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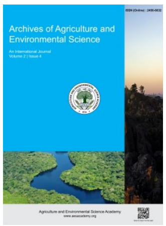

ORIGINAL RESEARCH ARTICLE

Different stocking densities and species combinations effects the growth and production in carp polyculture

Md. Hashibur Rahman[1*], Mohammad Ashraful Alam[2], Flura[2], Md. Moniruzzaman[2], Sharmin Sultana[3], Anik Talukdar[4] and Md. Rakibul Islam[4]

[1]Bangladesh Fisheries Research Institute, Headquarters, Mymensingh, BANGLADESH
[2]Bangladesh Fisheries Research Institute, Riverine Station, Chandpur, BANGLADESH
[3]Bangladesh Fisheries Research Institute, Freshwater Station, Mymensingh, BANGLADESH
[4]Bangladesh Fisheries Research Institute, Freshwater Sub-station, Jashore, BANGLADESH
[*]Corresponding author's E-mail: hasibkhan94bfri@gmail.com

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ABSTRACT

A comparative experiment was undertaken to assess the effectiveness of different carp species i.e., Rohu (*Labeo rohita*), Catla (*Catla catla*), Mrigal (*Cirrhinus cirrhosus*), and Silver Carp (*Hypophthalmicthys molitrix*) with variable stocking densities. Three treatments each with three replicates were maintained and the stocking densities of carps were 40, 80, and 120 fish/decimal in T_1, T_2, and T_3, respectively. The stocking ratio of Rohu, Catla, Mrigal, and Silver Carp was 2:1:2:1. The experimental diet included rice bran (25%), wheat bran (25%), fish meal (25%), and mustard oil cake (25%), with a total protein content of 28%. This dietary supplement was administered twice daily. The fish were supplemented with 5% of their body weight for the first month, 4.5% for the next three months, and 2% for the final two months. The Water quality parameters i.e., pH, temperature, dissolved oxygen and transparency were measured every 14 days interval. In T_1, Silver Carp obtained the highest weight (188.86±17.86g) followed by Mrigal (106.78±14.23g), Catla (74.0±3.80g), and Rohu (67.72±6.03g). In T_1, Silver Carp also attained the highest length at 26.33±0.63 cm, followed by Catla at 14.40±2.10 cm, Mrigal at 14.09±0.89 cm, and Rohu at 14.07±0.59 cm, respectively. Nevertheless, both weight gain and length gain were lowest for all species in T_3. The highest SGR% was found in T_1 for Silver Carp (3.22±0.06), whereas the lowest SGR% was found in T_3 for Catla (1.69±0.07). In addition, T_2 yielded the highest production (3090.91±119.57 kg/ha), followed by T_3 (2949.80±137.67 kg/ha) and T_1 (2946.21± 129.00 kg/ha). The experimental findings suggest that, the stocking density of 80 fingerlings/decimal (T_2) yielded the highest production in carp polyculture.

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INTRODUCTION

Fish is the major protein source contributing about 58% of the total animal protein intake. At present, fish consumption of Bangladesh is 67.8 g/day against the set target of 60.0 g/day of daily animal protein intake of its people (DoF, 2023). In 2021-22, fish production was 47.59 lakh MT; Which is 55.42% more than the total production of 2010-11 fiscal year (30.62 lakh MT). In 1983-84 the total production of fish in the country was 7.54 lakh MT. At present, 1.24% of the export income of the countries comes from the fisheries sector (DoF, 2023). Fish is exported to more than 50 countries in the world. In the last fiscal year, 74042.67 MT of fish and fish products have been exported earning 5191.76 crore BDT, which is 26.96% more than the previous year. Bangladesh has abundant fisheries resources but they have never been utilized properly on a scientific basis.

Moreover, the production of fish per hectare in our country is much lower due to lack of proper knowledge on the scientific fish culture and management practices. Pond fish culture is mainly major carp-oriented farming practices. Among different technologies of fish culture in Bangladesh, polyculture is one of the most important culture techniques. In addition, it is one of the most important culture techniques in aquaculture sector to increase the fish production and through this technique maximum production can be obtained. However, Polyculture might be more cost effective if we can maximize the utilization of available natural foods. Polyculture of carps in pond is a widespread practice in Bangladesh (Rashid, 2009). The system has been practiced with different species in the ponds occupying different niches with their complementary feeding habits, utilizing all the natural food available in the ponds and increasing fish production of the ponds (Wahab *et al*., 2001; Alam *et al*., 2001). Although, species of polyculture has not yet been widely undertaken, in species selection for polyculture, primary importance has given to Indian major carps. Sometimes, Common Carp (*Cyprinus carpio*) and silver carp (*Hypophthalmicthys molitrix*) have been introduced in polyculture for its better growth performance (Hossain *et al*., 2013). The polyculture method produces greater yields than monoculture in extensive systems due to the efficient utilization of more available natural food sources by various fish species (Wahab *et al*., 2001). If fish with diverse feeding habits are stocked in the proper ratio and combination (Talukder *et al*., 2017), polyculture may yield the desired results. Rohu (*Labeo rohita*), Catla (*Catla catla*), and Mrigal (*Cirrhinus cirrhosus*) are widely cultivated polyculture species in Asian countries farmers prefer to stock Common Carp as a bottom feeder over Mrigal because Common Carp grows faster than Mrigal and the overall production is greater when combined with Rohu and Catla in polyculture ponds (Rahman *et al*., 2006; Wahab *et al*., 2002). Compared to other culture systems, polyculture is more productive, capital-intensive, and profitable (Dev, 2009).

The significance of carp polyculture for enhancing fish productivity in Bangladesh is well documented (Azim and Wahab 2003; Hossain and Bhuiyan, 2007; Asadujjaman and Hossain, 2016). The fundamental principle of a fish polyculture system is the co-cultivation of compatible species with varying feeding habits in the same pond, maximizing the utilization of all natural food sources without negative consequences. Talukdar *et al*. (2012) compared to other systems, carp polyculture has the greatest potential for increasing fish production. Due to advancements in research and extension, aquaculture production in Bangladesh has nearly doubled over the past decade, with carp accounting for 45.35% of total pond fish production (DoF, 2017). In Bangladesh, existing carrying capacity of the ponds is very high. It should be determined with the proper stocking density in order to maximize the carrying capacity of the pond for the benefit of our producers. Therefore, it is necessary to evaluate the productivity of individual species in various species combinations. Rohu (*Labeo rohita*) and Catla (*Catla catla*) are indigenous, in-demand carps. Mrigal (*Cirrhinus cirrhosus*) and Silver Carp (*Hypophthalmicthys molitrix*) are essential for pond culture due to their high resistance to environmental fluctuations, feeding habits of consuming a wide variety of aquatic organisms, rapid growth rate, and high-quality flesh.

Nonetheless, despite feeding on a variety of aquatic organisms, the feeding habits of two or three species in distinct water levels cannot utilize all food resources available in the body of water. To achieve the greatest potential in a pond, it is necessary to investigate four-species-based polyculture. The present study was designed in order to compare the growth and production of Rohu, Catla, Mrigal, and Silver Carp at varied stocking densities and to determine a viable stocking density for carp polyculture.

MATERIALS AND METHODS

Study area and experimental design

This experiment was conducted from July to September 2019 in farmer-managed earthen ponds in the Muktagacha Upazila of the Mymensingh District of Bangladesh. The ponds had an average area of 4.5 decimal and a depth of 4 feet. Three replicates of each treatment were used to evaluate three distinct stocking densities (T_1-40/dec, T_2- 80/dec, and T_3- 120/dec) of Rohu, Catla, Mrigal, and Silver Carp in the ratio of 2:3:2:1. At 15-day intervals, measurements were taken of water quality parameters such as temperature, transparency, pH, and dissolved oxygen. At each weekly interval, fertilizer was administered. The A mixture of rice bran (25%), wheat bran (25%), fish meal (25%), and mustard oil cake (25%), containing a protein content of 28%, was used as supplemental feed twice in a day. The feed was supplemented at a rate of 5% of their body weight for the first month, 4.5% for the next three months, and 2% for the final two months. The fish growth, the amount of food was adjusted every month based on the total biomass of fish determined through sampling. In each sampling, 10% of the stocked fishes of each species were captured from each pond using a seine net for the observation of fish growth performance.

Preparation of the pond

Prior to conduct the experiment, the aquatic vegetation in every pond was removed, and the ponds were cleaned. Through repeated netting (seine net with a 12.5 mm mesh), unwanted fish and other species were removed. In addition, liming (CaO at the rate of 247 kg ha^{-1} as a base dose and 120 kg ha^{-1} $month^{-1}$ as a periodic dose) was carried out to preserve water quality. Fertilization was also performed with urea (basal dose, 50 kg ha^{-1}; periodic dose, 25 kg ha^{-1} $month^{-1}$) and Triple Super Phosphate (basal dose, 50 kg ha^{-1}; periodic dose, 25 kg ha^{-1} $month^{-1}$) to boost the production of natural feed. After three days of lime application, the soil was fertilized. After Karim and Rahim (2013), both liming and fertilization levels were maintained. All of the carp fingerlings were transferred from the nursery to the farmer-managed grow-out ponds for stocking.

Water quality monitoring

Important water quality parameters, including water temperature, transparency, pH, dissolved oxygen (DO), free carbon monoxide (CO), alkalinity, and ammonia- nitrogen, were monitored every two weeks. The water temperature was recorded using a centigrade thermometer between 0 and 120°C. Using a Secchi disc, the transparency of water (cm) was measured. A pH meter was used to measure the pH of pond water. With the aid of a dissolved oxygen meter (YSI MODEL 58, USA), the oxygen concentration (mgL^{-1}) in the pond water was measured. The free carbon dioxide (mgL^{-1}), alkalinity (mgL^{-1}), and ammonia-nitrogen (mgL^{-1}) concentrations in pond water were determined via digital titration using a HACH reagent.

Fish growth monitoring

In each sampling, 10% of the stocked fish of each species were captured from each pond using a seine net in order to determine the growth performance of fishes. Once the sampling was done, the fishes were released back into the ponds without physical damage. After Brett and Groves (1979), the growth of fishes was monitored using the following parameters:

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

$$\text{SGR per day (\%)} = \frac{\log W_2 - \log W_1}{T_2 - T_1} \text{ X } 100$$

$$\text{Percent weight gain (\%)} = \frac{\text{Mean final weight} - \text{Mean initial weight (gm)}}{\text{Mean initial (gm)}} \text{X100}$$

Production = No. of fishes harvested × average final weight of fishes

Data analysis

Using SPSS (Statistical Package for the Social Sciences, version 24), data on water quality parameters, fish growth, and yield of carp polyculture under various treatments were subjected to one -way analysis of variance (ANOVA). The normality of the data was examined before analysis. Additionally, the mean values were contrasted using the Duncan Multiple Range Test (DMRT; Gomez and Gomez, 1984) at a significance level of 0.05.

RESULTS AND DISCUSSION

Water quality parameters

The mean values for various water quality measurements are presented in Table 1. The pH levels of pond water were observed to range between 7.60 and 8.6. The average pH of the water in treatments T_1, T_2, and T_3 was 7.76±0.17, 7.38±0.14, and 7.54±0.11, respectively. Again, the range of dissolved oxygen concentrations in the various ponds ranged between 4 to 12. The concentrations of dissolved oxygen in the three treatments, T_1, T_2, and T_3, were observed to vary between 7.58±0.57, 5.47±0.33, and 6.78±0.73, respectively. The three treatments showed a significant difference ($p>0.05$) from one another (Table 1). The temperature of the pond water was found to be nearly similar across all treatments with no significant differences. The temperatures were 31.74±0.27°C, 31.51±0.21°C, and 32.19±0.28°C, in the T_1, T_2, and T_3 respectively. The highest temperature, 34°C, was recorded in July, and the lowest, 30°C, was recorded in September. The transparency of water ranged between 20 to 38 cm. The average water transparency for treatments T_1, T_2, and T_3 was 31.59±1.06 cm, 34.41±0.98 cm and 32.91±1.09 cm, respectively. The three treatments showed a significant difference ($p>0.05$) from one another (Table 1). According to the transparency values throughout the various treatments, pond water appeared to be within the productive range for fish culture (Alim *et al.*, 2005; Raihan, 2001).

Table 1. Water quality parameters in different treatment during experiments.

Treatments	pH	Dissolved oxygen	Temperature (°C)	Transparency
T_1	7.66±0.17	7.58±0.57^a	31.74±0.27	31.59±1.06^b
T_2	7.38±0.14	5.47±0.33^b	31.51±0.21	34.41±0.98^a
T_3	7.54±0.11	6.78±0.73^{ab}	32.19±0.28	32.91±1.09^{ab}

Table 2. Weight and length gain of different species during experiment.

Parameters	Treatments	Rohu	Catla	Mrigal	Silver carp
Initial weight (g)	T_1	0.45±0.00	0.50±0.00	0.55±0.00	0.45±0.00
	T_2	0.45±0.00	0.50±0.00	0.55±0.00	0.45±0.00
	T_3	0.45±0.00	0.50±0.00	0.55±0.00	0.45±0.00
Final weight (g)	T_1	68.17±6.03	74.50±32.80	107.33±14.23	189.31±15.76
	T_2	48.00±1.31	33.33±1.62	59.17±3.78	145.00±1.82
	T_3	32.17±2.54	30.90±3.04	46.34±2.29	67.50±13.80
Weight gain (g)	T_1	67.72±6.03^a	74.03±2.80	106.78±14.23^a	188.86±17.86^a
	T_2	47.55±1.31^b	32.83±1.62	58.62±3.78^b	144.55±1.82^a
	T_3	31.72±2.74^c	30.40±3.04	45.79±2.29^b	67.05±13.80^b
Initial Length (cm)	T_1	5.36±0.00	5.10±0.00	5.15±0.00	5.12±0.00
	T_2	5.36±0.00	5.10±0.00	5.15±0.00	5.12±0.00
	T_3	5.36±0.00	5.10±0.00	5.15±0.00	5.12±0.00
Final length (cm)	T_1	19.43±0.59	19.50±2.10	19.24±0.89	31.45±0.53
	T_2	17.13±0.25	16.51±0.24	18.89±0.56	25.75±0.15
	T_3	14.03±0.54	14.91±0.61	15.99±0.44	22.95±1.11
Length gain (cm)	T_1	14.07±0.59^a	14.40±2.10^a	14.09±0.89^a	26.33±0.63^a
	T_2	11.77±0.25^b	11.41±0.24^{ab}	13.74±0.56^b	20.63±0.15^a
	T_3	8.67±0.74^c	9.81±0.61^b	10.84±0.44^b	17.83±1.11^b

Table 3. Specific growth rate percentage of carp species in polyculture ponds.

Treatments	Rohu	Catla	Mrigal	Silver carp
T_1	2.56±0.06	2.17±016^a	2.84±0.08^a	3.22±0.06^a
T_2	2.31±0.01	1.89±0.03^{ab}	2.53±0.03^b	3.12±0.005^b
T_3	1.96±0.05	1.69±0.07^b	2.37±0.02^c	2.67±0.07^b

Table 4. Total production of fish (kg/ha/year) in three treatments.

	Cultivated species				
Treatments	Rohu	Catla	Mrigal	Silver carp	Total production (kg/ha)
T_1	444.12±52.67	919.70±37.28	830.43±98.43	751.96±56.62^b	2946.21± 129.00
T_2	451.34±19.87	697.31±32.84	818.42±47.78	1123.84±18.88^a	3090.91±119.57
T_3	421.01±53.44	794.23±95.78	929.15±41.17	805.41±64.31^a	2949.80±137.67

Growth and length performance at different treatments

There was a statistically significant difference ($p<0.05$) in weight gain between T_1 and the other treatments. Furthermore, there were considerable differences in weight gain between Mrigal and Silver Carp (Table 2). Similar to this, treatment T_1 provided the highest average length gain (cm) over the research period than T_2 and T_3. However, considerable variations were found across various fish species (Table 2). In the current study, Silver Carp exhibited the highest weight gain (188.86±17.86 g) in T_1 and Rohu showed the lowest weight gain (31.72±2.74 g) in T_3. According to Islam (2009), Rohu gained the maximum weight (31±0.87) over the 90-days culture period. This study had four times the stocking density of Islam (2009), which may have led to its lower growth performance. To the contrary, Rohu (8.67±0.74 cm) had the lowest length gain and Silver Carp (26.33±0.63 cm) had the highest. Again, all species observed that T_1 produced the highest length gain and that T_3 caused the least length gain. It could be because treatment T_3 had the highest stocking density whereas treatment T_1 had the lowest.

Specific growth rate (%)

There were no statistically significant variations observed in the specific growth rate (SGR%) of Rohu among the three treatments. The SGR values for Catla, Mrigal, and Silver Carp, however, demonstrated a significant difference ($p<0.05$) across treatments. Milstein *et al.* (2009) reported that SGR% of Rohu ranged from 1.16 to 0.99, whereas SGR% value of Rohu in T_1 was 2.56±0.06. The Mrigal, Catla, and Silver Carp all have a considerable difference in SGR%. In treatment T_1, Silver Carp had the highest SGR% (3.22±0.06) and Catla had the lowest SGR% (1.69±0.07). Similar to our findings, Modac (2006) discovered that the SGR% value of Rohu in the Indian Carp polyculture system was 1.65±0.74.

Growth performance of individual species (g)

The species combinations of Rohu, Catla, Mrigal, and Silver Carp were performed using three different treatments at a rate of 40 (T_1), 80 (T_2), and 120 (T_3) fingerlings/decimal, respectively. During the observed time period, T_1 accounted notable weight gain for the fish species Rohu, Catla, Mrigal, and Silver Carp, as depicted in Table 2. In addition, there was a significant difference ($p<0.05$) in the weight gain of Rohu, Mrigal, and Silver Carp. The observed weight gain of Catla, however, did not exhibit any statistically significant alterations as a result of the administered treatments.

Production performance (kg/ha)

The overall production was given as an expression in kg/ha (Table 4). The overall net production was highest in T_2 (3090.91±119.57kg/ha) followed by T_3 (2949.80±137.67 kg/ha), and T_1 (2946.21±129.00 kg/ha). The results of this investigation revealed that the production performance of each individual fish was not comparable across all three treatments (Table 4). The total fish production in T_2 was highest for all species compared to the other two treatments. This might be because of maintaining the proper stocking density (80/dec). On the other hand, the overall production for Catla higher in T_1 than the other two treatments (T_2 and T_3). In addition, T_1 and T_2 resulted in the same amount of production for Mrigal, but T_3 resulted in a higher amount of production. The overall yield of Silver Carp was the highest, while the production of Rohu was the lowest. In comparison, the production of Catla and Mrigal was practically same.

Interaction among the species

The highest yield was achieved with Silver Carp when the population of plankton was raised through fertilization. Mrigal had the second greatest production, which could be because of its bottom feeding nature. Because Catla and Rohu consume the same food, the middle layer, the production of these two species was lower than that of other species due to the intense competition for food and other resources. However, Rashid (2009) found that the pond ecology was unaffected by polyculture, which included species with a variety of feeding habits.

Total fish production

In this study, T_2 (3090.91±119.57kg/ha) had the highest overall production, followed by T_3 (2949.80±137.67kg/ha) and T_1 (2946.21±129.00kg/ha). The gross production from the polyculture system was 1,817 kg/ha by Kohinoor (2000) and 1,970 kg/ha by Kadir *et al.* (2006) during the course of the 5 months culture period. The findings of Sagor (2008) and Hossain (2008) were supported by the current study. According to this study, a stocking density of 80/dec is ideal for polyculture, and higher stocking densities will lead to lower overall productivity.

Conclusion

The polyculture of carps could be carried out with increased production using a stocking density of 80 fingerlings/decimal. The results indicated that Silver Carp gained the highest weight (188.86±17.86g) in T_1, followed by Mrigal (106.78±14.23 g), Catla (74.03±2.80 g), and Rohu (67.72±6.03 g). Similarly, Silver Carp achieved the highest length in treatment T_1 at 26.33±0.63 cm, followed by Catla (14.40±2.10 cm), Mrigal (14.09±0.89 cm), and Rohu (14.07±0.59 cm). However, both weight gain and length gain were lowest for all species in treatment T_3. The highest SGR% was found in T_1 for Silver Carp (3.22±0.06), while the lowest SGR% was found in treatment T_3 for Catla (1.69±0.07). In addition, T_2 yielded the highest production (3090.91±119.57 kg/ha), followed by T_3 (2949.80±137.67 kg/ha) and T_1 (2946.21±129.00 kg/ha). The results of this study indicate that, the stocking density of 80 fingerlings per decimal (T_2) is optimal for achieving the highest yield in polyculture.

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