Production of Nutrient-Rich Small Fish *Mola* and Freshwater Prawn Using Integrated Cage-Pond/Carp Polyculture for the Northwest Bangladesh

Production System Design and Best Management Alternatives/Experiment/13BMA03NC

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Abstract

The research aims to increase aquaculture production and household earnings and nutrition of rural farmers by incorporating additional crops (mola fish and freshwater prawn in cages) into current carp pond farming practices in Northwest Bangaldesh. This impoverished region currently lacks crop diversification and could substantially benefit from incorporating both high-value (prawns) and highly nutritious (mola) aqua-foods into traditional carp farming. A small baseline survey assessed the socioeconomic and food consumption patterns of farmers in the region. Almost 45% of income (average of 13,145 Tk or $164/mo) is spent on food. Approximately 30.26% of farmers worried about having enough food, 24% were not able to eat the kinds of foods preferred because of a lack of resources, 76% household members have to eat a limited variety of foods due to lack of resources and 83% of household members have to eat fewer meals in a day because there was not enough food. Households would benefit with additional production of crops, particularly high-value prawns and enhanced production of nutrient rich mola. To this end, an on-farm study was conducted in the Nandigram Upazilla of Bogra District, the Northwest part of Bangladesh to asses the production of nutrient rich small fish mola (*Amblypharyngodon mola*) stocked at different densities with the pond culture of Indian major carps rohu (*Labeo rohita*), catla (*Catla catla)*, mrigal (*Chirninus cirrhosis)* and cage culture of prawns (*Macrobrachium rosenbergii)*. The study evaluated the feasibility of cage-prawn culture, a novel method of culturing prawn. Carp ponds in North Bangladesh are deeper than the Southwest region and often result in significant mortalities. The experiment had three treatments: T_1, T_2 and T_3, where mola were stocked 2.5 m^2, 5.0 m^2, and 10.0 m^2, respectively with five replications for each. The stocking densities of the Indian major carps and prawn were the same in all treatments as each species of the Indian major carps was 0.33 m^{-2} and prawn 15 m^{-2}. Fifteen farmers' ponds with an average of 909 m^2 and an average depth of 1.5 m each were selected randomly for this research. Fertilizers were applied at a rate of 28 kg ha^{-1} and 7kg ha^{-1}, respectively in each pond bi-weekly throughout the study period. Commercial feed (containing 30% crude protein) was used only for prawns at 5% body weight during the study period. Water quality parameters did not vary significantly ($p>0.05$) among the treatments, except transparency and chlorophyll *a*. The individual harvesting weight and individual weight gain of mola were significantly ($p<0.05$) higher in T_1 treatment compared to T_2 and T_3 treatments, respectively but the gross and net yields of mola were significantly ($p<0.05$) higher in T_3 than T_2 and T_1, respectively. A significantly ($p<0.05$) higher individual harvesting weight, individual weight gain, specific growth rate, survival (%), gross and net yields of rohu were also obtained in T_1 treatment than T_2 and T_3 treatments, respectively. However, individual harvesting weight, individual weight gain, specific growth rate, survival (%), gross and net yields of *Catla*, mrigal and prawn did not differ significantly ($p>0.05$) among treatments. The combined gross yield of mola, prawn and the Indian major carps was significantly ($p<0.05$) higher in T_1 and T_2 than T_3 treatment but the net yield of

the same species was significantly higher (*$p<0.05$*) in T_1 than T_2 and T_3, respectively. It was found that the stocking density of mola had significant (*$p<0.05$*) effect on growth and production of the Indian major carps and prawn. The study revealed that mola, Indian major carps and prawn with a stocking density at 2.5 m^{-2}, 0.33 m^{-2} and 15 m^{-2}, respectively was found to provide an higher net production in the mola, prawn integrated cage-pond/carp polyculture system.

INTRODUCTION

Fish are the largest source of animal protein for Bangladeshis. Among fish, small-indigenous species (SIS) are particularly high in minerals or micronutrients. Mola *(Amblypharyngodon mola*) is a SIS is found in the rivers, canals, ponds and ditches, etc., of Bangladesh (Rahman 1989). It is recommended as a potential species in polyculture with carps (Akhteruzzaman et al. 1997, Kohinoor et al. 1998). It is rich in micronutrients and vitamin-content (Thilsted et al. 1997) and can meet the need of family nutrition if grown in the household ponds. Malnutrition of children is a major health problem in Bangladesh. Up to 38% of all pre-school children have vitamin A deficiency, with up to 55% exhibiting signs of iron-deficient anemia (Micronutrient Initiative/UNICEF 2004, West 2002). These effects may be alleviated through the consumption of SIS especially mola which is rich in vitamin A (Ahmed 1981). Four medium size mola, if eaten daily may provide more than 1500 IU of vitamin A, sufficient to save a child from night blindness caused by vitamin A deficiency.

The freshwater prawn (*Macrobrachium rosenbergii)* is a high-value export commodity traditionally cultured in the modified rice fields (ghers) of the Southern Bangladesh (Wahab et al. 2012). Freshwater prawn farming is a major aquaculture industry in many Asian countries because with over 98% of the global production coming from the region (Asaduzzaman et al. 2009a, b). The global production of all freshwater prawns increased from 82,089 to 458,564 tons between 1998 and 2007 (FAO 2009). It is a very popular species in Bangladesh for its attractive look, good taste and growth (Uddin 2007). The increasing demand and steadily rising price in international markets, particularly in the USA, Europe and Japan, and high price in local markets has stimulated development of freshwater prawn farming in Bangladesh (Asaduzzaman et al. 2009a, b; Ahmed et al. 2007), particularly in the southwest coastal areas (DoF 2007). It is contributing to 30% of the total shrimp export, valued at $135 million (Khondoker 2009). Therefore, it is currently one of the most important sectors of the national economy of Bangladesh, and its development has attracted considerable attention during the last two decades because of its high export potential (Ahmed et al. 2010a).

Polyculture is one of the most important and efficient methods for increasing fish production. It encompasses the stocking of different species with complementary feeding habits for better utilization of natural food niches within ponds, often leading to increased fish production (Wahab et al. *2*001). Polyculture of carps in ponds is widely practiced in Bangladesh (DoF 2002). There there is little information on integrated cage-pond/carp polyculture practice with mola and prawns in Bangladesh. Introduction of prawn to the Northern regions of Bangladesh has not been successful, as many carp ponds are too deep for prawn culture. This investigation will employ a novel method of cage prawn culture in Bangladesh. This study will determine the feasibility of cage-prawn culture, in the deeper ponds of North Bangladesh, with both mola and Indian Major Carps. Culture of mola and Indian major carps with high-value prawns will promote greater dietary nutrition with higher earnings among the rural households.

OBJECTIVES

- Conduct a small survey to determine the socioeconomic and food consumption pattern of farmers in the Bogra region;
- To determine the stocking densities of mola and prawns for integrated cage/pond aquaculture with Indian carps; and
- To identify the performances of this integrated system in terms of yields for all species, and effects on water quality.

MATERIALS AND METHODS

Study 1 — Socioeconomic and food consumption pattern of farmers in the Bogra region of Northwest Bangladesh. A survey was conducted using field survey method where the primary data were collected from the respondents. The study area was confined to Nandigram upazila in Bogra district, where the cultivation of indigenous fish is concentrated in family ponds and where AquaFish Innovation Lab on-farm trials are being done for Study 2. Purposive sampling technique was used for selecting the sample. Total sample size of the study was 15. All of the samples were collected from fish farmers. Simple statistical tools were applied for the data analysis in this survey report.

Study 2 — Evaluation of mola stocking density in prawn-cage carp polyculture, and its effect on production yield, market return, and environmental water quality

Experimental design

On-farm research was conducted using a completely randomized block design with three treatments, namely T_1, T_2, and $T_{3,}$ according to stocking density of mola 2.5 m^2, 5.0 m^2, and 10.0 m^2, respectively, with five replications for each to asses the production of nutrient rich small fish mola (*A. mola)* with the pond culture of Indian major carps rohu (*Labeo rohita*), *Catla* (*Catla catla*), mrigal (*Chirninus cirrhosis*) and cage culture of prawns (*Macrobrachium rosenbergii*). The stocking densities of the Indian major carps and prawn were same in all treatments as each species of the Indian major carps was 0.33 m^{-2} and prawn 15 m^{-2}.

Experimental site and pond preparation

The experiment was conducted at the Nandigram Upazila of Bogra District, the northwest part of Bangladesh. Fifteen farmer ponds with an average of 909 m^2 and an average depth of 1.5 m each were selected randomly for this research. All aquatic weeds were cleaned manually and all unwanted fishes were eradicated by repeated netting. Lime ($CaCO_3$) was applied at all ponds at the rate of 1 kg per decimal according to the existing farming system before stocking. Fertilizers like Urea and TSP were applied at a rate of 28 kg ha^{-1} and 7kg ha^{-1}, respectively in each pond. Ponds were left for seven days to allow plankton development in water column and subsequently stocked with prawn, mola and Indian major carps.

Stocking and post stocking management

Juveniles of freshwater prawn and fry of mola and the Indian major carps were procured from a nearby commercial hatchery, which was stocked in all ponds according to the experimental design. The prawn juveniles were stocked separately in an experimental 15 m^3 cages (L× W ×H: 5m × 3m× 1m; nylon netting) in all ponds following the experimental design. Commercial feed containing (30% crude protein) was used only for prawns at 5% body weight during the study period. After stocking fertilizers such as urea and TSP were applied at the same rate before stocking in each pond throughout the experimental period.

Determination of water quality parameters

The water quality parameters were recorded at biweekly interval throughout the experimental period. Water quality measurement and sample collection were made between 9:00 and 10:00 h on each sampling day. The physico-chemical parameters such as temperature (°C), dissolved oxygen (surface and bottom, mgL^{-1}), pH, transparency (secchi-disk, cm), ammonia-nitrogen (mgL^{-1}), nitrate-nitrogen (mgL^{-1}), phosphate-phosphorous (mgL^{-1}) and chlorophyll a (mgL^{-1}) were measured using HQ40d Portable Multi Parameter meter during the study period.

Feeding and growth sampling of prawn and fishes

Individual weights of minimum 10% of initially stocked prawn in numbers were recorded monthly to estimate the biomass and adjust the feeding rate. A seine net (1.0 cm mesh size) was used to observe the growth and health condition of prawn and other fishes and even to make some rough assessment of their growth trends. Weight of prawn and fishes in each sampling was measured by using a portable balance (OHAUS, model No.CT-1200-S). General pond conditions and health condition of prawn and fishes were also monitored frequently throughout the culture period. Care was taken to handle the sampled prawn and fishes due to their susceptibility to handling stress.

Partial harvesting of mola

Partial harvesting of larger mola by using the same seine net (1.0 cm mesh size) in all treatments was started on day 75 and continued with 15-day intervals until final harvest, because mola bred during 60 to 70 days of stocking in all ponds. The weights of partially harvested mola were recorded.

Harvesting of prawn and fishes

At the end of the experiment (after 110 days culture period), all cages were lifted up from each of the ponds manually. Partial harvesting of fishes was done by repeated netting with a fine meshed net towing over the pond. Afterward, water was completely drained out from each pond separately using shallow pump. The rest of the fishes were then harvested from each pond separately. All prawn and fishes were then counted, measured and weighted individually for each pond to assess the survival rate and production. 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 culture period. The following equations were used to determine the growth parameters.

Weight gain (g) = Mean final weight − Mean initial weight

SGR (% bw d^{-1}) = [{Ln (final weight) – Ln (initial weight)}/Culture period in days] x 100.

Survival (%) = (No of fish harvested / No fish stocked) x 100

Gross production = No of fish harvested x Final weight of fish

Net production = No of fish harvest x Weight gain of fish

Statistical analysis

One-way analysis of variance (ANOVA) was performed for comparing growth and production of prawn and tilapias among the treatments. Survival and percent data were analyzed using arcsine-transformed data but percent values were reported. The assumptions of normal distribution and homogeneity of variances were checked before analysis. All statistical tests were carried out at a 5% level of significance using SPSS (Statistical Package for Social Science) version 16.0.

RESULTS AND DISCUSSION

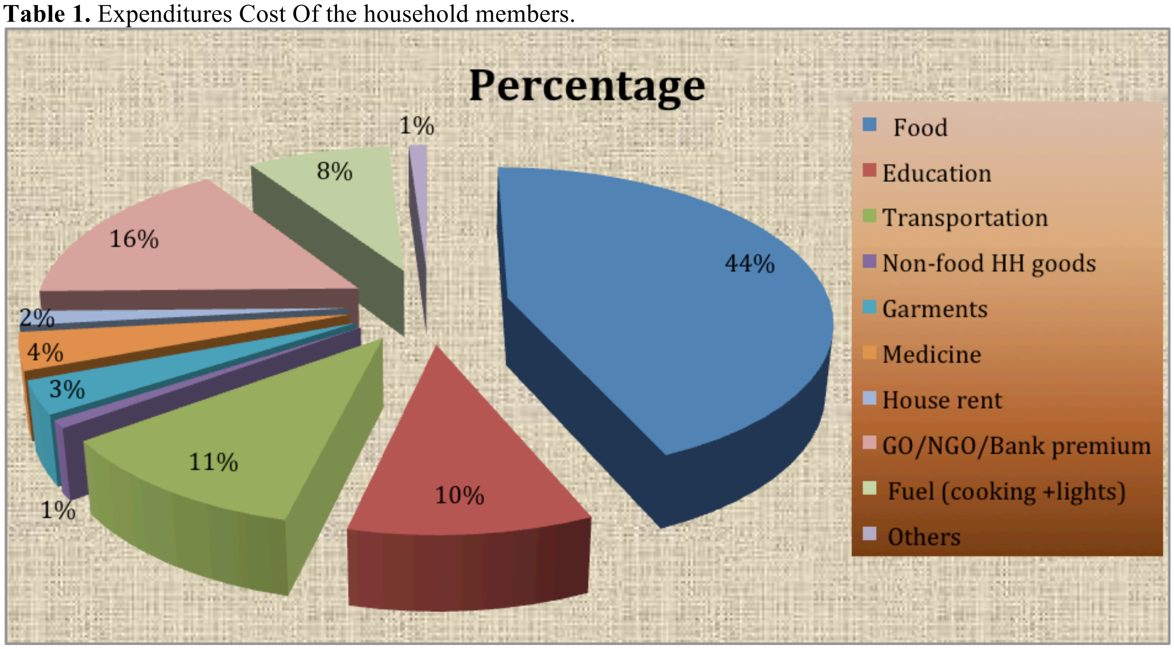
Study 1 — Socioeconomic and food consumption pattern of farmers in the Bogra region of Northwest Bangladesh. In the study area, the average age of farmers engaged in the fish farming activities is 40 years. All of the fish farmers have on average five household members. Among the farmers, 46.67% possess their own land, 33.33% have a small business, 6.67% are students and 13.33% are engaged with other services.

Around 26.67% of fish farmers have signature level qualification, 13.33% have PSC level (grade 5) and 13.33% SSC level (grade 10) of educational qualification, 33.33% have JSC level (grade 12) qualification and 13.33% are illiterate.

Average monthly income of farmers is 13,145 Tk, with 43.481% of income spent on food, 15.943% for repayment of loan to NGOs and banks, 10.246% for education, 11.295% for transportation, 3.442% for garment requirements, 3.899% for medicine, 8.296% for fuel (cooking + lights), and 0.850% for nonfood household requirements and 1.050% spend for others activities in their life (Table 1).

It was found that in the prior four weeks, 30.26% of farmers worried about having enough food, 23.81% were not able to eat the kinds of foods preferred because of a lack of resources, 76.19% household members have to eat a limited variety of foods due to lack of resources, 67.29% have to eat some foods that they really did not want to eat because of a lack of resources in obtaining other types of food, 75.97% of household members felt they had to eat a smaller meal because there was not enough food, and 82.87% of household members have to eat fewer meals in a day because there was not enough food. Also, 17.35% of household members went to sleep feeling hungry because there was not enough food

Table 1. Expenditures Cost Of the household members.



Expenditures Item	Cost Tk	Percentage
Food	**87000**	**43.481**
Education	**20500**	**10.246**
Transportation	**22600**	**11.295**
Non-food HH goods	**1700**	**0.850**
Garments	**6886**	**3.442**
Medicine	**7801**	**3.899**
House rent	**3000**	**1.499**
GO/NGO/Bank premium	**31900**	**15.943**
Fuel (cooking +lights)	**16600**	**8.296**
Others	**2100**	**1.050**
Total	**200087**	**100.00**

Over the prior six months, 76.67% of farmers produced some kind of vegetable. Around 25.67% of farmers consumed 25% of vegetables produced, 27.67% around 50% produced, 15.67 % farmers consumed 75%, and 17.67% farmers consumed all of the vegetables produced. In the past six months, farmers produced 67.67% vegetables on pond dyke.

In the prior six months, 48% of farmers that produced vegetables on their own land provided them to their children < 5 years of age, 17.67% farmers purchased vegetable from the market for their children and 34.23% farmers did not provide vegetables in the selected study areas.

In the prior six months, 42.5% of farmers fruit consumption came from fruits produced on their own land, 21.33% purchased fruits from the market and 11.33% purchased fruits from other sources. Around 15.33% of farmer households consumed a quarter, 37% a half, 22.33% three quarters, and 14.33% consumed all of the fruits produced. Seventy eight percent farmers could provide fruits for their children < 5 years of age and 22.00% farmers did not provide fruits to their children.

Around 73.67% of farmers cultivated fish in their own pond and 26.33% cultivated fish in rented ponds. Around 40.33% of farmers cultured carp fishes and 27.67% cultured small fish. Around 65% of farmers consumed fish each week with 46.33% of farmers consuming carp fish and 53.67% consuming small fish.

The baseline survey indicates there is wide range of scope for the development of mola fish and freshwater prawn.

Study 2 — Evaluation of mola stocking density in prawn-cage carp polyculture, and its effect on production yield, market return, and environmental water quality

Water quality

Water-quality parameters were analyzed in this experiment to observe any appreciable variation among the treatments and mean values and outcomes of one-way ANOVA in the different treatments are presented in Table 2. Water quality parameters did not vary significantly ($p>0.05$) among the treatments, except transparency and chlorophyll *a*. A significant ($p<0.05$) variation on different sampling dates (temporal effects) was also observed on the water quality parameters. No specific trends were observed for temperature, pH, dissolved oxygen, NH_3-N, NO_2-N, NO_3-N and PO_4-P but an increasing trend of transparency and a decreasing trend of chlorophyll *a* were observed in all treatments over the experimental period (Figure 1). Temperature varied from 25.10 to 30.9ºC in all the treatments during the study period. The highest temperature was recorded (30.9 ºC) in the 3rd week of August (August – December study period) in T_1 while the lowest temperature was observed the same week in T_3. DO content was found higher (8.44 mgL-1) in the first week of September in T_2 and lowest was recorded (5.26 mgL-1) in the 3rd week of September in T_1. The value of pH was found higher in T_3 (8.44) and lowest was in T_2 (6.81). The recorded value of transparency was found higher in T_3 than T_2 and T_1. The highest value of transparency (41.20 cm) was found at the first week of December in T_3 and the lowest was recorded before starting of the experiment in the same treatment. A more or less increasing trend of water transparency was observed in all treatments during the experimental period (Fig. 1). The total alkalinity content was observed higher in T_3 and lowest was in T_1. The highest content of NH_3-N was found in T_1 and lowest was in T_2. The level NO_3-N was recorded maximum in T_3 and minimum was in T_1. During the study period, the extreme level of NO_2-N was found in T_1 and lowest level was in T_2. The value of PO_4-P was observed higher in T_3 and lower was in T_2. The chlorophyll *a* concentration was higher in T_1 than T_2 and T_3. The highest value of chlorophyll *a* (204.15 µg L^{-1}) was found in T_1 before commencing the experiment and the lowest (74.0 µg L^{-1}) was recorded in T_3 at the end of the experiment. A decreasing trend of chlorophyll-content was found in all treatments during the experimental period (Figure 1).

Table 2. Mean values of water quality parameter (± SD) in different treatments.

Variables	**Treatments**			**Significance**
	T_1	**T_2**	**T_3**	
Temperature (^oC)	28.73 ± 2.05	28.57 ± 2.14	28.36 ± 2.49	NS
Transparency (cm)	33.40 ± 3.50^b	35.08 ± 3.45^{ab}	37.33 ± 5.4^a	*
pH range	7.60 ± 0.48	7.37 ± 0.63	7.49 ± 0.69	NS
Dissolved oxygen (mg L^{-1})	6.53 ± 1.01	6.41 ± 1.26	6.53 ± 1.06	NS
Total Alkalinity	74.80 ± 14.74	70.73 ± 17.17	78.30 ± 16.31	NS
Total NH_3-N (mg L^{-1})	0.19 ± 0.06	0.16 ± 0.04	0.19 ± 0.05	NS
NO_3-N (mgL^{-1})	0.07 ± 0.06	0.06 ± 0.05	0.06 ± 0.07	NS
NO_2-N (mg L^{-1})	0.041 ± 0.04	0.026 ± 0.04	0.026 ± 0.02	NS
PO_4-P (mgL^{-1})	0.17 ± 0.04	0.15 ± 0.07	0.23 ± 0.28	NS
Chlorophyll *a* (µg L^{-1})	141.88 ± 45.55^a	128.83 ± 36.12^{ab}	117.56 ± 38.64^b	*

NS, Values are not significantly different ($p > 0.05$)

*Values with different superscript letters in the same row indicate a significant difference at 5% significance level based on one-way ANOVA followed by Tukey's test.

The maintenance of good water quality is essential for both survival and optimum growth of culture organisms. Water quality in pond aquaculture are strongly dependent on pond management including combinations of cultured species, stocking densities, and the quantity and quality of the nutrient inputs (Milestein 1993, Diana et al. 1997). In the present study, all of the water quality parameters were within the acceptable range for aquaculture. The observed value of water temperature, dissolved oxygen concentration and pH were within the suitable range for freshwater prawn and tropical fish culture (Boyd and Zimmermann 2000; New 2002; Kunda et al. 2008; Asaduzzaman et al. 2008; Rahman et al. 2010b). Water transparencies, indicating sestonic food abundance, were found to fluctuate from 27–41cm in different treatments, exceeded the upper limit of the recommended range (15–40 cm) suggested by Boyd (1992), but were comparable to the values of Bangladeshi ponds (Wahab et al. 1995, Kohinoor 2000, Uddin 2002, Huq et al. 2004, Asaduzzaman et al. 2009a). Wahab et al. (1995) suggested that the transparency of productive water should be 40 cm or less. The transparency was lower at the beginning of the experiment, but it increased gradually over time in all treatments. These might be attributed to the higher grazing pressure of the cultured herbivorous organisms with the increasing biomass over time, which might be also evidence of the decreasing trends of chlorophyll *a*. It is reported that the transparency of water was affected by many factors such as silt, microscopic organisms, suspended organic matter, season of the year, latitude and intensity of light, application of manure, grazing pressure of fishes or prawns and rainfall (Boyd 1990).

The observed mean values of total alkalinity with the ranges in all treatments were approximately identical to those suggested by Boyd (1990). He showed that alkalinity below 30 mg L^{-1} as $CaCO_3$ limits primary production in well-fertilized ponds, while in unfertilized ponds alkalinity below 120 mg L^{-1} can reduce primary production. It is also reported that 40- 100 mg L^{-1} $CaCO_3$ are optimum for growth of *M. rosenbegii* (New and Singholka 1985), while 20 to 200 mg L^{-1} is optimal (Vasquez et al. 1989). However, the mean values with the ranges of total alkalinity are also comparable to the findings of other authors in this region in prawn polyculture system (Kohinoor 2000, Kunda 2008, Kunda et al. 2008, Asaduzzaman et al. 2010; Rahman et al. 2010a). In the present study, the mean concentrations of all nitrogenous compounds with the ranges were approximately identical suggested by Boyd (1998) in pond aquaculture, and were comparable to the values found by some researchers in prawn polyculture systems in Bangladesh (Asaduzzaman et al. 2008, 2009a, b, 2010; Rahman et al. 2010b). The recorded values of PO_4-P concentrations in different treatments were more or less similar to the Bangladeshi ponds (Wahab et al. 1995, Alim 2005, Khan 2009). Chlorophyll *a* in water body is widely used as an indicator of productivity. The mean values of chlorophyll *a* in all treatments were comparable to the findings of some authors in this region and elsewhere (Kohinoor 2000; Kadir et al. 2006; Milstein et al. 2006; Kunda et al. 2008; Asaduzzaman et al. 2008, 2009a, b, 2010; Rahman et al. 2010b). The observed decreasing trends of chlorophyll *a* in all treatments might be due to higher grazing pressure on phytoplankton by the cultured herbivorus fish over time, which might explain increasing trends of transparency in all treatments over the experimental period. The significantly lower chlorophyll *a* in T_3 followed by T_2 and T_1 treatments might be due to higher grazing pressure associated with greater density of mola. Khatrai (1984) reported a positive relationship between phytoplankton and chlorophyll *a*, whereas Rahman et al. (2010b) found a negative co-relation between Chlorophyll *a* and transparency in their all-male freshwater prawn-finfish polyculture research.

Growth and yield parameters of mola, rohu,* Catla, *mrigal and prawn

Growth and yield parameters of mola, rui, *Catla*, mrigal and freshwater prawn are shown in Table 3. The individual harvesting weight and individual weight gain of mola were significantly ($p<0.05$) higher in T_1 treatment compared to T_2 and T_3 treatments, respectively but the gross and net yields of mola were significantly ($p<0.05$) higher in T_3 than T_2 and T_1, respectively. A significantly ($p<0.05$) higher individual harvesting weight, individual weight gain, specific growth rate, survival (%), gross and net yields of Rohu were also obtained in T_1 treatment than T_2 and T_3 treatments, respectively. However, Individual harvesting weight, individual weight gain, specific growth rate, survival (%), gross and net yields of Catla, Mrigal and prawn did not differ significantly among treatments ($p>0.05$). The combined gross yield of mola, prawn and the Indian major carps was significantly ($p<0.05$) higher in T_1 and T_2 than T_3 treatment but the net yield of the same species was significantly higher ($p<0.05$) in T_1 than T_2 and T_3, respectively.

Growth and yield of fish depends on the stocking size, stocking density, species combination, inclusion of shelter, management practices, and other factors. The higher individual harvesting weight and individual weight gain of mola in T_1 compared to T_2 and T_3 treatments might be due to lower stocking density of mola resulting in less intra-species competition for natural food and space. Mola is a phytoplankton feeder (Mamun et al. 2004) and density affects the amounts of natural food available per fish, and the level of supplementary feeding required (Moore 1986, Hepher 1988). It was noted that mola was generally a surface feeder and the food of the adult fish consisted of unicellular and filamentous algae, protozoan and rotifers (Mustafa 1991). However, the individual size of mola at harvest (3.80-5.3 g) in the present study was encouragingly higher than the size reported in other experiments in earthen ponds (Chowdhury et al. 2000 and Das 2002, Kadir et al. 2007, Kunda et al. 2008). The higher gross and net yields of mola in T_3 than T_2 and T_1, respectively, is likely due to the higher number of fish stocked rather than harvesting weight, which was lowest among the groups.

The significantly ($p<0.05$) higher individual harvesting weight, individual weight gain, specific growth rate, survival (%), gross and net yields of Rohu in T_1 treatment compared to T_2 and T_3 treatments might be due to less inter-species completion between Rohu and mola as both are phytoplankton feeder. It has been reported that Rohu feed on zooplankton in fry stage but juveniles and adults show a strong positive selection for phytoplankton, vegetable debris and aquatic plants and a negative selection for all zooplanktonic organisms (Chondar 1999). The individual harvesting weight, individual weight gain, specific growth rate, survival (%), gross and net yields of Catla, Mrigal and prawn did not differ among treatments. This might be due to their preferences for different food niches resulting in less competition. Catla is the fastest growing fish and a suitable species for polyculture (Rahman et al 2010). It is surface feeder and planktophagus, and the main item of its diet is zooplankton (Jhingran 1991). Khan and Siddique (1973) also stated that the food of the adult C. catla was chiefly composed of zooplankton and some phytoplankton. They also reported that the main food of adult C. cirrhosus was decayed organic matter, sand and mud supplemented by plankton. It is known that prawns feed on benthic organisms (Tidewell et al. 1995), detritus (Valenti 1993), and feces of other fishes (Zimmermann and New 2000). Prawn also preferred forage on animals like trichopterans, chironomids, oligochaetes, nematodes, gastropods and zooplankton. In addition, commercial feed was given only for prawn in cages; therefore, there is little opportunity to compete for feed with other species. Consequently, the production of prawn was same in all treatments. The combined net yield of mola, prawn and the Indian major carps was significantly ($p<0.05$) higher in T_1 than T_2 and T_3, respectively which likely reflects the higher production of rohu as well contribution to net yield. However, the combined production was higher than Rahman et al (2010) and lower than Haque (2014). This might be due to difference on culture techniques, stocking density, stocking size, location, duration and so on.

Table 3. Growth and yield parameters (mean ± SD) of mola, *Catla*, rohu, mrigal and prawn in different treatments during a 110-day culture period.

Variables	**Treatments**			**Significance**
	T_1	**T_2**	**T_3**	
Mola (*A. mola*)				
Individual stocking weight (g)	1.5±0.07	1.4 ± 0.11	1.4 ± 0.01	NS
Individual harvesting weight (g)	$5.16{\pm}0.11^a$	$4.70{\pm}0.26^b$	$3.98{\pm}0.18^c$	*
Gross yield (kg ha^{-1} 110 d^{-1})	$75.02{\pm}3.61^c$	$103.86{\pm}11.89^b$	$123.23{\pm}8.33^a$	*
Net yield (kg ha^{-1} 110 d^{-1})	$105.86{\pm}5.96^c$	$149.88{\pm}13.55^b$	$190.16{\pm}7.91^a$	*
Catla (*C. catla*)				
Individual stocking weight (g)	42.20±2.95	43.80±1.79	43.00±1.87	NS
Individual harvesting weight (g)	284.88±6.09	281.70±10.57	281.82±4.97	NS
Individual weight gain (g)	242.68±7.65	237.90±10.90	238.82±6.37	NS
Specific growth rate (% bw d^{-1})	1.59±0.08	1.54±0.06	1.56±0.06	NS
Survival (%)	80.49±10.76	79.20±5.34	73.56±3.40	NS
Gross yield (kg ha^{-1} 110 d^{-1})	755.39±98.83	734.89±58.60	683.65±36.39	NS
Net yield (kg ha^{-1} 110 d^{-1})	642.70±76.59	620.76±54.59	579.28±31.60	NS
Rohu (*L. rohita*)				
Individual stocking weight (g)	43.60±1.82	45.00±1.58	45.00±1.87	NS
Individual harvesting weight (g)	$379.60{\pm}8.56^a$	$342.20{\pm}11.26^b$	$308.00{\pm}2.92^c$	*
Individual weight gain (g)	$336.00{\pm}8.22^a$	$297.20{\pm}10.47^b$	$263.00{\pm}3.08^c$	*
Specific growth rate (% bw d^{-1})	1.86±0.04a	1.72±0.03b	1.61±0.04c	*
Survival (%)	$82.26{\pm}2.36^a$	$76.25{\pm}1.48^b$	$71.06{\pm}2.51^c$	*
Gross yield (kg ha^{-1} 110 d^{-1})	$1029.80{\pm}51.92^a$	$862.03{\pm}42.89^b$	$724.32{\pm}25.70^c$	*
Net yield (kg ha^{-1} 110 d^{-1})	$911.55{\pm}46.93^a$	$748.71{\pm}39.19^b$	$618.55{\pm}24.24^c$	*

Mrigal (*C. cirrhosus*)				
Individual stocking weight (g)	32.34±1.96	33.84±2.17	33.80±2.68	NS
Individual harvesting weight (g)	281.14±14.88	291.46±10.41	283.58±10.25	NS
Individual weight gain (g)	248.80±16.25	257.62±11.89	249.78±10.90	NS
Specific growth rate (% bw d^{-1})	1.85±0.11	1.85±0.10	1.82±0.09	NS
Survival (%)	77.63±4.67	74.49±5.48	70.82±2.79	NS
Gross yield (kg ha^{-1} 110 d^{-1})	741.91±62.10	738.09±59.78	681.95±26.90	NS
Net yield (kg ha^{-1} 110 d^{-1})	656.59±60.44	652.28±54.15	600.56±24.38	NS
Freshwater prawn (*M. rosenbergii*)				
Individual stocking weight (g)	6.50±0.31	6.16±0.38	6.08±0.66	NS
Individual harvesting weight (g)	13.70±0.29	13.76±0.20	13.52±0.15	NS
Individual weight gain (g)	7.20±0.55	7.60±0.56	7.44±0.70	NS
Specific growth rate (% bw d^{-1})	0.08±0.10	0.17±0.11	0.17±0.17	NS
Survival (%)	65.73±2.03	63.33±3.92	63.47±3.03	NS
Gross yield (kg ha^{-1} 110 d^{-1})	15.69±1.24	14.54±1.99	13.46±0.32	NS
Net yield (kg ha^{-1} 110 d^{-1})	8.25±0.86	8.07±1.59	7.41±0.73	NS
Combined				
Gross yield (kg ha^{-1} 110 d^{-1})	2648.70 ±112.60[a]	2499.40±119.32[a]	2293.50 ±57.80[b]	*
Net yield (kg ha^{-1} 110 d^{-1})	2294.10±84.51[a]	2133.70 ±109.99[b]	1929.00 ±48.63[c]	*
Contribution to yield				
Mola net yield (kg ha^{-1} 110 d^{-1})	75.03±3.61[c]	103.86±11.90[b]	123.23±8.33[a]	*
Catla net yield (kg ha^{-1} 110 d^{-1})	642.70±76.59	620.76±54.59	579.28±31.60	NS
Rohu net yield (kg ha^{-1} 110 d^{-1})	911.55±46.93[a]	748.71±39.19[b]	618.55±24.24[c]	*
Mrigal net yield (kg ha^{-1} 110 d^{-1})	656.59±60.44	652.28±54.15	600.56±24.38	NS
Prawn net yield (kg ha^{-1} 110 d^{-1})	8.25±0.86	8.07±1.59	7.41±0.73	NS

CONCLUSION

The net and gross production of mola, *Catla*, rohu, mrigal and prawn in T_1 was significantly higher than T_2 and T_3, which indicate that these are the suitable candidate species in integrated cage-pond polyculture system due to their synergistic effects. From this research, it was revealed that the culture of mola, Indian major carps and prawn with a stocking density at 2.5 m^{-2}, 0.33 m^{-2} and 15 m^{-2} may be an appropriate polyculture technology for rural poor, and it would allow simultaneous production of mola for family consumption and large carps, prawn as cash crop.

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