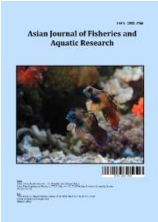

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Culture Suitability of *Macrobrachium rude* with Carp Polyculture in Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. Author MK did the methodology, conduct research, writing original draft, data analysis, supervison. Author MSA did the methodology, conduct research, writing original draft, data analysis, review & editing. Author AB did the methodology, supervison, funding acquisition. Author MZA did the supervison, funding acquisition. Author YM did the supervison, funding acquisition. All authors read and approved the final manuscript.

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ABSTRACT

The experiment assessed the production performance of Gura Chingri (*Macrobrachium rude*) in polyculture systems across different stocking densities over six months from February 2023 to July 2023. Three treatments (T_1, T_2, and T_3), replicated three times each, were implemented, with varying stocking densities for Gura Chingri, Suborno Rui, Catla, and Silver carp. Following stocking, formulated feeds containing 28-30 % protein was administered, initially at 8% of biomass, gradually reduced to 3%. After six months, the highest mean final weights for individual Prawn (1.10±0.10) g, Suborno Rui (445.68±24.6) g, Catla (511.80±15.72) g, and Silver carp (560.15±13.26) g were recorded in the T_2 treatment. Suborno Rui exhibited significantly lower growth performance in T_1 compared to T_2 and T_3, while Chingri showed statistically significant higher growth performance in T_2 compared to T_1 and T_3 ($p < 0.05$). The food conversion ratio (FCR) was significantly lowest in T_2 (1.66) and highest in T_1 (1.78) ($p < 0.05$). Additionally, the highest survival rates were observed in T_2

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for Prawn (62.21%) g, Suborno Rui (98.7%) g, Catla (98.5%) g, and Silver carp (99.82%) g. Based on these findings, carp polyculture can be an effective way for the farmers to achieve optimal production and financial benefits in Gura chingri culture. Further research is needed to develop consistant and environmentaly sustainable culture system of Gura chingri.

Keywords: Macrobrachium rude; carp polyculture; FCR; cost-benefit.

1. INTRODUCTION

Bangladesh is endowed with abundant water resources dispersed throughout the nation in the form of lakes, canals, estuaries, beels, haor, and baor (Oxbow Lake) (Alam et al., 2023). Due to the availability of water bodies and fish species, this land has significantly contributed to global fish production. Bangladesh has a longstanding tradition of local prawn farming in coastal and inland regions. She has the third largest aquatic fish biodiversity in Asia after China and India (Alam et al., 2024). Communities have engaged in diverse shrimp and prawn cultivation methods, utilizing brackish water ponds and adapting rice fields during the monsoon season. Aquaculture in Bangladesh is intensifying because of the rising demand for protein and the declining output of open-water fisheries. Bangladesh is considered one of the most suitable countries in the world for freshwater prawn farming because of its favorable Agro-climatic conditions (Ahmed, 2013). About twenty-four species of freshwater prawns, including 10 species of *Macrobrachium* sp. are found in Bangladesh (Ahmed et al., 2008) and this sector has evolved to prioritize sustainable practices while navigating the delicate balance between economic prosperity and environmental preservation. Over the last two decades, prawn farming has come to farmers attention because of its easy operation, significant export potential, and lower susceptibility to diseases compared to marine shrimp (*Penaeus monodon*) (DoF, 2022). As a result the total prawn production in Bangladesh in the 2020-21 fiscal year was 2,05,667 MT (DoF, 2022), and Bangladesh is an impressive contributor in the global shrimp and prawn industry. In 2020-2021, Bangladesh earned 4088.96 core BDT by exporting seafood of which shrimp and prawn alone contributed 90% by exporting 30615 MT frozen marine shrimp and freshwater prawn DoF (2022). Among the available prawn species in Bangladesh, most of the *Macrobrachium* sp., locally known as “Gura Chingri” has great potential for culture in freshwater ponds. But in practice, the culture of this species in the country is still in the very primitive stage. The natural stock of this species has been declining over the years due to a combination of environmental, economic, and social factors (Van et al., 2011). The prawn farming industry in Bangladesh continues to face challenges such as disease outbreaks, market fluctuations, and the need for improved management practices. That’s why it needs a transition from traditional to commercial farming, accompanied by economic benefits and environmental concerns.

Considering the popularity of small prawns and the high market price treated as a promising cultured species in Bangladesh. Till now, no research work has been carried out in Bangladesh on the culture of Gura chingri (*M. rude*). Considering the above facts, the current study was conducted to find out the production performance and culture technique of Gura chingri (*M. rude*) in pond conditions with carp polyculture.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was carried out for a period of 6 months from February 2023 to July 2023 in earthen ponds located at the Freshwater Station of Bangladesh Fisheries Research Institute, Mymeningh, Bangladesh (Fig. 1).

2.2 Experimental Design

The investigation involved three different experimental treatments (T_1, T_2, and T_3), each of which was replicated three times each treatment having pond size of 3 decimal. The stocking densities for the polyculture of Gura chingri (*M. rude*) alongside Suborn rui (*Labeo rohita*), Catla (*Catla catla),* and silver carp (*Hypophthalmicthys molitrix*) across these treatments and their corresponding replications are detailed in (Table 1).

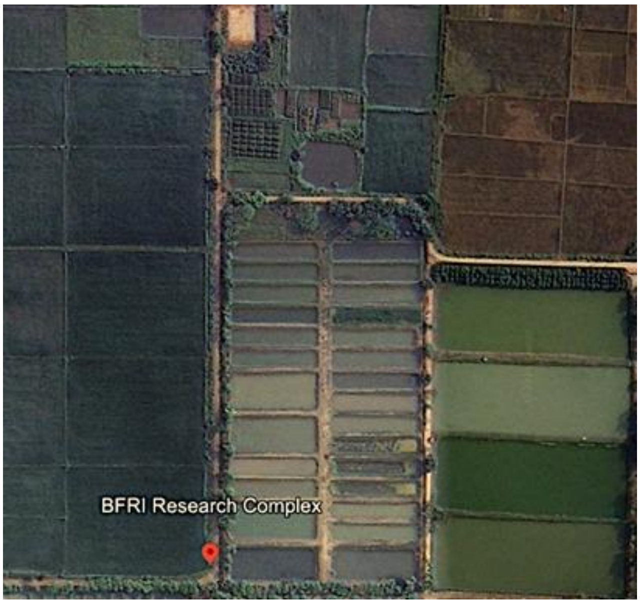

Fig. 1. Polyculture earthen ponds of Freshwater Station, Bangladesh Fisheries Research Institute (BFRI), Mymeningh, Bangladesh location ($24^0$72'06"N, $90^0$42'04"E). The image was extracted from Google Earth and illustrated by Arc GIS (Version 2.2)

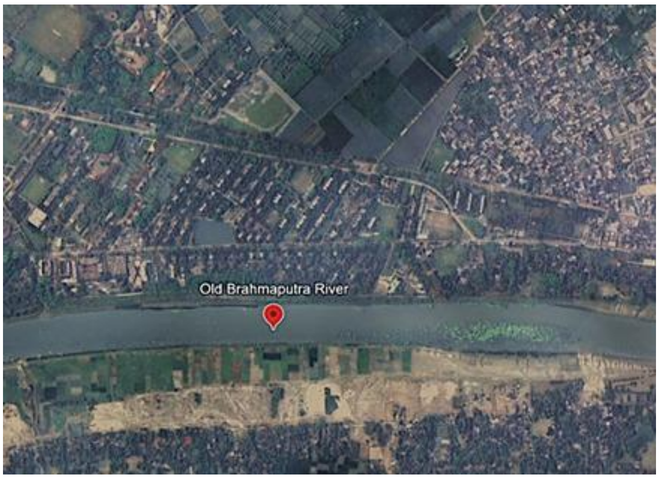

Fig. 2. Collection point of studied fishes, old Brahmaputra River, Mymensingh, Bangladesh ($24^0$72'85"N, $90^0$43'87"E). Images were extracted from Google Earth and illustrated by Arc GIS (Version 2.2)

Table 1. Experimental layout of the poly-culture technique of small prawn, Rui, Catla, and silver carp fish in the pond

Treatments	Replications	Culture period	Stocking density			
			M. rude Gura chingri (kg/dec.)	*L. rohita* Rui (nos./dec)	*C. catla* Catla (nos./dec)	*H. molitrix* Silver carp (nos./dec)
T_1			3			
T_2	3	180 Day	4.5	10	3	9
T_3			6			

Table 2. Proximate composition of feed used to fed fishes over 180 days

Moisture (Max)	Crude Protein (Min)	Fat (Min)	CHO (Max)	Fiber (Max)	Ash (Max)	Calcium (Max)	Pho (Min)
11%	32%	7%	20%	3.5%	10%	3%	2%

2.3 Pond Preparation

The ponds were equal in size, shape, depth, and basin configuration, including water supply facilities. The size of each pond was 3 decimals each with an average depth of 1.5 m. The ponds were prepared by draining out the water. Lime was applied at the rate of 250 kg/ha. One week after lime application, the ponds were filled with water to maintain water quality. The pond water was changed at regular intervals using water from a deep tube-well supply. Five days after fertilizer application, when the water turned green, small prawns were stocked. For increasing the primary productivity of water, 15 kg/ha TSP and 25 kg/ha urea and Mustard oil cake (MOC) were applied at fortnightly intervals.

2.4 Stocking of Small Prawns and Fishes

Small prawns, Rui, Catla, and silver carp fishes were collected from the old Brahmaputra River (Fig. 2) and the renowned government hatchery of Mymensingh district. Healthy and vigorous small prawns and fishes were collected and transported in oxygenated polythene bags, then kept in a cistern for acclimatization. After acclimatization, small prawns and fish were transferred to the research ponds.

2.5 Feed and Feeding

After stocking of prawns and fish, formulated feeds containing 28-35% protein were supplied with a mixture of raw materials such as fish meal, mustard oil cake, rice bran, soya bean meal, wheat bran, vitamin premix with other additives (Table 2). Analysis of proximate composition were done in fish nutrition laboratory of Bangladesh Fisheries Research institute. At the beginning of the experiment, feeding was done at the rate of 8% of biomass and gradually it was readjusted to 3%. in all treatments.

Sampling: Sampling was done regularly at 30 days interval to know the growth performance of prawns and fishes.

2.6 Harvesting

The first partial harvesting for only Gura chingri (*M. rude*) was done in April 2023 after three months of culture period. The final harvesting of all species was done in July month by dewatering after the completion of the experiment.

2.7 Data Analysis

Collected data were analyzed statistically by MS Excel and SPSS version 26. One-way ANOVA was performed with a 5% level of significance for each analysis. Duncan's post-Hoc test was also applied to conduct multiple comparisons for assessing significant differences.

3. RESULTS

The experimental ponds were harvested after 180 days of culture. To evaluate the fish growth performance weight gain (g), specific growth rate (SGR), Food conversion ratio (FCR), Survival rate (%), Individual and total production were measured after the end of the experiment. Following formulas were employed to calculate these parameters.

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

SGR (% per day) =

$$\frac{\text{Ln final weight} - \ln \text{initial weight}}{\text{Number of experimental days}} \times 100$$

Food conversion ratio (FCR) =

$$\frac{\text{Feed fed (dry matter)}}{\text{Live weight gain}}$$

Survival rate = $\frac{\text{No.of fish harvested}}{\text{No.of fish stocked}} \times 100$

After 06 months of culture, the highest final mean weight of prawn, suborno rui, catla and silver carp fishes were found to be 1.10±0.10g, 445.68±24.61g, 511.80±15.72g and 561.15±13.26g respectively, in T_2 treatment (Table 3). Suborno rui exhibited significantly lower growth performance in T_1 compared to T_1 and T_2. On the other hand, chingri showed significantly higher ($p < 0.05$) growth performance in T_2 than in T_1 and T_3. The food conversion ratio was significantly lowest in T_2 and highest in T_1. Furthermore, the highest specific growth rate (SGR) values were observed for prawn, suborno rui, catla, and silver carp fishes at 1.13±0.36, 2.01±0.25, 0.87±0.03 and 1.14±0.16 in T_2 treatment, respectively (Table 3). However, it was observed that species-wise production of rui, catla, and silver carp were not significantly different among the treatments except prawn and rui. The production of chingri was recorded significantly higher ($p < 0.05$) in T_3 than in T_1 and T_2. The total highest productions of prawn and carp fishes were recorded in T_2 (3,491 kg/ha/6 months), followed by T_3 (3,438 kg/ha/6 months) and T_1 (2,824 kg/ha/6 months) (Table 3).

3.1 Water Quality Parameters

The physicochemical parameters of pond water, including temperature, pH, transparency, alkalinity, and dissolved oxygen (DO), were monitored fortnightly across all treatments, and the recorded data are presented in (Table 4). Water temperature exhibited consistent levels across different ponds, with mean temperatures of 30.59 ± 2.26 °C, 30.36 ± 2.11 °C, and 30.17 ± 2.18 °C in T_1, T_2, and T_3, respectively. The mean pH values were 7.94 ± 0.32, 8.21 ± 0.29, and 8.53 ± 0.34 in T_1, T_2, and T_3, respectively. Similarly, mean DO concentrations were 5.39 ± 0.57, 5.47 ± 0.51, and 5.64 ± 0.36 in T_1, T_2, and T_3, respectively. Among the treatments, T_2 exhibited the highest mean alkalinity values (135.34 ± 3.16), while T_1 displayed the lowest (132.40 ± 3.21). Additionally, T_2 recorded the highest mean ammonia values (0.002 ± 0.0015), whereas the lowest values were observed in T_3 within the culture system.

Table 3. Growth performance and production of fishes

Parameters	Species	T_1	T_2	T_3
Initial mean weight (g)	*M. rude*	0.14±0.07^a	0.12±0.04^a	0.12±0.04^a
	L. rohita	15.05±7.49^a	12.99±6.15^a	12.06±7.82^a
	L. catla	106.71±7.35^a	107.18±7.08^a	104.42±7.47^a
	H.molitrix	74.80±18.24^a	74.55±19.45^a	77.36±16.56^a
Final mean weight (g)	*M. rude*	0.95±0.6^c	1.10±0.10^a	1.03±0.94^b
	L. rohita	393.37±41.07^c	445..68±24.6^a	411.09±43.47^b
	L. catla	446.28±35.10^b	511.80±15.72^a	458.91±14.19^b
	H.molitrix	528.31±16.44^b	560.15±13.26^a	532.99±15.13^b
Mean weight gain (g)	*M. rude*	0.81±0.43^c	0.97±0.48^a	0.91±0.27^b
	L. rohita	378.32±40.47^b	432.69±26.53^a	399.03±42.0^b
	L. catla	339.57±32.12^b	404.62±13.92^a	354.50±16.41^b
	H.molitrix	453.51±28.04^b	485.59±27.81^a	455.63±18.85^b
Specific growth rate (%/day)	*M. rude*	0.95±0.35^c	1.13±0.36 ^{a}	1.10±0.27^b
	L. rohita	1.88±0.29^b	2.01±0.25^a	1.96±0.24^b
	L. catla	0.79±0.04^a	0.87±0.03^a	0.82±0.04^a
	H.molitrix	1.10±0.15^a	1.14±0.16^a	1.07±0.13^a
Survival rate (%)	*M. rude*	58.35±1.37^b	62.21±1.34^a	61.38±0.51^a
	L. rohita	98.26±0.34^a	98.7±0.41^a	98.8±0.52^a
	L. catla	98.39±0.23^a	98.5±0.65^a	97.9 ±1.17 ^{a}
	H.molitrix	99.88±0.13^a	99.82±0.49^a	99.85±0.83^a
FCR		1.78±0.10^a	1.66±0.14^c	1.73±0.11^b
Species-wise Production (kg/ha/6 month)	*M. rude*	330.98±24.69^c	810.16±9.52^b	899.08±16.13^a
	L. rohita	973.18±21.16^c	1101.62±18.21^a	1015.17±13.51^b
	L. catla	343.33±7.56^a	333.45±9.32^a	340.86±10.24^a
	H.molitrix	1175.72±28.81^b	1244.88±31.65^a	1183.14±37.34^b
Total production (kg/ha/6 month)		2,824	3,491	3,438

Values are means of data obtained from Mean±Std analysis. Deviation of monthly determinations. Values in the same row with same superscripts are not significantly different (P>0.05). Absence of superscripts indicates no significant difference between treatments

Table 4. Water quality parameters of experimental ponds during February-July /2023

Water Temp. (°C)	30.59 ± 2.26 [a]	30.36 ± 2.11 [a]	30.17 ± 2.18 [a]
pH	7.94 ± 0.31 [a]	8.21± 0.29 [a]	8.53± 0.34 [a]
DO (mg/L)	5.39 ± 0.57 [a]	5.47 ± 0.51 [a]	5.64 ± 0.36 [a]
Total Alkalinity (mg/L)	132.40 ± 3.21 [a]	135.34 ± 3.16[a]	134.62 ±3.09 [a]
NH_3 (mg/L)	0.019±0.0012 [a]	0.002±0.0015 [a]	0.0014±0.00 [a]

Values are means of data obtained from Mean±Std analysis. Figures in the same row having the same superscripts are not significantly different (p ≥ 0.05)

Table 5. Cost-benefit analysis

Item wise expenditure / Operational costs	T_1	T_2	T_3
A. Cost			
1. Pond lease value for 6 months (BDT)	25,000	25,000	25,000
2. Price of fingerlings			
2.a Prawn @ BDT 600/kg	4,44,600	6,66,900	8,89,200
2.b Bfri Subarno rui @ BDT 4.00/piece	9,880	9,880	9,880
2.c Catla @ BDT 4.00/piece	2,964	2,964	2,964
2.d Silver carp @ BDT 3.00/piece	6,669	6,669	6,669
3. Feeds (BDT)	2,16,333	2,41,600	2,64,150
4. Lime, fertilizer etc. (BDT)	3,000	3,000	3,000
5. Human labor, Transport etc. (BDT)	30,000	30,000	30,000
Total cost (BDT)	**7,38,446**	**9,86,013**	**12,30,863**
B. Incomes			
Prawn (1200 (BDT/ kg)	3,97, 176	9,72,192	10,78,896
Bfri Subarno rui (260 (BDT/ kg)	2,53,027	2,86,422	2,63,945
Catla (250 (BDT/ kg)	86,450	83,363	85,250
Silver carp (220 (BDT/kg)	2,58,659	2,73,874	2,60,480
Total return (BDT)	9,95,312	16,15,851	16,88,571
Net Profit (B-A) (BDT)	2,56,866	6,29,838	4,57,708
BCR	1.35	1.64	1.37

3.2 Cost-benefit Analysis

A cost-benefit analysis was conducted on the polyculture system of Gura chingri with carp fishes in one-hectare ponds over a culture period of six months to evaluate the return on investment and profitability. The proper combination and stocking densities in polyculture were summarized in (Table 5). The total farming costs in (BDT/ha) were lower in T_1 (7,38,446) compared to T_2 (9,86,013) and T_3 (12,30,863). Net benefits were derived from the three treatments, amounting to BDT 2,56,866, 6,29,838, and 4,57,708 per hectare for T_1, T_2, and T_3, respectively. The highest benefit-cost ratio (BCR) was found to be 1.64 in the T_2 treatment, while the lowest value of 1.35 was observed in the T_1.

4. DISCUSSION

Integrated aquaculture significantly contributes to the livelihoods and socio-economic development of rural communities in numerous Asian countries (Nair et al., 2012; Tran et al., 2020). Specifically, the integration of various crops within a unified system offers notable advantages, including increased productivity, reduced fertilization costs, waste reduction, and enhanced pest control, thereby providing additional income opportunities for farmers. This study investigated the suitability of culturing *Macrobrachium rude* (Gura Chingri) along with carp species in a polyculture system in Bangladesh. Over a six-month period, the investigation delves into various aspects of aquaculture, encompassing stocking densities, growth performance, economic viability, and water quality management. The study reveals that the final weight gain of *M. rude* across treatments ranged from 0.95±0.6 g to 1.03±0.94 g at stocking densities between 3 and 6 kg/dec, surpassing previous findings by Siddique et al. (1999). Similarly, weight gains in rohu, catla, and silver carp exceeded those reported by Siddique et al. (1999) in polyculture with *M. rosenbergii*. A key aspect illuminated by this study is the significant influence of stocking densities on the growth and production of Gura Chingri and carp species. Treatment T_2, characterized by a stocking density of 4.5 kg/decimal, demonstrated the most favorable outcomes in terms of final mean weight, growth performance, and overall production. Optimizing stocking densities is crucial for maximizing yield and profitability in aquaculture operations (Holthuis, 1980). However, it is imperative to consider ecological factors and potential environmental impacts to ensure long-term sustainability.

The enhanced growth performance of *Macrobrachium rude* observed in this study, compared to previous findings by Siddique et al. (1999), may be attributed to the absence of mrigal, a bottom feeder that competes for food and space with prawn. In a polyculture system, prawns and carp efficiently utilize different food resources. Polyculturing prawns without bottom feeder species allows prawns to access their share of pelleted feed, as some of the feed sinks to the bottom. Additionally, it enables prawns to graze on bacterial films on the bottom substrate, ultimately enhancing their growth performance.

The food conversion ratio (FCR) was significantly lower in treatment T_2 and higher in T_1, which aligns with values reported by Siddique et al. (1999) at a total stocking density of 15,000/ ha of prawn and carps. New (2000) reported that for *M. rosenbergii*, an FCR of 1.8-3.0 may be acceptable for dry diets, while moist diets made on the farm containing waste prawn heads, trash fish, etc., would have an FCR of 3.0-5.0.

In the present study, the survival rates of prawn ranged from 58.35% to 61.38%, aligning closely with previous findings by Ali et al. (2003), but differing from those reported by Hoq et al. (1996) as reported survival range of 32.2% to 75.5% for *M. rosenbergii* in polyculture with a supplemental feed mixture of rice bran and oilcake (1:1). Conversely, the average survival rate of carp in this study exceeded 97%, which is some or less similar with Siddique et al. (1999). However, the lower survival rate of catla compared to rohu and silver carp in the present study may be attributed to variations in the stocking densities of carp presented in (Table 1).

Notably, significantly higher productions of *Macrobrachium rude* were observed in treatments T_3 and T_2, consistent with findings by Jose et al. (1992) and Islam et al. (1999). Jose et al. (1992) reported a gross production of 106-254 kg/ha of prawn over a culture period of 160 days, where *M. rosenbergii* were stocked at 10,000/ha with rohu, catla, and mrigal (2:2:1) at a density of 1000/ha. Similarly, Islam et al. (1999) reported a production of 172 kg/ha/year, where stocking of *M. rosenbergii* was at 15,000/ha with silver carp, catla, rohu, and mrigal (1.75:0.75:1.50:1.0) at a stocking density of 5000/ha in each pond. The production of prawn in the present study surpassed that of Haque et al. (2003), who used prawn stocking densities ranging from 3750 to 10,000/ha alongside catla, rohu, and mrigal stocked at a density of 11250/ha, resulting in a production of 120.9-216.1 kg/ha, while the production for carps ranged from 2248.8-2359.2 kg/ha. Moreover, in the current study, the faster growth rates of prawns compared to carp may be due to the omnivorous and coprophagous behavior of *Macrobrachium rude*. In addition, the polyculture system promotes rapid growth of prawns due to a suitable combination of water quality, temperature, as well as feeding regimes. Environmental parameters especially the water quality parameters play a pivotal role in maintaining a healthy aquatic environment and optimizing the production. The consistent observation of water quality parameters across the treatments and the findings of this study indicates effective management practices in maintaining favorable growth conditions for fish and prawn in polyculture system. Water temperature, influenced by solar radiation and air temperature, is a critical factor that regulates the growth, reproduction, metabolism, and feeding intensity of poikilotherms (Saenger & Holmes, 2018). In this study, the water temperature remained around 30ºC, a range recommended by Ling (1969) as suitable for prawn culture. pH, indicating the acidity or alkalinity condition of a water body, is another important factor in fish culture. The pH range observed in the ponds ranged from 7.94 to 8.53, which is within the suitable range for the culture of *M. rosenbergii* reported in previous studies by (Jia-Mo et al., 1988; Hossain et al., 2000). Additionally, the range of dissolved oxygen observed in this study was (5.39-5.64 mg/L) which aligns closely with values reported for the culture of *M. rosenbergii* in earthen ponds by Hossain et al. (2000). Moreover, the economic assessment carried out in this study offers an understanding of financial viability in the polyculture system. Treatment T_2 (Table 5) exhibited the highest net profit and benefit-cost ratio, underscoring its superior economic feasibility compared to other treatments. These findings emphasize the importance of integrating economic considerations alongside production parameters when formulating aquaculture strategies.

5. CONCLUSION

Overall, this study contributes significant insights into the aquaculture sector in Bangladesh by furnishing empirical evidence regarding the suitability of Gura Chingri in conjunction with carp polyculture techniques. The findings highlight the critical role of optimizing stocking densities, considering economic aspects, and implementing effective water quality management practices to enhance production efficiency and profitability in aquaculture endeavors. Based on growth and production outcomes, the resulting combination of prawn, catla, rohu, and silver carp may be financially feasible for rural farmers in Bangladesh. Nonetheless, further research is recommended to explore additional factors influencing culture performance and to refine management strategies for ensuring sustainable development and prosperity in aquaculture of Bangladesh.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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