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The growth of tiger shrimp (*Penaeus monodon*) and its dynamics of water quality in integrated culture

ROSA AMALIA♥, SRI REJEKI, LESTARI LAKSHMI WIDOWATI, RESTIANA WISNU ARIYATI
Department of Aquaculture, Faculty of Fisheries and Marine Science, Universitas Diponegoro. Jl. Prof. Soedharto, S.H. Tembalang, Semarang 50275 Central Java, Indonesia. Tel./fax. +62- 24-7465403, ♥email: rosaamalia@lecturer.undip.ac.id

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Abstract. *Amalia R, Rejeki S, Widowati LL, Ariyati RW. 2021. The growth of tiger shrimp (*Penaeus monodon*) and its dynamics of water quality in integrated culture. Biodiversitas 23: 593-600.* Intensive shrimp culture with high density will have an impact on environmental problems. One of them is the accumulation of organic materials. Integrated Multi-trophic Aquaculture (IMTA) is an alternative effort to reduce the environmental impact of aquaculture activities, which can help maintain the balance of the ecosystem. Seaweed and shellfish in the culture system can improve environmental quality. Therefore, it can assist in optimizing friendly environmental shrimp culture. This study aimed to find out the growth of tiger shrimp and the role of seaweed and blood cockles and its dynamics of water quality. Twelve fiberglass tanks containing 800 L of brackish water and filled with ± 10 cm of clay sediment were arranged randomly. This study used 4 treatments and 3 replications, including treatment A (tiger shrimp), B (tiger shrimp+seaweed), C (tiger shrimp+blood cockle), and D (tiger shrimp+seaweed+blood cockle). The data of tiger shrimp growth was monitored weekly, while the growth of blood cockle and seaweed was collected at the end of the study. The water quality parameters such as DO, pH, temperature, and salinity were monitored daily. Meanwhile, the data of Total organic matter (TOM), total ammonia nitrogen (TAN), NO_2, and NO_3 were measured weekly. The result of the research showed that the highest specific growth rate (SGR) was treatment D (5.75±0.03% day-1). While the highest SR value was treatment B 90.33±0.58%. However, survival rate (SR) on treatment B did not have a significant difference ($p<0.05$) with treatment C and D. In general, there was significant interaction ($p<0.01$) in organic waste parameters (TOM, TAN, NO_2, and NO_3) for all treatments. In removal rate (RR), treatment D was more effective in reducing TOM (19,20%). Meanwhile, the highest level of TAN reduction was achieved by treatment C (50%). In addition, the highest reduction in nitrite and nitrate variables was in treatment D (40% and 33,33%). In contrast, treatment A got a negative removal rate in all parameters.

Keywords: Blood cockle, IMTA, seaweed, tiger shrimp, water quality

INTRODUCTION

Indonesia has great potential for Fisheries production. It results from catching and aquaculture. According to the Ministry of Marine Affairs and Fisheries (2015), gross domestic product (GDP) reached IDR 177,8 trillion. To fulfill global fish needs that regularly increase, it depends not only on fish catch but also on aquaculture activities.

Successful aquaculture activities happen if the organism can be harvested on targeted consumption with a high survival rate (SR) and sustainability can be maintained. Unfortunately, in recent conditions, many farmers do intensive aquaculture with a high density of organisms and much artificial feed. This will affect environmental problems such as the accumulation of nutrition, especially in inorganic nitrogen (Yang et al. 2017) in the form of ammonia, nitrite dan nitrate. The high ammonia concentration in culture media can harm fish health and reduce culture production (Yang et al. 2017). So that, it causes the complexity of nitrogen waste in pond. This impacts the reduction of water quality. In addition, low water quality in a pond causes trimming fish production.

On the other hand, the traditional aquaculture method depends on natural conditions to support organisms' growth. Therefore, it is inappropriate for optimizing pond productivity. The low carrying capacity of the pond environment cannot supply the organisms needed to grow optimally. Therefore, it is necessary to upgrade technology to achieve the goal of optimizing aquaculture production. In addition, it can minimize the negative impact on water quality. Integrated Multi Trophic Aquaculture (IMTA) provides a solution to decrease waste from aquaculture before it is released into the environment. It also reduces the environmental impact of aquaculture, where organisms can utilize waste from the higher trophic level of organisms at the lower trophic level.

The IMTA concept is a development of polyculture that can help maintain the balance of the ecosystem. This happens because each culture organism has different levels such as omnivore, herbivore, and filter feeder. The principle of the IMTA is to recycle waste from the aquaculture process produced by the main cultured species, e.g., shrimp that has a source of energy and nutrients for other species benefit (Chopin 2013).

Shrimp is the main commodity in the brackish water ponds due to domestic and international large market interest. In the IMTA concept, shrimp is cultured by feeding on the traditional plus or semi-intensive culture system to support the growth. Other organisms utilize the shrimp feces and uneaten feed with lower trophic levels such as seaweed and shellfish. Meanwhile, shrimp benefits from better water quality (Rejeki et al. 2016; Widowati et al. 2020).

This IMTA Culture-based system has been widely used for laboratory systems and its application on a pond scale in the field. Based on previous research (Abreu et al. 2011; Irisarri et al. 2013; Ahmed and Glaser 2016; Rejeki et al. 2016; Biswas et al. 2020; Widowati et al. 2020), IMTA characteristics of various organisms used seaweed (*Gracilaria verrucose* (Hudson) Papenfuss), Green Mussels (*Perna viridis* Linnaeus, 1758), blood cockles (*Anadara granosa* Linnaeus, 1758), Tilapia (*Oreochromis niloticus* Linnaeus, 1758) as organisms that have role to improve the water quality of the target organisms. Several studies have shown evidences that seaweed and shellfish can be used as cultivated organisms. It also functions to improve the quality of the environment for their growth (Abreu et al. 2011; Hidayati et al. 2011; Huo et al. 2012; Rahmaningsih 2012; Irisarri et al. 2013). However, there has not been accurate information and evidence about the composition of these organisms. Therefore, this research will try to apply multi-species culture. The main observations are made on the effect of using seaweed (*Gracilaria* sp.) and blood cockle (*Anadara granosa* Linnaeus, 1758) in optimizing environmentally friendly shrimp culture.

MATERIALS AND METHODS

Samples collection

The samples used in this study include tiger shrimp, seaweed, and blood cockle (Figure 1). Seaweed was collected from bulusan ponds, Demak, Central Java, Indonesia by considering the quality of the thallus: color, size, and appearance (Widowati et al. 2021). Blood cockle seeds with an initial body weight of 2.26 ± 0.18 g were purchased from natural catches in Demak. Meanwhile, tiger shrimp juvenile (PL23) with an average initial body weight of 0.29 ± 0.006 g/ind. were obtained from Balai Besar Penelitian Budidaya Air Payau, Jepara, Central Java, Indonesia.

Procedures

This research used twelve fiberglass tanks of 1 m3 (1x1x1 m) filled with ± 10 cm of pond soil (pH 6.5). It was used to provide the mesocosm of brackish water ponds and blood cockle's base. Furthermore, fiberglass tanks were filled with 800 liters of brackish water (salinity of 21 ppt). The PL shrimp, blood cockle larvae, and seaweed were stocked after 4 days to allow the suspended soil particles to sediment. The water in the experimental tanks was not changed during the study. However, the water volume was consistently kept by adding water from the same source.

Each tank was continuously aerated using Resun® LP-60 low noise air pump to maintain dissolved oxygen level above 5 mg L^{-1}, thus largely above the recommended level and the 3 mg L^{-1} (Boyd and Tucker 1998). In addition, the experiment tanks were covered with sheltered plastic to reduce water temperature fluctuation, light intensity and avoid rainwater.

In this research, seaweed was cultured using the long-line method. Blood cockle was using the broadcast method and the shrimp were fed using commercial shrimp feed. It contains 41 % protein, 5% fat, 2% fiber, 13% ash, and 11% moisture. The 5% feed of total shrimp biomass was given every day. Then it was changed after the weekly weight scale. At satiation, the feeding frequency was given three times a day at 7 am, 2 pm, and 7 pm. The feed was put on 40 x 40 cm tray submerged 10 cm above the bottom of each tank.

Experimental design

This study is a modification from Widowati et al. (2021). It used a completely randomized design with 4 treatments and 3 replications. The systematical treatment was: (i) A. 100 juveniles individu tiger shrimp (1.0000.000 juveniles/ha). (ii) B. 100 juveniles tiger shrimp + 100 g/m^2 of seaweed (1.000.000 kg/ha). (iii) C. 100 juveniles tiger shrimp + 90 g/m^2 of blood cockle (398 ind./ha). (iv) D. 100 juveniles tiger shrimp + 100 g/m^2 seaweed + 90 g/m^2 of blood cockle

Data collection

The shrimp body weight was checked weekly to adjust the food given. The weighing was done with an A&D® HL-100 electronic weighing scale with a precision of 0.01 g. The observed data include specific growth rate (SGR), SR, and water quality.

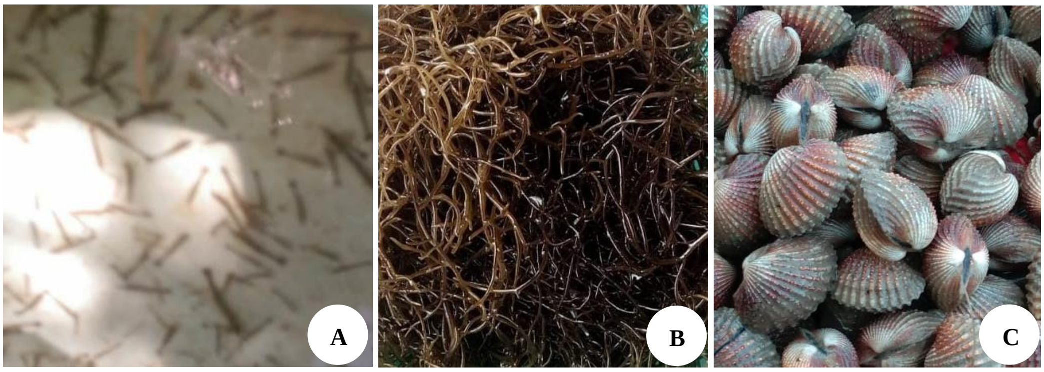

Figure 1. The samples used in this study include: A. Tiger shrimp, B. Seaweed, C. Blood cockle

SGR of the tiger shrimp was calculated with the formula of Busacker et al. (1990)

SGR= (lnWt-lnWo)/t ×100%

Where:
SGR : Specific growth rate (%/day)
Wt : Final body weight (g)
Wo : Initial body weight (g)
t : Duration of the experiment (days)

Survival rate (SR) of the tiger shrimp was calculated using the formula of Busacker et al. (1990)

SR= Nt/No ×100%

Where:
SR : Survival rate (%)
Nt : the number of shrimp at the end of study
No : the number of shrimps initially stocked

Water quality

Four water quality parameters such as temperature (T), pH, salinity, and dissolved oxygen (DO) are monitored daily. Water temperature was observed daily using an electronic thermometer with an accuracy of 0.1°C. pH using a pH meter HANNA ® HI98129 with an accuracy of 0.01. Salinity using an ATAGO® PAL-06s refractometer with an accuracy of 1 ppt. DO was recorded using the YSI@Pro DO meter (read in 0.1 mg L^{-1}).

Organic waste is defined by Total organic matter (TOM), total ammonia nitrogen (TAN), nitrite (NO_2), nitrate (NO_3). Weekly concentrations were plotted in a graph showing the trends and comparing each treatment. The removal rate of TOM, TAN, NO_3, and NO_2 is defined as the difference before and after the cultivation period and is calculated using the formula by Srisunot and Babel (2015).

RR = (Ct – Ci)/Ci x 100%

Where
RR : Removal rate (%)
Ct : Final concentration (g L^{-1})
Ci : Initial concentration (g L^{-1})

Data analysis

The SGR and SR data of shrimp and water quality parameters were tested by one-way ANOVA using the SPSS® application. One-way ANOVA analysis was used to see significant interactions. However, the previous data were tested for normality using the Lilliefors test, and for homogeneity using the Levene test (Steel and Torrie 1983). The data is ensured to be normally distributed and homogeneous. In addition, If the one-way ANOVA showed a significant interaction. Duncan's multiple comparison test was performed to determine the differences between treatments.

RESULTS AND DISCUSSION

One-way ANOVA analysis confirmed a significant interaction of the data ($p<0,01$). The data of organic waste concentration (TOM, TAN, NO_3, and NO_2) data for each treatment were presented in Table 1.

Specific growth rate (SGR) of tiger shrimp in integrated culture

The result of statistic analysis showed that the integrated culture between seaweed and blood cockle in tiger shrimp culture had a significant effect ($p<0.01$) on SGR value (Table 1). Each treatment was increased with integrated seaweed and blood cockle in tiger shrimp culture. The slowest growth was at treatment A (5.62±0.04%day-1) compared to other treatments. Treatment D (5.75±0.03%day-1) had the highest significance (Figure 2). Meanwhile, treatment B (5.68±0.04%day-1) and C (5.65±0.03%day-1) did not significantly differ.

Survival rate (SR) of tiger shrimp in integrated culture

On the other hand, the SR shrimp showed that it was 86.33±1.15% to 90.33±0.58%. Treatment A was significantly ($p<0.05$) lower than three other treatments with the SR value 86.33%. The highest value was found in treatment B was 90.33%. Followed by treatment D was 90% and treatment C was 87.33%. However, statistically, the SR of tiger shrimp in treatments B, C, and D did not significantly differ (Table 1, Figure 3).

Water quality

Water quality such as temperature, pH, salinity, and DO was analyzed descriptively. Based on the water quality data (Table 2) during the study on all treatments, the water temperature ranged from 26.2 to 32.1ºC. The lowest pH found in treatment B ranged from 7.28 to 8.30. Salinity ranged from 23 to 27 ppt. Meanwhile, DO levels ranged from 3.10 to 6.90 mg/L. Even though there were differences between treatments, the water quality parameters were still in recommended ranges.

Total organic matter (TOM)

The concentration of TOM (mg/L) in the integrated culture of tiger shrimp with seaweed and blood cockle was significantly ($p<0.01$) lower than the control (treatment A). In treatment A, the concentration of TOM increased every week. It has the highest TOM content reaching 326 mg/L. This condition was in contrast to treatments B, C, and D, which decreased every week. In addition, an intense decrease occurred in treatments D and C. However, the overall decrease in TOM concentration for each treatment ranged from 300 mg/l to 220 mg/l (Figure 4). The weekly chart decrease in TOM concentration occurred significantly in the 4^{th} week.

Total ammonia nitrogen (TAN)

The concentration of TAN in this study was significantly ($p<0.01$) lower than the control (treatment A). There was a decrease in the concentration of TAN continuously in the three treatments every week (Figure 5). Moreover, a significant decrease in the last week of the study. There was a sharp drop from 0.16 to 0.09 mg/L in treatment B from the 3^{rd} week to the 4^{th} week. The sharp drop from 0.18 to 0.065 mg/L in 1^{st} week to 3^{rd} week in treatment C (tiger shrimp +, but an increase again from 0.065 to 0.09 mg/L at 3rd week to 4th week. Meanwhile, treatment D shrimp+ seaweed+blood cockle) decreased TAN concentration steadily from 1st week to the end of the study.

Nitrite (NO_2)

The presence of seaweed and blood cockle in integrated shrimp culture significantly reduced ($p<0.01$) nitrite in the water (Table 1) for treatments B, C, and D (Figure 6). For treatment B, (the nitrite concentration was decreased from 0.006 mg/L to 0.004 mg/L. For treatment C, it was from 0.005 to 0.004 mg/L. For treatment D, it was from 0.005 mg/L to 0.003 mg /L. However, the nitrite concentration in treatment A was increased sharply from 0.006 mg/L to 0.01 mg/L every week. On the other hand, the nitrite concentration decreased sharply in the 1st to the 2nd week for treatment D. It reduction rate was from 0.005 mg/L to 0.002 mg/L. But on the 3rd week, it was increased again to 0.004 mg/L. Then on the 4th week, it was decreased to 0.003 mg/L.

Nitrate (NO_3)

During the study, nitrate concentration in integrated culture was significantly ($p<0.01$) trend on the decrease (Table 1, Figure 7). In the 4th week, the nitrite concentration in treatments B), C and D were decreased. The average decrease was around 1.78 mg/L to 0.6 mg/L. Contrarily, treatment A was increased from 1.675 mg/L to 1.87 mg/L. In treatment B, the nitrate concentration fluctuated every week. In the 1st week to the 2nd week, it decreased from 1.668 mg/L to 1.191 mg/L, then increased again from 1.191 mg/L to 1.96 mg/L. However, in the 4th week, it was decreased to 1,203 mg/L. Likewise, in treatment C, it was decreased from the 1st week to the 3rd week. That was 1.78 mg/L to 1.11 mg/L. However, there was a slight increase in nitrate concentration as much as 1.55 mg/L on the last week. Meanwhile, in treatment D, the nitrate concentration was decreased dynamically from the 1st week (0.9 mg/L) to the last week (0.6 mg/L).

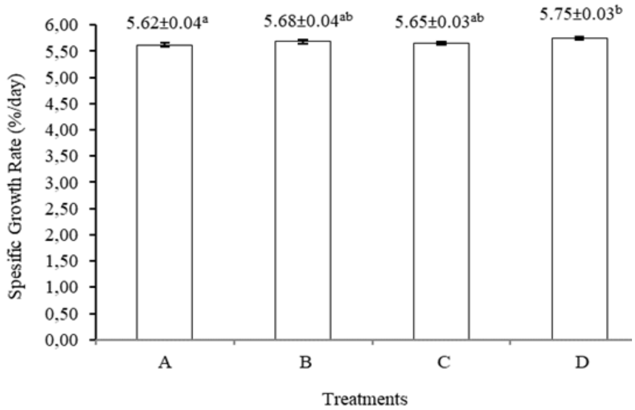

Figure 2. The SGR of tiger shrimp in integrated culture. Note: The mean of different numbers with the same superscript letter showed the same value (P<0.01) according to Duncan's multiple test

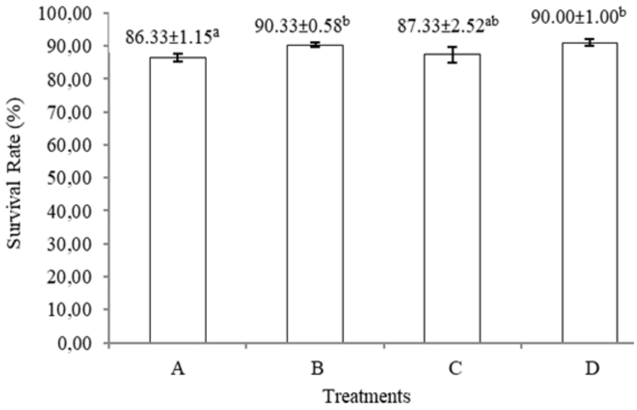

Figure 3. The SR of tiger shrimp in integrated culture. Note: The mean of different numbers with the same superscript letter showed the same value (P<0.01) according to Duncan's multiple test

Table 1. Result of the one way ANOVA test on TOM, TAN, nitrite (NO_2), and nitrate (NO_3) in the integrated culture

Dependent variables	df	Mean square	F	sig
TOM	3	4783.922	11.979	0.001*
TAN	3	0.015	15.998	0.000*
Nitrite (NO_2)	3	0.000	10.054	0.001*
Nitrate (NO_3)	3	0.782	12.490	0.001*

Note: Legend: df: degrees of freedom; F: F-value, Significant differences are denoted by *p< 0.01

Table 2. The range of water quality in the integrated tiger shrimp culture

Variables	Treatments				Recommended ranges
	A	B	C	D	
Temperature (^{0}C)	26.2 – 31.50	26.50 – 31.90	26.70 – 32.10	27.2-30.30	27-32*
pH	7.56 – 8.70	7.28 – 8.30	7.12 – 8.51	7.21-8.34	7.2-8.6**
Salinity (ppt)	23 – 26	23 – 27	24 – 27	24-27	17-35**
DO (mg/L)	3.20 – 6.20	3.10 – 6.90	3.10 – 6.34	3.15-6.50	> 3***

Note: *Brito et al. (2014); **Carbajal-Hernández et al. (2013); Chaitanawisuti et al. (2013); ***Boyd and Tucker (1998)

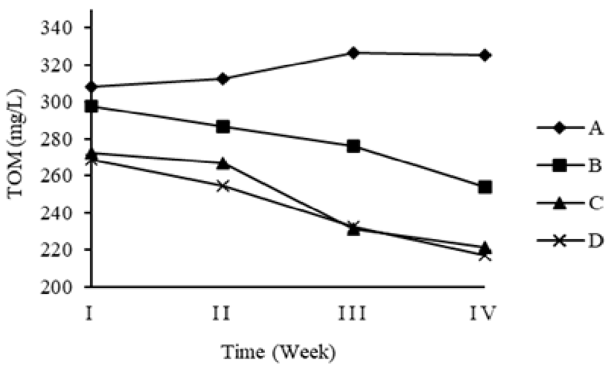

Figure 4. Concentration dynamics of TOM (mg/L) in the Integrated tiger shrimp culture

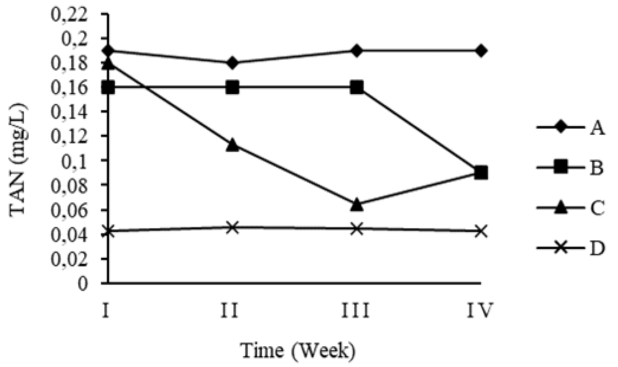

Figure 5. Concentration dynamics of TAN (mg/L) in the Integrated tiger shrimp culture

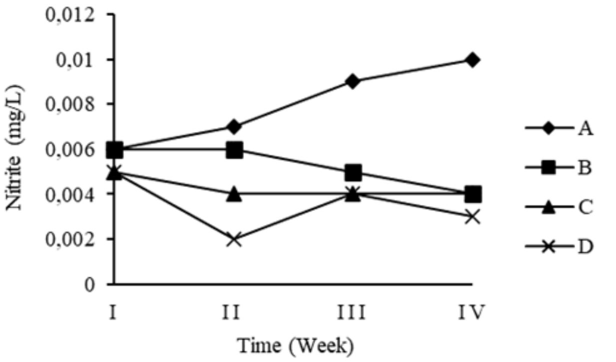

Figure 6. Concentration dynamics of nitrite (mg/L) in the Integrated tiger shrimp culture

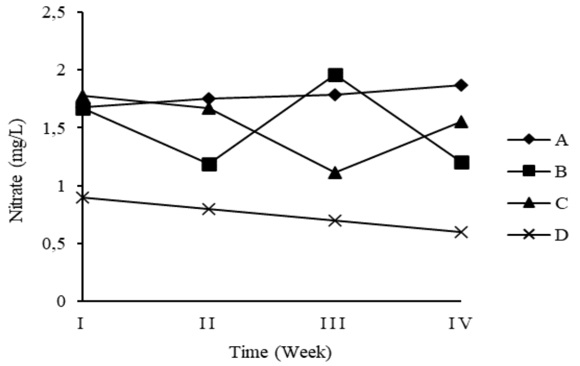

Figure 7. Concentration dynamics of nitrate (mg/L) in the Integrated tiger shrimp culture

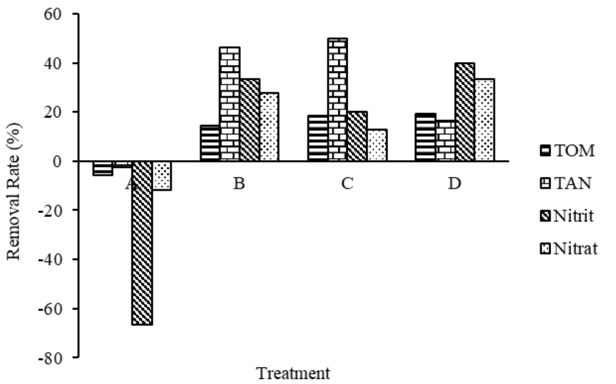

Figure 8. Removal rates (RR) of TOM, TAN, nitrite, and nitrate in the Integrated Tiger Shrimp Culture

Removal rates (RR)

Removal rate (RR) value without using seaweed or blood cockle (treatment A) showed negative results in all variables. Its means that the content during the study was increased. On the other hand, positive RR values were obtained for the four parameters in integrated tiger shrimp culture with seaweed or blood cockle. Positive values were shown in treatments B, C, and D (Figure 8).

In the integrated tiger shrimp culture with seaweed or blood cockle, the highest level of TOM reduction was achieved by treatment D (19.20%). Then, it was followed by treatment C (18.64%) and treatment B (14.61%). In comparison, treatment C achieved the highest TAN reduction level (50%). It was followed by treatment B (46.15%) and treatment D (16.28%). In addition, the level of reduction in the nitrite and nitrate variables obtained the highest value. It was achieved by treatment D, followed by treatment B, and then treatment C.

Discussion

Specific growth rate (SGR) and Survival rate (SR)

SGR data is higher than the results of Rejeki et al. (2016) which showed the SGR level ranged from 3.53 to 4.46%/day. Another integrated system experiment showed lower results with milkfish and seaweed, which were 5.21-5.66%/day (Mangampa and Burhanuddin 2014). On the other hand, Chatterji et al. (2015) research showed that the SGR of tiger shrimp could reach 46.9%/week and tends to decrease along with its growth. According to Biswas et al. (2020), the integrated culture system is considered efficient in utilizing and converting nutrients into the shrimp body. It can be seen from the high value of SGR. Based on the result of the study, it can be concluded that the integration of seaweed and blood cockle in tiger shrimp culture is the most effective way to increase SGR's shrimp.

The SR observed is lower than that observed in the integrated culture of *Molobicus tilapia*, white shrimp, and seaweed by Casing et al. (2019) and Capinpin et al. (2020). In Casing et al. (2019), they observed 98.33%, 96.67% and 88%. While in Capinpin et al. (2020), they observed 88.33%-100%. That result differed from Pantjara et al. (2015), which showed SR of tiger shrimp culture integrated with red tilapia, oyster, and seaweed was 50.68-59.28%. However, it was assumed that seaweed and blood cockle were sufficient to influence the tiger shrimp culture. If seen from the effect, this integrated culture impacts increasing the SR of tiger shrimp. This state is supported by water quality data (Table 2) during the study, which supports shrimp life. The interaction between seaweed and blood clams provides good water quality conditions, thus giving the SR value 90%.

Total organic matter (TOM), total ammonia nitrogen (TAN), nitrite (NO_2), nitrate (NO_3), and Its removal rate (RR)

The presence of organic waste is one of the factors that can harm tiger shrimp rearing activities. Nitrogen is one of the organic wastes in water sources from feed and cultivar feces. Several organic compounds in water are formed from nitrogen that are TAN, nitrite, and nitrate. Changes in the content of organic matter (TAN, nitrite, nitrate, TOM) in the maintenance of tiger shrimp during the study were inseparable from the involvement of associated organisms, namely seaweed and blood cockle. The study results showed that the presence of seaweed and/or blood cockle could reduce the organic matter content in the rearing tank.

The reduced concentration of TOM (Figure 4) in treatment B was thought to be because the growing seaweed absorbed dissolved organic matter (OM) that had been degraded by microorganisms, thereby reducing the level of OM in the water. In addition, seaweed also extracts colloidal particles from OM, thus making the waters clearer (Widowati et al. 2021). Another finding in treatment C, the concentration of TOM at week 2 increased. This increase was caused by the release of dissolved nutrients contained in shellfish manure (Tantanasarit and Babel 2014). The results of our study showed that treatment D, which combined seaweed and blood cockle in integrated shrimp culture, gave the lowest average TOM concentration. This illustrates the dynamics of the tropical level between seaweed and blood cockle which have different roles based on their level in reducing organic matter and maintaining/enhancing water quality in integrated tiger shrimp culture, confirming the findings of Rabiei et al. (2014) and Zhang et al. (2018). In this different study, the concentration of organic matter such as ammonia (Figure 5), nitrite (Figure 6), and nitrate (Figure 7) had significant values in each treatment. The air quality content in treatments B, C, and D had lower values than treatment A. This was due to the role of seaweed and blood cockle in reducing particles and inorganic organics used to supply their growth needs. The use of macroalgae in aquaculture systems has proven to be one of the most effective approaches to utilize inorganic nutrients such as nitrogen (Biswas et al. 2020). This is in line with the concentrations of ammonia, nitrite, and nitrate in the integrated system, which were 0.05 ppm, 0.003 ppm, and 0.44 ppm lower than the concentrations in the non-integrated system. In addition, organic particles are used efficiently by the filter feeder, where the value of the organic matter in the air is efficiently lower in the IMTA system (MacDonald et al. 2011; Strand Ø et al. 2019).

Compared to treatment A and cultivation with one or two other types of organisms, treatments B, C, and D were more efficient in reducing inorganic nitrogen (nitrite, nitrate, and TAN). Moreover, in treatment D, which used a complete range of polyculture organisms from various trophic levels, inorganic components were reduced more effectively by macro-match and shellfish as extractive species (Biswas et al. 2020). This is presumably because seaweed and blood cockle cannot stand alone in influencing these water quality components. Seaweed plays a role in utilizing inorganic nutrients and blood cockle in the absorption of organic particles. Meanwhile, mussels build their bodies by degrading suspended organic particles and algae (uneaten feed, feces, phytoplankton) filtered from the water and absorbing dissolved inorganic nutrients from the water (Handå et al. 2012; Buck et al. 2017). In the process, shellfish release nutrients such as carbon, nitrogen, and phosphorus (Tantanasarit and Babel 2014).

Treatment A got a negative removal rate (Figure 8) at all concentrations such as TOM, TAN, nitrite, and nitrate. This means that the organic waste in the waters increases. The increase in TOM in shrimp culture is caused by the exposure of marine nutrient compounds, including those contained in the feces (Beardsley et al. 2011; Herbeck et al. 2013). Meanwhile, the removal rate in treatments B, C, and D showed a positive value, where there was limited additional organic waste into the waters. Compared with Treatment A, it can be concluded that the integrated system is more effective at reducing inorganic components and organic components (Biswas et al. 2020).

Water quality

From the data in Table 2, it was found that the water temperature is in the same range for all treatments (26-32ºC). It is also comparable to previous studies on integrated shrimp culture of oyster seaweed ranging from 27-32ºC (Brito et al. 2014) and around 32ºC (Arias-Moscoso et al. 2018). The measurement of pH for all treatments is 7.12-8.70. We found the lowest pH value was 7.21 in treatment C. It was suspected that the presence of blood cockle caused the nitrification process. This process decreased the excreted ammonia nitrogen. It is also decomposed by a microorganism that causes the pH to drop (Widowati et al. 2021). Nevertheless, it is still within the recommended range: 7.2 to 8.6 (Carbajal-Hernández et al. 2013).

Salinity is an important parameter because it is related to the osmotic and ionic water pressure both as an internal and external medium. The salinity value of tiger shrimp (*Penaeus monodon* Fabricius, 1798) in the treatment was ranged from 23-27 ppt. Most species of penaeid shrimp are known as biota that can survive in a wide range of salinities. The optimal salinity range for shrimp growth is between 17-35 ppt (Carbajal-Hernández et al. 2013; Chaitanawisuti et al. 2013). Furthermore, the study of Ponce-Palafox et al. (2019) found the adequate range for juvenile shrimp survival was 16.5-33.5 ppt and that for growth was 20-30 ppt. A range of 20-30 ppt is also recommended to cultivate juvenile *P. monodon* (Ye et al. 2009).

DO concentrations are within the recommended levels >3 ppm (Boyd and Tucker 1998) and were in the highest range found by Furtado et al. 2014 (5.9 to 6.3). Therefore, it can be concluded that water quality parameters such as temperature, DO, pH, and salinity were not different among the treatments. Cultivation treatment with several species polyculture did not significantly affect changes in temperature, pH, and salinity (Biswas et al. 2020). In general, water quality parameters in all treatments were stable during maintenance and were suitable for the growth of tiger prawns, seaweed, and blood clams.

It can be concluded that the integrated culture of shrimp, seaweed, and blood cockle (treatment D) was significantly improved water quality by reducing the concentrations of TOM, TAN, NO_2, and NO_3. In addition, it can improve the SGR of tiger shrimp. However, there was no significant difference in SR.

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