EFFECT OF DYNAMICAL WATER QUALITY ON SHRIMP CULTURE IN THE INTEGRATED MULTITROPIC AQUACULTURE (IMTA)

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ABSTRACT

One of the technologies to improve the productivity of shrimp farms are environmentally friendly shrimp farming multitrophic integrated system known as Integrated Multitrophic Aquaculture (IMTA). The aims of the study were to observe the water quality dynamic on the integrated multitrophic aquaculture and the effect on the production. This study was used four plots which each of pond had 4,000 m^2 in sizing, located in experiment pond, at Research and Development Institute for Coastal Aquaculture, Maros. The main commodities used were tiger and vannamei shrimp. In the A pond was cultivated the tiger shrimp with density 12 ind./m^2, in B pond was tiger shrimp with density 8 ind./m^2, C pond was vannamei shrimp with density 50 ind./m^2, and D pond was vannamei shrimp with density 25 ind./m^2. Other commodities were red tilapia (*Oreochromis niloticus*). Each pond had stocking density 2,400 ind./plot which was divided into 5 hapas having a size of (6 m x 4 m x 1.2 m)/each, mangrove oysters (*Crassostrea iredalei* and *Saccostrea cucullata*) with density 7,500 ind./4,000 m^2 and seaweed (*Gracilaria verrucosa*) of 500 kg/4,000 m^2. The observation of dynamic water quality in the pond was conducted every day i.e. temperature, dissolved oxygen, salinity, and measured pH, while the total organic matter total (TOM), total ammonia nitrogen (TAN), nitrite, nitrate, phosphate were taken every two weeks. The measurements methods of water quality in laboratory was refered to APHA (2008); and Boyd (1990). During the study, absorption of N and P in seaweed were measured, the obtained plankton was identified and the ratio of carbon and nitrogen during the observation was also calculated. To determine the effect of dominant water quality on production was used the principal component analysis (PCA). The result showed that water quality during the study was suitable for shrimp and red tilapia culture. The dominant water qualities which effected the shrimp production in IMTA system were total ammonia nitrogen (TAN), oxygen, total organic matter (TOM), phosphate, and salinity. The survival rate of the tiger shrimp in intensive pond and semi intensive pond was 50.68% and 59.28% respectively, while the survival rate of the vannamei shrimp in intensive and semi intensive was 71.26% and 68.06% respectively. The highest shrimp production in the cultivation of IMTA reached was 1,488 kg/pond (3,720 kg/ha) in C pond. The lowest feed conversion ratio (FCR) was obtained in the D pond (0.89). The highest production of red tilapia in IMTA reached in C pond (426.65 kg/pond).

KEYWORDS: **water quality, shrimp culture, integrated multitrophic aquaculture**

INTRODUCTION

In fisheries sector, shrimp can be relied as an export commodity. In the last few years, the production of shrimp in Indonesia tends to stagnan due to disease spread after the revitalization program proclimed by the Ministry of Marine and Fisheries. The production is not significantly increased and most of the shrimp production decreased because of the environmental conditions.

The same condition also occured in Thailand and other Asian countries resulted the failure of shrimp cultivation which was especially in the intensive managed ponds because of the declining capacity of the environment (Briggs & Smith, 1994a; 1994b) and progression of various diseases either by bacteria or virus in the pond (Atmomarsono, 2004; Charatchacool *et al*., 1998). The cases of shrimp deaths due to the disease attack such as TSV, WSSV, IHHN, and *Vibrio harveyii* were not only happened in Indonesia but also in several countries such as India (Sathish *et al*., 2004), Chinese (Wu *et al*., 2005), and America (Galavis-Silva *et al*., 2004; Guevara & Meyer 2005), Korea (Kim *et al*., 2004).

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Most of intensive ponds were initially productive farms but right now they become unproductive because of various of problems which were especially the declining in aquatic environments. Other problems which were found in some coastal areas in the north coast of Java, South Lampung and some districts in South Sulawesi become less productive farms. Nevertheless, this kinds of pond productivity can be improved through a corrective management and application of good aquaculture practice. Those efforts include repairing the pond inlet and outlet, removing of sludge from waste intensive ponds, using of seed and feeds which have a best quality (Boyd *et al*., 2002; Burford *et al*., 2001; Jackson *et al*., 2003; Merican, 2004). Moreover, an appropiated technology that can be utilized the waste of cultivation is required and so does the commodities that can grow well in the pond so that it can increase the pond productivity.

One technology that can improve the shrimp pond productivity and environmentally friendly is Integrated Multitrophic Aquaculture (IMTA). A high commercial value commodities for IMTA has to be marketable in domestic and exports sector such as shrimp, *Tilapia* sp., oyster, and seaweed (Pantjara, 2011). IMTA technology applied in intensive ponds could reduce the load of waste from shrimp and fish farming, especially the leftover feed, excretion, and metabolite of shrimp. The principle of IMTA is the utilization of energy from leftover feed and the waste from shrimp or fish (as the first tropical commodities) into organic and anorganic nutrients, to be utilized for the other commodities (oyster and seaweed) in the lower trophic levels (Chopin *et al*., 2001; Matos *et al*., 2006; Pullin *et al*., 2001).

Oyster and seaweed cultivation technology are not as complicated as shrimp farming and the oyster and seaweed have the ability to absorb an excess organic nutrients in the intensive cultivation so that the suitable commodity for IMTA could be as a biofilter to improve water quality in ponds (Pantjara & Gunarto, 2011). The advantages of using IMTA technology are gained more than one commodity, increasing the carrying capacity of the land, conserving water, repairing the environment (water quality), sustaining and reducing the risk of the crop failure rather than using monoculture shrimp farming (Yang *et al*., 2001; Yi *et al.*, 2003). Pantjara *et al*. (2011), stated that IMTA technology could improve productivity and reduce the risk of harvest failure. IMTA research in the pond have not been much information yet, however, some researchers have started to apply on their farm although they were still in extensive plus technology. The aims of the study were to observe the effect of dominat water quality on shrimp culture in the integrated multitrophic aquaculture.

MATERIALS AND METHODS

The study was conducted during 120 days in the Experimental Pond Installation, Research and Development Institute for Coastal Aquaculture (RICA) Maros, which is located in Takalar Regency at South Sulawesi. The study was used four ponds and each of ponds had a size of (6 m x 4 m x 1.2 m). The pond was A and B as semi-intensive pond which was provided with two paddle wheels and four paddle wheels used in C and D as an intensive ponds. The position and placement of the paddle wheel were adjusted to the condition of the pond and water flow in order to generate oxygen and to distribute nutrients stream to the lower trophic commoditie levels so that the process of energy and nutrients naturally occured (Figure 1).

Pond preparation was conducted by repairing the leaked and damaged pond dyke, repairing the water inlet and outlet, and then soil remediation (soil cul-

Figure 1. Design of semi-intensive and intensive farming technology through the application of integrated multitrophic aquaculture

tivation, drying, inundation and flushing). At the drying pond soil, the dried soil had to reach a positive redox value (+> 30 mV) while to eradicate the pests, saponin was applied with dosage 30-40 kg/ha, then liming with dolomite of 500 kg/ha and applicating of urea and super phosphat (SP-36), each of them was 125 kg/ha with the purpose to grow the natural food (plankton) before stocking shrimp seed in ponds.

The commodity used for IMTA was the tiger shrimp (*Penaeus monodon*), vannamei shrimp (*Litopenaeus vannamei*), red tilapia (*Oreochromis niloticus*), mangrove oysters (*Crassostrea iredalei* and *Saccostrea cucullata*), and seaweed (*Gracilaria verrucosa*). Commodity compositions of each pond are presented in Table 1.

Red tilapia used in this research had 3-5 cm in size and placed on hapa with sizing of 24 m^2 (480 fish/hapa) and each pond was placed with 5 hapas. Four hapas placement were in the corner of the pond (± 5 m from the dyke) and one hapa was placed in the middle of the pond. The weight of shrimp and fish were measured every two weeks. The survival rate and production of tiger prawn, vannamei, red tilapia, and seaweed were conducted at the end of study.

The observation of dynamic water quality in the pond was conducted every day i.e. temperature, dissolved oxygen, salinity, and measured pH, while the total organic matter total (TOM), total ammonia nitrogen (TAN), nitrite, nitrate, phosphate were taken every two weeks. The measurements methods of water quality in laboratory was refered to APHA (2008) and Boyd (1990). During the study, absorption of N and P in seaweed were measured, the obtained plankton was identified and the ratio of carbon and nitrogen during the observation was also calculated. To determine the effect of dominant water quality on production was used the principal component analysis (PCA).

RESULTS AND DISCUSSION

Dynamic Water Quality

One key success in shrimp farming is to maintain a good water quality and to reduce waste contamination (Smith *et al*., 2002; Thakur & Lin, 2003). The result of study shown that the water quality had regression value (r) = 0.50, with determination (R^2) = 0.708. This indicated that 70.8% of the measured water quality variables were determined by concentration value of nitrite, nitrate, TAN, TOM, PO_4^{2-}, salinity, and oxygen or there was a relationship between variables which 29.2% of water quality were determined by other causes. Thus, the regression model can be used to predict the value of water quality or to determine the concentration of nitrate, nitrite, ammonia, organic matter dissolved, phosphate, salinity, and oxygen. Three main axes (eigenvalues > 1) explained 70.821% of all the information containing the measured variables (Figure 2).

On the first dimention with 2.56 eigenvalues explained that 36,511% of the variability were determined by total ammonia nitrogen (TAN), oxygen, total organic matter (TOM), phosphate, and salinity. The second dimention with 1,264 eigenvalues explained that 18.059% of the variability were determined by nitrate and phosphate. The third dimention with 1,138 eigenvalues explained that 16.251% of the variability were determined by nitrite and salinity. Waste accumulation in intensive pond that occurred every day during cultivation increased the nitrogen in ponds that were able to degrade the quality of water. It was caused by the organic waste consisting of proteins, carbohydrates, and fats.

Table 1. The composition of commodity used (tiger shrimp, vannamei shrimp, red tilapia, oyster, and seaweed) in each pond on integrated multitrophic aquaculture

Commodities composition	Stocking density in each pond			
	A	B	C	D
Tiger shrimp (ind./ha)	120,000	80,000	-	-
Vannamei shrimp (ind./ha)	-	-	500,000	250,000
Red tilapia (ind./pond)	2,400	2,400	2,400	2,400
Oyster (ind./pond)	10,000	10,000	10,000	10,000
Seaweed (kg/ha)	1,500	1,500	1,500	1,500

Remark: An intensive pond system composed of tiger shrimp, red tilapia, oyster, and seaweed (A); Semi-intensive pond system composed of tiger shrimp, red tilapia, oyster, and seaweed (B); An intensive pond system of vannamei shrimp, red tilapia, oyster, and seaweed (C); Semi-intensive pond system composed of vannamei shrimp, red tilapia, oyster, and seaweed (D)

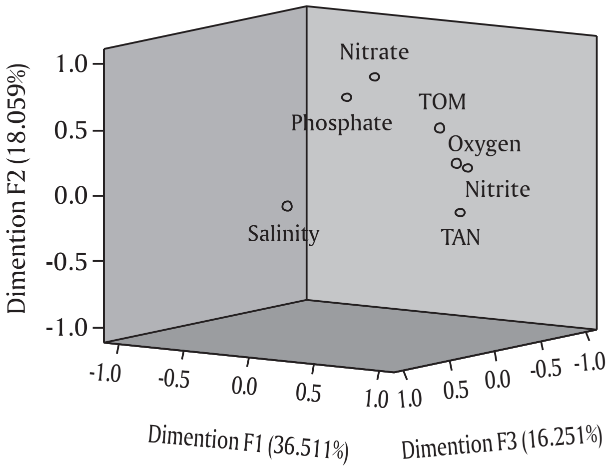

Figure 2. Principal Component Analysis (PCA) of water quality on semi-intensive and intensive farming technology through the application of integrated multitrophic aquaculture

The observation of oxygen in the pond which was conducted in the morning (06.00 am) reached 3-7 mg/L and in the night (at 09:00 pm) was 2.8 to 4.7 mg/L while in the midnight (02.00 am) reached 2,6-3.6 mg/L. The optimum range of water quality for shrimp as follows; dissolved oxygen (5.0-9.0 mg/L), temperature (28°C-32°C), CO_2 (< 20 mg/L), pH (7.0-8.3), salinity (0.5-35 ppt), total alkalinity (> 100 mg/L), NH_3^+ (< 0.03 mg/L), NO_2^- (<1.0 mg/L), and NO_3^- (< 60 mg/L).

Decomposition of organic waste which was carried by microorganisms produced CO_2, NH_4^+, NO_3^-, $SO_4^=$, $H_2PO_4^-$ (Smith & Briggs, 1998). According to Moriarty (1997), there was a relationship between the ratio of the amount of carbon with the amount of nitrogen on the rate of decomposition of organic matter. The result of nitrogen analysis in pond water (NH_4^+, NO_2^-, and NO_3^-) in each pond fluctuated from each observation. The concentration of total organic matter (TOM) in the water during experiment in all pond seemed fluctuation.

The highest content of TOM reached in A pond with average 39.260±10.746 mg/L, followed by C pond with an average of 38.938±11.5671 mg/L, B pond with an average 38.374±14.0821 mg/L and D pond with an average of 36.460±10.2624 mg/L. While the TOM content in sea water sources and reservoir reached an average of 36.606±11.938 mg/L and 35.146±12.7532 mg/L (Figure 3). Effendi (2003) and Hargreaves (1989), stated that the highest dissolved organic matter content of in the pond was caused by some dissolved organic material from organic waste.

The highest ammonia content obtained from C, followed by D, A, and B ponds, was 0.316±0.2550 mg/L, 0.243±0.1411 mg/L, 0.193±0.1310 mg/L, and 0.162±0.1406 mg/L, respectively, while the average content of ammonia in sea water sources and reservoirs reached 0.100±0.0552 mg/L and 0.107±0.0643 mg/L, respectively.

Boyd (1990) reported that, the secure ammonia levels for shrimp life were less than 0.1 mg/L. The nitrite concentration in the water for all ponds fluctuated (Figure 3). The nitrite content in the pond fluctuated and were still within the limits of tolerance for the life of shrimp. Boyd (1990) reported that the optimum of nitrite content was less than 0.001 mg/L and it was uncommon and probably impossible even in the intensive pond containing high organic waste. The highest content of nitrite was obtained on A pond, reaching an average of 0.099±0.057 mg/L, followed by B, C, and D ponds which were 0.059±0.1315 mg/L, 0.054±0.0304 mg/L and 0.036±0.0182 mg/L respectively. While an average content of nitrite in sea water source and reservoir was 0.040±0.0416 mg/L and 0.045±0.0439 mg/L.

Amonification process in water is faster than nitrification so that the formation of nitrate run slowly, especially in the process of nitrification from nitrite to nitrate. Nitrates in the pond water is required for growing plankton (fitoplakton, zooplankton) and other algae. The highest nitrate content was obtained on C, followed by A, B, and D pond, which were 0.607±0.6668 mg/L, 0.523±0.4519 mg/L, 0.349±0.4566 mg/L, and 0.285±0.2041 mg/L respectively. While the average of nitrate content in sea water source and reservoir reached of 0.573±0.7310 mg/L and 0.634±0.6060 mg/L. Nitrate content in the water pond is classified in the low level and fluctuated at each observation. However, the optimum nitrate content for the life of shrimp is 20-100 mg/L. The effect of the density on vannamei shrimp to get food, either in the daytime or night were able to be predicted, it required fewer feed than that of tiger shrimp.

The observations of the total N content in each A, B, C, and D ponds were as follows; A (0.8150±0.4797 mg/L/day), B (0.961±0.6083 mg/L/day), C (0.628±0.442 mg/L/day), and D (0.507±0.3098 mg/L/day) respectively. The nitrogen water content of A and B ponds was higher than that of C and D ponds. Ratio of carbon and nitrogen during the observation fluctuated with feeding thus increasing the total organic matter in the water which was also part of the waste water, went through the process of decomposition (Figure 4).

The content of PO_4^{2-} in pond water was classified on the low level and the concentration fluctuated in all ponds. The highest of PO_4^{2-} content was obtained in D, followed by A, B, and C pond which were 0.568±0.5331 mg/L; 0.370±0.2988 mg/L; 0.329±0.3210

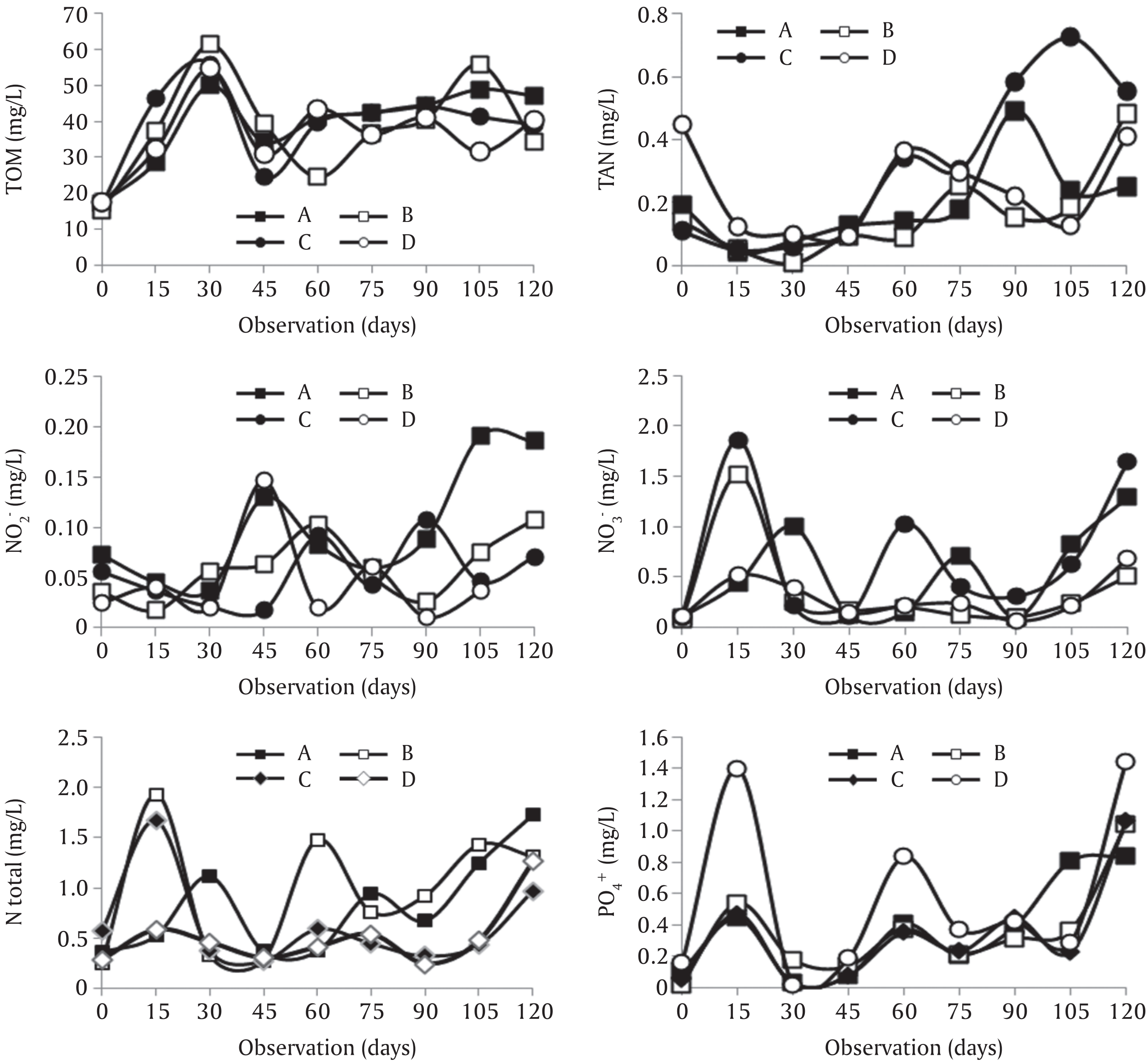

Figure 3. Fluctuations of water quality in shrimp farming system in integrated multitrophic aquaculture (IMTA). Intensive tiger shrimp, red tilapia, oyster, and seaweed (A); Semi-intensive tiger shrimp, red tilapia, oyster, and seaweed (B); Intensive vannamei shrimp, red tilapia, oyster, and seaweed (C); Semi-intensive vannamei shrimp, red tilapia, oyster, and seaweed (D)

mg/L; and 0.329±0.3210 mg/L; respectively, while the phosphate content in sea water source and reservoir reached an average of 0.131±0.1718 mg/L and 0.183 ±0.2544 mg/L.

Absorption of N and P in Seaweed

The protein content in commercial feed are generally in the range of 28%-35%. Protein is really needed for shrimp growth, but in the fact, unutilized food remains by the shrimp was often found. Feed waste that accumulated in the bottom of the pond gradually dissolved in the pond water so that it added a number of nutrients (N and P) in the water and increase the fertility pond water (Schuenhoff *et al*., 2003). In shrimp cultivation with IMTA system, the resulting nutrients from aquaculture wastes could be useful to stimulate the growth of plankton and others microbial communities which were further exploited by oyster. Some soluble nutrients were distributed and absorbed by the seaweed so that it reduced the nutrients and a balance in the pond naturally.

The amount of feed were given to each pond based on the estimated quantity and average weight of shrimp and fish, so that each pond received a different nutrient load. The highest stocking density and increasing weight of the shrimp and fish leaded a higher feed requirement. It increased a number of the nutrients in the pond. The shrimp feed given had 33% protein content meaning that each 1 kg of feed contained 330 g of protein. This protein content was

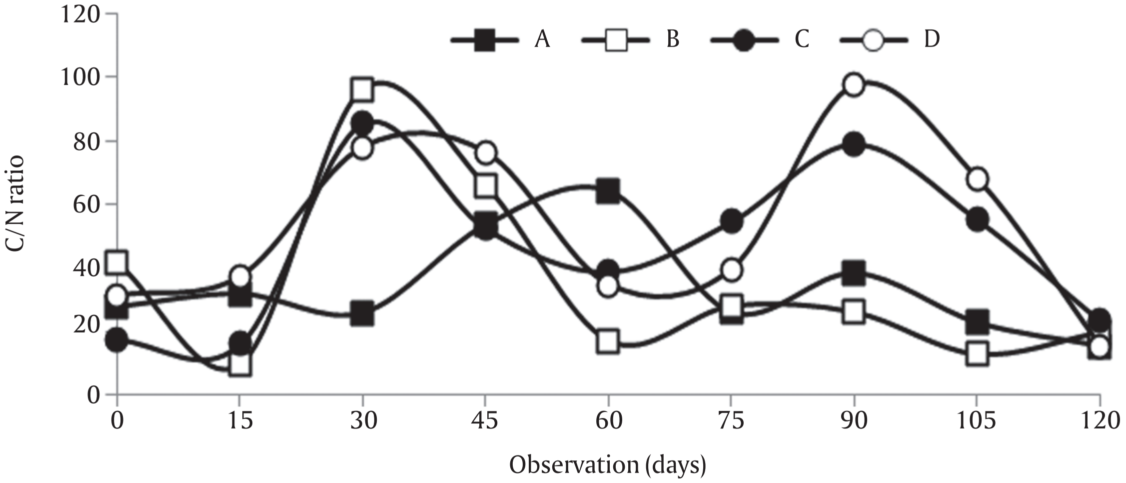

Figure 4. Fluctuations of C/N ratio in integrated multitrophic aquaculture (IMTA). Intensive tiger shrimp, red tilapia, oyster, and seaweed (A); Semi-intensive tiger shrimp, red tilapia, oyster, and seaweed (B); Intensive vannamei shrimp, red tilapia, oyster, and seaweed (C); Semi-intensive vannamei shrimp, red tilapia, oyster, and seaweed (D)

sufficient to fill up the nutrient requirements of shrimp that required a minimum 30% of protein content.

Primavera & Apud (1994) and Boyd (1995) estimated that 85% of the feed were used by the shrimp for their growth and survival. The prediction of 15% of shrimp feed was not consumed so that it become deposited organic waste in the bottom of pond and was decomposed by the bacteria and some waste become soluble in water. According to Kennedy & Gewin (1997), the organic waste decomposition velocity was influenced by organic matter availability, the abundance of bacteria as decomposers of organic matter and environmental factors that were suitable for bacteria life. Feed waste decomposition is modified into soft of organic particles and dissolved (suspended solids) so that the nutrient contents increase in the pond. The waste produced in the ponds are determined by capacity of the pond production such as feed, excretion, and other metabolites.

The waste production in pond can be give an effect on N and P ratio. According to the Primavera & Apud (1998), the nitrogen and phosphate from the waste aquaculture in the pond were about 67% and 83.33%. N and P Nutrient in the IMTA pond were used by seaweed for growing. The abilities of seaweed to absorb N and P in each pond are presented in Table 2.

The seaweed uptake was almost the same in A, B, C, and D pond which was 0.0088; 0.0091; 0.0089; and 0.0090 mg/L/day, respectively. Similarly, the seaweed ability to absorb P from each pond reached of 0.0019 mg/L/day.

According to Santoso *et al*. (2007), the total absorption rate of phosphate to *Gracilaria* sp. was about

Table 2. N and P uptake by seaweed, *Gracilaria verrucosa* on integrated multitrophic aquaculture

Pond	Unit	Uptake per day	
		N	P
A	mg/L	0.0088	0.0019
B	mg/L	0.0091	0.0019
C	mg/L	0.0089	0.0019
D	mg/L	0.0090	0.0019

Remark: An intensive pond system composed of tiger shrimp, red tilapia, oyster, and seaweed (A); Semi-intensive pond system composed of tiger shrimp, red tilapia, oyster, and seaweed (B); An intensive pond system of vannamei, red tilapia, oyster, and seaweed (C); Semi-intensive pond system composed of vannamei, red tilapia, oyster, and seaweed (D)

0.98 to 5.08 mg/L (7.76% to 41.80%) per day. In this research P which was absorbed by seaweed was low because the study was conducted during dry season so that the water salinity increased to over 40 ppt (Figure 5) and seaweed, *Gracilaria* sp. grew well in the range of 15-30 ppt salinity. The stress on seaweed could be caused by the high salinity and influenced the callus formation and morphogenetic development. The effect of salinity could also disturbe seaweed respiration. It was caused by the difference in concentrations between the fluid inside and outside the cell, pushing Golgi the body to constantly strive to be balance until become isotonic.

This condition required more energy, it affected the growth and the development of seaweed which become small and shrink. Synergistic and beneficial nature of these three commodities (seaweed, fish,

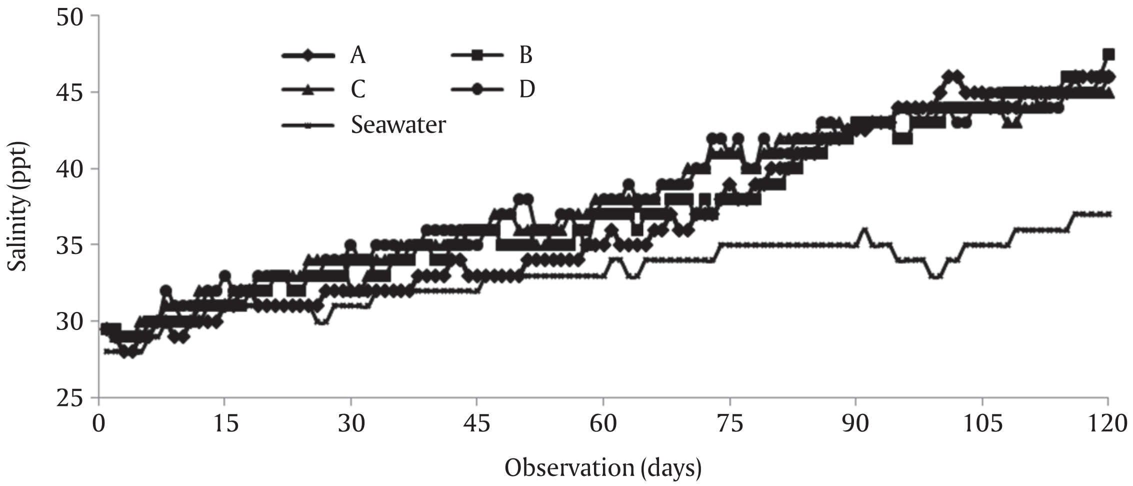

Figure 5. Water salinity at IMTA system of shrimp culture for 120 days. Intensive tiger shrimp, red tilapia, oyster, and seaweed (A); Semi-intensive tiger shrimp, red tilapia, oyster, and seaweed (B); Intensive vannamei shrimp, red tilapia, oyster, and seaweed (C); Semi-intensive vannamei shrimp, red tilapia, oyster, and seaweed (D)

and oysters) caused water quality become stable condition.

Plankton Population and The Growth of Oysters

Pantjara (2009), reported that the microorganisms in the pond developed due to the microorganism capability of utilizing available carbon from organic waste. The microorganisms utilized carbon from organic waste and produced carbon dioxide. Anaerobic condition of the bottom pond caused the growth of bacteria which were dominated by anaerobic bacteria and their decomposition process produced CH_4, CO_2, NH_3, H_2S, and other organic acids and formed the oxidized compounds that was not suitable or newly formed biomass materials as a result of decomposition. However, the increasing of bacterial population in this research did not always be stable and the highest population occured in C (8.52 x 10^4 cfu/mL) and the lowest was on B (1.06 x 10^4 cfu/mL). According to Moriarty (1997), an increase of microorganisms activities were influenced by environmental conditions with the availability of carbon and oxygen which was used to oxidize organic compounds and released carbon dioxide. The microorganisms which had a role as organic matter decomposer did not identify in detail. Pantjara (2008), reported that the microorganisms species decomposed the organic waste in intensive shrimp ponds, such as *Pseudomonas* sp., *Vibrio* sp., *Bacillus* sp., *Flavobacterium* sp., *Micrococcus* sp., *Cytophaga* sp., and *Enterobacterium* sp. The growth of microorganis in the pond water were dominated by aerobic bacteria which obtained the oxygen from the paddle wheel.

Decomposition of organic wastes by microorganisms on integrated multitrophic aquaculture produced nutrient NH_4^+, NO_2^-, NO_3^-, and PO_4^{2-} that in turn to be utilized by plankton and seaweed for photosynthesis and growth. According to Mesple *et al*. (1996), the waters that planted with more fitoplankton, often there were encountered zooplankton. Then, Plankton abundance was used by the oyster for growth energy source. During the study, plankton that was identified were about 26 plankton genera that consisted of 20 phytoplankton and 6 zooplankton. The identified phytoplanktons were *Achananthes* sp., *Bidulphia* sp., *Chaetoceros* sp., *Coscinodiscus* sp., *Cyclotella* sp., *Gleotrichia* sp., *Navicula* sp., *Nitzschia* sp., *Oscillatoria* sp., *Thallasionema* sp., *Thallassiosira* sp., *Parapodia* sp., *Lauderia* sp., *Melosira* sp., *Pedinomonas* sp., *Climosphenia* sp., *Gymnodinium* sp., *Protocentrum* sp., *Streptotheca* sp., and *Strombidium* sp. Meanwhile, the zooplankton is *Apocyclops* sp., *Brachionus* sp., *Copepods* sp., *Oithona* sp., *Polychaeta* sp., and *Tortanus* sp.

In this study, the growth of oysters were slowly as they were seen from the average meat weight (without shell), which reached 0.6-1.2 g/individual, while many oyster (*Crassostrea iredalei*) were found dead in the bottom pond. At the end of the research, 89% oysters (*Saccostrea cucullata*) dominated and were obtained the survival rate as follows; A (58.1%), B (54.9%), C (62.0%), and D (52.8%), respectively. The low survival rate of oysters were caused by the influence of high salinity which was over 35 ppt (Figure 5). In this study the existence of oyster in the pond contributed to the improvement of water quality because the oysters absorbed the food which consists of phytoplankton, bacteria, fungi, flagellates, dissolved organic matter, detritus in the mud together with the organic silt and organic matter (Pantjara & Gunarto, 2011).

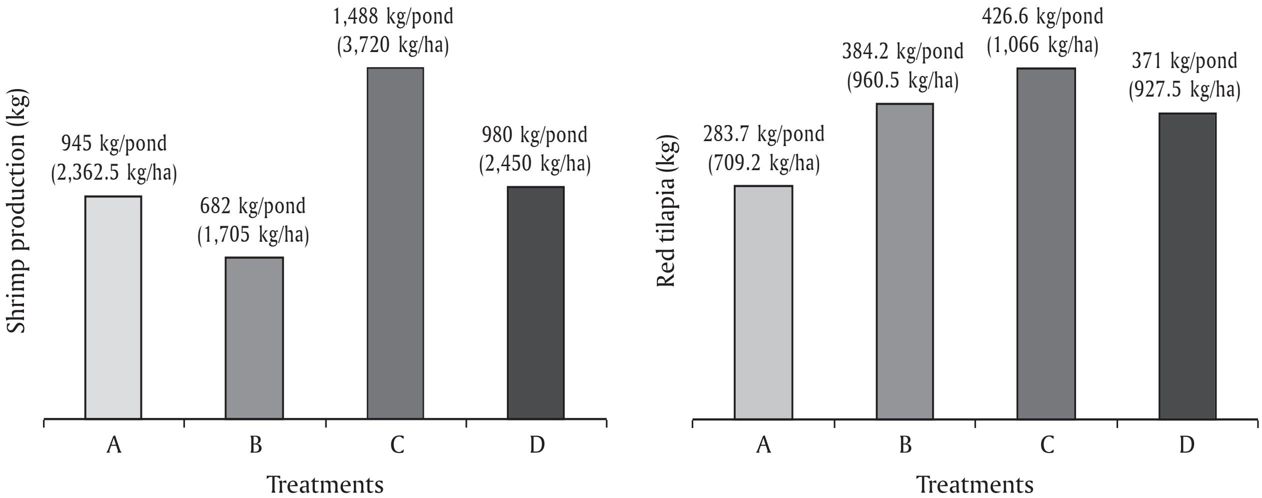

Figure 6. Production of tiger shrimp and vannamei shrimp (left) and red tilapia (right) on the cultivation shrimp IMTA systems. Intensive tiger shrimp, red tilapia, oyster, and seaweed (A); Semi-intensive tiger shrimp, red tilapia, oyster, and seaweed (B); Intensive vannamei shrimp, red tilapia, oyster, and seaweed (C); Semi-intensive vannamei shrimp, red tilapia, oyster, and seaweed (D)

Growth and Production of Shrimp and Red Tilapia

Providing a good quality feed and a properly pond water conditions determined the success of intensive shrimp farming. Good water quality could produce optimal shrimp growth with a highly survival rate. At the end of the research, the growth of tiger shrimp on A and B pond reached an average weight of 15.4 and 14.38 g/shrimp, while the growth of vannamei shrimp in C and D pond reached an average weight of 11.36 and 13 g/shrimp (Figure 6).

The survival rate of tiger shrimp on A and B was 50.68% and 59.28% respectively, this result was lower than that of the vannamei shrimp on C and D, which reached 71.26% and 68.06%. Meanwhile, the survival rate of red tilapia of A, B, C, and D pond, was 25.1%; 25%, 25%, and 30% respectively. The highest shrimp production in IMTA systems reached on C pond which was about 1,488 kg/pond (3,720 kg/ha), followed by D, A, and B pond, 980 kg/pond (2,450 kg/ha), 945 kg/pond (2,362.5 kg/ha) and 682 kg/pond (1,705 kg/ha) respectively (Figure 6).

The highest feed conversion ratio (FCR) was 1.32 in A pond and the lowest was in the D, C, and B pond, with FCR value 0.89, 1.06, and 1.11, respectivelly. The growth of red tilapia in this study was slowly. However, the the growth of red tilapia on C pond was higher than that of B, A, and D ponds. At the beginning of the study, the average weight of red tilapia had a size of 2.6 g/fish and at the end of the study, the average weight on each A, B, C, and D pond, were of 144.8; 145.0; 161.0; and 140 g/fish respectively. In this study, the slow-growing of red tilapia was caused by the water salinity which reached more than 40 ppt. The osmotic differences which was faced by the tilapia caused the osmotic pressure on the fish fluids which required quite large energy for osmoregulation and effected the feed intake level. Meanwhile, the red tilapias usually grow and survive at salinities ranging from 0 to 35 ppt. The production of red tilapia on each ponds was A (283.720 kg/pond); B (384.25 kg/pond); C (426.65 kg/pond); and D (371.0 kg/pond).

CONCLUSIONS

Water quality during the study was suitable for shrimp and red tilapia culture. The dominant water qualities which effected the shrimp production in IMTA system were total ammonia nitrogen (TAN), oxygen, total organic matter (TOM), phosphate, and salinity.

The survival rate of the tiger shrimp in intensive pond and semi-intensive pond was 50.68% and 59.28% respectively, while the survival rate of the vannamei shrimp in intensive and semi intensive was 71.26% and 68.06% respectively. The highest shrimp production in the cultivation of IMTA reached 1,488 kg/pond (3,720 kg/ha) in C pond. The lowest feed conversion ratio (FCR) was obtained in the D pond (0.89). The highest production of red tilapia in IMTA reached in C pond (426.65 kg/pond).

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