



## Influence of stocking density on the culture potential of endangered riverine catfish *Rita rita* (Hamilton, 1822) in raceway

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### ABSTRACT

Endangered catfish *Rita rita* were reared in a cemented raceway to evaluate its culture potential at three different stocking densities of 4, 8 and 16 juveniles m<sup>-2</sup> under three treatments viz., T1, T2 and T3 respectively, with three replications each. The mean initial length and weight of the juveniles were 20.15±1.51 cm and 100.26±6.57 g, respectively. The fish were reared by providing clean poultry viscera (containing 48.56% crude protein) at 5-2% of biomass once a day. Water quality parameters were monitored daily. Growth parameters such as final mean total length, relative length gain, mean body weight, relative weight gain, specific growth rate (SGR) and condition factor were significantly higher (p<0.5) in T1. The survival rate was 100% in all the treatments and the gross and net production of the fish were significantly (p<0.5) higher in T3 (8.38±0.04 and 6.78±0.004 kg m<sup>-2</sup>) than in T2 (4.49±0.03 and 3.69±0.003 kg m<sup>-2</sup>) and T1 (2.36±0.02 and 1.96±0.002 kg m<sup>-2</sup>). Though the growth performance of *R. rita* was significantly influenced by the lowest stocking density, the survival rate and production suggest that this species can be reared at a minimum density of 16 juveniles m<sup>-2</sup> in cement raceway with suitable environment and adequate supplemental feed.

Keywords: Endangered fish, Poultry viscera, Raceway, *Rita rita*, Stocking density

### Introduction

*Rita rita* (Hamilton, 1822) a bagrid catfish belonging to the order Siluriformes, is popularly known as 'Rita' in Bangladesh and the Indian subcontinent. It is a highly valued species in Bangladesh. It is one of the giants of its genus, growing to a length of 150 cm (Talwar and Jhingran, 1991). Generally, it inhabits muddy to clear water (Bhuiyan, 1964) and grows in large rivers (Shaji, 1995) and shallow water of estuaries, *haor*, *baor*, *beels* and brackishwater ecosystems (Mirza, 1982; Talwar and Jhingran, 1991; Rahman, 2005; Yashpal *et al.*, 2006; Siddiqui *et al.*, 2007). It is a potamodromus, bottom and column feeder, usually feeding on insects, molluscs, shrimps, fishes, roots of aquatic plants and also putrid carcass of animals (Bhuiyan, 1964; Rahman, 2005; Siddiqui *et al.*, 2007). The abundance of this fish was reported as very rich in Afghanistan, Pakistan, India, Nepal, Bangladesh and Myanmar in the past (Tripathi, 1996). Though the fish is harvested from the wild in fairly large quantities annually, its catch is progressively declining due to the collective effect of different factors, such as massive siltation in natural habitats, loss of breeding and nursery grounds, overexploitation, alteration of habitats and ecological modifications like blocking of migratory channels by construction of flood control dams,

roads and highways, townships and other developmental infrastructures, irrigation schemes, destructive fishing pressure (IUCN, 2015), aquatic pollution through pesticides and chemicals (Parveen and Faisal, 2002; World Bank, 2005) as well as short term leasing of *haor*, *baor* and *beels*. Consequently, the species has been documented as "Endangered" in Bangladesh (IUCN, 2015), "Near Threatened" in India (Dubey, 1994; CAMP, 1998; Gupta, 2015) and as of "Least Concern" globally (IUCN, 2015). As natural population of the species is declining fast, planners, policy makers, aquaculturists and fishery biologists are thinking of its domestication and cultivation through farming to sustain and augment its production. The fish is very popular for its good taste. Its flesh is rich in protein (17.22-19.55%), low in fat (1.01-2.70%) and has good amount of minerals (0.89-1.07%) compared to other teleosts as well as catfishes (Mitra *et al.*, 2017). Considering its high market demand, the riverine catfish *R. rita* could be a prospective candidate for aquaculture in Bangladesh and there is an urgent need to establish domestication, cultivation and artificial propagation of the species, to augment the natural population, meet the high demand and help in conservation of the species. Some attempts have been taken to develop culture techniques for the fish, such as induced breeding (Mollah *et al.*, 2008), induced breeding and larval rearing (Taslina and

Mollah, 2012) and effect of different feeds on growth and survival (Amin *et al.*, 2010). But the influence of stocking density on the production of this important fish is yet to be elucidated.

Stocking density is known to have a profound influence on fish growth, survival, behaviour and production in any aquaculture system, especially in monoculture. Studies have indicated that lower stocking density produced higher weight gain, specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER) and lowest yield in *Pangasius sutchi* (Azimuddin *et al.*, 1999), higher survival rate and lower yield in case of *P. pangasius* (Razzaque *et al.*, 2003), lowest gross and net yield in *P. sutchi* (Islam *et al.*, 2006), *Clarias gariepinus* (Edward *et al.*, 2010) and *Mystus gulio* (Siddiky *et al.*, 2015), highest mean weight gain, SGR, survival rate and yield in *Heteropneustes fossilis* (Rahman *et al.*, 2014; Monir and Rahman, 2015) and maximum profit in *C. gariepinus* (Suleiman and Solomon, 2017). Sometimes excellent fish seed do not execute satisfactory growth except with correct stocking practices (Sanches and Hayashi, 1999). The full utilisation of space for highest fish production through intensive culture can improve the profitability of the fish farm, whereas under-stocking results in failure to maximise possible utilisation of the space, and overstocking can cause stress, which leads to higher energy requirements and causes reduced growth and food utilisation (Leatherland and Cho, 1985). It has also been investigated that fish stocked at higher stocking density generally is associated with problems such as reduction in FCR, condition factor and growth performance (Lymbery, 1992; Ellis *et al.*, 2002; Sanches, 2013). Thus, stocking density is a key factor to total production, farm economics and profitability for fish farming (Watanabe *et al.*, 2002). Identifying the optimum stocking density for a species is therefore a critical factor in designing an efficient aquaculture system. So, the objective of this study was to evaluate the effect of initial stocking density on the growth, survival and yield of the riverine catfish, *R. rita*, in raceway. It is hoped that the results will contribute to some extent to the knowledge of culture requirements of the species.

## Materials and methods

The study was conducted in a raceway system of the Department of Fisheries Biology and Genetics, BAU, Mymensingh. It was conducted for a period of twelve months from January to December 2016.

### Collection and stocking of fish

Juvenile *R. rita* were collected during November-December, 2015 from the Brahmaputra River near Bangladesh Agricultural University (BAU) campus with

the help of fishermen, who caught the fish by *berjal* and box trap. Juveniles were selected for the study on the basis of good health, bright body colour, uniform length and weight, active movement and absence of injuries and parasites. They were transported to the experimental area in plastic half drums (one juvenile per litre of water) without aeration, using a van and stocked in large cement tanks filled with ground water for acclimatisation. Transportation was done as quickly as possible without any delay, to reduce mortality. Only healthy and active juveniles were released into the tanks that were previously prepared for the experiment. The fish were acclimatised for a period of one week. Length (cm) and weight (g) of each fish was recorded before releasing into the experimental raceway.

### Experiment design

In order to study the growth, survival and production potential, three treatments were used in the experiment, each with three replications. Nine chambers of the experimental raceway were divided into three groups, each group comprising three chambers. The volume of each chamber was 1.83m×1.12m×1.0m cubic meter and the chambers were separated from each other with nylon net attached by means of an iron frame. Juveniles were released in triplicate into the three sets of chambers maintaining a stocking density of 4, 8 and 16 nos. m<sup>-2</sup>, respectively. The initial average length and weight of the fish were 20.15±1.51 cm and 100.26±6.57 g, respectively.

### Feeding of fish

Wet poultry viscera were used as feed for the experiment. The viscera were collected from the local market and cleaned very carefully. The proximate composition of poultry viscera was analysed as per AOAC (2005). The poultry viscera contained 85.45% dry matter with 48.56% crude protein, 14.50% crude lipid and 6.82% ash. Feed was supplied at 5-2% of body weight once a day in the afternoon. The amount of feed supplied to T1, T2 and T3 is given in Table 2. Feeding ration was adjusted in accordance with increase in body weight (Hogendoorn and Koops, 1983) and diet allotments were increased monthly depending on the growth. The leftover feed particles were siphoned out after 30 min of feed supply.

### Water quality monitoring

Temperature was measured using mercury glass bulb thermometer. Dissolved oxygen was monitored using a dissolved oxygen meter (Hanna, Romania) and pH with a portable pH meter (Milwaukee, Romania). To maintain the water quality, waste products were siphoned out with rubber hose daily in the morning, 30% water was exchanged every alternate day and the tanks

were completely drained out at monthly intervals, when the fish were removed for growth measurements. Diluted lime was spread on the bottom and side walls of the raceway and left for about an hour, after which the tanks were cleaned before restocking the fish.

#### *Fish growth, survival and production evaluation*

The experimental fish were sampled at monthly intervals. Total length of juvenile catfish in different treatments was recorded using fish measuring board to the nearest 0.01 cm and the weight was determined using an electronic balance (Bel, Italy) to the nearest 0.01 g. The following parameters were then estimated:

$$\text{Length gain (cm)} = L_2 - L_1,$$

where,  $L_2$  is final total length (cm) and  $L_1$  is initial total length (cm) over a sampling period.

$$\text{Relative length gain (RLG) (\%)} = \left\{ \frac{\text{Length gain by fish (cm)}}{\text{Initial length (cm)}} \right\} \times 100$$

$$\text{Weight gain (g)} = W_2 - W_1,$$

where  $W_2$  is final weight (g) and  $W_1$  is initial weight (g) over a sampling period.

$$\text{Relative weight gain (RWG) (\%)} = \left\{ \frac{\text{Weight gain by fish (g)}}{\text{Initial body wt (g)}} \right\} \times 100$$

Specific growth rate (SGR) =  $(\ln W_2 - \ln W_1) / T \times 100$ , (Hepher, 1988), where  $\ln$  = Natural log,  $W_2$  = Final mean weight,  $W_1$  = Initial mean weight and  $T$  = Time interval.

Condition factor (K) =  $100 \frac{W}{L^3}$  (Bagenal, 1978), where  $W$  = Final weight (g),  $L$  = Final standard length (cm).

Survival rate (%) (S) =  $N_2 / N_1 \times 100$  (Fasakin *et al.*, 2001), where  $N_2$  = Final number of fish at the end of

experiment and  $N_1$  = Initial number of fish at the beginning of experiment.

$$\text{Production (kg)} = \left\{ \frac{\text{Final mean weight (g)} \times \text{Number of fish survived}}{1000} \right\}$$

#### *Statistical analysis*

All the data collected were subjected to analysis using Analysis of variance (ANOVA). Standard deviation was calculated to identify the range of means. Duncan's multiple range test (DMRT) was used to determine the level of significance among treatments (Duncan, 1955).

## **Results**

#### *Water quality parameters*

As the chambers of raceway in all the treatments are separated only by nylon net, the water quality parameters were found similar and within permissible range in all treatments (Table 1).

#### *Growth performance, survival and production of *R. rita**

There was a decreasing trend of growth in terms of mean length (cm) and weight (g) increment when stocking density was increased (Fig. 1 and 2). The summary of growth indices, survival and production are presented in Table 2.

#### *Length gain*

A significant difference ( $p < 0.05$ ) was observed in final total length of *R. rita* at different stocking densities in different treatments (Table 2). For mean final total length (MFTL), mean length gain (MLG) and relative length gain (RLG), all the treatments were significantly different ( $p < 0.05$ ) from each other. Treatment-1 (T1) with stocking density of 4 fish  $m^{-2}$  gave the highest MFTL of  $34.19 \pm 0.11$  cm followed by  $32.29 \pm 0.12$  cm in T2 stocked with 8 fish  $m^{-2}$  and  $30.83 \pm 0.12$  cm in T3 stocked with the density

Table 1. Water quality parameters recorded (Mean  $\pm$ SD) during the experimental period

Months	Parameters		
	Temperature ( $^{\circ}$ C)	Dissolved oxygen (mg $l^{-1}$ )	pH
Jan.	20.75 $\pm$ 65	5.43 $\pm$ 0.33	7.63 $\pm$ 0.08
Feb.	22.75 $\pm$ 65	6.40 $\pm$ 0.33	7.85 $\pm$ 0.11
Mar.	25.00 $\pm$ 0.91	5.93 $\pm$ 0.36	8.25 $\pm$ 0.11
Apr.	27.28 $\pm$ 0.81	6.38 $\pm$ 0.75	8.58 $\pm$ 0.15
May	28.80 $\pm$ 0.50	6.56 $\pm$ 0.43	8.65 $\pm$ 0.11
Jun.	29.85 $\pm$ 0.44	6.75 $\pm$ 0.65	8.60 $\pm$ 0.12
Jul.	30.00 $\pm$ 0.44	5.83 $\pm$ 0.24	8.22 $\pm$ 0.15
Aug.	29.02 $\pm$ 0.68	6.73 $\pm$ 0.80	8.50 $\pm$ 0.22
Sept.	28.55 $\pm$ 0.42	7.10 $\pm$ 0.68	8.53 $\pm$ 0.15
Oct.	27.63 $\pm$ 0.75	6.02 $\pm$ 0.29	8.48 $\pm$ 0.13
Nov.	25.50 $\pm$ 1.29	5.88 $\pm$ 0.33	8.25 $\pm$ 0.18
Dec.	23.50 $\pm$ 1.29	5.55 $\pm$ 0.25	7.93 $\pm$ 0.26

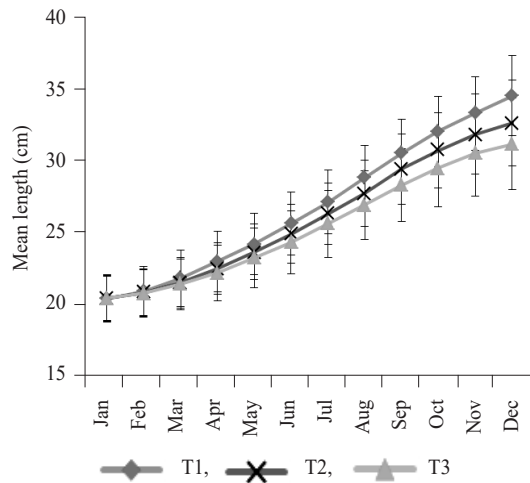


Fig. 1. Monthly mean length increment of *R. rita* cultured in raceway at various stocking densities during the experimental period

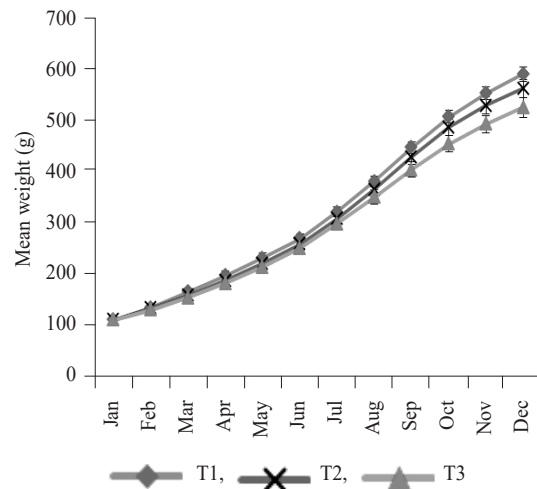


Fig. 2. Monthly mean weight increment of *R. rita* cultured in raceway at various stocking densities during the experimental period

of 16 fish m<sup>-2</sup>. The highest ( $p < 0.05$ ) MLG of 14.08±0.11 cm was observed in T1 followed by 12.14±0.11 cm in T2 and 10.67±0.1 cm in T3. Similarly, maximum RLG of 69.96±0.64% was recorded in T1 followed by 60.26±0.58% in T2 and 52.92±0.48 % in T3 (Table 2).

*Weight gain*

The mean final body weight of the fish at different stocking densities showed significant differences ( $p < 0.05$ ) among the treatments (Table 2). The highest final body weight of 590.50±0.50 g was observed in T1 followed by 561.63±0.40 g per fish in T2. The lowest body weight

of 523.77±0.25 g was recorded in T3. Similarly, the highest weight gain of 490.28±0.48 g was obtained in T1 followed by 461.39±0.39 g in T2 and 423.50±0.25 g in T3. When the relative weight gain was analysed, a significant ( $p < 0.05$ ) effect of stocking density was observed among the treatments. The highest relative weight gain (RWG) of 489.21±0.38 g was obtained in T1 followed by 460.28±0.35 in T2 and 422.36±0.25 g in T3.

*Specific growth rate (SGR)*

The SGR of *R. rita* juveniles grown for 12 months in raceway at different stocking densities showed significant

Table 2. Growth performance of *R. rita* in raceway at various stocking densities during the experimental period

Parameters	T1	T2	T3
Stocking density (juveniles m <sup>-2</sup> )	4	8	16
MITL (cm per fish)	20.12±1.62	20.15±1.51	20.17±1.61
MFTL (cm per fish)	34.19±0.11 <sup>a</sup>	32.29±0.12 <sup>b</sup>	30.83±0.12 <sup>c</sup>
MLG (cm per fish)	14.08±0.11 <sup>a</sup>	12.14±0.11 <sup>b</sup>	10.67±0.10 <sup>c</sup>
RLG (% per fish)	69.96±0.64 <sup>a</sup>	60.26±0.58 <sup>b</sup>	52.92±0.48 <sup>c</sup>
MIBW (g per fish)	100.22±6.70	100.24±6.53	100.27±6.95
MFBW (g per fish)	590.50±0.50 <sup>a</sup>	561.63±0.40 <sup>b</sup>	523.77±0.25 <sup>c</sup>
MWG (g per fish)	490.28±0.48 <sup>a</sup>	461.39±0.39 <sup>b</sup>	423.50±0.25 <sup>c</sup>
RWG (% per fish)	489.21±0.38 <sup>a</sup>	460.28±0.35 <sup>b</sup>	422.36±0.25 <sup>c</sup>
SGR (% per day)	0.49±0.05 <sup>a</sup>	0.47±0.06 <sup>b</sup>	0.45±0.08 <sup>c</sup>
FCR	1.39±0.10 <sup>c</sup>	1.41±0.14 <sup>b</sup>	1.46±0.18 <sup>a</sup>
Condition factor (K)	1.48±0.02 <sup>a</sup>	1.67±0.02 <sup>b</sup>	1.79±0.02 <sup>c</sup>
Survival rate (%)	100 <sup>a</sup>	100 <sup>a</sup>	100 <sup>a</sup>
Feed used (kg m <sup>-2</sup> , Dry matter basis)	2.72±0.01 <sup>c</sup>	5.21±0.01 <sup>b</sup>	9.89±0.02 <sup>a</sup>
Gross production (kg m <sup>-2</sup> )	2.36±0.02 <sup>c</sup>	4.49±0.03 <sup>b</sup>	8.38±0.04 <sup>a</sup>
Net production (kg m <sup>-2</sup> )	1.96±0.002 <sup>c</sup>	3.69±0.003 <sup>b</sup>	6.78±0.004 <sup>a</sup>

All values are reported as mean±SE. Values in the same row having different superscripts are significantly different ( $p < 0.05$ )  
 MITL: Mean initial total length; MFTL: Mean final TL; MLG: Mean length gain; RLG: Relative length gain; MIBW: Mean initial body weight;  
 MFBW: Mean final body weight; MWG: Mean weight gain; RWG: Relative weight gain

difference ( $p < 0.05$ ) among the treatments (Table 2). The finest SGR of  $0.49 \pm 0.05\%$  was found in T1, followed by  $0.47 \pm 0.06$  in T2 and  $0.45 \pm 0.08\%$  in T3.

#### Food conversion ratio (FCR)

The FCR estimated at various stocking densities of the riverine catfish reared in the raceway showed a significant difference ( $p < 0.05$ ) among the treatments (Table 2). The highest FCR of  $1.46 \pm 0.18$  was recorded in T3 followed by  $1.41 \pm 0.14$  in T2 and  $1.39 \pm 0.10$  in T1.

#### Condition factor (K)

The condition factor of the catfish stocked at various densities in the raceway demonstrated significant differences ( $p < 0.05$ ) among the treatments (Table 2). The highest condition factor of  $1.79 \pm 0.02$  was recorded in T3 followed by  $1.67 \pm 0.02$  in T2 and  $1.48 \pm 0.02$  in T1.

#### Survival rate and production

There was no difference in survival rate among the treatments at various stocking densities and the survival rate was 100% in each treatment (Table 2). However, a significant difference ( $p < 0.5$ ) in production of *R. rita* at different stocking densities was observed (Table 2). The highest gross and net production of  $8.38 \pm 0.04$  and  $6.78 \pm 0.004$  kg m<sup>-2</sup> were obtained in T3 followed by  $4.49 \pm 0.03$  and  $3.69 \pm 0.003$  kg m<sup>-2</sup> in T2 and  $2.36 \pm 0.02$  and  $1.96 \pm 0.002$  kg m<sup>-2</sup> in T1.

## Discussion

Water temperature, dissolved oxygen (DO) and pH estimated during the experimental period were within the acceptable ranges as recommended for tropical aquaculture (Viveen *et al.*, 1985; Beveridge, 1996). The water quality parameters recorded in this study conform to the recommendations suggested for other catfish (Ajani *et al.*, 2015). With regular monitoring of water quality, it was ensured that stocking density was the only variable between the three treatments.

Stocking density plays a vital role in the growth and survival of fish in any fish culture operation (Weatherley, 1976; Rahman and Verdegem, 2010). In intensive aquaculture, stocking density is an important indicator that determines the economic feasibility of the production system (Papst *et al.*, 1992). Increase in stocking density results in rising stress, leading to higher energy requirements, causing a reduction in food utilisation and growth rate (Suziki *et al.*, 2001). The present study provides pioneer evidence on the effects of stocking density on growth, survival and production of *R. rita*. There are no previous studies comparing the effects of stocking density on growth, survival and production of *R. rita*, in any aquaculture system. In this

study, growth among the *Rita* juveniles was found to be inversely related to stocking density; *i.e.* fish grown at lower density attained the highest length and weight gain. The length and weight gain were significantly different ( $p < 0.5$ ) among the treatments. This finding was similar to that of *P. pangasius* in ponds (Razzaque *et al.*, 2003), *P. sutchi* in cages (Azimuddin *et al.*, 1999; Islam *et al.*, 2006), Dutch *Clarias* juveniles in out-door hapas (Sogbesan *et al.*, 2009), *C. gariepinus* in concrete tanks (Edward *et al.*, 2010) and *Heterobranchus bidorsalis* (♀) x *C. gariepinus* (♂) hybrid juveniles in three different culture tanks made of concrete, metal and plastic (Oguguah *et al.*, 2011). Significant reduction in weight was also observed with increasing stocking rates (Olivier and Kaiser, 1997; Hossain *et al.*, 1998). The RLG of *R. rita* (52.92-69.96%) was comparatively lower than that observed in *C. gariepinus* (113.64-136.00%) cultured in concrete tanks (Edward *et al.*, 2010) and *H. bidorsalis* x *C. gariepinus* hybrid catfish (561.72-744.78%) in concrete tanks (Oguguah *et al.*, 2011). The RWG of *Rita* catfish (422.36-489.21%) was relatively lower than that of *P. pangasius* (555.12-963.02%) in ponds (Razzaque *et al.*, 2003), *H. bidorsalis* x *C. gariepinus* hybrid catfish (563.09-775.18%) in concrete tanks (Oguguah *et al.*, 2011) and *P. sutchi* (1526.56-2259.70%) in net cages (Azimuddin *et al.*, 1999), but higher than that of *C. gariepinus* (77.30-330.50%) and *Heterobranchus longifilis* (129.92-210.23%) in ponds (Toko *et al.*, 2007) and *C. gariepinus* (123.07-134.27%) reared in concrete tanks (Edward *et al.*, 2010).

Highest SGR was recorded in lowest stocking density of *Rita*; the value decreased with the increase of stocking density and was significantly different among the treatments ( $p < 0.5$ ). A similar trend of SGR was reported in *P. sutchi* in cages (Azimuddin *et al.*, 1999), *C. macrocephalus* in cages (Bombeo *et al.*, 2002), Dutch *Clarias* juveniles in out-door hapas (Sogbesan *et al.*, 2009), *C. gariepinus* in concrete tanks (Edward *et al.*, 2010) and in aquaria (Ajani *et al.*, 2015). The SGR of *Rita* (0.45-0.49) was comparatively higher than that of Dutch *Clarias* (0.23-0.35) in out-door hapas (Sogbesan *et al.*, 2009) and lower than that of *H. fossilis* (1.06-1.23) in earthen ponds (Rahaman *et al.*, 2014) and *P. bocourti* (2.04-2.38) in cages (Jiwyam, 2011).

The FCR values obtained from feeding of cleaned and chopped poultry viscera (containing 48.56% crude protein) in this study were satisfactory. FCR was directly related to the stocking density *i.e.*, lowest FCR was observed in lowest stocking density and the value was significantly different ( $p < 0.5$ ) among the treatments. Thus, feed intake increased with the increase of stocking density. This indicated that feed conversion was more efficient

when competition was less. This FCR (1.39-1.46) was higher than the FCR reported in Dutch *Clarias* juveniles (0.06-0.17) reared with formulated pellet feed containing 45% crude protein (Sogbesan *et al.*, 2009) and *C. gariepinus* (1.01-1.40) fed with commercial diet containing 45% crude protein (Ajani *et al.*, 2015); similar to that of hybrid catfish (*C. gariepinus* x *H. longifiliis*) (1.28-1.60) fed with commercial diet (Ofor and Afia, 2015) and lower than that of other catfishes like *P. bocourti* (1.54-1.98) fed with commercial pellet feed containing 40% crude protein (Jiwyam, 2011), *P. sutchi* (1.73-2.04) reared with an experimental diet containing 35% protein (Azimuddin *et al.*, 1999) and *P. pangasius* (7.06-7.72) provided with farm-made feed (Razzaque *et al.*, 2003).

The mean condition factor illustrated that fish in all the treatments were in good condition throughout the experimental period. The condition factor obtained in this study was above 1.0, indicating that the feeds were properly utilised for good growth and production. This finding conforms to the results obtained with *C. gariepinus* (Edward *et al.*, 2010).

The survival rate recorded in this study was 100% in all stocking densities after one year culture period and it was not affected by stocking density. The high survival rate may be attributed to proper handling and feeding of fish and possibly good water quality parameters. The survival rate of *P. hypophthalmus* in cemented tanks was also not clearly influenced by stocking density (Malik *et al.*, 2014). This was also in agreement with the results of cage culture of sutchi catfish *P. sutchi* (Rahman *et al.*, 2006), African catfish *C. gariepinus* and vundu catfish *H. longifilis* (Toko *et al.*, 2007), Asian river catfish *P. bocourti* (Jiwyam, 2011) and *C. gariepinus* (Dasuki *et al.*, 2013). The survival rate of Rita (100%) was similar to that of *C. gariepinus* (100%) and *H. longifilis* (96.7 - 100%) cultured in ponds (Toko *et al.*, 2007) and was higher than that of many other catfishes such as hybrid catfish *C. gariepinus* x *H. longifilis* (37-59%) reared in tanks (Ofor and Afia, 2015), *M. gulio* (50.17-64.41%) reared in earthen ponds (Siddiky *et al.*, 2015), *C. gariepinus* (70-80%) reared in concrete tanks (Edward *et al.*, 2010) and *H. fossilis* (71-87%) reared in farmer's ponds (Kohinoor *et al.*, 2012) with varying stocking densities of all the catfishes.

It was observed that the riverine catfish *R. rita* did not survive in earthen ponds, and they have better growth and survival in concrete raceways, cisterns and tanks (Md. Rafiqul Islam Sarder, per. comm.). It is easy to maintain improved water quality and ensure proper feeding, grading, precise disease treatments, collection

of fish wastes and harvesting of fish in raceway culture system (Masser and Lazur, 1997) and that is why the present experiment was conducted in concrete raceway.

In the present study, though the best individual growth, both in length (14.08±0.11 cm) and weight (490.28±0.48 g) of fish was observed in T1 at the stocking density of 4 fish m<sup>-2</sup>, the highest gross and net production (8.38±0.04 and 6.78±0.004 kg m<sup>-2</sup>) was obtained in T3 at the stocking density of 16 fish m<sup>-2</sup>. It is clear from the results that both production and yield increased with increase of stocking density. Results of the study are strongly supported by the results of studies in riverine catfish *P. pangasius* in net cages (Sarder and Mollah, 1991) and in earthen ponds (Razzaque *et al.*, 2003), sutchi catfish *P. sutchi* in cage aquaculture (Islam *et al.*, 2006), African catfish, *C. gariepinus* reared in concrete tanks (Edward *et al.*, 2010), Asian river catfish *P. bocourti* cultured in cages (Jiwyam, 2011) and nona tengra *M. gulio* cultured in earthen ponds (Siddiky *et al.*, 2015). While the net production of *R. rita* (1.96-6.78 kg m<sup>-2</sup> yr<sup>-1</sup>) was quite higher than the yield of *M. gulio* (0.13 - 0.19 kg m<sup>-2</sup> yr<sup>-1</sup>) at a density of 8-16 fry m<sup>-2</sup> in earthen ponds (Siddiky *et al.*, 2015), *C. gariepinus* (0.31-2.28 kg m<sup>-2</sup> yr<sup>-1</sup>) and *H. longifilis* (0.61-1.51 kg m<sup>-2</sup> yr<sup>-1</sup>), both at density of 4-8 juvenile m<sup>-2</sup> in ponds (Toko *et al.*, 2007) and *H. fossilis* (1.51-1.81 kg m<sup>-2</sup> yr<sup>-1</sup>) at stocking density of 12.5-25 fry m<sup>-2</sup> in farmer's ponds (Kohinoor *et al.*, 2012). It was similar to the production of *P. sutchi* (3.00-6.70 kg m<sup>-2</sup> yr<sup>-1</sup>) with rearing density of 60-150 fish m<sup>-2</sup> in cages suspended in a river channel (Islam *et al.*, 2006) and fairly lower than the production of *C. gariepinus* (4.08 - 8.51 kg m<sup>-2</sup> yr<sup>-1</sup>) at stocking density of 5-10 fish m<sup>-2</sup> fed with chicken viscera in earthen ponds (Abou *et al.*, 2016), *C. gariepinus* (4.00-10.00 kg m<sup>-2</sup> yr<sup>-1</sup>) in ponds with 25% water exchange per day (Hecht *et al.*, 1988) and *Pangasianodon hypophthalmus* (7 - 85 kg m<sup>-2</sup> yr<sup>-1</sup>) with stocking density of 18-125 fish m<sup>-2</sup> in ponds (Phan *et al.*, 2009).

This study suggests that *R. rita* can be cultured at high densities in raceway system provided that suitable physical, environmental and nutritional conditions are met. As the stocking density has significant effects on production, higher densities may be used to obtain higher biomass and to increase farm profitability. While the final harvest and production values are directly related to stocking density, there will be a density at which mortality would be lower, growth would be higher and production would increase. This critical point was not examined in the present experiment and the highest stocking density was maintained as 16 fish m<sup>-2</sup>. Further studies are required to establish the optimum stocking density for the riverine catfish cultured in the raceway system, which would

help fish farmers to produce fish of desirable size with maximum profit.

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