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Development of breeding and fingerling production techniques for endangered long-whiskered catfish *Sperata aor* in captivity

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Abstract

An experiment was undertaken to develop a suitable seed production technique for *Sperata aor* in captivity. Naturally produced fry of aor was reared at different densities in nine nursery ponds 0.012 ha in size with an average depth of 0.8 m each. Three stocking densities tested, each of which was triplicated. Fry of aor stocked at 100,000/ha was designated as treatment-1 (T_1), 150,000/ha as treatment-2 (T_2) and 200,000/ha as treatment-3 (T_3). All stocked fry were from the same age group with mean length and weight of 1.78 ± 0.28 cm and 0.24 ± 0.05 g, respectively. Fry in all the treatments were fed with SABINCO nursery feed (32.06% crude protein) for the first 14 days and starter-I (31.53% crude protein) for days 15 to 56. Physico-chemical parameters and plankton population of pond water were within the optimal level being better in T_1 than those in T_2 and T_3. Growth in terms of final weight and length, weight and length gain, specific growth rate, daily growth rate, and survival of fingerlings were significantly higher in T_1 followed by T_2 and T_3. Food conversion rate was significantly lower in T_1 than in T_2 and T_3. Significantly higher number of fingerlings was produced in T_3 than those in T_2 and T_1. Despite this, consistently higher net benefits were achieved from T_1 than from T_2 and T_3. This is the first time report that stocking of 100,000 fry/ha appears to be the most suitable density for rearing of aor fingerlings in nursery ponds.

Keywords: *Sperata aor*, Fry, Stocking density, Fingerling, Growth, Production

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Introduction

The long-whiskered catfish *S. aor* (Actinopterygii: Siluriformes: Bagridae) is locally known as "Ayre or Aor" in Bangladesh (Rahman, 2005). It is one of the commercially important freshwater catfish, and was once abundant in canals, rivers, floodplains, inundated fields, swamps, ditches, ponds and reservoirs in Bangladesh, Pakistan, Nepal, India and Myanmar (Jayaram, 1977, 2002; Jhingran, 1991; Talwar and Jhingran, 1991; Ferraris and Runge, 1999; Menon, 1999; Rahman, 2005). The longest specimen measuring 94 cm in total length and weighing about 5.0 kg was recorded from the Gacher Dahar Bill fishery in Sylhet district of Bangladesh (Rahman, 2005). It has been considered as one of the most admired edible fish among indigenous catfish species due to excellent taste and high market demand (Tripathi, 1996).

The fish is carnivorous in nature and readily feeds on live or frozen food, smaller fishes, shrimps, frogs, snakes, insects, earthworms, tadpoles, crustaceans and prepared foods such as pellets (Arunachalam *et al*., 2000; Rahman, 2005). In natural habitat, it builds nest during reproductive period and guard its nest, and normally breeds twice a year from May to July and from September to November (Talwar and Jhingran, 1991; Rahman *et al*., 2005a). Absolute fecundity of this fish varies from 16,147 to 105,760 with a size range between 34.60 and 48.60 cm, with egg diameter estimated between 0.90-1.40 mm (Rahman unpub. data). There are several reasons for the lack of aquaculture of the tropical bagrid catfishes. These fishes are difficult to make spawn artificially using inducing agents, are sensitive to water quality changes and are easily stressed (Rahman *et al*., 2005a). Therefore, hatcheries face difficulties in synchronizing maturity between male and female brood stock of this fish and a lack of naturally collected or artificially produced seeds for stocking (Muchlisin *et al*., 2004).

In the past, Aor was abundantly available in Bangladesh, but in recent years, the natural habitats and spawning grounds of this bagrid catfish have been severely degraded due to poor management, increasing water pollution, destruction of spawning grounds and over-fishing. As a result, natural stock of this important fishery is declining at a daily rate (Rahman *et al*., 2005a). The International Union for Conservation of Nature and Natural Resources (IUCN), listed *S. aor* as one of the endangered native catfish species in Bangladesh (2000). While, very few work have reported on the taxonomy, biology, population characteristics and distribution patterns of *S. aor* (Jhingran, 1991; Talwar and Jhingran, 1991; Rahman, 2005; Khan *et al*., 2011; Sarkar *et al*., 2013), no systematic attempts have been made to develop breeding protocols and culture techniques. A few attempts have recently been made on induced breeding without success (Rahman *et al*., 2005a). Because of the non-availability of seeds in natural waters, not much success has been achieved in commercialization of aquaculture and conservation of this species (Rahman *et al*., 2005a). Hence, it is now most important to conserve this endangered species in a sustainable manner. In the present study, aor was bred for the first time under natural propagation techniques and the produced fry were reared at different stocking densities to optimize the best density considering the highest growth, production and benefit of the endangered *S. aor* fingerlings in a nursery management system.

Materials and methods

Broodstock collection and rearing

In total, 100 individuals of adult aor weighing from 700 to1250 g were collected from the Brahmaputra river-basin and floodplains of greater Mymensingh region during January-February, 2007. Immediately after collection, the fishes were transported to Freshwater Station, Bangladesh Fisheries Research Institute, Mymensingh and then reared in earthen ponds with supplementary feeds comprising rice bran (30%), mustard oilcake (29%), fish meal (40%) and vitamin-premix (1%) at the rate of 5-6% of the estimated biomass. The pond was fertilized at fortnightly intervals with cow dung (1,000 kg/ha) and Urea & TSP (50 kg/ha).

Natural propagation

For stimulating natural propagation of aor, artificial holes (nests) were made on the pond bottom. Each hole was 0.7 m in diameter and 0.3 m in depth. A total of 30 holes were made in a pond having an area of 0.08 ha. Three months before the onset of the breeding season, 30 pairs of Aor breeders (700-1250 g) were stocked in the pond and fed with supplementary feed as stated above. Fresh ground water was supplied everyday to maintain natural phenomena for breeding. During mid May to early June 2007, a total of 19,428 Aor fry were collected from the holes by complete drying of the pond and then reared for 8 weeks in nursery ponds.

Rearing of fry and fingerlings in nursery ponds

The collected fry of aor was reared for 8 weeks from 10 June to 5 August in nine earthen nursery ponds with a surface area of 0.012 ha and an average depth of 0.8 m each. To assess optimum growth and survival of fingerlings, different stocking densities of fry (No./ha) *viz.*, 100,000 (T_1), 150,000 (T_2), and 200,000 (T_3) were tested with three replicates for each. After dewatering, quicklime (CaCO, 250 kg/ha) was spread over the pond bottom. Ponds were then filled with ground water and fertilized with organic manure (cowdung, 2500 kg/ha). Seven days after manure application, the pond water was sprayed with dipterex (2, 22-Trichloro-1-Hydroxy Ethyl Phosphate, manufactured by Ciba Ltd.) at the rate of 1.0 ppm to kill harmful insects and pathogens. Fry having an average length of 1.78± 0.28 cm and weight of 0.20±0.03 g were then stocked in the nursery ponds.

Fry in all the experimental ponds were fed with commercial Saudi Bangla (SABINCO) fish feed *viz.*, nursery (32.06% crude protein) for the first 14 days and starter-I (31.53% crude protein) from days 15 to 56. The rate of feeding was 14% of the estimated body weight of fry for the first two weeks, 12% for the second two weeks, 10% for the third two weeks and 8% for the fourth two weeks. After stocking, the ponds were fertilized with cow dung (1000 kg/ha) at weekly intervals to hasten the primary productivity of the ponds.

Physico-chemical parameters of pond water were monitored weekly between 09.00 and 10.00 h. Temperature (°C) and dissolved oxygen (mg/L) were determined directly by a digital water quality analyzer (YSI, model 58, USA), pH by a digital pH-meter (Jenway, Model 3020, UK) and transparency (cm) by a secchi disc and ammonia nitrogen by a HACH water analysis kit (DR 2000, USA). Total alkalinity was measured following the standard method (Stirling, 1985; APHA, 1992).

Quantitative and qualitative estimates of plankton in the nursery ponds were taken weekly. Ten liters of water collected from different locations and depths of each pond were filtered through fine-meshed plankton net (25 µm) to obtain a 50 ml sample. The samples were preserved immediately with 5% buffered formalin in plastic bottles. A Sedgwick–Rafter (S–R) cell was used under a compound microscope for plankton counting. Plankton count was performed using the formula proposed by Rahman (1992) and Stirling (1985).

Each pond was sampled for thirty individuals each per week until fry attained fingerling stage. Growth in terms of length and weight, specific growth rate (SGR), daily growth rate (DGR) and food conversion ratio (FCR) was estimated. SGR, DGR and FCR were calculated according to Castell and Tiews (1980), and De Silva and Anderson (1995), respectively. At the termination of the experiment, the fingerlings were harvested by repeated netting, followed by drying of the ponds. The live fingerlings were counted and weighed individually. Survival (%) and production (number/ha) of fingerlings were then estimated and compared among the treatments.

Data analysis

The data on growth, survival, production, water quality parameters and plankton abundance of different treatments were tested through one-way analysis of variance (ANOVA) using 'Stat View' version 4.0 followed by Duncan's New Multiple Range test (Duncan, 1955). The level for statistical significance was set at 0.05%. A simple cost-benefit analysis was implemented to estimate the net benefits from different treatments.

Results

Water quality assessment

The values of physico-chemical parameters of pond water over the 8-week nursing of Aor fingerlings are shown in Table 1. Temperature, pH, alkalinity, and ammonia-nitrogen did not exhibit any significant ($p>0.05$) differences among the treatments, while transparency depths increased significantly ($p<0.05$) with increasing fish density from T_1 to T_3 but dissolved oxygen concentration followed the opposite trend of transparency depth.

Table 1: Mean values (±SD) and ranges of water quality parameters of weekly samples over the 8-week experiment.

Parameters	Treatments		
	T_1 (100,000 fry/ha)	**T_2 (150,000 fry/ha)**	**T_3 (200,000 fry/ha)**
Water temperature (°C)	30.94 ± 1.32[a] (29.20–32.40)	30.90 ± 1.30[a] (29.10–32.30)	30.97 ± 1.35[a] (29.30–32.50)
Transparency (cm)	33.88 ± 3.58[c] (31.50–41.50)	44.25 ± 3.95[b] (39.00–49.50)	53.66 ± 3.85[a] (48.50–58.00)
Dissolved oxygen (mg/L)	5.65 ± 0.86[a] (4.70–6.40)	4.66 ± 0.68[b] (4.10–5.80)	3.95 ± 0.63[c] (3.60–5.10)
pH	7.95 ± 0.51[a] (7.50–8.40)	7.76 ± 0.38[a] (7.30–8.20)	7.58 ± 0.35[a] (7.20–8.00)
Total alkalinity (mg/L)	135.28 ± 26.36[a] (88.50–171.00)	133.88 ± 26.05[a] (87.50–166.50)	131.72 ± 27.88[a] (76.50–165.00)
Ammonia-nitrogen (mg/L)	0.28 ± 0.17[a] (0.01–0.70)	0.30 ± 0.20[a] (0.01–0.80)	0.32 ± 0.22[a] (0.01–0.90)

Values in the same row having the same superscript are not significantly different (p>0.05)

Plankton enumeration

The mean and ranges of plankton population in the experimental ponds are summarized in Table 2. The recorded phytoplankton population comprised of four broad groups *viz.*, Chlorophyceae (14genera), Bacillariophyceae (5genera), Cyanophyceae (7genera) and Euglenophyceae (3 genera). Significantly higher (p<0.05) abundance of Chlorophyceae, Bacillariophyceae and Euglenophyceae was recorded in T_1 followed by T_2 and T_3, but the values of Euglenophyceae in T_2 and T_3 were not statistically significant (p>0.05). Among the phytoplankton groups, Chlorophyceae was the most dominant group followed by Bacillariophyceae, Cyanophyceae and Euglenophyceae, respectively. The mean total phytoplankton abundance was significantly higher (p<0.05) in T_1 than that in T_2 and T_3. The estimated zooplankton population consisted of two main groups viz., Rotifera (7genera) and Crustacea (5genera), and Rotifera were dominant over Crustacea during the entire experimental period. Nevertheless, the abundance of Rotifera and Crustacea in T_1 was significantly higher (p<0.05) than those recorded in T_2 and T_3. The abundance of total zooplankton was also significantly higher (p<0.05) in T_1 than those in T_2 and T_3.

Table 2: Mean (± SD) values and ranges of plankton abundance of pond water of weekly samples over the 8-week experiment.

Plankton group	Treatment-1	Treatment-2	Treatment-3
Phytoplankton(cells/L)			
Chlorophyceae	4592 ± 245[a] (4230-4820)	4032 ± 250[b] (3660-4390)	3281 ± 279[c] (2980-3870)
Bacillariophyceae	3818 ± 223[a] (3480-4080)	3335 ± 218[b] (3110-3650)	2782 ± 228[c] (2480-3170)
Cyanophyceae	3052 ± 224[a] (2770-3340)	2670 ± 256[b] (2290-3020)	2180 ± 275[c] (1880-2660)
Euglenophyceae	2598 ± 255[a] (2340-2980)	2295 ± 242[b] (2020-2670)	2086 ± 258[b] (1730-2460)

Table 2 continued:			
Total	14060 ± 877[a] (12820-15220)	12342 ± 766[b] (11080-13730)	10350 ± 566[c] (9050-12160)
Zooplankton(Individuals/L)			
Rotifera	9674 ± 508[a] (9070-10560)	8520 ± 520[b] (7840-9270)	6890 ± 548[c] (6080-7740)
Crustacea	7865 ± 466[a] (7480-8730)	6548 ± 570[b] (5940-7580)	5230 ± 630[c] (4460-6280)
Total	17539 ± 1279[a] (16650-19290)	15068 ± 1394[b] (13780-16850)	12120 ± 1175[c] (10540-14020)

Values in the same row having the same superscript are not significantly different ($p > 0.05$).

Growth and production of fingerlings

Growth in terms of length and weight of fingerlings at weekly intervals is shown in Figs. 1 and 2. The highest length and weight increase was attained in T_1 followed by T_2 and T_3. The growth, survival and production parameters of fingerlings under different treatments over the 8-week experiment are summarized in Table 3. The mean final length and weight of the fingerlings were significantly higher ($p<0.05$) in T_1 than in T_2 and T_3, respectively. Weight and length gains were also followed the same trends as final weight and final length. SGR and DGR were significantly higher ($p<0.05$) in T_1 than in T_2 and T_3. Significantly lower FCR was obtained in T_1 than those in T_2 and T_3. Survival (%) was also highest in T_1 followed by T_2 and the lowest in T_3 ($p<0.05$).

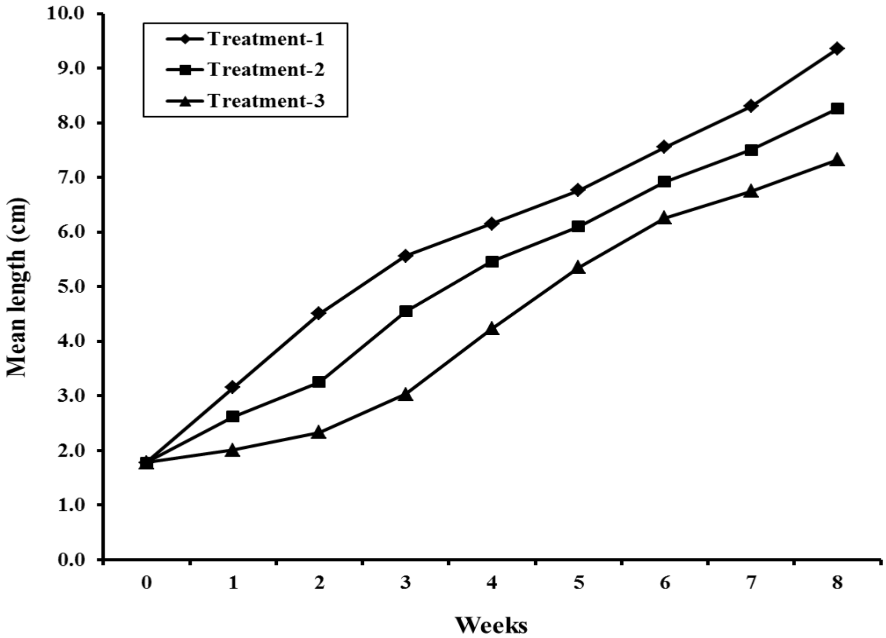

Figure 1: Mean length increase of *S. aor* fingerlings at different stocking densities during the rearing period of 8 weeks in nursery ponds.

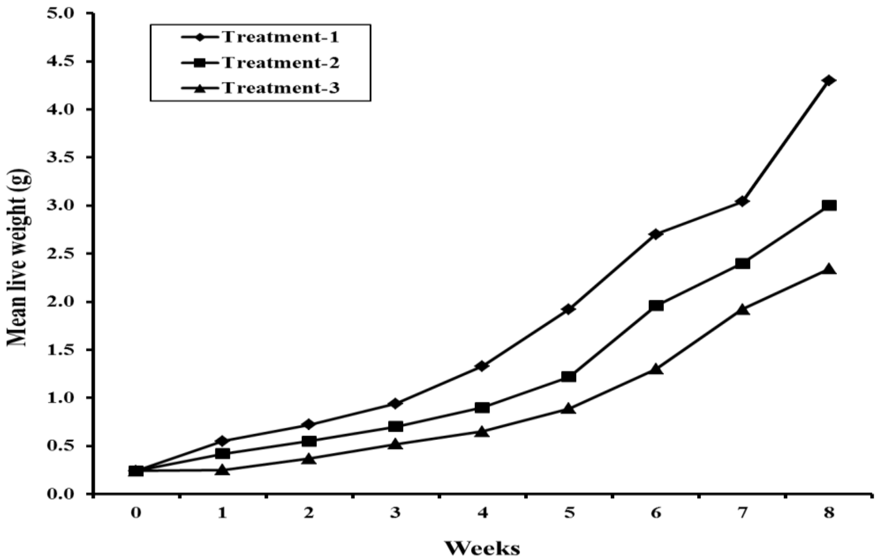

Figure 2: Mean weight increase of *S. aor* fingerlings at different stocking densities during the rearing period of 8 weeks in nursery ponds.

Table 3: Growth performance, survival, feed utilization and production of *S. aor* fingerlings after 8 weeks of rearing. All values represent mean ± SD with range in parentheses.

Parameters	Treatments		
	T_1 (100,000 fry/ha)	**T_2 (150,000 fry/ha)**	**T_3 (200,000 fry/ha)**
Initial length (cm)	1.78 ± 0.28[a] (1.30-2.40)	1.78 ± 0.28[a] (1.30-2.40)	1.78 ± 0.28[a] (1.30-2.40)
Final length (cm)	9.35 ± 0.17[a] (9.18-9.51)	8.26 ± 0.12[b] (8.15-8.38)	7.32 ± 0.14[c] (7.18-7.45)
Initial weight (g)	0.24 ± 0.05[a] (0.16-0.28)	0.24 ± 0.05[a] (0.16-0.28)	0.24 ± 0.05[a] (0.16-0.28)
Final weight (g)	4.30 ± 0.10[a] (4.20-4.39)	3.00 ± 0.14[b] (2.87-2.14)	2.34 ± 0.09[c] (2.25-2.36)
Weight gain (g)	4.06 ± 0.10[a] (3.96-4.15)	2.76 ± 0.14[b] (2.63-2.90)	2.10 ± 0.09[c] (2.01-2.18)
Length gain (cm)	7.57 ± 0.17[a] (7.40-7.73)	6.48 ± 0.12[b] (6.37-6.60)	5.54 ± 0.14[c] (5.40-5.67)
Specific growth rate (SGR) (%/day)	5.15 ± 0.04[a] (5.11-5.19)	4.50 ± 0.08[b] (4.43-4.59)	4.07 ± 0.07[c] (4.00-4.13)
Daily growth rate (DGR %)	7.25 ± 0.17[a] (7.07-7.41)	4.92 ± 0.24[b] (4.70-5.18)	4.18 ± 0.15[c] (4.02-4.32)
Feed conversion ratio (FCR)	1.65 ± 0.09[c] (1.57-1.74)	2.22 ± 0.10[b] (2.15-2.34)	2.62 ± 0.10[a] (2.55-2.74)
Survival (%)	69.65 ± 4.10[a] (65.95-74.05)	57.71 ± 3.06[b] (54.80-60.90)	45.29 ± 3.30[c] (42.40-48.88)
Production*	69,650 ± 4095[c] (65,950-74,050)	86,567 ± 4589[b] (82,200-91,350)	90,567 ± 6590[a] (84,800-97,750)

Values in the same row having the same superscript are not significantly different (p>0.05).
*Total number of fingerlings produced per hectare after a rearing period of 8 weeks.

Significantly higher number of fingerlings were produced in T_3 (90,567/ha) than those in T_2 (86,567/ha) and T_1 (69,650/ha) (Table 3). On the contrary, the total cost of production was found to be the lowest in T_1 (149,142 Tk./ha) followed by T_2 (200,845

Tk./ha) and the highest in T_3 (250,723 Tk./ha). In spite of this, the highest net benefit was obtained in T_1 (338,408 Tk./ha) followed by T_2 (231,990 Tk./ha) and T_3 (111,545 Tk./ha) (Table 4).

Table 4: Costs and benefits from the nursing of *S. aor* fingerlings in 1-ha earthen ponds for a rearing period of 8 weeks.

Items	Treatments		
	T_1 (Tk.)*	**T_2 (Tk.)**	**T_3 (Tk.)**
Chapter 1 A. Cost			
Pond lease (Tk. 30,000.00 ha/yr)	4,615	4,615	4,615
Lime (Tk. 6.00/kg)	1,500	1,500	1,500
Cow dung (Tk. 0.35/kg)	2,975	2,975	2,975
Dipterex (Tk. 800.00/kg)	6,848	6,848	6,848
Fry (Tk. 1.00/piece)	100,000	150,000	100,000
Feeds:			
a. Nursery (Tk. 25.00/kg))	2,099	2,422	2,747
b. Starter-1 (Tk. 23.00/kg)	20,765	22,145	21,698
Labour (Tk. 70.00/day)	7,840	7,840	7,840
Miscellaneous	2,500	2,500	2,500
Total costs	149,142	200,845	250,723
Chapter 2 B. Gross benefit			
Fingerlings**	487,550	432,835	362,268
Net benefits (B-A)	338,408	231,990	111,545

*1 US$ = Tk. 70.00.

**Price of fingerlings fixed by the Institute was Tk. 7.00/piece (T_1), Tk. 5.00/piece (T_2) and Tk. 4.00/piece (T_3).

Discussion

The environmental parameters exert high influence on the maintenance of a healthy aquatic environment and production of food organisms. Growth, feed efficiency and feed consumption of fish are normally governed by a few environmental factors (Brett, 1979). Water temperature in the experimental ponds were within the acceptable range for nursing of fish fry agreeing well with the findings of Haylor and Mollah (1995), Mollah and Hossain (1998) and Rahman *et al*. (2005b, 2013). Transparency was consistently higher in T_3, possibly due to the reduction of the plankton population as a result of the higher density of fish (Rahman, 1992; Haque *et al*., 1994; Rahman *et al*., 2005b, 2008, 2009).

The concentration of dissolved oxygen was low in ponds stocked with a higher density of fish compared to ponds where stocking density was low, due to the higher consumption rate of oxygen by the higher density of fish and other aquatic organisms (Boyd, 1982). However, the DO level was within the suitable range for fish culture (Mollah and Hossain, 1998; Rahman *et al*., 2005b, 2008, 2009, 2013). The pH values agree well with the findings of Mollah and Hossain (1998), Rahman and Rahman (2003) and Rahman *et al*. (2005b), and are within the range of good water quality for rearing of fry/fingerlings in nursery ponds. Higher total alkalinity values might be due to higher amount of lime doses during pond preparation and subsequent liming during the experimental period (Boyd, 1982; Jhingran, 1991; Rahman *et al*., 2005b). The level of ammonia-nitrogen recorded from the experimental ponds is lower than that reported by Dewan *et al*. (1991). However, the level of ammonia-nitrogen in the ponds was not lethal to the fishes (Kohinoor *et al*., 1998, 2001; Rahman *et al*., 2008, 2013).

The quantity of both phytoplankton and zooplankton in our study was inversely related with the stocking density of fry. The quantity of plankton was higher in T_1 where stocking density of fry was low compared to those in T_2 and T_3. The phytoplankton abundances were consistently higher than that of zooplankton. Similar results have also been recorded in various grow-out fish and fry or fingerling rearing ponds (Wahab *et al*., 1994; Haque *et al*., 1998; Kohinoor *et al*., 1999; Chakraborty *et al*., 2003; Rahman *et al*., 2008, 2009). The higher abundance of phytoplankton compared to zooplankton might be due to regular fertilization and excess uneaten feed (Keshavanath *et al*., 2002; Islam, 2002; Rahman *et al*., 2005b, 2008). However, the highest plankton densities in T_1 increased the productivity of pond water and thus enhanced the growth performance, feed utilization and survival of Aor fry in rearing system.

Growth (final length, length gain, final weight, weight gain, specific growth rate and daily growth rate) and survival of Aor fingerlings was significantly higher in T_1 where the stocking density of fry (100,000/ha) was low compared to those of T_2 (150,000/ha) and T_3 (200,000/ha) although the same food was applied at an equal ratio in all the experimental treatments. The reasons behind this might include competition for food and space due to higher number of fish. The results of the present study agree well with the findings obtained by Houde (1975), Haque *et al*. (1994), Kohinoor *et al*. (1994), Mollah and Hossain (1998), Islam (2002), Rahman and Rahman (2003), and Rahman *et al*. (2005b, 2009, 2013) during fry/fingerlings rearing experiments of various carp, barb and catfish species. The FCR values of the present study are lower than the FCR values reported by many other researchers (e.g., Reddy and Katro, 1979; Das and Ray, 1989; Islam, 2002; Islam *et al*., 2002; Rahman *et al*., 2005b etc). The causes for this might be higher digestibility and proper utilization of feed (De Silva and Davy, 1992). Nevertheless, the lower FCR value in this study indicates better food utilization efficiency, despite the values increased with increasing stocking densities.

During our study, significantly higher number of fingerlings was produced in ponds stocked with 200,000 fry/ha (T_3) than the ponds with 150,000 fry/ha (T_2) and 100,000 fry/ha (T_1), respectively. In spite of this, consistently higher net benefits were gained in T_1 than in T_2 and T_3. The higher market price of the larger fingerlings produced in ponds with 100,000 fry/ha, greatly increased the net benefits compared to the smaller fingerlings produced at higher stocking densities. Similar results were also obtained by Rahman *et al*. (2005b), Chakraborty and Mirza (2007) and Rahman *et al.* (2013) from their fry/fingerling rearing trials with critically endangered mahseer (*Tor putitora*), bata (*Labeo bata*) and gulsha (*Mystus cavasius*), respectively. Overall, the highest growth performances, survival, production and net benefits of fingerlings were obtained in ponds stocked with 100,000 fry/ha, compared to the ponds with higher stocking densities. During the entire experiment, the physico-chemical parameters of pond water were within the suitable range for nursery management, the growth of fingerlings to a greater extent was dependent on the quality and quantity of food available. However, availability of plankton varied among the ponds, being more abundant in ponds stocked with lower densities. In the present experiment, the amount of feeds supplied in different ponds were based on the number of fry stocked and this amount was kept at the same level. Hence, the resulted low growth at higher stocking densities could be due to less availability of natural food and some variations in environmental factors. These results are in close agreement with the findings obtained by Kohinoor *et al*. (1994, 1997), Rahman and Rahman (2003), Rahman *et al*. (2005b, 2009, 2013), and Chakraborty and Mirza (2007).

The present study revealed that the growth, survival, production and net benefits of *S. aor* fingerlings were inversely related to the stocking densities of fry. In all respects, a stocking density of 100,000 fry/ha performed better than those obtained at higher stocking densities. Therefore, in light of the present study, a stocking density of 100,000 fry/ha is recommended for rearing of the endangered *S. aor* fingerlings for 8 weeks in earthen nursery ponds. This study represents the first successful attempt to produce fingerlings of *S. aor* through natural propagation. Further steps should be undertaken to develop artificial breeding techniques for large scale seed production, aquaculture as well as conservation and stock enhancement of *S. aor* in captivity.

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