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Polyculture of small fish species (*Systomus sarana, Pethia ticto and Rasbora daniconius*) with Indian Major Carps

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Abstract

The present study aimed to evaluate the growth performance and survival of small indigenous fish species *Systomus sarana, Pethia ticto, and Rasbora daniconius* in polyculture with Indian Major Carps (IMCs) including Labeo rohita, Catla catla, and Cirrhinus mrigala. The experiment was conducted from August to December in the Shade-II hatchery of the Department of Zoology and Applied Aquaculture, Barkatullah University, Bhopal. Two treatments were designed: Treatment-1 (T1) consisted of both IMCs and small fish species, while Treatment-2 (T2) included only the small fish species. Each tank held 60 individuals, and both were managed under similar feeding, fertilization, and water quality monitoring protocols. Water quality parameters such as temperature, pH, dissolved oxygen, free CO_2, total alkalinity, and hardness remained within optimal ranges for fish growth throughout the culture period. The final average weights of small fish species were slightly higher in T2 (e.g., *Rasbora daniconius* 9.41 g) compared to T1 (9.29 g), suggesting mild competition for resources in the mixed stocking environment. Among IMCs, Cirrhinus mrigala exhibited the highest growth (13.47 g). Survival rates were high in both treatments, with T2 showing a slightly better average (86.6%) than T1 (82.35%). The results indicate that small indigenous fish species can be co-cultured with IMCs without significantly compromising their growth or survival, offering a promising approach for enhancing fish yield and biodiversity in freshwater aquaculture systems.

Keywords: Polyculture, Small fish species, Indian Major Carps

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1 Introduction

Aquaculture has emerged as a rapidly expanding industry due to the rising global demand for fish and seafood (Cao et al., 2007), now accounting for approximately 46% of the total food fish supply (Nyanti et al., 2012). Beyond meeting dietary needs, aquaculture plays a significant role in generating employment opportunities, especially in rural communities. Fish serves as a vital source of animal protein and is considered one of the most efficient systems for producing protein-rich food from aquatic resources. It complements the carbohydrate-dominated diets prevalent among many low-income populations in developing nations.

Fish and fisheries contribute substantially to food security, with small-scale fisheries holding particular importance, as highlighted by the Food and Agriculture Organization (FAO, 2003). Among the various aquaculture methods, polyculture is notably effective in increasing yield. This technique, which involves raising multiple fish species together, utilizes natural food resources in ponds more efficiently than monoculture systems, especially in extensive and semi-intensive setups (Jhingran, 1982; Lin, 1982; Hassan, 1990; Hassan et al., 1997). Successful polyculture depends on selecting species with diverse feeding habits and stocking them in suitable combinations and proportions (Halver, 1984). Ahmed (1992) emphasized the importance of Indian major carps rohu (*Labeo rohita*), catla (*Catla catla*), and mrigal (*Cirrhinus mrigala*) in polyculture systems. Additionally, small indigenous fish species (SIS), typically growing to less than 25 cm (or 9 inches), contribute significantly to nutrition and livelihoods, especially among the poor and marginalized. Popular SIS species like mola (Amblypharyngodon mola), chapila (*Gudusia chapra*), tengra (*Mystus vittatus*), pabda (*Ompok pabda*), colisha (*Colisa fasciata*), punti (*Puntius sophore*), and chela (*Chela cachius*) are in high demand in both rural and urban markets.

Most SIS species are under 10 cm in length and are usually consumed whole, including bones and organs. These fish are rich in calcium and are likely good sources of iron and zinc (Tripathy, 1997). Certain species, such as *Amblypharyngodon mola, Osteobrama cotio*, and *Rasbora daniconius*, also provide significant amounts of vitamin A (Thilsted et al., 1997). Most of the SIS have a short life cycle and require only a few months to grow to sexual maturity. Many SIS have a fast growth rate and a good food conversion ratio (Rajts et al., 1997). SIS are often more hardy and resistant to water quality and temperature fluctuations than the species of Indian carp (Akhteruzzaman et al., 1997). The black line *Rasbora*, *Rasbora daniconius*, is a popular indigenous ornamental fish of India (Mahapatra et al., 2004; Mahapatra et al., 2005). Its body is compressed and oblong. It is also a popular food fish for economically weak communities because of its low price (Kumar et al., 2006). The ticto barb, *Pethia ticto* (Hamilton, 1822), is one of the Cyprinid fish species. It is a small, indigenous and admirable fresh and brackish water popular fish species. It is commonly known as “ticto” or “two-spot barb”. The *P. ticto* is a valuable fish food item and an important source of micronutrients essential in preventing malnutrition and vitamin and mineral deficiencies in rural communities. *Systomus sarana* (Hamilton, 1822) is a member of the family Cyprinidae, commonly known as “Olive barb” The conservation status of the fish has been referred to as critically endangered (IUCN Bangladesh, 1998; Ameen et al., 2000; Hussain and Mazid, 2004). It is a tasty, the most popular and favourite table fish among barb species, having high nutritional and market value in Bangladesh as well as other Asian countries (Chakraborty et al., 2006).

Despite their relatively small size (100–200 grams), the strong consumer demand for these species makes them ideal candidates for expanding carp farming (Gopakumar et al., 1999; Chakraborty et al., 2003). Fish farming plays a crucial role in enhancing people's nutritional intake and in the efficient use of water and land resources (Abbas et al., 2010; Sarker et al., 2014). It also stimulates the development of related industries. The polyculture of Indian Major Carps (IMC) such as Labeo catla (*Catla*), Labeo rohita (*Rohu*), and Cirrhinus mrigala (*Mrigal*) is a common and effective practice, as these species naturally occupy different ecological zones within water bodies. Rather than removing native small indigenous species (SIS) from aquaculture systems, efforts should be made to maximize their production, as they utilize otherwise untapped food sources and ecological niches in ponds (Roos, 2001; Ross et al., 2003). Historically, SIS were plentiful in rivers, ponds, streams, beels, ditches, and floodplains, but their populations have declined due to habitat destruction, overfishing, pesticide use, and disease outbreaks such as EUS, all of which threaten biodiversity. Therefore, it is essential to focus on the cultivation of SIS, as they are rich in vitamin A and essential minerals (Thilsted et al., 1997). Incorporating SIS into polyculture systems alongside large carps can improve both household nutrition and income for low-income families. In terms of nutritional benefits, the cultivation of SIS is comparable to home gardening, which is widely encouraged as a strategy to address vitamin deficiencies, boost food production, and improve food availability for the underprivileged.

2 Materials And Methods

a. Study location

The present study was conducted from August to December in the hatchery Shade-II of the Department of Zoology and Applied Aquaculture, Barkatullah University.

b. Experimental design

The experiment was conducted in two treatments. In treatment-1, three major Indian carps, rohu- *Labeo rohita, catla- Labeo catla and mrigal- Cirrhinus mrigala* and three small fish species, such as *Systomus sarana, Pethia ticto and rasbora-* Rasbora daniconius were stocked. In treatment-2, only small fish species (*Systomus sarana, Pethia ticto and Rasbora daniconius*) were stocked.

Table 1 Layout of the experiment (fish species composition)

Species	TANK 1	TANK 2
Labeo rohita	8	
Labeo catla	8	
Cirrhinus mrigala	12	
Systomus sarana	10	20

Pethia ticto	10	20
Rasbora daniconius	12	20
TOTAL	60	60

3 TANK PREPARATION

All unwanted leaves and insects were eradicated from the tank. Tanks were cleaned and treated with potassium permanganate ($KMnO_4$). Later, the tank was fertilized with cow dung at fortnightly intervals.

1. Collection of fishes

The fingerlings of small fish species and IMCs were collected through netting from the pond in the department of Zoology and Applied Aquaculture, Barkatullah University, Bhopal. Fingerlings were brought to the experimental site through hundi.

2. Fry stocking

The fry and fingerlings were transferred into the hundi and released into the tank. The length and weight of all the fingerlings were measured to estimate initial stocking biomass and to adjust the initial feeding rate for the fish.

3. Feeding of fishes

Common agricultural by-products like fine rice bran and mustard oil cake were used as supplementary feed, mixed in equal proportions to form a dough. This feed was provided to the fish daily at a rate equivalent to 4% of their total body weight.

4. Fertilization

The tanks were fertilized with cow dung and were given at a 7-day interval throughout the culture period.

5. Growth sampling of fish

Fish were sampled fortnightly at every two weeks through netting from both T1 & T2. To assess the growth of the fish and adjust the feeding rate. The length of the fishes was measured by measuring scale and weight of the fishes were measured by using the RTB 200gm weighing machine. Fishes were sampled with dragnets of suitable mesh sizes. Fishes were handled carefully to avoid stress during sampling.

6. Water quality analysis

Water quality plays a vital role in fish growth. Key water quality parameters—including temperature (°C), pH, dissolved oxygen (DO), carbon dioxide, and alkalinity—were monitored on a weekly basis. Water samples were taken from both tanks (T1 and T2). Temperature was measured using a handheld mercury thermometer, pH was assessed using pH paper, and other parameters such as DO, carbon dioxide, hardness, and alkalinity were determined using the titrimetric method, following the guidelines of APHA (1995).

7. **Survival Rate**

The survival rate of the fish was calculated by using the following formula:

Survival Rate (%) = No. Of fish harvested /No. of fish stocked

8. **Specific Growth Rate (SGR) (%)**

X 100 It is related to the increase in weight of the fish's body after a certain point in time. It is calculated as follows:

SGR = In (final weight in gm) – In (initial weight in gm) /Days of culture X 100

Fig.1: Tank 1 (IMCs with SIFs)

Fig.2: Tank 2 (Small fish species)

Fig.3: Tank treated with $KMn0_4$

Fig.4: Collection of fish

Species cultured

1. SIS

Fig.5: ***Systomus sarana***

Fig.6: ***Pethia ticto***

Fig.7: Rasbora daniconius

2. IMCs

Fig.8: Labeo rohita

Fig.9: Labeo catla

Fig.10: Cirrhinus mrigala

RESULTS

The overall mean values of each water quality parameter in both the tank (1&2) are presented in table 1 & 2.

Table 2 Physico-chemical parameters of Tank- 1

Parameters	August		September		October		November		December		Mean ± SD	Min-max
	12th	27th	11th	26th	11th	26th	10th	25th	10th	25th		
Temperature (⁰C)	25	27	26	28	27	26	22	24	25	23	25.3±1.88	22-28
pH	6.9	6.8	7.0	7.3	7.4	7.8	7.6	7.7	7.5	7.2	7.32±0.34	6.8-7.8
Free CO_2 (mg/l)	0.8	1.3	0.7	2.1	2.3	1.7	2.4	2.1	2.5	3.0	1.89±0.753	0.7-3
DO (mg/l)	6.4	6.6	7.0	6.9	7.3	7.4	7.1	7.5	7.3	7.2	7.07±0.352	6.4-7.5
Total Alkalinity (mg/l)	121	141	119.6	145.7	170.8	114.6	150.6	165.3	148.7	130.2	140.75±19.21	114.6-170.8
Total Hardness (mg/l)	114.6	136	123	154.3	147.1	99.7	161	134.8	128.8	138	133.73±18.35	99.7-161

Table 3 Physico-chemical parameters of Tank- 2

Parameters	August		September		October		November		December		Mean ± SD	Min-max
	12th	27th	11th	26th	11th	26th	10th	25th	10th	25th		
Temperature (⁰C)	27	26	28	25	27	24	23	25	24	22	25.1±1.91	22-28
pH	6.8	7.0	6.9	7.1	7.3	7.7	7.5	7.6	7.4	7.3	7.26±0.302	6.8-7.7

Free CO_2 (mg/l)	0.9	1.5	0.8	2.1	2.5	1.8	3	2.2	2.7	2.3	1.98±0.731	0.8-3
DO (mg/l)	6.4	6.8	7.1	7.7	7.3	6.6	7.5	7.2	7.4	7.3	7.13±0.411	6.4-7.7
Total alkalinity (mg/l)	127.1	134	147.3	157.3	164	168.4	119.2	150.7	141	144	145.3±15.70	119.2-168.4
Total Hardness(mg/l)	115	128.1	94.6	145.4	162.5	136.5	140.7	151	134	155.2	136.3±20.07	94.6-162.5

The water temperature in both tanks (T1 and T2) was fairly consistent. The average temperature in T1 was 25.3 ± 1.88°C, ranging from 22 to 28°C, while in T2 it was 25.1 ± 1.91°C within the same range. pH levels in both tanks showed fluctuations, ranging from 6.8 to 7.8 in T1 and 6.8 to 7.7 in T2. The lowest pH value (6.8) was recorded on August 12th in T2, and the highest (7.8) was noted on October 26th in T1. Free CO_2 levels in T1 reached up to 3 mg/L with a mean of 1.89 ± 0.753 (range: 0.7–3), while in T2 the mean was significantly higher at 7.13 ± 0.411 (range: 6.4–7.7). The mean pH values were 7.32 ± 0.34 in T1 and 7.26 ± 0.302 in T2. Dissolved oxygen levels ranged between 6.4 and 7.5 mg/L in T1 (mean: 7.07 ± 0.352), and between 6.4 and 7.7 mg/L in T2 (mean: 7.13 ± 0.411). No significant differences were observed between the mean values across the tanks. Total alkalinity fluctuated throughout the experiment, with average values of 140.75 ± 19.21 mg/L (range: 114.6–170.8) in T1 and 145.3 ± 15.70 mg/L (range: 119.2–168.4) in T2. Total hardness ranged from 114.6 to 138 mg/L in T1 and 115 to 155.2 mg/L in T2, with mean values of 133.73 ± 18.35 and 136.3 ± 20.07, respectively.

Table 4 Showing observed average Length (cm) under both Tank (1&2)

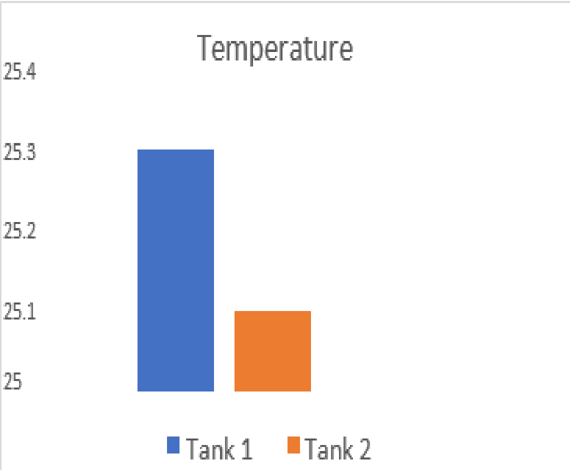
Tank	Fish species	Initial average Length (cm)	Observed average Length (cm)										Final average Length (cm)
			August		September		October		November		December		
			12th	27th	11th	26th	11th	26th	10th	25th	10th	25th	
T-1	*Labeo rohita,*	9.2	9.97	10.2	10.08	10.31	11.43	11.5	11.66	11.7	11.8	12.4	11.10
	Labeo catla	8.8	9.90	10.3	10.7	11	11.04	11.4	11.6	11.75	11.81	12	11.15
	Cirrhinus mrigala	10	10.35	10.58	10.9	11.2	11.33	11.67	11.8	12.8	13.3	13.5	11.74
	Systomus sarana	5.9	6.81	7.34	8.7	9.4	9.7	9.91	10.4	10.7	10.9	11	9.48

	Pethia ticto	6.2	6.70	7.16	8.5	8.8	9.4	9.61	9.7	9.8	10	10.9	9.05
	Rasbora daniconius	6.68	7.53	8.8	9.5	10.1	10.6	11.2	11.6	11.87	12.3	12.5	10.6
T-2	*Systomus sarana*	6	6.87	7.8	8.5	9.6	9.8	10	10.8	11.1	11.5	12	9.79
	Pethia ticto	6.5	7.6	8.3	8.45	9.4	9.7	10.2	10.51	10.6	10.9	11.4	9.70
	Rasbora daniconius	6.8	7.1	7.5	8.8	9.18	9.35	9.7	10.62	11.2	12.4	12.6	10.11

On the basis of the final growth attained by each species, it was observed that among all species, the highest growth was obtained from the mrigal. The final average weight of mrigal attained 13.47g in tank 1. Catla reached an average weight of 12.58g, and rohu is 11.73g. The average higher growth of small fish species (*Systomus sarana*, *Pethia ticto and Rasbora daniconius*) was 8.97g, 8.98g and 9.41g in tank-2, where no IMCs were kept. The average weight of *Systomus sarana*, *Pethia ticto and Rasbora daniconius* in tank-1 is 8.8g, 8.73g and 9.29g. There was not much significant difference in the survival rates of both the tanks, which were 82.35% in tank-1 and 86.6% in tank-2.

Table 5 Showing Survival Rate of both Tanks (1&2)

Tank	Fish species	Survival Rate (%)	
		Species wise	Average
T-1	*Labeo rohita,*	80	82.35
	Labeo catla	87.5	
	Cirrhinus mrigala	83.3	
	Systomus sarana	80	
	Pethia ticto	80	
	Rasbora daniconius	83.3	
T-2	*Systomus sarana*	85	86.6
	Pethia ticto	85	
	Rasbora daniconius	90	



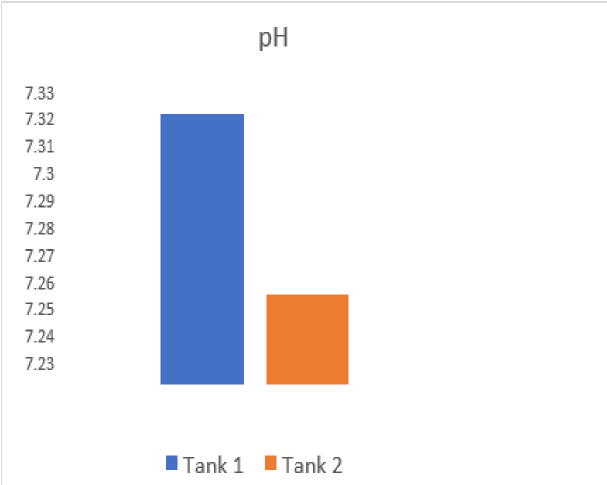


Fig 12: Graph showing variation in CO2 in tank (1&2)

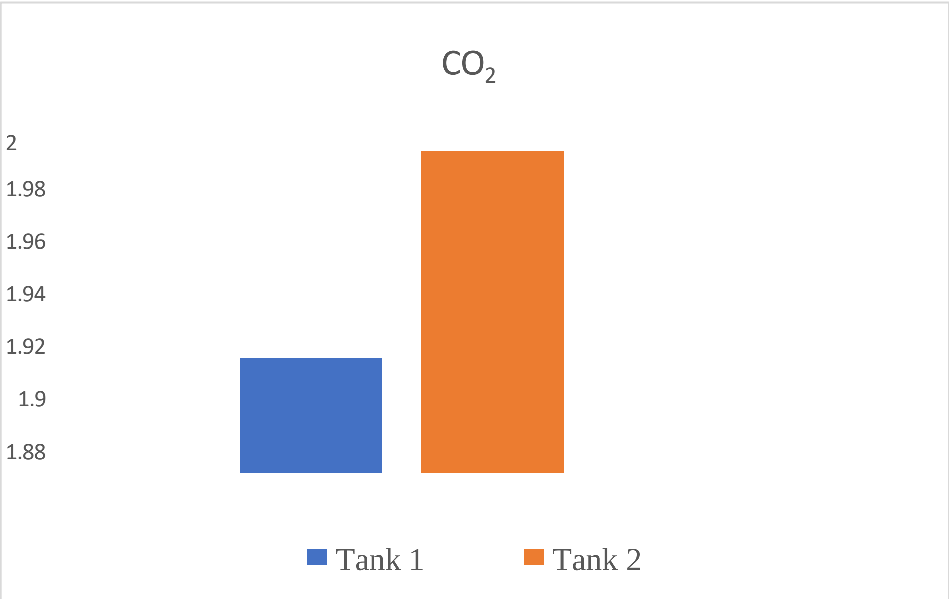


Fig 13: Graph showing variation in DO in tank (1&2)

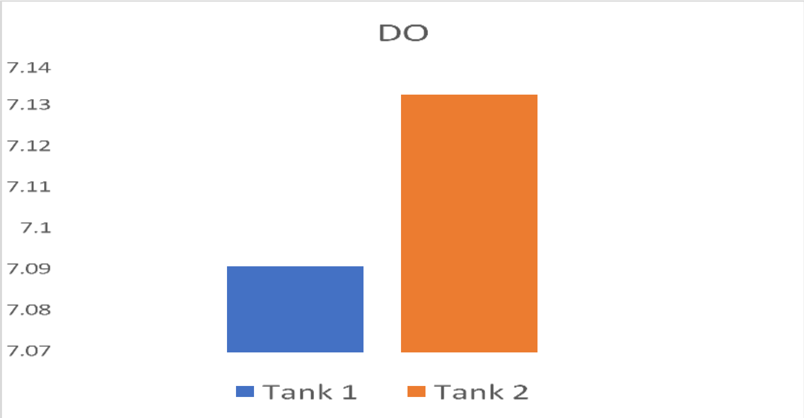


Fig 14: Graph showing variation in pH in tank (1&2)

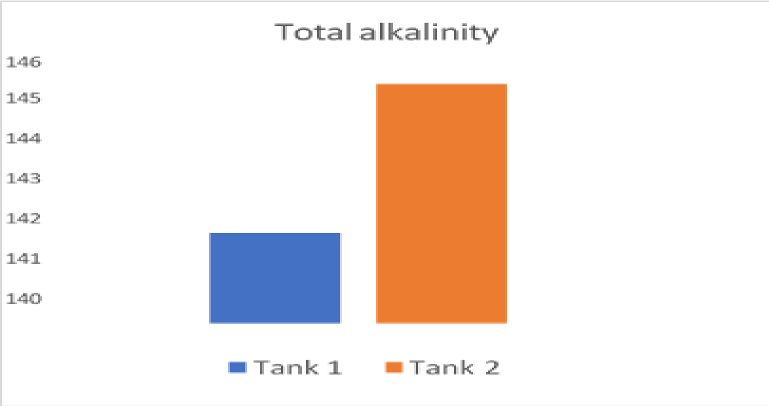


Fig 15: Graph showing variation in Total alkalinity in tank (1&2)

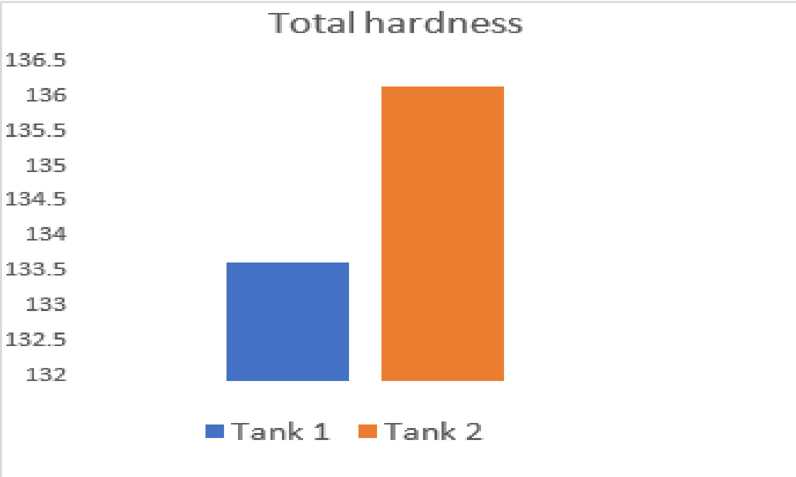


Fig 16: showing variation in Total hardness in tank (1&2)

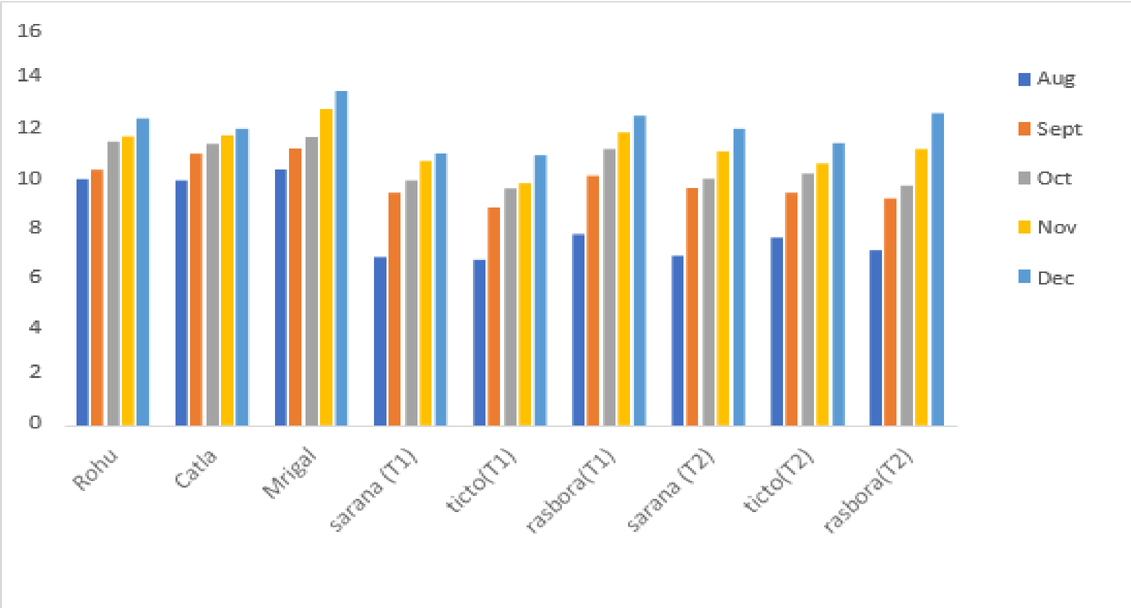


Fig 17: Graph showing variation in length of fish in tank (1&2)

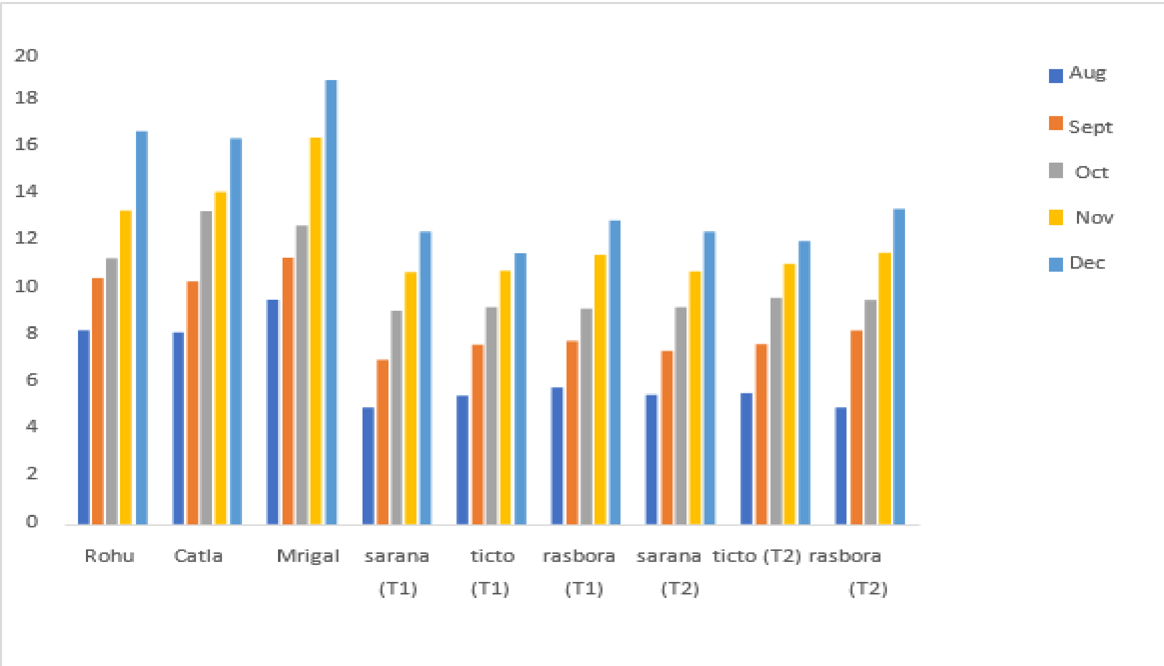


Fig 18: Graph showing variation in weight of fish in tank (1&2)

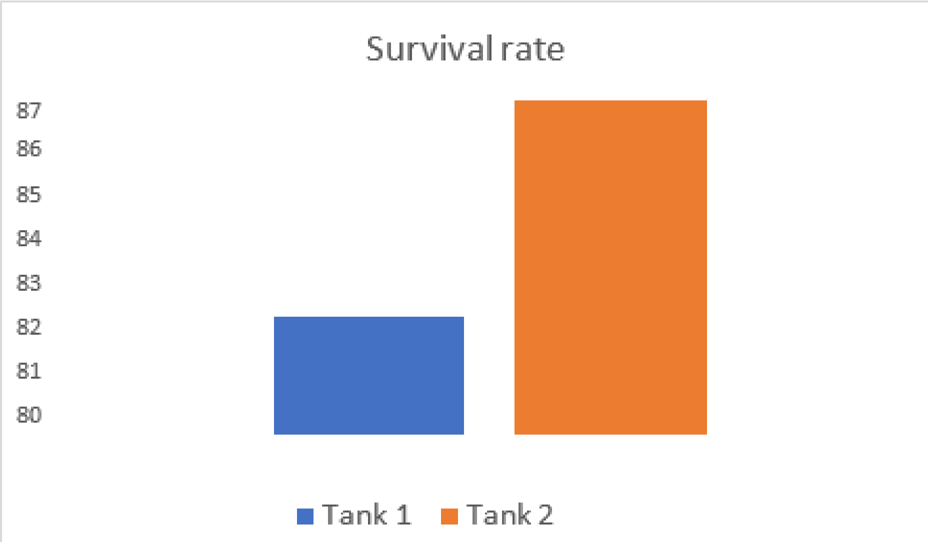


Fig 19: Graph showing survival rate of fish in tank (1&2)

4 Discussion

Small fish species have traditionally played a vital role in meeting the nutritional needs of rural poor communities. However, these species are now under threat of extinction due to overfishing and habitat degradation. Integrating small fish with carp in polyculture systems could provide both commercial benefits and support conservation efforts. Therefore, this study discusses and compares various water quality parameters and growth data observed during the experiment. Overall, water quality remained within acceptable limits across all treatments, with no abrupt changes detected in any parameter. Among these, water temperature is a key environmental factor that affects the physical, chemical, and biological dynamics of aquatic systems. In this study, temperatures ranged from 22°C to 28°C in both tanks. The highest temperatures were observed in August, while the lowest were recorded in November and December. Previous studies have reported similar findings, such as Hasan et al. (2002), who observed a temperature range of 24.4–33.0°C in ponds at the BAU campus in Mymensingh, Bangladesh. Similarly, Rahman et al. (1992) found that water temperatures between 25.5°C and 30.0°C conditions favorable for fish culture.

pH is another critical parameter in aquaculture. An acidic pH can negatively affect fish growth, metabolism, and other physiological functions (Swingle, 1967). An optimal pH range for pond fish culture lies between 6.5 and 9.0, while levels above 9.5 are unsuitable due to the lack of free CO_2. In the current study, pH levels ranged from 6.8 to 7.8 in Tank 1 (T1) and 6.8 to 7.7 in Tank 2 (T2), falling within the ideal range for fish farming. In comparison, Mollah and Haque (1978) recorded pH levels between 5.66 and 7.44 in ponds at the BAU campus, and Kohinoor et al. (1998) reported pH values ranging from 7.18 to 7.24 in research ponds at the same location. Dissolved oxygen (DO) levels in this study ranged from 6.4 to 7.5 mg/L in T1 and 6.4 to 7.7 mg/L in T2, with average values of 7.07 ± 0.352

mg/L and 7.13 ± 0.411 mg/L, respectively. The highest DO concentrations were recorded in November, and the lowest in August. Throughout the study, fish showed no signs of oxygen stress, indicating that DO levels were adequate. In contrast, Wahab et al. (1995) reported DO levels between 2.0 and 7.2 mg/L during experiments at the BAU campus.

Total hardness in Tank 1 ranged from 114.6 to 138 mg/L, while in Tank 2 it ranged from 115 to 155.2 mg/L. The average hardness values were 133.73 ± 18.35 mg/L in T1 and 136.3 ± 20.07 mg/L in T2. The highest hardness levels were recorded in November, and the lowest in September. According to Wahab et al. (1995), total hardness typically falls within the range of 45–108 mg/L. Swingle (1997) proposed that 50.5 mg/L (as $CaCO_3$) serves as the dividing line between soft and hard water. He further noted that waters with hardness above 15 mg/L are generally sufficient for fish farming without the need for lime, whereas those below 12 mg/L require liming to improve fish production.

In this study, the highest weight gains among small fish species *Systomus sarana, Pethia ticto, and Rasbora daniconius* were observed in Tank 2, where Indian major carps (IMCs) such as Catla, Rohu, and Mrigal were not stocked. In contrast, the lowest weight gains occurred in Tank 1, where small fish were cultured alongside IMCs. This suggests that competition for food occurred, especially between the small fish and Catla and Rohu. As noted by Chandra (1986), Catla and Rohu primarily feed on plankton, while Mrigal is an omnivore and bottom feeder. Weight gain for *S. sarana, P. ticto, and R. daniconius* was recorded as 12.5g, 11.6g, and 13g in Tank 1, and 12.5g, 12.1g, and 13.5g in Tank 2, respectively. For IMCs (Labeo rohita, Labeo catla, and Cirrhinus mrigala), the weight gains were 16.8g, 16.5g, and 19g. Length gain for the same small fish species was 11cm, 10.9cm, and 12.5cm in Tank 1, and 12cm, 11.4cm, and 12.6cm in Tank 2. Corresponding length gains for the IMCs were 12.84cm, 12cm, and 13.5cm.

Survival rates were 82.35% in Tank 1 and 86.6% in Tank 2, with no statistically significant differences between the treatments. The study found that lower stocking densities led to relatively higher survival rates. Hasan et al. (2002) reported similar results, with survival rates ranging from 82.67% to 88.00% in ponds at the BAU campus in Mymensingh, Bangladesh.

5 Conclusion

The findings of this study clearly demonstrate that incorporating small fish species into carp polyculture systems is a practical and effective approach for achieving satisfactory production alongside Indian major carps. The inclusion of small fish species can enhance overall fish growth, and their presence did not significantly hinder the growth performance of *Rohu, Catla, and Mrigal*. These small fish, *Systomus sarana, Pethia ticto, and Rasbora daniconius* play a crucial role in providing essential nutrition, food security, and additional income, especially for the poor and marginalized communities. Their integration into polyculture systems contributes valuable micronutrients, including vitamin A, thereby supporting better household nutrition. Consequently, efforts to promote and conserve such fish production systems should be prioritized. Furthermore, small and shallow water bodies hold great potential and should be effectively utilized for the cultivation of small fish species.

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