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PERFORMANCES OF TIGER SHRIMP CULTURE IN ENVIRONMENTALLY FRIENDLY PONDS

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ABSTRACT

Mangrove ecosystem plays an obvious role in maintaining the biological balance in the coastal environment where shrimp ponds are usually constructed. The removal of mangroves around shrimp ponds has frequently brought about harvest failure. The study evaluated the performance of tiger shrimp culture in ponds provided with water from a water body where there was mangrove vegetation (hereafter mangrove reservoir). Twelve ponds, each measuring 2,500 m^2, were filled with seawater from the mangrove reservoir until the water depth of 100 cm and then stocked with 20-40 PL/m^2. In the first six ponds, the bottom water was released into the reservoir when the water depth reached 140 cm and then the water depth was maintained at 100 cm. In the second six ponds, the water was released from the ponds until the water depth reached 60 cm and then refilled with reservoir water until a depth of 100 cm. Both treatment ponds received water from the reservoir which also received the wastewater. The feeds for the shrimps were broadcast into the ponds twice a day to meet the 3% shrimp biomass requirement, which adjusted every other week through sampling. The result showed that mangrove vegetation is capable of removing excessive nutrients, up to 70% for NO_3-N and NH_4^+-N, reducing $PO_4^=$-P fluctuation, and producing bioactive compounds. In the second treatment ponds, shrimp mortality started to occur in day 28 and most died by day 54 after stocking due to white spot disease outbreak. Mass mortality took place 54 days after stocking in two out of six of the first treatment ponds.

[*Keywords*: *Penaeus monodon*, fish culture, ponds, mangroves]

INTRODUCTION

Harvest failures in shrimp culture occur mostly in ponds that were originally mangrove forest. Poor water exchange and reduction of biodiversity due to the extinction of mangroves create unsuitable environment for the shrimps and finally lead to more frequent disease outbreaks which resulting in shrimp mortality. Mangroves have long been known to have many functions from preventing abrasion to maintaining the biological balance in coastal ecosystem (Hagler 1997). Disturbance in its function through conversion into shrimp ponds is suspected to create biological imbalance in the ponds and eventually stimulates rapid development of pathogens.

Previous study showed that bacterial, mostly *Vibrio* spp., population levels and the concentration of total organic matters in the 20% and 30% water exchange rate ponds provided with mangrove reservoir exceeded shrimp tolerance thresholds and caused mass mortalities (Ahmad and Mangampa 2002). Soediro (1997), Verhagen (2000), and Ahmad *et al.* (2001) reported that the capability of mangroves in absorbing nutrients and producing antibacterial agents may reduce the negative impacts of shrimp culture practices, and should, therefore, be conserved rather than converted into culture ponds.

Ahmad (1988), Boyd *et al.* (1998), and Boyd (1999) claimed that mangrove forest is not a good site for shrimp pond 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 used to be mangrove forest and presently facing the problems of harvest failure mostly due to disease outbreak. According to Boyd *et al.* (1998), the negative environmental impacts of aquaculture can be alleviated through good design and construction of ponds, as well as good management practices which consider the larger environment. Therefore, shrimp ponds can only be built in the sites behind mangrove forest in which the slope and soil maturity are suitable and the mangroves will protect the ponds from abrasion and, according to Chong *et al.* (2000), provide the shrimp with natural food.

The present experiment aims at a better management practice application of shrimp culture in a semi-closed system provided with mangrove reservoir. Expectedly, the practice would solve the problems of cultured shrimp harvest failure and protect the mangrove ecosystem as well.

MATERIALS AND METHODS

The experiment was carried out in an area of shrimp ponds of which a part of the area was reconverted into mangrove forest and used as water reservoir for the ponds. Inlet and outlet canals (Poernomo 1988; Boyd *et al.* 1998) were constructed in between the ponds and the reservoir to develop a semi-closed system (App. 1). The total area of the reservoir was about 5 ha including the canals.

The shrimp ponds were twelve, 2,500 m^2 each, and randomly separated to facilitate the application of two water exchange techniques to simulate the tide pattern (low and high water level) in the area. Each pond was filled with seawater flowed from the reservoir to set up 100 cm average water depth.

In the first six ponds, water exchange was carried out by releasing the bottom water into outlet canal, after the water depth in the pond elevated up to 140 cm by pumping the water from reservoir, until the 100 cm water depth achieved, hereinafter referred as the first ponds. On the contrary, water exchange in the rest of the six ponds was conducted by releasing the bottom water into outlet canal until the water depth in the ponds reaching 60 cm and then the water from reservoir was pumped into the ponds to sustain 100 cm water depth, hereinafter referred as the second ponds. The water exchange in all ponds was conducted every 3 days.

Each pond was stocked with 20 shrimp fry of PL-40/m^2 after plankton densely grew. A week after stocking, artificial pelleted feed was given twice a day as much as 15% of total biomass, and one month after stocking, the feed ratio was reduced to 3% of total biomass. Shrimp weight and water quality were measured at pretermined time (forthnightly).

Shrimp mortality was observed every day by observing the number of dead or sick shrimps on the dykes. The survived shrimps were harvested at 90 days after stocking.

The capability of the predominating mangrove (*Rhizophora mucronata*) in removing excessive nutrients and in producing bioactive compounds mainly bactericides was observed in a separate fiberglass tank. The nutrient concentrations and water quality variables monitored every other week were nitrate and phosphate both in control and fertilized (1 mM NH_4 + 100 μM PO_4) tanks. Total bacteria number was estimated from colony count on thiosulphate citrate sucrose agar (TCBSA).

RESULTS AND DISCUSSION

The shrimps in both types of ponds grew at different rate, where in the first 2 weeks, the shrimps in the second ponds grew faster than those in the first ponds (Fig. 1). However, the fast growing shrimps died sooner than the rest of the shrimps (App. 2), because the shrimps seem to be more susceptible to white spot disease. Based on the diagnosis in the field and in the laboratory, white spot baculo virus (WSBV) or septicemia monodon baculo virus (SEMBV) was the main cause of mass mortality of the shrimps starting 28 days after stocking. Virus, including WSBV, attacks the cell of the host and causing the cell to swell. Consequently, in the first 2 weeks, the infected shrimps grew faster than the healthy one (Atmomarsono pers. comm.). The shrimps which grew faster or showed no indication of growing were most probably the carrier of WSBV and survived in a relatively short period (less than 2 weeks). In the second ponds, the reduction of water level down to 60 cm seems to harm the shrimp, most probably due to changes in dissolved oxygen, temperature, and NH_4^+-N concentration which made the shrimps more susceptible to diseases (Chuah *et al.* 2000).

The total shrimp biomass yield was very low due to high mortality caused by white spot disease outbreak. Regardless the very high mortality, the shrimps in three out of the first six ponds survived until the end of the experiment and achieved marketable size. The main cause of harvest failure was the difficulties in obtaining disease-free fry and sufficient fresh sea water supply. Insufficient fresh

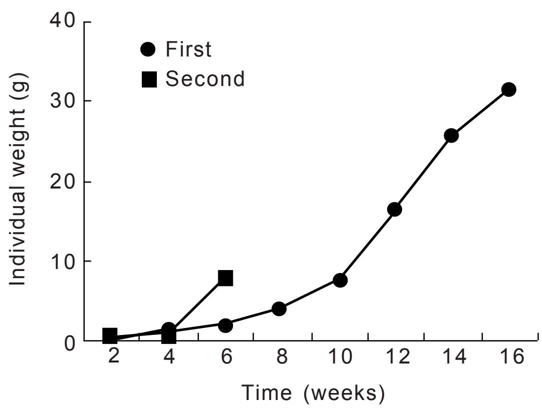

Fig. 1. The growth of shrimps reared in ponds with maximum water depth of 100 cm (second ponds) and 140 cm (first ponds).

sea water supply and high temperature, 27-34^{o}C, and intense evaporation resulted obvious increase of salinity, from 34 ppt in the beginning to 48 ppt in the end of the experiment. The increase of salinity strengthened the effect of NH_4^+-N concentration on shrimps that were susceptible to WSBV.

The concentration of NH_4^+-N kept increasing in the range of tolerable concentration for shrimps (Fig. 2). Deionization of NH_4^+-N is affected by temperature and pH resulting in deionise ammonia (NH_3) which is toxic to shrimps. Boyd (1991) reported that total ammonia nitrogen of 1.93, 0.89, and 0.56 mg l^{-1} at pH 8.5, 9.0, and 9.5, respectively, produces 0.40 mg NH_3-N l^{-1} . Mass mortality of the shrimps occurs at NH_3-N concentration of 1.29 mg l^{-1} and concentration of 0.45 mg l^{-1} retards the shrimp growth by 50% (Poernomo 1986).

NH_4^+-N seems to be built up more intensively in the second ponds than in either the first ponds or reservoir. Poernomo (1986) reported that the main contributor of NH_4^+-N accretion in shrimp ponds is feed. However, the concentration of NH_4^+-N kept increasing even though no more feed added after the mass mortality occurring 2 weeks after stocking. Most probably, the organic matters from reservoir, mainly mangrove litter, decomposed in the ponds and produced N compounds. In the first ponds and reservoir, NH_4^+-N concentrations were fluctuating in lower concentrations. The shrimps growing in the ponds seem to play obvious role in maintaining the ecological balance in the ponds which keep the lower concentration of NH_4^+-N in the first ponds than in the second ponds (Fig. 2).

Different pattern of NH_4^+-N fluctuation was observed in the tanks planted with *R. mucronata* (Fig. 3). The wider fluctuation of NH_4^+-N concentrations in

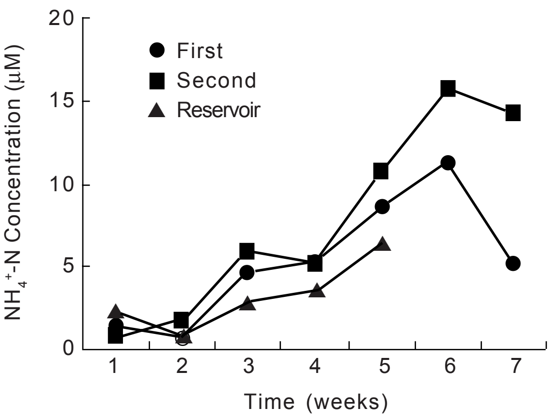

Fig. 2. The average concentration of NH_4^+-N observed in shrimp ponds with maximum water depth of 100 cm (second ponds) and 140 cm (first ponds).

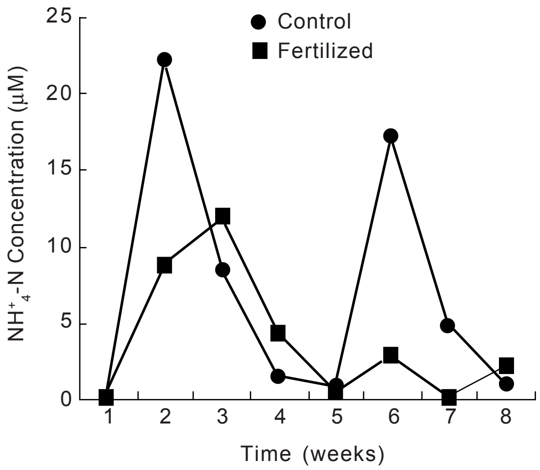

Fig. 3. The concentration of NH_4^+-N in tank containing *Rhizophora mucronata*.

control tanks showed that *R. mucronata* is both NH_4^+-N absorber and producer.

Based on the highest water pH and temperature in the ponds, the highest concentration of NH_3-N was observed in the first treatment ponds. In the third week after stocking, the concentration of NH_4^+-N achieved 6 µM which at pH 8.0 produced 0.018 mg NH_3-N l^{-1} which is much below the range of LC 24-72 hours for shrimps (Boyd 1991). Comparable condition was observed in the first treatment ponds starting the fifth week after stocking. The concentration of NH_3-N is suspected not to harm but to lessen the resistance of the shrimp towards vibriosis and WSBV. White spot syndrome virus and luminescent bacteria or vibrio are commonly suspected to be the main cause of cultured shrimp mass mortality (Madeali *et al.* 1993; Wythyachumnarnkul *et al.* 1998; Chuah *et al.* 2000).

Mangrove vegetation growing in the reservoir appears to be capable of removing some of the nutrients from the water (Fig. 4). However, the capability is distinctively affected by contact time (Hallide 1998). In this experiment, the water released from the ponds was held for 3 days in reservoir for excessive nutrients and turbidity reduction as shown in tank containing *R. mucronata*. The concentration of NH_4^+-N which was always lower in reservoir and in the fertilized tank indicated that mangroves are capable to remove the nutrient from the surrounding water. Boyd (1999) reported that mangroves have many functions, among other is to remove excessive organic matters indirectly from water. Ahmad *et al.* (2001) found that to some extent mangroves are able to remove excessive nutrients and retard the growth of pathogen population.

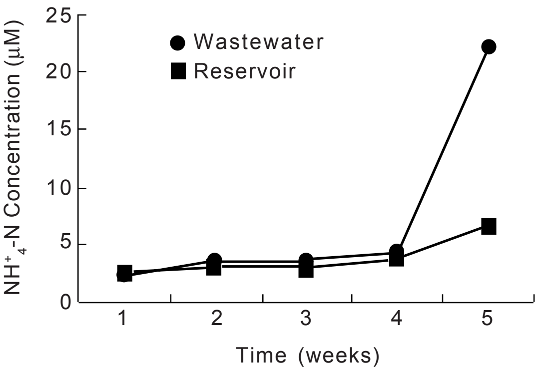

Fig. 4. The concentration of NH_4^+-N in shrimp pond wastewater and in the waste held for 3 days in reservoir planted with mangrove trees.

Choo and Tanaka (2000) showed that NH_4^+-N concentration in shrimp wastewater ponds during harvest is high. Mangrove vegetation planted in the reservoir seems to absorb some of the waste as shown in Fig. 4. The concentration of NH_4^+-N in the water released from shrimp ponds at every water exchange is high, from 2.3 to 22.3 µM or from 0.04 to 0.40 mg l^{-1}. However in 3 days held in the reservoir, the concentration reduced up to 70%.

Mangroves also have capability to remove NO_3-N from pond wastewater (Fig. 5). The concentration of NO_3-N in wastewater fluctuated follows its concentration in the pond water, ranged from 0.45 to 13.90 µM, but the fluctuation did not apparently affect the NO_3-N concentration in the reservoir. In the first 2 weeks after stocking, the shrimps were regularly fed and consequently the concentration of NO_3-N increased. As most of the shrimp in the first ponds died in the second week, no feed was added into the ponds and it obviously reduced the concentration of NO_3-N in the wastewater. The feed intensively added into the second ponds, started in the second week, allows the remaining shrimps to survive and led to the rise of NO_3-N concentration in the fourth week. Poernomo (1992) and Green *et al.* (1997) reported that unconsumed feeds contribute nutrients to pond water.

In the case of $PO_4^{=}$-P, both the ponds and reservoir seem to have a certain role in P assimilation and as a result there was no distinct fluctuation of $PO_4^{=}$-P concentration (Fig. 6 and 7). The capability of mangrove vegetation to absorb $PO_4^{=}$-P is distinctively indicated in the 6-9th week after fertilization in the tank. Based on this findings, a semi-closed shrimp culture system provided with mangrove

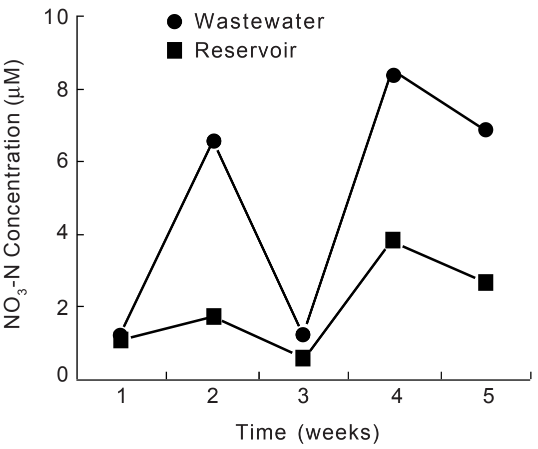

Fig. 5. The concentration of NO_3-N in shrimp pond wastewater and in reservoir planted with mangrove trees.

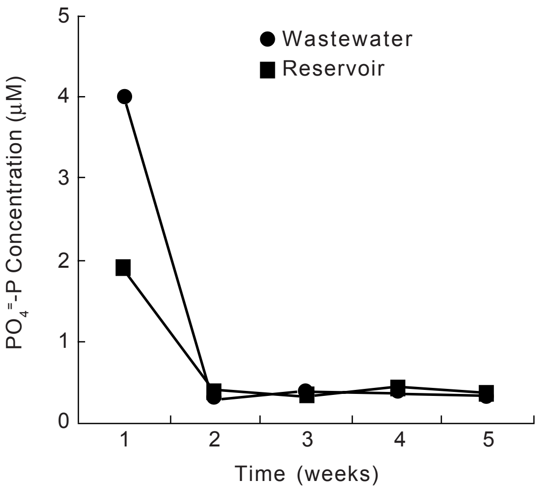

Fig. 6. The concentration of $PO_4^{=}$-P in shrimp pond wastewater and in reservoir planted with mangrove trees.

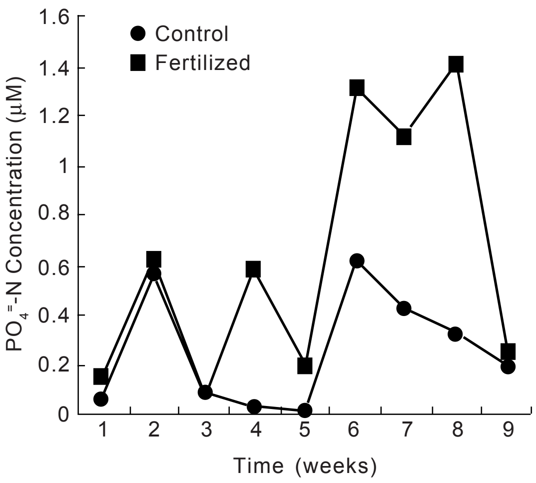

Fig. 7. The concentration of $PO_4^{=}$-P in the supported experiment.

planted reservoir appears to be not polluting the environment with P. Further, the increase of N compound would change the ratio between N and P in the water which encourages the growth of phytoplankton and diatom population. Both phytoplankton and diatoms are natural food for young shrimps (Boyd 1999; Chong *et al*. 2000) and capable of suppressing the development of *Vibrio* (Taufik *et al.* 1996).

Plankton population in the supported experiment, which was not observable, and higher $PO_4^{=}$-P concentration in fertilized tanks than in control tanks indicated that *R. mucronata* alone is not a good P remover. Boyd (1999) suggested to release the wastewater from shrimp ponds directly into mangroves to reduce the possibility of polluting the environment. Further, Richardson and Qian (1999) found that P loading into environment below P assimilating capacity (PAC) will not result in significant changes in ecosystem structure. As well, organic matters produced in mangrove area would enrich the water which in turn stimulates the growth of natural food population.

Mangroves also produce many kinds of bioactive compounds which can be used for bactericides (Soediro 1997). Suryati *et al*. (2001) found that *Excoecaria agallocha* (associate mangrove) contains bactericide which is effective for *Vibrio mimicus* and *V. costicola* and suspected to be peptide compound. The total bacteria in all ponds never exceed the harmful threshold, 10^3 CFU ml^{-1} (Atmomarsono *et al*. 1995), most probably due to the bactericide compounds produced by mangroves which released to the environment through decomposing litter. Low population of total bacteria in mangrove shrimp ponds was also reported by Ahmad *et al.* (2001). Apparently, mass shrimp mortality occurred in almost all ponds was not caused by bacterial disease, but most probably by viral diseases (WSBV). So far, there is no study reporting that mangroves also produce antivirus substance.

Among the mangroves grew in the reservoir, eight species contain bioactive compounds (Table 1) which effectively retard the growth of bacteria. Harahap (1997) and Soediro (1997) also reported that mangroves are source of bioactive compounds which can be used as bactericides. Further, according to Azwar *et al.* (1999) and Chong *et al.* (2000), mangroves are source of nutrition for prawn juvenile. The conversion of mangroves into shrimp ponds would then automatically reduce the availability of nutrients, including the bactericides, for the shrimps.

Bacteria, mainly *Vibrio* spp., population which was always lower in reservoir than in pond water (Fig. 8) was obvious evidence that mangrove vegetation would control pathogen population in the mangrove ecosystem especially in the water. In bottom soil, however, bacteria population which was always higher than that in the water (Fig. 9) is suspected to harm the bottom dwellers, especially shrimps. In fact, all the bacteria listed in Table 1 are the opportunistic pathogens for cultured shrimps, except *V. harveyi* which is the real pathogen. The stressed shrimps are more susceptible to viral diseases (Atmomarsono *et al.* 1995) which commonly followed by mass mortality.

The reduction of bacteria population in either shrimp pond or reservoir bottom soil did not minimize the stress towards the shrimps because it occurs above 10^3 CFU ml^{-1}. Mass mortality of shrimps is commonly observed at bacteria population of 10^4 CFU ml^{-1} (Madeali *et al.* 1993).

The use of specific pathogen free (SPF) or specific pathogen resistant (SPR) fry, which have been produced since late 1990s (Kamiso 1996), has been suggested to avoid harvest failure (Soleh and Kontara 2002). The use of $CaOCl_2$ to control pathogen and its carriers in the ponds and formaldehyde to screen the shrimp post-larvae have been introduced (Soleh and Kontara 2002).

The use of SPR or SPF fry followed by chemical application has been proven to be effective in shrimp

Table 1. The bioactive of mangrove vegetation.

Mangrove species	Bioactive	Target species
Avicenia alba	Cyclohexasiloxane	*Vibrio leiognathy*
Acanthus ilicifolius	2–methyl piperazine	*V. costicola, V. mimicus*
Carbera manghas	Furanon gamma-crotonolactone	*V. splendidus, V. methchicovi*
Clerodendron inerme	Unidentified	*V. leiognathy*
Euphatorium inulifolium	n-decane/isodecane	*V. splendidus, V. methchicovi*
Exoecaria agallocha	Cyclohexasiloxane	*V. splendidus V. mimicus*
Osbornia octodonta	2 heptamine-6 methyl-amino-6	*V. harveyi, V. leiognathy*
Soneratia caseolaris	L-galactopyranocide	*V. harveyi, V. leiognathy*

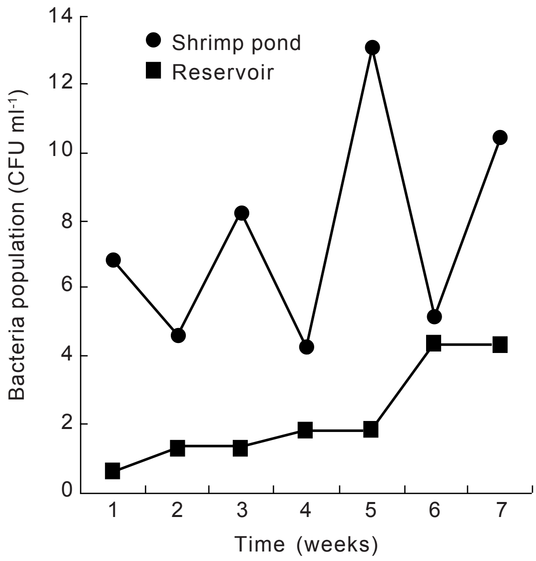

Fig. 8. Bacteria population (10^2), mostly *Vibrio* spp., in reservoir and shrimp pond water.

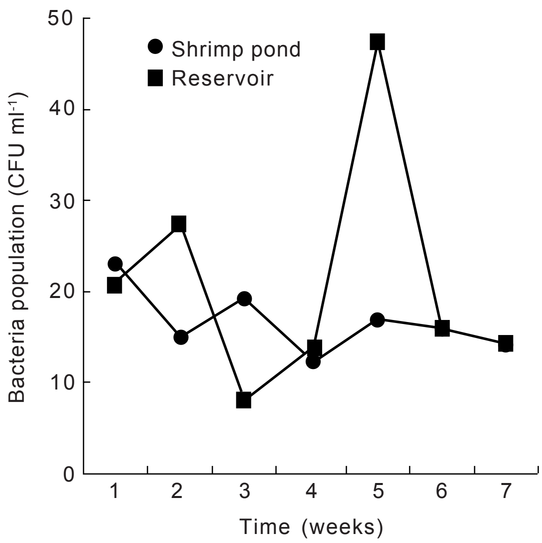

Fig. 9. Bacteria population (10^3), mostly *Vibrio* spp., in shrimp pond and reservoir bottom soil.

culture, however, it is too costly for most farmers. The combination of using mangrove reservoir and screened SPF or SPR fry is expected to reduce the cost and the risk of chemical application. Unfortunately, either SPF or SPR fry was not available when the experiment was carried out and to be consistent with the methods, chemicals were not applied in this experiment, consequently the mass mortality occurred. Chemicals are not believed as a safe long term problem solving in shrimp culture as stated by Boyd (1999).

CONCLUSION

Shrimp culture performs better when water exchange practice simulating high tide than low tide pattern. Mangroves, to some extent, are able to absorb N and P compounds from shrimp culture waste, therefore reduce the possibility of shrimp culture polluting the environment. However, mangrove reservoir alone is not so effective for shrimp culture to perform at its best. Hopefully, the combination of using mangrove reservoir along with screened SPF or SPR fry would elevate the chance of having shrimp harvest success without distressing the environment. In the other words, the use of mangroves and SPF or SPR fry gives the impression to be promising for sustainable, productive, and environmentally friendly shrimp culture development, which in turn would reduce mangrove conversion into shrimp ponds.

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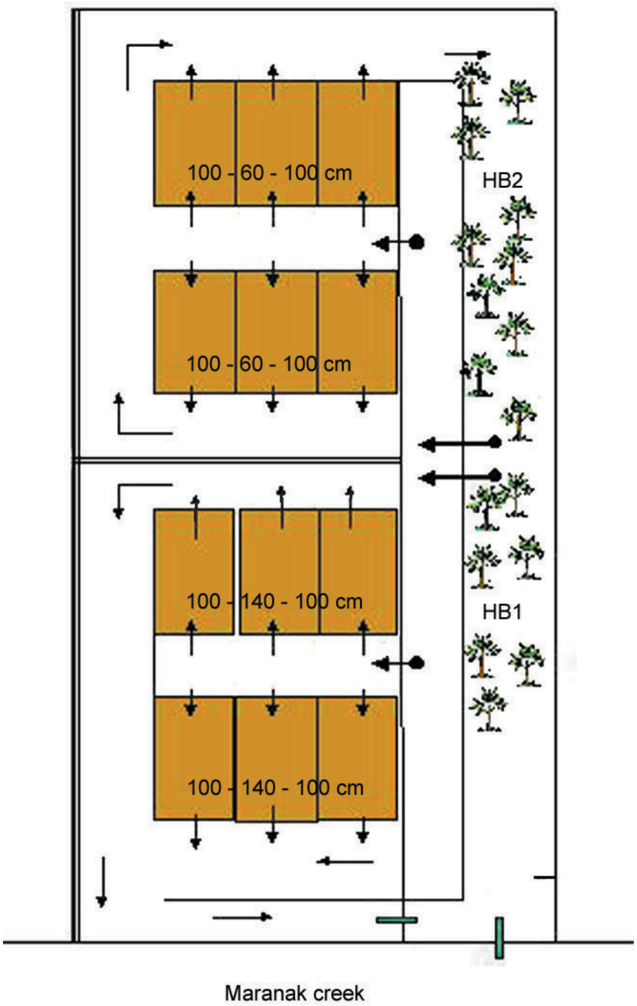

Appendix 1. Lay out of the experimental ponds.

Appendix 2. Individual weight (g) of tiger shrimps raised in the ponds with different water exchange techniques.

Water depth (cm)	Replication	Sampling							
		Initial	I	II	III	IV	V	VI	VII
100 to 140 to 100 water exchange every 3 days	1	0.3	0.82	2.59	3.50	8.09	15.30	(-)	(-)
	2	0.3	1.07	1.99	3.75	7.87	16.89	24.90	30.00
	3	0.3	1.73	(-)	(-)	(-)	(-)	(-)	(-)
	4	0.3	1.91	2.99	5.42	7.62	20.28	25.60	31.20
	5	0.3	1.22	7.80	(-)	(-)	(-)	(-)	(-)
	6	0.3	1.59	3.01	3.93	7.44	18.30	26.50	32.45
100 to 60 to 100 water exchange every 3 days	1	0.3	0.95	(-)	(-)	(-)	(-)	(-)	(-)
	2	0.3	1.02	(-)	(-)	(-)	(-)	(-)	(-)
	3	0.3	0.82	5.73	(-)	(-)	(-)	(-)	(-)
	4	0.3	0.28	(-)	(-)	(-)	(-)	(-)	(-)
	5	0.3	1.07	7.75	(-)	(-)	(-)	(-)	(-)
	6	0.3	0.47	9.90	(-)	(-)	(-)	(-)	(-)

(-) = mass mortality