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Monitoring of Aquatic Environmental Factors on the Growth of Whiteleg Shrimp (*Litopenaues vannamei* Boone, 1931)

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ABSTRACT The environment is an important aspects and can be an indicator of the success of whiteleg shrimp culture. Stable water quality is a condition when water quality meets the requirements of growing whiteleg shrimp. This study aims to determine the aquatic environmental factors on the growth of whiteleg shrimp. There were 3 ponds observed in this research with an area of 2.000 m^2, 2.500 m^2, and 350 m^2 respectively. The result of the research shows that the water quality of whiteleg shrimp culture is still in the feasible category. Several parameters show fluctuated results beyond optimal values such as dissolved oxygen, salinity, total ammonia nitrogen, and total organic matter. The results of the correlation test showed that all the quality parameters of whiteleg shrimp culture had varying degrees of relationship. The highest correlation level was obtained in salinity, nitrate, nitrite, ammonia, temperature, and dissolved oxygen. Water quality in each pond has a very strong relationship to the growth of mean body weight (10.31 g/tail, 10.92 g/tail, and 11.39 g/tail), average daily growth (0.4142 g/day, 0.4971 g/day, and 0.3557 g/day), and survival rate (92.4%, 92.4%, and 92.3%).

Keywords: Average body weight; *Litopenaeus vannamei*; mean body weight; water quality

INTRODUCTION

The environment is a major factor in the whiteleg shrimp farming system. Whiteleg shrimp can grow optimally in a cultivation environment that is in accordance with growing requirements Cultivation that is not environmentally friendly can cause serious problems for cultivation activities and environmental stability (Barbieri *et al*., 2014). A healty environment is very important to create balanced conditions between the various components of the water. Water components consist of biotic and abiotic components. Changes in environmental conditions may affect the interaction between the components in the aquatic ecosystem. According to Akbarurrasyid *et al*. (2023), interactions in aquatic ecosystems are divided into 3: (i) interactions between biotic and biotic components; (ii) interactions between abiotic and abiotic components; and (iii) interactions between biotic and abiotic components or vice versa.

Whiteleg shrimp is an important aquaculture commodity due to its relatively fast growth, high appetite rate, disease resistance, and high selling value (Putra & Abdul, 2014). According to Akbarurrasyid *et al*. (2023) growth in mean body weight (MBW) ranges from 1.61-21.11 g/individual, average daily growth (ADG) ranges from 0.14-0.62 g/day, size is 49 individuals/kg and biomass is 7.680 kg. The survival rate obtained was around 84.87-95.07%, while the feed convertion ratio (FCR) ranged from 1.2-1.5. Biotic components of the aquatic ecosystem are all types of living creatures or aquatic organisms that exist naturally or are cultivated. Aquatic organisms that are cultivated are strongly influenced by environmental factors. Environmental factors can be traced based on the level of water quality. Changes in water quality can affect the balance and stability of aquatic ecosystems which have an impact on the growth of aquatic organisms. Whiteleg shrimp is an aquatic organism whose growth is strongly influenced by the media and the quality of the water. To carry out sustainable aquaculture activities, the whiteleg shrimp farm must be managed properly, especially the management of whiteleg shrimp culture waste. Aquaculture waste has an impact on the plankton structure (natural feed) in the pond. Changes in the plankton community occur according to the environmental conditions of the waters. Environmental conditions affect changes in the composition, type and amount of plankton associated with the trophic structure of the waters by the phytoplankton group (Sirait *et al*., 2018).

The source of whiteleg shrimp culture waste are feces, unused feed residue, and aquaculture activities such as the use of drugs and chemicals. Aquaculture waste mostly accumulated in a water column and settles at the bottom of the water in the form of organic and inorganic waste. Organic and inorganic waste must be managed properly and appropriately to avoid water quality degradation. Degradation of water quality is a serious threat to whiteleg shrimp farm activities (Akbarurrasyid *et al*. 2023). Water quality degradation is affected by high stock density, high feed input, and low efficiency of feed use (Supono, 2018). Degradation of water quality such as transparency, temperature, pH, dissolved oxygen, Biological Oxygen Demand (BOD), and carbon dioxide can affect the growth of whiteleg shrimp (Soliha *et al*., 2016).

Whiteleg shrimp grow optimally in a optimal aquatic environment. Stable water quality is a condition when water meets the requirements of growing whiteleg shrimp. Stable water quality affects the feed conversion value which has an impact on the growth of whiteleg shrimp (Ariadi *et al*., 2020). On the other hand, poor water quality can cause slow growth, low appetite rate, weak shrimp conditions, and stimulate the growth of anaerobic bacteria at the bottom of the pond which can lead to production failures that have an impact on whiteleg shrimp productivity. This study aims to monitor aquatic environmental factors on the growth of whiteleg shrimp.

MATERIALS AND METHODS

Description of the study sites

The research was conducted in Garut, West Java, Indonesia (7°35'57.5"S-107°38'7"E) for two months (November to December 2021). The research was carried out by observation in production ponds with their respective carrying capacities. Research is limited to production activities on different pond areas and densities. The ponds observed were 3 plots with an area of 2.000 m^2, 2.500 m^2, and 350 m^2. The total area of each pond is different and affects the stocking density of 191 idv/m^2 (pond 1), 212 idv/m^2 (pond 2), and 188 idv/m^2 (pond 3). A similar setting is performed such as water depth (120 cm), daily water change (10-20%), and the same type of feed (32% protein), and each pond is provided with a mill for aeration purposes. The total capacity of the mill used is 12 horsepower (pond 1), 16 horsepower (pond 2), and 2 horsepower (pond 3).

Analysis of aquatic environmental factors

Aquatic environmental factors are observed daily. Environmental factors observed in this research were focused on the most crucial factors in whiteleg shrimp farming activities. The method of observing or monitoring aquatic environmental factors (Table 1) is carried out in situ and ex-situ. Statistical regression analysis was carried out to determine water quality and its level of relationship with culture and other parameters.

Table 1. Methods of monitoring aquatic environmental factors.

No	Aquatic environmental factors	Observation technique	Methods
1	Temperature	In situ	Multi probe
2	Dissolve Oxygen	In situ	Multi probe
3	pH	In situ	Multi probe
4	Salinity	In situ	Survey
5	Nitrate	Ex situ	Spectro-photometric
6	Nitrite	Ex situ	Spectro-photometric
7	Phosphate	Ex situ	Spectro-photometric
8	Total Ammonia Nitrogen	Ex situ	Spectro-photometric
9	Ammonia	Ex situ	Spectro-photometric
10	Carbon dioxide	Ex situ	Titration
11	Alkalinity	Ex situ	Titration
12	Total Organic Mater	Ex situ	Titration

Analysis of whiteleg shrimp growth.

Mean body weight (MBW)

Mean body weight (MBW) is the average weight of shrimp obtained during sampling once a week with a total of 50 shrimp in each pond. According to Haliman & Adijaya (2005), MBW can be calculated using the following formula:

$$WBW\,(g/tail) = \frac{Sample\ weight\ (g)}{Number\ of\ sample\ (tails)}$$

Average daily growth (ADG)

The speed of shrimp growth is based on the average daily weight gain of shrimp obtained during sampling once a week with a total of 50 shrimp in each pond. According to Haliman & Adijaya (2005), ADG can be calculated using the following formula:

$$ADG\,(g/day) = \frac{MBW\ current\,(g/tail)\ -\ MBW\ before\,(g/tail)}{Sampling\ time\ Interval\,(days)}$$

Size

Shrimp size is the number of shrimp in 1 kg (1000 g) of shrimp weight. The size calculation can be formulated as follows:

$$Size = \frac{1000\,(g)}{MBW\,(g/tails)}$$

Biomass

Weight of cultured shrimp as a whole. According to (Effendi, 2000), the calculation of biomass can be calculated using the following formula:

$$Biomass = \frac{harvest\ population\ x\ total\ MBW}{1000}$$

Survival rate (SR)

Percentage of shrimp at the end of cultivation activities. The SR value was obtained by calculating the number of initial stockings and the number of shrimp at the end of aquaculture. According to Effendie, (1979), the calculation of SR can be done using the following formula:

$$SR = \frac{Final\ number\ of\ hrimp\ (tails)}{Initial\ number\ of\ shrimp\ (tails)}\ x\ 100\%$$

Statistic analysis

Data analysis was carried out using statistical regression analysis of environmental factors and the growth of whiteleg shrimp. Analyzed environmental factors were the relationship of water quality parameters that affect the growth of whiteleg shrimp, while the growth of whiteleg shrimp was analyzed based on the relationship of water quality parameters with the growth of whiteleg shrimp.

RESULTS AND DISCUSSION

The environment is an important aspect of whiteleg shrimp aquaculture activities. Whiteleg shrimp can grow optimally in an aquatic environment that meets the requirements. The results of observations of aquatic environmental factors can be seen in Table 2.

Based on the average value of standard deviation, the observation result shows the quality of vannamei shrimp culture is still in the feasible category. Although there are fluctuations in parameters that exceed the optimal values

Table 2. Environmental factors of pond waters.

	Parameter	Pond 1 Min – max (mean ± SD)	Pond 2 Min – max (mean ± SD)	Pond 3 Min – max (mean ± SD)	Optimum value
1	Temperature (°C)	28-30 29.16±0.674	28-30 29.12±0.711	28-30 29.12±0.711	27-32 (Suprapto, 2005)
2	Dissolved Oxygen (mg/L)	5.09-7.27 6.54±0.523	4.48-7.65 6.51±0.675	4.67-7.51 6.66±0.649	3-7.5 (Putra & Fatchurizal, 2014)
3	pH	7.79-8.17 7.98±0.099	7.75-8.15 8.01±0.096	7.8-8.2 8.01±0.101	6.5-8.5 (Boyd, 1989)
4	Salinity (ppt)	23-30 25.48±1.746	23-31 25.48±1.835	23-31 25.48±1.835	20-28 (Putra & Fatchurizal, 2014)
5	Nitrite (mg/L)	0.010-0.118 0.043±0.025	0.011-0.168 0.048±0.030	0.011-0.211 0.043±0.038	0.1-1 (Suprapto, 2005)
6	Nitrate (mg/L)	2.3-3.0 2.916±0.227	2.3-3.0 2.916±0.227	2.3-3.0 2.916±0.227	3.9-15.5 (Febrinawati *et al.*, 2020)
7	Phosphate (mg/L)	0.026-0.393 0.153±0.128	0.021-0.552 0.131±0.117	0.030-0.492 0.109±0.106	0.1-0.25 (Fahrizal, 2014)
8	TAN (mg/L)	0.322-1.022 0.705±0.200	0.291-1.815 0.735±0.298	0.396-1.868 0.714±0.287	<1.22 (Ferreira *et al.*, 2011)
9	Ammonia (mg/L)	0.010-0.042 0.022±0.007	0.012-0.059 0.024±0.010	0.012-0.066 0.024±0.010	<0.1 (Atmomarsono *et al.*, 2014)
10	CO_2 (ppm)	0.0-40 9.44±10.42	0.0-28 6.40±7.50	0.0-28 8.64±8.51	5-60 (Boyd, 1989)
11	Alkalinity (ppm)	124-176 143.04±13.20	120-180 141.28±14.47	120-180 141.76±14.49	>100 (Atmomarsono *et al.*, 2014)
12	TOM (ppm)	37-73 56.82±7.87	40-69 56.52±6.49	37-87 57.58±9.58	<55 (Kilawati & Maimunah, 2015)

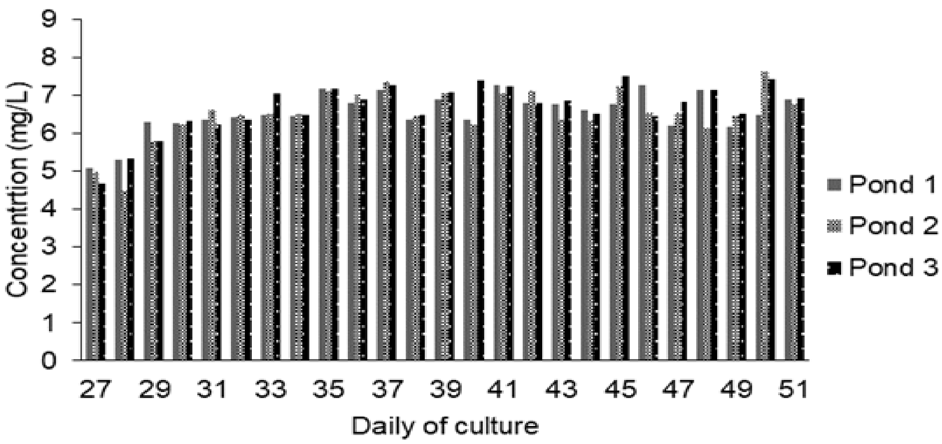

Figure 1. Fluctuations in dissolved oxygen concentration

such as dissolved oxygen, salinity, total ammoniac nitrogen (TAN), and total organic matter (TOM) this condition is still acceptable and feasible for aquaculture activities. The lowest dissolved oxygen value (mean ± standard deviation) was obtained in pond 2 and the highest in pond 3. Fluctuations in dissolved oxygen value (Figure 1) were influenced by the atmosphere and photosynthesis of aquatic plants. Dissolved oxygen in water is obtained through diffusion from air into water, mechanical aeration, and photosynthesis of aquatic plants (Mubarak *et al.*, 2010). Photosynthesis is important in aquaculture because it provides a source of organic matter for plants and a source of oxygen for aquatic organisms (Boyd, 1989). In general, the dissolved oxygen value of the three ponds was still at the optimal value. According to Putra & Abdul (2014), the optimal value for cultivation activities ranges from 3 to 3.75 ppm. Low dissolved oxygen values can reduce survival rates and shrimp production and increase feed conversion values (Boyd & Queiroz, 2014).

Salinity is an important chemical parameter that affects the growth of whiteleg shrimp. The optimal salinity value of whiteleg shrimp culture ranges from 20-28 ppt (Putra & Abdul, 2014). Based on the average value ± standard deviation, the salinity values observed in 3 ponds were still in the feasible category. The salinity value for culture fluctuated (Figure 2) but it was still in the reasonable category for whiteleg shrimp culture. According to Amri & Kanna (2008) whiteleg shrimp can grow in the salinity between 5-45 ppt. Salinity affects the level of shrimp osmotic pressure, where the difference in osmotic pressure in shrimp hemolim and large pond water causes shrimp to lose energy for adaptation and slows their growth (Supono, 2018).

The TAN value (mean ± standard deviation) in whiteleg shrimp aquaculture ponds is still in the optimal category. However, there is a fluctuation in the TAN value (Figure 3) which exceeds the required optimal value. The required optimal value of TAN for whiteleg shrimp aquaculture is <1.22 mg/L (Ferreira *et al.*, 2011). Fluctuations in TAN values can be caused by the accumulation of organic matter at the bottom of the pond which comes from unutilized feed residues and the remains of cultured shrimp feces. The reduction of nitrogen in shrimp pond waste can take place with the nitrification process (Xu *et al.*, 2020). The accumulation of organic matter at the bottom of the pond affects the concentration of ammonia (NH_3) and ammonium (NH_4). The TAN value is a combination of NH_3 and NH_4 (Fahrur *et al.*, 2014).

TOM is the concentration of total organic matter contained in water. TOM in the waters can be found in the form of dissolved, suspended, and colloidal organic matter. The TOM value (mean ± standard deviation) in the three whiteleg shrimp aquaculture ponds was slightly higher than the required optimal value. The required optimal value is <55 ppm (Kilawati & Maimunah, 2015). The high TOM value is caused by fluctuations in the TOM value (Figure 4) which is above the optimum limit. Pond water siphon is carried out to remove sludge and accumulation of aquaculture waste through the outlet. Physical filtration through siphon activity will help reduce the amount of accumulated sludge waste and minimize its negative impact on the stability of water quality in ponds (Fleckenstein *et al.*, 2020). High organic matter content has an impact on increasing nutrient content, decreasing dissolved oxygen and pH, and increasing biological activity processes which have an impact on cultured shrimp (Ghufron *et al.*, 2018).

Fluctuations in water quality have a huge impact on other water parameters. Based on correlation test data (Table 3), all water quality parameters for whiteleg shrimp culture have varying degrees of relationship. Compared to other parameters, the highest correlation level was obtained in salinity, nitrate, nitrite, ammonia, temperature, and dissolved oxygen. Salinity has a positive relationship with temperature, on the other hand, salinity has a negative correlation with nitrate, nitrite, and ammonia. This relationship shows that high salinity has an impact on low nitrate, nitrite, and ammonia content and vice versa. Besides affecting temperature, salinity concentrations also affect the concentration of ammonia (Mayunar, 1990). Ammonia concentration has a positive correlation with the concentration of nitrate

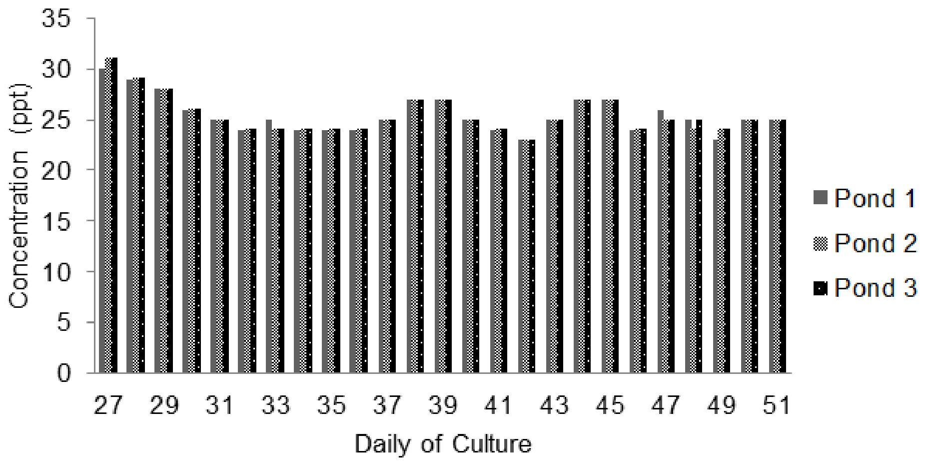

Figure 2. Salinity concentration fluctuation.

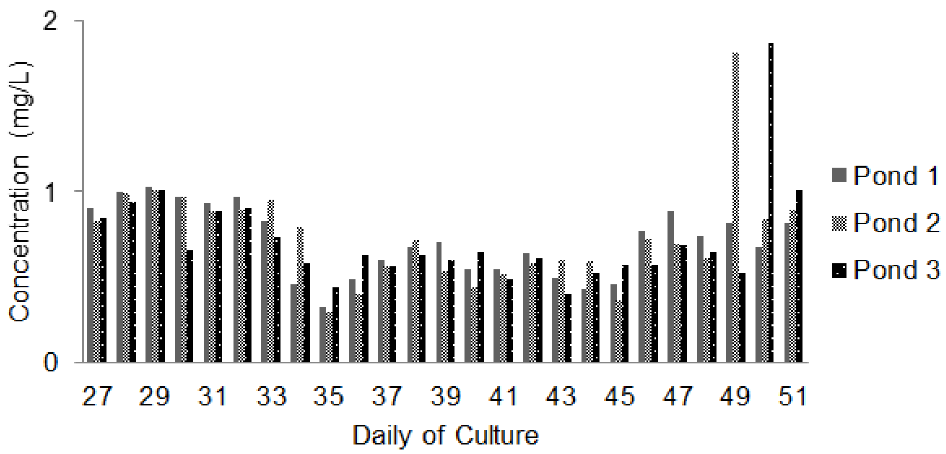

Figure 3. Fluctuations in the concentration of total ammonia nitrogen (TAN).

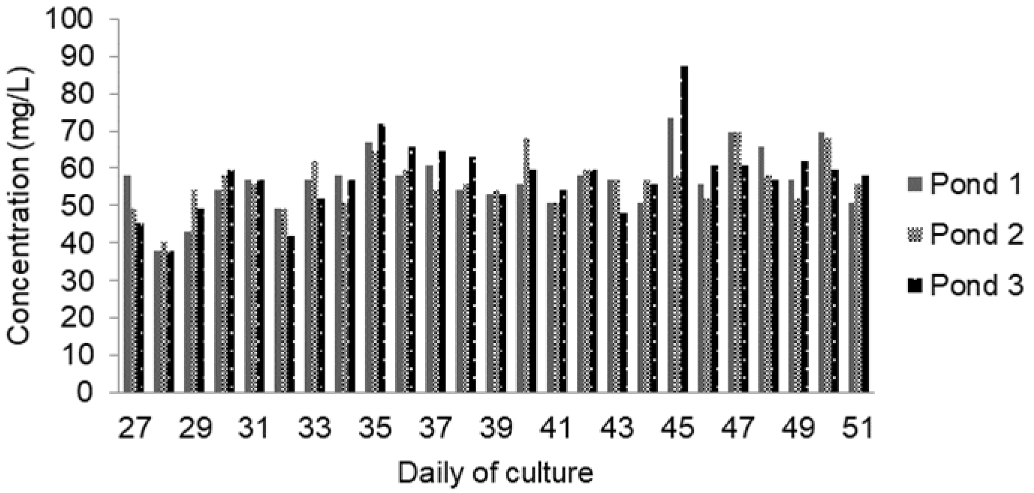

Figure 4. Fluctuations in total organic matter (TOM) concentration.

Table 3. Multiple correlation test of water quality.

	Temperature	DO	pH	Salinity	Nitrate	Nitrite	Phosphate	Ammonia	TAN	CO_2	Alkalinity	TOM
Temperature	1											
DO	-0.341	1										
pH	-0.985	0.499	1									
Salinity	0.500	0.644	-0.342	1								
Nitrate	-0.500	-0.644	0.342	-1.000	1							
Nitrite	-0.507	-0.637	0.349	-1.000	1.000	1						
Phosphate	0.871	-0.759	-0.943	0.010	-0.010	-0.018	1					
Ammonia	-0.731	-0.393	0.601	-0.957	0.957	0.959	-0.301	1				
TAN	-0.995	0.249	0.963	-0.581	0.581	0.588	-0.819	0.793	1			
CO_2	0.703	0.428	-0.569	0.967	-0.967	-0.969	0.263	-0.999	-0.769	1		
Alkalinity	0.965	-0.081	-0.904	0.711	-0.711	-0.716	0.710	-0.885	-0.986	0.866	1	
TOM	-0.240	0.994	0.405	0.721	-0.721	-0.715	-0.686	-0.487	0.145	0.521	0.024	1

and nitrite. The concentration of nitrite in waters is mostly determined by the concentration of ammonia and nitrate because it is a transitional form of these two parameters (Putri *et al.*, 2019). Ammonia is in contrast with carbon dioxide, total organic matter (TOM), and alkalinity. Alkalinity is very important and related to the abundance of mineral and lime ions for post-molting growth and the osmoregulation balance of the shrimp body (Chitra *et al.*, 2017).

The ammonia value has a positive correlation with the concentration of total ammonia nitrogen (TAN). This relationship shows a linear change in ammonia concentration with TAN concentration because the TAN value is largely determined by the form of ammonia and ammonium in the waters (Wahyuningsih *et al.*, 2020). The temperature value is positively correlated to the phosphate concentration and alkalinity. Temperature is affected by nitrate concentration (Irwan *et al.*, 2017). Excess nitrate will accelerate the process of eutrophication in the waters and increase the phosphate concentration of the waters (Rustadi, 2009). Eutrophication is a result of an abundance of phytoplankton. Phytoplankton productivity is also influenced by the availability of alkalinity (Supono, 2018). Temperature affects chemical and biological processes in water such as pH, TAN, and dissolved oxygen. Temperature affects feed consumption, metabolism, and growth of shrimp (Ariadi *et al.*, 2020). Dissolved oxygen is negatively correlated with nitrate, nitrite, ammonia, and phosphate. High dissolved oxygen accelerates the oxidation reaction of nitrite in the form of ammonia and nitrate through the denitrification process. The final form of denitrification is a nitrate which can be used for the photosynthesis process of phytoplankton in addition to phosphate. The content of nitrite, nitrate, and phosphate has the same pattern as dissolved oxygen (Fahrur *et al.*, 2014).

The growth of the mean body weight (MBW) of whiteleg shrimp increased up to the 51st daily of culture (DOC) (Figure 5). The highest MBW growth was obtained in pond 3 (11.39 g/idv) (6.96±3.87 g/idv) and the lowest was in pond 1 (10.31 g/idv) (6.07±3.48 g/idv). The increase in growth was caused by several factors such as feed and water quality which related to the requirements for the growth of whiteleg shrimp. The feed fulfills 18-35% of the protein requirement of shrimp (Witoko *et al.*, 2019). Mean-

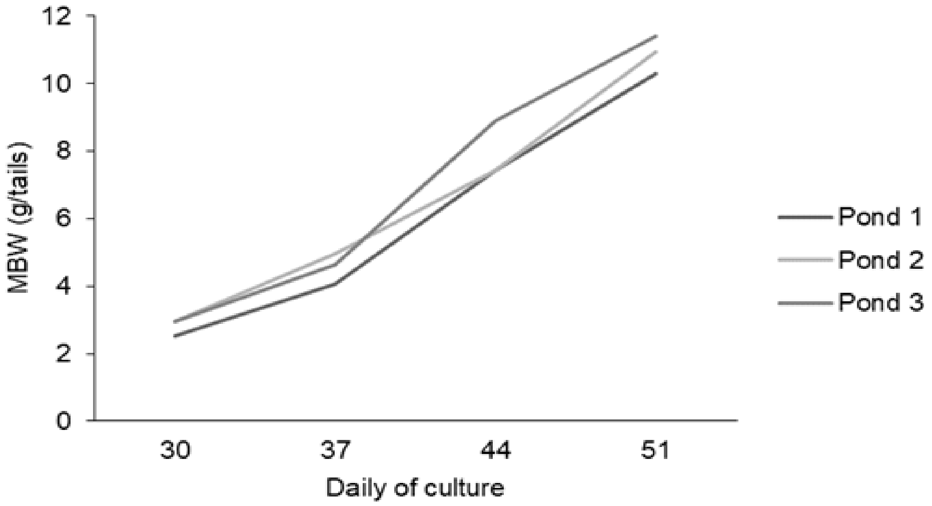

Figure 5. Mean body weight (MBW).

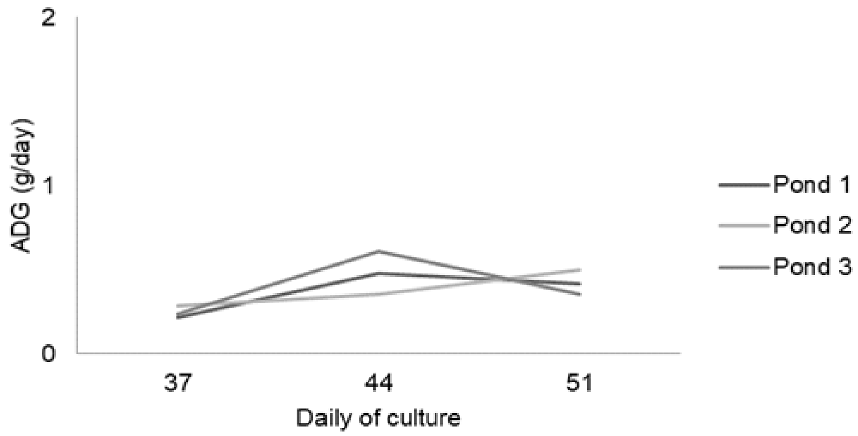

Figure 6. Average daily growth (ADG).

while, good water quality can reduce the risk of death and increase shrimp growth (Fuady *et al.*, 2013). Water quality parameters such as physical, chemical, and biological have a strong relationship with pH, phosphate, nitrite, and total organic matter (TOM), while dissolved oxygen has a strong relationship with microbiological parameters (Ariadi *et al.*, 2020).

The decrease in ADG values in ponds 1 and 3 at 51st DOC was caused by weather and shrimp molting activity. Weather changes have a direct impact on decreasing shrimp appetite. The decrease in shrimp appetite results in a decrease in metabolism which has an impact on shrimp growth (Witoko *et al.*, 2019). While molting causes unbalanced conditions between the body's calcium ions and the environment energy is mostly used to maintain survival (Yulihartini *et al.*, 2017). The highest ADG of whiteleg shrimp at the 51st DOC was obtained in pond 2 (0.497 g/day), while the lowest was obtained in pond 3 (0.035 g/day). A high ADG value is directly proportional to the obtained biomass,

Table 4. Whiteleg shrimp growth performance

No	Parameter	Pond 1	Pond 2	Pond 3
1	Size (ind/kg)	97	92	98
2	Biomass (kg)	5285	7694	987
3	Survival Rate (%)	92.4	92.4	92.3

size, and survival rate. The growth of ADG obtained was compatible with the observed performance of whiteleg shrimp (Table 4).

CONCLUSION

The results of the research on monitoring the water quality of whiteleg shrimp culture are still in the feasible category. Several parameters such as dissolved oxygen, salinity, total ammonia nitrogen, and total organic matter shows fluctuated beyond optimal values. Fluctuations in water quality parameters show an effect on other water quality parameters. The results of the correlation test showed that all water quality parameters in whiteleg shrimp culture had varying degrees of relationship. The highest correlation level was obtained in salinity, nitrate, nitrite, ammonia, temperature, and dissolved oxygen compared to other parameters. Water quality in aquaculture ponds has a very strong relationship to the growth of MBW (pond 1 is 10.31 g/idv, pond 2 is 10.92 g/idv, and pond 3 is 11.39 g/idv), ADG (pond 1 is 0.4142 g/day, pond 2 is 0.4971 g/day, and pond 3 is 0.3557 g/day), and Survival rate (pond 1 and pond 2 is 92.4%, and pond 3 is 92.3%).

AUTHOR'S CONTRIBUTIONS

The author's contribution to this research is as follows, MAK, EAP contributed to finding ideas, developing ideas, concepts and drafting the manuscript. MA contributed to data collection and technical details. WPA and AS conceptualization, formal analysis and draft review. KS contributed to drafting the manuscript. All authors actively contributed to ideas, concepts, data collection, data analysis and manuscript preparation.

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