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Optimization of stocking density of Gulsha (*Mystus cavasius*) in circular shaped net cages in pond conditions

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Abstract. Influence of stocking density on growth and production of *Mystus cavasius* (local name: gulsha) in circular shaped cages was studied in earthen pond conditions for a period of 90 days. The cages were uniform in size of 1.80 m^3 and were stocked with gulsha fry at the rate of (i) 200 fry/ m^3 (T1), ii) 300 fry/ m^3 (T2), and (iii) 400 fry/ m^3 (T3). No significant differences were observed among the treatments in weight gain {11.46±0.16g (T1); 11.40±0.14g (T2); 11.48±0.04g (T3)}, SGR {2.77±0.06 (T1); 2.70±0.10 (T2); 2.71±0.09 (T3) day-1}, and survival rates {87.3±6.6 (T1); 85.7±4.7 (T2); 84.9±5.4 (T3) %}. A significantly higher ($p<0.05$) gross production of 4.29±0.32 kg/ m^3 in 90 days was obtained in T3 (400 fry/ m^3) treatment compared to T2 and T1. The coefficient of determination values (r^2) of length-weight relationship (LWR) was 0.95, 0.94, and 0.94 in T1, T2, and T3 treatments, respectively indicating a good linear regression between length and weight. The results demonstrate that the cage culture of gulsha in pond condition is possible where 400 fry/ m^3 stocking density in circular shaped cages may be suitable for higher growth, survival and production.

Keywords: *Mystus cavasius*, Circular cage, Stocking density

Introduction

Bangladesh has been experiencing a quiet revolution in aquaculture with more than 25-fold growth in farmed fish production over the last three decades. Within the last 10-12 years, the contribution of farmed fish to net fish production has grown from 43 to 56.76 % (DOF, 2019), meaning that cultured fish now overtakes the volume of captured fish. In the face of increasingly scarce productive land and water areas due to massive development works, further horizontal expansion of pond-based aquaculture is facing a big challenge. The research question has now been raised how to address this challenge through minimizing land usage and increasing demand of fish production? Diversified utilization of existing pond water resources for fish production may be considered as a focus area of research.

Cage culture is one among the different fish production systems, which is mainly practiced in open waters where fish utilizes water but remain enclosed in a cage allowing water to pass freely between the fish and surrounding environment. Closed ponds can also be used as potential site for cage culture provided that the water quality is suitable and there is adequate water depth beneath the cages to allow water movement (Soltan 2016). Integration of in-pond cage culture with open pond fish culture system may be a potential area of intervention not only for maximizing the resource utilization and increasing production, but also benefitting farmers with diversified crops and income. While cage fish culture is concerned, size and shape of cages play a key role in depending on the behavior of fishes. While circular shaped cages found to be the best for schooling fishes such as salmon, milkfish, the less active species such as the tilapia and common carp are found to be more particular with rectangular cages.

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Besides reports on cage culture of tilapia (Golder *et al.* 1996), common carp (Kohinoor *et al.*, 2015), *Mystus cavasius* (Kohinoor *et al.* 2015) in open flowing water system, there have been a very few research reports on cage culture of Thai strain *Anabas testudineus* (Mondal *et al.* 2010); *Clarias gariepinus* and Nile tilapia (Mondal *et al.* 2014); *Heteropneustes fossilis* (Rahman *et al.* 2017) in pond are available. None of these reports addressed effects of cage shapes except that of Hasan (2014) who reported relatively higher net yield of *Heteropneustes fossilis* in modified square shaped cages than that of ordinary and rectangular shaped cages. Owing to the significance and plausibility of cage culture in pond-based aquaculture system, the present study was undertaken to compare the suitability of three different stocking densities of (i) 200 fry/ m^3 (T1) ii) 300 fry/ m^3 (T2), and (iii) 400 fry/ m^3 (T3), respectively for culturing a silurid catfish *Mystus cavasius* in pond in circular shaped cages. The reason of selecting the species was because it is one of the small indigenous species native to the region, having culture potential in local environment, tolerance to crowded condition and high market value.

Materials and Methods

The present experiment was carried out in a closed earthen pond of the Faculty of Fisheries, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh for a period of 90 days from the 1st September to 2nd December 2019.

Experimental design: The experiment was designed for three different stocking densities of (i) 200 fry/ m^3 (T1) ii) 300 fry/ m^3 (T2), and (iii) 400 fry/ m^3 (T3), respectively in circular shaped cages having a similar volume of 1.80 m^3 with 1m height. Each treatment had three replications and was assigned into a Completely Randomized Design (CRD). The fish species was a high valued threatened indigenous silurid catfish species *Mystus cavasius*, which is locally known as "gulsha".

Construction and installation of net cages: The cages were made of colored iron bars, covering and tying with high density polyethylene net of about 1 cm mesh. The cages were placed in the pond fastening with bamboo platform and poles, maintaining a distance of 1 m from one cage to another. The heights of all the cages were uniformly raised to about 25 cm to expose from water surface and 50 cm from the pond bottom. One edge of the upper surface of each cage was kept tied with nylon threads in a way so that it could be opened for stocking fish, delivering feed and periodical sampling.

Fish stocking in cages and feeding: Overwintered gulsha fry of average 3.91-4.10 cm length and 0.97-1.20 g weight were collected from a fish farm, transported to pond site and stocked according to the experimental design. Prior to stocking, fishes were acclimatized to the pond water for about 30 minutes. The fish in all cages were fed with a commercial floating pellet feed (Mega 002). The proximate composition of fish feed, according to manufacturer (Spectra Fish Feed Ltd) is presented in (Table I). Initially the fishes were fed at the rate 25% of average body weight, which was gradually reduced to 8%. Feeding adjustment was done every two weeks with the progressive increase in average body weight. Feed was applied twice a day at dawn and dusk.

Table I. Proximate composition of the fish feed

Components	% composition
Moisture	12
Crude Protein	36
Lipid	5
Carbohydrate	31
Crude Fiber	5
Ash	10

***Monitoring water quality and fish growth*:** The water quality parameters such as temperature (°C), dissolved oxygen (mg/l), pH, transparency (cm), ammonia (mg/l) were recorded at weekly interval, inside and outside the cages, throughout the experimental period at 9.00-10.00 hrs using centigrade thermometer, portable DO meter (Model Lutron PDO-519), portable pH meter (HANNA HI 8424), Secchi disc, and Ammonia test kit (Freshwater, HANNA), respectively.
The fishes ($n \approx 25$) from all cages were collected using a scoop net for measuring individual length (cm) and weight (g) at fortnight interval. Standard wooden measuring board and portable digital balance (Denver-xp-3000) were used to measure length and weight, respectively.

***Harvesting and estimation of yield parameters*:** After 90 days of culture period, treatment-wise cages were lifted from the water and fishes were harvested by scoop net and hand picking. The individual length (cm) and body weight (g) of fishes ($n \approx 60$) and number of harvested fish were recorded for estimating different yield parameters as follows:

a) Survival rate (%) = Number of fish harvested ÷ Number of fish stocked × 100
b) Specific growth rate (SGR, %day^{-1}) = [ln (final weight) – ln (initial weight) ×100]/ No. of days of the experiment
c) Final weight gain (g) = Final individual weight – Initial individual weight
d) Feed conversion ratio (FCR) = Feed applied (dry weight)/ Live weight gain
e) Net production (kg/m^3) = total biomass at harvest – total biomass at stocking

Length-weight relationship (LWRs): The measured length and weight of fish of each treatment at harvest were subjected to estimating length-weight relationships (LWRs).
The log transformation formula of Le Cren (1951) was used to establish LWRs. A simple linear relationship in the form of Y = (a + bX) exists between two length dimensions of fish where "Y" is Log Body Weight (BW) and "X" is Log Total Length (TL).
To estimate the correlation coefficient, r, the following formula was used:

$$r = [n \Sigma XY - \Sigma X \Sigma Y] / \sqrt{([n \Sigma X2-(\Sigma X) 2] [n\Sigma Y2-(\Sigma Y) 2])}$$

The coefficient of determination, r^2 or the square of the correlation coefficient showed the proportion of the variability in the Y observations which could be assigned by the variability in the X observations.

***Data analysis*:** Growth and yield parameters of fish were analyzed statistically by a one-way analysis of variance (ANOVA) using the statistical software Statistix 10. The ANOVA was followed by DMRT (Duncan Multiple Range Test) at 5% level of significance. The length-weight data were subjected to regression analysis for estimating 95% Confidence Interval (CI) of a and b, and the coefficient of determination (r^2).

Results and Discussion

The water quality parameters showed variations during the culture period, but were similar ($p>0.05$) and noted within the recommended range for the growth performance of cultured fish. The mean temperature, dissolved oxygen, pH, transparency, and ammonia, inside and outside the cages, are presented in (Table II).

The initial weight, harvest weight, weight gain, average daily weight gain (ADWG), specific growth rate (SGR), survival and gross yield of gulsha are presented in (Table III). The survival rate of gulsha was 87.3±6.60%, 85.7±4.70%, and 84.9±5.40% in T1, T2, and T3 respectively, with no significant differences among the treatments ($p>0.05$). The survival rate of gulsha in the present experiment, irrespective to the stocking density was higher compared to that has been reported (52-66%) for the same species reared in rectangular cages with 500 fry/ m^3, 600 fry/ m^3, and 700 fry/ m^3 stocking densities in open water (Kohinoor *et al.* 2015). Different survival rates of 98.67% in climbing perch (*Anabas testudineus*) and 86.67% in tilapia (Mondal *et al.* 2010); 29 to 55.30% in African catfish (*Clarias gariepinus*) and 75.50 to 86.10% in tilapia were reported in pond-cage culture system (Mondal *et al.* 2014).

Table II. Mean and range values of water quality parameters inside and outside of cages during the experimental period of 90 days

Water quality parameters	Outside Cages	Inside Cages		
		T1 (200 /m^3)	T2 (300/m^3)	T3 (400/m^3)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Water Temperature (°C)	31.40 ± 1.30a (30.10-32.70)	31.40 ± 1.30a (30.10-32.70)	31.40 ± 1.30a (30.10-32.70)	31.40 ± 1.30a (30.10-32.70)
pH	7.70 ± 0.10a (7.60-7.80)	7.50±0.20a (7.30-7.70)	7.40 ± 0.20ab (7.40-7.60)	7.10 ± 0.40b (6.70-7.50)
DO (mg l^{-1})	5.60 ± 0.40a (5.20-6.00)	5.40 ± 0.50a (4.90-5.90)	5.30 ± 0.50a (4.80-5.80)	5.10 ± 0.60a (4.50-5.70)
Transparency (cm)	32.60 ± 1.80a (30.80-34.40)	33.10 ± 2.10a (31.00-35.20)	33.10 ± 2.40a (30.70-35.50)	33.30 ± 2.30a (31.00-35.60)
Total ammonia (mg l^{-1})	0.09 ± 0.04a (0.05-0.13)	0.14 ± 0.07a (0.07-0.21)	0.16 ± 0.08a (0.08-0.24)	0.17 ± 0.09a (0.08-0.26)

Values within the same row with a common letter (s) do not differ significantly ($p>0.05$)

Gulsha grew steadily in all the treatments (T1, T2, T3) and reached to an average final weight of 12.32- 12.72 g with no significant difference ($p>0.05$) among the treatments (Table III; Fig. 1). The specific growth rate (SGR) of gulsha ranged from 2.70 to 2.77 % day^{-1} with progressively a declining rate (Table III). The SGR of gulsha in all the treatments (T1, T2, and T3) were similar with no significant difference ($p>0.05$) among the treatments.

The SGR of gulsha in the present experimental condition was much lower than that reported (4.80 to 5.50% day^{-1}) for 210 days of monoculture (All Hosen *et al.* 2017), but more or less similar to that reported (1.56 to 1.75 % day^{-1}) for 180 days of polyculture of the same species in earthen ponds (Kohioor *et al.* 2011-12). The SGR of climbing perch and Nile tilapia reared in cages in pond has been reported as 1.17 and 1.15% day^{-1} for 120 days of culture period (Mondal *et al.* 2010), which is lower than the SGR of gulsha in the present study.

Table III. Growth and production performance of *M. cavasius* under three different stocking densities during the 90 days of culture period

Parameters	Treatment		
	T1 (200 fry/ m^3)	T2 (300 fry/ m^3)	T3 (400 fry/ m^3)
Initial Length (cm)	3.97±0.06 a	4.00±0.10 a	4.03±0.06 a
Final Length (cm)	12.71±0.16 a	12.71±0.10 a	12.78±0.14 a
Initial Weight (g)	1.03±0.06 a	1.10±0.10 a	1.10±0.10 a
Final Weight (g)	12.49±0.17 a	12.50±0.11 a	12.58±0.14 a
Weight Gain (g)	11.46±0.16 a	11.40±0.14 a	11.48±0.04 a
SGR (% day^{-1})	2.77±0.06 a	2.70±0.10 a	2.71±0.09 a
Survival (%)	87.3±6.60 a	85.7±4.70 a	84.9±5.40 a
Gross Production (Kg/$m^{3)}$	2.19±0.21 c	3.21±0.21 b	4.29±0.32 a
Net Production (Kg/m^3)	2±0.18 c	2.93±0.20 b	3.90±0.26 a
FCR	2.23±0.06 a	2.17±0.02 a	2.09±0.06 a

Mean values with different superscript letters in the same row are significantly different *(P< 0.05).*

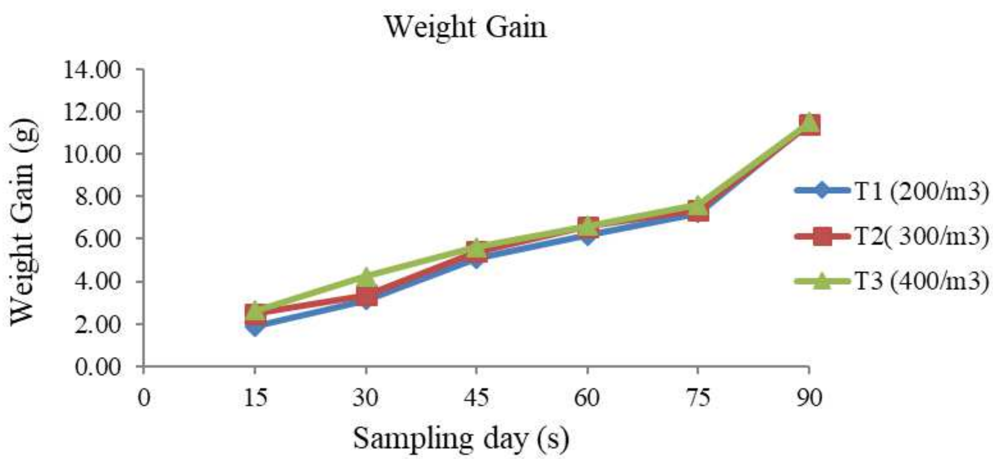

Fig. 1. Growth performance of gulsha in circular shaped cages in different treatments during the experimental period of 90 day (s).

The mean values of FCR ranged from 2.09-2.23 among the treatments (Table III) with no significant difference ($p<0.05$). In this study, the FCR was comparatively lower compared to the values of 2.46 to 3.04 which has been reported by Kohinoor *et al.* (2015) in case of cage culture of the same species in open water. Corresponding to higher stocking densities and similar growth and survival, T3 treatment (400 fry/ m^3) resulted in the significantly higher ($p<0.05$) gross mean production of 4.29 kg/m^3 and net production of 3.90 kg/m^3 for 90 days of culture period (Table III). The mean gross production rate of gulsha in T1 (200 fry/ m^3) and T2 (300 fry/ m^3) were 2.19 kg/m^3 and 3.21 kg/m^3, respectively and the net production were 2.00 kg/m^3 and 2.93 kg/m^3 with significant difference ($p<0.05$). Kohinoor *et al.* (2015) reported a production rate of 8.14 kg/m^3 of gulsha at 500 fry/m^3 stocking density for a culture period of

210 days in rectangular cages in open water environment. Considering the culture period and stocking density of the present study and that of Kohinoor *et al.* (2015), it could be inferred that the gulsha yield in circular cages in the present experimental condition was higher than that in rectangular tanks in open water conditions (Kohinoor *et al.* 2015). The overall experimental results of the present study demonstrated that the highest production was found in T3 treatment at a stocking density of 400 fry/ m^3 in the circular cage might be possibly attributed due to its shape, which provided suitable environment to manipulate the schooling behavior of this catfish species. The highest mean gross production (4.29 kg/ m^3) in T3 at a stocking density of 400 fry/ m^3 in circular cage treatment indicates that there was less stress of fishes for movement.

The suitability of shape of an enclosure depends on behavior of the culture species and their movement preference in the culture medium. The fish species that have the habit to move in a rotary motion with schooling, enclosure with rounded corners, or circular, sometimes hexagonal serves the purpose better in place of rectangular one (Mukerjee 1990). Circular holding facilities were found to be best for schooling fishes as salmon and milk fish. In Philippines, milk fish when put in square cages for breeding, injure themselves but this problem had been overcome by putting them in circular cages (Yu *et al.* 1979).

In the present study, it was observed that during feeding most of the fishes in circular cages, came to surface, feed actively and move in circles surrounding the cage wall. In addition, a similar water quality values between cage and open pond water indicates that circular movement of the fish might have led to a vertical flow along the center line of the net cage resulting in a regular water flow between water within cage and open pond. Thus, the circular cage might have provided a less stressful environment to the test catfish species, *M. cavasius* for their growth and survival.

***Length-weight relationship* (*LWRs*):** Logarithmic linear regression relationship of pooled data between total length and body weight of *M. cavasius* in three different stocking densities in cages over the study period was estimated respectively as y=0.97x + 0.07, y=0.97x + 0.08, and y=1.02x - 0.03 as shown in Table IV. The intercept "Ln a" values were 0.07, 0.08 and 0.03 and values for slope "b" were 0.97, 0.97 and 1.02 for T1, T2 and T3 fish respectively, indicating the pattern of negative allometric growth of this species at three different stocking density as b < 3. It means that they favor to increase in length than in mass in cage environment. Earlier study on length-weight relationship on catfish (*Pangasianodon gigas*) showed negative growth pattern where b values were 2.63 and 2.03 ((Paiboon and Mengumphan 2015). In all cases scattered diagrams showed almost linear relationship. Chakraborty *et al.* (2019) estimated length-weight relationship on *Mystus vittatus* in two different aquatic habitats and found a negative allometric growth. With the regression coefficient (b) of 2.71, a negative allometric growth has been reported for *Mystus cavasius* from natural catch (Latif *et al.* 2018).

Table IV. Length-Weight Relationship (LWR) WRs of *M. cavasius* in different stocking densities in pond condition

Stocking density	n	Relationships	Equations	a	b	r^2
T1(200/m^3)	60	TL vs. Wt.	$y = 0.97x + 0.07$	0.07	0.97	0.95
T2(300/m^3)	60	TL vs. Wt.	$y = 0.97x + 0.08$	0.08	0.97	0.95
T3(400/m^3)	60	TL vs. Wt.	$y = 1.02x - 0.03$	0.03	1.02	0.94

There is little significant difference of the “b” values of this species among three different stocking densities in cages. Although $b < 3$ at all three different stocking densities in cages but T3 treatment gave a comparatively higher gross and net production than T1 and T2, perhaps the fish might not get any environmental stress and competition for food and space.

Cage culture is practiced in open waters which in most cases have only limited use for other purposes. However, cage culture in pond may offer the farmer a chance to utilize existing water resources for diversified aquaculture systems. The results of the present study suggest that cage culture of a high valued small indigenous threatened catfish species, gulsha (*M. cavasius*) in circular shaped cages in pond may be possible. Among the three different stocking densities, 400 fry/ m^3 treatment may be the most suitable for the growth, survival and production the species. The fishes in cages exhibit a similar growth pattern, in respect to length-weight relationships, as has been reported in open pond and natural environment. The cage culture of gulsha may be integrated with conventional open pond culture system as a potential option for increasing productivity of pond and availability of this but threatened indigenous small species in the market and diet.

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