

Pond Culture of Mud Crab *Scylla serrata* (Forsk.) Fed Formulated Diet With or Without Vitamin and Mineral Supplements

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Abstract

The effects of three diets (Diet 1 – with vitamin and mineral supplements, Diet 2 – without vitamin and mineral supplements, and Diet 3 – fish bycatch) and monosex culture (male or female) on the growth, survival, feed conversion ratio (FCR), and production of mud crab *Scylla serrata* were investigated using a 2 x 3 factorial experiment with three replicates per treatment. Juvenile mud crabs were stocked at 1.0-m⁻² in 150 m² ponds and reared for 156 days. Results showed no significant interaction between monosex culture and diets ($P > 0.05$) so that data were pooled by sex and dietary treatment. Mean final body weight of male crabs (427 g) was significantly higher ($P < 0.05$) than female crabs (400 g). However, crab carapace length (CL) and width (CW), specific growth rate (SGR), FCR, survival, and production were not significantly different ($P > 0.05$) between the two sexes. Regardless of sex, crabs fed fish bycatch (Diet 3) gave significantly higher ($P < 0.05$) mean body weight (435 g) than those fed Diet 2 (395 g). Mean final body weight (410 g) of crabs fed Diet 1 was not significantly different from those fed Diets 2 or 3. The CL and CW, SGR, FCR, survival, and production of mud crabs fed the three diets, however, were not significantly different ($P > 0.05$). The economic viability of using a diet without vitamin and mineral supplements was comparable to that of a complete diet having about the same cost of production and return on investment of 74 to 75%. The study shows that cost-effective formulated diet could be used as alternative feed for fish bycatch thus saving on feed and storage costs.

Introduction

Various studies on the important facets of mud crab aquaculture have been undertaken in the Indo-Pacific region (Angell 1992). In the Philippines, pond culture trials on the monoculture of mud crab to determine its optimum stocking density (Baliao et al. 1981) and in polyculture with milkfish (Lijauco et al. 1980) have been reported to yield economically viable production (Agbayani et al. 1990,

Samonte and Agbayani 1992). Triño et al. (1999) demonstrated that stocking density could be increased from an optimum of 0.5-m^2 (Baliao et al. 1981) to 1.5-m^2 using monosize and monosex culture (Cholik and Hanafi 1992), and the provision of shelter for molting and post-molt crabs (Hill et al. 1982, Fielder et al. 1988 and Chen 1990) to minimize the loss of stock due to cannibalism. High growth rates were obtained indicating the profitability of mud crab culture in ponds. Apparently, information leading to the development of mud crab aquaculture technology in the Philippines has significantly increased since the first published report (Arriola 1940) on the pond culture of mud crab six decades ago.

The use of fish bycatch and other fresh or fresh-frozen unprocessed feeds for mud crabs is prevalent among the cited reports and is presently a common practice among mud crab culturists. The costs of these feeds continue to increase and in time its use may no longer be profitable, especially in the Philippines, because of their high storage cost and limited availability. Formulated diets using cheap and indigenous feed ingredients could be an alternative feed. How-Cheong et al. (1992) observed that formulated diets were well accepted by mud crabs. Marasigan (1999) reported that the SGR of mixed species of mud crabs fed prawn pellets was comparable with those fed unprocessed feed. Similar results were found by Kuntiyo (1992) when crabs were fed commercial prawn pellets and fish bycatch.

Feed cost is considered the most expensive single factor in the culture of mud crabs as it constitutes 40 to 50% of the total cost of production (Triño et al. 1999). Commercial prawn feeds are very costly since most of the ingredients are imported and prices are continually rising (Millamena and Triño 1997). Thus it is necessary to use cheap and locally produced feed materials in order to save on feed cost.

Another way of reducing feed cost is by eliminating vitamin and mineral supplements from the diet. Vitamin and mineral supplements account for about 20 to 23% of the total feed cost (Triño and Sarroza 1995). Vitamins and minerals are essential nutrients for animals but the dietary requirements are low (Morrison 1957) and may be obtained from feedstuffs used, natural food organisms and other sources (Akiyama et al. 1991, Lovell 1991). Triño and Sarroza (1995) have shown that the elimination of vitamin and mineral supplements from the diet did not affect the growth and survival of *P. monodon* juveniles in ponds where natural food organisms were available. To date, there is no information on the performance of mud crab *S. serrata* fed diets with or without vitamin and mineral supplements.

The present study was undertaken to evaluate the growth, survival and pond production of male or female mud crabs fed formulated diets with or without vitamin and mineral supplements and to demonstrate the economic viability and profitability of the various treatments.

Materials and Methods

The study was conducted in 18 units of 150 m^2 earthen ponds at the Western Visayas Demonstration Fish Farm (WVDF) in Molo, Iloilo City,

Philippines. A 2 x 3 factorial experiment in a completely randomized design with three replicates per treatment was carried out for 156 days. The performance of monosex male or female mud crabs fed the three diets [Diet 1 – with vitamin and mineral supplements, Diet 2 – without vitamin and mineral supplements, and Diet 3 – fish bycatch (*Lieognathus* sp)] was determined. The crabs were stocked at 1.0·m⁻². The enclosures and ponds were prepared following Triño et al. (1999).

Crab juveniles were collected from their natural habitat in Samar, Philippines. The crabs were stocked two days after the pond water reached 80 cm. Thereafter, water depth was maintained at 80 to 100 cm. For three consecutive days during spring tide periods, 30% of the water volume in the pond was drained and replenished for the first month, 40% for the second month, 50% for the third month, and 60% for the fourth month until the end of the culture period. Plankton and seaweed *Gracilariopsis bailinae* growth were maintained with 45-0-0 and 16-20-0 (N-P-K) fertilizers at the rate of 12 kg and 25 kg·ha⁻¹, respectively, after the end of the three-day water replenishment. Water temperature, salinity, dissolved oxygen concentration, pH, and water depth were monitored daily at 0730 h.

The crabs were fed the formulated diets a day after stocking at the rate of 5% of the crab biomass daily when the CL was <6 cm, and 2% when the CL was ≥6 cm (Kuntiyo 1992). Fish bycatch was given at 10 and 5% on wet weight basis, respectively (Yalin and Qengsheng 1994). The daily feed ration was equally divided and given at 0730 h and 1700 h feeding schedules. This was adjusted monthly based on the new estimated biomass for each treatment replicate from the stock sampling.

The growth, apparent feed conversion ratio (FCR), survival, and production were calculated from the total harvest. The means were compared by analysis of variance and Duncan's multiple range test at 5% level of significance (SAS Institute 1988).

Cost-return and partial budgeting analyses were done to compare the viability and profitability of the various treatments used (Shang 1990).

Results

Pond water quality did not vary much between ponds. Values recorded for the duration of the experiment were: temperature, 27.8 to 29.6°C; salinity, 25.2 to 30.2 ppt; D.O., 3.7 to 8.9 ppm; pH, 7.8 to 8.9. The values were within the ranges reported by Triño et al. (1999) and were generally within acceptable levels for pond culture (Boyd 1990).

Table 1 shows the composition and cost·kg⁻¹ of the experimental diets. The elimination of vitamins and minerals has reduced the cost of Diet 2 by 20% compared to Diet 1. Proximate composition of the test diets (Diets 1 and 2) is shown in table 2. There is very little variation in crude protein, crude fat and crude fiber but substantial in nitrogen free extract and ash. Diet 3 gave the highest crude protein but lowest in crude fat, nitrogen-free extract and estimated metabolizable energy values.

Growth, FCR, survival, and production of pond-reared male or female crabs fed the diets are shown in table 3. There was no significant interaction between sex and diet (Table 3) in growth, FCR, survival and production so that data were pooled by sex and dietary treatment (Table 4). Mean body weight of male crabs (427 ± 8.42 g) was significantly higher ($P < 0.05$) than female crabs (400 ± 8.57 g). However, crab CL and CW, SGR, FCR, survival, and production were not significantly different ($P > 0.05$). Regardless of sex, crabs fed fish bycatch (Diet 3) reached a significantly higher ($P < 0.05$) mean body weight (435 ± 9.62 g) than those fed Diet 2 (395 ± 11.0 g). Mean body weight of crabs fed Diet 1 was not significantly different ($P > 0.05$) from those fed Diets 2 and 3. The CL and CW, SGR, FCR, survival and production of crabs, however, were not significantly different ($P > 0.05$) among dietary treatments.

Table 1. Composition (kg) and cost per kg of the experimental diets

Ingredient	Diet 1		Diet 2	
	Composition (PhP)	Cost (PhP)	Composition	Cost
Fish meal	0.25	5.62	0.25	5.62
Brown mussel meat meal	0.25	5.00	0.25	5.00
Rice bran	0.095	0.35	0.125	0.45
Corn bran	0.10	0.50	0.10	0.50
Bread flour	0.17	1.92	0.17	1.92
Seaweeds	0.05	0.60	0.05	0.60
Cod liver oil	0.025	2.12	0.025	2.12
Soybean oil	0.025	1.12	0.025	1.12
Vitamin mix ¹	0.02	4.00	0.00	0.00
Mineral mix ¹	0.01	1.30	0.00	0.00
Ethoxyquin	0.005	0.05	0.005	0.05
Sub-total	1.00	22.58	1.00	17.38
Processing cost		3.00		3.00
Total	1.00	25.58	1.00	20.38

¹Deshimaru and Kuroki (1974)

Table 2. Moisture and proximate composition % of the experimental diets on a dry matter basis

	Diet 1	Diet 2	Diet 3
Moisture	7.41	6.56	4.76
Crude protein	40.22	40.14	66.14
Crude fat	11.42	11.92	6.91
Crude fiber	1.57	1.44	1.56
Nitrogen-free extract	36.56	37.93	3.43
Ash	10.23	8.57	21.96
Metabolizable energy (kcal-100g) ^a	393.00	399.00	364.00

Analysis was done according to AOAC (1979)

^aMetabolizable energy was calculated based on the standard physiological values of 4.5 kcal-g protein, 3.3 kcal-g carbohydrate and 8 kcal-g fat (Brett and Groves 1979). Diet 3 consisted of *Leiognathus* sp.

Table 5 summarizes the investment cost for a one hectare male or female mud crab culture (on a per crop basis) fed the diets (using pooled data from table 4). The total investment was expressed in terms of capital cost and working capital. The capital cost include the cost of materials and labor for the construction of the net enclosures. The cost of equipment was added in Diet 3 since a freezer for the storage of fish bycatch was used. Pond development cost was not included in the analysis as it was assumed that the ponds were ready as they were in this study. The major components of the working capital were the feed (41 to 48% of the total working capital), crab juveniles (34 to 38%) and materials for pond preparation (6 to 7%). Caretaker's salary was computed on a per hectare basis assuming that a caretaker paid PhP1,500 could efficiently handle three hectares of crab culture ponds and has rendered service for six months (includes pond preparation). The amount of PhP200 for repairs and maintenance was low as there was little repair done within one year after construction. Annual pond rent was PhP8,000. The computation for pond rent was based on a per crop basis assuming that there are two crops in one year.

Table 3. Mean final body weight (BW), carapace length (CL) and width (CW), specific growth rate (SGR), apparent food conversion ratio (FCR), survival and production of male or female *S. serrata* fed the test diets for 156 days.

Sex	Male			Female		
	D-1	D-2	D-3	D-1	D-2	D-3
Diet						
BW (g)	419.3	410.3	451.5	401.6	379.9	418.8
CL (cm)	9.0	8.9	9.4	8.7	9.0	9.2
CW (cm)	13.2	13.0	13.8	13.0	13.2	13.5
SGR (%/day)	1.8	1.8	1.9	1.9	1.8	1.9
FCR	2.5	3.0	2.2	2.1	2.3	2.2
Survival (%)	45.8	40.2	51.6	48.9	49.1	45.8
Production (kg)	28.8	24.8	35.0	29.5	28.0	28.8

There was no significant interaction between sex and diet at $P > 0.05$, on dry weight basis.

Table 4. Mean body weight (BW), carapace length (CL) and width (CW), SGR, FCR, survival and production of pond-reared male or female mud crabs *S. serrata* fed the test diets*

	Monosex culture		Diet		
	Male	Female	Diet 1	Diet 2	Diet 3
BW (g)	427.20±8.42 ^a	400.10±8.57 ^b	410.50±9.01 ^{ab}	395.40±11.00 ^b	435.10±9.62 ^a
CL (cm)	9.00±0.12 ^a	8.99±1.12 ^a	8.87±0.13 ^a	8.94± 0.11 ^a	9.33±0.10 ^a
CW (cm)	13.30±0.16 ^a	13.20±0.17 ^a	13.02±0.21 ^a	13.11± 0.17 ^a	13.64±0.12 ^a
SGR (%/day)	1.85±0.01 ^a	1.86±0.01 ^a	1.84±0.01 ^a	1.82± 0.01 ^a	1.87±0.01 ^a
FCR	2.53±0.16 ^a	2.18±0.11 ^a	2.29±0.15 ^a	2.62± 0.20 ^a	2.16±0.15 ^a
Survival (%)	45.85±2.29 ^a	47.92±2.31 ^a	47.33±2.00 ^a	44.67± 3.17 ^a	48.67±3.32 ^a
Production (kg)	29.54±1.96 ^a	28.76±1.21 ^a	29.14±1.20 ^a	26.49± 1.65 ^a	31.82±2.40 ^a

*Since there was no significant interaction ($P > 0.05$) between sex and diet, data were pooled by sex or dietary treatment. Means ± SE with similar superscripts between sexes or among dietary treatments are not significantly different ($P > 0.05$).

The cost-return and partial budgeting analysis for male or female mud crab culture (on a per hectare basis) fed the diets (using pooled data from table 4) is shown in table 6. The unit cost-kg⁻¹ of crab produced was based on the price offered by export brokers during the harvest. Marketable *S. serrata* are on the medium (300 to 499 g) and large (500 g) group classifications for export so that *S. serrata* < 300 g are rejected.

Table 5. Investment cost (PhP) for male or female mud crab cultures fed the test diets

	Monosex culture		Diet		
	Male	Female	Diet 1	Diet 2	Diet 3
Capital cost:					
Construction of net enclosures	27,445	27,445	27,445	27,445	27,445
Chest Freezer, 12 ft ³					24,000
Total capital cost	27,445	27,445	27,445	27,445	51,445
Working capital:					
Crab juveniles	85,000	85,000	85,000	85,000	85,000
Feeds	115,651	98,368	114,087	92,932	114,000
Materials for pond preparation	15,096	15,096	15,096	15,096	15,096
Storage cost (electricity)	3,750				
Miscellaneous expenses ¹	7,877	10,314	18,279	16,687	19,687
Caretaker's salary	3,000	3,000	3,000	3,000	3,000
Repairs and maintenance	200	200	200	200	200
Pond rent	4,000	4,000	4,000	4,000	4,000
Interest on capital ²	10,331	9,737	10,864	9,774	11,847
Total working capital	241,155	225,715	250,526	226,689	256,580
Total investment	268,600	253,160	277,971	254,134	308,025

Data based on table 4.

Values are on a per hectare per crop basis (in Philippine Peso). Prevailing market price in Iloilo, Philippines as of December 1997 (in Philippine Peso; US\$=PhP40).

¹2% of revenues

²8% of investment per year

Table 6. Cost-return and partial budgeting analysis for male or female mud crab fed the three diets

	Monosex culture		Diet		
	Male	Female	Diet 1	Diet 2	Diet 3
Total harvest (kg):					
Male	1,969		960	826	1,167
Female		1,910	982	933	957
Total revenues at sale price of PhP270·kg ⁻¹ for female and PhP200·kg ⁻¹ for male	393,800	515,700	457,140	417,110	491,790
Less:					
Working capital (Table 5)	241,155	225,715	250,526	226,689	256,580
Net revenue	152,645	289,985	206,614	190,421	235,210
Production cost (PhP·kg ⁻¹)	122	118	129	129	121
Return on investment (ROI, %)	57	115	74	75	76
Incremental benefit		212,900	40,030		34,650
Incremental cost		(15,440)	23,837		6,054
Net benefit		140,340	16,193		28,596

Data based on table 4

Values are on a per hectare per crop basis (in Philippine Peso).

Monosex males or females that fed on the three diets showed a high net revenue and a return on investment (ROI) of 57 and 115%, respectively (Table 6). Comparative cost-return analysis showed that higher net revenue and ROI and lower cost of production were attained by monosex females and Diet 3. Partial budgeting analysis showed that a higher profit (PhP140,340) can be earned using monosex females rather than monosex males. On the other hand, more net benefit can be obtained by using Diet 1 (PhP16,193) rather than Diet 2; and Diet 3 (PhP28,596) rather than Diet 1.

Discussion

After 156 days, mud crab monosex culture significantly influenced the final body weight but not the CL and CW, SGR, FCR, survival, and production. The males obtained significantly higher body weight than females as also reported by Cholik (1999) and Triño et al. (1999).

Regardless of sex, the growth, FCR, survival, and production of mud crabs fed Diet 2 (no vitamin and mineral supplements) were not significantly different from those fed Diet 1. Although the final body weight of mud crabs fed Diet 2 was significantly lower than those fed Diet 3. The other parameters (CL, CW, SGR, FCR, survival and production) did not differ significantly, suggesting that the overall performance of crabs fed Diet 2 is comparable with those crabs fed Diet 3. These findings are similar to the results of Kuntiyó (1992) and Marasigan (1999) who noted a comparable performance of mud crab fed prawn pellets and fish bycatch.

Since feed is one of the major inputs in production, lowering feed cost is important in making mud crab culture viable and profitable. The elimination of vitamin and mineral supplements from the diet is one way of saving on feed cost.

Studies on other crustacean species conducted on farm conditions showed that vitamin and mineral supplementation is not necessary when natural food organisms are present in ponds (Castille and Lawrence 1989, Triño et al. 1992, and Triño and Sarroza 1995). Natural food comprises an important food source of cultured aquatic species in a pond ecosystem. Rubright et al. (1981) attributed an increase in shrimp production in fertilized and artificially fed ponds to the abundant occurrence of polychaetes, copepods and nematodes. The tracer experiment of Anderson et al. (1987) with pond-reared *Penaeus vannamei* stocked at 20·m⁻² showed that the natural food organisms accounted for 53 to 77% of the growth of the cultured shrimp.

The ponds used in the present study were observed to have an abundance of fiddler crabs, gastropods, polychaetes, copepods, chironomid larvae and mosquito fish before and a few days after stocking. Thereafter, their numbers declined in time suggesting that the cultured mud crab preyed on them. Small crabs, crustaceans, and mollusk are the major prey groups of

S. serrata in the wild and their importance as food source for mud crab from the standpoint of energy/protein and essential nutrient requirements was pointed out by Hill (1979).

Mud crab survival for the present study range from 45 to 49% and were lower compared to those attained by Triño et al. (1999) for mud crab raised at three stocking densities (0.5, 1.5, and 3.0 individuals·m⁻²). Since the stocking density used in the present study (1.0·m⁻²) is within the range recommended by Triño et al. (1999), crab survival rates may be expected to be within the range (57 to 98%) and not lower. This could be a result of added mortalities due to extension of culture duration to 156 days to obtain an exportable size of mud crabs at harvest. Whereas, Triño et al. (1999) had their rearing duration for only 120 days. Mud crabs are highly cannibalistic and the more they are exposed to each other the more mortalities are incurred due to cannibalism. This was further aggravated by pollution towards the last month of culture, caused by the construction of a building and the establishment of a motor pool and a terminal of a bus company immediately adjacent to the experimental ponds. Cement powder were carried by the winds into the ponds while being poured into a mixer at the construction site. On rainy days, greasy water coming from the motor pool found its way into the ponds. No water and soil analyses, however, were conducted to determine the extent of pollution.

Despite low survival due to the above mentioned occurrences, comparative cost-return analysis showed higher net revenue, ROI and lesser cost of production·kg⁻¹ for female monosex culture than for males. Partial budgeting analysis showed an increase in revenues and a decrease in working capital when female crabs were used for culture. This resulted in a substantial net benefit indicating that more profit can be earned from female culture. In contrast, Triño et al. (1999) concluded that more profit can be earned from male crab culture, primarily, because the price·kg⁻¹ margin offered by export brokers among sexes was not too wide compared to the price offered in the present study. Prices of mud crab in the Philippines are not stable and fluctuate depending on sex and season. They are relatively highest during the months of December, January and February. The trend in market price indicates that females are offered a much higher price, thus, widening the price margin between females and males or mixed sex mud crabs.

The formulated diets used in the present study cost less than commercial prawn feeds. The reduced feed cost, from PhP34·kg⁻¹ for a commercial feed used by Kuntiyo (1992) to PhP20-26·kg⁻¹ for formulated diets used in this study can result in reduced costs of production, increased net revenue and a higher ROI.

Although the economic evaluation revealed that a higher net revenue and a lower cost of production were attained by Diet 3, the ROI varied very little among the diet treatments suggesting that the use of low-cost formulated diets (with or without vitamin and mineral supplements) is a viable alternative for fish bycatch as feed for mud crab. A cold storage equipment to keep fish bycatch and other unprocessed feed requires

electricity to operate, thus, the use of low-cost formulated diet can eliminate these expenses.

The study shows the economic viability of using formulated diets with or without vitamin and mineral supplements. Both incurred similar costs of production and gave 74 and 75% ROI.

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