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Modified Mangrove Pens for Polyculture System in Mud Crab *(Scylla serrata)* and Milkfish *(Chanos chanos)* Production

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ABSTRACT

The mangrove pens were modified to produce mud crab *(Scylla serrata)* and milkfish *(Chanos chanos)* in a polyculture system. The modification of mangrove pens was done by adding excavations inside the pen. The water quality parameters (dissolved oxygen (DO), pH, salinity, and temperature) were monitored, and the recovery and production rates in each pen were evaluated. The experiment was conducted for a rearing period of 143 days in nine mangrove pens, each having an area of 32 m^2 and an average net enclosure height of 3 m from the soil surface. The three different pens constructed (existing design: canal only, 43% excavation by area, and 54% excavation by area) were designated as T_1, T_2, and T_3, respectively. The water quality parameters recorded in the pens were favorable for the growth and recovery of the mud crab and milkfish, except for DO. For mud crab, the highest mean recovery was recorded in T_2, followed by T3, and the lowest in T_1. The production rate followed the same pattern as the recovery, with T_2 having the highest, followed by T_3, and T_1 having the lowest. The statistical analysis revealed that the variations in mud crab recovery were not significant, while in terms of production rate, modified mangrove pens were found to be more effective than the existing design. Due to the total mortality of the cultured milkfish, the current set-up of modified mangrove pens was found to be unsuitable for the polyculture system of milkfish and mud crab production.

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RESUMO

Os currais de mangue foram modificados para produzir caranguejo-da-lama (Scylla serrata) e peixe-leite (Chanos chanos) em sistema de policultivo. A modificação dos currais de mangue foi feita adicionando escavações dentro do curral. Os parâmetros de qualidade da água (oxigênio dissolvido (OD), pH, salinidade e temperatura) foram monitorados e avaliadas as taxas de recuperação e produção em cada curral. O experimento foi conduzido durante um período de criação de 143 dias em nove currais de mangue, cada um com área de 32 m2 e altura líquida média do recinto de 3 m da superfície do solo. Os três diferentes currais construídos (projeto existente: apenas canal, 43% de escavação por área e 54% de escavação por área) foram designados como T1, T2 e T3, respectivamente. Os parâmetros de qualidade da água registrados nos currais foram favoráveis ao crescimento e recuperação do caranguejo-da-lama e do peixe leiteiro, com exceção do DO. Para o caranguejo-da-lama, a maior recuperação média foi registrada no T2, seguida do T3, e a menor no T1. A taxa de produção seguiu o mesmo padrão da recuperação, sendo T2 a mais elevada, seguida de T3 e T1 a mais baixa. A análise estatística revelou que as variações na recuperação do caranguejo da lama não foram significativas, enquanto em termos de taxa de produção, os currais de mangais modificados foram considerados mais eficazes do que o projecto existente. Devido à mortalidade total do peixe leiteiro cultivado, a actual configuração de currais de mangais modificados foi considerada inadequada para o sistema de policultura de produção de peixe leiteiro e caranguejo da lama.

Palavras-chave:
Aquasilvicultura, oxigênio dissolvido, manguezais, recuperação

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Introduction

Mangrove forests are among the most productive ecosystems, providing an array of significant uses. It performs various economic and ecological functions such as habitat for different fish species and birds. Aside from the many forest products that they provide and the vast biodiversity that thrives in them, mangroves serve as a vital nursery and breeding ground for a host of crustaceans, mollusks, fishes, and other organisms, and as a “carbon sink”. Mangroves also protect the shoreline from erosion and damage due to wave action (Guerrero, 2006).

Mangroves are found in some 120 countries covering 14-15 million hectares, of which a third is in Southeast Asia (Giri et al., 2010; Spalding et al., 2010). Mangrove declines worldwide from 18 million hectares in the early to mid-1990s and shows a steep downward slope within the last few decades (Spalding et al., 1997). Estimated to cover 400,000-500,000 hectares at the turn of the century, Philippine mangroves have decreased by more than half to 240,800 hectares as of 2010 (Long et al., 2013) due to overexploitation by coastal dwellers, and conversion to agriculture, salt ponds, industry, and settlements. Among these factors, aquaculture remains the major cause of mangrove deforestation, as mangroves declined at the rate of 5,000 hectares per year in the 1950s through the 1970s when the government promoted a pro-aquaculture policy (Long et al., 2013; Primavera, 1995).

To mitigate and reduce the conflicts associated with coastal aquaculture development and its implication on mangrove disappearances, as well as to find out the most suitable and sustainable model for the harmonized integration, a form of mangrove aquaculture integration was introduced. The Aquaculture Department, Southeast Asian Fisheries Development Center (AQD-SEAFDEC), has implemented the Mangrove-Friendly Aquaculture (MFA) Program which integrates the rearing of aquatic organisms and maintenance of healthy mangrove trees. One of the applications of MFA is in silvofisheries or aquasilviculture where the low-density culture of crabs, shrimps, and fishes are integrated with mangroves (Primavera, 2000).

Among MFA systems, mangrove pens for monoculture of mud crab can be considered as the most environment-friendly and financially feasible because it only requires net enclosures with minimal impacts on mangrove hydrodynamics and vegetation (Primavera, 2000). Mud crab is a suitable species for this system because it can survive even during low tide when the pen was drained.

In ponds and pens where mud crabs are commonly grown, the possibility of increasing fish yield per unit area through polyculture is considerable when compared with the monoculture system of fish or crabs. In this polyculture system, culturing more than one type of aquatic organism in the same pond or pen can be done. Hence, this culturing practice could be helpful to make mangrove pens more productive.

It is almost two decades since mangrove pen technology was first introduced in the Philippines. With the abovementioned advantages of this farming technique, it is still noticeable that the technology is not yet very much accepted by the local farmers. One of the reasons for this is the low productivity of the pen system under monoculture of mud crab which has low optimum stocking density. A mangrove pen in monoculture of mud crab has a production of 70 g/m^2 (Primavera et al., 2009) while ponds in polyculture have a production of 75 g/m^2 of mud crab and 50 g/m^2 of milkfish (Yap et al., 2007).

In earthen brackish water ponds, mud crabs are commonly cultured with fish even if they are cannibalistic. Cannibalism in crabs is reduced by lowering the stocking density and maximizing the space by stocking fish like milkfish and tilapia. However, this culturing system does not apply to the existing mangrove pen design because, during the lowest tide, there is no enough ponded water within the pen that could support the survival of fish until the tide returns.

Hence, there is a necessity to enhance the current set-up of the mangrove pen to make it more productive. This study was conducted to modify the existing design of the mangrove pen to make it suitable for the polyculture system of mud crab and milkfish production.

Methodology

Construction of the Mangrove Pens

The study was conducted at Nanipsan, Mandaon, Masbate, Philippines (12°11'47.82" N, 123°18'1.05" E). The study site had a total area of approximately 1,577.8 m^2 where nine mangrove pens were installed. There were three types of mangrove pens used which also served as treatments: existing design of mangrove pen (control – T_1); modified mangrove pen with 43% excavation (T_2); and modified mangrove pen with 54% excavation (T_3).

The mangrove pens were constructed following the design of existing mangrove pens, fish pens, cages, and ponds (Shelley & Lovatelli 2011; FAO, 1983). It was rectangular with a dimension of four (4) meter by eight (8) meter that mainly composed of the canal, fence, excavation, and nursery. All pens had a canal, one meter width by 0.5-meter depth, and additional 1.2-meter depth excavations for the modified mangrove pens. The pen area was enclosed by polyethylene netting (0.02 m mesh) set on bamboo poles with 1.6 meter spacing, entrenched 0.5 meter in the mud. The effective height of the pen was 1 m higher than the highest tide in the site. Nursery pens were also installed at the center of the excavated portion of the modified mangrove pens.

Stocking and Rearing

Before stocking crablets, the mud crab pens were cleared from potential predators, large crabs, and any unwanted species. Baited traps or "bintol" were used to remove all mud crabs from pens before stocking. Once a good number of baited traps had been set for several days in a pen and no crabs were trapped, it was considered free of big mud crabs and ready for stocking.

The same clearing process was done before stocking milkfish fingerlings to the nursery and grow-out pens. Large fish and any unwanted fish species were removed with the use of small mesh fishnets.

The two different culturing practices in mud crab and fish production, monoculture, and polyculture, were adopted in the study. Mud crabs were grown in monoculture to the existing design of the mangrove pen. Mud crabs and milkfish were cultured under a polyculture system in the modified mangrove pens. For T_1, each pen was stocked with 31 pieces of crablets, while T_2 and T_3 had a stock of 31 crablets and 130 pieces of milkfish fingerlings. All the stocks used were acquired from the nearest provider in the study site.

Stocking of milkfish was done upon the arrival of the fingerlings. It was acclimatized at site temperature upon arrival by allowing the plastic container of fingerlings to float inside the nursery pen for 20-30 minutes. Plastic bags containing the fingerlings were opened and poured with water from the pen little by little to let them acclimatize to the water's salinity and pH. Fingerlings were counted and released to the water by scooping from the bag using a food bowl. Fish were supposed to be released to the grow-out pen after 45 days and the nursery pen was removed and cleaned.

For mud crab, its stocking was done also upon the arrival of the crablets. They were counted, divided, and placed in different containers and randomly assigned to each experimental unit. Acclimatization was done by pouring seawater over the crablets before finally releasing them into the pen. Dead stocks within 24 hours after stocking were replaced with live ones.

A conventional way of feeding in fishponds and pens was adopted in this study. Mud crabs were fed with fish biomass or corn, depending on its availability. Feeding of mud crabs was undertaken just before, or during an incoming tide as when crabs emerge from their burrows in the mud to eat. On the other hand, the milkfish was fed with pellets at feeding rate and feeding time according to [Bureau of Fisheries and Aquatic Resources (BFAR), 2007].

Monitoring the Water Quality Parameters

The temperature, salinity, pH, and dissolved oxygen (DO) of ponded water in pens during low tide were monitored using handheld and portable instruments (Horiba LAQUAtwin Compact Meters and Horiba Handheld DO Meter). Data gathering was done during low tide that lasted for 10 hours or above (long duration low tide). Four data collections were done for every data gathering. The first data were collected before the falling of sea level to the edge of the excavation. It served as the initial water quality. The second data were obtained one hour after the level of water fell below the edge of the excavation and the third was before sea level rouse back to the pens. For the second and third data, the water samples were from the excavations or canals to determine the initial and final values of the water quality parameters during low tide when fish stay only in the excavation. The fourth data were collected from the incoming tide to determine and compare the water quality in the excavation and the incoming water.

Harvesting

Total harvesting of mud crabs was carried out, 143 days after stocking. It was done during low tide when the water left in the pens are those in the excavations and canals only. Water was drained totally with the use of a mechanical pump. Crabs in each pen were collected by manual picking. The production rate (*P*) of each mangrove pen was computed using (1):

$$P=TWM/A \tag{1}$$

where *TWM* is the total weight of mud crabs harvested in g, and *A* is the area of each pen in m^2.

Equation (2) was used to determine the recovery, *R*, in each mangrove pen. It is the percentage of the mud crabs collected, *MC*, during harvesting to the total number of stocks, *S*.

$$R=(MC/S)100 \tag{2}$$

Statistical Analysis

Analysis of Variance (ANOVA) for single factor Randomized Complete Block Design (RCBD) was used to compare the production rate and recovery obtained in each treatment. The variances of average initial weights of stocks were also compared to prove that its difference was not significant or the stocks used in different pens were almost the same in size. The computations were done with the aid of Statistical Tool for Agricultural Research (STAR) Version 2.0.1.

RESULTS

Description of the Modified Mangrove Pens

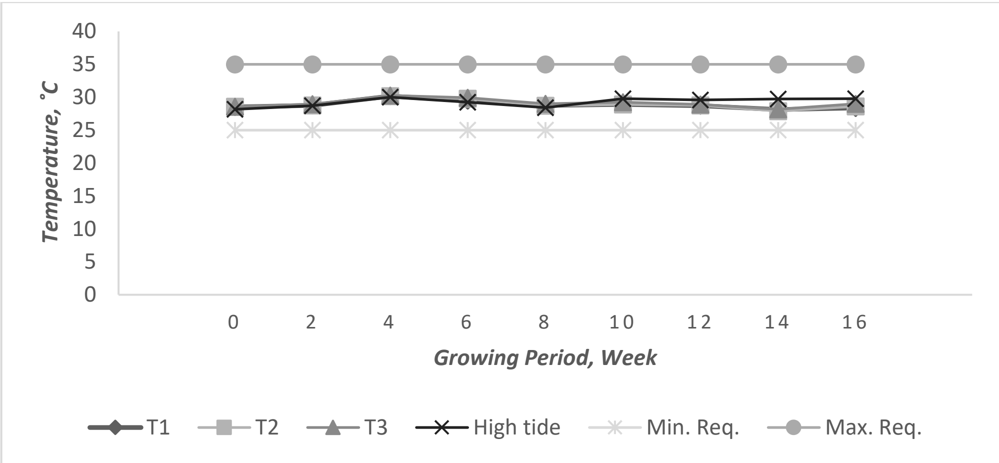
The modifications made in mangrove pens increased the ponded water inside the pen where the mud crabs and milkfish stayed during low tide. Initially, the existing mangrove pen (T_1) could only hold 3.23 m^3 of water during low tide. However, through the excavations made in the modified mangrove pens, the ponded water increased to 9.77 m^3 and 12.13 m^3 using T_2 and T_3, respectively. But, due to soil erosion, the volume of water contained by the pens during low tide decreased. Four months after construction, ponded water decreased to 2.37 m^3, 8.20 m^3, and 9.87 m^3 in T_1, T_2, and T_3, respectively.

Water Quality Parameters

Throughout the experimental period, the water temperature in three treatments was conducive to the growth of the mud crab and milkfish for it only varied between 28.04ºC and 30.35ºC. Minor difference of water temperature in each treatment were observed as shown in figure1.

Figure1.

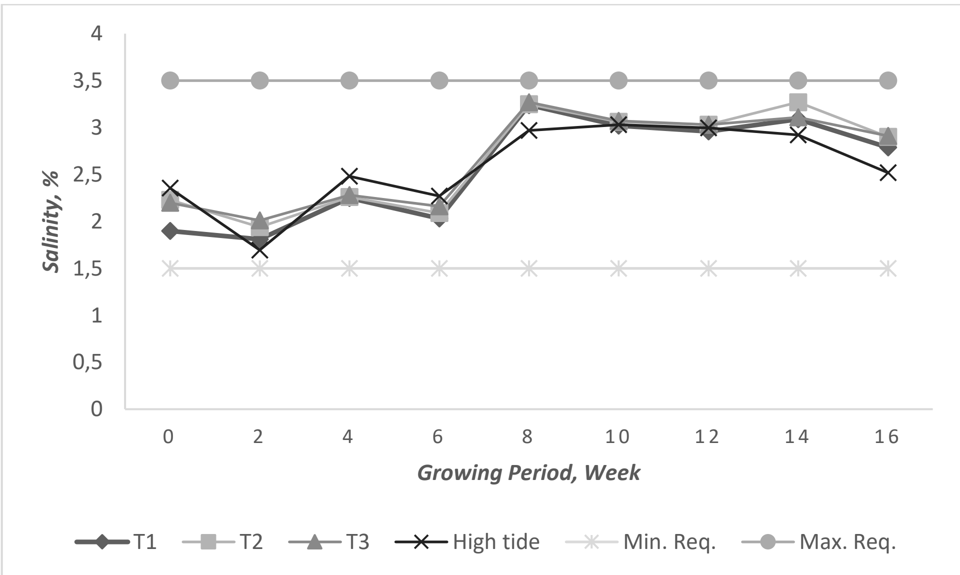
Average water temperature in the experimental area



For 16 weeks of data gathering, the water salinity varied between 1.84% and 3.45% as shown in figure 2. An increasing trend of salinity was also observed in the later part growing period. But the values obtained in each treatment are still in the recommended water salinity level for optimum growth of mud crab and milkfish.

Figure 2.

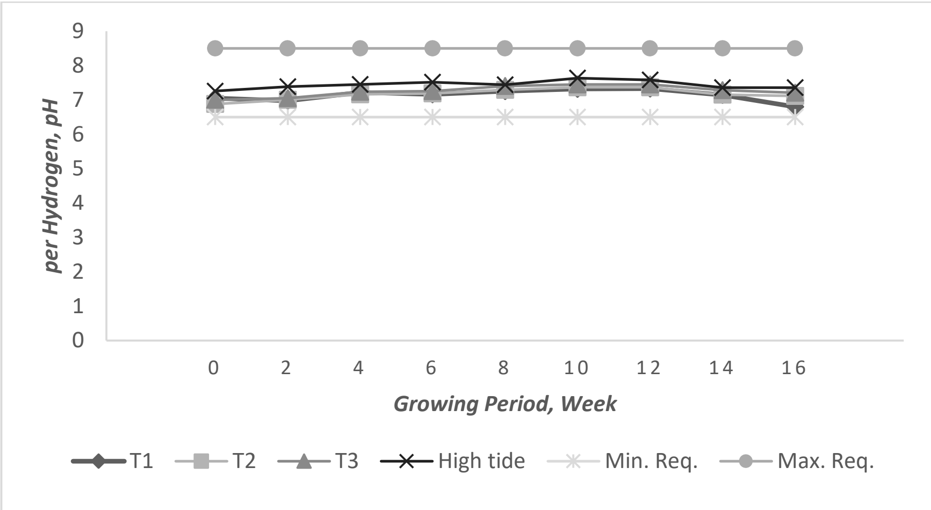
Average water salinity of the experimental area



The pH levels in three treatments were relatively more stable since the pH values of the ponded water during the experimental culture indicated a slight variation from 6.98 to 7.54 as shown in figure 3.

Figure 3.

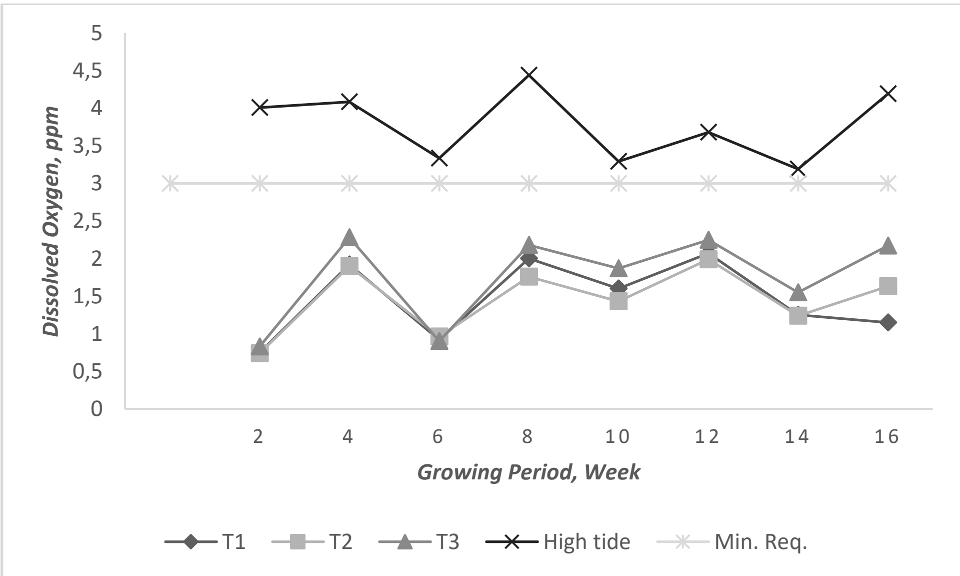
Average water pH of the experimental area



The DO level of the ponded water in each treatment was shown in figure 4. The recorded DO (0.64-2.57 ppm) in the excavations and canals of the mangrove pens is lower than the minimum requirement for milkfish and other aquatic organisms which is 3.0 ppm. It was also lower than the recorded DO level of water inside the pens during high tide.

Figure 4

Average DO of water in the experimental area



Recovery and Production Rate

No milkfish were harvested at the end of the study. The mortality was first observed on the third week of rearing when some dead fish were seen floating in the pens. The mass fish kill was observed on the sixth week of rearing. It was on the tenth week when there was no more visible milkfish in the nursery pens in all the modified pens. The absence of milkfish was confirmed by checking each nursery with the use of a scoop made from a small mesh net. After finding out the absence of swimming milkfish, the nurseries were removed and cleaned.

Mud crabs were able to survive in the pens. Table I presents its mean percent recovery and production rate in each treatment.

Table 1.

Average recovery and production rate of mud crab per treatment.

Treatment	Recovery, %	Production rate, g/m^2
1 (Control)	21.50	34.87^b
2 (with 43% excavation)	34.41	74.49^a
3 (with 54% excavation)	26.91	55.00^a

Note: Means in a column with the same superscript are not significantly different at 5% level.

The results shows that mangrove pens with excavation significantly produced more mud crabs than to those pens that followed the existing design. However, the number of mud crabs recovered from different pens are not significantly different (*P>0.05)*.

Discussions

The eroded soils that accumulated in the bottom of the excavations resulted in to decrease in water retained in the excavations during low tides. Over time, soil erosion occurs nearby, meaning that soil gets worn away and carried by things like water or wind (Eakin, 202; Hudson, 2015). This eroded soil ends up settling at the bottom of the excavation. During low tides, when the water level is naturally lower, this eroded soil takes up space at the bottom of the excavation. As a result, there's less room for water to be retained in the excavation because it's partly filled with soil instead.

For the experimental period, the water temperature in three treatments was conducive to the growth of the mud crab and milkfish for it only varied between 28.04°C and 30.35°C. The slight variation in the temperature was due to the shade of mangroves that cover the pens. Even during the daytime, the sunlight cannot fully penetrate the mangroves, which resulted in cooler water temperature in the pens.

The salinity fluctuated between 1.84% and 3.45% due to the occurrence of rainfall in the area and nearby estuary. In the early part of the rearing period (September – November), low salinity was recorded since frequent rainfall occurred in this period. It resulted in a freshwater intrusion in the research area through runoff from the nearby watershed. The high salinity recorded in the latter part of the study was due to the non-occurrence of rainfall. The salinity of the ponded water which was recorded, which ranged from 1.84-3.45% is favorable for the cultured species. In pond and pen culture, optimal salinity values range between 1.5% and 3.5% (BFAR, 2007; Baliao et al., 1999).

The pH levels in the three treatments were relatively more stable, due to a good water exchange in the mangrove pens during the culture period as the enclosure was located in an intertidal area where water changes from time to time due to regular changing tides. The pH values of the ponded water during the experimental culture indicated a slight variation from 6.98 to 7.54 as shown in Fig. 3. This is consistent with the findings of Hassea et al. (2005) and within the requirement of pH 6.5–8.5 (BFAR, 2007; Cholik & Hanafi, 1992).

The recorded DO (0.64-2.57 ppm) in the excavations and canals of the mangrove pen is lower than the minimum requirement for milkfish and other aquatic organisms which is 3.0 ppm and above (BFAR, 2007; Fatihah, 2017). It was also lower than the recorded DO of seawater outside the pens. This could be due to the limited movement of water in the excavations and canals during low tide since it was covered with mangrove trees and dikes of the adjacent pond. Wind cannot flow freely on the water surface hence, mixing of water or natural aeration does not occur.

Supposedly, with the constant water movement, the surface area of the water exposed to the air also increases. When the water has more contact with the air, the rate of fusion of the atmospheric oxygen to the water becomes higher. The fused atmospheric oxygen to the water becomes dissolved oxygen (DO) which is used by the aquatic plants and animals for respiration. Since there is limited movement or mixing of water in the excavations, the production of DO also becomes limited. Unlike water in the pens during high tide, the level of DO is higher than the minimum requirement because of the broad surface area that is in contact with the air and constant water mixing caused by the wave actions.

The aquatic flora also contributes to the production of oxygen in the water. Photosynthesis is responsible for the generation of oxygen in the presence of light; this explains the DO fluctuations during the day/night cycles and in the different seasons (Ibanez et al., 2008). The canopy of mangroves prevented the sunlight from directly penetrating the water in the canals and excavations, minimizing the photosynthetic activity of aquatic plants even during the daytime.

As milkfish grow, they consume more oxygen for survival. The mortality of milkfish can be attributed to the insufficiency of the DO on the ponded water during low tides. The recorded DO in the excavations throughout the study ranged from 0.64-2.57 ppm, which is lower than the recommended level (3.0 ppm and above) for milkfish production (Primavera et al., 2009; BFAR, 2007; Fatihah, 2017). Hassea et al. (2005) also added that DO values ranging from 5.10-6.0 mg/L are favorable for the growth of the cultured species.

The low level of DO appeared to have no great impact on the mud crabs' mortality for there is recorded recovery of stocks. It is because mud crabs can get out of the water and stay in the soil/mud if water quality is not favorable for them.

Even though there are variations on the recoveries obtained from different pen systems, it is not enough to prove its effectiveness in improving the recovery. The current mud crab recovery in modified mangrove pens is higher than the recovery obtained by Hassea et al. (2005). The previous researchers cultured mud crab juveniles for 71 days in a net enclosure at mangrove areas of Rouillard, Butte à l'Herbe, Nosaic, and Virginia Barachois. The current result is also consistent with Genodepa (1999) in the mud crab pen culture experiment in mangrove areas of Iloilo, Philippines. The present findings are also in agreement with the result of the stocking density trial conducted by Rani Saha (2016). The study was carried out in a brackish water pond where they obtained the best mud crab recovery (31%) using 10,000 crabs per hectare stocking density.

From the results of the present study on the production rate of mud crab, the high production in T_2 and T_3 can be attributed to the modifications done in the mangrove pen. Mud crabs were used to stay in the water most of the time. Therefore, during low tides, crabs stay into the parts of the pen where there is water, at canals and/or excavations. For Treatment 1 where there is a canal only, the grazing area of crabs is smaller and they cannot move freely compared to those in T_2 and T_3 where it has canals and excavations. Hence, the mud crabs became crowded in the canal area. In this condition, the food competition becomes higher which limits the growth of the stocks. Also, when the density is higher, the chance for mud crabs to encounter each other increases. And due to smaller areas, mud crabs cannot easily escape from their predators. Through these, greater cannibalism might occur in pens with canal only that resulting in higher mortality and lower production rate.

The average production rate obtained for the modified mangrove pen, specifically in T_2, is higher than production in a feed trial of mono-cultured mud crab in a mangrove pen of Primavera et al. (2009). The rate observed in this study is consistent with those reported by Yap et al. (2007) in their experiment on polyculture production of mud crab and milkfish in ponds. The present findings also supported the claim of Baliao et al. (1999) that higher stocking density usually resulted in lower production due to high mortality. Similar condition from the experimental culture of crabs in cages by Mwaluma (2003), where the production was lesser in crowded cages compared to those cages with lower stocking density.

Conclusion

The study was carried out to modify the existing design of the mangrove pen to make it suitable for the polyculture system of mud crab and milkfish production. The modifications done significantly improved the productivity of the mangrove pen for culture of mud crabs. The use of either modified or original mangrove pen is both ecologically viable since there is no need to remove mangroves or build aquaculture ponds. However, the current set-up of modified mangrove pen is not suitable for milkfish production since it cannot maintain the required level of DO in the water during the lean tide. For effective mud crab and milkfish culture in a modified mangrove pen, further research is needed to assess its profitability and effectivity using aerators to improve the DO level during low tides.

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