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Growth of Vannamei Shrimp (Litopenaeus vannamei) in Intensive Cultivation Systems

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Abstract: Vaname shrimp (Litopenaeus vannamei) is one of the shrimps that is widely cultivated in Indonesia. The aim of this research is to analyze the growth and dynamics of water quality in vaname shrimp cultivation ponds using an intensive system. This research is a descriptive study with a survey method conducted in January-April 2023. The research location is in a vaname shrimp cultivation pond with an intensive system with a stocking of 116 individuals/m^3. The research results showed that the average weight of shrimp at the end of cultivation was 18.48 grams/fish. Average daily growth ranges from 0.1-0.41 grams. The survival rate (SR) of cultivated vaname shrimp is 75.8% with a feed quantity ratio (FCR) of 1.47. The results of water quality measurements include temperatures ranging from 27.4-30.1 °C, brightness 25-65 cm, salinity 21-26 ppt, pH 8-9, dissolved oxygen 4.2-6.7 ppm, carbon dioxide 24.5- 67.1 ppm, ammonia 0.11-1.67, TOM 2.78-108.70 ppm and total vibrio $1x10^3$-$3.9x10^3$ CFU/ml. Shrimp growth in ponds is classified as good with water quality suitable for cultivation.

Keywords: Growth rate; FCR; *Litopenaeus vannamei*; SR; Water quality

Introduction

Vaname shrimp (Litopenaeus vannamei) is a species of shrimp that is widely cultivated in Indonesia. This is because this species has several advantages compared to other shrimp, including fast growth, more resistance to disease attacks and high economic value (An et al., 2020). Vannamei shrimp have great economic potential due to high market demand, both domestically and abroad (Octovianus et al., 2023).

During sustainable shrimp cultivation, there are various obstacles such as environmental degradation, decreasing water quality, competition for land use, and infectious diseases (Irani et al., 2023). Water quality is an important part of the cultivation process which can directly influence shrimp cultivation activities. Environmental conditions that are not supportive can cause cultivated organisms to become stressed, causing disease and even death. White vaname shrimp require good water quality for optimal growth and survival (Harlina et al., 2022).

Several water quality parameters such as temperature, salinity, acidity, dissolved oxygen, carbon dioxide, ammonia and other quality parameters have a direct or indirect impact on the growth and health of vaname shrimp. Water quality during vaname shrimp cultivation with various cultivation systems fluctuates as cultivation time increases with a decreasing tendency (Muhammad et al., 2022). Inappropriate water quality can cause shrimp stress, failure to grow and disease, which can result in crop failure (Ritonga et al., 2021).

Based on this explanation, this research aims to analyze the growth and dynamics of water quality in vaname shrimp cultivation ponds using an intensive system.

Method

Location and Time of Study

This research will take place in January-April 2023. The research location is in vaname shrimp cultivation ponds, the Brackish and Marine Water Fisheries

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Laboratory belonging to the Faculty of Fisheries and Marine Sciences, Brawijaya University which is located in Mayangan District, Probolinggo City, East Java. Testing was carried out at the Freshwater Fisheries Laboratory and Aquatic Products Technology Science Laboratory, Fisheries Product Safety Division, Faculty of Fisheries and Marine Sciences, Brawijaya University. A map of the research location can be seen in Figure 1.

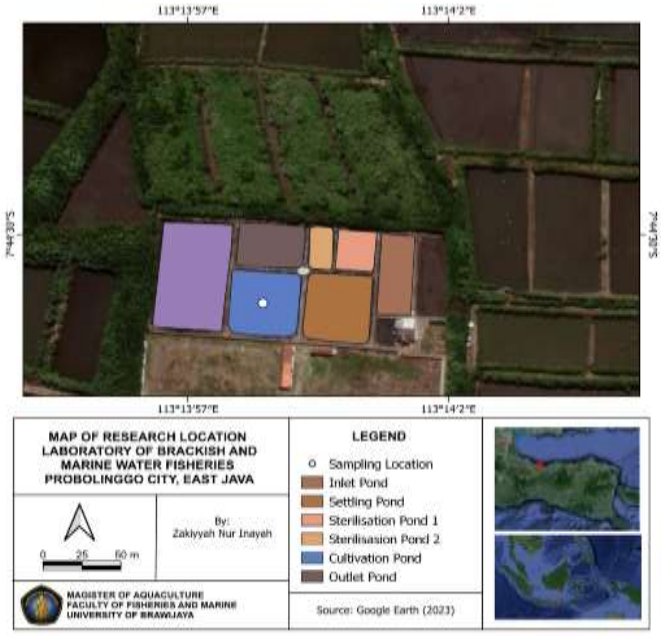

Figure 1. Map of research locations

Research Design

This research is descriptive research with a survey method. The data used is primary data and secondary data. This research was carried out in intensive ponds with an area of 1600 m^2 and a stocking density of 110 fish/m^2. The cultivation process is carried out for 98 days. Sampling of shrimp growth and pond water quality was carried out weekly after the 47th cultivation day. Shrimp sampling using anco. Shrimp growth is measured by weighing the weight of the shrimp sampled.

Water Quality Parameter Measurement

Water quality measurements carried out include physical (temperature, brightness and salinity), chemical (pH, dissolved oxygen, carbon dioxide, ammonia and TOM) and biological (total vibrio) parameters. These measurements were carried out in situ and out situ. In situ measurements include temperature, brightness, salinity, pH, DO, and carbon dioxide. Ammonia, TOM, and total vibrio parameters were carried out ex situ. Tools and methods for measuring water quality can be seen in table 1.

Table 1. Water quality measurement methods

Parameter	Tool - Method
Temperature and DO	DO meter
Brightness	*Secci disc*
pH	pH paper
CO2 dan TOM	Titration
Ammonia	Spectrophotometer Method
Total Vibrio	Spread Method with TCBSA (Thiosulfate Citrate Bile Salts Agar) media

Data Analysis

The data obtained was collected and analyzed statistically using Microsoft Excel 2016. The results obtained were then explained descriptively.

Shrimp Growth Calculation

Growth parameters calculated include survival rate, average weight, daily growth and feed consumption ratio. The calculation formula Rakhmanda *et al*. (2021) as follows:

$$\text{Survival Rate (SR)}(\%) = \frac{Initial\ number\ of\ individuals}{Final\ number\ of\ individuals} \times 100 \quad (1)$$

$$\text{ABW (g)} = \frac{Total\ weight\ of\ the\ individual\ (g)}{Number\ of\ individuals\ (ekor)} \quad (2)$$

$$\text{ADG (g/day)} = \frac{Final\ average\ weight - Initial\ average\ weight}{Cultivation\ Time} \quad (3)$$

$$\text{FCR} = \frac{Total\ dry\ weight\ of\ feed\ given\ (Kg)}{Total\ weight\ of\ biomass\ (Kg)} \quad (4)$$

Result and Discussion

Shrimp Growth

The results of the average weight (ABW) of vaname shrimp for 98 days can be seen in Figure 2. The weight growth of the shrimp increased as cultivation time increased. The average weight of vaname shrimp obtained at the end of cultivation was 18.48 g/head and was classified as good. The ideal average weight in the production of vaname shrimp aged 80-120 DOC is 12.1 – 20.0 grams (Pramudia *et al*., 2022). Factors that influence shrimp body weight include age, nutritional requirements for feed, stocking density and quality of cultivation media (Pratiwi *et al*., 2021).

Daily growth yield (ADG) ranges from 0.10-0.41 grams (Figure 3), which is quite good for vaname shrimp cultivation. ADG values between 0.12-0.17 grams/day are still considered good for vaname shrimp cultivation,

with an ideal value of 0.22 grams/day (Katmoko *et al*., 2021). The ADG value increased from week 8 to week 10 but decreased at week 11. This is thought to be because the shrimp are experiencing stress due to the partial harvest. According to Cahyanurani dan Hariri (2021), partial harvest can cause cultivated shrimp to become stressed. This is because the nets for harvesting are carried out repeatedly which also results in a decrease in water quality because the waste at the bottom of the pond will be stirred up and pollute the cultivation water.

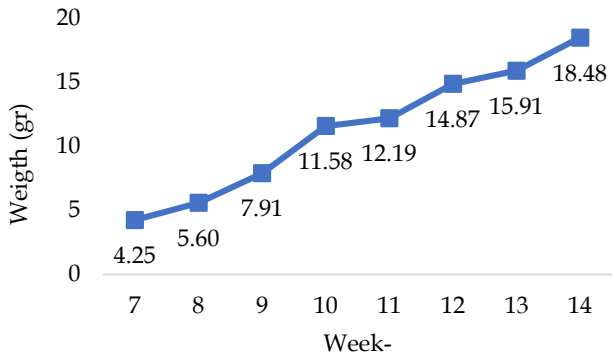

Figure 2. Average weight (ABW) of vaname shrimp

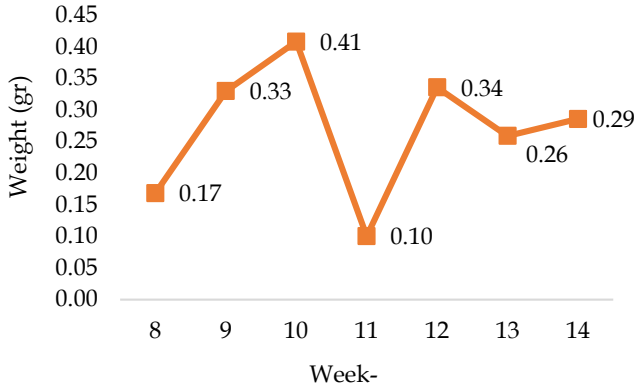

Figure 3. Daily growth (ADG) of vaname shrimp

According to Pratiwi *et al*. (2022), growth in crustaceans is growth in length and weight that occurs periodically after molting. The molting process is the process of replacing the old skin with new skin in animals that have an exoskeleton. Factors that influence moulting consist of internal factors, namely the production of moulting hormones (ecdysteroids) and moulting inhibitor hormones, as well as external factors in the form of cultivation water quality (temperature, salinity or pH) and feed nutrition.

According to Hassan *et al*. (2022), the growth of vaname shrimp in cultivation is influenced by stocking. High stocking densities result in competition for food due to the smaller space for shrimp to move. High density also results in dominance and aggressive behavior of large shrimp over small shrimp, which also affects the survival rate of shrimp. The amount of feed in high-density ponds is also greater and increases the decline in water quality from residual feed and metabolism. This causes stress and the shrimp's immune system decreases, resulting in slow shrimp growth and even death.

The survival rate (Survival Rate/SR) of vaname shrimp at the end of cultivation (DOC 98) was 75.8%. This value is included in the high category for ponds with intensive systems. The survival value of vaname shrimp during cultivation is classified as high if it is >70%. This high value can be influenced by the low death rate. Factors that influence mortality rates include nutritional requirements for feed and water quality during cultivation (Akbarurrasyid *et al*., 2023). According to Nadiro *et al*. (2023), less than optimal water quality will cause fish stress and end in death. Apart from that, stocking density affects competition for space and food, thus affecting the survival of organisms.

Feed Conversion Ratio (FCR) is the ratio of the amount of feed to the amount of biomass. The FCR value is used to determine the amount of feed needed to produce one kilogram of meat. The FCR results in this study were 1.47, which means that to get 1 kg of shrimp meat you need 1.47 kg of feed. This FCR is considered good for vaname shrimp cultivation. According to Cahyanurani dan Edy (2022), the feed conversion ratio (FCR) is related to the efficiency of feed absorption by shrimp. A low FCR value indicates that the feed provided is more efficient, able to be digested and utilized well by the shrimp, thereby supporting their growth. The optimal FCR value in vaname shrimp cultivation generally ranges between 1.3-1.7.

Water Quality Parameters

Temperature

The temperature values obtained ranged from 27.4-30.1 °C and fluctuated every week (Figure 4). These fluctuations are caused by environmental conditions such as unstable weather. There are often changes in hot and rainy weather. Even though temperature conditions fluctuate, they are still in good condition for vaname shrimp cultivation.

Factors that influence water temperature include weather and climate (Latupeirissa and Latupeirissa, 2022). Extreme weather changes cause fluctuations in cultivation water temperature. This affects the morphology, growth, physiology, appetite, behavior, swimming activity, reproduction, metabolism and survival of cultivated organisms (Wang *et al*., 2019; Azzahra *et al*., 2023). Vaname shrimp can adapt to certain levels of temperature fluctuations. The optimal temperature for growing vaname shrimp ranges from

26-32 °C. Temperatures below 25 °C can cause shrimp to slowly lose their appetite and shrimp become disturbed if the temperature is above 32 °C, thereby causing high production costs (Harlina *et al*., 2022).

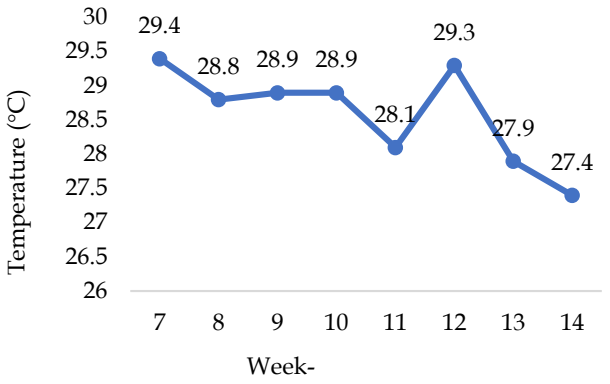

Figure 4. Temperature graph

Brightness

Pond brightness ranged between 25-65 cm and decreased as cultivation time increased (Figure 5). This is related to the addition of particles in the water as cultivation time increases, such as organic material in the form of leftover feed or feces and the growth of plankton. Weather conditions at the time of measurement such as the intensity of light entering the water and cloud cover also affect the brightness of the pond.

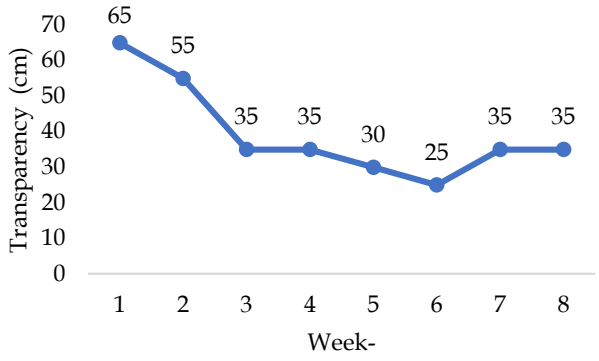

Figure 5. Brightness graph

The brightness measurement results were still within the normal range for vaname shrimp cultivation. The optimum brightness value for shrimp growth is 20-40 cm from the water surface. Brightness shows that the light entering the pond has an effect on phytoplankton, low brightness values can cause a decrease in their growth. Light is used by phytoplankton in the photosynthesis process (Musa *et al*., 2023). Low brightness can also indicate that the particles and phytoplankton in the pond are too dense so water changes need to be carried out (Katmoko *et al*., 2021).

Salinity

The salinity value ranges from 21-26 ppt (Figure 6). Pond salinity is influenced by evaporation and weather conditions such as rain (Mulyani et al., 2023). Circulation patterns or water changes in ponds can also influence salinity values (Rahmi *et al*., 2023). A decrease in temperature outside the optimal range can also reduce DO in water, thereby increasing salinity conditions which can trigger a stress response in aquatic organisms so that their growth decreases and affects cultivation productivity (Fakhriyah et al., 2022).

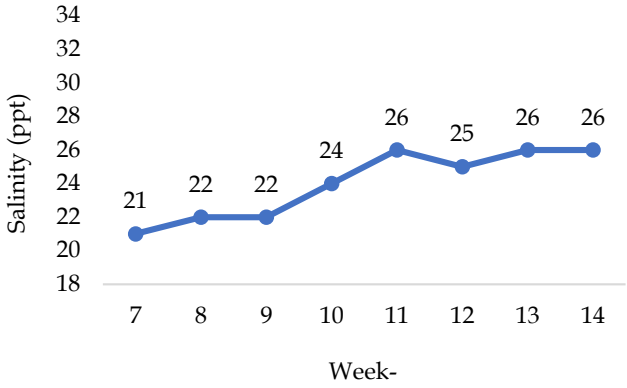

Figure 6. Salinity graph

White vaname shrimp can tolerate salinity in the range of 4 – 32 ppt (Rakhmanda *et al*., 2021). According to Harlina *et al*. (2022), salinity is related to the osmotic pressure of water which influences osmoregulation and shrimp growth. High salinity can also cause a reduction in dissolved oxygen content in ponds. The ideal salinity value for the growth of vaname shrimp is 15-25 ppt.

Acidity (pH)

The results of the degree of acidity (pH) obtained were relatively the same, ranging between 8-9. This value can be categorized as good for vaname shrimp cultivation. The suitable pH range for shrimp cultivation is between 7.5 – 8.5. The factors that determine the pH value in ponds are the processes of photosynthesis and respiration. The use of carbon dioxide in the photosynthesis process reduces the concentration of carbonic acid in the water, so that the pH increases (Musa *et al*., 2020; Elfiza et al., 2023).

According to Renitasari dan Musa (2020), A pH of less than 4.5 or more than 9.0 can cause shrimp to be susceptible to disease, decreased appetite, weakness and shrimp to become porous and mossy. According to Supardiono et al. (2023), the pH range suitable for aquatic organisms is not the same depending on the type of organism, but most aquatic organisms are sensitive to

changes in pH and have a pH tolerance of around 7 – 7.5. A pH value of 6 – 6.5 can cause a decrease in the diversity of plankton and macrobenthic animals.

Dissolved Oxygen (DO)

The results of dissolved oxygen measurements in vaname shrimp ponds ranged from 4.2 to 6.7 ppm (Figure 7). Dissolved oxygen fluctuates every week, but can still be categorized as good for vaname shrimp cultivation. According to Supriatna *et al*. (2017), the optimal level of dissolved oxygen in ponds for the growth of vaname shrimp is in the range of 3.5 – 7.5 ppm. DO < 3 in a short time can cause stress and susceptibility to disease, low appetite and slow shrimp growth. DO < 2.0 ppm has the potential to kill aquatic organisms.

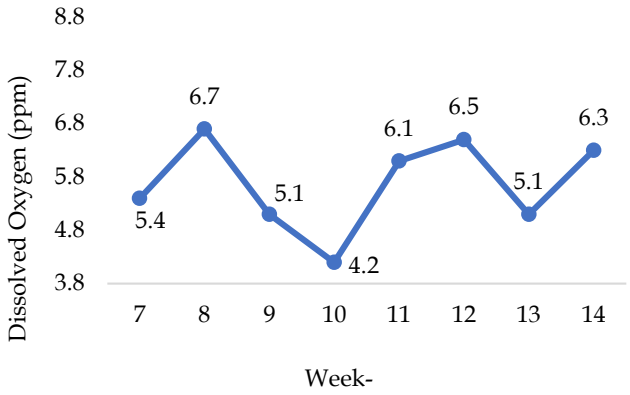

Figure 7. Dissolved oxygen graph

Dissolved oxygen (DO) is an important factor that influences the growth and health of vaname shrimp. Oxygen is used for shrimp respiration, apart from that it is also used in the decomposition process of organic material by microorganisms. Low oxygen levels in water can affect biological functions, inhibit growth or even cause the death of aquatic organisms (Bosman et al., 2021). According to Lien dan Giao (2020), the need for oxygen increases with increasing feed and shrimp waste which accumulates at the bottom of ponds over time. According to Dhea et al. (223), the source of DO in waters comes from oxygen diffusion by 35% and the photosynthetic activity of phytoplankton.

Carbon Dioxide (CO_2)

The results of carbon dioxide in vaname shrimp ponds can be seen in Figure 8. Carbon dioxide ranges between 24.5-67.1 ppm, increasing as cultivation time increases. Carbon dioxide levels increase with increasing cultivation time. Factors that influence CO_2 in ponds include organism respiration, decomposition of organic material and photosynthesis. The photosynthesis process utilizes CO_2, increasing pH and DO so that free CO_2 is reduced. The high CO_2 in ponds over time can be caused by the large amount of cultivated biomass which causes increased respiration processes and decomposition of organic material (Supono, 2018).

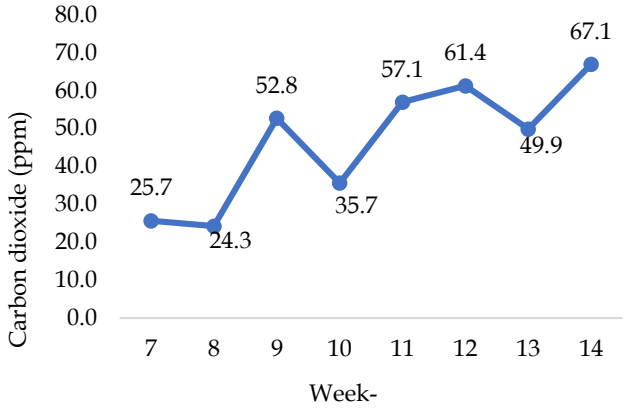

Figure 8. Carbon dioxide graph

Sources of carbon dioxide in pond waters include rainwater, atmospheric diffusion and the results of respiration of aquatic biota and the decomposition of organic matter by bacteria. The optimum CO_2 concentration for cultivation activities such as vaname shrimp is <5 ppm and most aquatic animals can still survive at carbon dioxide concentrations of 20 – 60 ppm. Carbon dioxide concentrations > 60 ppm will disrupt breathing and ultimately cause death in cultivated organisms (Rahmi *et al*., 2023).

Ammonia

The ammonia value was relatively stable, and suitable for shrimp cultivation, except in the last week (Figure 9). This happens because of the stirring of the pond bottom during harvest. Ammonia is a toxic form of inorganic nitrogen in ponds that comes from the breakdown of organic material by heterotrophic bacteria. The ammonia concentration in unpolluted water should be below 0.2 ppm to ensure healthy shrimp growth. High ammonia concentrations can cause a decrease in shrimp survival rates (Musa *et al*., 2020).

Ammonia in ponds is a product of shrimp metabolism and decomposition of organic materials, such as food waste and feces. Optimal ammonia levels are a good source of nitrogen for phytoplankton, increasing dissolved oxygen levels in the water and as natural food for shrimp. High values of ammonia are dangerous for shrimp, causing detrimental effects such as being susceptible to pathogens, increasing molting frequency, reducing osmoregulatory capacity, affecting growth and survival (Cavalheiro *et al*., 2023).

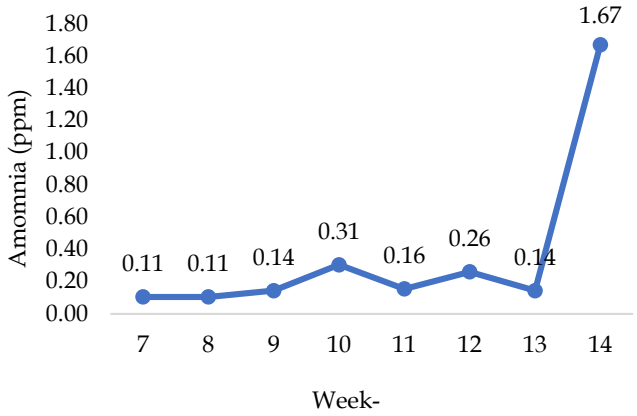

Figure 9. Ammonia graph

Total Organic Matter (TOM)

The results of measuring total organic matter in vaname shrimp ponds can be seen in Figure 10. The results show that the total organic matter content in ponds is still in the good category, except in the 8th week where the value is higher than the other weeks. This can be caused by the high content of organic matter in ponds such as plankton, leftover feed, or feces, and the pond water has not been changed. According to Musa *et al.* (2023), TOM levels in intensive vaname shrimp cultivation should be <90 ppm

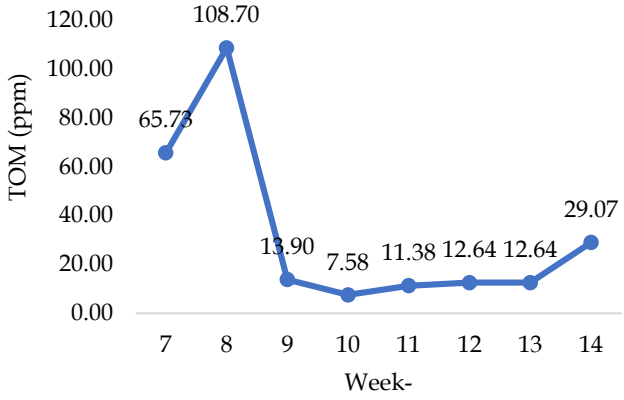

Figure 10. Total organic matter graph

The maximum level of total organic matter in vaname shrimp ponds is 150 ppm. The main sources of organic material in aquaculture ponds are organic fertilizer, feces, food waste, phytoplankton, zooplankton and benthos, zooplankton and benthos (Jefri *et al.*, 2020). The accumulation of organic material that is appropriate to the pond's carrying capacity has a positive impact, because it can produce nutrients that are beneficial for aquatic organisms. Excessive accumulation of organic matter has a negative impact because it will increase the rate of decline in oxygen in the water and increase oxygen demand. If this continues, it will worsen the condition of the cultivation environment, especially the bottom water layer, which produce toxic compounds such as NH3, CH4 and H2S which are dangerous for shrimp. This causes shrimp stress, reduced appetite, and is susceptible to disease and even death (Suwoyo *et al.*, 2015).

Total Vibrio

The results of testing for total vibrio in vaname shrimp pond water can be seen in Figure 28. Total vibrio increased with increasing cultivation time with the highest value of 10^4 CFU/ml in week 5. It is suspected that in that week the vibrio bacteria could grow well because Water quality supports its growth, especially salinity. The salinity in the 5th week was quite high and supported the growth of vibrio, which is a natural seawater bacteria. According to Pariakana dan Rahima (2021), salinity has a strong influence on the number of vibrios in water. High salinity values can cause high numbers of bacteria. The presence of vibrio bacteria can increase at salinity > 20 ppt and further increases at salinity > 28 ppt. According to Armenta-Bojorquez et al. (2021), low salinity causes an unstable environment for Vibrio spp. Number of Vibrio and Bacillus spp. increases with increasing water salinity.

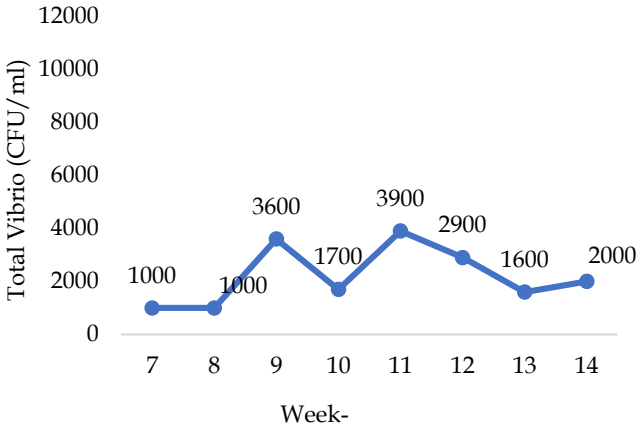

Figure 11. Total vibrio graph

The total vibrio is still within the normal range for vaname shrimp cultivation. According to Sani *et al.* (2020), generally the presence of vibrio in vaname shrimp cultivation of 2.5 ± 0.5 x 10^4 CFU/ml is not yet pathogenic for healthy shrimp, but it should be < 10^4 CFU/ml. This is because a vibrio density of 10^4 CFU/ml has a susceptibility to vibriosis infection which can result in mass deaths in cultivated shrimp. The height of Vibrio sp. in ponds it can be caused by high levels of organic matter in ponds from leftover feed or feces which supports the growth of bacteria. Reducing vibrio in ponds can be done with good water quality management and selecting shrimp seeds.

Conclusion

Shrimp growth in vaname shrimp ponds with an intensive system has increased with increasing cultivation time and is classified as good. Water quality is considered good for cultivation even though there are several parameters that fluctuate.

Author Contributions
All authors contributed to the completion of this article, including sampling, data analysis, and article preparation.

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Conflicts of Interest
The authors declare no conflict of interest.

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