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Development of Polyculture Engineering Technology on Milkfish and Mud Crab Farming

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ABSTRACT

The current study aimed to evaluate the role of polyculture engineering technology on milkfish and mud crab farming and observe the growth and survivability of different milkfish and mud crab combinations. The study used milkfish, which was received artificial feed containing 35 % protein content enriched with vitamin E (3%/biomass/day). The study used completely randomized design with 4 treatments (n = 3): T1 = 5 milkfish + 5 mud crab, T2 = 10 milkfish + 5 mud crab, T3 = 5 milkfish + 10 mud crab, T4 = 10 milkfish + 10 mud crab. The following parameters were measured: absolute weight growth, survival rate, feed conversion rate (FCR), and water quality. The difference in the density of milkfish and mud crabs significantly affected ($p < 0.05$) the growth and survivability of milkfish and mud crabs. The polyculture cultivation system exhibited a significant increase in absolute weight growth of milkfish and mud crabs, which is the highest increase found in T4 treatment (187.85 g ± 0.9 g and 60.65 g ± 0.95 g, respectively). Meanwhile, the survival rate of milkfish and mud crab was 95% ± 0.3% and 95% ± 2.3%, respectively, followed by a lower FCR at T4 (1.54 ± 0.10). The water quality remained good for fish and mud crabs to survive. Milkfish and mud crab polyculture greatly affect the abundance of phytoplankton, demonstrating good community structure.

Keywords: Growth, milkfish, mud crabs, polyculture, survivability

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INTRODUCTION

Nowadays, the problem in cultivating milkfish and mud crab is high mortality (80 % to 95 %). It is due to bacterial attack through nutritional intake of feed such as fish waste and the low quality of environmental water (Samidjan & Rachmawati, 2016). Recently, aquaculture production has increased dramatically, as evidenced by a model structure of biomass production that could boost biomass production by modifying harvesting techniques (Suhartono & Istiyanto, 2014). Furthermore, because of its high economic value, which can be sold abroad, the mangrove crab is one of the most crucial cultivated species globally, particularly in Asia (Samidjan & Rachmawati, 2016).

According to Samidjan and Rachmawati (2016), polyculture black tiger shrimp, fish, and seaweed aquaculture produced poor results. Similarly, several other studies in polyculture cultivation of milkfish, black tiger shrimp, vannamei shrimp, seaweed, and mud crab have led to the development of fisheries in Indonesia. The use of aquacultural technology and the expansion of mud crab farming (*Scylla paramamosain*). It used battery plastic models in ponds to promote the export trade fishery to enhance productiveness. Furthermore, Samidjan and Rachmawati (2016) investigated the innovation of polyculture technology through biofilter systems and different stocking densities of milkfish and white shrimp in water quality improvement, leading to a higher performance of milkfish in the feasibility of white shrimp and milkfish life. Therefore, the current study sought to evaluate the role of technology engineering in polyculture milkfish and mud crab farming and observe the growth and survivability of different milkfish and mud crab combinations.

MATERIALS AND METHODS

Preparation of Milkfish and Mud Crab

This study used milkfish [*Chanos chanos* (Forsskal, 1775)] with 5 cm ± 0.025 cm in length and mud crab [*Scylla paramamosain* (Estampador, 1949)] with 4.85 cm ± 1.02 cm in length. The number of fish seeds used was five individuals of milkfish (MF)/m^2 to ten individuals of milkfish (MF)/m^2 and between five individuals of mud crab (MC)/m^2 to 1,200 m^2 and ten individuals of mud crab/m^2 to 1,200 m^2 pond culture. The fish were then received artificial feed containing 35 % protein supplemented with vitamin E (0.9 g/kg feed and 3% feed/biomass/day) (Table 1). Pure protein and vitamin E was purchased from Toko Kimia Indrasari and Sarika Majapahit Pharmacy, Semarang, respectively.

Table 1
Test feed formulation

Raw material of feed composition	(g/100g)
Vitamin E	0.9
Fish flour	34.3
Soy flour	33.3
Corn starch	9.4
Bran flour	8.1
Dextrin	9.2
Fish oil	1.31
Corn oil	1.31
Mineral vitamin	1.1
Carboxymethyl cellulose (CMC)	1.1
Total	100
Proximate analysis	
Protein (%)	35
Lipid (%)	11.5
Nitrogen free extract (NFE) (%)	33.75
Energy (cal/g)	300.05
Ratio of energy/protein (E/P) (kcal/g)	8.57

Experimental Design

The current study used a completely randomized design with 4 treatments ($n = 3$): T1 = 5 MF + 5 MC (feeding five individuals of milkfish/m^2 and five individuals of mud crab/m^2), T2 = 10 MF + 5 MC (feeding ten individuals of milkfish/m^2 and five individuals of mud crab/m^2), T3 = 5 MF + 10 MC (feeding five individuals of milkfish/m^2 and ten individuals of mud crab/m^2), T4 = 10 MF + 10 MC (feeding ten individuals/m^2 milkfish and ten individuals of mud crab/m^2).

Plankton Abundance

Diversity Index. Diversity index was calculated using Shannon Wiener's diversity index (Spellerberg & Fedor, 2003):

$$H' = -\sum_{i=1}^{s} p_i ln p_i \tag{1}$$

where:
H' : Shannon Wiener's diversity index
p_i : Individuals/Total individual (ni/N)
ln : The natural logarithm
S : Number of species

Uniformity Index. The following formula below was used to calculate the uniformity index (Ulfah et al., 2019):

$$E = \frac{H'}{Hmax} \quad (2)$$

where:
H' : Shannon-Wiener diversity index
H_{max}: Maximum *H'* (ln S)
S : Number of species

Dominance Index. The following formula below was used to calculate the dominance index (Samidjan et al., 2020):

$$D = \frac{\sum_{i=1} ni(ni-1)}{N(N-1)} \quad (3)$$

where:
D : Dominance index
n_i : Number of individuals
N : Total number of individuals

Growth Parameter

Absolute Growth Rates. The absolute growth rate was determined using the following formula (Samidjan et al., 2020):

$$W = W_t - W_0$$

where:
W : Absolute growth rate
W_t : Final weight (g)
W_0 : Initial weight (g)

Feed Conversion Ratio (FCR). The feed conversion ratio was measured using the following formula (Samidjan et al., 2020):

$$FCR = \frac{F}{(W_t + d) - W_0}$$

where:
FCR: Food conversion ratio
F : Food consumed (g)
W_0 : Initial weight (g)
Wt : Final weight (g)

Survival Rate. The following formula was used to calculate the survival rate of animals (Samidjan et al., 2020):

$$SR = \frac{N_t}{N_0} \times 100\%$$

where:
SR : Survival rate
N_0 : Initial number of animals
N_t : Final number of animals

Water Quality Parameter

Water pH and dissolved oxygen were measured using Jenway 3510 standard digital pH meter (Jenway, United Kingdom) and Jenway 970 dissolved oxygen meter (Jenway, United Kingdom). In addition, the ammonia level, temperature, and salinity were measured using a HI-8633 portable conductivity meter (Hanna Instruments Inc., USA).

Statistical Analysis

Data were included absolute growth of milkfish (g), absolute growth of mud crab (g), the survival rate of milkfish (%), the survival rate of mud crab (%), and FCR of milkfish and mud crab. Data were expressed as mean ± standard deviation (SD) and analyzed using analysis of variance

(ANOVA), and Duncan's multiple range test (DMRT) with $p < 0.01$ was used as statistical significance.

RESULTS AND DISCUSSION

The highest absolute weight growth of milkfish and mud crabs was detected in T4 treatment, 187.85 g ± 0.9 g and 60.65 g ± 0.95 g, respectively. In addition, the survival rate of milkfish was 95% ± 0.3% and 95% ± 2.3% for mud crab, while lower feed conversion (FCR) of T4 was 1.54 ± 0.10 (Table 2).

Table 2
Absolute growth of milkfish and mud crab

Parameter	Treatments in polyculture			
	T1 (5 MF + 5 MC)	T2 (10 MF + 5 MC)	T3 (5 MF + 10 MC)	T4 (10 MF + 10 MC)
Absolute growth of milkfish (g)	180.18 ± 3.14^{b}	184.27 ± 0.49^{ab}	185.18 ± 0.61^{a}	187.85 ± 0.9^{a}
Absolute growth of mud crab (g)	47.85 ± 0.95^{c}	54.45 ± 0.62^{b}	58.76 ± 0.75^{a}	60.65 ± 0.95^{a}
Survival rate milkfish (%)	81.67 ± 1.81^{b}	85.40 ± 4.15^{b}	94.07 ± 2.16^{a}	95 ± 0.3^{a}
Survival rate of mud crab (%)	78.13 ± 1.10^{b}	81.0 ± 3.12^{b}	93.43 ± 1.0^{a}	95 ± 2.3^{a}
FCR of milkfish and mud crab	3.45 ± 0.43^{a}	2.89 ± 0.48^{a}	2.09 ± 0.33^{b}	1.54 ± 0.10^{b}

Note.
T1 = 5 MF + 5 MC (feeding 5 milkfish/m^2 and 5 mud crab/m^2)
T2 = 10 MF + 5 MC (feeding 10 milkfish/m^2 and 5 mud crab/m^2)
T3 = 5 MF + 10 MC (feeding 5 milkfish/m^2 and 10 mud crab/m^2)
T4 = 10 MF + 10 MC (feeding 10 milkfish/m^2 and 10 mud crab/m^2)

MF = Milkfish; MC = Mud crab; Data were expressed as values ± SD and analyzed using analysis of variance (p<0.01). Different superscript letters in the same rows indicated highly significant differences between group treatments (p<0.01)

Absolute Weight Growth of Milkfish

T4 polyculture exhibited the milkfish's highest absolute weight growth (Table 2). This feeding treatment enhanced the absolute weight growth of milkfish (187.85 g ± 0.9 g), which is higher than the T1, T2, and T3 group ($p < 0.01$). The used polyculture milkfish and mud crab enhance growth and improve absolute growth.

The artificial feeding of milkfish containing 35% protein enriched with vitamin E increased the absolute weight growth of milkfish from 179.5 g to 185.25 g (Agbayani, 2001; Gaillard, 2010; Martan, 2008; Primavera, 2006). Changes in the number of cells that make up human tissue and morphologically changing observable growth are signs of physical growth. When the energy requirements for metabolism and body growth have been met, growth will occur (Araújo-Silva et al., 2014; Chopin, 2013; Davis, 2011; Martan, 2008; Samidjan & Rachmawati, 2018; Siskey & Baldwin, 2011; Yuan et al., 2010). It had also happened when the quantities of feed consumed were more than what was required for body growth, and the fish used it as an energy source (Lall, 2000).

Absolute Growth of Mud Crabs. The polyculture technique of rearing milkfish and mud crabs in the same pond with each plot of 100 m^2 had a strong influence on absolute mud crab weight ($p < 0.1$) (Table 1). T4 group had the highest absolute weight of mud crab (60.65 g ± 0.025 g).

Furthermore, a highly significant difference was found in mud crab absolute weight growth ($p < 0.01$). It was related to the simultaneous maintenance of mud crabs and milkfish, which can grow well and thus have an excellent synergistic relationship. Adding vitamin E-enriched artificial feed to the diet resulted in optimal growth because it serves as an antioxidant to reduce highly unsaturated fatty acid (HUFA) oxidation. As a result, HUFA availability in the feed can be conserved (Agbayani, 2001; Gaillard, 2010; Xie et al., 2011), and HUFA oxidation in the cell membrane or intercellular free radicals can be eliminated. Indirect feed contributes to the growth and survival rate of metabolism in addition to vitamin E enrichment (Agbayani, 2001; Davis, 2011; Gaillard, 2010; Yang & Fitzsimons, 2002).

Mud crabs have a remarkable capacity to absorb vitamin E, allowing them to gain weight. Vitamin E could prevent oxidative damage, such as carotene degradation in the gut, by performing as an antioxidant (Asadujjaman et al., 2015; Ghosh et al., 2011; Ihsan, 2012; Malleo, 2011; Miroslav et al., 2011; Monwar et al., 2017; Nunes et al., 2003; Sun & Boyd, 2013; Venugopal et al., 2012). Vitamin E has been shown to reduce cell membrane damage, allowing metabolic processes to run more smoothly and nutrients to enter cells appropriately (Agbayani, 2001; Gaillard, 2010; Solomon & Ezigbo, 2010). Herbivorous fish are expected to possess more vitamin E than carnivorous fish (Laxmappa & Khrisna, 2015). The feed requirement for red sea bream was 442 mg/kg of feed (Ali et al., 2009).

An increase in body size is referred to as growth. The rate of absolute weight growth on the mud crab began with the rate of carapace (shell) width and length growth (Agbayani, 2001; Gaillard, 2010). Because the body cannot grow linearly, absolute weight growth may be critical for mud crabs. The mud crab can grow when the old shell is removed and replaced with a new and larger shell. The process of this change was called the molting process. Molting crabs have been discontinued due to their hard and inelastic shells, as the molting process softens the shell (Agbayani, 2001; Gaillard, 2010).

Survival Rate of Milkfish and Mud Crab. The maximum survival rate of fish maintained at T4 treatment was 95% ± 2.3% (Table 2). The milkfish had a good survival rate due to the high-water quality in the maintained fish polyculture system. It was supported by Barman et al. (2012), who mentioned that adequate water quality in polyculture might boost the survival rate up to 80%–90%. Therefore, water quality in fish farming could affect survival, proliferation, and growth. T4 treatment had the highest mud crab survival rate (95% ± 2.3 %) (Table 2).

Food Conversion Ratio (FCR). In the polyculture milkfish and mud crab farming system, the feed conversion ratio is crucial because it decides whether the feed can improve the growth of fish and mud crabs still growing well (Davis, 2011). The feed conversion values can also determine how much the feed broadened the mud crab or kept fish body. A lower feed conversion rate (FCR) at T4 resulted in a higher absolute weight of high growth, implying a more efficient feed. Table 2 shows that artificial feed with a reduced FCR value for T4 given to the polyculture system effectively increased mud crab growth.

The feed conversion ratio indicates how many grams of feed are required to create one gram of milkfish bodyweight. Feed efficiency is obtained by calculating the FCR as the value consumed per fish weight unit. A good quality feed has a reduced conversion ratio (FCR), which improves the feed's performance and improves absolute growth (Gaillard, 2010). It was determined as a feed conversion index based on total feed used for growth, with lower values indicating higher feed conversion. It was efficient when the feed conversion value was less than 3. Vitamin E supplements in the diet may potent antioxidants, assisting in preserving vitamins (Agbayani, 2001; Gaillard & Juliette, 2010). The proper nutrients in the feed have an impact on the feed utilization rate because it will help the milkfish and mud crab grow faster in polyculture (Ali et al., 2009; De-shang & Shuang-lin, 2000; Jamerlan et al., 2014; Jaspe et al., 2011; Laxmappa & Khrisna, 2015; Solomon & Ezigbo, 2010).

The Abundance of Phytoplankton. Bacillariophyceae (8 genera), Chlorophyceae (1 genus), Cyanophyceae (1 genus), and

Dinophyceae (1 genus) were detected in aquaculture systems polyculture of milkfish and mud crab (Tables 3 and 4). Furthermore, the study found 118.75 individu/L of phytoplankton species, which is higher than milkfish and mud crab. According to Dolgov and Prokopchuk (2018), the number of phytoplankton is higher than in the polyculture system of milkfish and mud crab using biofloc in ponds. The constant availability of nutritional components through the feed is responsible for the high percentage of phytoplankton. The increase in genus and individuals is related to feeding and fertilizer (Napiórkowska-Krzebietke, 2017).

Table 3

Plankton genus observed during the study

Treatment	Phytoplankton genera
T1 (5 MF + 5 MC)	*Ceratium*, *Coscinodiscus*, *Bacteriastrum*, *Chaetoceros*, *Geotrichia*, *Navicula*, *Odontella*, *Oscillatoria*, *Pleurosigma*
T2 (10 MF + 5 MC)	*Chaetoceros*, *Ceratium*, *Coscinodiscus*, *Bacteriastrum*, *Geotrichia*, *Navicula*, *Odontella*, *Oscillatoria*, *Thalassionema*
T3 (5 MF + 10 MC	*Coscinodiscus*, *Geotrichia*, *Navicula*, *Bacteriastrum*, *Chaetoceros*, *Ceratium*, *Pleurosigma*, *Thalassionema*
T4 (10 MF + 10 MC)	*Bacteriastrum*, *Oscillatoria*, *Pleurosigma*, *Thalassionema*, *Chaetoceros*, *Ceratium*, *Coscinodiscus*, *Geotrichia*, *Navicula*, *Odontella*

Note. MF = Milkfish; MC = Mud crab

Table 4

The diversity index (H'), uniformity (E) and dominance (D) phytoplankton

Treatments	Number of individuals (individu/L)	Index		
		Diversity (*H'*)	Uniformity (E)	Dominance (D)
T1 (5 MF + 5 MC)	112	1.093	0.765	0.725
T2 (10 MF + 5 MC)	115	1.072	0.753	0.606
T3 (5 MF + 10 MC)	119	1.804	0.785	0.595
T4 (10 MF + 10 MC)	129	1.907	0.895	0.578
Mean	118.75	1.469	0.7995	0.626

Note. MF = Milkfish; MC = Mud crab

This study found that an increase in phytoplankton abundance caused by several factors, such as planktonic genera during the dry season, could enhance the abundance of some genera. During the rainy season, it can raise the phytoplankton abundance. Temperature, nutrient concentration, predation of milkfish and mud crab, pH, disease, weather, phytoplankton, light, competence between species, and algae toxins influence the phytoplankton abundance (Sun & Boyd, 2013). The low abundance of phytoplankton grows very densely simultaneously (Kwon et al., 2018). The addition of feed significantly affected the cultivation of milkfish and mud crab polyculture systems within ponds ($p < 0.05$).

The milkfish and mud crab have an impact on phytoplankton abundance and community structure. Phytoplankton as substitute feed resulted in decreased feed intake without declining feed ratio (Tan et al., 2016). Therefore, FCR can predict the feed required for phytoplankton and seaweed maintenance. Similarly, adding natural food and other feed will reduce FCR values close to or equal 1 (Samidjan et al., 2019). According to Table 4, the diversity index (*H'*) in T1, T2, T3, and T4 treatments were 1.093, 1.072, 1.804, and 1.907, respectively. The average diversity value was 1.469 (*H'*> 1). The plankton conditions in pond waters are shown to be relatively good. This result indicates that the community's condition (plankton, milkfish, and mud crab) has remained generally steady as the pond's environment changes. If *H'* is less than 1, the biota community is unstable (Basmi, 2000). The biota community is classified as moderately stable if *H'* is between 1–3 and as stable if *H'* is more than 3.

Table 4 shows that the uniformity index of T1, T2, T3, and T4 treatment was 0.765, 0.753, 0.785, and 0.895, respectively. The average uniformity index was 0.7995, indicating that the number of individuals in each genus is relatively similar. If E is greater than 0.75, the uniformity value is high, while the value of E is less than 0.75, the uniformity value is low (Table 4). The dominance index of T1, T2, T3, and T4 treatment was 0.725, 0.606, 0.595, and 0.578, respectively. The average dominance index was 0.626, suggesting that no phytoplankton genus dominates the other genus. According to Ali et al. (2009), the dominance index ranges from 0 to 1, with zero indicating no genus dominating the other genus in the biota community structure.

Water Quality. Water quality maintenance for milkfish and mud crab polyculture media was crucial for cultivation success. Table 5 revealed that the dissolved oxygen (4.87 mg/L to 6.25 mg/L), temperature (27.5 °C to 31.25 °C), salinity (22 g/L to 28.5 g/L), pH (7.5 to 8.5), and ammonia (0.02 mg/L to 0.256 mg/L) could support fish life and mangrove crabs cultivated in polyculture.

Table 5

Water quality parameters in polyculture system of milkfish and mud crabs

Parameters	Results	Reference (Sun & Boyd, 2013)
Dissolve oxygen (mg/L)	4.87 to 6.25	4 mg · L^{-1}
Temperature (°C)	27.5 to 31.25	26.5 to 35 °C
Salinity (g/L)	22 to 28.5	15 to 30 ppt
pH	7.5 to 8.5	7.5 to 8.7
Ammonia (mg/L)	0.02 to 0.256	< 1 mg · L^{-1}

CONCLUSION

The study revealed that the difference in the density of milkfish and mud crabs exhibited a significant effect ($p < 0.05$) on the growth and survivability of milkfish and mud crabs. The polyculture cultivation system showed a significant increase in absolute weight growth of milkfish and mud crabs, which is the highest increase found in T4 treatment (187.85 g ± 0.9 g and 60.65 g ± 0.95 g, respectively). Meanwhile, the survival rate of milkfish and mud crab was 95% ± 0.3% and 95 % ± 2.3%, respectively, followed by a lower FCR at T4 (1.54 ± 0.10). The water quality remained good for fish and mud crabs to survive. Milkfish and mud crab polyculture significantly affect the abundance of phytoplankton, demonstrating a good community structure.

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