Journal of Vocational in Aquaculture (JAVA)
November 2024 - Vol. 01 No. 01 (in press)

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

Asmi Al Husnyah Rukmana[1)], Wiyoto Wiyoto[1*)], Sigid Ary Santoso[2)], Dian Eka Ramadhani[1)], Mohamed Elsayed Megahed [3)]

[1] Study Program of Technology and Management of Applied Aquaculture, 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

*Corresponding author: wiyoto@apps.ipb.ac.id

Kumbang St. No.14, Bogor City, Indonesia 16128

Received : 01 Oct 2024; Revised: 09 Oct 2024; Accepted: 10 Oct 2024

ABSTRACT

Fluctuations in various pond water quality parameters can lead to low survival rates and suboptimal shrimp growth, ultimately affecting production targets. One of the factors influencing the water quality is the presence of phytoplankton. This study aimed to analyze the dynamics of phytoplankton abundance and composition, as well as their impact on the specific growth rate of Pacific whiteleg shrimp. The method consisted of water sampling, identification and calculation of phytoplankton abundance, water quality measurement, and shrimp growth sampling. The abundance of phytoplankton in the B5 pond ranged from 4.78±4.35 × 10^5 mL^{-1} cells. The abundance of phytoplankton in the B6 pond was approximately 4.14±2.14 × 10^5 mL^{-1} cells. Phytoplankton abundance in the B7 pond ranged from 5.05±3.57 × 10^5 mL^{-1} cells. The abundance of phytoplankton in all ponds fluctuated, and the composition of phytoplankton was in accordance with the standards for all three ponds. Based on the results of the Pearson correlation test, there was no direct relationship between phytoplankton abundance and the specific growth rate.

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

1. INTRODUCTION

Shrimp is an export commodity to various countries such as the United States, the European Union, Japan, and several Asian countries (Rosyidah *et al.* 2020). The Pacific whiteleg shrimp *Penaeus vannamei* is widely cultivated in Indonesia. In 2021, Indonesia became the 4th largest shrimp exporter after India, Ecuador, and Vietnam. Shrimp production in 2020 was 881,599 tons and has increased from 2021 to 884,939 tons (DJPB 2021). Shrimp market competition at the global level is tighter with other competing producer countries. Improving domestic shrimp production needs to be efficient and competitive to fill the global market. The increase in Pacific whiteleg shrimp production is supported by the advantages of Pacific whiteleg shrimp, such as 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, which depends on the size of the Pacific whiteleg shrimp (Rosyidah *et al.* 2020), fast growth rate, low feed conversion ratio, high stocking density (Syaifullah 2018), and nonborrowing habit (Wiyoto *et al.* 2022).

The components that affect shrimp growth are 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 one of the factors that affect the growth of Pacific whiteleg shrimp, because fluctuations in various water quality parameters in the water of shrimp growth can cause low survival, and the growth of shrimp is not optimal and continues to the production target is not achieved (Supriatna *et al.* 2020). Water quality is something that needs to be considered in Pacific whiteleg shrimp farming activities (Akbarurrasyid *et al.* 2022). Water quality parameters that are closely related to the shrimp growth, namely temperature with low fluctuations, have a positive impact on shrimp because they affect 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). The dissolved oxygen content in water depends on the presence of phytoplankton in pond waters. This is because phytoplankton perform photosynthesis and produce dissolved oxygen in water as a source of energy (Liwutang *et al.* 2013). Monitoring the abundance and type of phytoplankton needs to be done to prevent algal blooms from harmful phytoplankton species in Pacific whiteleg shrimp farming activities. Phytoplankton abundance is affected by several factors such as phytoplankton composition, organic matter, and water salinity. The study was to analyze the dynamics of phytoplankton abundance and composition, as well as its impact on Pacific whiteleg shrimp specific growth rate.

2. MATERIALS AND METHODS

2.1 Phytoplankton Sampling

Data collection in this study used three Pacific whiteleg shrimp ponds with three points in each pond (inlet, anco bridge, and outlet). Water sampling was performed twice a day at 05.00 and 13.30 WIB. Observations were made every day when the dissolved oxygen content was low or high to determine how the dynamics of plankton abundance (Masithah *et al.* 2018). The sampling method involves tying the bottle to the secchi disk and inserting it into the pond vertically. Water samples were collected at a depth of 50 cm above the water surface (Akbarurrasyid *et al.* 2022). The water samples (250 mL) were placed in sample bottles for observation and identification in the laboratory. The 250 mL water sample was preserved using as many as 5 drops (0.25 mL) of 1% lugol (Winarsih and Susanto 2023) and then homogenized.

2.2 Identification and Calculation of Phytoplankton Abundance

The identification of phytoplankton species and calculation of phytoplankton abundance were carried out using an Olympus CX-22 microscope. Samples that had been preserved were then taken (1 mL) using a drop pipette and dripped in the hemocytometer as much as one drop (0.05 mL) with the type of Neubauer improved and then closed using a glass cover measuring 30 mm × 30 mm. Observed under a microscope with a magnification of 10 × ocular lens and 40 × objective lens. Determination of phytoplankton species was performed according to the guidebook to determine the genus found and the Web Culture Collection of Algae and Protozoa (CCAP). The abundance was calculated using the sweep method (Apriadi *et al.* 2021). This method counts all areas using a hemocytometer. Phytoplankton identification was carried out simultaneously with the abundance calculation process using a hemocytometer. Phytoplankton abundance 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

Shrimp growth was sampled every five days. The sampling activities were conducted at 05.00 WIB. Sampling was performed at two sampling points in each pond, namely on each side facing. The sampling method used was using cas nets that were stocked, after which weighing was performed using buckets and digital scales, and then the number of shrimp was calculated to determine 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:

$$SGR = = \frac{lnWt - lnW0}{t} \times 100$$

Description:

SGR : specific growth rate (% day^{-1})

Wt : average weight at time t (g shrimp^{-1})

W0 : average weight at time 0 (g shrimp^{-1})

t : observation period (days)

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

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 observed in situ were temperature using an Hg thermometer, brightness using a secchi disk, dissolved oxygen using a DO Meter (YSI 550A), water color, water level, and weather visually when taking water samples while ex situ pH was measured using a pH meter (Hanna Instrument HI98107) with a value range of 0-14 and salinity using a refractometer (Trans Instrument) with a value range of 0–100 g L^{-1}. The water quality parameters observed weekly were nitrite using a test kit, nitrate using a test kit (Salifert with a value range of 0–1 mg L^{-1}), phosphate using a test kit (Salifert with a value range of 0–3 mg L^{-1}), ammonia using a test kit (Monitor), alkalinity, and Total Organic Matter (TOM) using the titrimetric method (SNI 2004).

2.5 Data Analysis

Data were processed using a number processing software program, *Microsoft Excel* 2016. The relationship between phytoplankton abundance and the specific growth rate of Pacific whiteleg shrimp was tested for normality, followed by the Pearson correlation test using SPSS version 27.0. Water quality parameters were descriptively analyzed.

3. 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.

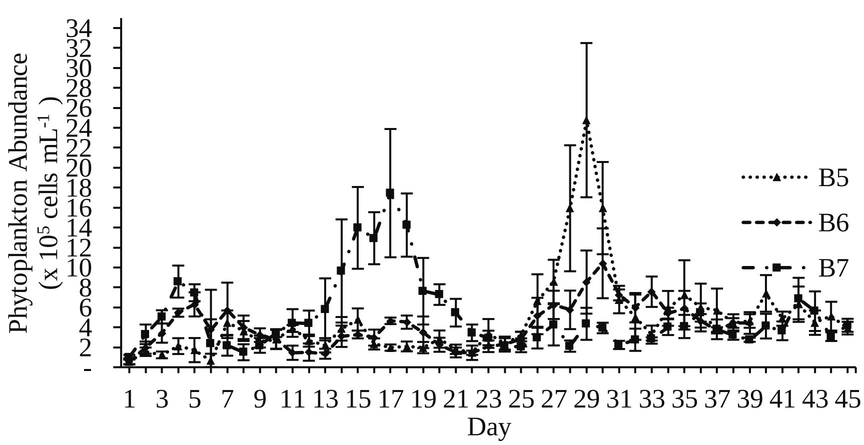

Figure 1 Phytoplankton abundance during the 45-day rearing period in Pacific whiteleg shrimp *Penaeus vannamei* pond

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.

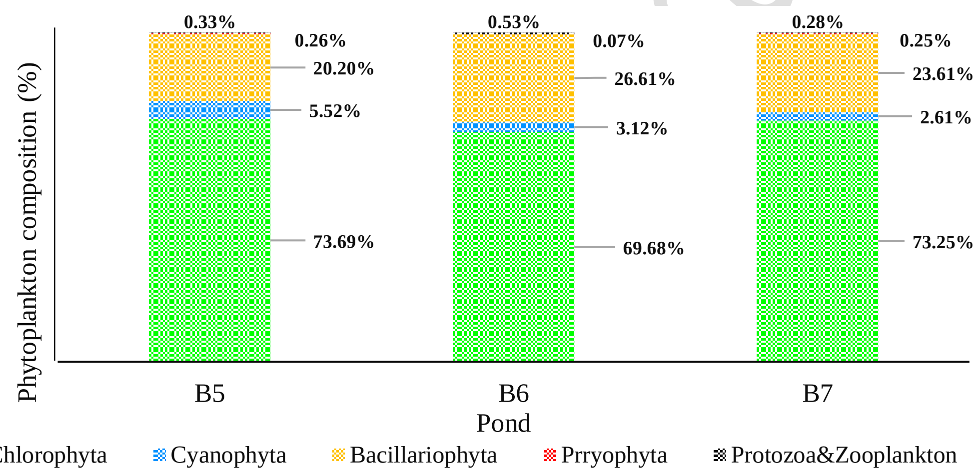

Figure 2 Phytoplankton composition during the 45-day rearing period in the Pacific whiteleg shrimp *Penaeus vannamei* pond

3.2 Specific Growth Rate

The specific growth rate of shrimps in each pond varied. The range of the specific growth rate in pond B5 was 4.66 ± 0.92% day^{-1}. Pond B6 had only one SGR value of 5.42% day^{-1} because the harvest was done on day 39. In pond B7, the specific growth rate was 3.95 ± 1.26% day^{-1}. The specific growth rate data are presented in a diagram in Figure 3.

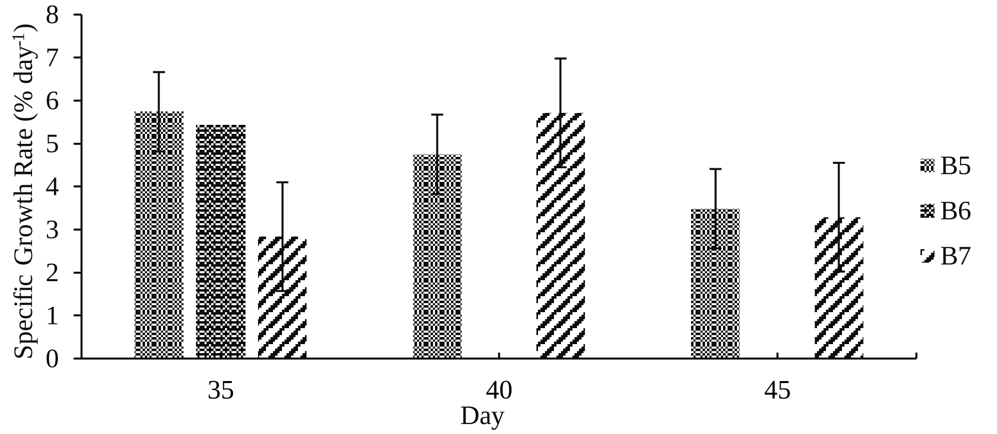

Figure 3 Specific growth rate of Pacific whiteleg shrimp *Penaeus vannamei* during the 45-day rearing period in the pond

3.3 Average Daily Growth

The average daily growth of Pacific whiteleg shrimp in each pond varied. The value of the daily growth rate of pond B5 ranged from 0.41 ± 0.01 g day^{-1}. Pond B6 has only one data value for the daily growth rate of 0.17 g day^{-1}. In pond B7 the daily growth rate ranged from 0.15 ± 0.04 g day^{-1}. The daily growth rate values are presented in the form of diagrams in Figure 4.

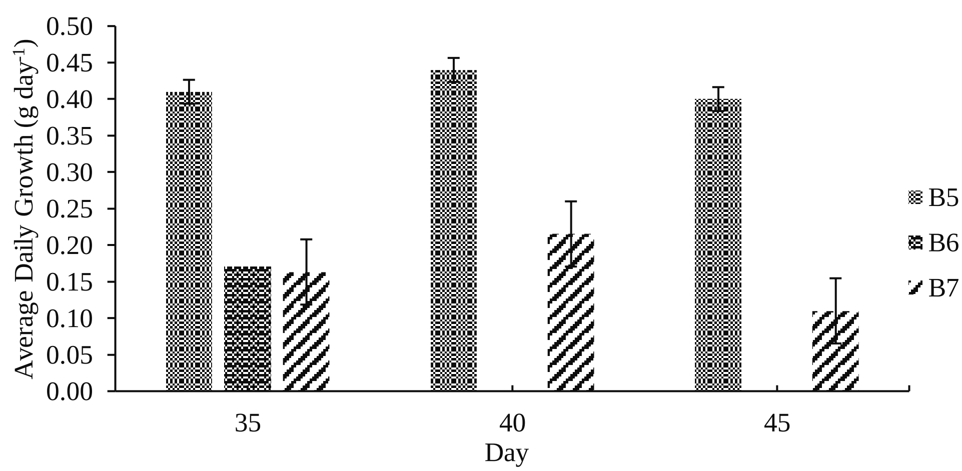

Figure 4 Average daily growth of *Penaeus vannamei* Pacific whiteleg shrimp during the 45-day rearing period in the pond

3.4 Average Body Weight

The average weight of shrimp with the age 30-45 days in each pond tended to increase. Pond B5 has an average weight of each week increased the average weight range of B5 is 9.49 ± 2.13 g shrimp^{-1}. In pond B6, an average weight of 6.15 ± 0.82 g shrimp^{-1}. The average weight of pond B7 is in the range of 8.48 ± 1.75 g shrimp^{-1}. The average weight is presented in diagram form in Figure 5.

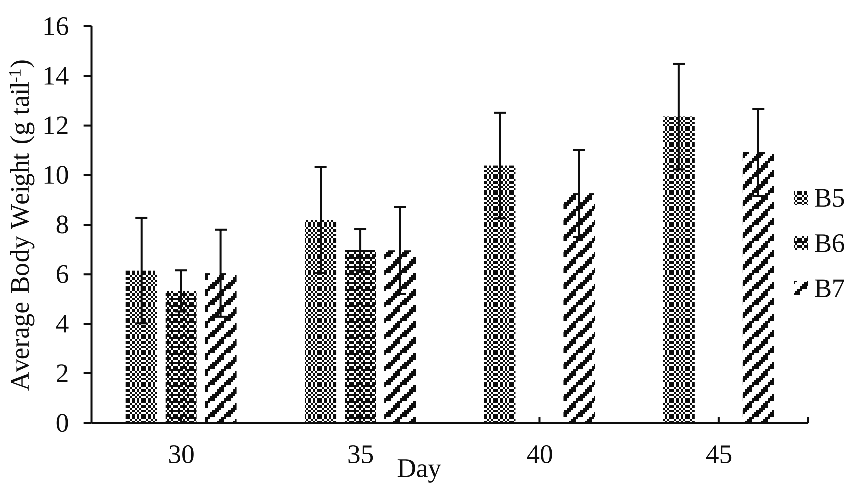

Figure 5 Average body weight of Pacific whiteleg shrimp *Penaeus vannamei* during the 45-day rearing period in the pond

3.5 Analysis of the relationship between phytoplankton abundance and specific growth rate

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

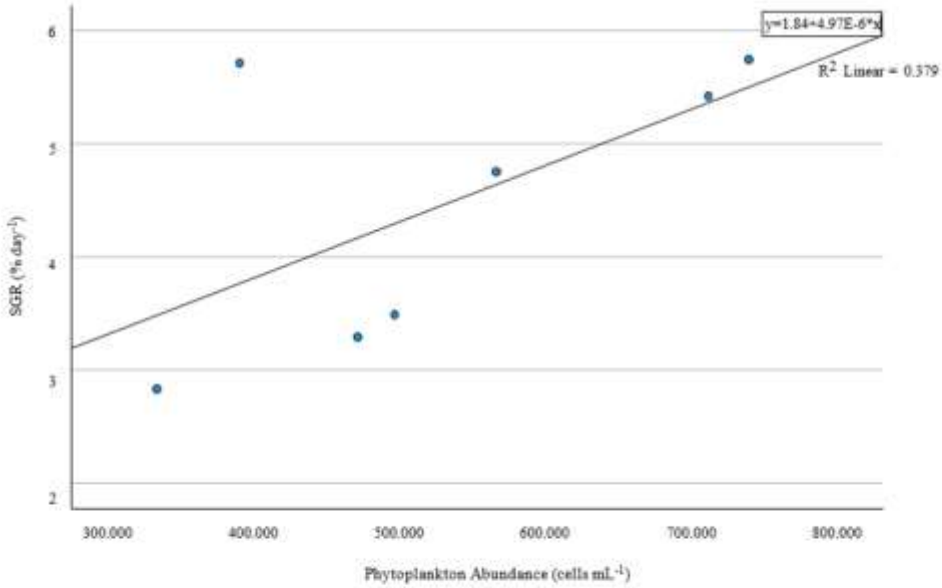

Figure 6 Scatterplot of the relationship between phytoplankton abundance and specific growth rate of Pacific whiteleg shrimp *Penaeus vannamei* for 45 days

3.6 Water Quality

The daily water quality parameters observed were temperature, brightness, salinity, pH, and DO. The temperature range in the three ponds was the same (28–33℃). This value is the accumulation of temperatures in the morning and afternoon, and has a significant value. The lowest salinity value was 21 g L^{-1} in all ponds, and the highest was 33 g L^{-1} in pond B5. The lowest brightness value was 30 cm in ponds B5 and B6, whereas the highest brightness value was 115 cm in pond B7. The lowest pH value was 7.65 in pond B6, and the highest pH was 8.7 in pond B5. The lowest and highest DO values were in pond B5 which amounted to 2.79 mg L^{-1} and 5.89 mg L^{-1}. The weekly water quality parameters were nitrate, phosphate, and ammonia. The lowest and highest ammonia values were in pond B5, which amounted to 0.03 mg L^{-1} and 0.05 mg L^{-1}. The highest nitrate value was observed in pond B5 which is 0.05 mg L^{-1}. The highest phosphate value (1 mg L^{-1}) was observed in ponds B5 and B6.. The lowest Total Organic Matter (TOM) value was observed in pond B7 at 83 mg L^{-1} and the highest value was observed in pond B6 at 135 mg L^{-1}. The values of the water quality parameter are presented in tabular form in Table 1.

Table 1 Water quality parameters during the 45-day rearing period in the growth out of *Penaeus vannamei* Pacific whiteleg shrimp in the pond

Parameters	**Pond B5**	**Pond B6**	**Pond B7**	**Standar Baku Mutu PERMEN-KP No. 75 Tahun 2016**
Temperature (℃)	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)

4. DISCUSSION

As a primary producer in water, phytoplankton is highly dependent on nutrients and the quality of the aquatic environment (Wiyarsih *et al.* 2019). According to Arifin *et al.* (2018), the presence of phytoplankton in Pacific whiteleg shrimp pond waters supports the availability of natural food and creates ideal environmental conditions for shrimp farming. Good environmental conditions, including water quality in accordance with quality standards, support the growth of Pacific whiteleg shrimps (Akbarurrasyid *et al.* 2022). Water quality management is important for Pacific whiteleg shrimp farming. One of the water quality management methods is to monitor phytoplankton abundance to understand the description of phytoplankton dynamics and composition in Pacific whiteleg shrimp pond waters. Good phytoplankton abundance dynamic conditions for pond water are sufficiently influenced by temperature, brightness, light intensity, current speed, dissolved oxygen (DO), salinity, pH, nitrate, and phosphate (Apriadi *et al.* 2021).

The phytoplankton expected to grow in pond waters are Chlorophyta and Bacillariophyta. Pacific whiteleg shrimp farming standards regarding the percentage of phytoplankton species in the culture pond contain chlorophyta 50-90%, Cyanophyta (<10%,) Crypsophyta 50-90%, Dinoflagellates (<5%), and protozoa <10% (Nasuki *et al.* 2022). Chlorophyta and Bacillariophyta divisions are beneficial phytoplankton species. Some genus from the chlorophyta division that are beneficial are *Chlorella* sp., *Oocystis* sp., *Tetraselmis* sp., *Chlamydomonas* sp., and Pediastrum. The genera derived from the division of Bacillariophyta or diatoms are *Navicula* sp., *Spirogyra* sp., *Chaetoceros* sp., *Skeletonema* sp., *Thalassiosira* sp., *Nitzschia* sp. Phytoplankton that are detrimental to pond waters are composed of pyrrophyta division or dinoflagellates belonging to the genera *Gyrodinium* sp., *Nocticula* sp., *Alexandrium* sp., *Amphidinium* sp., and *Ceratium* sp. The cyanophyta or blue-green algae (BGA) division with the genus *Oschillatoria* sp., *Chroococcus* sp., *Anabaena* sp., and *Microsyctis* sp. The protozoan division with the genera *Vorticella* sp., *Zoothamnium* sp., and *Epistylis* sp. Based on the results of research by Arifin *et al.* (2018), Chlorophyta is a division of phytoplankton that dominates ponds with a high SGR value of 6.64% day^{-1}. Fauziah and Laily (2015) stated that most of the Chlorophyta division is a single-celled and motile phytoplankton that has chlorophyll pigment, which is effective in carrying out the photosynthesis process. The effectiveness of photosynthesis will increase the dissolved oxygen levels that will be used by Pacific whiteleg shrimp as an energy source for growth.

Phytoplankton abundance is not directly correlated with the specific growth rate of Pacific whiteleg shrimp, because the growth of Pacific whiteleg shrimp does not depend on the abundance of phytoplankton (Sinaga 2022). The results of the correlation test did not indicate that phytoplankton abundance had no impact on the growth of Pacific whiteleg shrimp. The contribution made by phytoplankton only helps support the pond water environment in good conditions, so that water quality becomes optimal and supportive in the growth of Pacific whiteleg shrimp. Phytoplankton also has a suspected antibacterial activity, thus will be a competitor for pathogenic bacteria so that its development is inhibited. Phytoplankton and bacteria have a negative correlation relationship, where chlorophyll-a derived from phytoplankton increases during the day and decreases at night. The number of bacteria during the day will decrease and increase at night (Kadowaki and Tanaka 1994). This is because of the photosynthesis of phytoplankton cells that produce organic matter in the form of carbohydrates or polysaccharides (Austin *et al.* 1992). Both results suggest that carbohydrate polysaccharides play an important role in suppressing the development of bacteria. Suppression of bacterial development can create optimal conditions for the growth of Pacific whiteleg shrimp in pond waters.

Water quality parameters, in the form of daily temperature, had a fluctuation value of <3 ℃. This is in line with the idea of Yunarty *et al.* (2022), who stated that daily temperature fluctuations should not be <3 ℃. The pH, nitrate, and phosphate parameters ware in accordance with the quality standards of PERMEN-KP No.75 of 2016. Low dissolved oxygen (DO) content is caused by high rainfall, which causes the photosynthesis process carried out by phytoplankton to be suboptimal. The problem can be overcome using more wheels. This is in line with the opinion expressed by Anggakara (2012) that waterwheels have the function of making water flow.

5. CONCLUSION

Phytoplankton abundance fluctuated and remained within the safe limits in all ponds. The phytoplankton species composition in all three ponds was in accordance with the standard. Pond B5 has high phytoplankton abundance, phytoplankton species composition, and water quality values, which tend to be better than those of the other ponds. Based on the Pearson correlation test results, there was no direct relationship between phytoplankton abundance and the specific growth rate.

ACKNOWLEDGEMENT

The authors would like to thank PT Hasil Sukses and Situbondo for their support of all research activities and facilities during the implementation of this study in Situbondo for a year.

AUTHORS' CONTRIBUTION

The final manuscript has been contributed by all authors. Each author's Contribution All listed below: All authors have contributed to the final manuscript. The contributions of each author are as follows: Asmi (AHR) devised the main conceptual ideas, drafted the manuscript, collected data, and designed the table and graph. Wiyoto (WYT): critical revision of the article, drafting of the manuscript, and advice on the data. Muhammad (MHM); critical revision of article and drafted the manuscript. Sigid (SAS): critical revision of the article and drafting 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.

REFERENCES

Akbarurrasyid, M., Prajayanti, V. T. F., Nurkamalia, I., Astiyani, W. P., Gunawan, B. I. 2022. Hubungan kualitas air dengan struktur komunitas plankton tambak udang vannamei. *Jurnal Penelitian Sains*. 24(2):90–98.

Alfizar, H., Naufal, A., & Ridwan, R. 2021. Kelayakan usaha dan produktivitas budidaya udang vaname (*Litopenaeus vannamei*) tambak intensif farm mahyuddin Desa Deah Raya Kecamatan Syiah Kuala Kota Banda Aceh. *Jurnal Tilapia*. 2(2):47–56.

Anggakara, S. A. 2012. Kincir air alternatif dengan timer sebagai penyuplai kandungan oksigen (*Dissolved Oxygen*) pada kolam pembenihan lele berbasis mikrokontroler ATmega8 [skripsi]. Yogyakarta: Universitas Negeri Yogyakarta.

Apriadi, T., Muzammil, W., Melani, W. R., Zulfikar, A. 2021. Buku Ajar Planktonologi. Tanjungpinang: Umrah Press.

Arifin, N. B., Fakhri, M., Yuniarti, A., Hariati, A. M. 2018. Komunitas Fitoplankton pada sistem budidaya intensif udang vaname *Litopenaeus vannamei* di Probolinggo, Jawa Timur. *Jurnal Ilmiah Perikanan dan Kelautan* 10(1):46–53.

Austin, B., Baudet, E., Stobie, M. 1992. Inhibition of bacterial fish pathogens by *Tetraselmis suecica*. *Journal Fish Diseases.* 15(1):55–61.

Dahlan, J., Hamzah, M., Kurnia, A. 2019. Pertumbuhan udang vaname (*Litopenaeus vannamei*) yang dikultur pada sistem bioflok dengan penambahan probiotik. *Jurnal Sains dan Inovasi Perikanan.* 1(2):19–27.

[DJPB] Direktorat Jenderal Perikanan Budidaya. 2021. Laporan Kinerja DJPB Tahun 2021. *Kkp.Go.Id.*:1–82.

Elovaara, A. K. 2001. *Shrimp farming manual: practical technology for intensive commercial shrimp production*. United State: Arnold K. Elovaara.

Fauziah, S. M., Laily, A. N. 2015. Identifikasi mikroalga dari divisi chlorophyta di waduk sumber air jaya dusun krebet Kecamatan Bululawang Kabupaten Malang. *Bioedukasi Jurnal Pendidikan Biologi*. 8(1):20–22.

Haliman, R. W., Adijaya, D. 2005. *Udang vannamei, pembudidayaan dan prospek pasar udang putih yang tahan penyakit.* Jakarta: Penebar Swadaya.

Ilham, F. 2021. Perbedaan model budidaya dengan fluktuasi kualitas air untuk pertumbuhan udang vaname *(Litopenaeus vannamei*) pola intensif. *Journal Fisheries Marine Research.* 5(3):508–515.

Kadowaki, S., Tanaka, Y. 1994. Interrelationship between phytoplankton and bacteria in culture pond of kuruma prawn, *Penaeus japonicus*. *Aquaculture Science.* 42(2):371–375.

Kurniawan, I. H. 2023. Pemeliharaan larva udang vannamei (*Litopenaeus vannamei*) dengan genetika berbeda di CV. Manunggal Rasa [thesis]. Lampung: Politeknik Negeri Lampung.

Liwutang, Y. E., Manginsela, F. B., Tamanampo, J. F. W. S. 2013. Kepadatan dan keanekaragaman fitoplankton di perairan sekitar kawasan reklamasi Pantai Manado. *Jurnal Ilmiah Platax*. 1(3):109–117.

Masithah, E. D., Pursetyo, K. T., Amin, M. N. G. 2018. Kandungan microcystin perairan tambak dalam hubungan dengan keragaman dan dominasi plankton [skripsi]. Surabaya: Universitas Airlangga.

Mydlarz, L. D., Jones, L. E., Harvell, C. D.2006. Innate immunity, environmental drivers, and disease ecology of marine and freshwater invertebrates. *Annu. Rev. Ecol. Evol. Syst.* 251–288.

Nasuki, N., Edi, M. H., Alauddin, M. H. R., Abrori, M., Ritonga, L. B., Primasari, K., Rizky, P. N. 2022. Penggunaan silikat terhadap pertumbuhan udang vanname skala rumah tangga. *Chanos Chanos*. 20(2):117.

Padang, A. 2023. *Planktonologi.* Jakarta: BRIN.

Persada, A. Y., Navia, Z. I., Saputri, A., Putri, K. A., Al, B. 2019. Inventaris jenis fitoplankton di Pulau Pusong, Langsa, Aceh. *Journal of Islamic Science and Technology*. 5(1):67–75.

Rakhfid, A., Halida, W. O., Rochmady, Fendi. 2018. Aplikasi probiotik untuk pertumbuhan dan kelangsungan hidup udang vaname *Litopenaeus vannamei* pada padat tebar berbeda. *Akuatikisle Jurnal Akuakultur, Pesisir dan Pulau-Pulau Kecil*. 2(2):41–48.

Ritonga, L. B. R., Sudrajat, M. A., Arifin, M. Z. 2021. Manajemen pakan pada pembesaran udang vannamei (*Litopenaeus vannamei*) di tambak intensif CV. Bilangan Sejahtera Bersama. *Chanos Chanos*. 19(2):187–197.

Rosyidah, L., Yusuf, R., Deswati, H. 2020. Sistem distribusi udang vaname di Kabupaten Banyuwangi, Provinsi Jawa Timur. *Buletin Ilmiah "MARINA" Sosial Ekoneomi Kelautan dan Perikanan.* 6(1):51–60.

Sachlan, M. 1982. *Planktonologi.* Semarang: Fakultas Peternakan dan Perikanan Universitas Diponegoro.

[SNI] Standar Nasional Indonesia. 2004. Uji Nilai Permanganat Secara Titrimetri.1–10.

Saepudin, Wijaya, R., Sahroji, Sofiatunisa, Agustin, N. D., Wahyuni, S., Yusuf, M., Pratiwi, N. E. 2022. Pendampingan kepada petani tambak udang untuk meningkatkan hasil panen petani tambak di Desa Wanayasa, Kecamatan Pontang, Kabupaten Serang. *Jurnal Abdimas Bina Bangsa*. 3(1):27–33.

Sinaga, W. A. 2022. Analisis hubungan plankton dengan pertumbuhan udang vaname

(*Litopenaeus vannamei*) pada tambak intensif di Kota Probolinggo, Jawa Timur [skripsi]. Malang: Universitas Brawijaya.

Supono. 2015. *Manajemen Lingkungan untuk Akuakultur*. Yogyakarta: Plantaxia.

Supriatna, Mahmudi, M., Musa, M., Kusriani. 2020. Hubungan pH dengan parameter kualitas air pada tambak intensif udang vannamei (*Litopenaeus vannamei*). *Journal Fisheries Marine Research.* 4(3):368–374.

Syaifullah, M. I. 2018. Manajemen budidaya udang vannamei (*Litopenaeus vannamei*) pada kolam beton di tambak udang intensif PT. Surya Windu Kartika, Kecamatan Rogojampi, Kabupaten Banyuwangi, Jawa Timur [skripsi]. Surabaya: Universitas Airlangga.

Wahyuni, R. S., Rahmi, R., Hamsah, H. 2022. Efektivitas oksigen terlarut terhadap pertumbuhan dan sintasan udang vaname (*Litopenaeus vannamei*). *Jurnal Perikanan Unram*. 12(4):536–543.

Winarsih, L., Susanto, D. 2023. Efektifitas larutan pengawet pada sampel plankton pada pemeriksaan di laboratorium. *Indonesian Journal of Laboratory*. 1(3):226–236.

Wiyarsih, B., Endrawati, H., Sedjati, S. 2019. Komposisi dan kelimpahan fitoplankton di Laguna Segara Anakan , Cilacap. *Buletin Oseanografi Marina*. 8(1):1–8.

Wiyoto, W., Sukenda, S., Harris, E., Nirmala, K., Djokosetiyanto, D. 2016. Water quality and sediment profile in shrimp culture with different sediment redox potential and stocking densities under laboratory condition. *Indonesian Journal Marine Science*. 21(2):65.

Wiyoto, W., Sukenda, S., Harris, E., Nirmala, K., Djokosetiyanto, D. 2021. Pacific whiteleg shrimp (*Litopenaeus vannamei*) behaviour, oxygen consumption and sediment oxygen demand at different sediment redox potential. *Aquaculture, Aquarium, Conservation and Legislation.* 14(6):3510–3516.

Wulandari, D. Y., Tunjung, N., Pratiwi, M., Adiwilaga, E. M. 2014. Distribusi spasial fitoplankton di Perairan Pesisir Tangerang. *Jurnal Ilmu Pertanian Indonesia*. 19(3):156–162.

Yunarty, Y., Kurniaji, A., Budiyati, B., Renitasari, D. P., Resa, M. 2022. Karakteristik kualitas air dan performa pertumbuhan budidaya udang vaname (*Litopenaeus vannamei*) secara intensif. *Pena Akuatika: Jurnal Ilmu Perikanan dan Kelautan.* 21(1):71.

Zokaeifar, H., Balcázar, J. L., Saad, C. R., Kamarudin, M. S., Sijam, K., Arshad, A., Nejat, N. 2012. Effects of *Bacillus subtilis* on the growth performance, digestive enzymes, immune gene expression and disease resistance of white shrimp, *Litopenaeus vannamei*. *Fish Shellfish Immunol.* 33(4):683–689.