E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2018; 6(4): 463-467

www.fisheriesjournal.com
Received: 15-05-2018
Accepted: 16-06-2018

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Performances of wild sourced Indian major carps and hatchery produced exotic carps under different stocking combinations in polyculture ponds

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Abstract
Performances of wild sourced Indian major carps and hatchery produced exotic carps were studied during July to December 2014 in polyculture ponds of Faridpur district, Bangladesh. Three different combinations of species (surface: catla, *Catla* catla, silver carp, *Hypophthalmichthys molitrix* and bighead carp, *Aristichthys nobilis* + column: rui, *Labeo rohita* + bottom: mrigel, *Cirrhinus mrigala* and carpio, *Cyprinus carpio* + all layer: grass carp, *Ctenophryngodon idella*) were tested under three treatments as T_1 (30% + 40% + 29% + 1%), T_2 (30% +30% + 39% + 1%) and T_3 (40% + 30% + 29% + 1%), each with four replications. As surface feeder, silver carp was dominant in treatment T_1 and that of catla in treatments T_2 and T_3. Semi intensive carp polyculture was followed for all the treatments. Water quality for the treatments was found within the suitable range. Fish yield and net return varied more significantly ($P<0.05$) with treatment T_1 than others.

Keywords: Polyculture, species combination, carps, hatchery, wild

1. Introduction
Suitable species combination and quality seeds are important factors to find expected production from polyculture [13]. For the efficient farms, improved stock is one of the options available for increasing the productivity and income [18]. Polyculture of carp in pond is a popular technique in Bangladesh where carp contributes 45.35% of the total inland production (Indian Major Carps, IMCs 31.64% and exotic carps, ECs 13.71%) [9]. This popular carp polyculture technique is facing problems with less return due to poor growth of the IMCs in culture operation. And lack of effort to solve this problem may lead to more utilization of the exotic fishes for farming and thereby creation of more loss of fish production and biodiversity as well [9]. In fact, many hatchery breeding programs result in lower quality fish through inbreeding depression [20]. It has been observed that some of the hatcheries are careful in selection of their brood stock while practices followed by others result in inbreeding and genetic deterioration of stocks. Common practice in small hatcheries often involves the use of a small number of brood fish of each species; the high fecundity of carps allows adequate seed production in this situation. However, over successive generations and low effective population sizes lead to inbreeding depression with reduced growth rates, loss of fecundity and poor survival [19]. Synergetic effects between some species also support the higher fish production in polyculture ponds, for example, the production of common carp can be higher if reasonable quantities of silver carp and grass carps are in the same pond [10]. Therefore, it is necessary to use quality seeds through proper identification especially of the IMCs and suitable combination of IMCs and exotic carps in polyculture ponds to ensure the benefit of the farmers. Already better performances of *Labeo rohita* from Padma river, *Catla catla* from Halda river and *Cirrhinus mrigala* from Jamuna river are noted in polyculture ponds [17]. Stocking combination based research using hatchery and natural seeds [18] carried out to date are mostly found to be focused with the use of limited species and there is a lack of comprehensive research. This study evaluated the performances of wild sourced IMCs and hatchery produced ECs under different species combinations in polyculture ponds. Specific objectives of the present study were to monitor the water quality and fish growth; to evaluate the economics of carp polyculture; and to recommend suitable species combination of IMCs and ECS towards profitable farming in pond.

2. Materials and methods

The present experiment was carried out in farmer managed ponds (mean area of 0.24±0.01 ha and depth of 0.17± 0.12 m) located at Sadar upazila of Faridpur district, Bangladesh ($23^0$55'88.7"N, $89^0$84'58.6"E /$23^0$62'94.4"N, $89^0$86'17.2"E; elevation from 15 to 22 m) for a period of six months from July to December, 2014. The experiment was designed under Randomized Completely Block Design (RCBD) following three different treatments of species combinations with better performed wild sourced Indian major carps (IMCs) (catla, *C. catla* from Halda river, rui, *L. rohita* from Padma river and mrigal, *C. mrigala* from Jamuna river) and hatchery produced exotic carps (ECs) (silver carp, *H. molitrix*, bighead carp, *A. nobilis*, carpio, *C. carpio* and grass carp, *C. idella*) from hatchery. Each treatment had four replications (Table 1). The different treatments were T_1: silver carp dominant(silver carp 40%, catla 35.71% and bighaed carp 23.80%) surface feeder 30%+ column feeder 40%+ bottom feeder 29%+ all layer species 1%; T_2: catla dominant (silver carp 35.71%, catla 59.51% and bighaed carp 4.78%) surface feeder 30% + column feeder 30%+ bottom feeder 39% + all layer species 1% and T_3: catla dominant (silver carp 12.50%, catla 50% and bighaed carp 37.49%) surface feeder 40% + column feeder 30% + bottom feeder 29% + all layer species 1%). Density (6,916 fishes/ha) and initial weight of the stocked fishes (catla, *C. catla*: 97.83±3.82 to 103.38±2.49 g; silver carp, *H. molitrix*: 128.32±3.82 to 134.78±2.73 g; bighead carp, *A. nobilis*: 97.73±3.36 to 103.80±2.31 g; rui, *L. rohta*: 111.93±3.48 to 115.32±2.87 g ; mrigala, *C. mrigala*: 90.90±3.03 to 98.63±0.93 g; carpio, *C. carpio*: 81.83±3.26 to 85.46±2.4 g and grass carp, *C. idella*: 170.68±6.89 to 187.20±7.85 g) were same for all the treatments.

Table 1: Layout of the experiment

Parameters	Treatments and replications											
	T_1R_1	T_1R_2	T_1R_3	T_1R_4	T_2R_1	T_2R_2	T_2R_3	T_2R_4	T_3R_1	T_3R_2	T_3R_3	T_3R_4
Pond area (ha)	0.36	0.20	0.24	0.22	0.20	0.18	0.20	0.30	0.28	0.20	0.20	0.24
Pond depth (m)	1.6	1.6	1.5	2.0	1.5	1.9	1.9	1.7	2.0	1.4	1.4	1.9
Fish stocked (No.)	2490	1383	1660	1522	1383	1245	1383	2075	1936	1383	1383	1660

Aquatic weeds form all the ponds were removed manually. Unwanted fishes and other species were removed through repeated netting. Besides, liming (CaO @ 247 kg/ha as basal dose and 120 kg/ha as periodic dose) was done to maintain good water quality and fertilization (cowdung @ 2470 kg/ha as basal dose and 120 kg/ha as periodic dose; urea @ 50 kg/ha as basal dose and 25 kg/ha as periodic dose and TSP @ 50 kg/ha as basal dose and 25 kg/ha as periodic dose) was done to enhance the natural feed production in the experimental ponds. Both liming and fertilization doses were maintained after Karim and Rahman [16]. Daily supplementary feeding was done with a mixture of rice bran (25%), wheat bran (25%), fish meal (25%) and mustard oil cake (25%). Supplementary feed (dietary protein content of 24.25%) was used @ 4.5% of fish body weight.

Important water quality parameters like temperature, transparency, pH, dissolved oxygen (DO), carbon dioxide (CO_2), alkalinity and ammonia-nitrogen (NH_3-N) of water were monitored monthly for the experimental ponds. In each sampling, 10% of the stocked fishes of each species were caught from each pond with the help of a seine net to monitor the growth of fishes and to adjust the feeding ration. Several parameters were used to monitor growth of fishes after Brett and Groves [7] as follows:

Initial weight g) = Weight of fish at stock

Final weight (g) = Weight of fish at harvest

Weight gain (g) = Final weight (g) - initial weight (g)

Specific Growth Rate (SGR) (%, bwd^{-1}) = $[(\text{Ln } W_2 - \text{Ln } W_1) \times 100] / (t_2 - t_1)$

Where, W_1 and W_2 are the mean start and end weight (g fish^{-1}) and t_1 and t_2 (days) are the start and end of the period.

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

Net yield (kg ha^{-1}) = Fish biomass at harvest – Fish biomass at stocking

At the end of the study, fishes were harvested and sold to local market. Cost-benefit analysis of different treatments was calculated on the basis of the cost of lime, ash, fertilizer, fish seed and labor used; and the income from the sale of fishes. The prices are expressed in Bangladesh Taka (BDT) (77 BDT = 1 USD in the year 2014). All inputs and fish fingerlings corresponded to wholesale market prices in 2014 of Faridpur district, Bangladesh. Net benefit and cost-benefit ratio (CBR) were calculated as follows:

$R = I - (Fc + Vc + Ii)$

Where *R refers to* net return; *I*, total income from fish sold; *Fc for* Fixed costs, *Vc for* variable costs and *Ii for* interests on input costs.

CBR = Net benefit / Total investment

Data on water quality parameters, growth and yield of fishes and economics of carp polyculture under different treatments were subjected to one way ANOVA (Analysis of Variance) using computer software SPSS (Statistical Package for Social Science, version-15). The mean values were also compared to see the significant difference from the DMRT (Duncan Multiple Range Test) after Gomez and Gomez [11].When a main effect was significant, the ANOVA was followed by Duncan Multiple Range Test (DMRT) at 5% level of significance. The percentages data were analyzed using arcsine-transformed data. All data were expressed as mean ± standard error (SE).

3. Result and discussion

3.1 Water quality

The mean values of water quality parameters like water temperature, transparency, pH, DO, free CO_2, total alkalinity and ammonia nitrogen varied from 26.81±0.94 to 27.04±1.04 ^{0}C, 30.83±0.49 to 31.88±1.97 cm, 7.36±0.11 to 7.56±0.10, 6.18±0.54 6.40±0.58 mg/l, 3.41±0.26 to 4.08±0.29 mg/l, 96.96±5.27 to 100.92±3.57 mg/l and 0.03±0.01 to 0.04±0.01 mg/l, respectively (Table 2). Mean water quality parameters were not found to be varied significantly with the treatments. Rothuis *et al.* [25] recorded the mean values of water temperature, pH, dissolved oxygen and ammonia-nitrogen concentrations fluctuated from 28.40 to 34.30 ^{0}C, 6.46 to 6.79, 2.25 to 6.71 mg/l and 0.1-0.2 mg/l, respectively in fish culture system. Wahab *et al.* [31] recorded water temperature as 28.5 to 31.3 ºC in fish pond. Hossain *et al.* [14] recorded the mean values of NH_3-N as 0.30-0.34 mg /l with fish culture in rice field. The mean values of water temperature, pH, DO,

CO_2 and total alkalinity were recorded as 19 6.6 to32 ^{0}C, 6.6 to 8, 1.1 to 4.9 mg/l, 3.5 to 4.0 mg/l and 92 to 167 mg/l, respectively in polyculture pond [19]. Rahman [23] concluded that the transparency of productive water bodies should be 40.00 cm or less. Water temperature of 25 to 32°C is considered suitable for fish culture [5]. Swingle [30] considered pH values of 6.5 to 9.0 as satisfactory level for fish culture. Boyd [6] recommended a transparency between 30 to 45 cm as appropriate for fish culture. Boyd [5] recommended suitable ammonia-nitrogen as below 0.1 mg/l. Alikuhni [3] reported that total alkalinity more than 100 mg/l should be present in high productive water bodies. The suitable range of free CO_2 for fish culture is ranged from 1.0 to 10.0 mg/l [5] and the solubility of important gases, such as oxygen and carbon dioxide increases as temperature decreases [15].

Table 2: Water quality under different treatments during the study period

Water quality	Treatments			*P*- value
	T_1	T_2	T_3	
Water temperature (°C)	27.04±1.04^a	26.84±1.09a	26.81±0.94^a	0.99
Transparency (cm)	30.83±0.49^a	31.79±1.33^a	31.88±1.97^a	0.85
pH	7.36±0.11^a	7.38±0.12^a	7.56±0.10^a	0.86
DO (mg/l)	6.40±0.58^a	6.27±0.52^a	6.18±0.54^a	0.44
CO_2 (mg/l)	3.41±0.26^a	3.76±0.25^a	4.08±0.29^a	0.24
Alkalinity (mg/l)	97.38±3.10^a	96.96±5.27^a	100.92±3.57^a	0.25
NH_3-N (mg/l)	0.04±0.01^a	0.09±0.01^a	0.03±0.01^a	0.83

Figures bearing common letter(s) in a row as superscript do not differ significantly (P<0.05)

3.2 Fish growth and yield

Significant variation in final weight 712.50±26.03 g in T_3 to 794.75±31.88 g in T_1 was found with *C. catla* (Table 3). The final weight varied with *L. rohita* from 84.4 to 121.3 g, *C. catla* from 190.4 g to 208.9 g and *H. molitrix* from 161.5 to 221.8 g in a polyculture study by Shahin *et al*. [28]. Final weight of *L. rohita* from 215.0 to 974.8 g, *C. catla* from 256.7 to 972.1 g and *C. carpio* from 119.0 to 921.3 g were noted in a polyculture study by Abbasi *et al*. [1]. The highest weight gain (232.83±80.00 g) was attained with *L. rohita* followed by *C. mrigala (*230.63 g*), C. idella* (137.16 g), *C. catla* (116.17 g) *and H. molitrix* (87.73g), respectively [2]. In larger ponds *A. nobilis* reached at higher weight (0.735 kg) compared with smaller pond (0.354 kg) [21]. Weight gain from 609.12±24.93 g (T_2) to 696.12±29.18 g (T_1) and SGR from (T_2) to 1.18±0.01 (T_1) varied significantly for *C. catla* with T_1 in the present study. The SGR between 1.6 to 1.21% was observed in *C. carpio* by Hakim *et al*. [12]. The SGR of *H. molitrix, C. mrigala, C. catla, L. rohita* and *C. idella* varied from 0.59±0.11 to 1.05±0.06%, 1.19±0.24 to 1.35±0.06%, 0.77±0.17 to 1.14±0.24%, 0.97±0.04 to 1.27±0.42% and 0.33±0.06 to 0.99±0.18%, respectively [3]. No significant variations in survival rate were found among the treatments. Survival rate in *H. molitrix, C. mrigala, C. catla, L. rohita* and *C. idella* varied from 63.40 to 68.81, 64.85 to 72.24, 66.81 to 76.48, 39.11 to 45.46 and 39.43 to 46, respectively as reported by Ali *et al*. [2]. The survival rate of *C. catla* was 100% which attributed to larger stocking size as reported by Chatta *et al*. [8]. The survival rate of 68.5 to 92.6% was found in common carp by Parakrama and Heenatigala [22]. The mean survival rate of fishes in tilapia-carp polyculture varied between 95.2 to 96.8% by Sarker *et al*. [26].

The maximum yield was found in treatment T_1 (using silver carp dominant surface feeder 30%) which was 6.76% and 9.17% higher than that of treatment T_2 (using catla dominant surface feeder 30%) and T_3 (using catla dominant surface feeder 40%), respectively (Table 4). Yield variation among the treatments might be due to the variation in species combination. Silver carp contributed 17.48%, 13.54% and 6.91% of the total fish yield in treatment T_1, T_2 and T_3, respectively. Highest yield in treatment T_1 might be due to the inclusion of silver carp as dominant surface feeding carp that played a significant role to total yield contribution and also enhanced the growth of other carps. Silver carp had an innate affinity towards rapid growth due to continuous propagation what enhanced the growth of other carps [29]. Findings almost agreed with Asadujjaman and Hossain [4] who reported higher yield of silver carp while using silver carp dominant surface feeder in polyculture pond. Present findings also indicated that the yield obtained with the treatments were comparatively higher than the yield (2592.09 ±306.46 to 3450.40 ± 189.41 kg/ha/10 months) reported by Sayeed *et al*. [27] while working on carp polyculture in pond with the use of surface feeder 40%, column feeder 20%, bottom feeder 30% and all layer species 10%. Fish yield in polyculture of Indian major carps and exotic carps (*L. rohita, C. catla*, *C. mrigala, H.molitrix, C. idella* and *C. carpio*) varied from 2360 to 4022.5 (kg/ha) as reported by Raman [24]. Khan *et al*. (2018) [17] reported the total yield (kg/ha/6 months) of carp polyculture varied from 3743.30±59.18 (T_4) to 4011.20±90.98 (T_1) which is similar to the present study.

Table 3: Mean growth of fishes under different treatments (July-December, 2014).

Species	Treatments	Initial weight (g)	Final weight (g)	Weight gain (g)	SRG (%, bwd^{-1})	Survival rate (%)
C. catla	T_1	98.63±3.36^a	794.75±31.88^a	696.12±29.18^a	1.18±0.01^a	89.50±1.19^a
	T_2	97.83±3.82^a	771.78±35.16^{ab}	673.15±32.27^{ab}	1.13±0.02^{ab}	88.50±1.32^a
	T_3	103.38±2.49^a	712.50±26.03^b	609.12±24.93^b	1.15±0.02^b	89.00±1.58^a
P value		0.462	0.068	0.046	0.075	0.878
H. molitrix	T_1	134.78±2.73^a	1184.90±21.65^a	1050.12±18.92^a	1.15±0.00^a	91.50±0.87^a
	T_2	132.55±1.56^a	1064.00±30.17^a	931.45±26.35^a	1.15±0.00^a	91.25±1.70^a
	T_3	128.32±3.82^a	1047.30±12.28^a	918.98±10.72^a	1.15±0.00^a	92.00±1.29^a
P value		0.316	0.317	0.317	0.852	0.922
A. nobilis	T_1	98.75±4.27^a	1064.90±21.65^a	812.49±21.84^a	1.15±0.00^a	89.50±0.87^a
	T_2	97.73±3.36^a	1214.00±30.17^a	1010.05±17.97^a	1.15±0.00^a	89.25±1.31^a

	T_3	103.80±2.31^{a}	1047.30±12.28^{a}	780.62±29.60^{a}	1.15±0.00^{a}	89.75±1.29^{a}
P value		0.436	0.317	0.317	0.852	0.922
L. rohita	T_1	115.32±2.87^{a}	823.24±2268^{a}	707.66±19.82^{a}	1.15±0.00^{a}	90.75±0.85^{a}
	T_2	114.89±1.91^{a}	852.78±15.13^{a}	737.89±13.21^{a}	1.15±0.00^{a}	90.25±2.21^{a}
	T_3	111.93±3.48^{a}	782.42±27.52^{a}	670.49±24.04^{a}	1.15±0.00^{a}	89.75±2.06^{a}
P value		0.666	0.666	0.666	0.923	0.927
C. mmrigala	T_1	98.63±0.93^{a}	779.29±7.35^{a}	680.67±6.42^{a}	1.15±0.00^{a}	89.25±1.93^{a}
	T_2	90.90±3.03^{a}	718.29±24.02^{a}	627.39±20.98^{a}	1.15±0.00^{a}	88.25±1.31^{a}
	T_3	95.09±2.64^{a}	751.36±20.85^{a}	656.27±18.21^{a}	1.15±0.00^{a}	89.75±1.49^{a}
P value		0.126	0.126	0.127	0.760	0.801
C. carpio	T_1	81.83±3.26^{a}	647.48±25.76^{a}	565.66±22.50^{a}	1.15±0.00^{a}	89.50±0.65^{a}
	T_2	83.65±2.53^{a}	660.93±19.97^{a}	577.28±17.44^{a}	1.15±0.00^{a}	90.75±1.38^{a}
	T_3	85.46±2.43^{a}	675.36±19.25^{a}	589.90±16.82^{a}	1.15±0.00^{a}	89.50±1.76^{a}
P value		0.662	0.659	0.659	0.399	0.519
C. idella	T_1	170.68±6.89^{a}	1348.60±54.31^{a}	1177.90±47.43^{a}	1.15±0.00^{a}	91.75±3.19^{a}
	T_2	187.20±7.85a	1479.00±61.95^{a}	1291.80±54.10^{a}	1.15±0.00^{a}	89.50±2.75^{a}
	T_3	174.27±5.66^{a}	1377.00±44.71^{a}	1202.70±39.05^{a}	1.15±0.00^{a}	91.00±1.78^{a}
P value		0.253	0.253	0.253	0.736	0.832

Figures bearing common letter(s) in a column as superscript do not differ significantly ($P<0.5$)

Table 4: Fish yield (kg/ha/6 months) under different treatments

Species	Treatments			*P*- value
	T_1	T_2	T_3	
C. catla	461.63±24.44^{b}	735.73±31.44^{a}	749.74±32.48^{a}	0.001
H. molitrix	807.12±11.28^{a}	585.73±20.22^{b}	292.52±3.67^{c}	0.000
A.nobilis	359.22±8.80^{b}	89.24±3.80^{c}	726.52±13.78^{a}	0.000
L. rohita	1776.32±31.38^{a}	1380.17±34.56^{b}	1248.66±73.73^{c}	0.002
C. mrigala	750.25±15.94^{a}	746.39±26.67^{a}	738.60±30.45^{a}	0.101
C. carpio	382.28±12.14^{b}	706.71±14.12^{a}	397.02±14.90^{b}	0.000
C. idella	79.56±19.15^{a}	79.77±38.39^{a}	75.47±4.52^{a}	0.247
All species	4616.38±60.47^{a}	4323.74±69.36^{ab}	4228.53±48.52^{b}	0.039

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P<0.05$)

3.3 Economics of carp polyculture

During the study the total cost (BDT/ha/6 months) varied from 362110.00±3388.3 (T_1) to 363560.00±2551 (T_3) (Table 5). The net return (BDT/ha/6 months) significantly ($P<0.05$) varied from 460420.00±4689 (T_3) to 585500.00±19289 (T_1). The CBR significantly ($P<0.05$) varied from 1.27±0.04 (T_3) to 1.62±0.10 (T_1). The increased yield of treatment T_1 resulted in increased net return and CBR. The net return in treatment T_1 was 14.44% higher than that of treatment T_2 and 21.36% higher than that of treatment T_3. Present findings agreed with Asadujjaman and Hossain [4] who worked on carp polyculture (surface feeder 34%, column feeder 29%, bottom feeder 23% and all layer species 14%.) in pond and reported the total cost, return, net benefit and CBR as 123430.50±0.00 to 235930.50±0.0 BDT/ha/6 months, 235068.40±1965.31 to 418376.85±5125.59 BDT/ha/6 months, 111639.90±2056.87 to 206744.85±3221.73 BDT/ha/6 months and 0.77±0.02 to 1.67±0.18, respectively.

Table 5: Economics of carp polyculture under different treatments for 6 months

Items	**Treatments**			*P*- value
	T_1	**T_2**	**T_3**	
Variable cost (BDT/ha)				
Seed cost	96522.00±456.72^{a}	96754.00±772.32^{a}	96810.00±391.11^{a}	0.930
Feed cost	105760.00±3350.7^{a}	105320.00±2630.9^{a}	107300.00±2979.^{a}	0.889
Liming	6765.70±234.49^{a}	6957.30±328.14^{a}	6735.00±425.59^{a}	0.883
Fertilization	5273.70±37.33^{a}	5304.00±60.35^{a}	5237.00±32.13^{a}	0.600
Labour cost Fixed cost (BDT/ha)	35295.00±179.93^{a}	35453.00±109.81^{a}	35244.00±27.63^{a}	0.497
Lease value	112490.00±21.36^{a}	112600.00±33.00^{a}	112230.00±517.4^{a}	0.693
Total cost(BDT/ha)	362110.00±3388.3^{a}	362380.00±2480.5^{a}	363560.00±2551.^{a}	0.930
Net return (BDT/ha)	585500.00±19289^{a}	501590.00±6906.5^{b}	460420.00±4689^{b}	0.001
CBR	1.62±0.10^{a}	1.38±0.03^{b}	1.27±0.04^{ab}	0.002

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P<0.05$).1 USD = 77 BDT.

4. Conclusion

Treatments had no significant effect on the water quality parameters. Mean values of water quality parameters under the treatments were found within suitable range for aquaculture. Treatment T_1 (silver carp dominant surface feeder 30% + column feeder 40% + bottom feeder 29% + all layer species 1%) performed best in terms of water quality; growth and yield of fishes; and economics of carp polyculture.

5. Acknowledgements

Authors are thankful to “Indrozit Matshya Hatchery” of Faridpur district, Bangladesh for assistance in conducting the research through logistic and financial supports from their brood development program under Aquaculture for Income and Nutrition Project (AIN) of World Fish (Memo # Indrozit hat/Fpr/06/107/13).

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