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Influence of Water Quality and Phytoplankton Community on the Growth of *Litopenaeus vannamei* in Low-Salinity Semi-Mass Circular Ponds

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Abstract

This study examines the dynamics of vannamei shrimp (*Litopenaeus vannamei*) cultivation in low salinity aquaculture systems, focusing on water quality parameters, plankton diversity, and shrimp growth rates. Vannamei shrimp are favored in aquaculture due to their disease resistance, rapid growth, and high survival rates. Key water quality parameters, including dissolved oxygen (DO), temperature, light intensity, pH, and salinity, were monitored over a 30-day period in low salinity ponds. The results showed significant fluctuations in these parameters, influencing shrimp health and growth. DO levels varied from 5.8 to 8.39 ppm in the morning and from 5.14 to 7.8 ppm in the afternoon. Water temperature ranged from 27.3°C to 32.3°C, light intensity from 3,170 to 66,300 lux, pH from 7.72 to 8.73, and salinity from 5 to 6 ppt. Plankton diversity and density, including species like Microcystis, Cyclotella, and Rhizosolenia, were also assessed, highlighting their role in the aquatic ecosystem. The specific growth rate (SGR) of the shrimp was calculated, showing a favorable growth rate of 2.32% per day. These findings indicate that maintaining stable water quality and diverse plankton populations is crucial for optimizing shrimp growth in low salinity aquaculture systems. This research provides valuable insights into the environmental conditions necessary for successful vannamei shrimp cultivation, emphasizing the importance of regular monitoring and management to ensure sustainable aquaculture.

1. Introduction

The fishery production in Indonesia has increased in both capture fisheries and aquaculture sectors. One of the key aquaculture commodities is shrimp, which serves as a significant source of protein. Among the various types of shrimp cultivated in Indonesia, vannamei shrimp has become a leading production commodity Rasyidah *et al.* (2024). Vannamei shrimp is considered a superior variety due to several advantages: higher resistance to diseases, faster growth rates, tolerance to environmental fluctuations, shorter cultivation periods, higher survival rates, and efficient feed conversion. Although vannamei shrimp is smaller than tiger shrimp, its market price remains highly fluctuating. The Ministry of Marine Affairs and Fisheries (KKP) has reported continuous growth in both capture fisheries and aquaculture, with shrimp playing a vital role in export contributions (FAO, 2022, 2024; Fisheries, 2023; Wijaya *et al.*, 2021).

Low salinity aquaculture is a strategy aimed at addressing challenges arising from water quality fluctuations in aquaculture systems (Istiqomah *et al.*, 2024). The adoption of low salinity systems not only brings several advantages but also mitigates potential problems in shrimp farming. One major benefit is the ability to reduce toxicity levels from harmful gases such as ammonia and nitrite in pond environments, creating a safer habitat for shrimp. Additionally, low salinity systems help prevent oxygen deficits that can negatively impact shrimp and ultimately reduce the risk of mass mortality. Maintaining stable water quality in ponds is easier, protecting shrimp populations from stress that can affect their growth and well-being (Nan *et al.*, 2024; Roy *et al.*, 2010).

Based on recent research, optimal water quality is crucial for the cultivation of *Litopenaeus vannamei*. Key parameters include temperature (28-32°C), turbidity, pH (7.5-8.5), alkalinity (80-140 mg/L), ammonia content (0-0.12 mg/L), hardness, carbon dioxide content, and iron content. These factors significantly impact the growth and survival rates of the shrimp. Additionally, plankton diversity and density are essential for shrimp growth, serving as a natural and beneficial feed source (Schock *et al.*, 2013).

Phytoplankton, including zooplankton, play a crucial role in aquatic systems, particularly in shrimp farming, especially under low salinity conditions. As primary producers, phytoplankton generate organic substances that sustain various aquatic organisms, forming the base of the aquatic food chain, with shrimp being significant consumers (Burford, 1997). Adequate availability of phytoplankton in shrimp ponds is essential for ensuring the necessary food resources for shrimp growth and health (Neori *et al.*, 2004). Understanding the role and importance of phytoplankton in such environments is vital for optimizing environmental conditions and achieving successful shrimp cultivation. Furthermore, methods for pond water control, plankton density calculation, and shrimp weight measurement are crucial aspects to consider in shrimp farming (Yang *et al.*, 2020). This study aims to contribute to a comprehensive understanding of the dynamics within low salinity shrimp farming environments, ultimately ensuring optimal productivity and sustainability.

2. Material and methods

2.1 Materials

During the research, we observed vannamei shrimp (*Litopenaeus vannamei*) and water in low salinity circular ponds. We utilized various tools, including microtubes, scissors, micropipettes, pipettes, measuring cups, gloves, cameras, microscopes, haemacytometers, luxmeters, pH meters, refractometers, DO meters, and analytical balances. We observed shrimp weight, plankton density, and water quality. Samples used included water from circular ponds, shrimp, formalin, and alcohol.

2.2 Methods

2.2.1 Water quality sampling procedure

Sampling of water quality carried out is measuring temperature, salinity, pH, dissolved oxygen (DO), and light intensity. Data collection is carried out twice/day at 08:00 AM (morning) and 04:00 PM (afternoon).

2.2.2 Plankton density

Plankton algae are counted using a haemocytometer under a microscope at varying magnifications based on their size (Afianti and Endrawati, 2024). Larger forms are counted under low magnification, while smaller or more challenging-to-identify forms are observed under higher magnification, facilitated by an immersion oil to ensure accuracy even for very small algae. When larger plankton organisms are scarce, it's advisable to count them across the entire chamber bottom for reliability. However, in cases of high plankton density, counting only a portion of the chamber bottom, such as several diagonal fields, is sufficient to cover any irregularities while still providing representative data. This adaptable approach ensures accurate and reliable estimation of plankton density, tailored to the characteristics of the sample being analyzed (LeGresley and McDermott, 2010; Willén, 1976). These identification guides were for various common phytoplankton species in the waters, using Genkal (2012); Kilham and Hecky (1988); Reynolds (1984).

2.2.3 Specific Growth Rate (SGR)

The shrimp were randomly selected from the population in semi mass circular tank C2. During the rearing period, the shrimp's weight was measured using an analytical scale (OHauss, USA) on days 0 and 30. After the measurements were completed, the weight data could be used to calculate the specific growth rate (SGR) as follows :

$$SGR\% = \frac{(LnWt - LnWo)}{t} x100\%$$

SGR = Specific Growth Rate
Wt = Final weight
Wo = Initial weight

3. Results

3.1 Water Quality

3.1.1 Dissolved Oxygen (DO)

Based on Figure 1, the changes in Dissolved Oxygen (DO) levels in the shrimp circular tank over 30 days were observed at 08:00 AM (Figure 1a) and at 04:00 PM (Figure 1b). The highest DO value in the morning in pond C2 was on the 16th day at 8.39 ppm, while the lowest DO value in the morning in pond C2 was on the 8th day at 5.8 ppm. The highest DO value in the afternoon in pond C2 was on the 8th day at 7.8 ppm, while the lowest DO value in the afternoon in pond C2 was on the 30th day at 5.14 ppm. DO levels fluctuated in the morning and afternoon each day. The highest fluctuations in the morning and afternoon occurred on the 14th and 15th days. The morning DO values on the 14th and 15th were 5.99 ppm and 8.03 ppm, respectively, while the afternoon DO values on the 14th and 15th were 5.36 ppm and 7.59 ppm, respectively.

3.1.2 Temperature levels

Based on Figure 2, the changes in temperature levels in the shrimp pond over 30 days were observed at 08:00 AM (Figure 2a) and at 04:00 PM (Figure 2b). The highest morning temperature in pond C2 was on the 3rd day at 29.6 ˚C, while the lowest morning temperature in pond C2 was on the 29th day at 27.3 ˚C. The highest afternoon temperature in pond C2 was on the 5th day at 32.3 ˚C, while the lowest afternoon temperature in pond C2 was on the 4th day at 29.2 ˚C. Temperature levels fluctuated in the morning and afternoon each day. The highest morning fluctuations occurred on the 13th and 14th days with values of 28.1 ˚C and 29.3 ˚C, and the highest afternoon fluctuations occurred on the 4th and 5th days with values of 29.2 ˚C and 32.3 ˚C.

3.1.3 Light intensity

Based on Figure 3, the changes in light intensity in the shrimp pond over 30 days were observed at 08:00 AM (Figure 3a) and at 04:00 PM (Figure 3b). The highest morning light intensity in pond C2 was on the 26th day at 66,300 lux, while the lowest morning light intensity in pond C2 was on the 6th day at 20,600 lux. The highest afternoon light intensity in pond C2 was on the 3rd day at 28,500 lux, while the lowest afternoon light intensity in pond C2 was on the 29th day at 3,170 lux. Light intensity levels fluctuated in the morning and afternoon each day.

3.1.4 pH

Based on Figure 4, the changes in pH in the shrimp pond over 30 days were observed at 08:00 AM (Figure 4a) and at 04:00 PM (Figure 4b). The highest morning pH value in pond C2 was on the 7th day at 8.12, while the lowest morning pH value in pond C2 was on the 14th day at 7.72. The highest afternoon pH value in pond C2 was on the 5th day at 8.73, while the lowest afternoon pH value in pond C2 was on the 25th day at 7.93. The pH levels fluctuated in the morning and afternoon each day. The highest morning fluctuations occurred on the 6th and 7th days with values of 7.93 and 8.12, respectively, and the highest afternoon fluctuations occurred on the 4th and 5th days with values of 8.00 and 8.74, respectively.

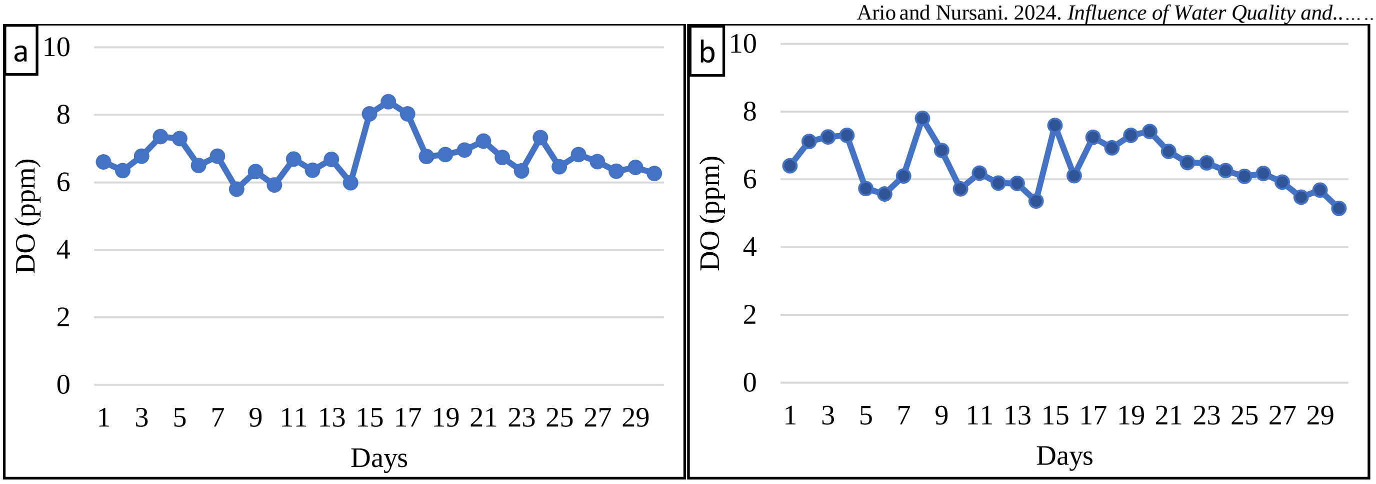

Figure 1. DO in shrimp pond C2 at 08:00 AM (a) and at 04:00 PM (b).

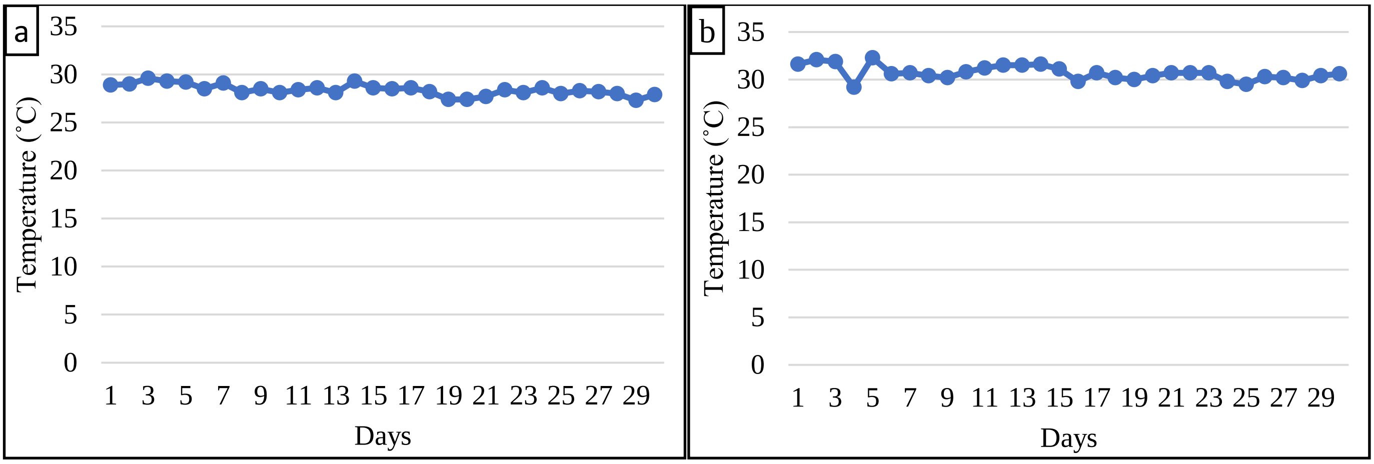

Figure 2. Temperature levels in shrimp pond C2 at 08:00 AM (a) and at 04:00 PM (b).

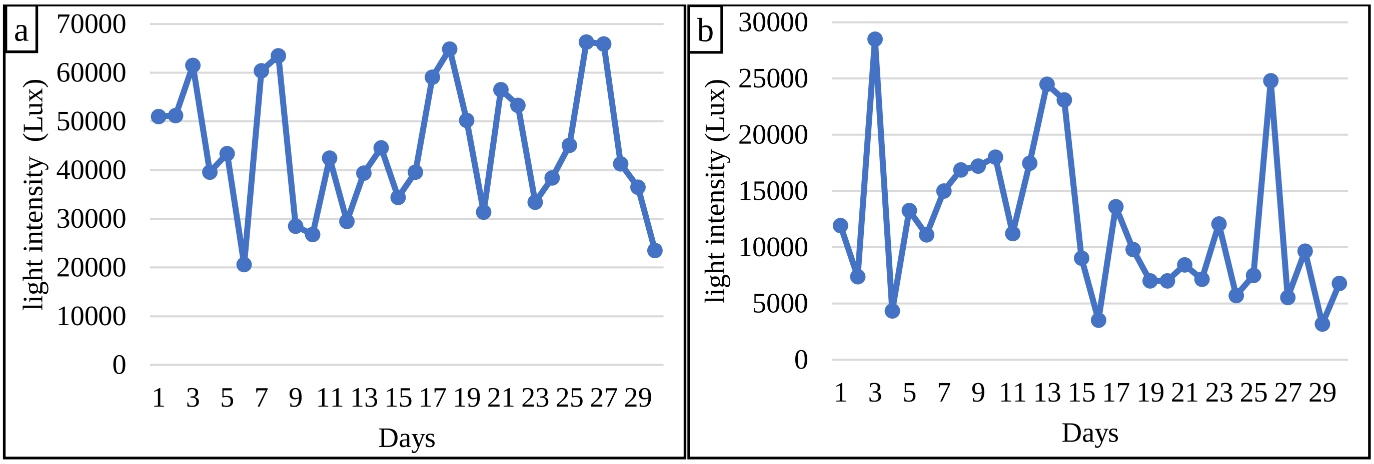

Figure 3. Light intensity in shrimp pond C2 at 08:00 AM (a) and at 04:00 PM (b).

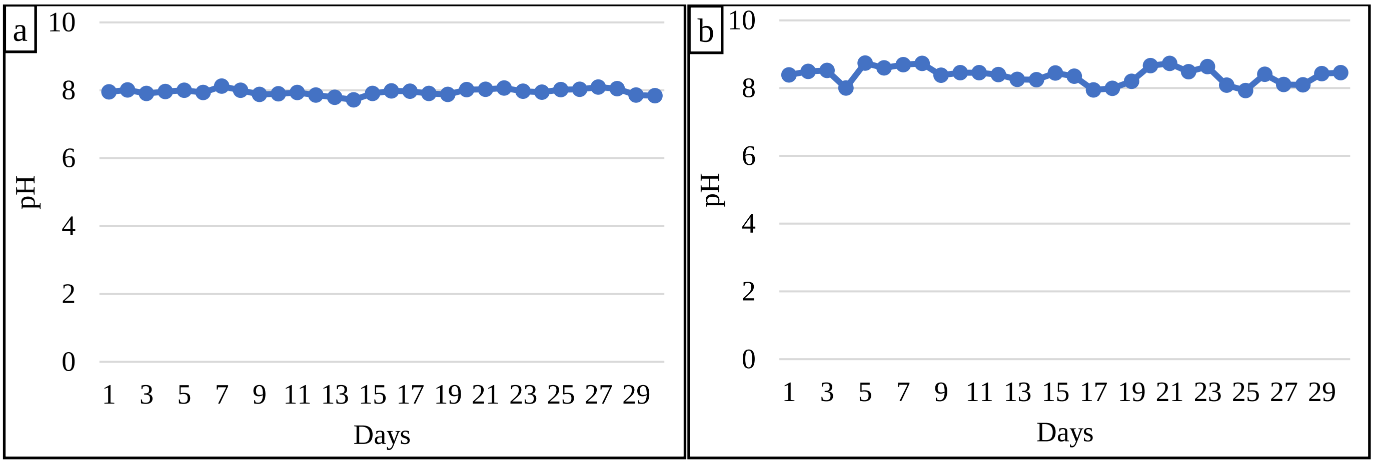

Figure 4. pH in shrimp pond C2 at 08:00 AM (a) and at 04:00 PM (b).

3.1.5 Salinity

Based on Figure 5, the changes in salinity in the shrimp pond over 30 days were observed at 08:00 AM (Figure 5a) and at 04:00 PM (Figure 5b). The highest salinity levels in the morning in pond C2 were on the 2nd, 11th, 22nd, and 23rd days, at 6 ppt, while the other values remained the same at 5 ppt. The highest salinity levels in the afternoon in pond C2 were on the 21st and 22nd days, at 6 ppt, while the other values remained the same at 5 ppt. Salinity levels fluctuated in the morning and afternoon each day.

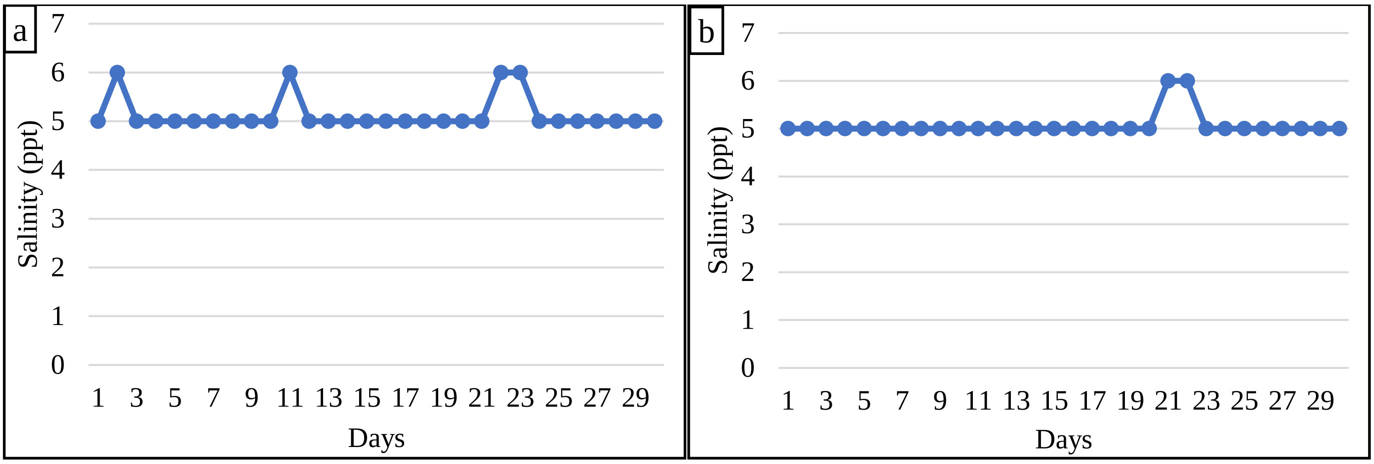

Figure 5. Salinity in shrimp pond C2 at 08:00 AM (a) and at 04:00 PM (b).

3.2 Diversity and plankton density

Through routine research and identification of plankton conducted weekly in each pond, a variety of phytoplankton species present in the environment were discovered, as presented in Table 1. Within this phytoplankton community, several species stand out due to their abundance. One notable phytoplankton genus is Microcystis, which belongs to the group of blue-green algae or cyanobacteria. Microcystis often produces characteristic blue-green pigments and is commonly found in various water bodies. Additionally, two genera of diatoms, Cyclotella and Rhizosolenia, were also identified in the plankton population in these ponds. Diatoms, with cell walls rich in silica, exhibit unique shapes and characteristics (Afianti and Endrawati, 2024).

Table 1. Diversity and plankton density

No	Genus	Plankton Density (x 10^4 cell mL^{-1})			
		7 Days	14 Days	21 Days	28 Days
1	Microcystis	2.2	5.2	74.1	
2	Cyclotella	40	31.5	7.6	1.9
3	Rhizosolenia	1.1	1.1	11.1	2.2

3.3 Specific Growth Rate (SGR)

Based on Table 2, the Initial weight and Final weight showed results of 2.94 ± 0.62 and 11.76 ± 0.65, respectively. The Specific Growth Rate showed a result of 2.32% per day.

Table 2. Weight of *Litopaneus vannamei*

Initial weight (gr)	Final weight (gr)	Specific Growth Rate (%)
2.94 ± 0.62	11.76 ± 0.65	2.32

4. Discussion

The observed variations in water quality parameters, including dissolved oxygen (DO), temperature, light intensity, pH, and salinity, in the shrimp pond over a 30-day period provide valuable insights into the environmental conditions influencing shrimp growth and health (Avnimelech, 2009; Boyd and Gautier, 2000; Boyd, 2019; Carbajal-Hernández *et al.*, 2013; Hargreaves, 2006).

Dissolved oxygen levels exhibited fluctuations throughout the day, with the highest values observed in the morning and the lowest values in the afternoon. This pattern may be attributed to photosynthetic activity and respiratory processes of aquatic organisms, as well as factors such as temperature and water movement (Hargreaves, 2006).

Temperature fluctuations, both diurnally and throughout the observation period, suggest dynamic thermal conditions within the pond. Temperature is a critical factor influencing shrimp metabolism, growth, and behavior (Boyd, 2019). Light intensity variations reflect changes in natural light exposure throughout the day, which can influence primary productivity and photosynthesis in the aquatic ecosystem (Hargreaves, 2006). pH fluctuations observed in the pond indicate variations in acidity or alkalinity levels over time. pH influences various biological processes, including nutrient availability, toxin solubility, and microbial activity, which can ultimately impact shrimp health and growth (Boyd, 2019). Salinity levels fluctuated between morning and afternoon samplings, potentially influenced by factors such as water exchange rates, and weather conditions (Ariadi *et al.*, 2019).

The diversity and density of plankton species identified in the pond ecosystem provide insights into the trophic dynamics and nutrient cycling within the aquatic environment (Hargreaves, 2006; Rasyidah *et al.*, 2024). The specific growth rate (SGR) of shrimp, calculated based on initial and final weight measurements, indicates the rate of biomass increase over time. The observed SGR of 2.32% per day suggests favorable growth conditions within the pond environment (Avnimelech, 2009).

5. Conclusions

The water quality parameters and phytoplankton diversity observed in semi mass circle pond culture were conducive to supporting healthy shrimp growth, as evidenced by the favorable specific growth rate. Maintaining these conditions through regular monitoring and management is crucial for continued success in shrimp aquaculture.

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

IAN : sample image collection, water quality sampling collection. RA : research ideas, 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

Referrences

Afianti, S., & Endrawati, H. 2024. The Influence of Differences in Silicate Concentration on the Growth of Microalgae *Thalassiosira* sp. at the Laboratory Scale. *Journal of Marine Biotechnology and Immunology.* 2(1): 10-14. https://doi.org/10.61741/7d56xf61

Ariadi, H., Fadjar, M., Mahmudi, M., & Supriatna, S. 2019. The relationships between water quality parameters and the growth rate of white shrimp (*Litopenaeus vannamei*) in intensive ponds. *AACL Bioflux.* 12: 2103-2216.

Avnimelech, Y. 2009. Biofloc technology. A practical guide book. The World Aquaculture Society. *Baton Rouge*.

Boyd, C., & Gautier, D. 2000. Effluent composition and water quality standards. *Global Aquaculture Advocate.* 3: 61-66.

Boyd, C. E. 2019. *Water quality: an introduction*. Springer Nature.

Burford, M. 1997. Phytoplankton dynamics in shrimp ponds. *Aquaculture Research.* 28(5): 351-360. https://doi.org/10.1046/j.1365-2109.1997.00865.x

Carbajal-Hernández, J. J., Sánchez-Fernández, L. P., Villa-Vargas, L. A., Carrasco-Ochoa, J. A., & Martínez-Trinidad, J. F. 2013. Water quality assessment in shrimp culture using an analytical hierarchical process. *Ecological Indicators.* 29: 148-158. https://doi.org/10.1016/j.ecolind.2012.12.017

FAO. 2022. The State of World Fisheries and Aquaculture 2022. *Towards Blue Transformation, Rome, FAO*. https://doi.org/10.4060/cc0461en

FAO. 2024. Fishery and Aquaculture Statistics – Yearbook 2021. *FAO Yearbook of Fishery and Aquaculture Statistics, Rome*. https://doi.org/10.4060/cc9523en

Fisheries, M. o. M. A. a. 2023. Ministry of Maritime Affairs and Fisheries Annual Report 2023. *https://kkp.go.id Accessed January 12, 2024*.

Genkal, S. I. 2012. Morphology, taxonomy, ecology, and distribution of *Cyclotella choctawhatcheeana* prasad (Bacillariophyta). *Inland Water Biology.* 5(2): 169-177. https://doi.org/10.1134/S1995082912020046

Hargreaves, J. A. 2006. Photosynthetic suspended-growth systems in aquaculture. *Aquacultural Engineering.* 34(3): 344-363. https://doi.org/10.1016/j.aquaeng.2005.08.009

Istiqomah, Z., Subagiyo, S., & Yudiati, E. 2024. The Influence of Enrichment with Ascorbic Acid and Fermipan on *Artemia* sp. Exposed to Salinity Shock. *Journal of Marine Biotechnology and Immunology.* 2(1): 19-23. https://doi.org/10.61741/668wpm55

Kilham, P., & Hecky, R. E. 1988. Comparative ecology of marine and freshwater phytoplankton1. *Limnology and Oceanography.* 33(4part2): 776-795. https://doi.org/10.4319/lo.1988.33.4part2.0776

LeGresley, M., & McDermott, G. 2010. Counting chamber methods for quantitative phytoplankton analysis-haemocytometer, Palmer-Maloney cell and Sedgewick-Rafter cell. *Microscopic and Molecular Methods for Quantitative Phytoplankton Analysis*: 25-30.

Nan, Y., Xiao, M., Duan, Y., & Yang, Y. (2024). Toxicity of Ammonia Stress on the Physiological Homeostasis in the Gills of *Litopenaeus vannamei* under Seawater and Low-Salinity Conditions. *Biology*, *13*(4). https://doi.org/10.3390/biology13040281

Neori, A., Chopin, T., Troell, M., Buschmann, A. H., Kraemer, G. P., Halling, C., Shpigel, M., & Yarish, C. 2004. Integrated aquaculture: rationale, evolution and state of the art emphasizing seaweed biofiltration in modern mariculture. *Aquaculture.* 231(1): 361-391. https://doi.org/10.1016/j.aquaculture.2003.11.015

Rasyidah, A., Sunaryo, S., Yudiati, E., & Widiasa, I. N. 2024. Physico-Chemical Dynamics of Vanname Shrimp (*Litopenaeus vannamei*) Cultivation Pond Water Quality with A Recirculation System. *Journal of Marine Biotechnology and Immunology.* 2(1): 1-9. https://doi.org/10.61741/8pvwk765

Reynolds, C. S. 1984. The ecology of freshwater phytoplankton.

Roy, L. A., Davis, D. A., Saoud, I. P., Boyd, C. A., Pine, H. J., & Boyd, C. E. 2010. Shrimp culture in inland low salinity waters. *Reviews in Aquaculture.* 2(4): 191-208. https://doi.org/10.1111/j.1753-5131.2010.01036.x

Schock, T. B., Duke, J., Goodson, A., Weldon, D., Brunson, J., Leffler, J. W., & Bearden, D. W. 2013. Evaluation of Pacific White Shrimp (*Litopenaeus vannamei*) Health during a Superintensive Aquaculture Growout Using NMR-Based Metabolomics. *PLoS One.* 8(3): e59521. https://doi.org/10.1371/journal.pone.0059521

Wijaya, R. A., Muliawan, I., Hafsaridewi, R., Suryawati, S. H., & Pramoda, R. 2021. Economic analysis of vannamei shrimp aquaculture in Aceh Besar Regency based on different land areas. *IOP Conference Series: Earth and Environmental Science*. 674(1): 012039. https://doi.org/10.1088/1755-1315/674/1/012039

Willén, E. 1976. A simplified method of phytoplankton counting. *British Phycological Journal*. 11(3): 265-278. https://doi.org/10.1080/00071617600650551

Yang, W., Zhu, J., Zheng, C., Lukwambe, B., Nicholaus, R., Lu, K., & Zheng, Z. 2020. Succession of phytoplankton community during intensive shrimp (*Litopenaeus vannamei*) cultivation and its effects on cultivation systems. *Aquaculture*. 520: 734733. https://doi.org/10.1016/j.aquaculture.2019.734733