Mindanao Journal of Science and Technology Vol. 13 (2015) 196-212

Feasibility of Blue Swimming Crab Portunus Pelagicus Linnaeus 1758 and Red Seaweed Kappaphycus alvarezii Doty Polyculture in Floating Net Cages

Nora O. Suerte
Northern Iloilo Polytechnic State College
Estancia, Iloilo
Suerte_nora@yahoo.com

Date received: January 9, 2015
Revision accepted: August 18, 2015

Abstract

The practice of polyculture in aquaculture has led to increased production. However, there is a need to develop a suitable culture scheme in order to optimize production. This paper evaluates the production and economic feasibility of the polyculture of two commercially important species, the blue swimming crab (Portunus pelagicus Linnaeus 1758) and red seaweed (Kappaphycus alvarezii Doty). Blue swimming crabs (initial weight 43.0 ± 1.4 g, CW 9.1 ± 0.4 cm) and red seaweeds were cultured in 1m^3 cage for 45 days. For crab production evaluation, 10 crabs were placed in a cage with varying seaweed stocking density: 10 + 500 (g red seaweed), 10 + 750 and 10 + 1,000. Treatment without red seaweeds (10 + 0) served as the Control. For seaweed production, two culture schemes (hanging and bottom method) were evaluated with the same stocking density used in crabs. However, set-up with 1,000 g red seaweed and without crab (0 + 1,000) served as Control. Each treatment consisted of five replicates. Stock sampling and determination of production parameters were done every 15 days until the end of the culture period. Production evaluation included specific growth rate, survival rate and net production while economic evaluation included computation of the ROI (Return on Investment) and payback period of the polyculture system as a whole. For crabs, highest net production ($P < 0.05$) was obtained in the 10 + 750 treatment. For seaweed production evaluation, the bottom culture scheme showed significantly higher ($P < 0.05$) net production and SGR. Further, red seaweeds cultured in the 10 + 750 showed highest net production ($P < 0.05$) among the stocking density combination evaluated. ROI was computed to be 40% and the payback period is 2.5 years. The study suggests polyculture of blue swimming crab and red seaweeds using the bottom culture scheme at 10 + 750 as the optimum stocking density.

Keywords: polyculture, portunus pelagicus linnaeus 1758, kappaphycus alvarezii doty, culture scheme, cage culture

1. Introduction

Crabs are considered as an important fisheries commodity. There is high demand for crabs in affluent markets worldwide (Marichamy, 1996). Thus, crabs are considered as high valued commodity (Batoy *et. al.,* 2006). Further, the global trade of blue swimming crabs has become important contributor to the economy of countries lying in the Indo-Pacific Region such as the Philippines.

In the country, the municipal fishery sector accounts to 95.38% while the commercial fishery contributes to 1.34% of the annual catch of crabs. Regional VI which faces the Visayan Sea is the largest contributor to crab production. Region VI production constitutes 32.23% of the national production (Philippine Fisheries Profile 2007). In 2010, the country exported 5,795 Metric Tons (MT) of various forms of crab products (Philippine Fisheries Profile, 2010). The volume exported makes the crab the fourth largest exported fisheries commodity of the country.

Most of the crabs exported come from wild caught population. *Portunus pelagicus* (blue swimming crab) contributes substantially in the species of crabs commercially exploited in the country. However, the demand for crabs has also exceeded the sustainable exploitation limit. The high price and increased demand contributed to over-exploitation in captured production of blue swimming crab. In the Visayan Sea, the blue swimming crab harvest declined from 20 kg day^{-1} fisherman^{-1} in the early 1990s to 5 kg day^{-1} fisherman^{-1} in between 2008 and 2009 (Eliserio and Mandreza 2010). Moreover, overfishing in the crab fisheries has become a global concern as there have been many examples of crab fisheries exceeding the sustainable catch. In Malaysia, there was also a mark decreased of landed catch in 2009 when compared with the previous year. While there have been an apparent gap between the supply of wild caught blue swimming crab and the demand, the problem has been persistent because of the lack of a developed aquaculture technology. Research on the blue swimmer crab fisheries and specifically its larval stages are few and limited (Kargas, 1997). Further, the hatchery of even the most established crab species, *Scylla serrata,* has been limited by very low survival in the zoea stage (FAO, 2011). Crabs also undergo molting (ecdysis) in order to grow. When they shed off their shell they become susceptible to other predators and even to pathogenic organisms. It is at these two periods- ecdysis and larval development- wherein large mortalities are commonly observed (Dat, 1999; Quinitio, 2001; Suprayudi *et. al.,* 2002). The problem with molting is very apparent because crabs are territorial and very antagonistic (Clark *et. al.,* 1999). Cannibalism can significantly reduce harvest (Triño *et. al.,* 1999).

Many techniques have been tested in various crab species to address the problem on cannibalism. Strategies to reduce cannibalism include provision of adequate food, sufficient shelters, size grading, trimming of dactylus, pollex and removal of chelipeds. In the communal rearing of mud crab, the claws of the crabs are removed to prevent cannibalism (Quinitio and Parado - Estepa, 2003). However, chelipeds are removed only in smaller crabs (<5cm CW) because growth may be affected in larger crabs. Trimming of dactylus, pollex and removal of chelipeds are tedious and applicable only for a small population of crabs (Quinitio and Parado - Estepa, 2003).

Crabs seek protection during molting. Triño *et. al.,* (1999) suggested the provision of shelter in the form of Gracilaria seaweed which can be considered as a polyculture system. The polyculture of crabs with other commercially important species has long been practiced. Cultivating fish, mollusks, or crustaceans and different seaweed species in ponds and in cages is a profitable aquaculture venture in Thailand and Taiwan (Chandkrachang, 1990; Chiang, 1992; Guanzon *et al.,* 2004). In China, the macro alga *Gracilaria* is polycultured with shrimp and crab (Wang *et. al.,* 2010). In Indonesia, the polyculture of blue swimming crab and tilapia *Oreochromis niloticus* in net pens was conducted and proved that the provision of shelter in sandy bottom helps the crab free from pollution (Juwana, 1998).

In many parts of northern Iloilo facing the Visayan Sea, red seaweeds (*Kappaphycus alvarezii Doty*) is cultivated. This seaweed is abundant in the wild in Panay Island (De Castro, 1991). Red seaweeds is an important source of carrageenan which is used in the processing of various commercial products (Armisen and Galatas, 1987). The Philippines is the leading exporter of carrageenan (Hurtado and Agbayani, 2000).

The culture method for red seaweeds is simple and the culture duration is also short. There is also high demand for red seaweeds which makes year round culture feasible. Thus, the use of red seaweeds for polyculture is ideal. Guanzon *et al.,* (2004) proved that the red seaweeds can be cultured with other commercially important fishes.

Review of existing literature indicates that the biological characteristics (both in terms habitat and physico-chemical conditions) of the blue swimming crab and red seaweeds are suited. Further, the requirements for their culture are also similar. Among all parameters, salinity has the most pronounced effect on the distribution of blue swimmer crabs as they prefer salinities between 30 – 40 g L^{-1} (Potter *et. al.*, 1983). While blue swimming crabs thrive in the optimum conditions, they can tolerate wide fluctuations in temperature and dissolved oxygen (DO) as they are bottom feeder and they prefer sandy to muddy substrate. The red seaweeds can also thrive in the preferred salinity of blue swimmer crabs.

The polyculture system is advantageous when compared with the monoculture system because the harvest of two or more crops provide a promising additional profit (Juwana, 1998). This paper develops a protocol for the polyculture of blue swimming crabs and red seaweeds. The protocol is based on the two dominant culture scheme used in seaweeds (Hanging and Bottom method) and on various stocking density combinations. As a general objective, this paper evaluates the feasibility of the polyculture of two commercially important species, the blue swimming crab (*Portunus pelagicus Linnaeus 1758*) and red seaweed (*Kappaphycus alvarezii Doty*). Specifically the study aims to:

1. Evaluate production parameters, which include Specific Growth Rate (SGR), Net Production and Survival Rate (blue swimming crabs only), of both blue swimming crabs and red seaweeds.
2. Provide economic analysis, based on computation of Return on Investment (ROI) and payback period, of the polyculture system as a whole.

2. Methodology

2.1 The study site

This study was conducted in Plandico (N 11°09’51.1” and E 123°05’42.3”), Concepcion, Iloilo, Philippines. The study site is situated in a cove as shown in Figure 1. Water circulation and movement in the area is suitable for aquaculture as it comes from and drains directly into the vast Visayan Sea. While population density in the area is low (total population of the adjacent barangay is 622), the area can be characterized as a multi-use zone. The area is used as a navigational lane of small outrigger boats and for aquaculture activities (including fish pen and fish cages). A portion of the coast of the mainland was also developed into a fishpond while the whole area on the other side of the cove was declared as Marine Protected Areas by virtue of Municipal Ordinance.

Figure 1. Map of the study site. The location of the study site was geo referenced as shown in the figure. The inset map shows the location of the study site in Panay Island. Map taken from Google Earth.

2.2 Experimental Culture System

Twenty five cages were used as experimental units (Figure 2). The cages were made of nylon nets of 2 cm mesh size measuring 1m x 1m x 1m and tied at four sides to a floating bamboo raft. The mesh size used is appropriate to prevent the blue crabs from escaping. Cage flooring made of plastic sack materials with polyvinyl frames measuring 1 x 1 m were tied to the bamboo raft. The raft was kept in place by tying into 20 feet long bamboo poles using polyethylene ropes (No. 8). The bamboo poles were staked firmly at the sea floor. Nine floaters made of blue plastic drums were installed under the bamboo raft to allow it to float. Plastic soft drink bottles were used as alternative floaters instead of Styrofoam for seaweeds monolines inside the cages. The cage depth extends to 1m below the water surface. The cages were installed in the coastal area having a water depth of 3 m during low tide.

Figure 2. The floating bamboo raft where net cages were attached.

2.3 Experimental animal and seaweeds

Blue swimming crab juveniles with mean initial weight of 43.9 ± 1.4 g were used in the study. The blue crabs were purchased from crab gatherers at Tinagong Dagat, Brgy. Plandico, Concepcion, Iloilo. Red seaweeds were bought from seaweed farm in Brgy Tiabas, San Dionisio, Iloilo. Young red seaweed fronds (10-15cm long) were seeded by tying to a cultivation rope of 100 cm long inside the cage. A total of 11 kg blue crabs and 32.5 kg seaweed were stocked. The crabs and seaweed used in the experiment were acclimatized to culture conditions prior to the start of the study.

2.4 Experimental Set-Up

The study consisted of blue swimming crab and red seaweed evaluation in a polyculture system. Ten (10) blue swimming crabs with an average weight 43.0 ± 1.4 g were stocked in each cage with young seaweed fronds (10-15cm long) using the long line method. Three stocking density combinations were used: 10 pieces blue swimming crab + 500g red seaweed (10 + 500), 10 pieces blue swimming crab +750g red seaweed (10 + 750) and 10 pieces blue swimming crab juveniles + 1000g red seaweed (10 + 1,000). The control group consisted of cage stocked with 10 pieces crabs and without red seaweeds (10 + 0). The same treatments were evaluated for seaweeds except that the Control set-up consisted of cages with 1,000 kg red seaweeds and without blue crabs (0 + 1,000). Five replicates per treatment were arranged in a completely randomized design (CRD). The experiment was done for 45 days.

2.5 Culture Protocol

Low cost fish by - catch (*Leiognathus elongatus*) was utilized as feed for blue crabs. The trash fish were fed to the blue crabs at 10% of the total biomass for the initial phase of culture. This was reduced by 1% every 15 days until the end of the culture period (Baliao *et al.,* 1999). The blue crabs were fed early morning and late afternoon daily using the formula of Quinitio et. al. (2004):

$$\text{Amount of food (g)} = (\text{average body weight (g)} \times 0.10)/\text{Total number of crabs}$$

The blue swimming crabs and red seaweeds were sampled every 15 days until the end of culture (45th Days of Culture-DOC). The Mean Average Body Weight (ABW) of blue crabs for each cage was determined and was used in the calculation of feeds given. The blue crabs were weighed *en masse* using a digital balance. Red seaweeds were sampled by weighing all the plants in each cage. The red seaweeds were cleaned of adhering particles, patted dried and weighed. Specific Growth Rate (SGR), Net Production (kg $cage^{-1}$) was computed both red seaweeds and blue swimming crabs at harvest. The survival rates across treatment of blue crabs were also obtained at harvest.

Water parameters were monitored daily between 8:00 and 9:00 A.M. Temperature (°C) was taken using an ordinary Mercury thermometer. Salinity (gL^{-1}) and pH were determined using a refractometer (Atago) and a pH meter (Hanna). Mean physico-chemical values were within the optimum range for the culture of both blue swimming crabs and red seaweeds: Temperature (24.00 – 27.92°C), Salinity (31.31 – 33.97 g L^{-1}) and pH (7.77 – 8.88). Further, the area has good water circulation and water movement is free flowing. Daily observations and closed monitoring (night time) of culture conditions did not indicate any sign of stress due to low oxygen conditions. There were no report of fish kills or epizootics in the adjacent aquaculture systems for the entire duration of culture.

2.6 Economic Analysis

Simple analysis to determine the economic feasibility of polyculture of blue swimming crab and red seaweed in floating net cages was done. Cost and returns based on 20% moisture content, was used to determine the return of investment (ROI). This was computed by dividing the annual net income by the investment. The payback period was computed by dividing the investment by the sum of the annual income and annual depreciation (Shang, 1976). Production costs were seed plants, plastic straw (tie – tie), net cages, ropes and bamboo raft, hired labor and depreciation. Depreciation was computed using the straight line method based on the estimated useful life of the asset production cost from gross returns. Costs and returns are based on a 25 m^3 area and the currency used in the computation is the Philippine peso (P44 = US $1) (Hurtado – Ponce *et al.*, 1997).

2.7 Data Analyses

Specific growth rate, survival rate and net production were expressed as mean values ± standard error of the mean (SEM). SGR is computed as: $(I\ln_{finalweight} - \ln_{initialweight}I/\text{days of culture})*100$ where it assumes a dimensionless absolute value. Net production rate (kg $cage^{-1}$) was calculated by weighing the entire cultured organism (blue swimming crabs or red seaweed) divided by the number of cages. Survival rate was determined by dividing the number of blue crabs left in each cage by the initial stock multiplied by 100. Growth parameters (ABW and Carapace Width) were also taken at harvest.

The growth parameters at harvest and production data were subjected to Levene's Test to determine equality of variance prior to analysis. Survival data (expressed as percent) with 100 percent or 0 percent survival were converted, 100 – 1/4n and 1/4n (where n = stocking density), respectively (Gomez and Gomez, 1984). Prior to statistical analysis, survival data were also transformed (arcsin√x, where x = percent survival). Growth (ABW and Carapace Width) and Production (SGR, Net Production and Survival Rate) parameters for blue swimming crabs were analyzed using one –way ANOVA. Further, production data (SGR and Net Production) for red seaweeds were analyzed by comparing the effect culture scheme (hanging versus bottom) on various stocking density combinations. A factorial design two-way ANOVA was used in the analysis (Glover and Mitchell, 2002). Level of significance was set at $\alpha = 0.05$ and Duncan Multiple Range Test (DMRT) was used in the p*ost hoc* analysis. SPSS version 16 was used in the data analysis.

3. Results and Discussion

The mean ABW and Carapace Width of blue swimming crabs obtained at harvest are shown in Figure 3. Blue swimming crabs polycultured with 1,000

g of red seaweeds showed significantly higher ($P < 0.05$) mean ABW than the rest of the treatment. Blue swimming crabs polycultured with 500 g of red seaweeds obtained the significantly lower ($P < 0.05$) mean ABW at the end of culture. However, blue swimming crabs cultured without red seaweeds and those cultured with 1,000 g red seaweeds have significantly bigger ($P < 0.05$) carapace width than those polycultured with 500 and 750 g of red seaweeds.

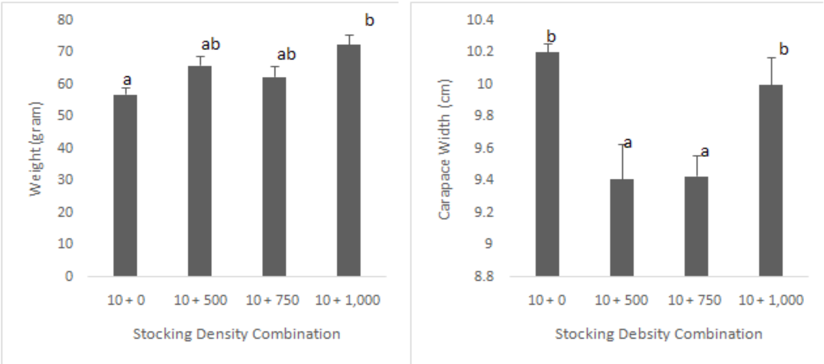

Figure 3. Mean ABW (left) and Carapace Width (right) at harvest of blue swimming crabs polycultured with red seaweeds in floating cages. Error bars indicate Standard Error of Mean. Superscripts indicate significant difference ($\alpha = 0.05$, one-way ANOVA).

SGR, Net Production and survival rate of blue swimming crabs polycultured with red seaweeds in floating net cages are shown in Table 1. Highest production parameters were obtained in blue swimming crabs polycultured with 750 g red seaweeds. Significantly higher SGR ($P < 0.05$) than the rest of the treatment as well as highest survival rate (although not significantly different from 10 + 500) translated to highest Net Production. This is significantly higher ($P < 0.05$) than the rest of the treatments.

There is a marked trend of increasing SGR and survival rates of blue swimming crabs as the stocking density of seaweeds increases. This increase reached peak at 10 + 750 and declined in the 10 + 1,000. However, Net Production obtained at harvest do not show any discernable pattern.

Table 1. Production Value of Blue Swimming Crabs Polycultured with Red Seaweeds. The table shows the comparison SGR, Survival Rate and Net Production. Mean±SEM values across treatment are shown. Superscripts indicate significant difference ($\alpha = 0.05$, one-way ANOVA).

Treatment	Production Parameters		
	SGR	Net Production (g)	Survival Rate (%)
10 + 0	0.33 ± 0.05^{a}	63.6 ± 2.5^{b}	08.0 ± 1.0^{a}
10 + 500	0.67 ± 0.05^{b}	54.9 ± 2.0^{a}	22.0 ± 1.6^{c}
10 + 750	0.94 ± 0.10^{d}	68.7 ± 2.3^{c}	24.0 ± 2.4^{c}
10 + 1,000	0.77 ± 0.10^{c}	65.1 ± 2.6^{b}	18.0 ± 1.7^{b}

SGR and Net Production of red seaweeds at various stocking density and different culture scheme are shown in Table 2. Highest SGR and Net Production was observed in the 10 + 750 treatment with the bottom method as the culture scheme. There was also an observed higher production in the bottom culture scheme when compared with the hanging culture scheme across all stocking densities evaluated.

Table 2. Production Data of Red Seaweeds in the Polyculture System. The table shows the raw data for SGR and Net Production classified into culture scheme (Hanging and Bottom method) across treatment (various stocking combinations). Mean±SEM values across treatment are shown.

Treatment	Culture Scheme	Production Parameters	
		SGR	Net Production (g)
10 + 500	Hanging	1.00±0.38	789±167
	Bottom	2.26±0.83	1,404±118
10 + 750	Hanging	1.07±0.40	2,294±169
	Bottom	2.37±0.88	2,460±247
10 + 1,000	Hanging	0.94±0.26	1,536±212
	Bottom	2.10±0.58	1,882±088
0 + 1,000	Hanging	0.91±0.24	1,540±158
	Bottom	1.42+0.19	1,900±071

Analysis using factorial design two way ANOVA ($\alpha = 0.05$) did not show any interaction effect between the culture scheme and stocking density combination. However, comparison of culture scheme (main effect) showed that the bottom method (n = 20) has significantly better ($P < 0.05$) production (SGR 2.03±0.32 and Net Production 1,912±101 g) than the method (n = 20, SGR 0.98±0.15 and Net Production 1,540±147 g).

Test of main effect of stocking density failed to show significant differences ($P > 0.05$) across stocking density treatment for SGR. However, significant difference ($P < 0.05$) was obtained for Net Production. The 10 + 750 stocking density combination (n = 10) resulted to highest Net Production (2,377±116 g) while 10 + 500 (n = 10) showed the lowest Net Production (1,097±141 g) as shown in Figure 4.

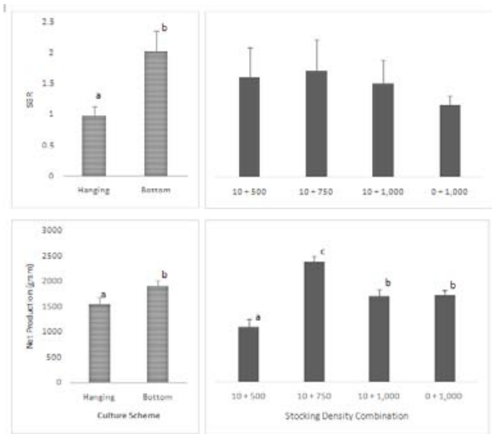

Figure 4. Comparison of production parameters for red seaweeds. SGR and Net Production are affected by the culture scheme. Stocking density combination showed significant differences only in Net Production. Mean+SEM values are shown. Superscripts indicate significant difference (α = 0.05, factorial design two-way ANOVA).

The individual growth parameters obtained at harvest showed a marked increase in the carapace width of blue swimming crabs in treatments without seaweeds and 1,000 g of red seaweeds. These treatments correspond to the lowest (10 + 0) and highest (10 + 1,000) density. Crabs increase in size only during molting (ecdysis). Crabs are known to undergo molting in stressful conditions. The presence of other crabs and the absence of shelter in the treatment without red seaweeds can cause stress. Shelters are usually provided to reduce stress and prevent cannibalism (Millamena and Bancaya, 2001). In the same manner, the overcrowding because of too much seaweeds can have the same effect. Crabs need space during molting process (Kargas, 1998). Increase in size (carapace width) does not always translate to a proportional increase in weight as the crabs can exhibit allometric growth pattern. This has been apparent in treatments without seaweeds as the mean ABW in this treatment is lowest among the stocking density combinations.

The data on production parameters also coincide with the data obtained for growth parameters at harvest. The low survival in treatments without seaweeds (10 + 0) and with the highest density (10 + 1,000) is an indication of a stressful condition. In the absence of shelter, the interaction of crabs in treatment without seaweeds would be more frequent. Crabs are highly cannibalistic and actually can prey on their own species (Ingles and Braum, 1991).

Among the treatments, the stocking density of 10 + 750 showed the best results. While the highest SGR can be due to variation in size of the wild caught blue swimming crab, the peak in survival rate and Net Production in this treatment is very apparent. The initial culture conditions are crucial for the survival of the cultured organism. The high seaweed density in treatment with 1,000 g seaweeds may have affected the ability of crabs to acclimatize with the culture environment at the onset of culture. The frequency of moulting is also higher during the early life as a strategy to enhance development of body parts and to attain large size such that they do not become subject to predation. Thus, ensuring suitable and optimum rearing condition at this stage is very imperative.

Red seaweed's grown better in the bottom culture method than the hanging method. The blue swimming crabs in the study were fed with trash fish. Nutrients from these food particles can increase the organic load in the water which can then utilized by seaweeds for their growth and eventually may also increase production (Dash *et al.,* 2003). Uneaten trash fish would normally settle in the bottom. Thus, red seaweeds at the bottom would have better chances of utilizing the nutrients from the uneaten trash fish. Further, since the area is wide and has good water circulation, fouling is prevented.

The best stocking density combination for red seaweeds in the polyculture system was 10 + 750. The best production parameters for blue swimming crabs were also obtained at this stocking density combination. The production of red seaweeds in this stocking density even surpassed that of the treatments initially stocked with 1,000 g seaweeds (10 + 1,000 and 0 +1,000). The synergistic effect observed in treatment stocked with 750 g red seaweeds but not with lower stocking density (500 g) and in the higher stocking density (1,000 g) warrants further investigation. It is suggested that species interaction (e.g. nutrient flow and immune response due to stress or crowding) between the blue swimming crab and red seaweeds be investigated so that differences in growth and production can be further elucidated.

Total investment for a 25 m^3 polyculture of blue swimming crab and seaweed was PhP 11,250 including cash outlays for capital assets (PhP 6,900) and working capital was (PhP 4,350) for the first cropping (Table 3). The annual production cost was (PhP 26, 064) (Table 4). Current price of seaweed (wet) is P45 kg^{-1} and P60 (dry). Gross returns $crop^{-1}$ is PhP 41, 095.30 with an annual net income of PhP 15, 031.30 in one run of production. Return of investment is 40% with a payback period of 2.5 years (Table 5).

Table 3. Investment for Polyculture of Blue swimming crabs and red Seaweeds in 25 m^3 floating net cages.

Item	Quantity	Unit Cost (PhP)	Total Cost (PhP)	Economic Life	Annual Depreciation
Capital Asset					
Bamboo Raft	1 unit	1,500	1,500	5	500
Polyvinyl Rope #8	1 roll	1,500	1,500	5	50
Pail	3 pcs	50	150	2	75
Nylon Net	125 m	30	3750	3	187
SUBTOTAL			**6,900**		**812**
Working Capital (First Crop)					
Labor in making net cages	25 persons	150	3,750		
Labor in constructing bamboo raft	4 persons	150	600		
SUBTOTAL			**4,350**		
Total Investment			**11,250**		

Table 5. Cost and returns from Polyculture of Blue crabs and Red Seaweeds in 25 m^3 floating net cages.

Item	**Quantity**	**Unit Cost**	**Total**
A. RED SEAWEED			
Seedling Density (kg.25 m^3)	32.5	30/kilo	975
Ave. Yield (kg fresh) (2.72% day^{-1})	152.32		
Less Seedling Allocation (kg)	32.5		
Net Yield (fresh. kg)	119.82	45'kilo	5,391.90
Dry Yield (20% moisture content kg)	23.96	60/kilo	1,437.60
SUBTOTAL			**5,391.90**
Gross Returns (SW)			**37,743.30**
B. BLUE SWIMMING CRABS			
Seedling Density (kg.25 m^3)	11		
Ave. Yield (kg) (0.94% day^{-1})	5.72	50/kilo	439
Less Seedling Allocation (kg)	11		
Net Yield (kg)	5.72	150/kilo	858
NET RETURNS			
A. First Crop			419
Gross Returns (Crab)			3,352
Less Production Cost			439
Net Returns 1st crop			419
Succeeding Crops (2nd-8th, crabs)			3352
B. Gross Returns (SW+ Crabs)	37,743.30	3352	41,095.30
Less Production Cost	SW- 22,552	Crab – 3,512	26,064
Annual Net Returns			**15,031.30**
ROI			40%
Payback Period (years)			2.5

The polyculture of blue swimming crab with red seaweed in floating net cages can provide additional income for the aquaclturist through sale of two commercially important commodities. The technology and the culture method used in the polyculture system is simple. The cultured commodity are also easy to harvest and can be sold on a daily basis. Live blue swimming crabs with complete limbs are priced well while dried seaweed has higher market value than fresh ones but 20% moisture loss is considered when computing for its economic yield.

The polyculture system using floating cage structures requires lower capital cost investment compared to land based farms. About 50% of the initial investment goes to the raft and cages. The cost of investment in the first run of production maybe high (Php 6,900) (Table 3) but is substantially reduced in the succeeding runs.

The study highlights the feasibility of the polyculture of blue swimming crabs and red seaweeds. However, more detailed economic analysis would be required to evaluate the polyculture of blue swimming crabs with red seaweeds at the optimum culture scheme and stocking density combination (10 + 750) determined in this study.

4. Conclusions and Recommendations

The polyculture of blue swimming crabs and red seaweeds was evaluated in the paper. The evaluation included analysis of production and economic parameters as well as the interaction of culture scheme and stocking density combination for the red seaweeds. Among the stocking density combination evaluated, blue swimming crabs stocked with 750 g of red seaweeds showed the best production parameters. Further, the seaweeds in this stocking density combination also showed the best growth. Comparison of the culture scheme showed best performance for red seaweeds grown using the bottom method. Also, the economic analysis showed an ROI of 40% and a payback period of 2.5 years.

The paper highlights the feasibility of the polyculture of blue swimming crabs and red seaweeds. Based on the results, the polyculture of 10 crabs in 1 m^3 floating cage with 750 g red seaweeds using the bottom culture scheme obtained the best results. However, the information derived from the study points to the need to do a more detailed economic analysis specifically on the derived optimum stocking density combination. Further, it is also suggested that species interaction (e.g. nutrient flow and immune response due to stress or crowding) between the blue swimming crab and red seaweeds be investigated so that differences in growth and production can be further elucidated.

6. References

Agbayani, R.F., (2001). Production, economics and marketing of mud crabs in the Philippines. Asian Fisheries Sciences. 14 (2): 201 – 210.

Armisen, R., and Galatas, F., (1987). Commercial seaweeds production properties and uses of agar. In: Production and utilization of products from commercial seaweeds. Paper No. 288 (Ed. by D.J. Mchugh).1-49. FAO Fish Tech., FAO, Rome, Italy.

Batoy, C., Sarmago, J., and Pilapil, B., (1998). Breeding season, sexual maturity and fecundity of the blue crab, *Portunus pelagicus (L.)* in selected coastal waters in Leyte and Vicinity, Philippines. Annals of Tropical Research 9: 157 - 177.

Chandkrachang, S., (1990). Seaweed/polyculture, a new approach in Thailand, In: Seventh Session of the Indo – Pacific Fishery Commission Working Party Of Fish Technology and Marketing, Bangkok, Thailand, Vol. 401, p. 307 – 308.

Chiang, Y.M., (1992). Seaweed culture in Taiwan. In: (ed. by I.C. Liao, J.H. Cheng, M. C. Wu and J.J. Guo). 143 -151. Institute of Oceanography, National University of Taiwan.

Clark, M.E., Wolcott, T.G., Wolcott, D.L., and Hines A.H., (1999). Intraspecific interference among foraging blue crabs *Callinectes sapidus*: interactive effects of predator density and prey patch distribution. Marine Ecology Progress Series 178: 69-78.

Dash, B., Kumar, S., and Rao, S., (2003). Integration of seaweed (*Kappaphycus alvarezii*) and pearl oyster (*Pinctada fucata*) along with Asian seabass (*Lates calcarifer*) in open sea floating cage off Andhra Pradesh Coast India. National Fisheries Development Board Central Fisheries Marine Research Institute, Kochi, Kuala, India.

Dat, H.D., (1999). Studies on the rearing on the larvae of the mudcrab (*Scylla paramamosain*) in South Vietnam. Pages 147 – 152 in Keenan,CP. And Blackshaw, A.W. (eds.) Mudcrab Aquaculture and Biology. Proceedings of an International Scientific Forum held in Darwin, Australia, 21-24, April 1997. ACIAR Proceedings No. 78 Watson and Ferguson Company, Brisbane, Australia.

De Castro, T.R., Guanzon, N.G. Jr., and Luhan, M.R.J., (1991). Assessment of natural stocks of Gracilaria in Panay Island, Philippines, Botanica Marina., 34. 383-391.

De Castro, T.R., and Guanzon, N.G. Jr., (1993) Growth of *Gracilaria sp* (Graciliarales, Rhodophyta) in brackishwater ponds at different stocking densities. The Israel Journal of Aquaculture – Bamidgeh 45, 89–94.

Eleserio, F.O., and Mandreza, M.M., (2010). Blue Swimming Crab Survey in Guimaras Strait and Capiz. Travel Report dated February 15, 2010. Bureau of Fisheries and Aquatic Resources, Quezon City, Philippines.

Eleserio, F.O., and Mandreza, M.M., (2010). Blue Swimming Crab Survey in Negros Occidental and Iloilo. Travel Report dated January 7, 2010. Bureau of Fisheries and Aquatic Resources, Quezon City, Philippines

FAO., (2011). Mud crab aquaculture: a practical manual. FAO Fihseries and Aquaculture Technical Paper 567. FAO, Rome, Italy

Glover, T., and Mitchell, K., (2002). An introduction to biostatistics. McGraw-Hill. New York. 416 pages.

Gomez, K., and Gomez, A., (1984). Statistical procedures for agricultural research (2^{nd} Ed). John Wiley and Sons, Singapore

Guanzon, N. Jr., Mallare, T., and Lorque, F., (2004). Polyculture of milkfish *Chanos chanos (Forskal)* and the red seaweed *Gracilariopsis bailinnae (Zang et Xia)*in brackish water earthen ponds. Aquaculture Research. 35: 423-431.

Hurtado, A., and Agbayani, R., (2000.) The farming of the seaweed *Kappaphycus*. Southeast Asian Fisheries Development Center - Aquaculture Department, Tigbauan, Iloilo, Philippines.

Ingles, J., and Braum, E., (1991). Reproduction and larval ecology of *Portunus pelagicus* from Ragay Gulf Philippines. Int. Rev. Gesanmt. Hydroboil. 74(5): 771-786.

Kargas, M.I., (1997). Synopsis of the biology and exploitation of the blue swimming crab *Portunus pelagicus Linnaeus* in Western Australia: Fisheries Research in Reports. Western Australia Marine Research Laboratories: (1) 1- 17.

Marichamy, R., (1996). Mudcrab culture and hatchery. Bulletin Central Marine Fisheries Research Institute. 48: 103 – 107.

Millamena, O.M., and Bangcaya, J.P., (2001). Reproductive performance and larval quality of pond raised *Scylla serrata* females fed with various broodstock diets. Asian Fisheries Science.14 (2): 153 – 159.

Millamena, O.M., and Quinitio, E.T., (2000). The effects of diets on the reproductive performance of eyestalk ablated and intact mud crab *Scylla serrata*. Aquaculture. 181 (1-2): 81-90.

Juwana, S., (1998). Experiment on the polyculture of *Portunus pelagicus* and *Oreochromis niloticus* in the net pens. *Oseanologidan Limnologi di Indonesia*. 34 (2): 151 - 179.

Potter, I.C., Chrystal P.J., and Loneragan N.R., (1983). The biology of the blue manna crab *Portunus pelagicus* in an Australian estuary. Marine Biology 78: 75 – 85.