Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 26(6): 1285 – 1299 (2022)
www.ejabf.journals.ekb.eg

Finding the suitable catfish species for cage aquaculture in a freshwater swamp

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ARTICLE INFO

Article History:
Received: Jan. 26, 2022
Accepted: Aug. 29, 2022
Online: Dec. 29, 2022

Keywords:
Cage culture
Ratargul Swamp Forest
Production performance
Profitability

ABSTRACT

The experiment was carried out for 94 days in the renowned Ratargul Freshwater Swamp Forest of Bangladesh in order to assess the production performance and economics among three locally high-demand catfish species with a view to selecting suitable species for cage culture. Magur (*Clarias batrachus*), pabda (*Ompok pabda*) and pangas (*Pangasianodon hypophthalmus*) were stocked in Treatment-1 (T_1), Treatment-2 (T_2) and Treatment-3 (T_3), respectively at stocking densities of 40 fish/m^3, 60 fish/m^3 and 40 fish/m^3, respectively with three replications each. The mean initial weights of fish were 25.35±0.55 g in T_1, 15.45±0.30 g in T_2, and 18.16±0.55 g in T_3. Fishes were supplied with commercial floating starter feed at the rates of 10-5% live body weight of fish for the first month, and grow-out feed at the rate of 4% body weight from the second month to till the end of the experiment. Species were sampled monthly. Results show that the average individual harvesting weight of fish was 141.93±9.86 g in T_1, 53.22±3.07 g in T_2 and 363.75±12.09 g in T_3 at the end of the experiment which was significantly different among the treatments. Total yield was found significantly higher in pangas (13.20±0.69 kg/m^3) than magur (3.71±0.14 kg/m^3) and pabda (2.86±0.27 kg/m^3). Though there were no significant differences among the benefit-cost ratios for all the treatments, the highest was accounted for T_3 (1.25±0.08), followed by T_1 (1.22±0.05) and T_2 (1.19±0.11). The findings of the present experiment suggest that pangas could be a suitable species followed by magur and pabda for cage farming in freshwater swamps.

INTRODUCTION

Bangladesh is geographically endowed with a vast area of water resources, including ponds, natural depressions (*haors* and *beels*), lakes, canals, rivers, estuaries, etc. (Morsheduzzaman *et al*., 2010; DoF, 2020; Sunny *et al*., 2021a; Pandit *et al*., 2021; Saha *et al*., 2021). According to FAO report, recently Bangladesh ranked 3rd in inland open water capture fisheries production and 5th in world aquaculture production (Sunny *et* *al*., 2021b). In 2019-2020 total fish production of this country was 4.50 million metric ton of which 2.58 million metric ton was solely contributed by inland aquaculture sector (DoF, 2020; Kawsar *et al.*, 2022). Though the total fish production recently become almost saturated in Bangladesh and plays an important role in the socio-economic development of fishers (Islam *et al*., 2016), till now a large portion of inland waters are kept fellow or not intensively used for fish production. Cage culture is such a technique which can be used successfully to utilize those inland waterbodies properly and thus would have significant impacts on aquaculture production, income, and employment generation.

In the late 1970s, cage aquaculture was first introduced in Bangladesh through a series of experiments conducted at Bangladesh Agricultural University (Hasan *et al.*, 1982; Ahmed *et al.*, 1984; Ahmed *et al.*, 1997) to demonstrate the potential of cage aquaculture. Due to the high capital cost, lack of technical know of fish culture in cages, and comparatively complex management technology, it could not attract farmers at that time. Although Asia is leading in cage culture for the last three decades, Bangladesh is still far behind despite having huge water resources (Baqui and Bhujhel, 2011). However, during the last two decades cage culture is gradually getting priority in some areas of Bangladesh. In spite of such huge opportunities to expand this technology it was rarely adopted in the *haor* regions of the country.

For any aquaculture system including cage culture, selection of species is important because of the culture suitability to that system and commercial viability. Some fishes have shown consistent success in cage aquaculture, such as tilapia (*Oreochromis niloticus*), Thai sharpunti (*Barbodes gonionotus)*, grass carp (*Ctenopharyngodon idella*), Thai pangas (*Pangasianodon hypophthalmus*), prawn (*Machrobrachium* sp.), koi (*Anabas testudineus*), etc. (Hossain, 2008; Sangma *et al.*, 2017; Chowdhury *et al.*, 2020). Among these, tilapia is the most common (56%) cultured fish followed by pangas (12%), Thai sharpunti (11%), grass carp (8%), and others (13%) (CARE, 2000). According to Sangma *et al.* (2017) climbing perch (*Anabas testudineus*), tilapia, and walking catfish (*Clarias batrachus*) are the main contributory species in cage culture of Bangladesh. However, among these various fish species catfishes are particularly important for their fast growth, lucrative size, good taste and nutrition, and high market demand (Ara *et al.*, 2020). They can survive even at low oxygen levels of water. Hence, catfishes are desirable species for cage culture in the low-depth *haors* of Bangladesh.

Abundance of native catfishes is reducing day by day in the inland open waters due to overfishing, fishing by dewatering, use of illegal fishing gears, degradation of fish habitat (natural breeding and feeding grounds), climate change, etc. (Pandit *et al.*, 2015, 2021; Islam *et al.*, 2019; Akter *et al.*, 2020; Talukder *et al.*, 2021; Mia *et al*., 2022). At this situation, cage culture of less or rarely available catfishes could be a solution for the conservation of these fish species because their production in cage culture is thus supposed to decrease the pressure on catfishes in natural waterbodies.

When compared to other species in our nation, the Thai pangas is one of the most widely farmed fish in the aquaculture industry (Begum *et al.*, 2012). Alike other cultivated catfishes, Thai pangas is well-known for its faster growth, simple culture system, high disease resistance capacity, and tolerance of a wide range of environmental parameters (Stickney, 1979; Begum *et al.*, 2012). However, many commercially important indigenous catfishes of Bangladesh, such as pabda (*Ompok pabda*) and magur (*Clarias batrachus*) have shown potentials in aquaculture due to faster growth and high market demand. Thus, this study has been undertaken to compare the growth, production performance and economics of these three important species for better understanding on species suitability for profitable cage aquaculture in the freshwater swamps of Bangladesh.

MATERIALS AND METHODS

Study area:

Ratargul Swamp Forest is one of the endemic freshwater swamp forests of the world located on the bank of the Shari-Goyain River at Gowainghat upazila under Sylhet district of Bangladesh (Kunda *et al.*, 2022). This forest plays a significant role in ecosystem management by providing desirable habitat for a wide variety of plant, mammal, reptile, amphibian, fish, and bird species (Choudhury *et al.*, 2004). The study was carried out at the Rangakuri *Beel* (25°00'47.88"N latitude and 91°55'30.25"E longitude) of Ratargul Swamp Forest (Fig. 1) for a period of 94 days from 18 April to 20 July, 2019.

Cage preparation and set-up:

Nine cages were constructed each with 36 m^3 (6 m × 3 m × 2 m) in size. The water volume of each cage was 27 m^3. The cages were made of galvanized iron pipe frame and covered by 2 cm 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. One edge of upper side of each cage was kept unsewed unlike the other parts of the net and loosely tied by nylon threads so that it can be opened for management like feeding, sampling, and harvesting of fish. A large iron pipe frame supported by bamboo was used to surround the periphery of the whole cage set-up. Twenty pieces of empty metal drums (200 l capacity each) were fixed with the peripheral iron frame to fix nine cages and keep them floating. Each cage was tied up with a rope to fix it with the bamboo frame. Then the cages with frame were settled into the water with anchor and vertical bamboo poles one week prior to stocking of fish fry. To prevent spill-out of floating feeds from the cages by the natural flow of water, all the cages were covered with fine meshed net to a length of 30 cm along the water surface level.

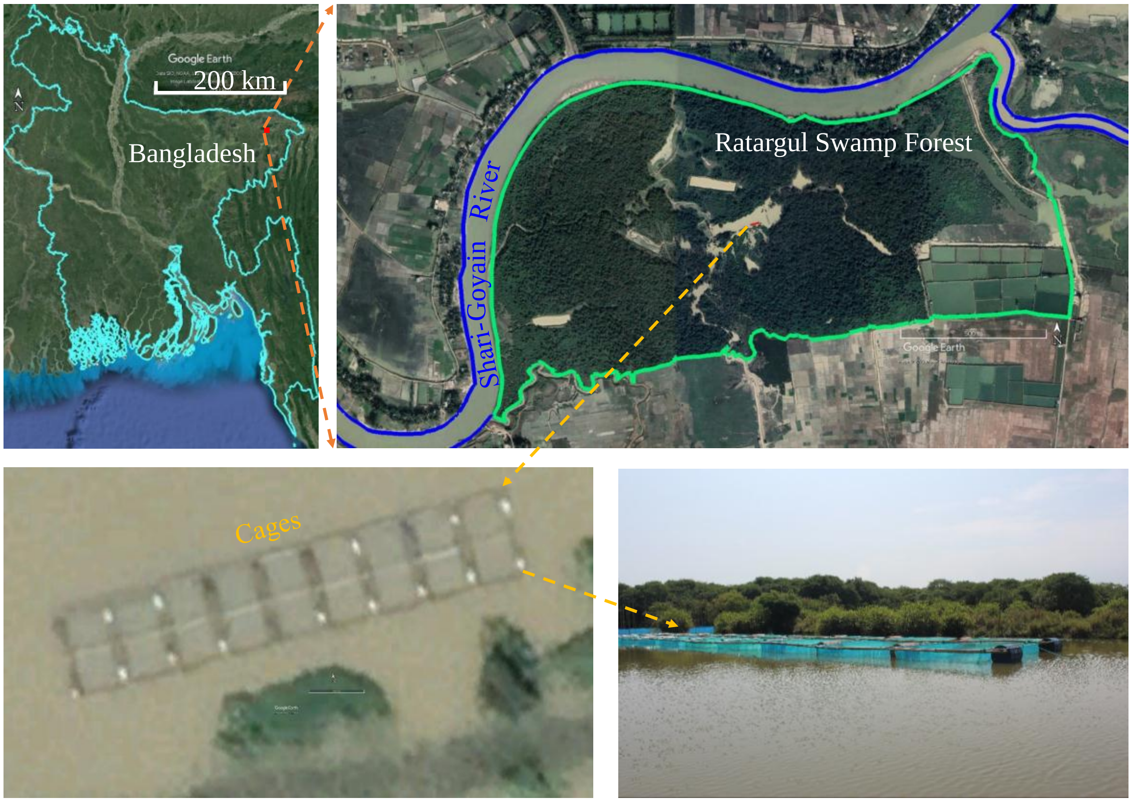

Fig. 1. Map of Bangladesh (inset) showing the cages in the study area at Ratargul Swamp Forest.

Study design:

In this study, three treatments were conducted with three replications. Magur was stocked in Treatment-1 (T_1), pabda was stocked in Treatment-2 (T_2) and pangas was stocked in Treatment-3 (T_3). 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). Stocking densities in T_1, T_2 and T_3 were 40, 60, and 40 fish/m^3, respectively.

Stocking of fish fry:

Healthy and uniform sized fish fingerlings were collected from Delta Agro Fisheries, a local fish hatchery in Bishwanath upazila, Sylhet. Before transportation fishes were kept unfed and acclimatized for 2 hours in rectangular *hapa* set in a large fish holding tank with continuous flow of water. Fish seeds were transported to the pier on the Shari-Goyain River close to the study site by a pickup truck after packing the fingerlings in two layers packed oxygenated polybags. Then the fingerling containing polybags were transported to the study area by two large mechanized boats without delay. Then the polybags were kept in water at the study site and water from the waterbody were splashed in the polybags to slowly match the temperature with the environment before releasing in the cages. All of those transportation and releasing of fingerlings were done in early morning. Before stocking length and weight of 20 fries were randomly recorded for each of the cages; and thus average weight of each species were estimated. At the beginning of the experiment, *C. batrachus*, *O. pabda* and *P. hypophthalmus* average individual weights were 25.35±0.55 g, 15.45±0.30 g and 18.16±0.55 g, respectively, and average individual lengths were 15.50 cm, 14.53 cm and 14.08 cm, respectively.

Feeding management:

Feeding was initialized with commercially available floating starter feed at 10% of live body weight of fish and gradually decreased up to 5% of body weight till the end of the 1st month, and from the 2nd month to the end of the study grower floating feed was supplied at 4% of live body weight of fish. Feeds were distributed over the cages through the upper opening. The daily ration was divided into two equal half and supplied in the early morning (around 5:00 am) and in the evening (around 6:30 pm). Feeding rate was adjusted at every 15 days by increasing the amount by 10% according to Phan *et al.* (2009).

Sampling and monitoring of fishes:

Health conditions of fishes were checked monthly during sampling. Length and weight of randomly selected 20 individuals were measured and recorded from each of the cages a monthly basis throughout the study period. Length of fish was measured by wooden scale and weight of fish was measured by digital weighing machine (three digit precision). Moreover, the conditions of cages and the nets were monitored weekly to check and clean nets clogged with algae or debris and damaged net parts were repaired immediately.

Measurement of water quality parameters:

Water quality parameters, namely temperature, pH, conductivity, dissolved oxygen, and total dissolved solids (TDS) were monitored fortnightly by using a digital multi-sensor (YSI Multi-Sensor, model: Professional Plus, Brand: YSI, Origin: USA). Water quality parameters were measured separately from all the cages. Transparency and water depth were measured by using a Secchi disc and weighted rope, respectively.

Estimation of growth, yield and survival rate of fish:

All fishes were harvested at the end of the study period. During harvesting, length and weight of 20 individuals from each cage were measured randomly. Bulk weight of all fishes was taken to calculate the total production of each cage.

Weight gain (g) = Final weight (g) - Initial weight (g)

$$\text{Survival rate (\%)} = \frac{\text{Number of fish harvested}}{\text{Initial number of fish stocked}} \times 100$$

Gross yield = Number of fish harvested × Average final weight

Net yield = Number of fish harvested × Average weight gain

The feed conversion ratio (FCR) is expressed by the amount of food consumed to the weight gain. Specific growth rate (SGR) was calculated as % growth per day (Kunda *et al*., 2021).

Benefit-cost analysis:

Benefit-cost ratios (BCRs) of the different treatments were analyzed on the basis of the prices of fish seed (including transport), feed, labour cost, and the return from the sale of fish. The analysis was based on market prices of fish, and all other items are expressed in Bangladeshi Taka (BDT) (1 USD was equivalent to around 85 BDT at the time of analysis). Total cost was calculated on the basis of fry cost, feed cost and cage cost (cage cost calculated as 5 years depreciation cost). The net benefit was estimated as a finite difference between gross return and the total cost. Benefit-cost ratio was done as a ratio of the gross return over the total cost (Kunda *et al*., 2021).

Statistical analysis:

At the end of the experiment statistical analysis of all collected data was performed by using One Way Analysis of Variance (ANOVA) where the mean values were compared to Duncan's Multiple Range Test (DMRT). The software Statistical Package for the Social Sciences (SPSS) version 20.0 was used for all the analysis. Probabilities of $p < 0.05$ were considered to test the significance level.

RESULTS

Water quality parameters

Mean (±SD) values of water temperature, conductivity, TDS, and transparency were recorded and found within the suitable limit without any significant variation during the experimental period (Table 1). However, dissolved oxygen and pH were below the standard level for fish culture (Boyd, 1990).

Table 1. Water quality parameters of cages during the study period.

Parameters	Value (mean±SD)
Water temperature (˚C)	28.69±1.19
Dissolved oxygen (mg/l)	3.92±1.17
Conductivity (µS)	51.61±13.91
TDS (ppm)	26.72±9.79
pH	6.05±0.53
Transparency (cm)	36.33±8.20
Depth (m)	4.13±1.44

Growth variation in fishes:

Monthly growth variation (weight and length) of different species are shown in Fig. 2 and Fig. 3. Final individual harvesting weights of fishes were recorded as 141.93±9.86 g in T_1, 53.22±3.07 g in T_2 and 363.75±12.09 g in T_3. Final individual harvesting length of fishes was recorded 23.07 cm in T_1, 19.90 cm in T_2 and 30.36 cm in T_3.

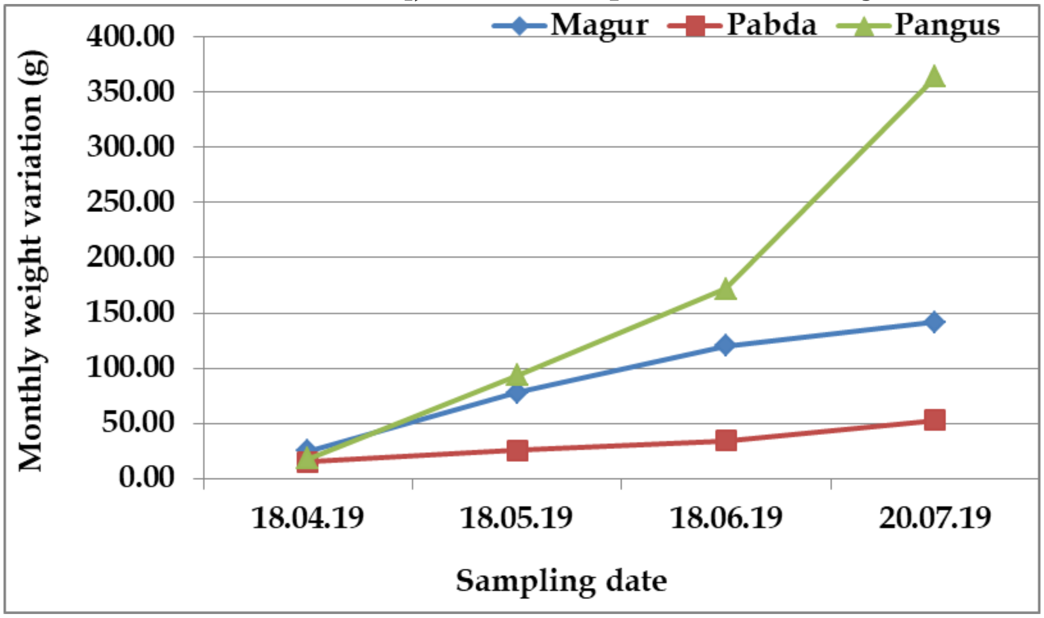

Fig. 2. Monthly average weight variation among three treatments.

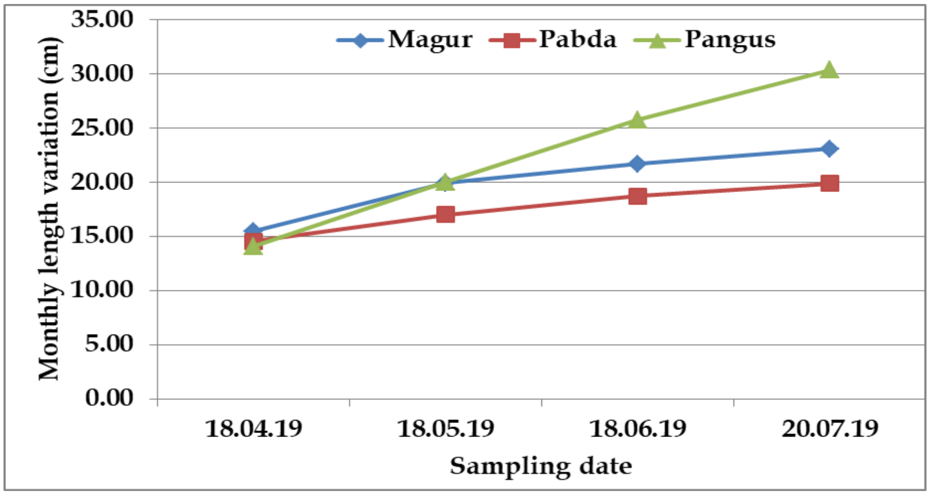

Fig. 3. Monthly average length variation among three treatments.

Survival rates of fishes:

The survival rates of fishes were found 65.46±4.99%, 89.59±5.31% and 90.71±3.82% in T_1, T_2 and T_3, respectively. Survival rate of T_1 was significantly lower than those of other two treatments (Table 2).

Production and growth performances:

Significantly higher total production (kg/cage) were recorded form the cages with *P. hypophthalmus* (356.34±18.52 kg) followed by *C. batrachus* (100.03±3.72 kg) and *O. pabda* (77.29±7.24 kg) (Table 2). The SGR (%/day) of *P. hypophthalmus* was significantly higher (3.22±0.03), followed by *C. batrachus* (1.85±0.09) and *O. pabda* (1.33±0.07) (Table 2). The FCR in T_3 was 1.26±0.07 which is significantly lower than those of T_1 (2.07±0.12) and T_2 (2.17±0.27), but there were no significant differences observed between T_1 and T_2. Total yield was significantly ($p < 0.05$) higher in case of *P. hypophthalmus* than those of *O. pabda* and *C. batrachus*, but there were no significant differences between total yields of *O. pabda* and *C. batrachus*.

Table 2. Comparisons of yield parameters (mean±SD) among different treatments.

Parameter	Treatments (species)		
	C. batrachus	***O. pabda***	***P. hypophthalmus***
Initial weight (g)	$25.35±0.55^{a}$	$15.45±0.30^{c}$	$18.16±0.55^{b}$
Final weight (g)	$141.93±9.86^{b}$	$53.22±3.07^{c}$	$363.75±12.09^{a}$
Total yield (kg/cage)	$100.03±3.72^{b}$	$77.29±7.24^{b}$	$356.34±18.52^{a}$
Total yield (kg/m^3)	$3.71±0.14^{b}$	$2.86±0.27^{b}$	$13.20±0.69^{a}$
SGR (%/day)	$1.85±0.09^{b}$	$1.33±0.07^{c}$	$3.22±0.03^{a}$
Survival rate (%)	$65.46±4.99^{b}$	$89.59±5.31^{a}$	$90.71±3.82^{a}$
FCR	$2.07±0.12^{a}$	$2.17±0.27^{a}$	$1.26±0.07^{b}$

*Superscripts in individual row indicates significant difference among the treatments at $p < 0.05$.

Benefit-cost analysis:

At the end of the study period, the gross incomes obtained were significantly higher in T_3 than those in T_1 and T_2. Total revenue was calculated with the sale value of fish. Due to natural calamities (frequent flash flood, high sunlight in summer, etc.), production was comparatively poor, so that overall benefit of all species was not satisfactory. Total revenue estimated for T_1, T_2 and T_3 were 35,511±1,321, 27,823±2,607 and 39,402±374 BDT/cage, respectively. Estimated Net benefit from T_1, T_2 and T_3 were 6,501±1,321, 4,499±260 and 9,562±374 BDT/cage, respectively. BCR was the highest in pangas (1.25±0.08) followed by magur (1.22±0.05) and pabda (1.19±0.11) at the end of the study (Table 3). Therefore, findings of the present experiment suggests that all three species can be cultured profitably whereas *P. hypophthalmus* could be the most suitable species for cage farming in the study site and could be a good option as alternative livelihood for local fishers.

Table 3. Comparisons of profitability among different treatments (mean±SD).

Parameter	Treatments (species)		
	C. batrachus	***O. pabda***	***P. hypophthalmus***
Total expenditure (BDT/cage)	29,010.00	23,324.00	29,840.00
Total revenue (BDT/cage)	35,511±1,321[b]	27,823±2607[c]	39,402±374[a]
Net profit (BDT/cage)	6,501±1,321[ab]	4,499±2,607[b]	9,562±374[a]
Benefit-cost ratio (BCR)	1.22±0.05	1.19±0.11	1.25±0.08

*Different superscript letter in the same row indicated significant differences ($p < 0.05$).

DISCUSSION

Survival rates of fish:

The survival rates of fishes were 65.46±4.99%, 89.59±5.31% and 90.71±3.82% in T_1, T_2 and T_3, respectively. Survival of T_1 was found significantly lower than those of two other treatments. After stocking there was no rain for many days. Thus, the water depth was low and summer sunlight was high which had accelerated organic decomposition in the bottom mud along with transportation stress caused high mortality in all the treatments, especially in case of *C. batrachus*. Soon after stocking coal mine effluent entered into the research site through flash flood which was also responsible for fish mortality (The Financial Express, 2021). The survival rate (%) of pabda varied between 75 and 87% in a study by Hossain (2008). Nath *et al.* (2014) found that the survival rate of *C. batrachus* fry was 83.33%.

Sayeed *et al*. (2008) found that the survival rates of *P. hypophthalmus* were 94 to 97% in nine earthen ponds for the study period of 11 months. Higher survival rate of pangas was coincided with the findings of Mian *et al.* (2019) who have reported that the survival of pangas ranged between 87 and 93% during their study period. Ara *et al.* (2020) found lower survival for *C. batrachus* during the study period, which might be due to their escaping tendency from the cage that caused physical injury and much mortality. Our study results for survival of *C. batrachus*, *O. pabda* and *P. hypophthalmus* species are similar to the findings of Ara *et al.* (2020) who found high survival rate of *P. hypophthalmus* compared to those of *C. batrachus* and *O. pabda*.

Production and growth performances:

The SGR (%/day) values in T_1, T_2 and T_3 were 1.85±0.09, 1.33±0.07 and 3.22±0.03, respectively. There were significant differences ($p < 0.05$) of SGR among three treatments. Nath *et al.* (2014) showed that specific growth rate performances of *C. batrachus* fry 0.308 and 0.81 in T_1 and T_2, respectively which was much lower than the present study. Sangma *et al.* (2017) reared *C. batrachus* in cage culture in pond environment where SGR was found 1.69 which is lower than present study. The possible reason behind the higher SGR in the present study is the circulation of water in the lotic environment. The specific growth rate (%/day) of pabda in different treatments for Hossain (2008) ranged between 2.98 and 3.28 which is higher than the present study.

The FCR in T_1, T_2 and T_3 were found 2.07±0.12, 2.17±0.27 and 1.26±0.07, respectively. Significantly ($p < 0.05$) better FCR observed in T_3 than T_1 and T_2, but there were no significant differences observed between T_1 and T_2. The FCR value of the present study indicated good utilization of food and might be another cause of availability of natural food in the *beel* where the cages were set up. Hossain (2008) observed the mean FCR of *O. pabda* for different diets varied between 2.07 and 2.45 which are similar to the present study. Amin *et al.* (2005) recorded FCR 1.65 for *P. hypophthalmus* culture with eight earthen ponds, which is higher than the value of the present study. Bhuyan *et al.* (2016) conducted 113 days study on *P. hypophthalamus* and FCRs were estimated 1.97 in T_1, 2.00 in T_2 and 2.03 in T_3.

The total yield of T_1, T_2 and T_3 were estimated 100.03±3.72, 77.29±7.24 and 356.34±18.52 kg/cage, respectively. On the other hand, the estimated total yield of (kg/m^3) in T_1, T_2 and T_3 were 3.71±0.14, 2.86±0.27 and 13.20±0.67, respectively, and there were significant ($p > 0.05$) differences among the treatments. Ara *et al.* (2020) found higher growth and production performance for pangas and lower for pabda among the four species, pangas, magur, pabda and gulsha tengra (*Mystus cavasius*). Different fish species have different protein and amino acid absorption ability (Sogbesan and Ugwumba, 2008) which might be responsible for the variation of growth performance. Pangas is well-known for its faster growth (Malik *et al.*, 2014). Comparatively lower production for all species associated with the high mortality and continuous acidic condition of the water body.

Benefit-cost analysis:

At the end of this study total estimated revenue in T_1, T_2 and T_3 were BDT 35,511±1,321, 27,823±2,607 and 39,402±374, respectively. Among three treatments, significantly higher revenue was found in T_3. Net benefit in T_1, T_2 and T_3 were estimated BDT 6,501±1,321, 4,499±2,607 and 9,562±374, respectively. On the other hand, due to high mortality of fish species satisfactory result were not found. There were no significant ($p < 0.05$) differences of BCR among three treatments. BCR among three species were 1.22±0.05, 1.19±0.11 and 1.25±0.08, respectively in T_1, T_2 and T_3. Fish mortality, flash flood, high summer sunlight, lower dissolved oxygen, and lower pH were responsible for less benefit of this study. Ara *et al.* (2020) found significantly higher BCR in gulsha followed by magur, pabda and pangas. After conducting economic analysis, they showed that pangas have significantly lower net income and BCR. They stated the possible reason might be due to very higher stocking density (100 fish/m^3) compared to our study. Chowdhury *et al.* (2020) worked on *P. hypophthalmus* cage aquaculture and found BCR 1.49±0.0, 1.48±0.01, and 1.44±0.01 in 19, 22 and 25 fish/m^3 stocking densities, respectively. Generally fish growth performance significantly decreased with increasing stocking densities which ultimately reduced net profit (Chowdhury *et al.*, 2020). Through this study it was found that *P. hypophthalmus* can survive in comparatively adverse environmental condition than that of *C. batrachus* and *O. pabda*.

CONCLUSION

This study revealed that all the experimental fishes are suitable for cage culture in freshwater swamp. Among the three species *P. hypophthalmus* is relatively more suitable species than *C. batrachus* and *O. pabda*, but *O. pabda* and *C. batrachus* can also be good candidates for cage aquaculture with suitable environmental condition. Additional experiments are suggested in future to fine tune the experiment and to determine the optimum stocking densities of these three studied catfishes in cages for better economic return.

Acknowledgments:

The authors express their gratitude to "Techniques Adoption and Formulation of Guidelines for Sustainable Management of *Haor* and *Beel* Fisheries", PIU-BARC, NATP Phase-II Project (Sub-project ID: 035) for funding this research .

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