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by Cek Turnitin

Submission date: 26-Jun-2023 12:44PM (UTC+0800)

Submission ID: 2122749476

File name: 6.pdf (1.3M)

Word count: 6961

Character count: 33997

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To cite this article: B Pantjoro et al 2020 IOP Conf. Ser.: Earth Environ. Sci. **621** 012001.

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Improved pond productivity through integrated cultivation of red tilapia (*Oreochromis niloticus*), tiger shrimp (*Penaeus monodon*) and seaweed (*Gracilaria verrucosa*) in Maros, South Sulawesi, Indonesia

B Pantjara^{1*}, A Sarljanah¹ and M Hermawan²

¹Research Institute for Coastal Aquaculture and Fisheries Extension, Ministry of Marine Affairs and Fisheries, Jl. Makmur Dg. Sitakka No. 129, Maros, South Sulawesi, Indonesia

²Agency for Marine and Fisheries Research and Human Resources, Ministry of Marine Affairs and Fisheries, Jalan Medan Merdeka Timur No. 16, Jakarta, Indonesia

*Corresponding author: bpantjara@yahoo.com

Abstract. Marginal land use for brackish water aquaculture has not been fully used optimally, due in various problems, especially low pond productivity caused by degradation of water and soil quality. One effort to increase pond productivity for aquaculture is integrated cultivation (polyculture) with various fisheries commodities. The purpose of this research was to increase the productivity of ponds through polyculture of red tilapia, tiger shrimp, and seaweed. Twelve earthen ponds were used for this study, each pond of 2,500 m². The nos polyculture systems employed in this study were A) red tilapia (1 no/m²), tiger shrimp (2 nos/m²) and seaweed (0,15 kg/m²); B) Tiger shrimp (4 nos/m²) and seaweed (0,15 kg/m²); C) red tilapia (1 no/m²) and tiger shrimp (2 nos/m²), and D) red tilapia (2 nos/m²) and seaweed (0,15 kg/m²). The results showed that the highest survival rate of red tilapia was recorded in D (87.3±3.15%) and the lowest in A (78.5±1.75%). Meanwhile, the highest tiger shrimp survival rate was achieved in B (72.2±6.53%) followed by A (64.0±3.02%) and C (62.6±3.15 %). The highest production of red tilapia was recorded in D (716.7 kg/2,500 m²), while the highest production of tiger shrimp was in B (100,04 kg/2,500 m²). The feed conversion ratio (FCR) in the red tilapia was the highest in D (1.19), followed by C and A (1.15 and 1.03), while the FCR for tiger shrimp in all the treatments was less than 1. Economic analysis showed that the highest profit per cycle was obtained in D.

1. Introduction

The aquaculture sector is an important part of the national in Indonesia. As part of maritime economic resources, the aquaculture sector contributes to the fisheries sector for Indonesia's gross domestic product (GDP). However, parallel with the increase in aquaculture production, especially brackish water cultivation has an impact on the development of new land for ponds. Indonesia has very large natural resources, so it has the opportunity to support increased aquaculture production, especially from brackish water aquaculture. Potential land for brackish water aquaculture reaches of 2,964,331 ha which is spread over several large islands such as Java, Sumatra, Sulawesi, Kalimantan, Maluku and Papua and other islands, but only around 650,509 ha (21.94%) has been used [1]. Aquaculture



development gets high success if it is carried out by ideal soils. Meanwhile, not all of the available land can be used for aquaculture ponds due to various problems, because in general coastal ponds are dominated by peat and acid sulphate soils or associations of the two types of soil [2].

At present, suitable land for aquaculture is limited, on the other hand the condition of ponds with low soil productivity has a potential to become abandoned ponds because it is difficult to use for fish or shrimp farming due to various problems. Meanwhile, intensive shrimp farming with high stocking density requires high amount of feed, and generates waste. Such waste can cause contamination and eutrophication in waters and an impact on environmental degradation in coastal areas [3-6].

As brackishwater Aquaculture ponds are usually located in tidal areas with low soil productivity and negative impact on water quality, such farming often fails to harvest [7, 8]. However, such ponds can be used to increase aquaculture production through polyculture of shrimp and fish [9]. In Indonesia, polyculture technology has been developing for a long time, but it has not been economically feasible till now.

The polyculture system can provide benefits especially in utilizing space and commodity diversification [10]. Meanwhile, fish growth influenced by internal factors, namely genetic and physiological characteristics, and external factors related to the environment especially water and feed quality [11, 12]. Some commodities that can be developed for polyculture in brackish water ponds include milkfish, tilapia, tiger shrimp, Pacific white leg shrimp, seaweed and molusca [9, 13-17]. However, the choice of these commodities is adjusted to the condition of the pond and the availability of commodities that are often found around the location of cultivation.

Physicochemical factors in aquaculture pond sand individual aquatic animals or their synergistic influence play an important role in the success of pond production [18]. The growth of fish, shrimp and sea weed also depends on the water quality in the ponds. Water quality is very important in fish farming, especially in relation to the survival and growth of fish and shrimp in ponds [5, 19-22]. In addition, the presence of seaweed in the polyculture can absorb excess nutrients or as a biofilter so that the water quality remains stable [23, 24].

The development of tiger shrimp farming in recent years has continued to decline, due to the impact of the low quality of the environment and the occurrence of various diseases of shrimp and through polyculture, it is expected that the production of tiger prawns in ponds can still be increased. Tiger shrimp, red tilapia and sea weed farming is simple technology, and the three commodities have excellent domestic and export marketing opportunities [25]. Red tilapia that are cultivated in ponds under polyculture system provide excellent weight growth because these fish besides eating artificial feed are also graze algae that grow in ponds. According to Troell [26] and Pantjara *et al.* [24], shrimp farming in ponds with a polyculture system reduces fish and shrimp mortality rates because it can improve water quality and inhibit the development of disease in ponds. In addition, polyculture can be efficient in water use and provide nutrients inorganic for seaweed [7]. This study aims to determine the increase in productivity of idle ponds through integrated cultivation of red tilapia, tiger shrimp and seaweed.

2. Materials and methods

The study was carried out from April-August 2015 in the experimental ponds of the Research Institute for Coastal Aquaculture, Maros, South Sulawesi. A total of nine earthen ponds each with an area of 2,500 m² were used for this study. Sampling of bottom soil in the experimental pond was conducted to determine the initial soil characteristic conditions. To improve the productivity of pond bottom soil, soil remediation was carried out which includes sun drying of the pond bottom soil water immersion, immersion water disposal, liming and fertilization. Drying on the bottom soil before cultivation was important to reduce organic matter and toxic compounds. Add two spaces after Full stop as state earlier drying was carried out for 1-2 weeks (depending on weather conditions). Pond drying was ready to be used for cultivation, if the soil bottom that visually characterized by cracks in the soil and the soil redox value reaches > +30 mV. Immersion water in ponds at a depth of 20-30 cm was carried out after drying the pond bottom with the aim of dissolving toxic compound after drying the soil.

Application of lime (dolomite) at a dose of 250 kg per pond (1.0 ton/ha) to increase the pH of pond water. In addition, to accelerate the growth of natural feed, pond bottom was fertilized with urea and super phosphat (SP-36), each given at a dose of 25 kg per pond (100 kg/ha) and 25 kg per pond (100 kg/ha).

The species of culture used for polyculture in this study consisted of red tilapia (*Oreochromis niloticus*), tiger shrimp (*Penaeus monodon*) and seaweed (*Gracilaria verrucosa*). Male monosex red tilapia seeds were obtained from a hatchery of Central Java. Adaptation and acclimatization of tilapia seeds to salinity was carried out before stocking in the pond. The size of fish stocked was 4.2-6.1 g/fish (average 4.8±0.58 g/fish).

Tiger shrimp seeds for this experiment were Post Larva of 20 days old (PL-20) obtained from a hatchery in Barru District, South Sulawesi; while seaweed (*Gracilaria verrucosa*) was obtained from ponds located around the study area.

The polyculture compositions tried in this study were as follows: A) red tilapia (1 no/m²), tiger shrimp (2 nos/m²) and seaweed (0.15 kg/m²); B) tiger shrimp (4 nos/m²) and seaweed (0.15 kg/m²); C) red tilapia (1 no/m²) and tiger shrimp (2 nos/m²) and D) red tilapia (2 nos/m²) and seaweed (0.15 kg/m²). Each composition here in treatment was replicated three times. Stocking of seaweed was performed 15 days earlier than tiger shrimp and red tilapia. Artificial feed (pellets) application is given after 10 days of tiger shrimp seed stocked on the ponds or predicted the abundance of natural food in aquaculture ponds has decreased. The dose of artificial feed for red tilapia and tiger shrimp each was 3% of body weight per day.

Soil quality measurements are carried out in the field and laboratory. Soil quality parameters measured were soil texture, pH_E and pH_{OX}, SO₄²⁻, Fe³⁺ and Al³⁺. The pH_E test measures the existing acidity in the soil: water phase and is therefore used to help identify if acid sulphate soil (ASS) are present. While pH_{OX} test is used to indicate the presence of iron sulfides or potential acid sulfate soils (PASS) are soils or sediments which contain iron sulfides and/or other sulfidic minerals that have not been oxidised. This test involves adding 30% hydrogen peroxide to soil sample. If sulfides are present a reaction will occur [27].

Water quality analyses were carried out every two weeks for temperature, dissolved oxygen, pH, total organic matter, ammonia, and Fe³⁺ following the methods describes in APHA [28]. Dissolved oxygen was measured by a portable water quality meter (YSI 550A) and salinity was measured using a hand refractometer (ATAGO, Japan) and pH was measured using a portable pH meter (Hanna, HI 83141). Nutrient quality of water such as total suspended solid (TSS), total organic matter (TOM), total ammonia nitrogen (TAN), nitrite and phosphate was measured following the procedures of APHA [28].

Water quality data obtained were analyzed descriptively. Meanwhile, survival rate, growth, and production of red tilapia and tiger shrimp were observed after 95 days and data were analysed using One-way analysis of variance (ANOVA) by SPSS 22. When significant differences were found, Tukey's test for multiple comparisons among means was applied in order to identify differences between parameters ($P < 0.05$). The survival were transformed ($\arcsine x^{0.5}$) before analysis. At the end of the study, economic analysis paste determine the polyculture feasibility.

3. Results and discussion

3.1. Pond soil analysis

The results of soil texture analysis confirmed that the pond used in this study was loam texture with a composition of silt, sand and clay, respectively with 48: 37: 16 percentages. According to Poernomo [8], a soil bottom with a texture of clay to sand was suitable for extensive or semi-intensive shrimp farming. The texture of clay with such composition was in the medium category to make pond dykes, especially in holding water seepage on dykes. However, loam texture is suitable for growing natural food and then used for fish or shrimp in ponds.

The results of soil analysis showed that the type of pond soil for the experiment was associated with acid sulphate soil (ASS). Sulfuric acid soil have actually been oxidized to produce acids [29]. The

soil usually has yellow or red patches on the soil profile [30]. However, this soil was still contains potentially high acidic sulphides. The results of the pond soil were as follows: soil pH_t reached of 5.2-6.16 and soil pH_{res} reached 3.18-5.16; P_2O_5 0.68-2.016 mg kg^{-1} ($1.15 \pm 0.732 \text{ mg kg}^{-1}$); soil organic matter reached of 5.0-7.7% ($5.25 \pm 0.572 \%$), SO_4^{2-} reached of 1,679.8-3,193 mg kg^{-1} ($2,320.62 \pm 821,159 \text{ mg kg}^{-1}$), Fe^{2+} reached of 26.81-88.75 mg kg^{-1} ($49.65 \pm 12.703 \text{ mg kg}^{-1}$) and Al^{3+} of 29.0-51.88 mg kg^{-1} ($38.13 \pm 8.608 \text{ mg kg}^{-1}$). The results showed that soil improvement at the pond bottom could improve water quality in all polyculture treatments.

3.2. Water quality

The dissolved oxygen content in all treatments though fluctuated, it was still within tolerance range for tiger shrimp and red tilapia culture. The value of oxygen in the morning (at 06:00 to 07:00 Central Indonesia Time) ranged from 2.5-3.8 mgL^{-1} , and during the day reached $>4.0 \text{ mgL}^{-1}$ because of the photosynthesis process by seaweed absorbing CO_2 and producing O_2 . The presence of oxygen in ponds affected solubility and availability of nutrition for aquatic organisms. Lack of dissolved oxygen cause increase in toxic metabolites in cultured fish. Oxygen concentrations $<2.5 \text{ mgL}^{-1}$ in the long term caused slow growth and even death for tiger shrimp due to a substantial increase in the level of toxic metabolites and inhibits the metabolic performance of shrimp. Meanwhile, the tolerance of dissolved oxygen for shrimp culture was $\geq 3 \text{ mgL}^{-1}$ (3-10 mgL^{-1}). According to Boyd and Tucker [5], the minimum dissolved oxygen requirement for prawn culture was about 4 ppm.

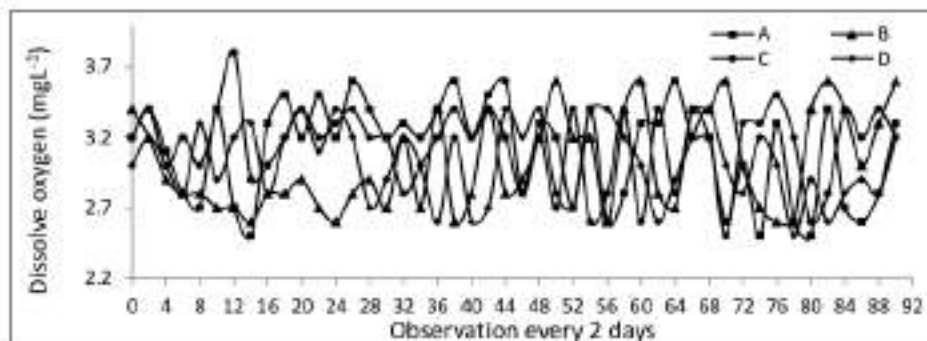


Figure 1. Temporal trend of dissolved oxygen in the morning (06:00-07:00) in ponds for three months of polyculture of red tilapia, tiger shrimp, and seaweed.

A stable water salinity was very important to avoid stress on red tilapia, tiger shrimp and seaweed. At high salinity, the growth of tiger prawns would be slow causing stress and even death in cultivated seaweed. If salinity was too low, it may cause the shrimp shell to become soft and susceptible to disease. Figure 2 showed that there was an increase in water salinity until the end of the study in all polyculture treatments. In this study, salinity in the experimental pool reached 19.3-36 ppt and a good salinity range for tiger shrimp growth is 15-25 ppt [31]. During the study it coincided with the dry season, so the water salinity in this experiment continued to increase due to water evaporation process and also water sources was influenced when adding water to aquaculture ponds.

Water pH in ponds during experiment is one of the environmental characteristics that determines the survival and growth of shrimp [32]. Water pH affects the metabolic and physiological processes of fish and tiger shrimps [5]. In this study, the pH of water in all the treatments did not differ significantly and ranged from 7.5-7.9. According to Poemomo [8] and Boyd and Tucker [5], the optimal pH range for growth and survival of tiger shrimps were 7.5 - 8.5.

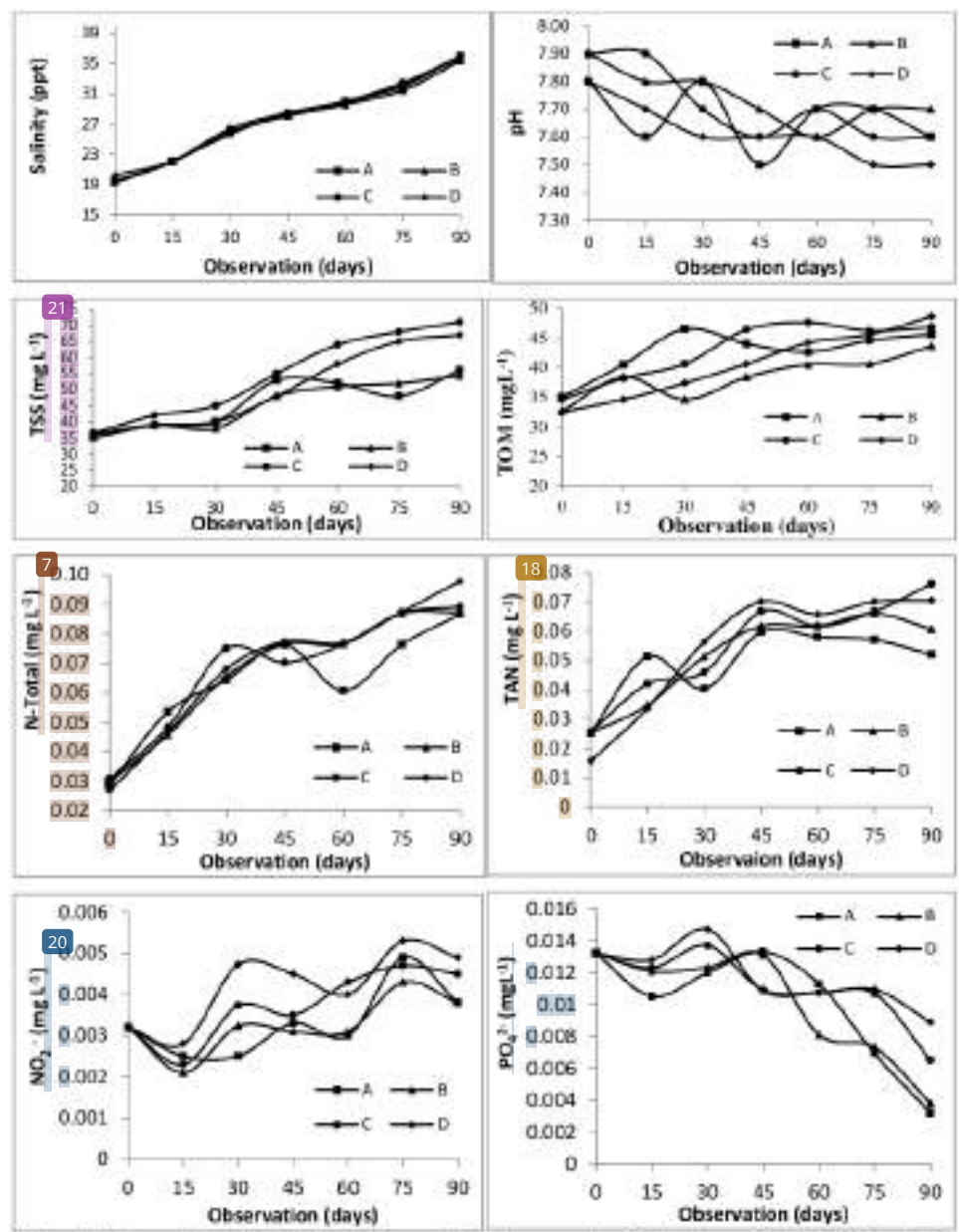


Figure 2. Temporal trend of water quality in ponds for three months of polyculture of red tilapia, tiger shrimp, and seaweed.

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 The pH of pond water was influenced by many factors, including pH of source waters, acidity of bottom soil, shrimp culture inputs and biological activity [9, 33, 34]. In this study, an effort to increase water pH is by adding dolomite with the dose of 2-5 mgL⁻¹.

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Water temperature directly affects metabolism, oxygen consumption, growth and survival of fish or tiger prawns [34]. The surface water temperature during the study in all treatments ranged from 24.5-32.5 °C and was still within tolerance for the life and growth of fish or shrimp being cultivated. According to Boyd and Tucker [5] that the optimal water temperature level for *P. Monodon* culture is 25-30 °C.

The total suspended solid (TSS) content in treatment A ranged from 35-52 mgL⁻¹ (46.14 ± 8.112 mg L⁻¹), B ranged from 36.1 to 55 mgL⁻¹ (45.5 ± 7.581 mgL⁻¹), C ranged from 36.5 to 71.0 mgL⁻¹ (54.5 ± 13.635 mgL⁻¹), and D with ranged from 36.2 to 67 mgL⁻¹ (50.46 ± 12.885 mgL⁻¹). TSS in all treatments seems to fluctuate. However, at the end of the study it was shown that in treatments A and B, TSS content was relatively stable due to the presence of seaweed in ponds, whereas in treatments C and D, TSS content increases with slow growth of seaweed and even tends to be depleted because of grazing by tilapia. TSS levels were still within the tolerance range for tiger shrimp culture, the optimal TSS for *Penaeus monodon* culture is 25-75 mgL⁻¹. The same condition was reported by Samocha *et al.* [35], that TSS <100 mgL⁻¹ was suitable for shrimp growth.

Organic matter in waters can be suspended, colloidal, dissolved, or in the form of particulates. The content of dissolved organic matter generally has greater levels. The range and mean of TOM in this study were still suitable for the cultivation of red tilapia, tiger shrimp and seaweed, in the A, B, C, and D treatments, as follows; A 35-46.5 mgL⁻¹ (mean 42.7 mgL⁻¹), B 32.6-43.6 ppm (38.4 mgL⁻¹), C 34.6 to 47.6 mgL⁻¹ (42.9 mgL⁻¹), and D 32.5-48.6 mgL⁻¹ (40.5 mgL⁻¹), respectively. The waters with organic matter was content above 26 mgL⁻¹ were classified as fertile waters. The optimal range of total organic matter in shrimp culture was no higher than 60 mgL⁻¹.

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The total N-content in all the treatments tended to increase till the end of the study (Figure 2). The total N-content in treatment A ranged from 0.029 to 0.087 mgL⁻¹ (0.064±0.0191 mgL⁻¹), B ranged from 0.030 to 0.087 mgL⁻¹ (0.067±0.0217 mgL⁻¹), C ranges from 0.031-0.089 mgL⁻¹ (0.068±0.0213 mgL⁻¹), D ranges from 0.027-0.0978 mgL⁻¹ (0.069±0.00245 mg L⁻¹), respectively. In this study, the average pond water was green due to plankton. However, it is still within reasonable limits and abundant plankton has not yet been seen. According to Boyd and Green [34], the N concentrations of 0.1 to 0.75 mgL⁻¹ in coastal waters caused plankton blooms.

Total ammonia nitrogen (TAN) concentrations tended to increase during the period of observation. In this study, ammonia content was still within the tolerance limit for tiger shrimp farming. TAN concentrations appear to fluctuate. However, the concentration of TAN increased until the end of the study. The range and mean TAN content during the study in each treatment were as follows; A (0.025-0.060 mgL⁻¹ and 0.049±0.0123 mgL⁻¹), B (0.0253-0.066 mgL⁻¹ and 0.055±0.0157 mgL⁻¹), C (0.0257-0.076 mgL⁻¹ and 0.055 ± 0.0176 mgL⁻¹), and D (0.016-0.070 mgL⁻¹ and 0.054 ± 0.0216 mgL⁻¹), respectively. High TAN concentrations were caused by increased management and increasing of feeding and the fertilization process that could increase the level of inorganic nutrient on pond ecosystems [36]. According to Chin [19], TAN content less of 0.1 mgL⁻¹ was still considered safe for shrimp culture. Excessive ammonia concentration (> 1 mgL⁻¹) could affect growth shrimp and even death of tiger shrimp in ponds [5].

The nitrite content in all treatments tended to increase, as was the case with TAN in this study (Figure 2). Nitrite content in treatment A ranged from 0.002-0.005 mgL⁻¹ (0.003 ± 0.0008 mgL⁻¹), B ranged from 0.002-0.005 mgL⁻¹ (0.003 ± 0.0007 mgL⁻¹), C ranged from 0.002-0.005 mg L⁻¹ (0.004 ± 0.0008 mgL⁻¹), and D ranged from 0.003-0.005 mgL⁻¹ (0.004 ± 0.0009 mgL⁻¹), respectively. High nitrite content could poison shrimp and fish, due to the oxidized iron in hemoglobin which could reduce the ability of blood to bind dissolved oxygen [37]. These values were within the limits that still tolerated for tiger shrimp life, while the recommended tolerance value for shrimp culture was less than 0.25 mgL⁻¹.

The phosphate content in all treatments to be fluctuating and tended to decrease (Figure 2). Phosphate in treatment A ranged from 0.0032-0.0133 mgL⁻¹ (0.0100 ± 0.0037mgL⁻¹), B ranged from 0.0038-0.0132 mgL⁻¹ (0.0100 ± 0.0036 mgL⁻¹), C ranged from 0.0065-0.0137 mg L⁻¹ (0.0111 ± 0.0024 mgL⁻¹), and D ranged from 0.0089-0.0147 mgL⁻¹ (0.1174 ± 0.0019 mgL⁻¹), respectively.

3.3. Growth and production of red tilapia, tiger shrimp, and seaweed

Weight gain in polyculture of red tilapia, tiger shrimp and seaweed in this study was shown in Table 2. The highest weight gain of red tilapia at the end of the study was occurred in treatment A of 178.23 ± 3.326 g/fish, followed by C of 170.5 ± 2.464 g/fish and D of 164.17 ± 0.950 g/fish, respectively and this value was significantly different ($P < 0.05$) from other treatments. The low growth of red tilapia in treatment D in this study was thought to be caused by higher levels of fish density compared to treatments A and C (Table 1). High fish density could cause competition between fish to get food. Fish that were nimble and strong and have a larger size could get food more often. The highest weight gain in treatment A indicated that red tilapia not only got nutrition from pellets but also from natural food. However, in this study, red tilapia growth in all treatments was slow, due to the fact that whose natural habitat was freshwater but subjected to culture in brackish water with salinity >25 ppt. Salinity was closely related to the osmoregulation process in a fish's body which is a physiological function that requires energy. To maintain and balance the concentration of salt in the body, red tilapia adapts and osmoregulates by increasing drinking water [38]. Environmental osmotic pressure higher than fish body fluids would flow into the environment through osmosis and salt ions or ions from the environment would enter the body of tilapia by diffusion [39]. Euryhaline fish had intermediates that could distinguish blood and urine from salt or water through active transport [40].

The weight of tiger shrimp at the end of the study recorded in identical weight gain and not significantly different ($P > 0.05$) from other treatments. The weight of tiger shrimp at the end of the study were as follows; A (13.2 g/ind), B (12.8 g/ind) and C 13.0 g/ind), respectively in the polyculture treatments. The highest weight gain occurred in treatment A, followed by C and B. This indicated that tiger shrimp not only utilized nutrients from pellets but also from natural food (algae) that grown in ponds for its growth.

The highest survival rate of red tilapia in this study was recorded in treatment D ($87.3 \pm 0.92\%$), followed by treatment C ($82.1 \pm 1.8\%$), while the lowest survival rate in treatment A ($78.5 \pm 1.75\%$). Treatment difference remained significant ($P < 0.05$). The highest survival rate in tiger shrimp occurred in B that was $72.2 \pm 6.53\%$, and the lowest in C was $62.6 \pm 3.15\%$ and showed a significant difference ($P < 0.05$), while the survival rate in the treatment A reached $64.0 \pm 3.0\%$ and was not significantly different ($P > 0.05$) from other treatments. The highest production of red tilapia occurred in treatment D (761.4 kg/ $2,500$ m²), followed by C (349.9 kg/ $2,500$ m²), and A (349.6 kg/ $2,500$ m²), respectively.

Table 1. Growth, production, survival rates and FCR in tilapia polyculture system, tiger shrimp and seaweed in ponds

Commodity	Treatment			
	A	B	C	D
Pond size (m ²)	2500	2500	2500	2500
Initial weight				
- red tilapia (g/fish)	5.1	-	5.1	5.1
- tiger shrimp (g/ind.)	0.05	0.05	0.05	-
- seaweed (kg/pond)	150	150	-	150
Final weight				
- red tilapia (g/fish)				
- tiger shrimp (g/ind.)	$178.2^a \pm 3.326$ $13.2^a \pm 0.551$	- $12.8^b \pm 1.770$	$170.5^b \pm 2.464$ $13.0^b \pm 0.624$	$164.17^a \pm 0.950$ -
Survival rate				
- red tilapia (%)	$78.5^a \pm 1.75$	-	$82.1^b \pm 1.18$	$87.3^c \pm 3.15$
- tiger shrimp (%)	$64.0^b \pm 3.02$	$72.2^b \pm 6.53$	$62.6^a \pm 3.15$	-
Yields				
- red tilapia (kg/plot)	$349.65^b \pm 11.101$ $42.27^a \pm 0.941$	- $100.05^b \pm 16.632$	$349.90^b \pm 0.624$ $40.69^a \pm 2.426$	$716.7^b \pm 9.777$ -

- tiger shrimp (kg/plot)	226.33±16.806	352±13.377	-	-
- seaweed (kg/pond)				
FCR				
- red tilapia	1.03	-	1.15	1.19
16 - tiger shrimp	0.95	0.93	0.98	-

The mean values at the same row with different superscript are significantly different ($P < 0.05$)

Remark: A. Red tilapia, tiger shrimp and seaweed; B. Tiger shrimp and seaweed; C. Red tilapia and tiger shrimp and D. Red tilapia

The results of statistical analysis on treatment D showed a significant difference ($P < 0.05$) compared to treatments on A and C. Meanwhile, the highest production of tiger prawns occurred in treatment B (100.5 kg/2,500 m² or 402 kg/ha), then followed by treatment C (40.7 kg/2,500 m² 13 162.8 kg/ha) and A (42.3 kg/2,500 m² or 169.2 kg/ha), respectively. Statistical analysis on treatment B showed a significant difference ($P < 0.05$) compared to treatments on A and C.

Feed Conversion Ratio (FCR) in polyculture describes the amount of feed taken by organism that have been cultivated to grow one kilogram of organism. Feed conversion ratio (FCR) of red tilapia in this polyculture produced was of > 1.0 and the lowest was obtained in treatment A (1.03), then followed by C and D, which were 1.15 and 1.19, respectively. Meanwhile, for tiger prawns in all treatments resulted in FCR of 0.9 and the lowest FCR was obtained in treatment B which was 0.93. The low average FCR was due to the availability of natural food in the ponds that is sufficient for the needs of fish and shrimp. In addition, good water quality, especially nutrient content and TSS (<100 mgL⁻¹) contribute to the growth of plankton in ponds.

3.4. Income analysis

Economic analyses revealed that treatment A required an operational cost of 4,695,000 IDR towards purchase of tiger shrimp, red tilapia seeds, seaweed, shrimp feed, fish feed, inorganic fertilizer and dolomite etc the revenue generated from the sale of red tilapia and shrimp amounted to 12,046,400 ± 263,026.7 IDR, and a profit of 7,348,067 ± 260,329 IDR per cycle with benefit cost (BC) ratio of 2.57±0.06.

In B, an operational cost of 2,301,666.7 IDR was needed. This operational cost was used to buy of tiger shrimp, seaweed, shrimp feed, fertilizer and dolomite. Furthermore, Revenue obtained from the sale of shrimp was 7,382,073±861,421 IDR and a profit of 5,080,407±720,103 IDR per cycle with BC ratio of 3.3±0.36. In C, an operational cost of 4,934,366.7 IDR was required. This cost was used to buy tiger shrimp, tilapia seeds, shrimp feed, fish feed, inorganic fertilizer and dolomite lime. Furthermore, revenue obtained from the sale of shrimp amounted to 11,894,767±178,561.5 IDR and profit of 6,960,350±379,889 IDR per cycle with a BC ratio of 2.42±0.14. While in D, an operational fee of Rp 8,013,333 was required.

Table 2. Costs and profits of the fish farming business for each treatment of the polyculture system in ponds

Parameters	Range	Average ± SD
A		
1. Operating Cost (IDR)	4,695,000-4,695,000	4,695,000
2. Revenue (IDR)	11,742,800-12,205,500	12,046,400±263,026.63
3. Profit per cycle (IDR)	7,047,800-7,510,500	7,348,067±260,329
4. BC Ratio	2.5-2.7	2.6±0.061
B		
1. Operating Cost (IDR)	2,135,000-2,385,000	2,301,667±144,337.6
2. Revenue (IDR)	6,404,750-8,030,970	7,382,073±861,420.9
3. Profit per cycle (IDR)	4,269,750-5,645,970	5,080,407±720,103.1

4. BC Ratio	3.0-3.7	3.3±0.36
C		
1. Operating Cost (IDR)	4,694,850-5,073,250	4,934,367±208,307
2. Revenue (IDR)	11,745,300-12,092,500	11,894,767±178,561.5
3. Profit per cycle (IDR)	6,710,300-7,397,500	6,960,350±379,889.15
4. BC Ratio	2.3-2.6	2.4±0.14
D		
1. Operating Cost (IDR)	7,560,000-8,325,000	8,013,333.3±401,694.33
2. Revenue (IDR)	17,560,000-18,122,500	17,776,167±303,000.14
3. Profit per cycle (IDR)	9,491,000-10,415,000	9,901,167±470,642.20
4. BC Ratio	2.2-2.4	2.2±0.13

This operational cost was used to buy red tilapia seeds, fish food, seaweed, inorganic fertilizer, and dolomite lime. Furthermore, revenue obtained from shrimp sales was 17,776,167±303,000 IDR and profit 9,901,167±470,642.2 IDR per cycle with a BC ratio was 2.24±0.12.

4. Conclusion

Water quality during the study was within the range of tolerance for the cultivation of red tilapia, tiger shrimp and seaweed. The highest survival rate and production of red tilapia occurred in treatment D (87.3 ± 0.92% and 716.6 kg/2,500 m²). Meanwhile, the highest survival rate and production of tiger shrimp occurred in treatment B (72.2±6.53 % and 100.04 kg/2,500 m²). Furthermore, income analysis showed that the highest profit per cycle is obtained in D and for polyculture obtained in A.

39 Acknowledgements

The author would like to thank Mr. Markus Mangampa and the pond technician for 44 assistance during the course of this study. The author also thanks the water quality laboratory analyst, Research Institute for Coastal Aquaculture, Maros for their support during observations.

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