# Development of Polyculture Technology for Giant Freshwater Prawns (*Macrobrachium rosenbergii*) and Mola (*Amblypharyngodon mola*)

Quality Seedstock Development/Experiment/09QSD03UM

Md. Abdul Wahab
Bangladesh Agricultural University
Mymensingh, Bangladesh

Liu Liping
Shanghai Ocean University
Shanghai, China

James S. Diana
University of Michigan
Ann Arbor, Michigan, USA

## ABSTRACT

This project evaluated potential developments in prawn polyculture by testing a variety of polyculture systems for growth and yield. Experiment 1 tested the effects of selective harvesting (SH) and claw ablation (CA) of blue-clawed (BC) prawns on an all-male freshwater prawn-finfish polyculture system. Ponds were stocked with all-male freshwater prawn *Macrobrachium rosenbergii*, silver carp *Hypophthalmichthys molitrix*, catla *Catla catla* and mola *Amblypharyngodon mola* at 12000, 2000, 500 and 20000 per ha, respectively. Prawns were fed with pelleted feed. Ponds were fertilized regularly with urea, triple super phosphate and cow-dung. SH of BC prawns in treatment SH and CA in treatment CA started on the 60th day during a 137-day culture and continued at 15-day intervals until the final harvest. Treatment SH resulted in a higher ($P<0.05$) net production of freshwater prawn (437 kg/ha), with better survival and mean weight, followed by CA (354 kg/ha) and Co (322 kg/ha). The combined net production of prawn plus finfish was also higher in SH (1244 kg/ha) as compared with CA (1161 kg/ha) and Co (1137 kg/ha), although the finfish production did not differ significantly.

In experiment 2, the potential of addition of the nutrient-dense, small fish mola into polyculture with freshwater giant prawn was evaluated at the Fisheries Field Laboratory, Bangladesh Agricultural University, Mymensingh during August to December 2010. The effects of mola at different densities in polyculture with freshwater prawn, and the production performance between all-male and all-female freshwater prawn in monoculture were evaluated. The experiment had five treatments: all male prawn + 1 mola $m^{-2}$, all male prawn + 1.5 mola $m^{-2}$, all male prawn + 2 mola $m^{-2}$, only male prawn and only female prawn ($T_1$, $T_2$, $T_3$, $T_4$ and $T_5$, respectively) with three replications each. Prawn stocking densities were the same (3 juvenile $m^{-2}$) in all treatments. Feeds were supplied twice daily for prawn in all ponds at appropriate feeding rates. Plankton, macro-benthos abundance and water quality parameters (except transparency and chlorophyll-a) did not vary significantly ($P>0.05$) among the treatments. Survival of prawn in monoculture irrespective of gender was lower than in polyculture with mola. Mean harvest weight, weight gain, specific growth rate, net and gross production of all female prawn was significantly ($P<0.05$) lower than all male and those of other treatments with different densities of mola. Addition of mola at different densities had no effect on survival, gain in weight, or production performance of freshwater prawn. Therefore, mola may be stocked as an additional species with freshwater prawn that would give higher total production, provide family nutrition as well as generate additional income.

In experiment 3, the effects of adding silver carp and catla to mola and freshwater giant prawn in polyculture systems were evaluated. The experiment had five treatments: $T_1$ (prawn and mola), $T_2$ (prawn, mola and catla), $T_3$ (prawn, mola and silver carp), $T_4$ (prawn, mola, catla, and silver carp), and $T_5$ (only mola), each with three replications. Stocking density of mola varied to produce approximately the same total fish biomass in all the treatments. Prawn stocking densities were 120 juvenile $dm^{-1}$ (dm=decimal =$40m^2$) and 6 carp $dm^{-1}$. Feeds were supplied twice daily for prawn at appropriate feeding rates. Water quality parameters (except transparency) did not vary significantly among treatments. Survival of freshwater prawn in prawn-mola-carps polyculture system were relatively higher where prawn and mola were stocked with silver carp and catla, and with silver carp, respectively than with only mola or with mola and catla. Net and gross production of prawn were significantly higher with silver carp and with silver carp-catla but not with only mola or mola-catla. Average weight gains, SGR, net and gross production were significantly lower for silver carp than in catla or in catla-silver carp treatments. The balanced stocking densities of prawn-mola with catla - silver carp developed a synergistic interaction resulting higher net and gross productions. Net and gross productions were significantly higher in treatment $T_5$, where only mola was stocked at higher densities. Therefore, carps can be added with prawn and mola to enhance total production, which would play a significant role in providing family nutrition as well as generating additional income.

# Experiment 1: Effects of Selective Harvesting and Claw Ablation on All-Male Freshwater Prawn Production

## INTRODUCTION

The present study was carried out to determine the effects of bi-weekly selective harvesting (SH) and bi-weekly claw ablation (CA) of blue-clawed (BC) freshwater prawns on the growth and production of all-male prawn *Macrobrachium rosenbergii* stocked in polyculture systems with silver carp *Hypophthalmichthys molitrix*, catla *Catla catla* and mola *Amblypharyngodon mola*.

## MATERIALS AND METHODS

The experiment was conducted using a completely randomized block design in 12 earthen ponds (nine ponds each with 100m2 and three ponds each with a150 m2 area) having1.0m water depth at the Fisheries Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh, during 137 days. The experiment included three treatments: SH, CA and SH+CA of all-male freshwater prawn and a control (Co) without SH and CA. Each treatment had four replicas. All ponds were treated with lime (powdered $CaCO_3$) before stocking, and fertilized with urea and triple super phosphate (TSP) at the rate of 25 kg/ ha and semi-decomposed cow-dung at 1000 kg/ha 13 days after liming. Seven days after fertilization, all ponds were stocked with all male prawn juveniles (mean weight 5.58 g each), silver carp (17.93 g), catla (23.07 g) and mola (0.52 g) at stocking densities of 1.2, 0.2, 0.05 and 2.0 per $m^2$ respectively. Male prawn juveniles were selected manually. Freshwater prawns were fed with pellets (28% crude protein) daily at a rate of 6% of body weight for the first month, 4% for the second month and 3% for the rest of the culture period. Half of the daily ration was supplied in the morning at 8:00 and the rest in the evening at 17:00. Ponds were fertilized at 5-day intervals with urea and TSP at a rate of 6.25 kg/ha and cow-dung at 125 kg/ ha to maintain natural food organisms.

Periodic selective harvest of BC from treatment SH and ablation of BC in treatment CA were started on day 60 after stocking. These procedures were continued every 15 days until the final harvest. BC prawns were identified by their blue-colored and long. A seine (1.0 cm mesh size) was used for SH and CA of BC. Seining was performed twice at each sampling time in the respective ponds. All seined BC in treatment SH were harvested, and blue claws of all seined BC in treatment CA were ablated. Selectively harvested BC prawns were not replaced, while claw-ablated BC prawns were released immediately into the respective ponds. Neither SH nor CA of BC prawns was performed in the control. Partial harvesting of larger mola using the same seine (1.0 cm mesh size) was started on day 75 and continued at 15-day intervals until the final harvest, because mola bred within 60-70 days of stocking in all ponds. The counts and weights of selectively harvested and claw-ablated prawns as well as the weights of partially harvested mola were recorded.

All prawns, silver carp and catla harvested from each pond were counted, measured and weighed individually. Mola of each pond were batch weighed. Survival rate, specific growth rate (SGR) and individual weight of this species were not considered for calculation as mola were self recruiting and bred in all ponds during the culture period. The specific growth rate and feed conversion rate (FCR) of prawn, silver carp and catla was calculated.

One-way analysis of variance (ANOVA) was performed for the statistical analysis of growth and production. Survival and per cent data were analyzed using arcsine-transformed data but per cent values are reported. All statistical tests were carried out at a 5% significance level using Statistical Package for Social Science (SPSS).

## RESULTS AND DISCUSSION

The average individual weight of harvested prawn was significantly higher in treatment SH (55.45 g), followed by treatments CA (52.83 g) and Co (49.60 g, Table 1). The survival of prawn was also higher in treatment SH (76%) than in treatments CA (66%) and Co (65%). The survival rate of prawn in treatment SH was calculated on the basis of accumulated harvests. The SGR was significantly lower in treatment Co (1.59 %) than in treatments SH (1.68%) and CA (1.64%). The net production of prawn differed significantly among the treatments, with better performance in treatment SH (437 kg/ha), followed by CA (354 kg/ha) and Co (322 kg/ha). FCR was calculated for prawn, which was significantly lower in SH (2.19) than in CA (2.77) and Co (2.95).

Table 1. Comparison of growth and production parameters (mean ± SE, N = 4) of prawn in control (Co), selective harvesting (SH) and claw ablation (CA) treatments during a 137-day culture period.

| **Species/parameters** | **Co** | **SH** | **CA** |
|---|---|---|---|
| Freshwater prawn | | | |
| Individual stocking weight (g) | 5.63 ± 0.05 | 5.57 ± 0.07 | 5.56 ± 0.57$^{b}$ |
| Individual weight at harvest (g) | 49.60 ± 0.62$^{c}$ | 55.45 ± 0.72$^{a}$ | 5.83 ± 2.44 |
| Survival (%) | 65.35 ± 0.52$^{b}$ | 75.69 ± 0.54$^{a}$ | 66.32 ± 1.02$^{b}$ |
| SGR (%bw/day) | 1.59 ± 0.01$^{b}$ | 1.68 ± 0.01$^{a}$ | 11.64 ± 0.01$^{a}$ |
| Gross production (kg/ha) | 481 ±10 | 462 ± 6 | 471 ± 5 |
| Net production (kg/ha) | 445 ± 9 | 427 ± 6 | 435 ± 5 |
| Gross production (kg/ha) | | | |
| Large (50 g and above) | 257 ± 9$^{b}$ | 407 ± 15$^{a}$ | 303 ± 20$^{b}$ |
| Medium (33.3–49.9 g) | 84 ± 12 | 84 ± 11 | 102 ± 16 |
| Small (33.2 g and below) | 48 ± 4$^{a}$ | 13 ± 1b | 15 ±1b |
| Total | 389 ± 8$^{c}$ | 504 ± 6$^{a}$ | 420 ± 8$^{b}$ |
| Net production (kg/ha) | 322 ± 8$^{c}$ | 437 ± 6$^{a}$ | 354 ± 8$^{b}$ |

Mean values with different superscripts indicate a significant difference ($P<0.05$) based on Tukey's test.
SGR, specific growth rate; bw, body weight.

Individual growth parameters of silver carp and catla and the amount of mola at every harvest did not vary significantly among treatments (Table 2). The combined productions of finfish were also not significantly different among the treatments. However, the combined net productions of all species including freshwater prawn were higher in treatment SH (1244 kg/ha) than those of treatments CA (1161 kg/ha) and Co (1137 kg/ha).

Table 2. Comparison of growth and production parameters (mean ± SE, N = 4) of silver carp and catla in different treatments during a137-day culture period.

| **Species/parameters** | **Co** | **SH** | **CA** |
|---|---|---|---|
| Silver carp | | | |
| Individual stocking weight (g) | 17.74 ± 0.40 | 17.66 ± 0.10 | 18.19 ± 0.29 |
| Individual weight at harvest (g) | 240.47 ± 4.86 | 231.06 ± 2.95 | 235.68 ± 2.44 |
| Survival (%) | 100 | 100 | 100 |
| SGR (%bw/day) | 1.90 ± 0.01 | 1.88 ± 0.01 | 1.87 ± 0.01 |
| Gross production (kg/ha) | 481 ±10 | 462 ± 6 | 471 ± 5 |
| Net production (kg/ha) | 445 ± 9 | 427 ± 6 | 435 ± 5 |
| Catla | | | |
| Individual stocking weight (g) | 22.83 ± 1.14 | 22.13 ± 0.90 | 24.05 ± 0.73 |
| Individual weight at harvest (g) | 477.27 ± 10.94 | 466.92 ± 7.19 | 468.38 ± 16.46 |
| Survival (%) | 100 | 100 | 100 |
| SGR (%bw/day) | 2.22 ± 0.05 | 2.23 ± 0.02 | 2.17 ± 0.01 |
| Gross production (kg/ha) | 242 ± 2 | 237 ± 4 | 238 ± 5 |
| Net production (kg/ha) | 231 ± 3 | 226 ± 4 | 225 ± 5 |
| Carp combined | | | |
| Gross production (kg/ha) | 723 ± 10 | 699 ± 3 | 709 ± 9 |
| Net production (kg/ha) | 676 ± 10 | 653 ± 3 | 660 ± 9 |

SGR, specific growth rate; Co, control; SH, elective harvesting; CA, claw ablation; bw, body weight.

The amount of bi-weekly selectively harvested BC in treatment SH was19% of stocked prawn, which constituted 29% in weight of total harvested prawn. BC individuals in treatment CA were ablated biweekly and released back into the respective ponds, and they constituted 18% of stocked prawn in number. The cumulative selective harvest of BC (2267 individual/ha) and claw-ablated BC (2125 individual/ha) did not vary significantly. The amount of BC at final harvest was significantly higher in treatment Co (1325 per ha) than that in treatments SH (758) and CA (758). However, treatment SH yielded a significantly higher total number of BC (3025 per ha), followed by CA (1741) and Co (1325). Aggregate number of all harvested prawn was also significantly higher in treatment SH (9083 per ha) than in CA (7958) and Co (7841).

The percentages of three different morphotypes among harvested male prawns within each treatment were estimated. Blue claws, orange claws (OC), and small males (SM) were 34.6%, 58.7% and 6.7% respectively in treatment SH; 22.9%, 68.5% and 8.6% in treatment CA; and 17.7%, 55.1% and 27.2% in treatment Co. Some female prawns (4-5% in number) were also recovered at harvest due to error in manual selection of juveniles before stocking. However, the percentage of female prawns did not vary significantly both by number and weight among treatments. Harvested females were of two morphotypes: females with eggs (berried) and females with wide open pleura, indicating that they had already spawned.

The mean weight of BC was significantly higher in Co (85.2 g) than in CA (71.8 g) and SH (68.3 g). The mean weight of OC and SM did not vary significantly among treatments; however, the mean weight of all types of male prawn collectively was significantly higher in SH (55.9 g), followed by CA (53.2 g) and Co (50 g).

Selective harvesting and CA contributed to a 36% and 10% increase in net production of freshwater prawn, respectively, over controls. These differences could have resulted from the survival rate and individual weight differences attained at harvest. While the SGR of prawn between treatments SH and CA did not vary significantly, the survival rate and individual weight at harvest were significantly higher in treatment SH. Interestingly, the numbers of selectively harvested BC in treatment SH and claw-ablated BC in treatment CA were almost similar. Thus, the remaining prawns in both treatments had an equal opportunity to remain free from the growth suppression due to BC (Karplus et al.,1989). However, periodic harvest of BC from treatment SH reduced the prawn density, which also minimized the intra-specific competition for food, space and shelter (Fujimura & Okamoto, 1972), which was not the case in treatments CA and Co. Significantly higher numbers of SM at harvest found in Co indicated that a large number of SM were not able to transform into BC through OC, and their growth was stunted (Karplus et al., 1992) by the suppression phenomenon of BC.

The amounts of prawn and fish harvested are important under the conditions in Bangladesh. Treatment SH yielded 504 kg/ha of prawn, which represented 30% and 20% increased production over Co and CA. This production figure is comparable to other reported values considering the stocking densities and culture period (Kunda et al., 2008; Jose et al., 1992; Nair et al., 1998). Treatment SH had the best FCR (2.2), although this index does not always reflect the direct contribution of diets (D'Abramo & New, 2000), because of natural productivity.

In most polyculture systems, there is a target species and some minor species. The yield of minor species is usually considered to be a bonus to the yield of the target species (Garcia-Perez et al., 2000). Freshwater prawn was the prime species and thus finfish might be considered as secondary species. Although the prawn production (31-37% of total production) was less than finfish production in terms of biomass, its value in sale price was much higher and would constitute about 70-77% of the total benefit in all treatments. This has implications for both profit and household finfish consumption.

## Experiment 2: Addition Of Mola Into Polyculture With Freshwater Giant Prawn

### INTRODUCTION

Bangladesh is considered one of the most suitable countries in the world for giant freshwater prawn farming, because of its favourable resources and agro climatic condition. The prawn and shrimp sector as a whole is the second largest export industry after readymade garments, generating US$ 380 million annually which is 5.6% of the total value of exports (DoF, 2006). Marine shrimp and freshwater prawn production for 2008-2009 was 145,585 MT. Therefore, this sector had good performance and is gradually changing economic status of the farmers, as well as creating new employment opportunities. But prawn production is low compared to neighboring countries. Males grow larger and faster than females at maturity and, therefore, all-male culture would be economically advantageous (Sagi and Aflalo, 2005). Monosex all male prawn culture may be one means to increase giant freshwater prawn production.

Mola is a very important small indigenous species which is a good source of essential nutrients, particularly vitamin A. Poor farmers in this country are incapable of providing protein rich meals to their children due to high price of commodities, including fish. Culture of freshwater prawn for export market and mola in the same pond for household consumption may be an innovative option. Introduction of mola will also improve the culture environment by controlling phytoplankton blooms, which are produced mainly due to wastes derived from the high protein diet used in prawn farming (Assaduzzaman et al., 2005). Therefore, the purpose of the proposed study is to develop a new sustainable polyculture technology for all-male giant freshwater prawns and mola to increase the average productivity of high-value prawns for export, as well as to provide highly nutritious fish for household consumption.

## MATERIALS AND METHODS

Experiments 2 was done in 15 earthen ponds (9 ponds 100 $m^2$ each and 6 ponds 140 $m^2$ each) for 135 days in a completely randomized design into five different treatments with three replications each (Table 3).

Table 3: Experimental design with density of mola and gender difference of prawn as the main variables.

| Species | Stocking density/ $m^{-2}$ | | | | |
|---|---|---|---|---|---|
| | Treatment 1 | Treatment 2 | Treatment 3 | Treatment 4 | Treatment 5 |
| Male prawn | 3 | - | 3 | 3 | 3 |
| Female prawn | - | 3 | - | - | - |
| Mola | - | - | 1 | 1.5 | 2 |

All unwanted fishes were eradicated by rotenone application at 30 g $decimal^{-1}$ (one decimal = 40 $m^2$) and lime was applied at 250 kg $ha^{-1}$ five days after rotenone application. Urea and TSP were applied at a rate of 50 kg $ha^{-1}$ in each pond after application of lime. Juvenile freshwater prawn (1.75 g) and mola (0.80 g) fry were collected from a nearby nursery in Mymensingh and stocked according to the experimental design.

Formulated feeds were applied at 10% body weight in the first month, reduced to 7% in the second month, then reduced to 3% until the end of the experiment. Feeds were prepared using a local pellet machine with following ingredients: fish meal 15%, mustard oil cake 20%, soybean meal 20%, rice bran 20%, maize flour 20%, molasses 4%, and vitamin-mineral premix 1%.

Water quality parameters were monitored on biweekly basis and growth sampling on monthly basis to adjust the feeding rate and to evaluate fish growth. A number of water quality parameters such as temperature ($^0$C), transparency (cm), pH, dissolved oxygen (mg $l^{-1}$), alkalinity (mg $l^{-1}$), phosphate-phosphorus (mg $l^{-1}$), nitrate-nitrogen (mg $l^{-1}$), nitrite-nitrogen (mg $l^{-1}$), ammonia-nitrogen (mg $l^{-1}$), and chlorophyll-a were measured biweekly. Temperature, transparency, pH and dissolved oxygen were measured in situ and the remaining parameters were measured at the Water Quality and Pond Dynamics Laboratory, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh.

Prawn and mola were sampled monthly using a seine. Length and weight of 10 individuals of each species from each pond were measured separately to assess health condition and growth. Length was measured using a centimeter scale and weight was taken using a portable balance (OHAUS, model No.CT-1200-S). Culture animals were completely harvested on 17 December 2010 after 135 days of rearing. Partial harvesting was performed by repeated netting, using a seine. Final harvesting was done by draining the ponds using a pump. During harvest, all individuals from each pond were counted and weighed to assess survival rate and pond production.

For the statistical analysis, a one-way ANOVA (Analysis of Variance) was done by using the SPSS (Statistical Package for Social Science) version-11.5. Significance was assigned at the 0.05 level.

## RESULTS AND DISCUSSION

The experiment had five treatments: all male prawn + 1 mola $m^{-2}$, all male prawn + 1.5 mola $m^{-2}$, all male prawn + 2 mola $m^{-2}$, only male prawn, and only female prawn, and were treated as $T_1$, $T_2$, $T_3$, $T_4$ and $T_5$, respectively with three replications each.

All physical and chemical parameters except transparency and chlorophyll-*a* did not differ significantly among different treatments (Table 4). In treatment $T_4$, and $T_5$, where mola was not stocked with prawn, transparency was significantly lower than the other treatments, where prawn was stocked with mola. There were no significant differences ($P<0.05$) among treatments in pH, dissolved oxygen, temperature, alkalinity, $NO_3$-N, $NO_2$-N, $NH_3$-N and $PO_4$-P. Highest average pH (8.06±0.28) was found in the treatment $T_1$ and lowest (7.91±0.27) in the treatment $T_2$. Dissolved oxygen and alkalinity were within a suitable range for prawn culture in all the treatments and did not differ significantly ($P>0.05$) among the treatments. Nitrate, nitrite, ammonia and phosphate did not show significant differences among treatments and were also in suitable range for aquaculture. In treatments $T_4$ and $T_5$, prawns were monocultured so that they could not utilize all the nutrients produced in the water body since formulated feed was supplied. On the contrary, in the treatments $T_1$, $T_2$, and $T_3$, mola was stocked with prawn, utilized the phytoplankton produced in the water-body, and transparency was higher in those ponds.

Table 4: Mean values (± SD, N= 33) of water quality parameters for each treatment. Means with the different superscripts are significantly different (*P<0.05*) based on Tukey's test.

| Variables | Treatments | | | | |
|---|---|---|---|---|---|
| | **$T_1$** | **$T_2$** | **$T_3$** | **$T_4$** | **$T_5$** |
| Transparency (cm) | 35.73±4.92$^a$ | 36.55±4.06$^a$ | 36.82±4.26$^a$ | 32.64±3.16$^b$ | 31.42±3.37$^b$ |
| pH | 8.06 | 7.91 | 7.95 | 7.94 | 7.95 |
| Dissolve oxygen (mg $l^{-1}$) | 6.17±0.77 | 5.99±0.73 | 5.87±0.67 | 5.79±0.69 | 5.78±0.67 |
| Temperature ($^0$C) | 29.80±2.18 | 30.41±1.84 | 30.08±1.95 | 29.64±2.01 | 28.91±3.02 |
| Alkalinity (ppm) | 118.09±39.99 | 118.36±37.65 | 111.64±34.84 | 113.27±41.08 | 113.27±41.08 |
| $NO_3$-N (mg $l^{-1}$) | 0.02±0.02 | 0.02±0.01 | 0.02±0.01 | 0.02±0.02 | 0.02±0.02 |
| $NO_2$-N (mg $l^{-1}$) | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| $NH_3$-N (mg $l^{-1}$) | 0.05±0.08 | 0.06±0.08 | 0.07±0.09 | 0.05±0.07 | 0.05±0.07 |
| $PO_4$-P (mg $l^{-1}$) | 1.68±1.10 | 1.45±1.21 | 1.35±0.86 | 1.45±0.74 | 1.45±0.74 |
| Chlorophyll-*a* (mg $l^{-1}$) | 98.55±39.07$^b$ | 94.48±45.41$^b$ | 97.80±47.10$^b$ | 135.48±61.63$^a$ | 131.77±48.05$^a$ |

Mean harvest weight of female prawns (21.67±1.53) was significantly lower than that of male prawns (Table 5). Mean harvest weight did not vary significantly in all treatments including male prawns. Therefore, female prawns showed lower growth rate than male. Mean weight gain showed similar trends as harvest weight. The rate of survival of male prawns did not differ significantly among treatments with different stocking densities of mola, but differed significantly ($P<0.05$) in monoculture of female and male prawn. At the same time, survival of male and female prawns in monoculture did not differ significantly. Survival of prawns in polyculture was higher than in monoculture. Specific growth rate (SGR) of female prawns was significantly lower treatment in $T_5$ than the SGR of male prawns either in monoculture or polyculture (Table 5). SGR did not vary significantly in all cultures including male prawns. Net production of prawns varied significantly between monoculture of males and females, but did not vary among different treatments including male prawn. Net production of male prawn monoculture was significantly (P<0.05) higher than net production of female prawn monoculture. The same trends were shown for gross production.

Mola of same initial weight were stocked in different densities to observe any effect on performance of prawns. There were no significant variations in terms of prawn production among different treatments with male prawns (Figure 1). None of the production characteristics of mola differed significantly among polyculture treatments, mainly due to high variation in mola growth among replicates. There were no significant differences in net production of prawns and mola among treatments, but gross production was highest in polyculture treatments.

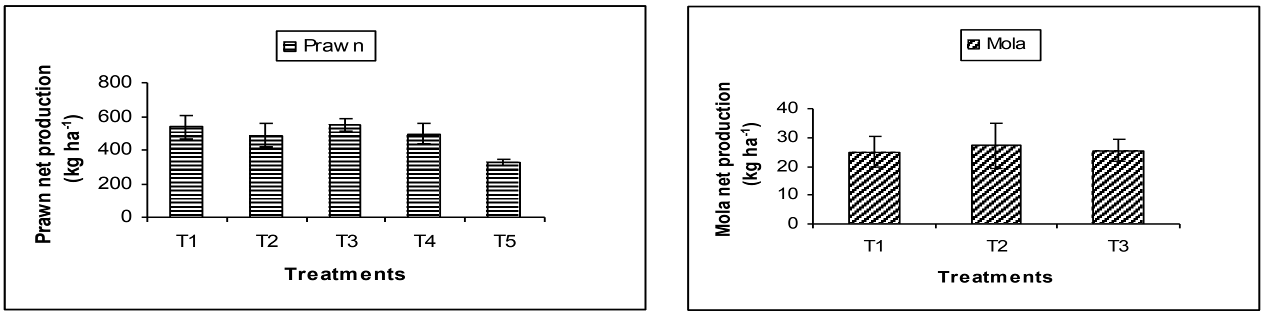


Figure 1. Net production of prawn and mola in different treatments.

Table 5: Production performance of prawn and mola in each treatment. Mean values (± SD,) with the different superscripts are significantly different (*P<0.05*) based on Tukey's test.

| Variables | Treatments | | | | |
|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
| ***Macrobrachium rosenbergii*** | | | | | |
| Mean stocking weight | 1.75±2.00 | 1.75±2.64 | 1.75±1.00 | 1.75±3.51 | 1.75±1.53 |
| Mean harvest weight (g) | 30.00±3.51$^a$ | 29.00±2.64$^a$ | 30.00±1.00$^a$ | 31.67±2.00$^a$ | 21.67±1.53$^b$ |
| Mean weight gain (g) | 29.92±3.51$^a$ | 27.25±2.64$^a$ | 28.25±1.00$^a$ | 28.25±2.00$^a$ | 19.92±1.53$^b$ |
| Survival (%) | 59.76±1.32$^{ab}$ | 59.48±2.77$^{ab}$ | 64.78±2.87$^a$ | 58.51±2.60$^b$ | 53.91±1.36$^b$ |
| SGR (% body weight) | 2.10±0.05$^a$ | 2.07±0.06$^a$ | 2.10±0.24$^a$ | 2.14±0.08$^a$ | 1.86±0.05$^b$ |
| Net production (Kg $h^{-1}$) | 536.62±68.04$^a$ | 487.63±70.56$^a$ | 549.19±36.53$^a$ | 496.89±57.19$^a$ | 321.71±17.93$^b$ |
| Gross production (Kg $h^{-1}$) | 538.05±42.11$^a$ | 518.86±71.99$^a$ | 583.20±37.84$^a$ | 557.63±86.07$^a$ | 350.01±17.39$^b$ |
| ***Amblypharyngodon mola*** | | | | | |
| Mean stocking weight | 0.08±0.00 | 0.08±0.00 | 0.08±0.00 | - | - |
| Mean harvest weight (g) | 3.567±0.71 | 2.767±0.49 | 2.800±0.20 | - | - |
| Mean weight gain (g) | 2.77±0.71 | 1.97±0.49 | 2.00±0.20 | - | - |
| SGR (% body weight) | 1.09±0.15 | 0.91±0.14 | 0.92±0.05 | - | - |
| Net production (Kg $h^{-1}$) | 24.98±5.27 | 27.12±8.05 | 25.42±3.83 | - | - |
| Gross production (Kg $h^{-1}$) | 32.39±5.92 | 38.18±8.96 | 35.56±4.45 | - | - |
| **Prawn and mola combined** | | | | | |
| Net production (Kg $h^{-1}$) | 561.60±69.46$^a$ | 494.30±64.49$^a$ | 569.64±52.77$^a$ | 515.29±70.84$^a$ | 328.74±25.41$^a$ |
| Gross production (Kg $h^{-1}$) | 570.44±41.34$^a$ | 529.34±63.19$^a$ | 610.89±60.15$^a$ | 583.04±105.68$^{ab}$ | 360.16±29.55$^b$ |

Mola mainly feed upon plankton grown in the water-body and prevent plankton blooms in the culture system. Dense growth of phytoplankton can deplete dissolved oxygen in the water-body. Freshwater prawn is an omnivorous species, but mainly a benthivore that utilizes artificial feed. So, a large amount of phytoplankton produced in monoculture ponds remains unutilized and nutrient decomposition associated with this causes heavy growth of phytoplankton, reducing transparency and depleting dissolved oxygen, which is harmful for prawn survival. Mola consume phytoplankton and help to retain better water quality without hampering prawn growth or competing with prawn for feed.

Addition of mola at different densities had no effect on survival, gain in weight, and production performance of prawn. Therefore, mola may be stocked as an additional species with freshwater prawn that would give higher total gross production, provide family nutrition as well as generate additional income. Freshwater prawn polyculture with mola has good potential to be implemented in Bangladesh and can be a sustainable way for income generation, as well as a good source of vitamin A. Moreover, water quality management will be easier and good pond ecology more sustainable for production of freshwater prawn.

## Experiment 3: Effects of Addition of Carps on Growth, Size Structure and Production of Prawn and Mola in A Polyculture System

### INTRODUCTION

Several methods have been employed to increase per unit production (kg/ha) of prawns, including increased size at stocking, increased stocking densities, grading animals prior to stocking and selective harvesting of the largest animals during the growing season, but it is still a challenge is to develop a technology that can raise pond productivity in a sustainable way, while minimizing the use of inputs like energy and capital.

The farmers of Bangladesh are incapable of providing protein rich meal to their children due to the higher price. Zafri and Ahmed (1981) reported that, mola contains 200 IU of vitamin-A per gram of edible protein. A medium size mola individual has about 2.0 g of edible protein in its muscles, which contain 400 IU of vitamin-A. This means that if four mola are eaten daily, it may provide more than 1500 IU of vitamin-A, sufficient to save children from night blindness caused by deficiency of vitamin-A. Introduction of mola also improves the culture environment by reducing phytoplankton blooms, which are mainly due to waste derived from high protein diet used in prawn farming (Assaduzzaman et al., 2005).

Aquaculture in Bangladesh has been developed through the culture of large carps of both native (e.g., rohu *(Labeo rohita)*, catla, and mrigal *Cirrhinus mrigala* and exotic (e.g., silver, grass *Ctenopharyngodon idella*, and common carp *Cyprinus carpio* origin. Several experiments have been carried out to evaluate any interference in the pond among feeding fish (Alim et al., 2004; Milstein et al., 2002; Wahab et al., 2001, 2002, 2003). Silver carp is expected to have a strong impact on the pond ecology because it is a very effective filter feeder and releases nutrients as feces (Milstein, 1992; Milstein et al., 1985). It also is significant to the farmer's family nutrition as it is a cheap fish that a family can afford to eat instead of selling. It is also easily accessible to the poorer section of the population because of its low market price. Among the Chinese carps, silver carp is popular due to its fast growth and unique food habits. They are mainly phytoplankton feeders and can reduce algal blooms. Catla is the fastest growing fish among the three Indian major carps and a suitable species for polyculture. It has also a good market value.

Development of appropriate culture technologies is one of the most important issues in Bangladesh to contribute to the national economy and to improve the standard of living of people through production of freshwater prawn along with high valued carps and nutrient rich small fish. Polyculture may produce increased yield if fish with different feeding habits are stocked in proper ratios and combinations (Halver, 1984). To address this issue, this study was designed to investigate impacts of including carps on growth, production, and pond ecosystem in freshwater prawn-carp-mola polyculture systems.

In order to develop prawn-carp-mola polyculture technology and to enhance overall production and economic benefit, the following objectives were set out for the proposed research: 1. To evaluate the effects of inclusion of catla and silver carp on growth and production of prawn and mola; and 2. To evaluate the effects of addition of carps on pond ecology, prawn-mola production and overall production in the system.

## MATERIALS AND METHODS

The experiment was carried out at the Fisheries Field Laboratory, Bangladesh Agricultural University, Mymensingh, Bangladesh in 15 earthen pond (all ponds are of 140 $m^2$ each) for a period of 70 days in a completely randomized design into five different treatments with three replications of each (Table 6).

Table 6: Stocking densities of animals in each treatment. To maintain same total biomass, mola stocking density varied among treatments.

| Species | Treatment (Stocking density per 40$m^2$) | | | | |
|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
| Prawn | 120 | 120 | 120 | 120 | - |
| Mola | 83 | 60 | 60 | 60 | 272 |
| Catla | - | 6 | - | 2 | - |
| Silver carp | - | - | 6 | 4 | - |

All unwanted fishes were eradicated by drying the pond, and lime was applied at 250 kg $ha^{-1}$ five days after drying. Urea and TSP were applied at 50 kg $ha^{-1}$ in each pond after application of lime. The average weight of freshwater prawn juveniles, mola, catla, and silver carp were 2.3, 1.5, 20.94, 20.82 g. They were collected from a nearby nursery in Mymensingh and stocked according to the experimental design. Stocking densities of mola were different in the treatments $T_1$ and $T_5$ in order to maintain comparable fish biomass among treatments.

Formulated feeds were applied at 10% body weight of prawn for the first month, reduced to 7% for the second month, then reduced to 5% until the end of the experiment. Feeds were prepared using a local pellet machine with following ingredients: Fish meal 15%, Mustard oil cake 20%, Soybean meal 20%, Rice bran 20%, Maize flour 20%, Molasses 4%, Vitamin-mineral premix 1%.

A number of water quality parameters, including temperature ($^0$C), transparency (cm), pH, dissolved oxygen (mg $l^{-1}$), alkalinity (mg $l^{-1}$), phosphate-phosphorus (mg $l^{-1}$), nitrate-nitrogen (mg $l^{-1}$), nitrite-nitrogen (mg $l^{-1}$), ammonia-nitrogen (mg $l^{-1}$), and chlorophyll-a were measured biweekly. Temperature, transparency, pH, and dissolved oxygen were measured on site and the remaining parameters were measured at the Water Quality and Pond Dynamics Laboratory, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh.

Prawn, mola, catla and silver carp were sampled monthly using a seine. Length and weight of 10 animals of each species from each pond were measured separately to assess growth and to adjust feeding rate.

Length was measured by using a centimeter scale and weight was taken by using a portable balance (OHAUS, model No.CT-1200-S). Animals were completely harvested on 10-12 September 2011 after 70 days of rearing. Partial harvesting was performed by repeated netting, using a seine. Final harvest was done by draining the ponds using a pump. During harvesting, all animals in each pond were counted and weighed individually to assess survival rate and pond production.

For statistical analysis of the data, one-way ANOVA (Analysis of Variance) was done by using the SPSS (Statistical Package for Social Science) version-11.5. Significance was assigned at the 0.05% level.

## RESULTS

The experiment had five treatments: prawn-mola, prawn-mola-catla, prawn-mola-silver carp, prawn-mola-catla-silver carp, and only mola, and were redorded as $T_1$, $T_2$, $T_3$, $T_4$ and $T_5$, respectively with three replications each.

All physical and chemical parameters, except transparency did not differ significantly among treatment (Table 7). Water temperature was about 2.8 ºC and transparency about 32 cm. In treatments $T_3$, where silver carp was stocked with prawn and mola, transparency was significantly higher than the treatments without silver carp (Table 7, Figure 2). pH was approximately 8.4, DO about 6.1 mg $l^{-1}$, and alkalinity 130 mg $l^{-1}$. Nitrate concentrations were about 0.02 mg $l^{-1}$, $NO_2$-N about 0.003 mg $l^{-1}$, $NH_3$-N about 0.03 mg $l^{-1}$, $PO_4$-P about 1.7 mg $l^{-1}$, and chlorophyll-*a* about 130 µg $l^{-1}$.

Table 7: Mean values (± SD, N= 18) of water quality parameters of different treatments. Means with the different superscripts are significantly different (*P<0.05*) based on Duncan's test.

| | Treatments | | | | |
|---|---|---|---|---|---|
| **Variables** | **$T_1$** | **$T_2$** | **$T_3$** | **$T_4$** | **$T_5$** |
| Transparency (cm) | 32.83±3.79$^{b}$ (28-42) | 32.33±3.28$^{bc}$ (28-37) | 36.67±3.64$^{a}$ (30-42) | 33.11±3.23$^{b}$ (26-38) | 30.44±1.85$^{c}$ (25-33) |
| pH | 8.42 (8-8.8) | 8.36 (7.9-8.9) | 8.31 (7.9-8.8) | 8.35 (8.0-9.2) | 8.4 (8.1-9.0) |
| DO (mg/l) | 6.17±0.77 (4.64-7.32) | 6.11±0.76 (4.61-7.72) | 6.11±0.84 (4.65-7.72) | 6.02±0.85 (4.01-7.01) | 6.09±0.80 (4.58-7.73) |
| Temperature (°C) | 28.01±2.87 (24.2-33.7) | 28.19±2.77 (24.6-33.9) | 28.41±2.95 (24.9-33.9) | 28.47±2.93 (25.2-33.9) | 28.41±3.04 (24.6-34.0) |
| Alkalinity (mg $l^{-1}$) | 137.16±30.05 (66-182) | 130.27±33.11 (78-178) | 134.05±36.34 (66-220) | 129.16±28.40 (64-172) | 134.27±34.18 (68-188) |
| $NO_3$-N (mg $l^{-1}$) | 0.02±0.01 (0.00-0.05) | 0.02±0.01 (0.00-0.06) | 0.02±0.02 (0.00-0.07) | 0.02±0.01 (0.00-0.06) | 0.03±0.02 (0.00-0.10) |
| $NO_2$-N (mg $l^{-1}$) | 0.0032±0.0028 (0.00-0.01) | 0.0035±0.0032( 0.00-0.01) | 0.0038±0.0036 (0.00-0.01) | 0.0035±0.0030 (0.00-0.01) | 0.0035±0.0030 (0.00-0.01) |
| $NH_3$-N (mg $l^{-1}$) | 0.03±0.05 (0.00-0.16) | 0.02±0.04 (0.00-0.14) | 0.03±0.07 (0.00-0.25) | 0.04±0.08 (0.00-0.34) | 0.04±0.06 (0.00-0.18) |
| $PO_4$-P (mg $l^{-1}$) | 1.75±1.14 (0.27-3.94) | 1.51±0.92 (0.32-3.26) | 1.74±1.12 (0.27-3.38) | 1.66±1.14 (0.41-3.56) | 1.77±1.17 (0.29-4.16) |
| Chlorophyll-*a* (µg $l^{-1}$) | 145.11±65.70 (54.74-270.13) | 134.13±61.22 (44.03-272.51) | 127.74±69.82 (34.51-318.92) | 118.86±61.13 (38.08-223.72) | 141.47±59.98 (73.78-252.28) |

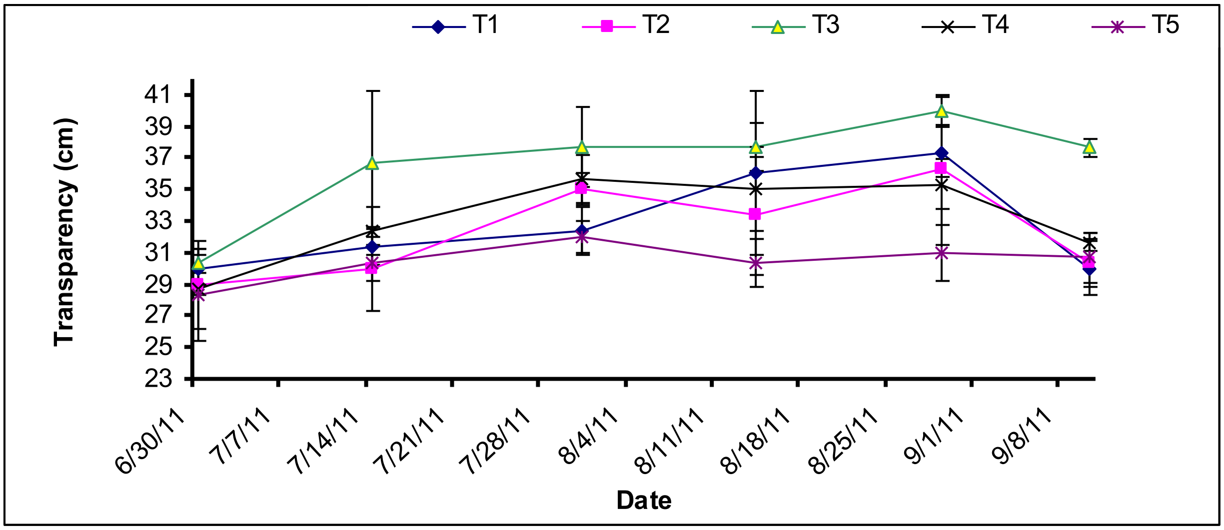


Figure 2. Variation in transparency among treatments.

There were no significant differences in harvested weight, weight gain, or specific growth rate of freshwater prawns in any treatment (Table 8). However, net and gross productions of prawn were significantly higher in $T_3$ and $T_{4,}$ than in $T_1$ and $T_{2,}$ indicating that polyculture with silver carp improved prawn yields.

Survival, weight gain, and daily growth rate of mola did not differ significantly among different treatments. The net and gross production of mola was significantly higher in $T_5$ than in other treatments. This was the result of a much higher stocking density of mola in monoculture ($T_5$) compared to polyculture.

The survival rates of carps were not significantly different among treatments (Table 8). However, average final weight, weight gain, and daily growth rate of carps were significantly lower in $T_3$ (silver carp-prawn-mola) than $T_2$ (prawn-mola-catla) and $T_4$ (prawn-mola-catla-silver carp), indicating that production performance of silver carp alone was lower than that of catla alone, or silver carp with catla. Both net and gross production were again significantly higher in the treatment $T_2$ and $T_4$ than in $T_3$.

As the experiment was designed on the basis of same biomass among different treatments, then total net production can be a good indicator to evaluate production performance among different combination of species. Total net production and total gross production were significantly higher in polyculture treatments $T_2$ and $T_4$ with catla or silver carp-catla compared to other treatments.

Table 8. Production performance of prawn, mola, and carps in each treatment. Mean values (± SD,) with the different superscripts in the same rows were significantly different (P<0.05) based on Duncan's test.

| Species | Characters | Treatment | | | | | Level of significance |
|---|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | |
| Prawn | Survival (%) | 34.92±7.27 | 37.06±6.88 | 55.39±14.92 | 56.34±13.87 | | NS |
| | Average final weight (g) | 12.65±2.09 | 12.59±1.45 | 13.18±1.03 | 12.16±2.17 | | NS |
| | Average weight gain (%) | 450.29±91.03 | 447.68±63.21 | 473.33±44.95 | 428.99±94.64 | | NS |
| | SGR (% bw day$^{-1}$) | 2.42±.25 | 2.42±.17 | 2.49±.11 | 2.36±.25 | | NS |
| | Net Production (kg ha$^{-1}$) | 65.09±40.77$^{b}$ | 72.87±41.07$^{b}$ | 147.38±42.11$^{a}$ | 131.47±24.35$^{ab}$ | | * |
| | Gross production(kg/ha) | 134.09±40.77$^{b}$ | 141.87±41.07$^{b}$ | 216.39±42.12$^{a}$ | 200.47±24.35$^{ab}$ | | * |
| Carps | Survival (%) | | 85.71±4.76 | 92.06±9.91 | 88.89±5.49 | | NS |
| | Average stocking wt (gm) | | 20.83±0.35 | 20.97±0.63 | 20.92±0.04 | | NS |
| | Average final wt (gm) | | 440.47±14.00$^{a}$ | 188.32±4.15$^{b}$ | 378.69±108.80$^{a}$ | | * |
| | Average weight gain (%) | | 2014.40±64.65$^{a}$ | 798.99±42.53$^{b}$ | 1710.23±520.30$^{a}$ | | * |
| | SGR (% bw day $^{-1}$) | | 4.35 ±0.04$^{a}$ | 3.13±0.06$^{b}$ | 4.10±0.38$^{a}$ | | * |
| | Net Production (kg ha$^{-1}$) | | 534.80±29.32$^{a}$ | 229.01±33.96$^{b}$ | 470.08±126.98$^{a}$ | | * |
| | Gross production (kg ha$^{-1}$) | | 566.5±28.86$^{a}$ | 260.45±33.19$^{b}$ | 501.46±126.99$^{a}$ | | * |
| Mola | Stocking no. | 290 | 210 | 210 | 210 | 950 | |
| | Average harvest no. | 410.00±60 | 326.67±66.58 | 304±75.29 | 256.67±70.95 | 1317.33±116.79 | NS |
| | Average final wt (gm) | 1.54±0.084 | 1.70±0.23 | 2.11±0.50 | 2.38±1.36 | 1.46±0.02 | NS |
| | Average weight gain (%) | 2.44±5.59 | 13.11±15.35 | 40.67±33.60 | 58.44±91.03 | -2.66±1.33 | NS |
| | Net Production (kg ha$^{-1}$) | 13.2±4.48$^{b}$ | 16.72±6.58$^{b}$ | 21.7±4.73$^{ab}$ | 16.65±10.11$^{b}$ | 35.57±12.01$^{a}$ | * |
| | Gross production (kg ha$^{-1}$) | 44.79±4.48$^{b}$ | 39.22±6.58$^{b}$ | 44.29±4.73$^{b}$ | 39.16±10.11$^{b}$ | 137.36±12.01$^{a}$ | * |
| Combined | Net Production (kg ha$^{-1}$) | 77.16±44.71$^{c}$ | 622.74±46.81$^{a}$ | 396.54±62.57$^{b}$ | 616.56±146.36$^{a}$ | 35.57±12.01$^{c}$ | * |
| | Gross production (kg ha$^{-1}$) | 178.88±44.71$^{c}$ | 747.14±46.71$^{a}$ | 521.13±61.63$^{b}$ | 741.09±146.37$^{a}$ | 137.36±12.01$^{a}$ | * |

## DISCUSSION

Suitable ranges of all water quality parameters are very important for fish culture, as they provide good environment for health, growth, and development of fish food. The ranges of water temperature in this study were similar to those recorded from rice field culture by Uddin (1998) and Das (2002), who found maximum carp production at those temperatures. pH was similar to values observed to values by Whitton et al. (1988), and dissolved oxygen to values observed by Uddin (1998) and Nirod (1997), again resulting in rapid growth. Similarly, $NH_3$ values were within acceptable ranges for goods survival growth.

Transparency ranged from 25-42 cm in the present study which was within the recommended optimum range 15-40 cm suggested by Boyd (1992). Significantly higher transparency in treatment $T_3$ was probably due to stocking silver carp. The silver carp is a phytoplanktivorous filter-feeder, consuming algae of various sizes (Cremer and Smitherman, 1980; Smith, 1989). It is an appropriate species for polyculture with freshwater prawn and other carps (Rahman, 2010). The fast-growing silver carp increased grazing pressure on phytoplankton, which increased water transparency. Catla consumes zooplankton that collects in open waters (Natarajan and Jhingran, 1961), while mola consume phytoplankton (Jhingran and Pullin, 1985). The number of phytoplankton increased dramatically in the absence of silver carp in ponds supplied with fertilizer, and at the same time, catla consume zooplankton to reduce grazing pressure on phytoplankton.

In the present study, average harvested weight of prawn was comparable with the findings of Karim (2001) for 70 days of culture. Average weight gain and SGR of prawn did not differ significantly among the treatments. Net and gross production values were comparatively lower than Lan et al. (2006) who reported net production at 194-373 kg $h^{-1}$. Net and gross production of prawn were significantly higher with silver carp and with silver carp-catla, but not with mola and mola-catla, probably due to the grazing interactions indicated above. Inclusion of carps did not harm the production of prawn, but maintained higher water quality. Milstein (1992) stated that silver carp can also raise benthophagous fish food resources through faecal pellets in polyculture systems.

Different combinations of carp species with prawn and mola did not show significant differences among treatments in terms of survival of carps. Gross production of catla and silver carp ranged from 260-566 kg $h^{-1}$ in 70 days, which were lower than annual finfish production of 660 kg $h^{-1}$ mentioned as expected by Asaduzzaman et al. (2006a). Average weight gain, SGR, net and gross production of all carps combined were significantly lower for silver carp alone than catla alone or catla-silver carp. Lack of a zooplankton feeding fish in the cultures without catla may have limited overall carp production in $T_3$. Balanced stocking densities of prawn, mola, catla and silver carp appeared to develop a synergistic interaction (Milstein, 2005) that resulted in net and gross production increases.

Average final weight and average weight gain of mola did not differ significantly among treatments as stocking density was adjusted to achieve the same biomass. Average weight gain was negative in treatment $T_5$, as mola offspring of smaller size were found during harvesting. Net and gross productions were significantly higher in treatment $T_5$ in which only mola was stocked in higher densities. But no significant difference was found in mola production with prawn, prawn-catla, prawn-silver carp, and prawn-catla-silver carp indicating there were no negative effects of polycultures on the growth and production of mola.

Net and gross productions were significantly higher when prawn and mola were stocked with catla or with catla-silver carp than with only silver carp or without carps. The lowest production was found by stocking only mola indicating mola was unable to utilize all of the water column and cannot be an economic monoculture system.

Freshwater prawn in polyculture with carps and mola have good potential to be implemented in Bangladesh. It can be a sustainable way for income generation due to high production as well as a good source of protein. Moreover, water quality management will be easier and good pond ecology can be assured. Above all, the farmers will make higher profit with prawn and carp and be able to provide nutrition to family members by inclusion of small indigenous fish, mola.

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