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Effect of stocking densities on growth and production of Angus, Labeo angra under polyculture system in semi-arid zone of Bangladesh

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ABSTRACT

An experiment was conducted in on-farm seasonal ponds of the Rangpur region to assess the growth and yield performance of Angra labeo fish in polyculture system and to determine the optimal species combination for semi-arid zones of Bangladesh. The study involved three treatments (T1, T2 and T3), each replicated, with Angus stocked at densities of 150, 200, and 250 individuals per decimal, respectively. Each treatment also included 10 Indian major carp (Catla), 5 Chinese carp (Silver carp), 10 Olive barb (Sarpunti) and 5 GIFT tilapia per decimal. After 150 days of culture, the average final weight of Angus were 21.10±1.20 g (T1), 25.40±1.0 g (T2) and 23.30±1.10 g (T3) with corresponding length of 16.30±0.20 cm, 17.20±0.03 cm and 16.60±0.04 cm. Initial weight and length were 0.50±0.1 g and 2.50±0.2 cm. T2 showed significantly higher weight gain (24.90±2.04 g), specific growth rate (2.61±0.2) and feed conversion ratio (1.74±0.01) compared to other treatments. Production of other fish species was also satisfactory: 4065±21 kg/ha (T1), 4306±20 kg/ha (T2), and 4157±19 kg/ha (T3). T2 yielded the highest total fish production (5372.40±24.7 kg/ha), Angus fish yield (1066.50±17.5 kg/ha) and benefit-cost ratio (1.43±0.04), with a gross margin of 455400±3690 BDT per hectare. Water quality remained suitable throughout the study. These findings suggest that the T2 combination is ideal for profitable polyculture in seasonal ponds of semi-arid zone of Bangladesh.

Keywords: Angra labeo, Polyculture, Stocking densities, Semi-arid zone.

1 | Introduction

Aquaculture has emerged as the fastest-growing sector in Bangladesh fisheries, playing a vital role in enhancing fish supply and meeting the protein needs of the large population. Increasingly, fishers are adopting aquaculture practices as it proves to be a lucrative livelihood option. Among various approaches, polyculture has gained prominence for its ability to optimize ecological resource use and boost productivity. By cultivating two or more compatible fish species together, polyculture systems can maximize pond biomass through efficient utilization of diverse food resources and ecological niches (Wahab et al., 2011).

Labeo angra (Common name: Angra labeo) locally known as Angus or Angrot, is a native freshwater species found in the hill streams and riverine systems of Rangpur, Dinajpur, Sylhet, Mymensingh, Chandpur, and Chattogram areas (Rahman, 2005). This species thrives in both lentic and lotic environments, including rivers, canals, and streams. Classified as a small indigenous species (SIS), Labeo angra can reach a maximum length of approximately 25 cm (9 inches) at full maturity (Saha et al., 2020).

The natural abundance of many indigenous fish species has been steadily declining over decades (IUCN, 2015). Notably, there has been a lack of scientific information regarding the reproductive biology, induced spawning, and nursing, rearing, and culture practices of Labeo angra. Addressing this gap, the Bangladesh Fisheries Research Institute (BFRI), Freshwater Sub-Station in Saidpur, has successfully developed induced breeding and nursery-rearing techniques for this species under captive conditions. These advancements have facilitated the availability of quality seed, enabling fish farmers to culture Angus either as a single species or in combination with short-cycle fishes in seasonal ponds. This approach offers the potential to enhance fish production per unit area, thereby contributing to improved household nutrition and socioeconomic upliftment (Islam et al, 2025). Despite these developments, polyculture or monoculture of stream-dwelling species like Angus is not yet widely practiced in farmers' field across the semi-arid zone of Rangpur division. In the northern districts of Bangladesh, approximately 55% of ponds are seasonal. Among these, 60% retain water for 4 to 6 months annually, while the remaining 40% hold water for 6 to 9 months, with some areas maintaining water even longer (Hasan et al., 2023). These seasonal water bodies present a promising opportunity for expanding the culture of indigenous species like Angus through improved aquaculture practices. To promote effective utilization of seasonal ponds, especially in semi-arid regions, the introduction of fast-growing carp species is recommended to enhance fish production and improve resource efficiency (Shah et al., 2008). This study aims to support economically disadvantaged fish farmers by offering a model for rapid financial returns through efficient aquaculture practices. Many underutilized water bodies in semi-arid region holds significant potential for fish cultivation. To harness this opportunity, the experiment incorporates Labeo angra in a polyculture system alongside fast growing, low-input carp species such as Catla (Catla catla), Silver carp (Hypophthalmichthys molitrix), Sarpunti (Barbodes gonionotus), and Genetically Improved Farmed Tilapia (GIFT) (Oreochromis niloticus). As a bottom-dwelling species, Angus does not compete for resources with the other surface- and column-feeding fishes, making it well suited for integrated polyculture. Introducing Angus in combination with these complementary species can significantly enhance pond productivity and profitability, particularly in seasonal water bodies. Hence, the present study is therefore designed to validate this polyculture under field conditions and demonstrate their practical benefits to farmers, with the goal of improving livelihoods and promoting sustainable aquaculture practices.

2 | Materials and Methods

2.1 Study area

This experiment was implemented on farmers field at Rangpur division under semi-arid zone of Bangladesh. For this study, a total of nine seasonal ponds were selected in different Upazilas of Dinajpur, Nilphamari and Rangpur districts (Fig. 1).

Figure 1 | Experimental sites under northern Bangladesh

2.2 Experimental design and pond selection

The farmers were selected based on their fish culture interest and fisheries related livelihood status. Three groups were formed from the nine ponds owners. Each group treated as one treatment e.g. treatment-I (T1), treatment-II (T2), treatment-III (T3) and each treatment have three replications. The areas of ponds ranged between 15 and 20 decimal (40 m^2) and depths between 1.0 and 1.5 m. The culture period was 150 days. Fish sampling data and water quality were collected fortnightly. Stocking pattern of three different treatment is presented in Table 1.

Table 1 | Polyculture pattern of Angus (*Labeo angra*) with other cultivable species

Treatments	Species combination	Stocking density (nos. dec^{-1})
T1	Angus+Catla+Silver carp+Sharpunti + GIFT	150+10+5+10+5
T2	Angus +Catla+Silver carp+Sharpunti + GIFT	200+10+5+10+5
T3	Angus+Catla+Silver carp+Sharpunti + GIFT	250+10+5+10+5

2.3 Pond preparation and stocking of fingerling

Before beginning the experiment, the native and unwanted fishes were removed from the pond by repetitive netting then ponds were completely dried to eradicate unwanted crustaceans/fishes/eggs that remained in cysts. Pond embankments were also repaired. Three layers of netting were done viz. slope netting, side netting and surface netting for complete restriction of unwanted predators like animals/birds. Pond bottoms were treated with lime ($CaCO3$) at the rate of 1 kg/decimal and left for 3 days. Then the ponds were filled with groundwater and fertilized with Urea, TSP and MoP 1.25 ppm, 1.50 ppm and 0.5 ppm per decimal, respectively. After few days, water turned with greenish color and Angus fingerlings (2-3 cm) and other fish species (10-15 cm) were stocked according to the stocking densities presented in Table 1 and the initial length and weight of fingerlings were measured before releasing into the pond.

2.4 Feeding and sampling

Commercial fish feed containing 30-35% protein was fed @ 8-5% of body weight twice daily. Length-weight data were collected fortnightly from 8.00 am to 9.00 am to determine the growth rate as well as food adjustment. Fish length was measured using a measuring scale (cm) and weight was taken by digital weight balance (1g to 1000g). Final harvest was done after completion 150 days of culture.

2.5 Analysis of water quality parameters

Water quality parameters such as water temperature (°C), pH, and Dissolved Oxygen (DO) (mg/L) conductivity (μS cm^{-1}), absolute conductivity (μS cm^{-1}), oxidation-reduction potential (mV ORP) and Total Dissolved Solid (TDS) (mg L^{-1}) were measured by HANNA (HI98494 pH/EC/DO) Multiparameter, and NH_3, Hardness, Alkalinity (mg/L) were measured by HACH kit (Hanna Co. Japan).

2.6 Growth parameters

$$\text{Weight gain (g)} = \text{Final weight (g)} - \text{Initial weight (g)}$$

$$\text{Percent weight gain (\%)} = [(\text{Final weight (g)} - \text{Initial weight (g)}) / \text{Initial weight (g)}] \times 100$$

$$\text{Average daily gain (ADG, \% day}^{-1}) = [(\text{Mean final weight (g)} - \text{Mean initial weight (g)}) / \text{Days}] \times 100$$

$$\text{Specific growth rate (SGR, \% day}^{-1}) = [(\ln W_2 - \ln W_1) / (T_2 - T_1)] \times 100$$

where W_1 is the initial live body weight (g) at time T_1 and W_2 is the final live body weight (g) at time T_2 (day) (Brown, 1957).

2.7 Feed utilization, survival and production

$$\text{FCR} = \text{Total dry feed intake (g)} / \text{Total wet weight gain (g)}$$ (Castell and Tiews, 1980).

$$\text{Survival rate (\%)} = (\text{Final number of fish} / \text{Initial number of fish}) \times 100$$

$$\text{Production (kg decimal}^{-1}) = (\text{Final number of fish harvested} \times \text{individual weight of fish}) / 1000$$

$$\text{Production (kg ha}^{-1}) = [(\text{Final number of fish harvested} \times \text{individual weight of fish}) / 1000] \times 247.1$$

2.8 Economic and statistical analysis

Economic analysis was done to find out benefit-cost ratio of polyculture. As Angus species first ever under culture practice in Bangladesh, economies analysis clarified the loss or benefits of farmers. These candidate species contain high nutrient profile and high market demand also (Bogard, 2015).

Data were analyzed using MS Excel and one-way analysis of variance (ANOVA) (Duncan, 1993) and SPSS 20 (Chicago, USA) to detect significant differences among the treatments at a 5% level. The values were given with means ±SD, and differences were considered significant at the subset for alpha = 0.05 ($p \leq 0.05$).

3 | Results and discussion

3.1 Physico-chemical parameters of experimental pond

The physico-chemical characteristics including temperature (°C), pH, dissolved oxygen (mg L^{-1}), ammonia (mg L^{-1}), conductivity (µS cm^{-1}), absolute conductivity (µS cm^{-1}), oxidation-reduction potential (mV ORP), total dissolved solids (mg L^{-1}), hardness (mg L^{-1}), and alkalinity (mg L^{-1}) were monitored throughout the 150-day culture period in selected farmers' ponds located in northern Bangladesh. The recorded ranges for these parameters are summarized in Table 2: water temperature varied from 25 to 31.6 °C, pH ranged between 7.3 and 7.8, dissolved oxygen levels were 5.0–6.50 mg L^{-1}, ammonia concentrations ranged from 0.03 to 0.10 mg L^{-1}, conductivity was 118–161 µS cm^{-1}, absolute conductivity ranged from 106 to 147 µS cm^{-1}, oxidation-reduction potential spanned 96–164 mV, total dissolved solids were between 65.9 and 95.6 mg L^{-1}, hardness ranged from 98.5 to 116 mg L^{-1}, and alkalinity varied from 101.2 to 128.5 mg L^{-1}. The corresponding mean ± standard deviation values are also presented in Table 2.

Table 2 | Water quality parameters of the experimental ponds

Parameters	T1	T2	T3
Water Temp. (°C)	29.0±2.2	28.8±2.0	28.3±3.3
Water pH	7.53±0.14	7.56±.20	7.64±0.16
DO (mg L^{-1})	6.2±0.12	6.5±0.08	6.4±0.10
Ammonia (mg L^{-1})	0.08±0.02	0.07±0.01	0.10±0.03
Conductivity (µScm^{-1})	136.71±18.7	155.12±.6.32	125.2±5.3
A. Conductivity(µScm^{-1})	114±8.96	123±6.87	142±4.5
ORP (mV ORP)	130.82±34.78	145.8±22.65	148.45±12.78
TDS (mg L^{-1})	72.4±4.5	88.3±7.3	76.6±6.4
Hardness (mg L^{-1})	109.4±4.4	112.22±3.8	103.2±4.7

During the 150-day experimental period, water temperature ranged from 25 to 31.2 °C, with no statistically significant differences ($p < 0.05$) observed among the treatment groups. These temperature values align with those reported by Kohinoor *et al.* (2004) and Hasan *et al.* (2023), who identified the 26–30 °C range as optimal for aquaculture. The recorded pH values were 7.53, 7.56, and 7.64 in treatments T1, T2, and T3, respectively, indicating a suitable range for fish culture. These findings are consistent with previous studies by Mou *et al.* (2018), which reported that pH levels between 7.5 and 8.2 are conducive to aquaculture. Dissolved oxygen (DO) concentrations varied between 5.0 and 6.50 mg L^{-1} across treatments, with no significant differences detected. Analytical observations revealed an inverse relationship between pH and DO levels with stocking density, as noted by Chakraborty *et al.* (2005). Ammonia concentrations ranged from 0.03 to 0.10 mg L^{-1}, with slightly elevated levels in T3, likely due to higher fish stocking densities. This supports the findings of Hasan *et al.,* (2023), who reported 0.13 mg L^{-1} ammonia in fish culture ponds. Alkalinity values recorded were 112, 122, and 108 mg L^{-1} for T1, T2, and T3, respectively, falling within the suitable range of 109–122 mg L^{-1} for productive aquaculture systems. According to Mithun *et al.,* (2024), total alkalinity exceeding 100 mg L^{-1} is indicative of highly productive water bodies, which corroborates the present findings. Furthermore, conductivity, total dissolved solids (TDS), and hardness values observed in this study ranging from 118–161 μS cm^{-1}, 65.9 – 95.6 mg L^{-1}, and 98.5–116 mg L^{-1}, respectively are consistent with the ranges reported by Islam *et al.,* (2020), who found conductivity between 22–423 μS cm^{-1}, TDS from 0–230 mg L^{-1}, and hardness between 4–110 mg L^{-1} in productive pond ecosystems. Overall, the physico-chemical parameters recorded across the three treatments indicate favorable conditions for fish polyculture.

3.2 Growth and yield performance of Angus (Labeo angra) under polyculture system

The growth performance of Angus (Labeo angra) was evaluated based on several key parameters, including specific growth rate (% day^{-1}), average daily weight gain (% day^{-1}), total yield of Angus (kg/ha), and total yield of carp species (kg/ha) after a 150-day culture period. Additional metrics such as feed conversion ratio, survival rate, and benefit-cost ratio were also assessed to determine economic viability. Statistical analysis of all collected data was conducted using SPSS to identify significant differences among treatments within the polyculture system. The results detailing the growth performance of Labeo angra under polyculture conditions in farmers' ponds are presented in Table 3.

Table 3 | Growth and yield performance of *Labeo angra* under polyculture

Parameters	Treatments		
	T1	T2	T3
Stocking density (indi.dec^{-1})	150	200	250
Culture period	150	150	150
Initial length (cm)	2.5±0.4	2.5±0.1	2.5±0.1
Initial weight (g)	0.52±0.1	0.50±0.1	0.51±0.1
Average final length (cm)	11.5±0.20c	13.2±0.4a	12.7±0.12b
Average final weight (g)	21.1±1.20c	25.4±1.0a	23.3±1.10b
SGR (% day^{-1})	2.46±0.6c	2.61±0.2a	2.54±0.3b
ADG (g day^{-1})	0.11±0.2b	0.13±0.1a	0.10±0.1b
Production of Angus (kg/ha)	704.5±27.5c	1066.5±17.5b	1179.8±14.4a
Total fish production (kg/ha)	4769.5±19.1c	5372.4±24.7a	5336.7±12.3b
FCR	1.78 ± 0.01b	1.74 ± 0.01a	1.85 ± 0.02c

Values with different letters within each row represent significant ($p < 0.05$) differences.

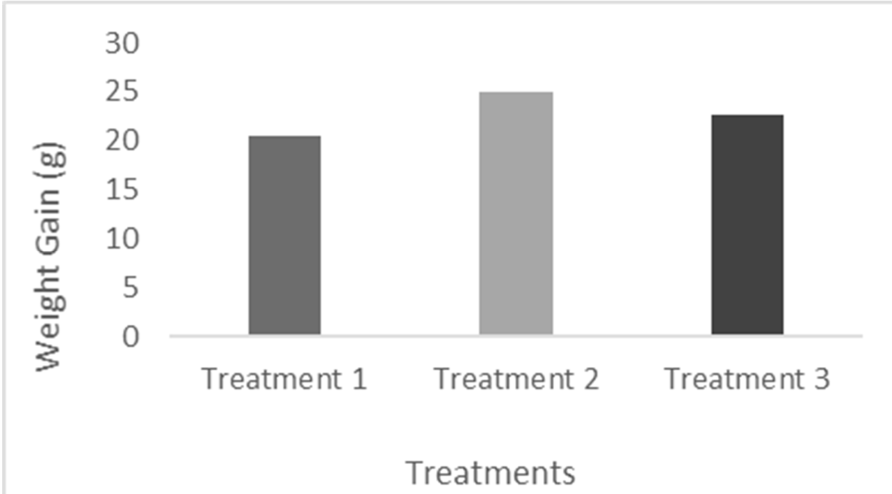

Figure 2 | Weight gain of Angus (*Labeo angra*) fish in different treatment

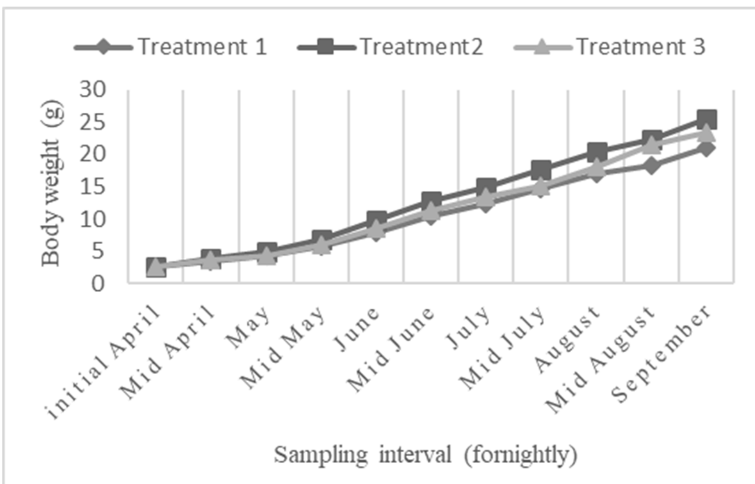

Figure 3 | Growth rate of Angus (*Labeo angra*) at fortnightly interval

The initial and final body weight of other associated fish species, which cultured with Angus under polyculture system are presented in Table 4.

Table 4 | Production of other fish species under polyculture

Species	Initial weight (g)	Final body weight (g) T1	Final body weight (g) T2	T3
Catla	255.8±12.86	831.33±18.69	874.3±15.58	843.5±13.8
Silver carp	200.6±11.54	757±21.31	794.11±17.31	772.1±23.8
Sarpunti	20.4±3.14	283.13±6.5	295.48±8.24	288.13±7.5
GIFT	25.3±2.92	307.23±9.2	355.33±8.11	332.3±8.8
Production (kg/ha		4065.6±21.2c	4306.04±20.3a	4157.1±19.5b
Survival rate (%)		99.02 ± 1.7a	98.06 ± 2.2b	96.04 ± 1.3c

Figure 2 | Survival rate of Angus (*Labeo angra*) in different treatment

The experiment was conducted using three stocking density treatments in farmers' ponds: T1 (150 Angus per decimal), T2 (200 Angus per decimal), and T3 (250 Angus per decimal), each supplemented with 10 Catla, 5 Silver carp, 10 Sarpunti, and 5 GIFT individuals per decimal. The average body weights of Labeo angra were 21.1 g, 22.4 g, and 23.3 g in T1, T2, and T3, respectively. The highest weight gain (24.90 g) was recorded in T2, while the lowest (20.58 g) was observed in T1 (Fig. 2). Statistical analysis revealed that weight gain was significantly higher ($p < 0.05$) in T2 compared to T1 and T3. Fig. 3 illustrates the growth trajectory of Labeo angra across different sampling intervals under the polyculture. The specific growth rates (SGR) were 2.46 ± 0.6, 2.61 ± 0.21, and 2.54 ± 0.20 % day^{-1} in T1, T2, and T3, respectively, showing significant differences ($p < 0.05$) among treatments. FCR values were highest in T3 (1.85 ± 0.02^c) and lowest in T2 (1.74 ± 0.01), indicating a direct relationship between stocking density and feed efficiency. Similar trends were reported by Saha et al., (2023), who found higher FCR (2.78) in T3 (700 individuals/decimal) and lower FCR (2.54) in T2 (600 individuals/decimal) for Barilius barila under polyculture. Survival rates were assessed at the end of the five-month culture period, with values of 90.1 ± 2.1%, 85.04 ± 3.7%, and 82.2 ± 2.6% in T1, T2, and T3, respectively, showing significant differences ($p < 0.05$) (Fig. 4). These findings are comparable to those of Kohinoor et al., (2004), who reported survival rates of 89%, 85%, and 79% for Mystus cavasius under similar treatments. Total fish production under polyculture was recorded as 4769.5 ± 19.10, 5372.4 ± 24.7, and 5336.7 ± 12.3 kg/ha in T1, T2, and T3, respectively (Table 3). Analytical results indicated that T2 yielded significantly higher production of Labeo angra and overall fish biomass ($p < 0.05$) compared to T1 and T3. This trend aligns with findings by Kohinoor et al., (2005), who observed that lower stocking densities resulted in higher production of Labeo bata, with yields of 2466 ± 78, 2395 ± 88, and 2074 ± 71 kg/ha from T1 (5000 ind./ha), T2 (7500 ind./ha), and T3 (10000 ind./ha), respectively, over a six-month period. In summary, the results of this study demonstrate that a stocking density of 200 Labeo angra individuals per decimal (T2), combined with other species, produced superior outcomes in terms of individual growth, total yield, feed efficiency, and economic viability under polyculture conditions.

3.3 Economic viability of Angus (Labeo angra) in polyculture

Economic viability of Angus culture under different treatments with other fish species in farmers pond is presented in Table 5.

Table 5 | Benefit and cost analysis of Angus (*Labeo angra*) under polyculture: item-wise expenditure

Item wise expenditure	T1	T2	T3
Pond preparation (Tk ha^{-1})	50,000.00	50,000.00	50,000.00
Fingerling cost (Tk ha^{-1})	1,92,000.00	1,98,000.00	2,04,000.00
Lime and fertilizer (Tk ha^{-1})	10,500.00	10,500.00	10,500.00
Feed cost (Tk ha^{-1})	6,62,000.00	7,29,000.00	7,69,000.00
Transport, labor, others etc. (Tk ha^{-1})	60,000.00	60,000.00	60,000.00
Total production costs (Tk ha^{-1})	9,74,500±1550a	10,47,500±1600b	10,93,500 ±1850c

Table 6 | Income, output and benefit-cost ratio

Income and output	T1	T2	T3
Total production (Tk ha^{-1})	4769.5±19.1c	5372±24.7a	5336±12.3b
Gross return (Tk ha^{-1})	12,97,800 ± 104c	15,02,900 ± 203a	14,09,500 ± 226b
Gross margin (Tk ha^{-1})	3,23,300± 3240c	4,55,400± 3690a	3,61,000± 3500b
Benefit cost ratio	1.33±0.02b	1.43±0.04a	1.29±0.02c

Within rows values with different superscripts are significantly different (p< 0.05)

An economic evaluation was conducted to determine the benefit-cost ratio (BCR) across different treatment groups of Labeo angra under polyculture conditions, as presented in Table 5. The total production costs over the six-month culture period-including expenses from pond preparation to harvesting were Tk 974,500 ± 1,550, Tk 1,047,500 ± 1,600, and Tk 1,093,500 ± 1,850 per hectare for T1, T2, and T3, respectively. The primary cost components were fingerlings and feed, while net profit was calculated by subtracting total management expenditures from the market value of harvested fish (Kunda et al., 2014). Gross returns (Tk/ha/six months) were recorded as Tk 1,297,800 ± 104 in T1, Tk 1,502,900 ± 203 in T2, and Tk 1,409,500 ± 226 in T3, with statistically significant differences ($p < 0.05$) among treatments. Corresponding gross margins were Tk 323,300 ± 3,240, Tk 455,400 ± 3,690, and Tk 361,000 ± 3,500 in T1, T2, and T3, respectively, also showing significant variation ($p < 0.05$). The highest BCR was achieved in T2 (1.43 ± 0.04), followed by T1 (1.33 ± 0.02) and T3 (1.29 ± 0.02), with all differences being statistically significant ($p < 0.05$). These findings are consistent with previous studies. Saha et al., (2023) observed the highest BCR (1.57) in T2, followed by T1 (1.45) and T3 (1.37) in polyculture of Barilius barila, which aligns with the present results. Based on the observed production and economic indicators, a stocking density of 200 Labeo angra individuals per decimal (T2), combined with other species, is recommended for short-term aquaculture in seasonal ponds within the semi-arid regions of Bangladesh.

3 | Conclusion

Given the persistent challenges in the semi-arid areas of northern Bangladesh such as year-round pond water scarcity, temperature fluctuations, and other climatic constraints the adoption of short-cycle fish species within polyculture systems emerges as a practical solution. Angus (Labeo angra) has demonstrated strong potential due to its nutritional value, market demand, and rapid growth to marketable size. The utilization of seasonal waterbodies in semi-arid zones through this culture approach has proven economically viable. Based on key performance indicators including growth rate, feed conversion ratio (FCR), benefit-cost ratio (BCR), and survival rate a stocking density of 200 Labeo angra individuals per decimal was identified as optimal for polyculture. The recommended culture period spans from April to September, emphasizing the use of overwintered fingerlings to ensure successful outcomes.

Author Contributions

Srebash Kumar Saha: data collection, data analysis, interpretation, manuscript writing, and editing. Sonia Sharmin: data collection, data analysis, manuscript writing, and editing. Maliha Hossain Mou: data collection, data analysis, interpretation, manuscript writing, and editing. Md. Abu Naser: data collection, data analysis, interpretation, manuscript writing, and editing. Md. Mahmudul Hasan Mithun: data collection, data analysis, interpretation, manuscript writing and editing. Azhar Ali: manuscript writing and editing, fund acquisition. Harunor Rashid: supervision, manuscript writing and editing Anuradha Bhadra: supervision, manuscript writing, and editing. All authors have read and approved the final published article.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

All data generated and analyzed during this study are included within the manuscript. No additional datasets are available.

Ethics Statement

Not applicable.

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