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Research Article

Use of Urban Open-Waterbody to Enhance Fish Production Through Cage Culture

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Abstract

The purpose of the experiment was to examine the effect of cage fish culture on the growth and production performances of Shing (*Heteropneustes fossilis*), Pabda (*Ompok pabda*) and Gulsha (*Mystus cavasius*). The stocking density for each fish species was 100 fish/m^3. Cages with Shing, Pabda and Gulsha were treated as T_1, T_2, and T_3, respectively. Fish were fed with artificial diet at the rate of 5-10% of body weight. The experiment was carried out in cages in the Beel from June to November 2019. The study revealed that water quality parameters were not varied significantly ($p > 0.05$) among the treatments. The growth and production performance were significantly ($p < 0.05$) higher for Pabda cage culture followed by Gulsha and Shing cultures in cages. Therefore, the total net return (BDT 17,028) and benefit cost ratio (2.48) were significantly ($p < 0.05$) higher for Pabda fish considering cost benefit analysis. It was concluded that, among the three different fish species, high-valued Pabda is a highly acceptable candidate for cage farming in the Belai Beel area, and cage farming in urban open waterbodies is a promising approach to increasing total fish production and improving the social and economic status of fish farmers.

Introduction

Fisheries resources are important for food security, employment, and foreign exchange earnings in Bangladesh's national economy, and they are among the most dynamic and productive resources (DoF, 2022; Hasan et al., 2021). Approximately 12% of Bangladesh's total population is employed in the fisheries sector, both full-time and part-time, and fish accounts for approximately 60% of animal protein consumption (DoF, 2022). Bangladesh's fisheries sector is broadly divided into three subsectors: inland culture, inland capture, and marine water. Inland capture fisheries encompass 853,863 ha of river and estuary, 177,700 ha of the Sundarbans, 114,161 ha of Beel, 68,800 ha of Kaptai Lake, and 2,695,529 ha of the floodplain (haor) (DoF, 2022; Islam et al., 2022). The subsectors of inland capture, inland culture, and marine fisheries contributed 28%, 57%, and 15% of total fisheries production, respectively (DoF, 2022). Inland capture fisheries are thus the primary source of total fish production, food security, job opportunities, and foreign earnings, but their contribution to national fish production has decreased from 36.42% in 2001-2002 to 28% in 2020-2021 (DoF, 2022). As a result, the consumption of fish from capture fisheries has decreased. As a result, we must find an alternative method of increasing the fish production of inland capture fisheries.

Cage culture is one such technique that can be used successfully to properly utilize those inland waterbodies, having a significant impact on aquaculture production, income, and job creation (Kunda et al., 2022). Because the net cages allow for free flow of water, fish can grow in existing water resources while enclosed in them. However, over the last two decades, cage culture has gradually gained prominence in some areas of Bangladesh (Kunda et al., 2022). Cages can be used to culture a variety of shellfish and finfish species in various water habitats such as fresh, brackish, and marine water. Other types of water bodies where cage culture can be used include strip pits, rivers, streams, ponds, lakes, and reservoirs (Kunda et al., 2022; Kunda et al., 2021; Ara et al., 2020; Begum et al., 2017). Furthermore, cage culture provides a fish-intensive culture system, enabling the use

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of intensive technologies and increasing biomass production (Islam, 2005). The method has the advantage of increasing the fish production of inland capture fisheries because the productivity per hectare of the water area of inland waterbodies in Bangladesh has not yet reached its optimum (DoF, 2022; Sogbesan and Ugwumba, 2008).

Cage fish farmers, on the other hand, face difficulties in maintaining a favorable habitat for fish species cultured in cages because fish do not consume all parts of the feed. As a result, unused amounts of feed, feces, and wastes produced by metabolism can create unwholesome environments for fish, acting as stress factors for fish health (Marma et al., 2017; Nyanti et al., 2012). Using only a small portion of their surface area, large and medium reservoirs can contribute a significant amount of fish to overall inland fish yield (Jiwyam, 2012; Imelda, 2009). Because of the ever-increasing demand for land for residential, agricultural, industrial, and other purposes as a result of the ever-increasing population, finding suitable land for the construction of ponds for fish production will be difficult in the future. That is why research into alternative fish production methods is sorely needed. Raising fish seeds and food fish in cages is a specialized technique that is gaining popularity for the exploitation of existing water bodies. In addition, the most common fish species grown in cage fish culture in Bangladesh appear to be Climbing Perch (*Anabas testudineus*) (Gorlach-Lira et al., 2013; Islam, 2005), Tilapia (*Oreochromis niloticus*) (Kunda et al., 2021; Jahan et al., 2018; Begum et al., 2017; Hossain et al., 2017; Nabirye et al., 2016; Hambrey and Roy, 2002) and Walking Catfish (*Clarias batrachus*) (Kunda et al., 2022; Shamsuzzaman et al., 2017). Catfishes are particularly important among the various fish species in Bangladesh due to their rapid growth, lucrative size, good taste, and high market demand (Kunda et al., 2022). Not only that, but catfish have an air-breathing organ that allows them to survive in low-oxygen environments and thus have a higher tolerance to adverse environmental conditions (Ara et al., 2020; Begum et al., 2017; Thirupathaiah et al., 2012; Akhteruzzaman et al., 1993; Akhteruzzaman et al., 1991).

Belai Beel is approximately 8 square kilometers in size and has an average depth of 9 feet (Arulampalam et al., 1998). It is situated in the Gazipur district's Kaliganj Upazila. This Beel has free access to the Shitalakhya and Turag Rivers. During the flood season, it transports floodwater from the Shitalakhya and Turag rivers. In recent years, urbanization and industrialization activities near the Turag River's bank have caused industrial pollution in that water, with the majority of industries discharging their effluents directly or indirectly into the Turag River without treatment, resulting in water pollution (Islam et al., 2022). This complex mixture of organic and inorganic hazardous chemicals entering the Belai Beel degrades not only the water quality but also the sediment, rendering the water unfit for recreation, agriculture, and aquaculture. Anthropogenic activities have become major problems for wetland fish production in recent years, as they contain various metallic ions that harm aquatic ecosystems (Islam et al., 2022). Although most information on fish species diversity and the livelihood status of cage fish culture is available in Bangladesh and around the world, information on cage fish culture in urban areas Beels is limited (Sogbesan and Ugwumba, 2008; Marma et al., 2017; Gorlach-Lira et al., 2013; Hambrey and Roy, 2002; Arulampalam et al., 1998; Mondal et al., 2010; Jeqel et al., 2018; Habib et al., 2015; Mallasen et al., 2012). Hence, the purpose of the present study is to determine the suitability of catfish production in the cage culture system of Belai Beel based on water quality parameter and to compare the fish production performance and economic returns of the cage fish farmers of the Belai Beel, Bangladesh.

Materials and Methods

Study area

The study was carried out through interrogation of cage farmers in the Baria village of Belai Beel (Figure 1). A distributary of the Balu River is directly connected with the Belai Beel. During the selection of cage farming sites, an important consideration is the approximate water flow and the connection of the floodplain to the river channel. The maximum depth of the distributary during the peak monsoon is approximately 3 m, but usually, the depth varies between 2 and 2.5 m. The study was carried out at the Belai Beel (23°58'18.45"N latitude and 90°31'19.64"E longitude) of Baria village, Gazipur, Bangladesh (Figure 1) for a period of 182 days from 01 June to 30 November 2019.

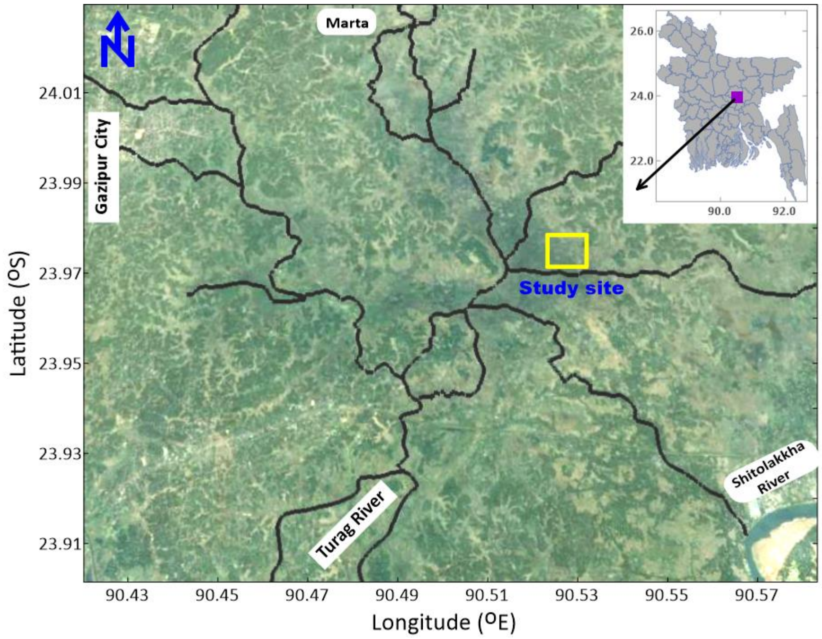

Figure 1. Location of the study areas in Belai Beel

Description of cages

Like most freshwater species, the shape of the cage can have an impact on productivity. The fixed cage is the most basic and extensively utilized in shallow water at a depth of 1-3 meters. Rectangular form cages are suitable from a performance perspective, and their selection is primarily based on other factors such as turbulence resistance, durability, cost, material availability, and ease of assembling and transporting the components. This research was conducted in a medium-sized cage (9 ft × 6 ft × 4 ft) (Figure 2). The frame and float were made of bamboo and plastic barrels, respectively. The cages were made of bamboo and plastic barrels and covered by 0.4 mm meshed nylon net tied with nylon twine in order to protect experimental fish fry from escaping and allow easy passage of water through the cages. For this experiment, a total of nine cages were installed in a row.

Figure 2. Cage fabrication

Experimental design

Total three catfish species were selected for cage culture trials as Shing (*Heteropneustes fossilis*), Pabda (*Ompok pabda*), and Gulsha (*Mystus cavasius*). The treatments T_1, T_2, and T_3 were assigned to Shing, Pabda, and Gulsha. Replication-wise cages were identified as Treatment-1 (T_1R_1, T_1R_2 and T_1R_3), Treatment-2 (T_2R_1, T_2R_2 and T_2R_3) and Treatment-3 (T_3R_1, T_3R_2 and T_3R_3). After the selection of fish fry, they were released in experimental cages by maintaining a stocking density of 100 fish per m^3 (Ara et al., 2020) and regular monitoring was done to record fish growth performance during the entire experimental period. Fish were fed at the rate of 5-10% of their body weight (Kunda et al., 2022; Ara et al., 2020).

Monitoring of water quality parameters

During the study period, water temperature and dissolved oxygen (DO) were recorded with a portable digital meter (Model: HQ30d, HACH). The pH meter (Model: sensION$^+$ EC72) was used to obtain the pH value. Nutrient analysis, including estimation of nitrite, nitrate, ammonia and inorganic phosphate was carried out in the laboratory and the values were determined by a spectrophotometric method (HACH, DR-6000, Germany, S/N: 1824775) at the laboratory of the Department of Fisheries Management, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh.

Fish growth monitoring

Fish were sampled monthly to monitor the growth and altered the feeding strategy when needed. The growth of 20 fish from each cage culture unit was measured with the help of a scoop net (Kunda et al., 2022; Ara et al., 2020). The following growth parameters (Kunda et al., 2022; Ara et al., 2020) were investigated during the study period:

Initial weight (g) = Weight of fish at the time of stocking
Final weight (g) = Weight of fish at the time of harvesting
Weight gain (g) = Mean final weight- Mean initial weight

$$\text{Percentage weight gain } (\%) = \frac{\text{Final weight (g)} - \text{Initial weight (g)}}{\text{Initial weight (g)}} \times 100$$

$$\text{Specific growth rate } (\%\ \text{day}^{-1}) = \frac{\ln \text{Final weight (g)} - \ln \text{Initial weight (g)}}{\text{Culture period}} \times 100$$

$$\text{Average daily gain(ADG)(g day}^{-1}) = \frac{\ln Final\ weight\ (g) - \ln Initial\ weight\ (g)}{\text{Culture period}}$$

$$\text{Survival rate } (\%) = \frac{\text{Total numver of fish harvest}}{\text{Total number of fish stocked}} \times 100$$

$$\text{Feed conversion ratio} = \frac{\text{Weight of feed fed}}{\text{Weight gain of fish}}$$

For estimation of fish production, total gross yield and production were calculated by the following formula (Kunda et al., 2022; Ara et al., 2020):

Gross yield (kg) = Number of fish harvested × average final weight (kg)
Gross production (ton/ha/182 days) = Gross weight (kg)/1000

Economics of fish farming

After a particular culture period, marketable size fishes were harvested and sold in the local market. To calculate the cost-benefit analysis of different treatments, the prices of inputs and labor to be considered, as well as the income from fish sold were used. The net return was calculated using the following equation (Ara et al., 2020):

$R = I - (F_c + V_c + I_i)$

Where,
R refers to net return;
I total income from fish sold;
F_c for Fixed costs;
V_c for variable costs and
I_i for interests on input costs.

The pricing had been given in Bangladeshi Taka (BDT). The wholesale market prices for all inputs and fish fingerlings in the research areas were used. By subtracting the total cost from the total revenue which come from the sale of fish, the net benefit was computed. The following formula was used to compute the benefit-cost ratio (BCR):

$$\text{BCR} = \frac{\textbf{Total revenue}}{\textbf{Total cost}}$$

Statistical analysis

The R program (version 4.0.3) was used to analyze water quality parameters, fish growth, production and economic performance at a 5%, 1%, and 0.1% level of significance. After the normality test (Shapiro-Wilk test) and homogeneity of variance test, Kruskal Wallis test were conducted using SPSS 22.0 to detect significant or insignificant spatial differences.

Results

Water quality parameter

Water quality parameters within cages were observed monthly after analyzing the water samples. For most of the treatments, the water depth was more or less the same. Figure 3 represents the water quality parameters of the experimental cages. Water temperature, dissolved oxygen (DO); pH; NH_4^+; NO_2^-; NO_3^-; PO_4^{3-} and Chlorophyll-a concentrations did not vary significantly within the cages. Water temperature ranges between 30.33±0.64 to 30.66±0.57 °C where p = 0.73; DO ranges from 6.97±0.51 to 7.16±0.3 mgL^{-1}. pH ranges between 7.35±0.32 to 7.44±0.42 where p=0.92 NH_4^+ ranges between 0.35±0.06 to 0.39±0.037 mgL^{-1} where p = 0.12; NO_2^- ranges between 0.004±0.0005 to 0.0053±0.001 mgL^{-1} where p = 0.24; NO_3^- ranges between 0.025±0.013 to 0.030±0.008 mgL^{-1} where p=0.099. Phosphate (PO_4^{3-}) is the limiting nutrient and chlorophyll-a is responsible for primary and ultimate secondary production. PO_4^{3-} ranges between 1.22±0.17 to 1.3 ±0.10 mgL^{-1} where p =

0.039; Chlorophyll-a ranges between 4.87±0.42 to 6.05±0.46 (µg/L).

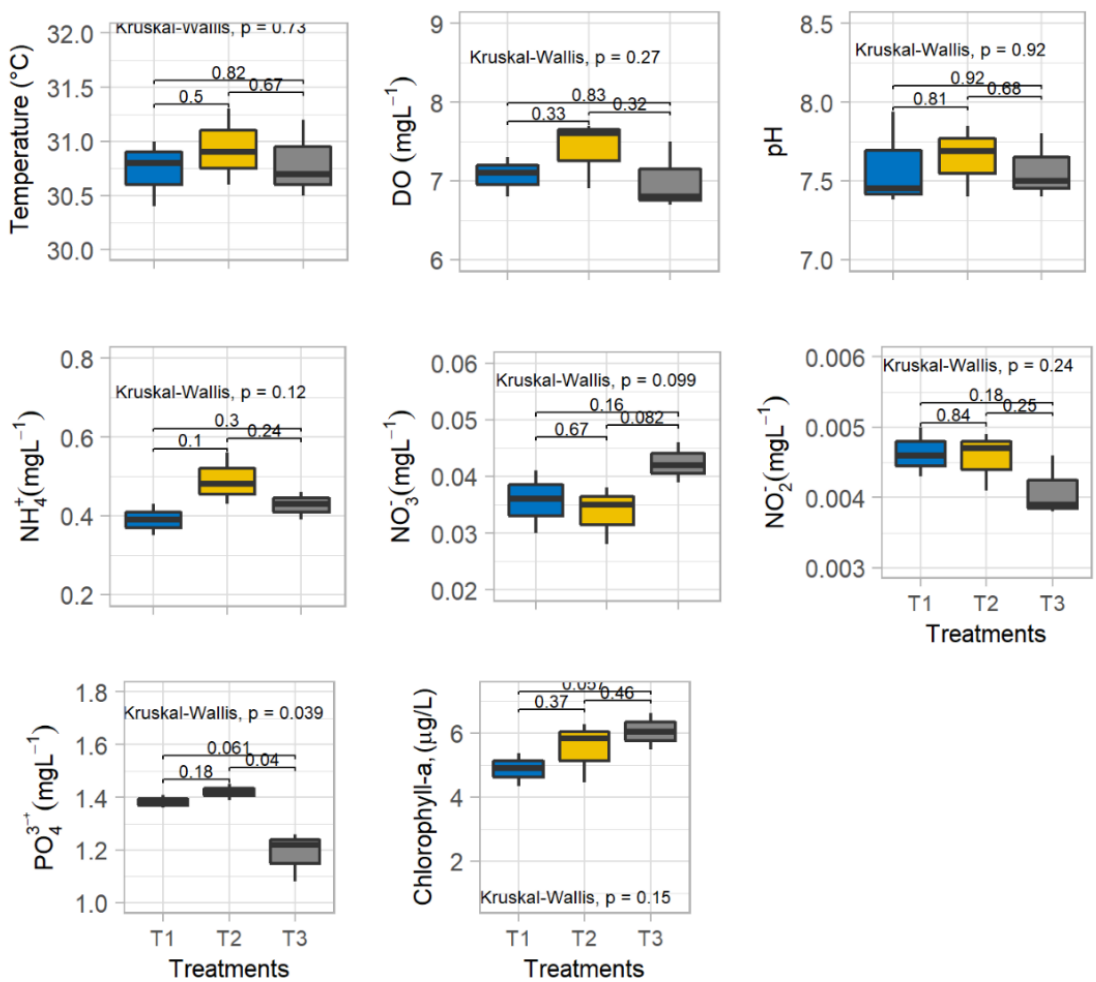

Figure 3. Water quality parameter in different treatments

The correlation coefficient ranges from −1 to +1 (Figure 4). The stronger the relationship between the variables, the larger the absolute value of the coefficient. An absolute value of 1 in the Pearson correlation denotes a perfect linear relationship. The variables do not have a linear relationship when the correlation is close to 0. Strong linear correlation was found between NO_2^- and PO_4^{3-}; no linear correlation was found between PO_4^{3-} and DO; negative linear correlation was found between NO_3^- and PO_4^{3-}; NH_4^+ and DO, respectively (Figure 4).

Growth performance of fish in cages

The growth performances and production of fish under different treatments at the completion of 182 days of cage-based fish rearing were shown in Table 1. The treatments had a substantial difference in the final weight, weight gain, percent weight gain, average daily gain (ADG) and specific growth rate (SGR). Figure 5 and Table 1 showed different growth parameter for the experimental fish in different treatments. Significant differences were recorded among final weight (g), average daily weight gain (ADG g/day), specific growth rate (%), survivability (%), feed conversion ratio (FCR), total production (kg), total return (BDT), total cost (BDT), net return (BDT) and BCR in T_1, T_2, and T_3, respectively. Highest mean final weight was gained in T_2 (68.64±1.20g) and lowest in T_1 (45.68±1.20g) cage; Average daily growth (ADG g/day) was highest in T_2 (0.375±0.006 g/day) and lowest in T_1 (0.248±0.006 g/day) cage; highest mean specific growth rate (SGR%/day) was found in T_2 (2.52±0.009 %/day) rather than in T_1 (2.13±0.01 %/day) cages; Catfishes are stress tolerance species, the survivability was highest in T_1 (70%) compared to T_2 (65%) and T_3 (65%) cages; FCR was best in T_2 (0.88±0.01) than T_1 (1.32±0.03) T_3 (1.19±0.01) cages and highest total biomass production was recorded in T_2 (43.88±0.77 kg) than T_1 (31.30±0.85 kg) and T_3 (32.67±0.45 kg) cages.

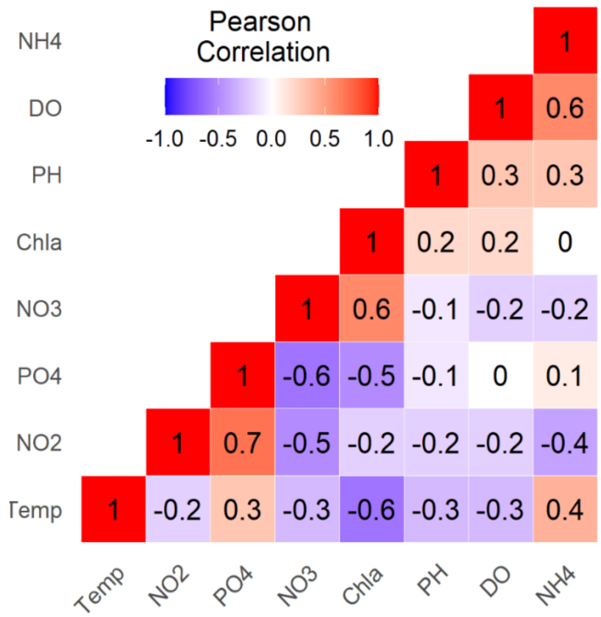

Figure 4. Pearson correlation matrix of different water quality parameters

Table 1. The growth performance of fish

Parameters	T_1	T_2	T_3
Mean initial length (cm)	4.05 0.12	5.86±0.044	4.13±0.01
Mean final length (cm)	23.3±0.32	29.61±0.46	22.62±0.22
Mean initial weight (g)	0.96±0.014	1.13±0.021	0.98±0.005
Mean final weight (g)	45.68±1.20	68.64±1.20	48.91±0.71
Average daily weight gain (g/day)	0.248±0.006	0.375±0.006	0.278±0.004
SGR (% /day)	2.13±0.01	2.52±0.009	2.19±0.007
FCR	1.32±0.03	0.88±0.01	1.19±0.01
Survival rate (%)	70±0.01	65±0.01	65±0.01
Gross yield (Kg/cage/182 days)	31.30±0.85	43.88±0.77	32.67±0.45

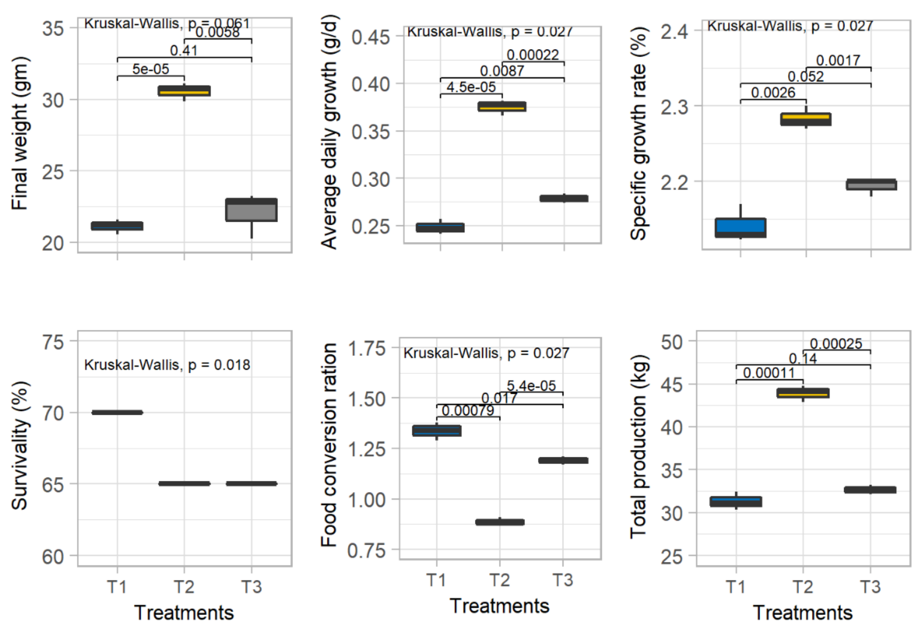

Figure 5. Growth performance parameter of different fish species in different treatments

Economics of cage culture

The T_2 treatment showed the highest total returns, which is significantly different from other treatments (Figure 6). The highest total return was recorded in T_2 (28,528 BDT) cages compared to T_3 (22,217 BDT) and T_1 (17,219 BDT) cages where, p=0.027; Total cost varied due to initial fingerlings cost, with the highest total cost observed in T_2 (11,500 BDT) cages than T_1 (10,800 BDT) and T_3 (10,500 BDT) cages (Figure 6; Table 2); Net return or net profit was highest in T_2 cages due to higher production of fish, highest net return was found in T_2 (17,028 BDT) cages than T_1 (6,419 BDT) and T_3 (11,717 BDT) cages and finally, benefit-cost ratio (BCR) was highest in T_2 (2.48) than in T_3 (2.11) and T_1 (1.59) (Figure 6).

Table 2. The benefit-cost ratio analysis of different treatments

Parameters	T_1	T_2	T_3
Cage preparation	4,000	4,000	4,000
Fingerling (1000)	1800	2500	1500
Feed (50 tk/kg)	3,000	3,000	3,000
Operational cost (BDT)	2,000	2,000	2,000
Total cost (BDT)	10,800	11,500	10,500
Total Return (BDT)	17,219±1234	28,528±1765	22,217±876
Net Profit (BDT)	6,419±1,122	17,028±1345	11,717±678
BCR	1.59±0.05	2.48±0.09	2.11±0.07

The value of the correlation coefficient ranges from −1 to +1 (Figure 7). The greater the correlation between the variables, the larger the absolute value of the coefficient. An absolute value of 1 in the Pearson correlation denotes a perfect linear relationship. A correlation close to ‘0’ suggests that the variables do not have a linear relationship. Most of the parameter showed a perfect and strong positive correlation except FCR, and survivability (%) showed a negative linear correlation with other parameters (Fig. 7).

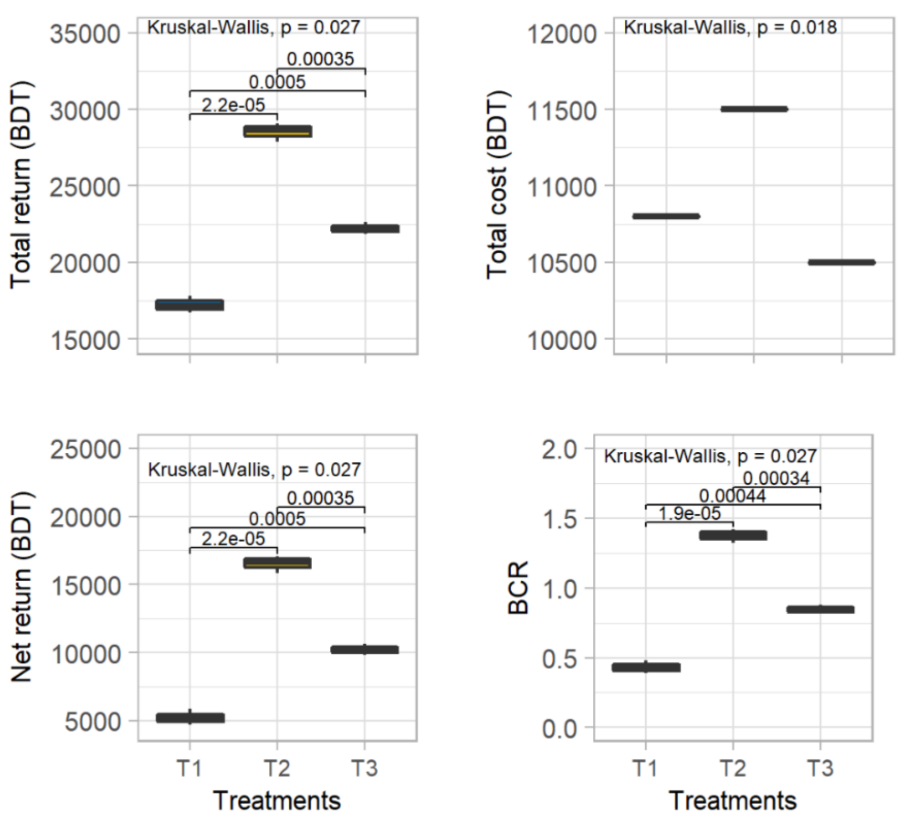

Figure 6. Different economic performance parameters of fish in cages

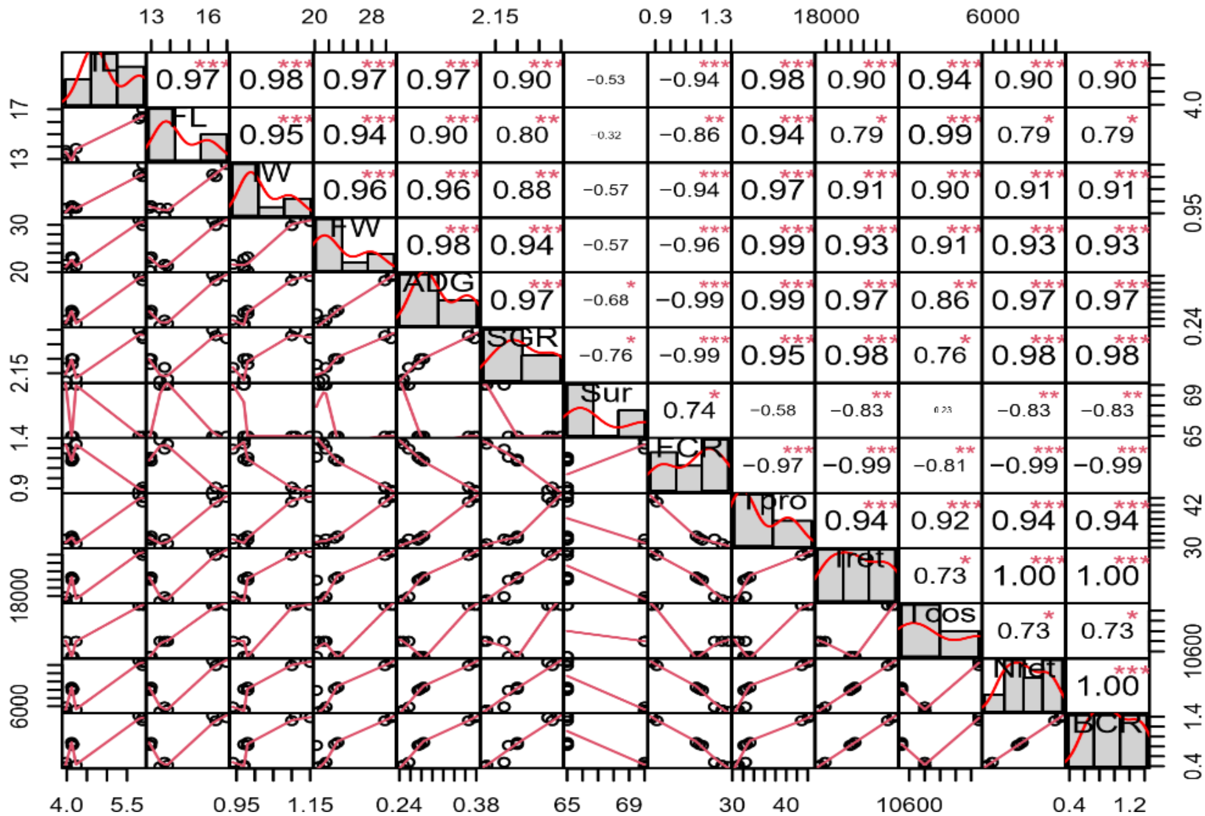

Figure 7. The correlation plot among the thirteen growth and production parameters. The values given around all the axes are the range of each parameter. Correlation coefficients (r) indicated with numeric values, while significance levels (*p*) are denoted by asterisks (*<0.05, **<0.01, ***<0.001)

Discussion

The water quality characteristics of the examined cage did not differ significantly due to the application of various treatments during the study period, which could be attributed to the floodplain water body chosen for cage culture. Wastes generated from unused feed particles by fish and metabolic wastes of cultured species are the primary causes of water quality issues in cage farming (Islam et al., 2005). Water temperature is the most important factor in maintaining the growth, reproduction, survival, and distribution of organisms in the physical environment, and it influences the distribution of living organisms, the rate of photosynthesis in the aquatic environment, and the rate of photosynthesis in the aquatic environment (Hasan et al., 2022). Because the temperature of the water is determined by the temperature of the surrounding atmosphere. Water temperature was not within suitable levels during the study period due to seasonal effects, reduced water depth, and high sunlight (Kunda et al., 2022; Jewel et al., 2018; Habib et al., 2015). pH and DO levels were determined to be within acceptable limits for fish growth and production (Ara et al., 2020; Uddin et al., 2016; Moniruzzaman et al., 2015). The use of an open water body as a study site ensures a clean environment during the research. Higher fish stocking density, uneaten feed particles, and fish feces are all causes of water degradation (Nabirye et al., 2016; Temporetti et al., 2001). In pond cage culture systems, DO and pH ranges were 4.91-4.92 mgL^{-1} and 7.2-7.4, 5.37-5.42 mgL^{-1} and 7.18-7.38, 4.90-6.70 mgL^{-1} and 7.50-7.90, respectively (Begum et al., 2017; Habib et al., 2015; Sangma et al., 2017), which were lower than the current findings. NH_4^+ concentrations ranged from 0.39 to 0.05 mgL^{-1}. According to some research, the ammonia concentration in cage culture systems ranged from 0.01 to 1.15 mgL^{-1} (Nyanti et al., 2012; Islam et al., 2005; Mallasen et al., 2012; Devi et al., 2017). The water current that regularly washed out unused feed particles and fecal matters from the cultured unit to the outside influenced the results of this study, highlighting the feasibility of cage farming of fish in an open water system. Nitrite is a by-product of oxidized NH_4^+, ranging from 0.004±0.0007 to 0.0053±0.001 mgL^{-1}. The nitrite concentration at cage stations was higher than the control due to the contribution of fish waste and excess feed (Nyanti et al., 2012). Nitrate is created during the nitrification process, which involves aerobic bacteria oxidizing NO_2^- to NO_3^-. Nitrate concentrations range from 0.0250±0.13 to 0.0300±0.08 mgL^{-1}. The ideal nitrate concentration for aquaculture is 0.2 to 10 mgL^{-1} (Kohinoor et al., 2011). Sewage and other nitrate-rich wastes have the potential to pollute surface water. Nitrate concentrations were low due to other industrial effluents in the floodplain area (Kohinoor et al., 2011). The optimal phosphate concentration in water seems to be between 0.005 and 0.2 mgL^{-1} (Kohinoor et al., 2011). A large number of cages in one location may exceed the carrying capacity of the aquatic environment, causing phosphorus problems (Mallasen et al., 2012). Chlorophyll-a concentration has been found to have a greater impact on primary productivity. The highest chlorophyll-a concentration was recorded in T_3 (6.050.46) and the lowest in T_1 (4.870.42), which are more or less similar (Mallasen et al., 2012).

Growth and production performance were significantly higher at this location, such as T_1 for Shing, T_2 for Pabda, and T_3 for Gulsha in terms of length. T_2 had the highest value as a result of the increase in fish body weight, while T_1 and T_3 had the lowest. The mean length gains in three different treatments were found to differ significantly. Based on the final weight attained at harvest under T_1, T_2 and T_3 were 45.68±1.20, 68.64±1.20 and 48.91±0.71 g, respectively. T_2 had the greatest harvesting weight, whereas T_1 and T_3 had the lowest. The mean harvested fish weight was significantly ($p < 0.05$) different among the three treatments. This study discovered that differences in growth performance exist because the genetic structure and feeding behavior of fish differ from species to species (Imelda et al., 2009; Kohinoor et al., 2011). We know that protein and amino acids are important nutrients for fish growth, but protein absorption ability varies between species (Marma et al., 2017), which explains why growth rates vary. Maximum weight is another factor that influences growth in various catfish species. Some authors' findings included mean ultimate weights of 32.0 g for Pabda and 24.66 g for Gulsha after a 6-month culture period (Kohinoor et al., 2011). The fish's specific growth rate (SGR% per day) varied across treatments. T_1 was the most valuable, while T_2 and T_3 were the least valuable. T_1 had significantly higher SGR than T_2, but T_1 did not differ significantly from T_2 and T_3, and T_2 did not differ significantly from T_3. T_2 has a much lower FCR than T_3 or T_1. The current study found that stress caused high mortality in all treatments, particularly Pabda and Gulsha, with a survival percentage of 70±0.01% in T_1, 65±0.01% in T_2, and 65±0.01% in T_3. When compared to T_2 and T_3 treatments, T_1 has the highest survival rate. There were no significant differences in survival rates between treatments ($p > 0.05$). The survival rate (%) of pabda varied between 75 and 87% in a study by Hossain (2008) and 89.59% for Pabda fish species (Kunda et al., 2022). T_2 had the highest net return of fish, rather than T_1 and T_3. T_2 had the highest net return and T_1 had the lowest. The Kruskal Wallis test revealed a significant difference in gross revenue ($p < 0.05$) between treatments. The mean total cost for T_1, T_2, and T_3 was calculated to be 10,800, 11,500, and 10,500 BDT, respectively. T_2 and T_3 had the highest and lowest overall costs, respectively, and the treatments differed significantly. T_2 had the highest average net return among the three treatments in terms of net profit for T_1 cages 6,419±467.80 BDT; T_2 cages 17,028±506.32 and T_3 cages 11,717±313.74 BDT. Significant differences ($p < 0.05$) in net return among different treatments were recorded.

As a result, total cost varied greatly between culture units, with T_1 having the highest total cost. It had significantly ($p < 0.05$) higher net returns and the benefit cost ratio (BCR) that indicates higher economic performance for T_2 (Pabda 1.37±0.041), which is also supported by (Kunda et al., 2022) than T_3 (Gulsa 0.85±0.024) and T_1 (Shing 0.43±0.037). On the contrary, while the experimental fish's growth performance was found to be suitable for Pabda, Shing, and Gulsha; Pabda had a much higher net return, and finally, the benefit-cost ratio revealed that Pabda had a stronger economic performance than other species. The main reason for this is that the market price of Pabda is higher than that of other experimental fishes. Furthermore, cage-grown catfish was more profitable than Tilapia or other fish farming (Temporetti et al., 2001).

Conclusion

Cage aquaculture is a potential source of food fish production in many parts of the world, particularly in areas with abundant natural water resources, and it also provides a source of income for resource-poor farmers. The current study found that cage fish farming in open water is environmentally friendly and has no significant negative impact on the surrounding environment. This study revealed that Pabda's response was to boost total output and growth performance. According to the overall economic analysis, Shing, Pabda, and Gulsha have a higher efficacy to be cultured in net cages by setting them up in an open water environment, which also increases the total inland open water capture fisheries production.

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Conflicts of Interest

The authors declare no conflict of interest.

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