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Growth, Yield and Returns to *Puntius sarana* (Hamilton) Sarpunti, in Bangladesh under Semi intensive Aquaculture

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Abstract

Production potential of Sarpunti, *Puntius sarana* in polyculture with Indian and exotic major carps were assessed at a stocking density of 9880•ha^{-1} in the treatment of T_1, T_2, T_3 and T_5 and in monoculture at 24700•ha^{-1} in the treatment of T_4 for a period of one year in different fish seed multiplication farms of greater Mymensingh district, Bangladesh. Treatment T_1 was designed with Catla catla, *Hypophthalmichthys molitrix*, *Labeo rohita*, *Cirrhina mrigala* and *P. sarana*, treatment T_2 contained *C. catla*, *L. rohita*, *C. mrigala* and *P. sarana*, treatment T_3 was designed without *C. catla*, treatment T_4 comprised of only *P. sarana* and treatment T_5 was designed without *P. sarana*. Sarpunti was stocked at densities of 2964, 3458, 3458 and 24700•ha^{-1} in treatments T_1, T_2, T_3 and T_4, respectively. Fish production in treatments T_1, T_2, T_3, T_4 and T_5 were 4818.88, 4199.93, 4305.12, 3851.21 and 4174.19 kg•ha^{-1}•yr^{-1}, respectively where *P. sarana* contributed to 9.22, 12.18, 10.92 and 100% to the total yield. The mean differences of gross yield among different treatments were significant (P<0.05). The physico-chemical and biological factors were found to be

in suitable level for fish culture. Despite the yield values, it is advocated that carps-*P. sarana* polyculture technology is a good proposition as an aquaculture technology to save the fish from being endangered and enhance the nutritional and socio-economic status of the rural people.

Introduction

Polyculture or composite fish culture is the system in which fast growing compatible species with different feeding habits are grown in the same pond (Jhingran 1975). Polyculture management techniques are based on the relationships between fishes at different levels of food chain and environment. Expected result of the polyculture depends on selection of appropriate species, species combinations and stocking densities. Polyculture is one of the major culture techniques that people have been using traditionally in Bangladesh. Usually three carps species such as rohu (*Labeo rohita*), catla (*Catla catla*) and mrigal (*Cirrhina mrigala*) and two Chinese carps such as, silver carp (*Hypophthalmichthys molitrix*) and grass carp (*Ctenopharyngodon idella*) are cultured together in the farmers' ponds for their rapid growth and favorable feeding habits.

In the past, indigenous *P. sarana* were abundant in rivers, cannals, beels, haors and baors of Bangladesh. But nowadays, this fish is hardly found in the open water system. Despite much aquaculture potential, small fish like *P. sarana*, *Amblypharyngodon mola*, *Rohtee cotio* etc. were considered undesirable in pond culture of Indian major and Chinese carps because it was assumed that these small fishes competed for food and space with the large carps. So, these species were eradicated from fish ponds before stocking. Nevertheless, small fish still provide a major portion of animal protein and micronutrients to the rural people (Roos et al. 1999). The culture technology of indigenous small fish in polyculture system is yet to be developed in Bangladesh.

To provide the poor farmers both financial and nutritional support, it is essential to develop a polyculture technology comprising of major carps and *P. sarana*. A good number of researches have been conducted on the polyculture of major carp but information on the growth performance of *P. sarana* under conventional polyculture system is meager. The present study was undertaken to evaluate *P. sarana* as a polyculture species and the overall impacts on the growth and production of fish in the polyculture system in Bangladesh.

Materials and Methods

Study area

The experiment was conducted for a period of one year from August 2002 to July 2003 in the different ponds of Field Research Complex of the Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh, Government and Non-Government fish seed multiplication farm of greater Mymensingh district. Ten ponds of different sizes varying from 0.08 to 0.13 ha with depths of 1.1 to 2.2 m were used for this study. The ponds were freed from aquatic vegetation and left exposed to sunlight.

Experimental design

The growth performance of *P. sarana* was evaluated under five treatments and was replicated twice. The catch statistics were maintained based on monthly samplings.

Pond preparation

All the ponds were dewatered, dried, freed from vegetation, limed (250 $kg{\bullet}ha^{-1}$) and manured (cowdung 2500 $kg{\bullet}ha^{-1}$). Thereafter, the ponds were filled with underground water and fertilized using urea and triple super phosphate at the rate of 12.5 and 6.25 $kg{\bullet}ha^{-1}$, respectively.

Stocking of fingerling

Fry was raised in rearing ponds at the Bangladesh Agricultural University campus for the period of two months. Then the fingerlings of *P. sarana* were supplied to different ponds of government and non government Fish Seed Multiplication Farm in greater Mymensingh district. The fingerlings were stocked at the rate of 9880 $fingerlings{\bullet}ha^{-1}$ in treatments T_1, T_2, T_3 and T_5, and 24700 $fingerlings{\bullet}ha^{-1}$ in treatment T4 (Table 1). The ponds were stocked with fingerlings after five days of fertilization. Before stocking, the total length and body weight of the fishes were recorded individually using a measuring scale and a sensitive portable balance (Model HL 400 EX).

Table 1. Details of species combination and stocking density with *P. sarana* in the different treatments.

Sl. No.	Species	Stocking densities (treatment wise)•ha^{-1}				
		T_1	T_2	T_3	T_4	T_5
1	*Catla catla* (Catla)	988	2964	-	-	1729
2	*Hypophthalmichthys molitrix* (Silver carp)	2964	-	2964	-	3458
3	*Labeo rohita* (Rui)	1235	1482	1482	-	1976
4	*Cirrhina mrigala* (Mrigal)	1729	1976	1976	-	2717
5	*Puntius sarana* (Sarpunti)	2964	3458	3458	24700	-
	Total number•ha^{-1}	9880	9880	9880	24700	9880

Supplementary feeding

In order to meet the increasing dietary demand, supplementary feed consisting of a mixture of rice bran, wheat bran, mustard oilcake and fish meal in 40:30:25:5 proportions with a protein content of 27.83% were supplied to the fish at the rate of 5 to 6% of their total biomass once daily in the morning commencing from the first day of stocking. Daily ration was adjusted by estimating the standing crop once in each month by random sampling of the stock.

Study of water quality parameters

Water temperature was recorded using a Celsius thermometer and transparency was measured by using a Secchi disc of 20 cm diameter. Dissolved oxygen and pH were measured directly using a digital electronic oxygen meter (YSI Model 58) and an electronic pH meter (Jenway Model 3020). Alkalinity was determined following the titrimetric method (Clesceri et al. 1989).

The plankton sample was collected every week using 0.55 blotting silk plankton net and later analyzed numerically with the help of a Sedgewick-Rafter counting cell (SR-cell) under a compound microscope (Clesceri et al. 1989). Calculation of the abundance of plankton was done using the following formula (Stirling 1985):

$$N = \frac{A \times 100 \times C}{V \times F \times L}$$

Where,

N= No. of plankton cells or units per liter of original water
A= Total no. of plankton counted
C= Volume of final concentrate of the sample in ml
V= Volume of field in cubic mm
F= Number of fields counted
L= Volume of original water in liter

Growth parameters

Fish were sampled once in each month to record their gain in weight (g). The growth rate was estimated by using the following formula:

$$\text{Growth (\%)} = \frac{W_2 - W_1}{W_1} \times 100$$

W_2 = Final weight of fish
W_1 = Initial weight of fish

$$\text{Survival rate (SR \%)} = \frac{\text{No. of fish harvested}}{\text{Initial no. of fish}} \times 100$$

$$\text{Average daily gain (ADG)} = \frac{\text{Mean final weight - Mean initial fish weight}}{T_2 - T_1}$$

Where, $T_2 - T_1$= culture period (days)

$$\text{Specific Growth Rate (SGR \%)} = \frac{\text{Ln}W_2 - \text{Ln}W_1}{T_2 - T_1} \times 100 \quad \text{(Brown, 1957)}$$

Where,

W_2 = the weight of fish at time T_2
W_1 = the weight of fish at time T_1
$T_2 - T_1$= culture period

Sampling of fish

Fish were sampled once a month by using seine and cast net. Length and weight of each species were measured separately to assess the health condition of fish and their growth. Then the length (cm) and weight (g) of individual fish were recorded separately on treatment-wise with the help of a measuring scale and a portable sensitive balance (Model HL 400 EX).

The experiment was terminated one year after stocking and the fish were harvested by repeated netting, followed by drying of ponds and the final growth and survival of fish were recorded.

Statistical analysis

The data were statistically analyzed through Microsoft Excel and Duncan's Multiple Range Test at 5% level of significance.

Results and Discussion

Water quality parameters

The primary productivity of water body is dependent on physical and chemical factors of water which are governed by environmental factors (Rahman et al. 1982). Pertinent data regarding temperature, transparency, pH, dissolved oxygen and total alkalinity of pond water in different treatments are shown in table 2.

Temperature varied from 14.15 to 32.50oC with mean values of 26.03±4.21, 25.73±7.06, 25.61±7.24, 25.92±5.20 and 26.01±5.34°C in five treatments, respectively. No significant differences in water temperature among different ponds were noted during the period of study. During the present study, the water temperature remained in desirable range for favorable growth of the fish and other aquatic organisms (Dewan 1973 and Roy et al. 2002).

Water transparency varied from 23.80 to 39.50 cm in treatment T_1, 24.40 to 32.40 cm in treatment T_2, 24.00 to 33.20 cm in treatment T_3, 24.10 to 33.00 cm in treatment T_4 and 24.30 to 32.80 cm in treatment T_5 with mean values of 26.48±2.19, 29.30±3.64, 27.24±2.16 29.14±3.06 and 28.84±2.66 cm in five treatments, respectively (Table 2). The close variation in transparency might be due to application manure and grazing pressure of stocked fish on plankton population. Dewan (1973) recorded a good correlation of transparency of water with the depth and rainfall. A transparency between 15.0 to 40.0 cm is appropriate for fish culture (Boyd 1979). In the present study water transparency values were within productive range.

Table 2. Physico-chemical parameters of experimental ponds under five treatments.

Parameters	Treatments				
	T_1	T_2	T_3	T_4	T_5
Temperature (°C)	26.03±4.21 (15.60-32.50)	25.73±7.06 (14.15-32.40)	25.61±7.24 (14.20-32.00)	25.92±5.20 (14.85-32.30)	26.01±5.34 (14.24-32.20)
Transparency (cm)	26.48±2.19^{c} (23.80-39.50)	29.30±3.64^{a} (24.40-32.40)	27.24 ±2.16^{b} (24.00-33.20)	29.14±3.06^{b} (24.10-33.00)	28.84±2.66^{b} (24.30-32.80)
pH	7.87 ± 0.30 (7.50-8.20)	7.88±0.33 (7.50-8.40)	8.0±0.31 (7.52-8.60)	8.2±0.30 (7.50-8.60)	7.92±0.33 (7.50-8.40)
Dissolved oxygen (mg•L^{-1})	4.62 ± 0.66 (3.6-5.7)	4.44±0.70 (3.5-6.10)	4.60± 0.88 (3.20-5.83)	4.40±0.68 (3.20-5.83)	4.80±0.56 (3.20-5.83)
Total alkalinity (mg.•L^{-1})	130.60±6.24^{c} (122.40-144.20)	175.23±16.69^{b} (136.60-201.20)	155.81±8.85^{a} (142.50-170.40)	145.43±7.80^{a} (140.20-171.40)	142.21±6.55^{a} (138.70-172.10)

Figures with different superscripts in the same row varied significantly (P > 0.05).
Figures in parentheses indicate the range.

The observed mean values of pH were 7.87±0.30 in treatment T_1, 7.88±0.33 in treatment T_2, 8.0±0.31 in treatment T_3, 8.20±0.30 in treatment T_4 and 7.92±0.33 in treatment T_5. There was no significant difference in the mean values of pH among different treatments. In the present study pH values of the ponds were found to vary from 7.50 to 8.60. The present findings agree with the findings of Roy et al. (2002).

The dissolved oxygen contents in the experimental ponds ranged from 3.20 to 6.10 mg•L^{-1} with mean values of 4.62±0.66, 4.44±0.70, 4.60±0.88, 4.40±0.68 and 4.80±0.56 mg•L^{-1} in five treatments, respectively. Comparatively lower level of dissolved oxygen as observed in the experimental ponds appeared to be related to the sampling time i.e. the dissolved oxygen was monitored at about 8:00 to 9:00 am when dissolved oxygen remains in lower concentration. Dissolved oxygen concentration rises to the optimal level a few hours after sunrise. According to Rahman et al. (1982) dissolved oxygen content of a productive pond should be 5 mg•L^{-1} or more. Wahab et al. (1995) recorded similar dissolved oxygen values that ranged from 3.18 to 7.58 mg•L^{-1}.

The values of total alkalinity were found to be 122.40 to 144.40 mg•L^{-1} in treatment T_1, 136.60 to 201.20 mg•L^{-1} in treatment T_2, 142.50 to 170.40 mg•L^{-1} in treatment T_3, 140.20 to 171.40 mg•L^{-1} in treatment T_4 and 138.70-172.10 mg•L^{-1} in treatment T_5. A more or less uniform fluctuation in total alkalinity was observed in different treatments. In the present study the alkalinity level (122.40 to 201.20 mg•L^{-1}) of water of the treated pond remained within the desirable range for pond fish culture. Dewan (1973) observed higher total alkalinity during winter and lower alkalinity during monsoon. He opined that the low value of alkalinity during monsoon might be associated to rainfall and cloudy weather or prevailing of soil condition.

Plankton population

Mean abundance of plankton with their different groups is shown in table 3. The plankton population of the all the ponds during the period of investigation were found to be more or less uniformly distributed and almost equally represented. Thirty genera of phytoplankton were recorded from ponds in treatment T_1, 32 genera in treatment T_2, 31 genera in treatment T_3, 32 genera in treatment T_4 and 31 genera in treatment T_5. The numerical abundance in different groups of phytoplankton recorded from various treatments is furnished in table 3. The zooplankton populations of the experimental ponds were comprised of two major groups viz., Rotifera and Crustacea. A total number of 11 genera of zooplankton were recorded from treatment T_1, whereas, in treatment T_2, T_3, T_4 and T_5, 12 genera of zooplankton were recorded. Wahab et al. (1994) reported 25 genera of phytoplankton belonging to Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae and five genera of zooplankton belonging to Crustacea and Rotifera.

Table 3. Average variations of phytoplankton (cell•ml) and zooplankton (organism•ml) population under different treatments.

Group Name	Treatments				
	T_1	T_2	T_3	T_4	T_5
Phytoplankton Chlorophyceae	19.98 ± 2.82^a (16.60-23.50)	17.82 ± 2.95^e (14.20-22.60)	19.48±1.78^b (18.27-21.03)	19.08±2.08^c (15.32-20.99)	18.88±1.78^d (17.22-22.03)
Bacillariophyceae	14.72 ± 3.25^e (10.50-20.40)	22.60 ± 2.08^a (16.54-19.13)	17.83 ± 1.23^c (15.60-19.30)	19.22 ± 1.23^b (13.60-19.80)	16.83 ± 1.23^d (14.40-19.22)
Cyanophyceae	10.38 ± 2.53^d (7.56-14.30)	8.98 ± 2.02^e (6.80-12.30)	13.97 ± 2.22^a (10.50-16.80)	12.46 ± 2.11^b (9.50-15.20)	11.70 ± 2.42^c (10.50-16.80)
Euglenophyceae	3.23 ± 0.87^d (2.30-4.60)	5.90 ± 2.64^a (2.80-8.90)	3.35 ± 1.36^c (1.80-5.20)	4.35 ± 1.36^{ab} (1.60-5.40)	3.05 ± 1.10^e (1.40-4.70)
Total	48.31 ± 7.09^d	50.30 ± 5.87^c	54.63 ± 7.25^b	55.11 ± 7.03^a	50.46 ± 7.06^c
Zooplankton Rotifera	13.69 ± 0.72^c (12.56-14.42)	11.14 ± 16.3^d (9.80-12.25)	15.19 ± 1.51^a (12.43-16.40)	14.20 ± 1.51^b (10.43-17.40)	11.12 ± 1.51^d (10.33-16.40)
Crustacea	6.66 ± 1.10^a (5.62-8.42)	5.50 ± 0.73^d (4.40-6.44)	6.12 ± 1.33^b (4.55-7.41)	5.12 ± 1.33^c (4.10-7.40)	6.10 ± 1.43^b (4.22-7.22)
Total	20.35 ± 4.97^b	16.64 ± 3.99^e	21.31 ± 6.41^a	19.32 ± 6.42^c	17.22 ± 3.55^d

Figures with different superscripts in the same row varied significantly ($P > 0.05$).
Figures in parentheses indicate the range.

The phytoplankton population comprised of four broad groups viz., Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae. Mean total of phytoplankton ranged from 48.31±7.09 to 55.11±7.03×10^4 cells•L^{-1} and mean total zooplankton ranged from 16.64±3.99 to 21.31±6.41×10^3 organisms•L^{-1} as observed in treatments T_1, T_2, T_3, T_4 and T_5, respectively. The values were found to be not significantly different among treatments when compared using ANOVA. Similar concentrations of phytoplankton in fertilized ponds were noted by Dewan et al. (1991) and Kohinoor et al. (1998).

Growth and production of fish

The growth and production of fish in terms of gain in weight under five treatments were investigated and monitored in each month. The results obtained are presented in table 4, which indicated that the growth in terms of weight showed much variation in each month and continued till final harvesting. The growth rate of sarpunti in monoculture and polyculture was very remarkable.

*Catla catla (***catla***)*

During the period of investigation, net increase in weight of Catla, *C. catla* was recorded to be 782.01±14.60, 793.04±11.03, and 594.05±11.14 g in treatments T_1, T_2 and T_5, respectively. Specific growth rates (% day) and average daily gain of *C. catla* were found to be 1.25±0.00, 1.26±0.01 and 1.17±0.01 and 2.14±0.04, 2.18±0.03 and 1.63±0.03 g in treatments T_1, T_2 and T_5, respectively (Table 4). There was no significant difference in the net gain of *C. catla* among the three treatments (P>0.05). The growth rate of catla was relatively higher in treatment T_2, which seemed be due to absence of competition with silver carp for food and space. Among the Indian major carps, *C. catla* is the fast growing species. The growth of catla in a year was reported to range from 223 to 918 g in India (Lakshmanan et al. 1971) and from 537.50 to 774.33 g (Ahmed et al. 1993) in Bangladesh which is similar to the present study.

*Hypophthalmichthys molitrix (***Silver carp***)*

The net increase in weight of Silver carp, *H. molitrix* was 893.63±11.79, 870.74±22.04 and 640.20±12.60 g in treatments T_1, T_3 and T_5, respectively. Silver carp was not included in treatments T_2 and T_4 to see whether the growth performance of *P. sarana* was increased in absence of silver carp and other Indian major carps. The average daily gains in silver carp were 2.45±0.04, 2.39±0.03 and 1.75±0.04 g; while specific growth rates (% day) were 1.31±0.06, 1.30±0.01 and 1.26±0.03 in treatments T_1, T_3 and T_5, respectively. There was no significant difference (P > 0.05) in ADG and SGR of silver carp among the three treatments. Silver carp exhibited a moderate growth rate of 901.33±11.69, 878±18.24 and 647.80±16.35 g in treatments T_1, T_3 and T_5, respectively over a culture period of one year. In general, silver carp exhibited

Table 4. Survival and production of fish as obtained under five treatments during July 2002 to June 2003.

Treatment	Fish species	At stocking ha^{-1}		At harvest ha^{-1}		Average daily gain (ADG)	SGR (% bw•day^{-1})	Survival (%)		Production (kg•ha^{-1}•yr^{-1})	
		No. of fish stocked	Initial weight (g)	Final weight (g)	No. of fish recovered			Species wise	Average	Species wise	Total
T_1	*Catla catla*	988	8.2±0.10	790.3±14.70	764	$2.14±0.04^d$	$1.25±0.00^b$	77.32	80.36 $±7.45^b$	$603.79±16.22^b$	4818.88 $±657.39^a$
	Hypophthalmichthys molitrix	2964	7.7±0.10	901.33±11.69	2330	$2.45±0.04^a$	$1.31±0.06_a$	78.61		$2100.10±13.74^a$	
	Labeo rohita	1235	6.5±0.10	680.33±17.61	1155	$1.85±0.05^c$	$1.27±0.02^c$	93.52		$785.78±16.28^b$	
	Cirrhina mrigala	1729	6.0±0.20	679.17±21.17	1303	$1.88±0.05^d$	$1.30±0.06^a$	75.36		$884.96±21.06^b$	
	Puntius sarana	**2964**	**8.2±0.10**	**196.57±8.68**	**2282**	$\mathbf{0.51±0.04^b}$	$\mathbf{0.87±0.03^a}$	**76.99**		**444.25**$±7.85^c$	
T_2	*C. catla*	2964	8.13±0.15	801.17±10.96	2237	$2.18±0.03^a$	$1.26±0.01^a$	75.47	77.78 $±3.86^b$	$1792.22±15.29^a$	4199.93 $±540.26^C$
	L. rohita	1482	6.4±0.20	708.63±10.61	1221	$1.92±0.04^b$	$1.29±0.02^a$	82.39		$865.24±11.50^a$	
	C. mrigala	1976	6.57±0.32	706.8±13.93	1459	$1.92±0.04^a$	$1.28±0.01^c$	73.84		$1031.22±16.22^a$	
	P. sarana	**3458**	**8.2±0.20**	**186.18±8.76**	**2746**	$\mathbf{0.48±0.03^c}$	$\mathbf{0.85±0.02^b}$	**79.41**		**511.25**$±6.48^a$	
T_3	*H. molitrix*	2964	7.7±0.18	878.44±18.24	2238	$2.39±0.03^c$	$1.30±0.01^b$	75.51	77.30 $±2.29^b$	$1965.95±25.24^b$	4305.12 $±638.56^b$
	L. rohita	1482	6.4±0.42	698.33±12.15	1182	$1.90±0.03^a$	$1.29±0.03^b$	79.76		$825.43±20.44^c$	
	C. mrigala	1976	6.0±0.26	702.50±14.88	1486	$1.91±0.02^b$	$1.30±0.06^a$	75.20		$1043.92±18.32^c$	
	P. sarana	**3458**	**8.2±0.35**	**172.60±8.99**	**2722**	$\mathbf{0.45±0.02^d}$	$\mathbf{0.83±0.02^c}$	**78.72**		$\mathbf{469.82±8.02^b}$	
T_4	***P. sarana***	**24700**	**8.2±0.32**	**196.44±7.92**	**19605**	$\mathbf{0.52±0.03^a}$	$\mathbf{0.87±0.02^a}$	**79.37**	**79.37** $±4.40^b$	**3851.21±8.91**	3851.21 $±8.91^d$
T_5	*C. catla*	1729	8.3±0.25	602.25±12.06	1349	$1.63±0.03^b$	$1.17±0.01^b$	78.02	73.15 $±5.67^b$	$812.44±20.11^c$	4174.19 $±446.86^c$
	H. molitrix	3458	7.6±0.18	647.80±16.35	2635	$1.75±0.04^b$	$1.26±0.03^c$	76.20		$1706.95±14.78^b$	
	L. rohita	1976	6.6±0.62	518.43±13.11	1446	$1.40±0.03^b$	$1.22±0.02^b$	73.18		$749.65±13.78^b$	
	C. mrigala	2717	6.2±0.26	511.66±17.85	1771	$1.38±0.02^c$	$1.21±0.03^b$	65.18		$905.15±11.78^b$	

Figure in the same column having the same superscript are not significantly different ($P<0.05$). Figure in the parenthesis indicate range.

better growth than any other species and it contributed (43.58, 45.66 and 40.89%) to the bulk of the total production under all treatments. The annual growth of silver carp from Bangladesh was reported from 745 to 855 g (Shahabuddin et al. 1994), 800 to 1350 g (Chanda et al. 2002) which are more or less similar to the present findings.

Labeo rohita (*Rohu*)

During the experimental period, net increase in weight of Rohu, *L. rohita* was found to be 673.83±17.72, 702.23±10.50, 691.93±12.15 and 511.83±16.54 g in treatments T_1, T_2, T_3 and T_5, respectively. The average daily gain were 1.85±0.05, 1.92±0.04, 1.90±0.03 and 1.40±0.03 g; specific growth rates (%) were 1.27±0.02, 1.29±0.02, 1.29±0.03 and 1.22±0.02 in treatments T_1, T_2, T_3 and T_5, respectively. There was no significant difference in the value of ADG and SGR ($P > 0.05$) of *L. rohita* among different treatments. In the present experiment, the growth of *L. rohita* in treatments T_1, T_2, T_3 and T_5 were recorded to be 680.33±17.61, 708.63±10.61, 698.33±12.15 and 518.43±13.11 g, respectively. A wide variation in the growth of rohu ranging from 285 to 1800 g•yr^{-1} has been reported by a number of researchers (Ahmed and Alam 1989). Lakshmanan et al. (1971) considered rohu above 500 g as marketable size.

Cirrhina mrigala (*Mrigal*)

During the period of investigation, Mrigal, C. mrigala was found to attain a net gain of 673.17±16.22, 700.23±12.41, 696.50±14.88 and 505.46±14.46 g in treatments T_1, T_2, T_3 and T_5 respectively. The average daily gain of mrigal were 1.88±0.05, 1.92±0.04, 1.91±0.02 and 1.38±0.02 g while specific growth rates (%) were 1.30±0.06, 1.28±0.01, 1.30±0.06 and 1.21±0.03, in treatments T_1, T_2, T_3 and T_5, respectively (Table 4). There was no significance difference ($P>0.05$) in ADG and SGR among the four treatments. The results of the present experiment showed that mrigal grew to a size of 679.17±21.17, 706.80±13.93, 702.50±14.88 and 511.66±17.85 g in treatments T_1, T_2, T_3 and T_5, respectively. Das et al. (1977) recorded 705 g weight of mrigal in India. Shahabuddin et al. (1994) and Mazid et al. (1997) reported the annual growth of mrigal to be in the range of 447 to 875.0 g in India and Bangladesh condition.

Puntius sarana (*Sarpunti*)

From an initial weight of 8.2 g, Sarpunti, *P. sarana* was found to attain the final weights of 196.57±8.68, 186.18±8.76, 172.60±8.99 and 196.44±7.92 g in treatment T_1, T_2, T_3 and T_4, respectively over a period of one year. Average daily gains were found to be 0.51±0.04, 0.48±0.03, 0.45±0.02 and 0.52±0.03 g; while SGR (%) were 0.87±0.03, 0.85±0.02, 0.83±0.02 and 0.87±0.02 in treatments T_1, T_2, T_3 and T_4, respectively (Table 4). No significant difference was found in the value of ADG and SGR among different treatments ($P<0.05$). The highest yield of *P. sarana* with Indian and exotic major carps was recorded to be 511.25 kg•ha^{-1}•.yr^{-1} in treatment T_2 and the lowest one (444.30 kg•ha^{-1}•yr^{-1}) in treatment T_1. The second highest production (469.82 kg•ha^{-1}•.yr^{-1}) of *P. sarana* in terms of weight (g) was found in treatment T_3 where *C. catla* was not stocked. But in monoculture practice, the yield of *P. sarana* was recorded to be 3890.42 kg•ha^{-1}•yr^{-1} in treatment T_4. Kohinoor et al. (1994) evaluated production and growth performance of local sarpunti (*P. sarana*) and raj punti (*P. gonionotus*) under semi-intensive culture system at a stocking density of 16,000 fish•ha^{-1} and they recorded a yield of 1304 kg•ha^{-1} for a period of six months and 2075 kg•ha^{-1} for a period of six months, respectively. This low level of polyculture yield as reported by Kohinoor et al. (1994) seemed to be due to feeding of poor quality rice bran.

Survival rate

The high percentage of survival obtained in all the species in all treatments suggest that such factors as healthy fish, predator free pond, favorable ecological condition etc. were important in influencing survival. Choudhury et al. (1978) stressed the important of those factors in governing the survival. The survival rate of various species in treatments T_1, T_2, T_3, T_4 and T_5 in the present study varied from 73.15 to 80.36% which are higher than the survival rate reported by Wahab et al. (1991) for Indian major carps in polyculture. Highest survival rate (80.36%) was found in treatment T_1 which ise similar to Haque (1998) who recorded 76.0 to 93.33% survival in case of carp culture.

Production

Total net production of fish as recorded in treatments T_1, T_2, T_3, T_4 and T_5 were 4818.88, 4199.93, 4305.12, 3851.21 and 4174.19 kg•ha^{-1}•.yr^{-1}, respectively. The fish production was higher in treatment T_1, where carps and sarpunti, *P. sarana* were stocked and lowest production was found in treatment T_4, where only *P. sarana* was stocked. Intermediate fish production results were obtained in treatments T_2, T_3, and T_5, where *C. catla*, *L. rohita*, *C. mrigala* and *P. sarana* were stocked in treatment T_2 and *H. molitrix*, *L. rohita*, *C. mrigala* and *P. sarana* were stocked in treatment T_3 and only carps were stocked in treatment T_5. The production levels were found to be more or less similar in treatments T_2 and T_5 and showed no significant ($P<0.05$) difference. The production levels were found to be slightly higher in treatment T_3

Table 5. Individual contributions of different species to net production in different treatments.

Treatment	Species	Production ($kg \cdot ha^{-1} \cdot yr^{-1}$) (Species wise)	Contribution to production (%) ($kg \cdot ha^{-1} \cdot yr^{-1}$)
T_1	*Catla catla*	603.79±16.22[b]	12.53
	Hypophthalmichthys molitrix	2100.10±13.74[a]	43.58
	Labeo rohita	785.78±16.28[b]	16.31
	Cirrhina mrigala	884.96±21.06[b]	18.36
	Puntius sarana	444.25±7.85[c]	9.22
T_2	*C. catla*	1792.22±15.29[a]	42.67
	L. rohita	865.24±11.50[a]	20.60
	C. mrigala	1031.22±16.22[a]	24.55
	P. sarana	511.25±6.48[a]	12.18
T_3	*H. molitrix*	1965.95±25.24[b]	45.66
	Labeo rohita	825.43±20.44[c]	19.17
	C. mrigala	1043.92±18.32[c]	24.25
	P. sarana	469.82±8.02[b]	10.92
T_4	*P. sarana*	3890.42±8.91[b]	100
T_5	*C. catla*	812.44±20.11[c]	19.47
	H. molitrix	1706.95±14.78[b]	40.89
	Labeo rohita	749.65±13.78[b]	17.96
	C. mrigala	905.15±11.78[b]	21.68

Figures with different superscripts in the same column varied significantly (P<0.05).
Figures in the parenthesis indicate range.

Table 6. Cost and return of fish production/ha under a polyculture system of management.

Item	Amount $Tk \cdot ha^{-1}$					Remarks
	T_1	T_2	T_3	T_4	T_5	
Total return (TR)	3,13,227/-[a]	2,72,995/-[b]	2,66917/-[d]	2,50,328/-[e]	2,58,800/-[c]	Price is related to size and species
a. Variable cost: 1.Price of fry	9,880/-	9,880/-	9,880/-	24700/-	7410/-	
2. Feed	1,09,298/-	1,04,615/-	1,05,461/-	81464/-	1,08,281/-	
3. Fertilizer	23,182/-	23,182/-	23,182/-	18285/-	23,182/-	
4.Human labour	15,000/-	18,000/-	16,600/-	14,000/-	18,000/-	
5. Chemicals	5,055/-	6,425/-	5,4.80/-	4055/-	6054/-	
6.Miscellaneous	9,772/-	8,155/-	7,780/-	5772/-	8672/-	
Total Variable cost (TVC)	1,72,182/-[a]	1,70,257/-[c]	1,68,383/-[c]	148276/-[e]	171599/-[b]	
b. Fixed cost : 1.Pond rental value	14,820/-	14,820/-	14,820/-	14,820/-	14,820/-	Tk. $14820 \cdot ha^{-1}$ according to MAEP
2.Interest of operating capital	18700/-	18507/-	18320/-	16309/-	18341/-	10% interest, according to BKB
Total fixed cost (TFC)	33,520/-	33327/-	33140/-	31129/-	33161/-	
Total cost (TC=TVC+TFC)	2,05702/-[a]	2,05,584/-[b]	2,01,523/-[b]	1,79,405/-[c]	2,04,760/-[b]	
Gross margin (GM=TR-TVC)	1,41,045/-[a]	1,02,738/-[b]	98,534/-[c]	1,02,052/-[b]	87,201/-[d]	
Net return (TR-TC)	1,07,525/-[a]	67,411/-[c]	65,394/-[d]	70,923/-[b]	54,040/-[e]	

MAEP= Mymensingh Aquaculture Extension Project, BKB= Bangladesh Krishi Bank.
Figures with different superscripts in the same row varied significantly (P > 0.05).

due to only stocking of fast growing *H. molitrix*. Treatment T_4 appeared to give the lowest production and differed significantly ($P<0.05$) from T_1 and T_3 but there was no significant difference ($P<0.05$) between treatment T_2 and T_5. It is clear from the present investigation that the stocking of *P. sarana* in large carp polyculture did not affect the growth of carps. In this experiment, the contribution of *P. sarana* to the total yield in treatments T_1, T_2, T_3 and T_4 were 9.22, 12.18, 10.92 and 100%, respectively. Hossain et al. (1997) found a production of 487.11 to 889.54 kg•ha^{-1} over a period of 5 months from a polyculture of carps with small fish chapila and Kohinoor et al. (1998) also got a net production of 1127 to 1448 kg•ha^{-1} over a period of 5 months in polyculture of Indian major carps with small fish mola. The production of fish in the range of 3851.21 to 4818.88 kg•ha^{-1}•yr^{-1} as obtained in this study are more or less similar to the above reports. In the present study, production of local sarpunti, *P. sarana* with Indian major carps and Chinese carps was found to be 444.25 kg•ha^{-1}•yr^{-1} in treatment T_1, 511.25 kg•ha^{-1}•yr^{-1} in treatment T_2, 469.82 kg•ha^{-1}•yr^{-1} in treatment T_3 and 3851.21 kg•ha^{-1}•yr^{-1} in treatment T_4. Ameen et al. (1984) obtained 4.49 t•ha^{-1} of mola and chola punti in composite culture. Roy et al. (2002) stocked major carps and small fish at the rate of 10,000 and 25,000 fish•ha^{-1}, respectively. They achieved a production of 2,176 to 2,560 kg•ha^{-1} over a period of 210 days. The weight gains (g) by local sarpunti in different densities in the present study showed significant difference ($P>0.05$). The highest yield of *P. sarana* was observed in treatment T_1 and the lowest in treatment T_3.

Economic analysis

A simple cost-benefit analysis was performed to estimate the amount of profit that has been generated from these five types of culture operations. The results of the analysis are shown in T_1, T_2 T_3, T_4, and T_5, respectively (Table 6). The gross margin (GM) were TK. 1,41,045/-, 1,02,738/-, 98,534/-, 1,02,052/- and 87,201/- but net return were TK. 1,07,525/-, 67,411/-, 65,394/-, 70,923/- and 54,040/- in treatments T_1, T_2, T_3, T_4, and T_5, respectively. Cost and benefit analysis showed that treatment T_1 generated the highest net return over a period of one year TK.1,07,525/- ha^{-1} and lowest net return was found TK. 54,040/- ha^{-1} in treatment T_5, where *P. sarana* was not stocked and the size of the fish comparatively was not bigger due to higher density. The price value of *H. molitrix* is comparatively low in the market of Bangladesh. So, more or less similar net return levels were found to be in treatments T_2 and T_3. Treatment T_5 appeared to give the lowest net return levels and differed significantly ($P<0.05$) from T_1, T_2, T_3 and T_4. The second lowest net return levels were found to be the treatment T_4 and differed significantly ($P<0.05$) from T_1. Hussain et al. (1989) got the net benefit of TK.72,827/- ha^{-1}•month^{-6} to culture Nile tilapia (*Oreochromis. niloticus*) where fish were fed with rice bran and mustard oil cake. In monoculture of Rajputi (*Puntius gonionotus*), Kohinoor et al. (1993) observed that TK. 68,135/- to 75,028/- ha^{-1}•$month^{-6}$ could be achieved by applying supplementary feed and fertilization. In the present study, the net return is more or less similar to the above findings but consideration of the endangered stage and nutritional aspects this *P. sarana* fish culture is more important to save the fish from being endangered and carps-*P. sarana* polyculture technology is a potential means of enhancing fish production and improving the nutritional status of rural pond owners.

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