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SILVOFISHERY MODEL IN AQUACULTURE AND ITS IMPACTS TO ECOLOGICAL STATUS OF WATER QUALITY ENVIRONMENT

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ABSTRACT

This study aims to analyze the ecological status of ponds using the silvofishery model through water quality observations. This study used a survey method. The ponds observed were shrimp ponds located on the north coast of East Java, Indonesia. Water quality analysis method used STORET. The results of measurements of physical parameters show that the temperature ranges from 29-32 °C, for chemical parameters pH is between 6-8, dissolved oxygen is between 4-7 mg/l, nitrite is between 0.02-0.06 mg/l, nitrate is between 0.4-1.0 mg/l, and ammonia is between 0.3-1.9 mg/l. Based on the STORET analysis, the total score of class II quality standard and class III quality standard in site 1, 2, 3, and 4 are -8, respectively. Based on these data, the four sites are classified as class B water quality, which indicated lightly polluted for class II and III. This means that aquaculture activities with the silvofishery model are able to reduce water pollution due to fishery activities. It is also proven that site 1, 2, 3, and 4 have the same value. Furthermore, silvofishery cultivation can be an environmentally friendly cultivation model and continue to be used.

KEY WORDS : Eco-friendly, Shrimp culture, STORET, Sustainable

INTRODUCTION

Shrimp farming is an effort to increase sustainable fishery production. However, the activities which are carried out continuously will give a negative impact, which is environmental degradation. This is caused by the presence of wastewater that is produced in the form of organic waste. Shrimp organic waste usually comes from shrimp feed and feces. This shrimp waste can disrupt the balance of the aquatic ecosystem (Arsad *et al*., 2017). One of the effective efforts to reduce pollution in the aquatic environment is integrating cultivation techniques between mangroves and ponds, or commonly called as Silvofishery. Mangrove is one of the ecosystems in the coastal area which has a function as a buffer between land and ocean ecosystems. Mangrove ecosystems are very rich in nutrients from both outside and inside the ecosystem and can function as an absorber of organic materials resulting from aquaculture activities, commonly called as phytoremediation (Dahuri *et al*., 1996; Saparinto, 2007; Hadiputra and Damayanti, 2013). One of the silvofishery models applied to shrimp ponds is the *komplangan* design. This study aims to analyze the effectiveness of the application of silvofishery in shrimp ponds by assessing the status of environmental water quality.

METHODOLOGY

The research method used in this study was the survey method. This research was conducted in a super intensive shrimp pond in the Probolinggo Brackish Water and Marine Fisheries Laboratory, East Java, Indonesia (-7.74212, 113.23379). This pond used a silvofishery system with the *komplangan* design. It had 11 ponds with an area of around 3,000 - 3,500 m^2 each. For the shrimp pond, the area used was 1600 m^2 with a stocking density of shrimp of 162 fish / m^2. The production of a pond with an area of 1600 m^2 is 8.5 tons / year (Schmittou calculation method) with the amount of organic waste produced of 14.875 tons/year with 697 kg of nitrogen/year and 116.87 kg of phosphorous / year. The characteristic of the research location was that the edge of the pond was surrounded by mangroves. The research location was determined by purposive sampling. The research location was divided into 4 sites (Figure 1), consisting of site 1 (inflow water of the mangrove area, 7 ° 44'28.6 "S 113 ° 14'01.5" E), site 2 (reservoir water, 7 ° 44'30.7 " S 113 ° 13'59.4 "E), site 3 (shrimp pond wastewater, 7 ° 44'30.7" S 113 ° 13'58.3 "E), and site 4 (outflow water of the mangrove area, 7 ° 44'28.6" S 113 ° 13'55.6 "E).

The characteristics of the utilization of each station were different. In Station 1, the water came from a mixture of river and sea water (brackish) with quite shallow water, the color of the water was slightly brown, there wasa presence of mud, and the water had no smell. At this site, there were plastic waste, leaves and wood waste. In site 2, the reservoir water came from a mixture of river and sea water, flown through a pipe. This reservoir water was filtered using chlorine. Filtration was carried out to improve water quality and eradicate pathogens before the water was used through a deposition processto reduce organic matter. The water conditions in the reservoir water were slightly clear, were little muddy and smell a bit like chlorine. Furthermore, site 3 was wastewaterfrom shrimp pond waste, originating from leftover feed as well as from shrimp droppings. Meanwhile, site 4 was the outflow water in the mangrove area. The water conditions at station 4 were cloudy and smelled bad. This water wasthe remaining from the disposal of shrimp pond waste. This station was in the mangrove area. Sampling was carried out every 2 weeks at 4 stations for almost 2 cycles of cultivation (± 6 months).

Water Quality Measurement

Water quality parameters measured included temperature (° C, AAQ Rinko 1183), pH (, AAQ Rinko 1183), dissolved oxygen (mg/l, AAQ Rinko 1183), nitrite (mg/l, Nitrate Test Kit Hanna Instrument 38743), nitrate (mg/l, Nitrate Test Kit

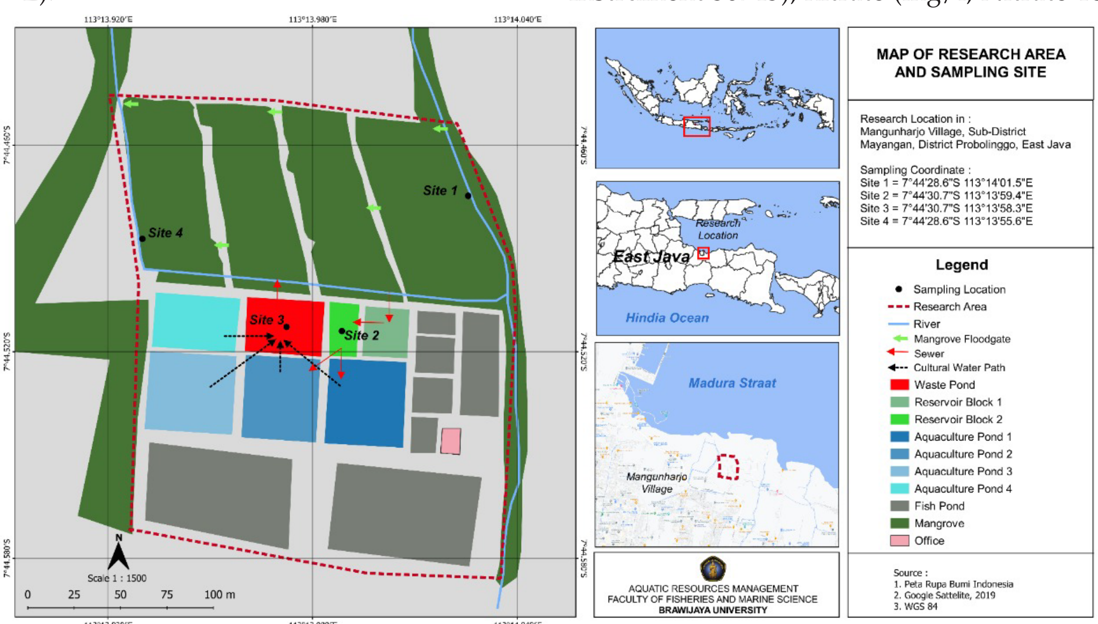

Fig. 1. Map of Research Area and Sampling Site

Hanna Instrument 38743) and ammonia (mg/l, Nitrate Test Kit Hanna Instrument 38743). All measurements were carried out *in situ*.

Data Analysis

The method used in determining the water quality status was the STORET method. The determination of water quality status using the STORET method refers to the Regional Regulation of the city of Surabaya Number 02 of 2004 and Decree of the Minister of Environment (KEPMEN LH) Indonesia No. 115 of 2003. The principle of the STORET method is to compare water quality data with water quality standards that are adjusted to their designated purpose to determine water quality status. The US-EPA (Environmental Protection Agency) value system was used to determine water quality status by classifying water quality into four classes (Table 1) below:

The stages of determining the status of water quality using the STORET method included collecting the water quality data periodically so as to form data from time to time, and comparing the data from the measurement of water parameters with the quality standard value according to the class of water. If the measurement result meets the quality standard value (the measurement result ≤ quality standard), then it is given a score of 0. However, if the measurement result does not meet the quality standard (the measurement result> quality standard), then the scores given can be seen in Table 2.

The negative numbers of all parameters were calculated, and the quality status was determined from the total score obtained using the value system.

RESULTS AND DISCUSSION

Water Quality Parameters

The results of the study report the parameters measured during almost 2 cycles of super intensive shrimp culture in ponds. Parameters measured for almost 2 cycles include temperature, pH, DO, nitrate and ammonia, while the other parameters (orthophosphate, total organic matter (TOM), salinity, and nitrite) were measured for 1 cycle (Table 3). The data arecompleted with the number of samples (N), minimum value, maximum value, average, standard deviation, and coefficient of variation. Based on the data obtained, the coefficient of variation shows that the measured parameters are homogeneous for the temperature, pH, DO, and salinity. Meanwhile, the parameters of nitrate, ammonia, orthophosphate, TOM, and nitrite show large coefficients, which means that the parameter values tend to be heterogeneous, and these parameters also fluctuate. This is due to the fact that the content of nitrate, ammonia, nitrite, orthophosphate, and TOM is strongly influenced by shrimp farming activities and is generated as organic waste from leftover feed and feces of the organisms.

Table 1. Water Quality Classification

No	Class	Indicator	Score	Evaluation
1.	Class A	Very good	0	Meet quality standards
2.	Class B	Good	-1 to -10	Lightly polluted
3.	Class C	Moderate	-11 to -30	Moderately polluted
4.	Class D	Poor	e” -31	Heavily polluted

Source: Canter (1977)

Table 2. Determination of the Value System to Determine Water Quality Status

Number of Parameters	Score	Parameter		
		Physics	Chemistry	Biology
< 10	Maximum	-1	-2	-3
	Minimum	-1	-2	-3
	Mean	-3	-6	-9
≥ 10	Maximum	-2	-4	-6
	Minimum	-2	-4	-6
	Mean	-6	-12	-18

Temperature

The temperature during the research is presented in Figure 2. The range of temperature is between 28 and 33 ° C in all sites. This value still belongs to the water quality standard. The optimal temperature for shrimp growth ranges from 28-32 ° C (Anggoro *et al.*, 2017). As for mangrove growth, a good temperature range is around 25-30°C (Poedjirahajoe *et al.*, 2017), and based on PP. 82 of 2001 and the Regional Regulation of the City of Surabaya Number 02 of 2004 concerning the quality standards of class II and class III of water temperatures, it is in deviation 3. So, it can be concluded that the water temperature around the shrimp ponds is in accordance with the water quality standards and supports the life of the cultivated organisms therein.

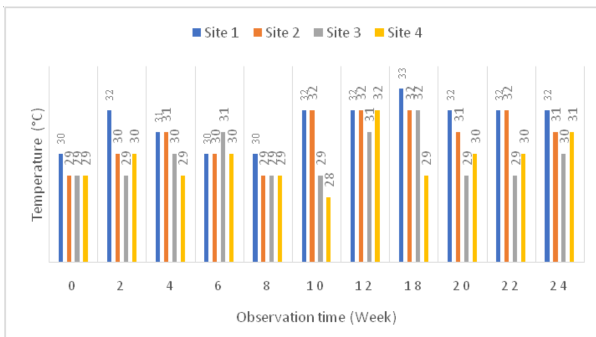

Fig. 2. Graph of the results of temperature measurement

The fluctuations in the water temperature can be caused by the high intensity of sunlight entering the water body. In addition, exposure to sunlight entering the water body and the density of vegetation in water areas can also affect water temperature. The higher the exposure to sunlight entering water bodies, the higher the water temperature. The intensity of sunlight is influenced by cloud cover, season and time of collection (Marlina, *et al.*, 2017). Temperature affects the solubility of oxygen in water, metabolic processes, and chemical reactions in water. An increase in the temperature in the waters can increase the metabolism of organisms including decomposing bacteria, so the decomposition process of organic matter also increases. This process causes the need for dissolved oxygen to be high, which further decreases the dissolved oxygen content in the water (Gazali *et al.*, 2013).

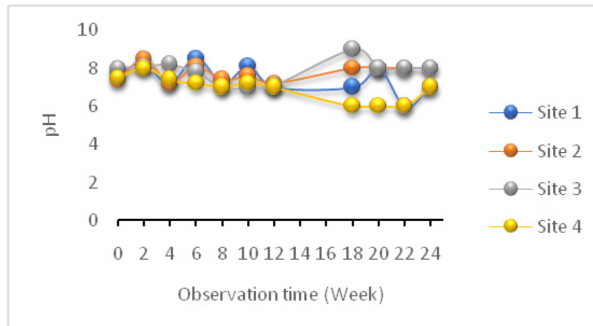

Fig. 3. Graph of average pH measurement

pH

Based on Figure 3, the pH range during the study ranges from 6 to 9. The results obtained are still classified as optimal and are in accordance with the quality standards set by the government. Waters with a pH of 7.5-8.5 are waters with very high productivity and are suitable for aquaculture activities, while the pH range of water between 6-8.5 is very suitable for mangrove growth (Putra *et al.*, 2017). However, waters with a pH of 5.5-6.5 and> 8.5 are considered less productive waters. Based on the Government Regulation No. 82 of 2001 and the Regional Regulation of the City of Surabaya No. 02 of 2004 concerning the pH quality standard for class II and class III of water (water recreation and fisheries activities, respectively), a good pH valueranges from 6-9.

The high and low pH level in waters can be

Table 3. Results of the measurements of water quality parameters

No.	Parameter	Unit	N	Min.	Max.	Mean	Std.Dev.	CV
1	Temperature	°C	44	28	33	30.45455	1.284153	4.216621
2	pH		44	6	9	7.497727	0.694325	9.260478
3	DO	mg/l	44	4	9	7	1.391751	21.40407
4	Nitrate	mg/l	44	0.1	2.2	0.6	0.50386	82.93993
5	Ammonia	mg/l	44	0.01	1.70	0.39	0.552502	141.5765
6	Orthophosphate	mg/l	28	0.001	0.150	0.042	0.04274	102.7223
7	TOM	mg/l	28	1.240	29.100	10.085	7.928768	78.61663
8	Salinity	‰	28	12	24	20	3.091206	15.45603
9	Nitrite	mg/l	16	0.02	0.06	0.036875	0.013022	35.31503

influenced by photosynthetic activity, temperature and ions, and fluctuations in O_2 and CO_2 content (Rukminasari and Awaluddin, 2014). The pH value can be influenced by the presence of organic and inorganic waste disposal into the water (Ali *et al*., 2013). The pH value of the waters affects the biota in the waters and the primary productivity of the waters (Hamuna *et al*., 2018). A pH value that is too acidic or alkaline can affect the survival of these organisms because the metabolic processes and respiration of aquatic biota can be disturbed and can cause an increase in the presence of toxic heavy metal compounds.

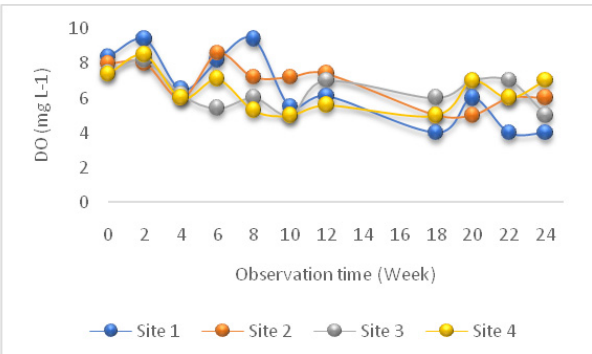

Fig. 4. Graph of the results of dissolved oxygen measurement

Dissolved oxygen

The results of measurements of dissolved oxygen (Figure 4) obtained in this study range from 4-9 mg/l. This shows that these waters meet quality standards. The depth of a water is related to the temperature, which ultimately affects dissolved oxygen. This is because at different depths and temperatures, the dissolved oxygen requirements in organisms are also different. The high availability of oxygen in the waters indicates that the water quality is still relatively good (Fachrul, 2016). The flowing water generally has a high dissolved oxygen content but has a low carbon dioxide content. This is because the movement of currents can also increase or increase the availability of dissolved oxygen in the waters. Based on PP No. 82 of 2001 and the Regional Regulation of the City of Surabaya Number 02 of 2004, for the value of the dissolved oxygen quality standard for class II the minimum dissolved oxygen limit is 4 mg/l, and for class III the minimum dissolved oxygen limit is 3 mg/l.

Nitrate

The results show that the nitrate content (Figure 5) obtained starts from 0.1 to 2.2 mg/l. The difference in the concentration of nitrate at each site can be caused by differences in the amount of organic matter input in the waters. At site 4. the nitrate content is higher, which can happen because in site 4 (outflow water of the mangrove area) there is more input of organic material, such as from pond wastewater disposal.

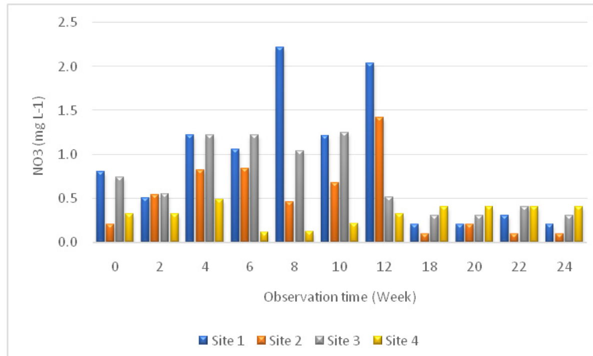

Fig. 5. Graph of the results of nitrate measurement

The difference in nitrate concentrations can be caused by differences in the supply of organic matter containing nitrates to the waters. The presence of nitrate can be seen from the indicators of pH, temperature, and dissolved oxygen. Changes in pH indicate a change in the concentration of organic matter in the waters. An increase in organic matter in the waters can cause an increase or decrease in the pH value in the waters. Nitrates can come from the breakdown of organic matter in the waters by aerobic bacteria. This decomposition requires dissolved oxygen so that it can cause a decrease in dissolved oxygen in the waters. An increase or decrease in dissolved oxygen levels is an indicator of an increase in the decomposition of organic matter to nitrate (Akbar *et al*., 2016). Nitrate concentrations in water can increase the growth and development of aquatic organisms if supported by the availability

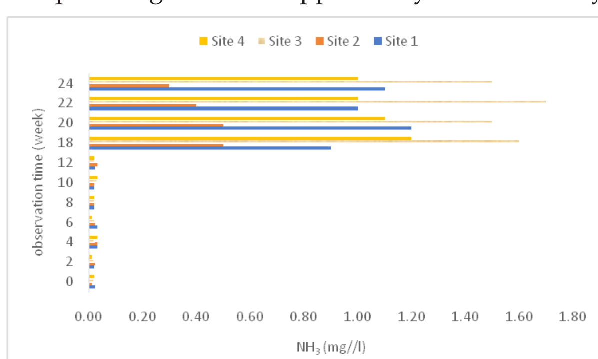

Fig. 6. Graph of the results of ammonia measurement

of nutrients (Patty, 2015). The ideal nitrate content for the growth of organisms ranges from 23.5 mg/l (Sumadwijaya, 1997) and based on PP No. 82 of 2001 and the Regional Regulation of the City of Surabaya Number 02 of 2004 the quality standard for nitrate forclass II (water recreation) water quality classification is 10 mg/l and for class III (fisheries activities) is 20 mg/l.

Ammonia

The value of ammonia obtained (Figure 6) in this study ranges from 0.01 to 1.7 mg/l. The difference in ammonia concentration in each site could be due to differences in the decomposition of organic matter carried out by bacteria and the presence of waste in that site.

The high concentration of ammonia in the waters can cause the death of aquatic biota. Ammonia is dangerous if it has a high concentration because it can reduce dissolved oxygen due to dissociation of ammonia and causing disturbances in physiological and metabolic functions such as respiration, which can also disrupt the function of hemoglobin. The increase in ammonia levels in the waters can be due to organic matter pollution from fisheries (Windusari and Sari, 2015). The presence of ammonia can affect the size of the chloroplast as it can reduce the size of the chloroplast; besides, it can cause thylakoid disorganization which can inhibit the photosynthesis process (Putri *et al*., 2019). The high concentration of ammonia can be caused by the increasing pH value in these waters (Supriyantini *et al*., 2017). Based on PP No. 82 of 2001 and the Regional Regulation of the City of Surabaya Number 02 of 2004, the quality standard of ammonia for class II and class III water quality is 0.02 mg/l for biota that is sensitive to changes in water quality.

Results of standard analysis using the STORET method

To see the health status of the waters used for aquaculture activities and the health status of open watersaround the ponds, the water health status test was carried out using the STORET method (KEPMEN LH No. 115 of 2003), and the results are presented in Table 4.

The data in the Table 4 shows that sites 1, 2, 3, and 4 are classified as good criteria with a lightly polluted status (Class B), both for class II quality standards which are designated for recreational infrastructure and facilities, freshwater and brackish water aquaculture activities, livestock, and irrigation and for class III which are designated for freshwater and brackish wateraquaculture, livestock, and irrigation.

Impact of Silvofishery on Water Quality Status

One of the advantages of using a Silvofishery model is management by minimizing input and reducing the impact on the environment. The silvofishery model used in this research location is the *komplangan* design with alternating pond designs or being adjacent to the land to be planted with mangroves. The land for mangroves and ponds is separated into two stretches of land regulated by water channels. Technically, the construction of the *komplangan* design is more complicated, but it is more environmentally friendly because mangrove land as a conservation area is separated from pond land as a cultivation area, which are regulated by a water channel with two separate gates. The separation of mangrove land and pond land in the *komplangan* design isbordered by an embankment between two gates so that this pattern can be an environmentally friendly solution for pond management.

The mangrove area functions as a biofilter center. When entering new water into the silvofishery pond unit, the water is first flown through the mapped mangrove area and then is stored with the aim of depositing organic and inorganic matter such as mud, sand, and the like particles that enter along with the water into the mangrove area (Figure 1).

Table 4. Results of water quality analysis using the STORET method

No.	Location	Class II.			Class III.		
		Score	Class	Evaluation	Score	Class	Evaluation
1.	Site1 (Inflow Water of Mangrove)	-8	B	Lightly polluted	-8	B	Lightly polluted
2.	Site 2 (Reservoir Water)	-8	B	Lightly polluted	-8	B	Lightly polluted
3.	Site 3 (Wastewater)	-8	B	Lightly polluted	-8	B	Lightly polluted
4.	Site 4 (Outflow Water of Mangrove)	-8	B	Lightly polluted	-8	B	Lightly polluted

After the new water is entered into the mapped mangrove area and it is estimated that it has undergone a perfect deposition process, it is then flown into the pond area through the gate between the mapped mangrove area and the pond. On the other hand, when there is a water change in the silvofishery pond unit, the water is removed from the plot of the pond area and is flown into the mapped mangrove area. The purpose of depositing organic and inorganic matter in the form of waste products from the cultivated organisms and toxic compounds such as ammonia, hydrogen sulfide, and the likeis to make sure that the water discharged from the pond does not pollute coastal waters.

From the determination of the status of water quality using the STORET method referring to the Decree of the Minister of Environment Indonesia No. 115 of 2003, it is shown that in all sites (1,2,3,4) the water conditions are classified as lightly polluted. This means that the water before entering the pond and leaving the pond has the same water quality, and it also means that that aquaculture using silvofishery is able to suppress the levelof wastewaterusing mangrove plants which break down the waste bytheir roots. Mangrove roots will absorb the waste with sediment because the roots are the part that is directly connected to the sediment and also waste filtration.

CONCLUSION AND RECOMMENDATIONS

The results of the measurement of water quality parameters show that the water quality parameters are still in the range of quality standards in allsites except for ammonia. The *komplangan* silvo fishery model that is applied has positive impacts on the health of the waters around the pond. The results of the measurement of water quality parameters show that the water before and after entering the pond have a relatively same water quality, and based on the STORET test the water is suitable for recreation and aquaculture.

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