 0.26%. Additionally, pond B6 had the highest percentage of protozoa and zooplankton, accounting for 0.53%. The overall phytoplankton composition percentages are presented in Figure 2.

Phytoplankton composition during the 45-day observation period was highest in pond B5, namely from the Chlorophyta group (73.69%), while the highest percentage of the Cyanopyhta group was in pond B5, the highest percentage of diatom or bacillariophyta group was in pond B6 by 26.61%, the highest percentage of dinoflagellate or pryophyta group was in pond B5 (0.26%), and the highest percentage of protozoa and zooplankton was in pond B6 (0.53%). The percentage of phytoplankton composition is presented graphycally in Figure 2.

3.2 Specific Growth Rate

The specific growth rate (SGR) of the shrimps in

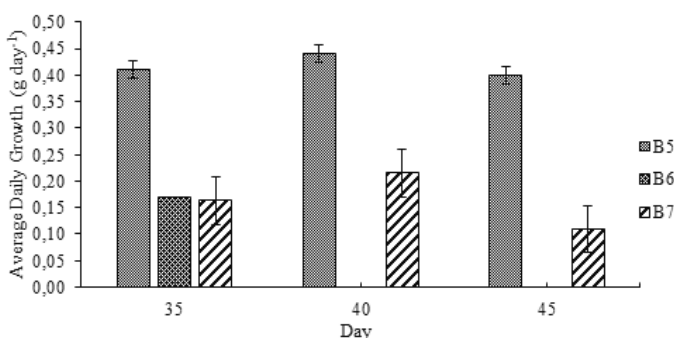


Figure 4. Average daily growth of Pacific whiteleg shrimp *Penaeus vannamei* during the 45-day rearing period in the pond

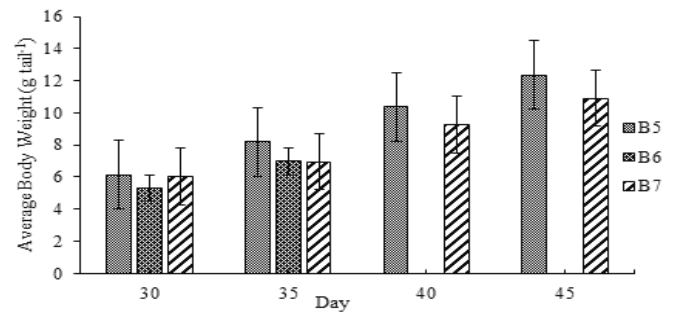


Figure 5. Average body weight of Pacific whiteleg shrimp *Penaeus vannamei* during the 45-day rearing period in the pond

each pond varied. The SGR in pond B5 ranged from $4.66 \pm 0.92\% \text{ day}^{-1}$. Pond B6 had a single SGR value of $5.42\% \text{ day}^{-1}$, as the harvest was conducted on day 39. In pond B7, the SGR was $3.95 \pm 1.26\% \text{ day}^{-1}$. The specific growth rate data are presented in the diagram in Figure 3.

3.3 Average Daily Growth

The average daily growth of Pacific whiteleg shrimp varied across the ponds. In pond B5, the daily growth rate ranged from $0.41 \pm 0.01 \text{ g day}^{-1}$. Pond B6 had a single recorded daily growth rate of 0.17 g day^{-1} . In pond B7, the daily growth rate ranged from $0.15 \pm 0.04 \text{ g day}^{-1}$. These daily growth rate values are presented in a diagram in Figure 4.

3.4 Average Body Weight

The average weight of shrimp aged 30–45 days in each pond tended to increase over time. In pond B5, the average weight increased weekly, with a range of $9.49 \pm 2.13 \text{ g shrimp}^{-1}$. In pond B6, the average weight was $6.15 \pm 0.82 \text{ g shrimp}^{-1}$, while in pond B7, the average weight ranged from $8.48 \pm 1.75 \text{ g shrimp}^{-1}$. The average weights are presented in a diagram in Figure 5.

3.5 Analysis of the relationship between phytoplankton

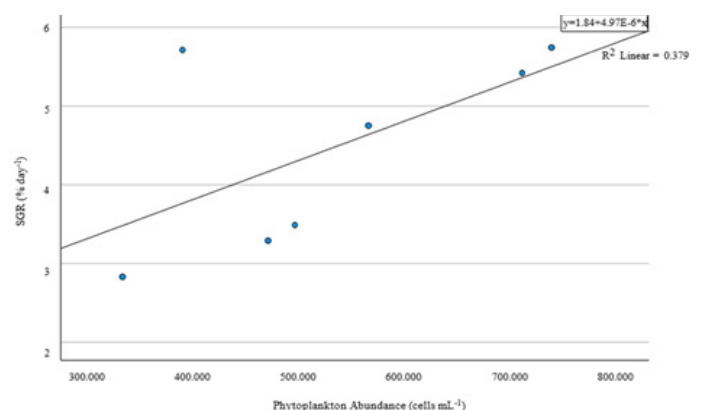


Figure 6. Scatterplot of the relationship between phytoplankton abundance and specific growth rate of Pacific whiteleg shrimp *Penaeus vannamei* for 45 days

Table 1. Water Quality Parameters During the 45-Day Rearing Period of Pacific Whiteleg Shrimp *Penaeus vannamei* in the Ponds

Parameters	Pond B5	Pond B6	Pond B7	National Standards PERMEN-KP No. 75 (2016)
Temperature (°C)	28–33	28–33	28–33	28–31
Brightness (cm)	30–100	30–105	55–115	20–45
Salinity (g L ⁻¹)	21–33	21–32	21–31	10–35
pH	7.70–8.70	7.65–8.55	7.70–8.60	7.50–8.50
DO* (mg L ⁻¹)	2.79–5.89	2.58–5.49	2.78–5.87	≥ 3.00
Ammonia (mg L ⁻¹)	0.03–0.30	0.03–0.50	0.03–0.30	≤ 0.10
Nitrate (mg L ⁻¹)	0.2–0.50	0–0.20	0–0.20	0.50
Phosphate (mg L ⁻¹)	0.03–1.00	0.03–1.00	0.03–0.50	0.10
TOM** (mg L ⁻¹)	90–116	97–135	83–114	≤ 90

*Dissolved Oxygen (DO), **Total Organic Matter (TOM)

abundance and specific growth rate

The Pearson correlation test results showed no significant correlation between phytoplankton abundance and the specific growth rate ($P > 0.05$). This indicates that there is no meaningful relationship between the two variables. The distribution of data along a linear line suggests a potential correlation; however, a more sloping linear line indicates a weaker relationship between the variables. The correlation between the two variables is presented as a scatter plot in Figure 6.

3.6 Water Quality

The daily water quality parameters observed included temperature, brightness, salinity, pH, and dissolved oxygen (DO). The temperature range across the three ponds was consistent, ranging from 28–33 °C, representing the accumulation of morning and afternoon temperatures, which showed significant values. The lowest salinity value recorded was 21 g L⁻¹ in all ponds, while the highest salinity was 33 g L⁻¹ in pond B5. The lowest brightness value was 30 cm, observed in ponds B5 and B6, whereas the highest brightness value was 115 cm in pond B7. The pH values ranged from a low of 7.65 in pond B6 to a high of 8.7 in pond B5. The lowest and highest dissolved oxygen (DO) values were recorded in pond B5, at 2.79 mg L⁻¹ and 5.89 mg L⁻¹, respectively. Weekly water quality parameters included nitrate, phosphate, and ammonia. The lowest and highest ammonia values were also observed in pond B5, at 0.03 mg L⁻¹ and 0.05 mg L⁻¹, respectively. The highest nitrate value, 0.05 mg L⁻¹, was recorded in pond B5. The highest phosphate value, 1 mg L⁻¹, was observed in both ponds B5 and B6. The

lowest Total Organic Matter (TOM) value was found in pond B7, at 83 mg L⁻¹, while the highest TOM value was recorded in pond B6, at 135 mg L⁻¹. The values of the water quality parameter are presented in tabular form in Table 1.

IV. DISCUSSION

Phytoplankton, as primary producers in aquatic ecosystems, rely heavily on nutrients and the overall quality of the aquatic environment (Wiyarsih *et al.*, 2019). Arifin *et al.* (2018) stated that the presence of phytoplankton in Pacific whiteleg shrimp pond waters maintains the availability of natural food and creates ideal conditions for shrimp farming. Good environmental conditions, including water quality that meets standards, are essential for the growth of Pacific whiteleg shrimp (Akbarurrasyid *et al.*, 2022).

Water quality management is crucial for Pacific whiteleg shrimp farming. One method of managing water quality is monitoring phytoplankton abundance to understand the dynamics and composition of phytoplankton in shrimp pond waters. Optimal phytoplankton dynamics in pond water are influenced by factors such as temperature, brightness, light intensity, current speed, dissolved oxygen (DO), salinity, pH, nitrate, and phosphate levels (Apriadi *et al.*, 2021).

The phytoplankton expected to grow in pond waters include Chlorophyta and Bacillariophyta. The standards for Pacific whiteleg shrimp farming regarding the percentage of phytoplankton species in the culture pond are as follows: Chlorophyta (50–90%), Cyanophyta (<10%), Cryptophyta (50–90%),

Dinoflagellates (<5%), and Protozoa (<10%) (Nasuki *et al.*, 2022). Chlorophyta and Bacillariophyta are beneficial phytoplankton divisions. Some beneficial genera from the Chlorophyta division include *Chlorella* sp., *Oocystis* sp., *Tetraselmis* sp., *Chlamydomonas* sp., and *Pediastrum* sp.

The genera derived from the Bacillariophyta division, or diatoms, include *Navicula* sp., *Spirogyra* sp., *Chaetoceros* sp., *Skeletonema* sp., *Thalassiosira* sp., and *Nitzschia* sp. Phytoplankton that are detrimental to pond waters belong to the Pyrrophyta division, or dinoflagellates, with genera such as *Gyrodinium* sp., *Noctiluca* sp., *Alexandrium* sp., *Amphidinium* sp., and *Ceratium* sp. The Cyanophyta division, or blue-green algae (BGA), includes genera like *Oscillatoria* sp., *Chroococcus* sp., *Anabaena* sp., and *Microcystis* sp.

The protozoan division includes genera such as *Vorticella* sp., *Zoothamnium* sp., and *Epistylis* sp. Based on research by Arifin *et al.* (2018), Chlorophyta is a division of phytoplankton that dominates ponds with a high specific growth rate (SGR) value of 6.64% day⁻¹. Fauziah and Laily (2015) stated that most species in the Chlorophyta division are single-celled, motile phytoplankton with chlorophyll pigments, which are effective in carrying out the photosynthesis process. The effectiveness of photosynthesis increases dissolved oxygen levels, which are then used by Pacific whiteleg shrimp as an energy source for growth.

Phytoplankton abundance is not directly correlated with the specific growth rate (SGR) of Pacific whiteleg shrimp because the growth of Pacific whiteleg shrimp does not depend solely on the abundance of phytoplankton (Sinaga, 2022). The results of the correlation test did not show that phytoplankton abundance had any impact on the growth of Pacific whiteleg shrimp. The role of phytoplankton is primarily to support the pond water environment, helping to maintain optimal water quality that is conducive to the growth of Pacific whiteleg shrimp.

Phytoplankton is also suspected to have antibacterial activity, potentially acting as a competitor to pathogenic bacteria, thereby inhibiting their growth. Phytoplankton and bacteria exhibit a negative correlation, where chlorophyll-a derived from phytoplankton increases during the day and decreases at night. As a result, the number of bacteria decreases during the day and increases at night (Kadowaki and Tanaka, 1994). This is due to the photosynthesis

process in phytoplankton cells, which produces organic matter in the form of carbohydrates or polysaccharides (Austin *et al.*, 1992). These findings suggest that carbohydrate polysaccharides play an essential role in suppressing bacterial growth. This suppression of bacterial development can create optimal conditions for the growth of Pacific whiteleg shrimp in pond waters.

Water quality parameters, such as daily temperature, showed fluctuations of less than 3 °C. This is in line with the findings of Yunarty *et al.*, (2022), who stated that daily temperature fluctuations should remain below 3 °C. The pH, nitrate, and phosphate parameters were in accordance with the quality standards outlined in PERMEN-KP No. 75 of 2016. Low dissolved oxygen (DO) content, caused by high rainfall, leads to suboptimal photosynthesis by phytoplankton. This issue can be solved by increasing the use of waterwheels. This is supported by Anggakara's (2012) assertion that waterwheels function to enhance water circulation.

V. CONCLUSION

Phytoplankton abundance fluctuated but remained within safe limits in all ponds. The phytoplankton species composition in all three ponds followed the standard. Pond B5 exhibited higher phytoplankton abundance, species composition, and water quality values, which were generally better than those of the other ponds. Based on the Pearson correlation test results, no direct relationship was found between phytoplankton abundance and the specific growth rate

ACKNOWLEDGEMENT

The authors would like to thank PT Hasil Sukses and Situbondo for their invaluable support in providing research facilities and assistance throughout the year-long study in Situbondo.

AUTHORS' CONTRIBUTION

All authors have contributed to the final manuscript. The specific contributions of each author are as follows: Asmi (AHR) developed the main conceptual ideas, drafted the manuscript, collected data, and designed the tables and figures. Wiyoto (WYT) provided critical revisions, contributed to drafting the manuscript, and offered advice on data analysis. Muhammad (MHM) assisted with critical revisions and contributed to drafting the manuscript.

Sigid (SAS) was responsible for critical revisions and drafting sections of the manuscript.

CONFLICT OF INTEREST

We certify that there are no conflicts of interest with any financial, personal, or other relationships with other people or organizations related to the material discussed in the manuscript.

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