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POTENTIAL OF MANGROVE SEEDLINGS FOR UTILIZATION IN THE MAINTENANCE OF ENVIRONMENTAL QUALITY WITHIN SILVOFISHERY PONDS

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ABSTRACT

Silvofishery system has been applied to aquaculture activities and it has been developed in the coastal area of Semarang City, Indonesia. However, information on the initial development of silvofishery ponds concerning the functionality of mangrove seedlings on environmental quality of fishponds had not been studied. This experiment aimed to determine the environmental conditions of silvofishery ponds and to analyze the effect of seedling stands of mangrove on environmental quality control. The presence of mangrove seedlings caused the decrease of temperature and the increase of salinity. ANOVA showed that mangrove species significantly affected water salinity, while canal width and mangrove species significantly affected turbidity and pH. Regression analysis showed that the height of *Rhizophora mucronata* had partially significant effect on Total Suspended Solids (TSS), Organic Matter (OM), as well as Nitrogen (N) and Phosphorus (P) concentrations. Diameter of *R. mucronata* affected temperature. The height and diameter of *Avicennia marina* affected Dissolved Oxygen (DO). Mixed populations of *A. marina* and *R. mucronata* had an effect on water turbidity, while population of only *A. marina* had a partial effect on water salinity. *R. mucronata* seedlings had dominant effect on the environmental quality. Mangrove seedlings can be used as environmental quality control within silvofishery ponds to maintain optimal conditions for fish growth. The application of silvofishery in early stage of mangrove seedlings should consider the more abundant plantation of *R. mucronata* compared to *A. marina*.

Keywords: Canal width, environmental quality, seedling, silvofishery, species composition

INTRODUCTION

The unsustainable utilization pattern of coastal areas has caused environmental damage (Primyastanto *et al.* 2010), and the most affected sectors by the damage is pond aquaculture activities (Pramudyanto 2014). However, the development of beach and upland areas also has contributed to degradation of environmental quality (Vatria 2010).

One of the applied methods to maintain the sustainability of pond culture activity is the silvofishery culture system (Surtida 2000). Silvofishery is an aquaculture system which combines mangrove trees with shrimp/fish ponds. The integration of mangrove stands within silvofishery ponds are expected to improve the environmental quality and increase the carrying capacity of the system (Wibowo & Handayani 2006). According to Suwarto *et al.* (2015), the existence of mangrove vegetation in ponds will improve primary productivity as well as assimilation capacity of pond effluents.

Several silvofishery pond models have been applied in many regions including *komplangan*, *empang parit* and enhanced *empang parit* (Bengen 2002). All three models integrate the mangrove community into the pond area (inlet/outlet). The function of mangroves within the ecosystem is to provide nutrients through nutrient trapping and litter production and to absorb pollutants. Mangrove should grow in both the inlet area as pollutant absorbers and in the outlet area to neutralize the pond effluent. However, the

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application of a mangrove community in both inlet and outlet of silvofishery systems had not been developed.

The potential utilization of mangrove in environmental quality control within aquaculture ponds through the application of silvofishery is expected to decrease the risk of aquaculture activity as well as to improve pond productivity (Lewis III & Gilmore 2007). However, the optimal function of mangrove stands to the environment may not be achieved until trees are mature. In the meanwhile, the growth of mangrove from seedling stage to tree requires a long period of time.

The influences of mangrove seedlings planted in seedling plantations on the quality of pond environment have received very little attention. Although the effect of mangrove seedlings on the control of environmental quality is not highly significant, the existence of mangrove seedlings should provide certain effects on water circulation pattern as well as absorption of nutrients or pollutants. Thus, the role of mangrove seedlings in silvofishery ponds, especially in early plantations needs to be studied.

Semarang City is a region in Indonesia that has experienced ecological disturbance from unsustainable development activities in the past as well as regional development leading to environmental stress increase in coastal areas. Pond culture occupying silvofishery system had been applied in Semarang City, but it is not optimized to support the productivity of aquaculture. This experiment aimed to determine the environmental conditions of silvofishery ponds and to analyze the effect of seedling stands of mangrove on environmental quality control.

MATERIALS AND METHODS

The experiment was conducted in Mangunharjo Village, Tugu District, Semarang City, Central Java Province, Indonesia from March to September 2015 by planting mangrove seedlings in silvofishery ponds at the inlet and outlet canals. Materials used were height and diameter of seedling stands as well as water and sediment quality parameters representing environmental quality i.e. temperature, turbidity, salinity, pH, Dissolved Oxygen (DO), Total Suspended Solids (TSS), Organic Matter (OM), as well as Nitrogen (N) and Phosphorus (P) concentrations.

Experimental design involved treatments of canal widths and mangrove compositions. Canal widths were 1, 2 and 3 m. Canal length was 5 m for all treatments. The size of culture ponds were 5 x 5 m^2 with 1.5 m depth. The canals were build on both sides of the ponds as inlet and outlet canals. Composition of the mangrove seedlings were: 1. *Avicennia marina* (A); 2. *Rhizophora mucronata* (R); or 3. a mixture of the two mangrove species (M). The plantation space among seedling stands was 1 x 1 m^2, so the number of mangrove stands for each treatments were 5 stands (1 m – L1); 10 stands (2 m - L2) and 15 stands (3 m – L3). The experiment was conducted with 3 replications. The design of the experiment is shown in Table 1 and the diagram of the experiment is shown in Figure 1.

Data collections and observations were conducted every 3 months i.e. in March, June and September 2015. Data collected were: 1. water quality parameters i.e. temperature, turbidity, salinity, pH, DO (Dissolved Oxygen) and TSS

Table 1 Design of the experiment

Seedling composition	Canal width		
	1 m	2 m	3 m
Avicennia marina	L1-A	L2-A	L3-A
Rhizophora mucronata	L1-R	L2-R	L3-R
Mixture of both mangrove species	L1-M	L2-M	L3-M

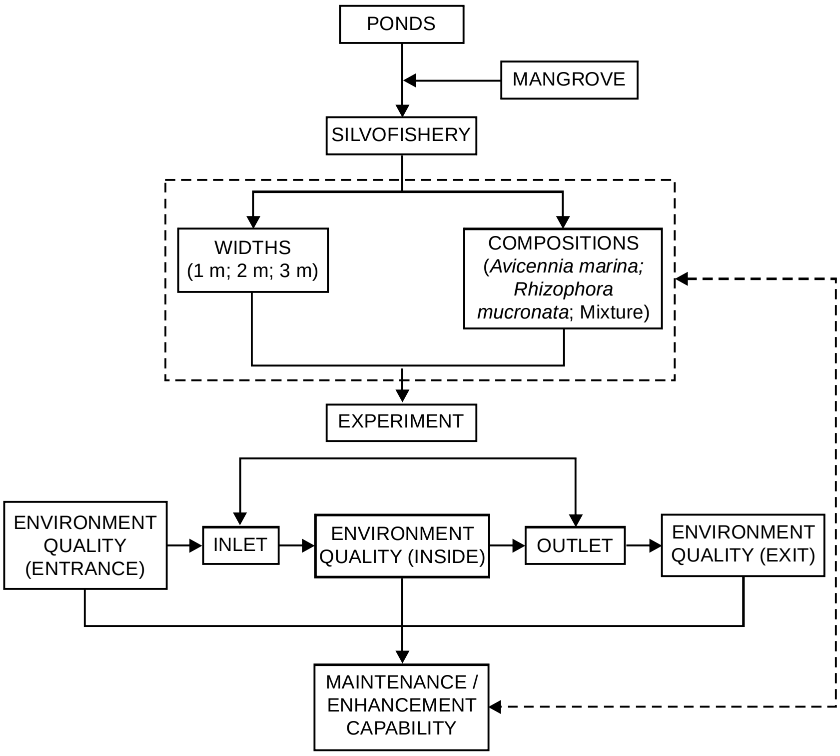

Figure 1 Diagram of the experiment

(Total Suspended Solids); and 2. sediment quality parameters i.e. OM (Organic Matter), as well as N (Nitrogen) and P (Phosphorus) concentrations. Data processing was conducted to determine the impact caused by mangrove stands on the environmental quality represented by water and sediment quality parameters value changes in the inlet and outlet canals. Factorial ANOVA and multiple regression analysis were used to analyze the collected data. Factorial ANOVA was conducted to analyze the impact of treatments involving the combination of canal widths and mangrove composition on water and sediment quality parameters. Multiple regression analysis was conducted to analyze the influence of seedling variations (including the combination of population, measurements and species compositions) on the value changes of environmental quality parameters. Multiple regressions analysis involved: 1. independent variables for respective mangrove compositions i.e. seedling height, seedling diameter and population of mangrove seedling particularly for *A. marina* and *R. mucronata*; and 2. dependent variables i.e. changes of temperature, turbidity, salinity, pH, DO, TSS, OM, N and P concentrations.

RESULTS AND DISCUSSION

Data collected showed changes in water and sediment quality parameters in the silvofishery ponds (Table 2).

Water temperature consistently decreased from the first to the third observations, while salinity consistently increased. Other parameters did not show any specific pattern of changes.

The observed water and sediment quality parameters within the inlet and outlet canals of silvofishery pond showed the decrease and increase of parameters values, before and after passing the canal with mangrove stands. The changes of water and sediment quality parameters value within the canals varied among treatments.

This experiment showed the value changes on water and sediment quality parameters within the pond canals i.e. temperature changes ranged from (-)5.5 to (+)6.4 °C; turbidity ranged from (-)710 to (+)769 NTU; salinity changes ranged from (-)6.3 to (+)6.1‰; pH ranged from (-)6.1 to (+)6.2; DO ranged from (-)4.1 to (+)4.5 mg/L; TSS ranged from (-)343.2 to (+)509.4 mg/L; OM ranged from (-)2.7 to (+)2.5%; N concentration ranged from (-)0.7 to (+)0.7%; and P concentration ranged from (-)50.9 to (+)52.8

Table 2 Changes in water and sediment quality parameters value observed during the experiment

No.	Parameter	Observation I	Observation II	Observation III
1.	Temperature (°C)	34.2	31.4	30.6
2.	Turbidity (NTU)	379.7	313.0	353.7
3.	Salinity (‰)	22.0	31.0	39.8
4.	pH	7.49	9.26	8.11
5.	DO (mg/L)	6.56	6.99	5.72
6.	TSS (mg/L)	411.37	492.04	218.00
7.	OM (%)	1.64	1.74	1.62
8.	N (%)	0.53	0.55	0.55
9.	P (ppm)	33.86	39.68	34.44

ppm. The changes indicated that water and sediment quality changed during the 3 observation periods. The range of parameter values varied among observation periods.

Height and diameter measurements on mangrove seedling stands also showed variations among the 3 observation periods. Height of *A. marina* stand ranged from 41 to 106 cm; from 43 to 101 cm; and from 39 to 106 cm with stand diameter range of 0.20 – 0.89 cm; 0.32 – 0.88 cm; and 0.15 – 1.94 cm for the first, second and third observations, respectively. Height of *R. mucronata* stand ranged from 28 to 60 cm; from 24 to 76 cm; and from 38 to 78 cm with stand diameter range of 0.22 – 1.90 cm; 0.30 – 1.32 cm; and 0.55 – 2.36 cm for the first, second and third observations, respectively. Decreased seedling height and diameter of each mangrove species was caused by the mortality of seedlings, hence seedlings replacements were conducted several times.

Data analysis with ANOVA to measure the effect of canal width and mangrove compositions (treatments) on water and sediment quality parameters showed that several parameters were significantly affected by the treatments, such as mangrove composition affected salinity, canal width and mangrove composition affected turbidity and pH. Significant effect on water salinity was achieved from silvofishery pond canals with *A. marina* and *R. mucronata*. While significant effect on water turbidity was achieved from different canal widths and from different mangrove seedling species. Significant effect on pH was achieved from combination of canal width and mangrove seedling species.

Multiple regression analysis to determine the effect of mangrove stands on the water and sediment quality parameters of silvofishery pond showed that there were significant effects of mangrove stand on several observed parameters (Table 3). Data analysis was conducted partially for each mangrove composition structure as well as water and sediment quality parameters.

Changes in environmental quality parameters within silvofishery pond canals were dominantly influenced by seedlings of *R. mucronata* (Table 3). Parameters partially influenced by *R. mucronata* stands included changes in TSS concentration, temperature, OM concentration, N concentration and P concentration. Seedlings combination of *R. mucronata* and *A. marina* influenced water turbidity and DO concentration. *A. marina* seedlings influenced water salinity.

There was significant effect of *R. mucronata* on TSS concentration. According to Furukawa and Eric (1996), mangrove stands can function as sediment trap. Sediment trapping processes by mangrove stands begins with the slowing down of water current, and this leads to the accumulation of TSS which finally gravitates. Also, sediment trapping is influenced by the tide condition (Kathiresan 2003).

Mangrove stand has negative effect on the change of temperature, which means that as the height and diameter of mangrove stands increase, water temperature decreases. According to Hadikusumah (2008), mangrove vegetation is capable of absorbing heat. The photosynthetic capability of mangrove seedling of *Rhizophora* occurs in the leaves and green stems, hence as the

Table 3 Effect of mangrove stands on changes of water and sediment quality parameters within canals of silvofishery ponds

No.	Mangrove composition	Independent variable	Dependent variable	Equation
1.	Single	Height of *R. mucronata* (X1)	TSS	Y = 524.574 – 8.483(X1)
2.	Mixed	Diameter of *R. mucronata* (X1); Height of *R. mucronata* (X2)	Temperature	Y = -1.091 + 0.057(X1) – 1.799(X2)
3.	Mixed	Population of *A. marina* (X1); Population of *R. mucronata* (X2)	Turbidity	Y = -81.627 – 209.753(X1) + 213.887(X2)
4.	Mixed	Population of *A. marina* (X1)	Salinity	Y = -0.432 + 0.103(X1)
5.	Mixed	Height of *A. marina* (X1); Diameter of *A. marina* (X2); Height of *R. mucronata* (X3)	DO	Y = 2.127 – 0.046(X1) + 7.410(X2) – 0.050(X3)
6.	Mixed	Height of *R. mucronata* (X1)	OM	Y = -1.796 + 0.050(X1)
7.	Mixed	Height of *R. mucronata* (X1)	N	Y = -0.587 + 0.017(X1)
8.	Mixed	Height of *R. mucronata* (X1)	P	Y = -41.303 + 1.142(X1)
9.	Mixed	Height of *R. mucronata* (X1)	TSS	Y = -248.833 + 6.794(X1)

stand height and diameter increase the amount of photosynthetic surface increases.

Water turbidity was affected significantly by both *A. marina* and *R. mucronata*. Seedling stands of *R. mucronata* inhibited water flow which increased the concentration of suspended sediment (Yang *et al.* 2013). On the contrary, *A. marina* seedlings had negative effect on the change of water turbidity. According to Weiffen *et al*. (2006), turbidity could be formed by the increasing population of plankton caused by the accumulation of sediment within the canal. The consumption rate of dissolved nutrient by *A. marina* probably was the cause of its negative effect on the water turbidity.

Water salinity was affected significantly by *A. marina* but not by *R. mucronata*, due to higher evaporation capacity of *A. marina* than *R. mucronata*. Evapotranspiration within a pond is able to decrease water concentration, while salt is excreted back to the environment through the leaves (Ball *et al*. 1988). Hence, the concentration of salt (salinity) increased.

Concentration of DO was negatively affected by height of both *A. marina* and *R. mucronata*, but was positively affected by diameter of *A. marina*. Stand height of mangroves were suggested to affect the canopy coverage which leads to the decreased light penetration (Kennedy *et al.* 2002). As the mangrove stand height increases, so does canopy coverage. On the contrary, mangrove seedlings still have chlorophyll in the stem, which means they are able to conduct photosynthesis. Photosynthesis has positive effect on seedling diameter and on the increase of dissolved oxygen concentration.

Nutrient concentration, including OM, N and P within the sediment was significantly affected by the height of *R. mucronata*, but not *A. marina*. Nielsen and Andersen (2003) stated that nutrient accumulation by *R. mucronata* is higher than that of *A. marina*. In the seedling stage, the capability to accumulate nutrients is related to diameter size of mangrove stand which is generally larger for *R. mucronata* than for *A. marina* stands. Therefore, *R. mucronata* has higher capacity to inhibit water flow and influence the accumulation rate of sediment which binds more nutrients than *A. marina*.

CONCLUSIONS

Silvofishery pond canals showed random pattern of environmental quality parameters value changes of turbidity, pH, DO, TSS, OM, N and P. Temperature was consistently decreased and salinity was consistently increased. Mangrove seedling stands for *A. marina* or *R. mucronata* had significant effects on the changes of environmental quality parameters involving various combinations on temperature, turbidity, salinity, DO, TSS, OM, N and P. Species that had most effect on environmental quality parameters value changes was *R. mucronata*.

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