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Original Article

Stocking density optimisation for gulsha, *Mystus cavasius* farming in pond under drought prone area of Bangladesh

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Abstract
Lack of appropriate stocking density is the constraint for aquaculture promotion of a potential species like gulsha, *Mystus cavasius* in ponds under drought prone area. With a view to addressing this problem, three different densities 98800, 123500 and 148200 gulsha individuals ha^{-1} were tested under three treatments (T_1, T_2 and T_3) in ponds under Paba Upazila of Rajshahi district, Bangladesh. Treatments were replicated thrice. Hatchery produced gulsha seeds were grown for a period of six months from July – December 2021 with commercial feed containing 35% protein. Water quality and fish growth were monitored fortnightly. Significantly ($p < 0.05$) lowest value of dissolved oxygen and highest values of carbon di-oxide and ammonia-nitrogen were observed in T_3. Significantly lowest values of final weight, weight gain, specific growth rate and survival rate were also observed in T_3. However, significantly ($p < 0.05$) highest yield and cost-benefit ratio were obtained in T_2.

Keywords: drought; gulsha; *Mystus cavasius*; pond; stocking density

1 | INTRODUCTION

Mystus cavasius (Hamilton-Buchanan, 1822), a freshwater catfish is commonly known as 'Gangetic mystus' and locally known as 'Gulsha tengra' or 'Kabashi tengra' or simply as 'Gulsha' in Bangladesh (Rahman 2005; Naser and Khan 2011). This species is widely distributed in ponds, canals, beels, haor, baor and rivers of many South-Asian countries likely Bangladesh, India, Myanmar, Pakistan, Sri Lanka, Nepal, Thailand etc. (Hossain *et al.* 1998; Rahman *et al.* 2004; Roy and Hossain 2006). Gulsha has been addressed as Near Threatened species in Bangladesh (IUCN Bangladesh 2015) because the catch of this indigenous fish from open water is being dwindled gradually due to increased fishing pressure to meet up the high market demand. Overexploitation, habitat destruction and ecological changes are also the causes of their low catch from inland waters (Galib *et al.* 2023; Parvez *et al.* 2023). Therefore, aquaculture efforts are required for protection and conservation of gulsha tengra. More than half of the total aquaculture production comes from carp species (Khan *et al.* 2022). Tilapia and pangas also occupied a large place among farmed fishes (Khan *et al.* 2022).

Small indigenous species (SIS) of fishes might have more farming potentials in terms of micronutrient supply than that of larger fishes. Apart from higher market price and taste, gulsha contains considerably higher percentage of protein (13.81%) with lower quantity of fat (2.26%) and it is also rich in calcium and phosphorus content (Hossain *et al.* 1999). This species can tolerate severe environmental conditions, such as low oxygen, wide range of temperature fluctuations and other poor water conditions (Akhteruzzaman *et al.* 1991). Thus, it has further potentials for promotion of nutrient rich short cycle aquaculture species in ponds under drought prone area. Drought is one of the most important constraints for fish culture in northwest region of Bangladesh which is typically characterised by limited rainfall and lack of sufficient water during the dry season (Islam *et al.* 2021; Rashid *et al.* 2021). This condition affects directly the physio-chemical condition, behaviour and growth of fish (Abbink *et al.* 2012); which indirectly affects the productivity, structure and composition of the aquatic ecosystems (Brander 2007). Determining the optimum stocking density is very important to develop sustainable culture system for high valued fish like *M. cavasius* at the drought-prone area of Bangladesh. In intensive system of aquaculture, stocking density plays a very important role in terms of economic viability of the production (Jannat *et al.* 2012). Although a positive effect of stocking density on growth is reported in some species, it is well accepted that the stocking density is critical factor for many aquatic animals for their growth and survival (Rahman and Verdegem 2010). Stocking density is directly related with the competition for food and space (Rahman et al. 2008; Rahman and Verdegem 2010). Increase in stocking density results in increasing stress, which leads to higher energy requirements, causing a reduction in growth rate and food utilisation (Rahman *et al.* 2013). Indeed, determining the optimum stocking density is a prerequisite for balanced growth and proper production of fish. Although fish compete less for food and space at low stocking densities than at high stocking densities (Rahman *et al.* 2013), it is still considered profitable to find the optimum stocking density for profitable fish farming.

Except few scattered works, not much information is available on the culture of *M. cavasius*. Although there are some stocking density based studies (Kohinoor *et al.* 2004; Hosen *et al.* 2017) in monoculture ponds but no study has yet been undertaken for *M. cavasius* farming under drought prone area. Thus, this study was aimed at optimising the stocking density in monoculture ponds under drought prone area. Specific objectives included in this study were to monitor the water quality and fish growth; evaluate the yield and economics of fish farming; and finally, to recommend suitable density for gulsha monoculture in ponds under drought prone area of Bangladesh.

2 | METHODOLOGY

2.1 Study duration and location

The study was carried out for a period of six months from July to December 2021 in farmer managed ponds located at Nalkhola village (24°23′28.3″N 88°41′07.7″E) of Paba Upazila under Rajshahi district, Bangladesh (Figure 1).

2.2 Experimental design

The experiment followed completely randomised block design where three different stocking densities of gulsha were tested under three treatments; T_1: 98800 fish ha^{-1}, T_2: 123500 fish ha^{-1} and T_3: 148200 fish ha^{-1} in monoculture ponds. Treatments were replicated thrice and varied with no significant difference for mean area and depth of the study ponds (Table 1).

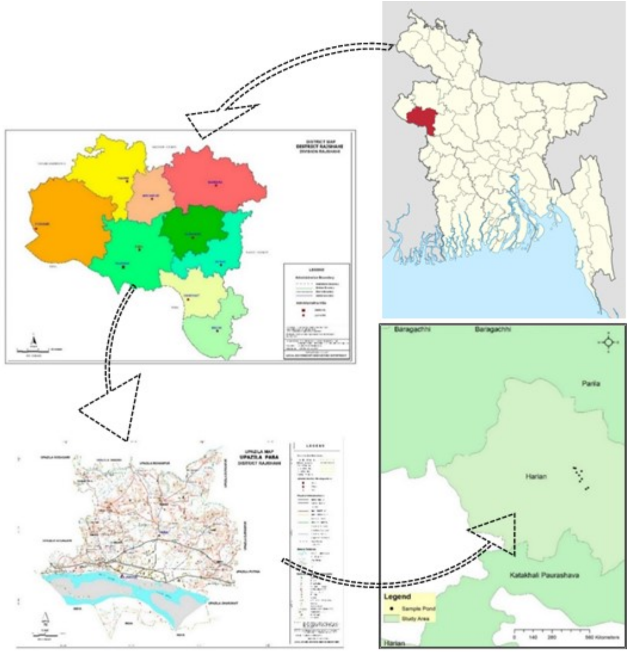

FIGURE 1 Location of the study area.

TABLE 1 Mean water area and depth of the experimental ponds.

Pond profile	Treatments			*F*-value	*p*-value
	T_1	T_2	T_3		
Area (ha)	0.04±0.01	0.04±0.00	0.04±0.00	0.06	0.940
Depth (m)	1.36±0.09	1.21±0.01	1.20±0.02	2.82	0.140

2.3 Pond management

Aquatic vegetation were removed manually from all the experimental ponds. Predator and unwanted fishes were also removed through repeated netting by using seine net. Liming was done at the rate of 250 kg ha^{-1} as basal dose and at the rate of as periodic dose. After three days of liming, basal fertilisation was done with only inorganic fertiliser like urea and triple supper phosphate, TSP (each at 40 kg ha^{-1}) to increase the natural food in the experimental ponds. TSP was wetted overnight to be diluted and spread over the ponds at following sunny day whereas urea was applied instantly. After five days of basal fertilisation, all the ponds were stocked with hatchery produced gulsha seeds (mean weight of 0.46 g) in morning between 06:00 and 07:00 hours. No periodic fertilisation was done except regular liming (50 kg ha^{-1} fortnight^{-1}) for the ponds. Fishes were fed with floating feed (35% protein content) at the rate of 7% of body weight. Feeding was done twice daily at afternoon (17:00 hours) and night (22:00 hours).

2.4 Monitoring of water quality parameters

Water quality parameters of the experimental ponds were recorded fortnightly between 09:00 and 10:00 hours. Water temperature was recorded with the help of a Celsius thermometer at 20 – 30 cm below of the water surface while water transparency was recorded with the help of a Secchi disk. HACH kit (model FF2, USA) was used for measuring free carbon di-oxide (CO_2), alkalinity and ammonia-nitrogen (NH_3-N). Dissolved oxygen (DO), pH and total dissolved solids (TDS) were recorded by a multimeter (model HQ 40 D, HACH; USA).

2.5 Monitoring of fish growth and yield

Fortnightly sampling was done to monitor fish growth and to adjust the feeding ration. During sampling, about 10% of the stocked fishes were caught from each pond using a cast net. Just after harvesting, all fishes were counted, weighted and released again without any harm. Fish growth and yield was calculated after Brett and Groves (1979) as follows:

Initial weight = Weight of fish at stock

Final weight = Weight of fish at harvest

Weight gain = Mean final weight – Mean initial weight

Specific growth rate (SGR %, bwd^{-1}) = $\frac{\text{Ln final weight} - \text{Ln initial weight}}{\text{culture period}} \times 100$

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

Yield = Fish biomass at harvest – Fish biomass at stock

2.6 Economic analysis

A simple cost-benefit analysis was done to evaluate the economics of gulsha farming in monoculture ponds. All the harvested fishes were sold in the local market. The actual prices of inputs and fish linked to the market prices in Rajshahi, Bangladesh in 2021 were expressed in Bangladesh currency (Taka) as BDT (1 US$ = 85.8952 BDT, as of 15 January 2022). Data on fixed (lime, fertiliser and labour) and variable costs (seed and feed) were recorded at the time of purchase to determine the total cost (BDT ha^{-1}). Total return was determined from the market price of fish at the time of sale and was expressed as BDT ha^{-1}. Net benefit was calculated by deducting the total cost from total return and was expressed as BDT ha^{-1}. Cost benefit ratio (CBR = Net benefit / total cost) was also determined following Shang (1990) for the present study.

2.7 Data analysis

The recorded data on water quality, fish growth, yield and economics of gulsha monoculture under different treatments of stocking densities were analysed by employing one way ANOVA (Analysis of Variance) in the SPSS (Statistical Package for Social Science, version-22, IBM Corporation, Armonk, NY, USA). Data normality was checked before analysis. The mean values were also compared by Duncan Multiple Range Test (DMRT) following Gomez and Gomez (1984) at 5% level of significance when a mean effect was significant. All data were expressed as mean ± standard error (SE).

3 | RESULTS AND DISCUSSION

3.1 Water quality

Mean values of water temperature, transparency, TDS, DO, CO_2, pH, alkalinity and NH_3-N varied from 31.24 ± 0.06 (T_1) to 31.34 ± 0.02 °C (T_3), 29.36 ± 0.03 (T_3) to 29.61 ± 0.12 cm (T_1), 629.97 ± 3.09 (T_3) to 639.31 ± 3.73 mg L^{-1} (T_2), 5.51 ± 0.03 (T_3) to 5.83 ± 0.05 mg L^{-1} (T_1), 1.87 ± 0.02 (T_2) to 2.10 ± 0.01 mg L^{-1} (T_3), 7.48 ± 0.02 to 7.55 ± 0.05 (T_2), 115.86 ± 1.32 (T_3) to 121.66 ± 2.35 mg L^{-1} (T_2) and 0.03 ± 0.00 (T_1 and T_2) to 0.05 ± 0.00 mg L^{-1} (T_3) respectively (Table 2). Significantly ($p < 0.05$) lowest value of DO and highest values of free CO_2 and NH_3-N were observed in treatment T_3 (i.e. receiving highest stocking density). This result was comparable with Oguguah *et al.* (2011) and Kohinoor *et al.* (2012) who reported lower DO with higher stocking density of fish. Findings indicated that water quality parameters under the treatments were found more or less within suitable range for fish culture.

All metabolic and physiological activities and life processes such as feeding, reproduction, movement and distribution of aquatic organisms are greatly influenced by water temperature (Jhingran 1975). Mean water temperature obtained with the treatments was closer to Boyd (1998) who recommended suitable water temperature of 25 to 32°C for tropical and subtropical species. Boyd (1998) reported transparency between 30 and 45 cm as good for fish culture. The mean TDS values obtained with the treatments seems to be suitable range of fish culture as fish do not appear to be affected by standard concentrations of TDS of 2000 mg L^{-1} (Rana and Jain 2017). DO content obtained with the treatments was found suitable for fish farming. According to Rahman *et al.* (1992), DO content of a good productive pond should be 5 mg L^{-1} or more. Banerjee (1967) and Bhuiyan (1970) reported 5.0 to 7.0 mg L^{-1} of DO content of water was fair or good in respect of high productivity and water having DO less than 5 mg L^{-1} to be unproductive.

Swingle (1967) stated good relationship between pH and fish growth and obtained satisfactory results at pH range of 6.5 to 9.0. He also reported that water with pH more than 9.5 was unproductive and pH more than 10.0 was lethal for fish. The pH value in alkaline condition in water was supposed to be helpful for proper growth and development of fishes and aquatic organisms (Jhingran 1975). Alikunhi (1957) reported that total alkalinity more than 100 mg L^{-1} should be present in high productive water bodies. Boyd (1998) suggested suitable value for ammonia-nitrogen as less than 0.1 mg L^{-1}. The NH_3-N was found lower than Rahman *et al.* (2014) who reported ammonia-nitrogen contents from 0.08 to 0.12 mg L^{-1} in the monoculture of *H. fossilis* farming ponds. Findings more or less also agreed with Nabi *et al.* (2020) who reported water temperature, transparency, TDS, pH, DO, alkalinity and NH_3-N as 29.83 ± 0.04 to 29.99 ± 0.22°C, 25.05 ± 0.11 to 25.33 ± 0.16 cm, 268.44 ± 4.19 to 280.02 ± 4.53 mg L^{-1}, 6.93 ± 0.04 to 7.11 ± 0.16, 5.33 ± 0.14 to 5.84 ± 0.08 mg L^{-1}, 86.39 ±2.07 to 87.17 ± 0.88 mg L^{-1} and 0.02 ± 0.00 to 0.03 ± 0.01 mg L^{-1} respectively while working on stinging catfish in ponds under drought prone area.

3.2 Fish growth and yield

Mean values of final weight, weight gain, SGR and survival rate during study period varied from 21.83 ± 0.35 (T_3) to 25.82 ± 0.31 g (T_1), 21.39 ± 0.35 (T_3) to 25.37 ± 0.30 g (T_1), 2.16 ± 0.02 (T_3) to 2.25 ± 0.01 % bwd^{-1} (T_2) and 74.29 ± 0.67 (T_3) to 88.91 ± 0.71% (T_1) respectively (Table 3). Significantly ($p < 0.05$) lowest values of final weight, weight gain, SGR and survival rate were observed in T_3 (i.e. receiving highest stocking density). Stocking density is very important to gain proper growth and survivability of aquatic organisms, especially fish (Jannat *et al.* 2012). Possible reasons of higher body weight in lower stocking density might be due to less competition for food and space compared to that of in higher stocking density. Lower stocking density is helpful for achieving highest individual weight gain (Hosen *et al.* 2017). Higher survival rate depends on lower stocking density (Kohinoor *et al.* 2004).

TABLE 2 Mean water quality parameters under different treatments during study.

Parameters	Treatments			*F*-value	*p*-value
	T_1	T_2	T_3		
Temperature (°C)	31.24 ± 0.06 [a]	31.30 ± 0.04 [a]	31.34 ± 0.02 [a]	1.30	0.340
Transparency (cm)	29.61 ± 0.12 [a]	29.42 ± 0.13 [a]	29.36 ± 0.03 [a]	1.67	0.270
TDS (mg L^{-1})	637.28 ± 3.89 [a]	639.31 ± 3.73 [a]	629.97 ± 3.09 [a]	1.87	0.230
DO (mg L^{-1})	5.83 ± 0.05 [a]	5.83 ± 0.02 [a]	5.51 ± 0.03 [b]	26.24	**<0.001**
CO_2 (mg L^{-1})	1.98 ± 0.05 [b]	1.87 ± 0.02 [b]	2.10 ± 0.01 [a]	10.77	**0.010**
pH	7.50 ± 0.02 [a]	7.55 ± 0.05 [a]	7.48 ± 0.02 [a]	1.31	0.340
Alkalinity (mg L^{-1})	119.78 ± 1.14 [a]	121.66 ± 2.35 [a]	115.86 ± 1.32 [a]	3.07	**0.120**
NH_3-N (mg L^{-1})	0.03 ± 0.00 [b]	0.03 ± 0.00 [b]	0.05 ± 0.00 [a]	10.50	**0.010**

Superscript figures in a row bearing common letter(s) do not differ significantly ($p > 0.05$). Boldface *p*-values indicate statistically significant values.

TABLE 3 Mean growth and yield of gulsha *Mystus cavasius* in ponds under different treatments.

Parameters	Treatments			*F*-value	*p*-value
	T_1	T_2	T_3		
Final weight (g)	25.82 ± 0.31[a]	25.45 ± 0.34[a]	21.83 ± 0.35[b]	43.73	<0.001
Weight gain (g)	25.37 ± 0.30[a]	25.00 ± 0.34[a]	21.39 ± 0.35[b]	43.83	<0.001
SGR (%, bwd^{-1})	2.25 ± 0.00[a]	2.25 ± 0.01[a]	2.16 ± 0.02[b]	15.36	<0.001
Survival rate (%)	88.91 ± 0.71[a]	85.83 ± 0.58[b]	74.29 ± 0.67[c]	139.80	<0.001
Yield (kg ha^{-1} $6months^{-1}$	2268.32 ± 28.97[c]	2697.73 ± 51.87[a]	2402.84 ± 27.50[b]	33.77	<0.001
Yield (kg ha^{-1} $year^{-1}$)	4536.64 ± 57.95[c]	5395.46 ± 103.75[a]	4805.67 ± 54.99[b]	33.76	<0.001

Findings indicated that lower weight gain of fish was observed during cooler months and that of higher in summer months. This might be due to the effect of temperature on fish growth. Higher temperature in summer month enhanced the metabolic activity of fish that ultimately increased the fish growth (Figure 2). Findings also indicated that comparatively higher values of SGR were recorded in earlier stage of fish. Almost similar observations were also noted by Nabi *et al.* (2020) while working with stinging catfish farming in ponds under drought prone area.

Mean values of yield during study period varied from 2268.32 ± 28.97 (T_1) to 2697.73 ± 51.87 kg ha^{-1} $6months^{-1}$ (T_2) (Table 3). Significantly lowest value of yield was observed in T_1 (i.e. receiving lowest stocking density). Comparatively higher values of final weight and survival rate were observed in T_1 and T_2. On the other hand, lower final weight and survival rate of fish were found in T_3. Fish yield of treatment T_2 was 15.92% higher than treatment T_1 and 10.93% higher than treatment T_3. With a similar stocking density (123500 fishes ha^{-1}), almost similar final weight (26.92 g) and survival rate (94 %) were recorded by Hosen *et al.* (2017) while working on gulsha monoculture for a period of four months with an initial stocking weight of 2 g. Comparatively slower growth in the present study might be due to the effect of individual stocking size on metabolism and thereby on the biomass. Actually the fish with lower body size results higher metabolic activity and thus produces lower biomass (Boyd 1998). However, such lower weight gain and yield were recorded also by Islam *et al.* (2021) while stocking lower stocking size of gulsha in pond.

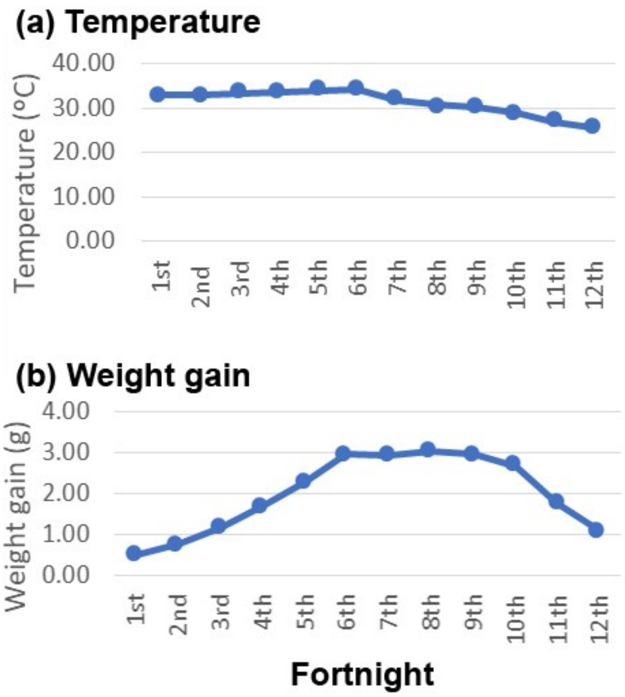

FIGURE 2 Fortnightly variations in water temperature (a) and body weight gain (b).

3.3 Economics of fish farming

Total cost, net benefit and CBR of gulsha farming under different treatments are shown in Table 4. The cost of fish production was highest in treatment T_3 and lowest in treatment T_1. The higher net benefit was obtained from T_2. Operational costs increased because of higher stocking density, expanding the total cost in T_3. Fish reared at a stocking density higher than the optimum density experienced limited production because of excessive competition for feed and available space (Kibria and Haque 2018). Fish growth and yield were found to be decreased with the increase in stocking density in treatment T_3 which resulted in the lowest net benefit and CBR. Statement almost agreed with Hosen *et al.* (2017) who reported that the lower density was helpful for obtaining higher individual weigh gain as well as higher profit from monoculture of *M. cavasius* in pond.

TABLE 4 Economics of fish farming under different treatment for a culture period of six months culture period.

Parameters	Treatments			*F*-value	*p*-value
	T_1	T_2	T_3		
Total cost (BDT ha^{-1})	608822.0 ± 2981.8^{c}	713688.1 ± 4127.8^{b}	768468.5 ± 5247.2^{a}	369.27	<0.001
Total return (BDT ha^{-1})	930288.4 ± 23890.2^{b}	1106634.3 ± 36480.3^{a}	825456.0 ± 30352.1^{b}	21.46	<0.001
Net benefit (BDT ha^{-1})	321466.5 ± 21075.0^{a}	392946.2 ± 32364.9^{a}	56987.5 ± 25467.5^{b}	43.90	<0.001
CBR	1.5 ± 0.03^{a}	1.6 ± 0.4^{a}	1.1 ± 0.03^{b}	57.68	<0.001

Superscript figures in a row bearing common letter(s) do not differ significantly ($p > 0.05$)

4 | CONCLUSIONS

Overall findings indicated that treatment T_2 (with a stocking density of 123500 fish ha^{-1}) was found best in terms of water quality, yield and economics. This study used only one dietary protein (35%) level for farming. Further study is required for optimising the dietary protein level for gulsha (*M. cavasius*) monoculture in pond under drought prone area of Bangladesh.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

AUTHORS' CONTRIBUTION

SKS research design, primary data collection and validation, statistical analysis and draft manuscript (MS) writing; MIK statistical analysis and GIS mapping of the study; MAH research design, review and validation of data and statistical analysis, critical review and finalisation of the MS.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on a reasonable request from the corresponding author.

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