PERFORMANCE OF MANGROVE-FRIENDLY SEMI-CLOSED SHRIMP POND

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ABSTRACT

Mangrove has been known to have special capability in absorbing nutrients and inhibiting the growth of bacteria, especially pathogens. The experiment aims at employing the capability of mangrove to carry out bioremediation in a semi-closed shrimp culture system. Sixteen, 0.25 ha each, ponds were used and separated into 2 groups. The first group, 8 ponds, was filled with seawater directly from the canal in an open system. The second group, another 8 ponds, was filled with seawater from reservoir planted with 2-year old mangrove, mostly *Rhizophora mucronata*, in a semi-closed system. The water depth in each pond was maintained at 1.0 m. Every 3 days, 40% of the water in each pond was exchanged with the water from reservoir for the second group ponds, and replaced with the water from the canal for the first group ponds. Each pond was stocked with 15 PL-40 of *Penaeus monodon*/m^2. The feed was broadcasted twice a day at the rate of 10%—3% total biomass. The water and shrimp were sampled every 15 days. The water in the semi-close system ponds was more productive than in the open system ponds as indicated by distinctly higher concentrations of NO_3^- (300%) and PO_4^- (150%) and the more abundance zooplankton at the end of the experiment. Regardless of the negative impact of long heavy rainfall during experiment, the survival rate and yield of the shrimp in the semi-close system, 2.07% and 27.03 kg, were significantly higher ($P<0.01$) than in the open system.

KEYWORDS: **mangrove, semi-close shrimp pond**

INTRODUCTION

The degradation of coastal environment which is suspected to be caused by, among others, the conversion of mangrove ecosystem into brackish-water ponds has brought about obvious nation-wide cultured shrimp production decrease. Carrying capacity of the ponds originated from mangrove forest is easily affected by the negative impact of excessive inputs such as feed, fertilizers, and chemicals used in shrimp culture. The frequent cases of bacterial as well as viral diseases outbreak are among the indications of how susceptible the shrimp culture in coastal area is.

Boyd *et al.* (1998) and Boyd (1999) reported that mangrove forest is not a good site for shrimp culture due to many reasons such as inadequate slope for drainage, excessive organic matters, and existence of acid sulphate soil or pyrite. Unfortunately, more than 90% of shrimp ponds in Indonesia were formerly mangrove forest and currently facing the problems of harvest failure mostly due to disease outbreak. The extinction of mangrove vegetations which has the capability to inhibit pathogens population growth (Soediro, 1999), absorb excessive nutrients (Ahmad & Tjaronge, 2000), and protect the facilities (Verhagen, 2000) in coastal waters is suspected to be the main cause of diseases outbreak cases in shrimp ponds. Obviously, shrimp culture implemented in the pond constructed in mangrove forest is not a sustainable farming system.

Ahmad & Mangampa (2000) carried out an experiment to identify the most appropriate water exchange for a semi-closed shrimp culture system equipped with mangrove planted reservoir and reported that the shrimps in the ponds with 40% water exchange rate every 3 days were survived until 90th day (the day to harvest) while the shrimps in the rest of the

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ponds all died in the 30th day. The mangrove grew in the reservoir area mostly *Rhizophora mucronata* which according to Soediro (1999) and Harahap (1998) having the capability to produce bacterio-static agent.

Based on the capability of mangrove to reduce turbidity (Hallide, 1998), absorb excessive nutrients, and inhibit pathogens growth, the experiment was designed to compare the performance of a semi-closed, equipped with mangrove planted reservoir, and an opened shrimp culture system. The result of the experiment is expected to be a basic of mangrove-friendly shrimp culture model.

MATERIAL AND METHODS

The experiment was carried out at brackishwater experiment ponds surrounded by mangrove, mostly *R. mucronata*, vegetations. The ponds inhabited by mangrove were used as reservoir for collecting, holding, and incorporating shrimp ponds waste water. Total shrimp ponds used were 16; the size of each pond was 0.25 ha. Of the 16 ponds, 8 ponds were filled with seawater directly from supply canal in an opened system (OS-pond). The other 8 ponds were filled with seawater from a mangrove occupied reservoir in a semi-close system (CS-pond). Water depth in each pond was maintained at 90—100 cm and was exchanged at 40% of total water volume every 3 days. In other words, the water for CS-pond was held for 3 days in the reservoir prior to be released into shrimp ponds. Two 8" submersible pumps were operated to maintain sufficient water exchange and depth. Prior filling water, ponds bottom were dried, limed, and fertilized (Boyd, 1997).

Black tiger shrimp (*P. monodon*) fry stocked into each pond were 15 PL-40/m^2 and fed pelleted feed at 10%—3% total biomass per day. Total biomass was calculated every 15 days based on the weight and numbers of shrimp (50 from each pond) sampled randomly by cast net. Shrimp samples were weighted individually using a 0.001 g accuracy top loading balance after being dried with tissue paper. Water quality was monitored everyday from 07.00 to 08.00 AM for salinity, DO, temperature, and pH. Due to diseases outbreak after a week heavy rainfall, most of the shrimp died 15 days after stocking and next sampling can only be carried out at harvest. Survival rate and average weight of the shrimps were calculated based on the yield at harvest.

Water samples were analyzed for NO_3-N, NH_4-N, NO_2-N, and PO_4-P concentrations every 15 days and bacteria population every 30 days. Brucine sulphate method was applied for analyzing NO_3-N and potassium sodium tartrate method for PO4-P. N-P ratio was calculated based on the data of total N and P at every sampling in each pond. Plankton was sampled from 100 L water filtered with No. 25 plankton net in each pond and identified based on Yamaji (1966) classification.

RESULTS AND DISCUSSION

Concentration of NO_3-N, one of the nutrients frequently related to water eutrophication, showed a relatively stable smooth increase from 0.06 to 0.09 µM in the first 6 weeks and a drastic increase from 0.09 to 1.76 µM in the last 6 weeks in CS-pond. In OS-pond, concentration of NO_3-N elevated from 0.09 to 0.32 µM in two weeks between day 45 and day 60 and then keeps steady at about 0.30 µM until day 90 (Figure 1). Mass shrimp mortality occurred 15 days after stocking followed by the reduced feeding seemed to instantly reduce the increase rate of NO_3-N in ponds water. In OS-pond, low feed input keeps concentration of NO_3-N stabilizing at around 0.30 µM. In CS-pond, decomposition of biomass or litter from mangrove is suspected to contribute to the significant increase of NO_3-N concentration starting on day 45.

Nitrification in both pond groups appeared to occur in a stable pace as indicated by similar pattern of NH_4-N, NO_3-N, and NO_2-N concentrations changes (Figure 2 and 3). Concentration of NH_4-N elevated drastically reaching 9.13 µM in the last 8 weeks followed by slight increase of both NO_3-N and NO_2-N in CS-pond. Similar pattern was observed in OS-pond, even though not so clear, especially of NO_3-N and NO_2-N concentrations. No further feeding after shrimp mass mortality is suspected to drop the concentration of NH4-N in OS-pond in the last 4 weeks. Choo & Tanaka (2000) reported the concentration of NH_4-N, NO_3-N, and NO_2-N concentrations as high as 25, 5, and 8 µM, respectively, in Matang Mangrove forest.

Concentration of PO_4-P had showed a tendency of elevation with a slight decrease on days 30 to 45 and 75 to 90 in OS-pond as well as on days 30 to 60 in CS-pond. Input accidentally supplied into inflowing water is suspected to bring about fluctuation of PO_4-P in OS-pond.

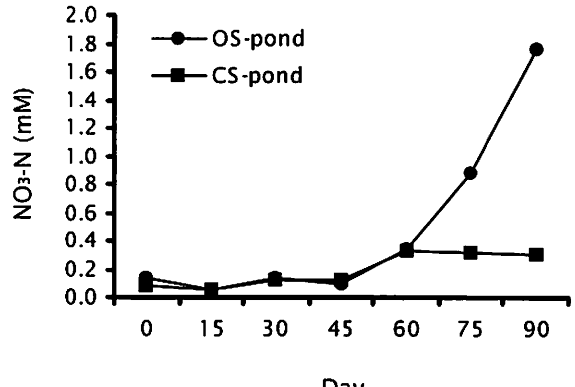

Figure 1. NO_3-N concentrations observed in opened (OS-pond) and semi-closed (CS-pond) shrimp culture system

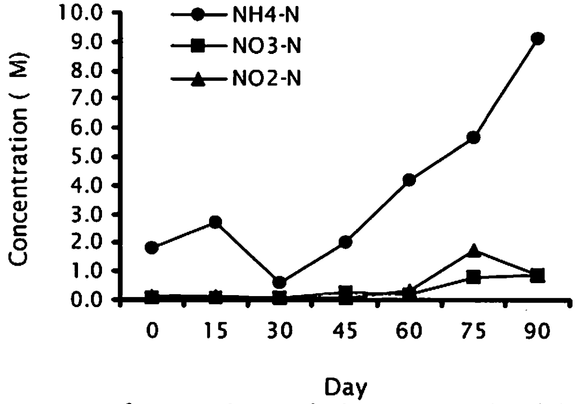

Figure 2. Concentrations of NH_4-N, NO_3-N, and NO_2-N in a semi-closed shrimp culture ponds

Feed, survived shrimps, and mangrove litters provided the subsequent increase of PO_4-P concentration in CS-pond. PO_4-P concentration in CS-pond reached the highest concentration, 0.31 µM, in the end of the experiment (Figure 4).

Based on the total nitrogen and phosphorous, N-P ratio in CS-pond was higher than in OS-pond in the first 30 days (Figure 5). The distinct elevation of NH_4-N resulted in a higher N-P ratio between days 30 and 60 but drop of NH_4-N concentration after day 60 lead to lower N-P ratio in OS-pond than that in CS-pond. N-P ratio according to Ahmad (1998) influences species diversity of plankton in pond water. Dinoflagellates usually dominate the plankton community in pond water with N-P ratio below 10 and at N-P ratio above 10 phytoplankton and diatoms are the most abundance. In the experiment, the lowest N-P ratio recorded was 5.6 observed at day 30 in both pond groups and the highest was obtained on day 60 in OS-pond. The higher increasing rate of PO_4-P than of NH_4-N obviously holds back the elevation of N-P ratio in CS-pond in the last 4 weeks of the experiment.

Species composition of plankton population in both pond groups was not very much different, even with plankton population reported in previous experiment (Ahmad & Mangampa, 2000), and diatoms tended to dominate. Plankton population was much more abundant in CS-pond (Table 1). Diatoms like *Nitszchia* sp. and *Chaetoceros* sp. and zooplankton such as *Acartia* sp. and *Brachionus* sp., dominating plankton population in CS-pond, are believed to be the part of main natural diets in aquaculture (Maeda, 1999). Diatoms and zooplanktons mostly dominated plankton population when N-P ratio in pond water was 20 and at N-P ratio above 20 there was no distinct species domination. *Oscillatoria* sp. domi-

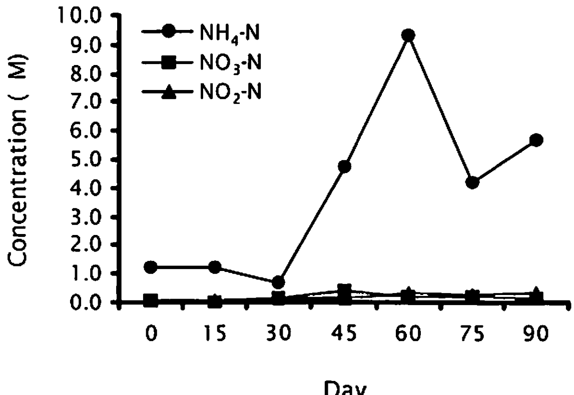

Figure 3. Concentrations of NH_4-N, NO_3-N, and NO_2-N in an open shrimp culture ponds

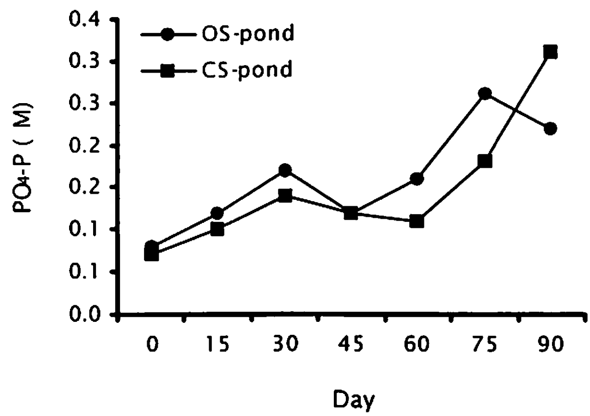

Figure 4. Concentrations of PO_4-P in opened (OS-pond) and semi-closed (CS-pond) shrimp culture system

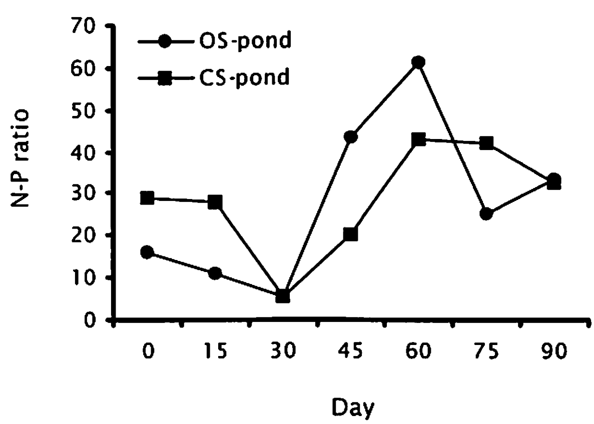

Figure 5. Calculated N-P ratio in opened (OS-pond) and semi-closed (CS-pond) shrimp culture system

Table 1. Plankton population developed in the opened and semi-closed shrimp culture systems

Culture system		Notes
Opened (CS-pond)	Semi-closed (CS-pond)	
Nitszchia spp.	*Nitszchia* spp.	The most abundant
Chaetceros spp.	*Chaetceros* spp.	More abundant in CS-pond
Pleurosigma spp.	*Pleurosigma* spp.	More abundant in CS-pond
Amphora spp.	*Amphora* spp.	More abundant in CS-pond
Acartia spp.	*Acartia* spp.	More abundant in CS-pond
Brachionus spp.	*Brachionus* spp.	More abundant in CS-pond
Oscillatoria spp.	*Oscillatoria* spp.	More abundant in CS-pond
Coscinodiscus spp.	*Coscinodiscus* spp.	Less than 500 cells/L
	Calotrix spp.	Less than 500 cells/L

nated plankton population when N-P ratio was under 10 with salinity ranged from 22 to 27 ppt. Zooplankton was abundant when N-P ratio slightly under 30, salinity around 20 ppt, and pH 7.3—7.6. Diatoms density seemed to affect population of bacteria, more specifically *Vibrio* spp., 15 days later and the survival rate of shrimp at harvest, mainly in CS-pond.

Plankton population in CS-pond, predominated by diatoms, was much denser than that in OS-pond at day 45, on the contrary on day 60 the population of *Vibrio* spp. was much denser in OS-pond (Figure 6). Population of bacteria, even at the densest level (3.87 CFU/mL), did not reach the level which enable opportunistic pathogen to convert into real pathogen (Madeali *et al.*, 1993; Atmomarsono *et al.*, 1995; Taufik *et al.*, 1996). Based on the fact that most of the dead shrimp showed white spots coloration, the mass mortality was not suspected by bacteria but rather by drastic changes of water quality and white spot syndrome virus disease-outbreak.

Water quality variables monitored everyday was not in the optimal range for shrimp except pH. Dissolved oxygen (DO), temperature, and salinity fluctuated and frequently reached unsuitable concentration for shrimp (Table 2). Combination of wide salinity fluctuation and unsuitable concentration of DO and temperature was believed to weaken the resistance of the shrimp toward diseases leading to mass mortality. DO below 3.0 mg/L even though would not completely kill shrimp but it would retard growth (Boyd, 1991).

Unsuitable water quality occurred in along period in the first weeks of the experiment. In fact, when the shrimp fry were being harvested from the nursery ponds and directly stocked into the grow-out ponds heavy rain fell all day for than a week and causing a drastic drop of dissolved oxygen, salinity, and temperature into unsuitable level for shrimp which leading to mass mortality. However, some of the shrimp survived (Table 3) until the experiment was terminated.

The average number of survived shrimp in CS-pond, 949, was more than a quarter fold of the survived shrimp in OS-pond, 215, so was the yield. Significantly higher yield in CS-pond was assumed not only due to the difference in survival rate but also the difference natural feed availability and diversity aside the insignificant different in average individual final weight. Heavy rain caused mass mortality to the shrimp but at the same times strengthened the evident of mangrove importance for shrimp culture as indicated by higher survival rate of the shrimp in CS-pond.

The CS-pond array was equipped with earthen reservoirs inhabited with mangroves (Table 4) as phytoremediators. The importance of mangrove for shrimp as a part of its daily diets has been reported by many researchers. Chong *et al.* (2000) gave a picture of mangrove detritus contributes 84% of the total assimilated carbon of healthy wild-caught shrimp. Azwar *et al.* (1999) reported that the survival rate of *P. monodon* juvenile fed blended *R. mucronata* leaves was significantly higher than of those

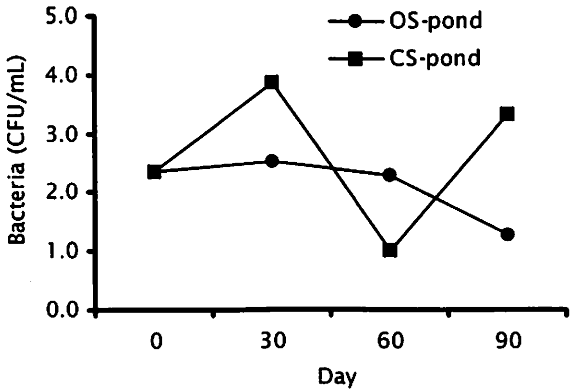

Figure 6. Population of bacteria developed in the opened (OS-pond) and semi-closed (CS-pond) pond water

Table 2. Range of dissolved oxygen, salinity, pH, and temperature in the open (OS-pond) and semi-close (CS-pond) pond water

Variable	Open (OS-pond)	Semi-close (CS-pond)
Dissolved oxygen (mg/L)	2.2–7.3	2.6–7.6
Salinity (ppt)	13.0–35.0	16.0–35.0
pH	7.2–8.3	7.0–8.0
Temperature (°C)	25.2–30.0	27.0–29.5

Table 3. The shrimp yield in the opened and semi-closed shrimp culture ponds

Variable	Opened (OS-pond)	Semi-closed (CS-pond)
Average yield (kg/pond)*	6.40 [a]	27.03 [b]
Average individual weight (g)*	29.72 [a]	28.47 [a]
Average survival rate (%)	0.57	2.53

* The values in the same row followed by similar superscript are not significantly different (P>0.05)

fed artificial diets.

Besides having importance function in shrimp diets, mangrove vegetations also have certain important role in shrimp culture environment improvement (Choo & Tanaka, 2000; Primavera, 2000). In addition, Harahap (1997) and Soediro (1997) reported that mangrove vegetations contain both bacterio-static and anti virus agents. Obviously, mangrove to some extent enhance living environment for shrimp by providing optimal water and soil quality, effective bacterio-static and anti virus agents, as well as abundant natural food. In other words, there is no doubt that mangrove vegetations do well to cultured shrimp. Mangrove destruction, therefore, would harm ecological balance in ponds leading to crop failure.

In addition, the environmental pressure from shrimp ponds has impact well beyond the boundaries of the immediate site itself. Therefore, a minimum area of productive ecosystem is required to sustain resource inputs and to

Table 4. Species of mangrove vegetations inhabited the reservoir in the semi-closed shrimp pond

Family	Species	Family	Species
Aviceniaceae	*Avicenia alba*	Pteridaceae	*Acrostichum aureum*
	A. lanata	Sterculiaceae	*Heritiera littolaris*
	A. marina	Rhizophoraceae	*Bruguiera cylindrica*
	A. officinalis		*B. gymnorhiza*
Combretaceae	*Lumnitzera littorea*		*B. parviflora*
	L. racemosa		*B. sexangula*
Euphorbiaceae	*Exoercaria agallocha*		*Ceriops decandra*
Lythraceae	*Phempis acidula*		*C. tagal*
Myrsinaceae	*Aecigeras corniculatum*		*Rhizophora apiculata*
	A. floridum		*R. lamarkii*
Myrtaceae	*Osbornia octodonta*		*R. .mucronata*

assimilate waste outputs from a shrimp culture operation, known as ecological footprint. (Hagler, 1997). In this experiment, the reservoir inhabited by mangrove is considered as a part of shrimp ponds ecological footprint which assimilates the waste output.

CONCLUSION

Semi-closed pond system provided with reservoir inhabited by mangrove promises a higher yield of shrimp and provides a better N-P ratio for plankton population growth and to some extent assimilates waste outputs more efficiently as well as more environmentally sound than opened pond system.

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