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Optimization of stocking density of Spotted Scat (*Scatophagus argus*) in brackishwater nursery

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Abstract. Spotted scats (*Scatophagus argus*) are euryhaline fish of the family scatophagidae inhabiting Indian and western Pacific oceans including Sundarbans estuary of Bangladesh and having good demand as food fish and aquarium. The present study describes the nursery rearing techniques of spotted scats to optimize the stocking densities for better survival, growth and production. Here, the experiment was designed with three treatments depending on the stocking density i.e., T1 (50 fry.m^{-2}), T2 (100 fry.m^{-2}), and T3 (150 fry.m^{-2}). Water quality was monitored in weekly basis and found all water quality parameters (e.g., temperature, salinity, pH, dissolved oxygen, alkalinity, and total ammonia) within the desired range for farming of *S. argus*. The observed spotted scats growth performance (i.e., final body weight, net weight gain, relative growth rate and specific growth rate) in T2 was significantly (p<0.05) higher than T1 and T3. Likewise, highest survival rate (73.33±1.70 %) was also observed in T2 which is significantly higher (p<0.05) in comparison with T1 (67.67±2.05 %) and T3 (60.33±2.49 %). Moreover, highest total production was also achieved in T2 (457.43±30.24 g.m^{-2}) which is significantly higher (p<0.05) than T1 (174.02±10.08 g.m^{-2}), but indifferent with T3 (436.34±23.82 g.m^{-2}). In summary, stocking scats on nursery pond with 100 fry.m^{-2} stocking density showed better growth performance, survival and production for *S. argus*. The findings of this study will be a cornerstone in rearing of spotted scats at coastal brackishwater nursery ponds for supplying inputs to grow out scats farms in Bangladesh.

Keywords: *Scatophagus argus,* Spotted scat, Stocking, Survival

Introduction

Scatophagus argus (Linnaeus 1766) commonly known as "Spotted Scat" due to numerous black spots on its skin (Bardach *et al.* 1972), is a member of the scatophagidae family under the order Perciformes. In some areas, this species known as leopard pomfret, butterfish, argus fish, spadefish and spotted spadefish (Barry and Fast 1988). This species is a popular aquarium fish throughout the world being colorful appearance, hardiness, slow growth, and calm behavior (Sivan *et al.* 2007, Sivan and Radhakrishnan 2011). Adult scats are consumed in Bangladesh, India and South East Asian countries as food fish due to their soft-textured flesh and palatable flavor (Mandal *et al.* 2020). Usually *S. argus* lives where the fluctuations in salinity, temperature, dissolved oxygen, tidal movements, river run off, turbidity, and turbulence. To survive in such a changeable environment, scats adapted them by many biological attributes which is highly desired in cultured finfish. (Barry and Fast 1988, Sivan 2007, Sivan *et al.* 2010). Scats have noticed very high temperature tolerant (41.3 °C) (Menasveta 1981, Gandhi 1998, Macahilig *et al.* 1988). Brackishwater reared spotted scat showed a higher growth rate compared to seawater and freshwater respectively (Chang *et al.* 2005). Spotted scats fry have good characters of being a cultured species by tolerating salinities over 40 ppt even at elevated temperatures and also tolerating lower dissolved oxygen concentrations even if less than 2 ppm and having a large pH tolerance range (Macahilig *et al.* 1988). Scats has some favorable characteristics for culture like calm nature, taste, appearance, and market value (Wongchinawit and Paphavasit 2009).

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Scats can be one of the economically important fish which could potentially thrive in tropical brackishwater aquaculture (Bardach *et al.* 1972, Sivan and Radhakrishnan 2011). Extensive polyculture of scats in the euryhaline (salinity 0–35 ppt) ponds we also reported (Biona Sr. *et al.* 1988). Obstacles related to the low and uncertain survival rate of newly hatched scat larvae reared in captivity have also been reported (Yangthong and Ruensirikul 2020). For that reason, mass-scale production of juvenile spotted scat from hatchlings is hardly available in hatchery conditions. Juvenile production of any teleost species in a hatchery should be economical and viable with good survival and growth rate (Le Vay *et al.* 2007, Rosenlund and Halldorsson 2007). The stocking density of larvae directly influences the growth, survival rate, water quality parameter in aquaculture systems, and finally production of juveniles. The effect of stocking density on survival and growth rate of several teleosts juveniles during nursery rearing has been reported in Turbot (*Scophthalmus maximus*) (Irwin *et al.* 1999), Russian sturgeon (*Acipenser gueldenstaedtii*) (Celikkale *et al.* 2005), Olive flounder (*Paralichthys olivaceus*) (Bolasina *et al.* 2006), California flounder (*Paralichthys californicus*) (Merino *et al.* 2007), Senegalese sole (*Solea senegalensi*) (Salas-Leiton *et al.* 2008), Dark barbel catfish (*Pelteobagrus vachelli*) (Zeng *et al.* 2010) and Mahanadi Rita (*Rita chrysea*) (Ferosekhan *et al.* 2019). Besides natural supply, this species is able to breed in captive conditions (Washim *et al.* 2022). In hatcheries, a high stocking density of larvae can impose stress leading to compromised growth, whereas low stocking density can be uneconomical to produce juveniles. Hence, optimization of stocking densities during indoor larval and outdoor nursery rearing is needed to produce quality spotted scat juveniles in hatcheries economically. So, this study aimed to know the optimum stocking density during nursery phase. This is the first-ever experiment on nursery rearing of *S. argus* in Bangladesh.

Materials and Method

Study area and animals: Optimizing the stocking density in the nursery management of spotted scat fry were done in the brackishwater earthen ponds for 90 days. This study was conducted at Bangladesh Fisheries Research Institute (BFRI), Brackishwater Station, Paikgacha, Khulna, Bangladesh. The experimental organisms were the fry of spotted scats nurture to the fingerling stage of their life cycle. Spotted scat fries (0.1±0.03 g) were collected from the finfish hatchery of Brackishwater Station of BFRI.

Experimental design: The study was designed with three different treatments (50 fry.m^{-2} in T1, 100 fry.m^{-2} in T2 and 150 fry.m^{-2}) and each of which was replicated thrice to optimize stocking density for the nursery management of spotted scat. For this experiment, the entire research was done for optimizing the stocking density of scats fry in the nursery pond.

Pond preparation: The brackishwater earthen ponds of 0.01 hectare capacity were selected for this study. The clay and organic substances were removed from the pond bottom after draining out the water. Agricultural lime ($CaCO_3$) at the rate of 250 kg.ha^{-1} was applied in the ponds. Afterwards, the ponds were sun dried for five days and filled with tidal water. Thereafter, Triple Super Phosphate (TSP) at the rate of 25 kg.ha^{-1} and Urea at the rate of 20 kg.ha^{-1} were applied about 7 days before stocking spotted scat fry. Besides, a mixture of 20 kg molasses, 10 kg rice bran and 200 g yeast power put together into a container with 50-liter water and leave it 48 hours for fermentation. After that, the extracted juice was applied per hectare pond area at every 15 days interval by screening with fine mesh net.

Feeding: Commercial floating feed with 32 % crude protein content were used as a feed for the fries in the nursery ponds at an initial rate of 12 % of their body weight for the first 15 days, then 10 % from 16-45 days of culture and finally adjusted to 5 % till the end of the trial period, following the standard of (Nandlal and Pickering 2004). Feeding was administered twice daily in the morning (06:00 am) and evening (06:00 pm).

Monitoring and sampling: The growth of experimental fishes were observed weekly basis for each pond random sampling method. At least 30 fishes were sampled with the help of a cast net to measure the growth to assess the health status and for feed adjustment. Growth parameters *viz.* net weight gain (NWG), relative growth rate (RGR), specific growth rate (SGR) with the survival rate (SR) and production were analyzed with formula as mentioned by Lugert *et al.* (2014).

$$NWG = fW - iW \quad (1)$$
$$RGR = \{(fW - iW)/t\} \times 100 \quad (2)$$
$$SGR = [\{Ln(fW) - Ln(iW)\}/t] \times 100 \quad (3)$$
$$SR = (N_t / N_o) \times 100 \quad (4)$$

Where, fW = final weight, iW = initial weight, t = days of culture, N_o = number of fries stocked and N_t = number of fingerlings harvested.

Moreover, the monitoring of temperature, salinity, pH, dissolved oxygen (DO), alkalinity and total ammonia nitrogen (TAN) concentration were done weekly basis at early in the morning (07:00 am) by following the standard procedures of AOAC (1990) and APHA (1992).

Statistical analysis: The collected data on scats *viz.* water quality parameters, weight increment and survival were compiled, categorized, computed and tabulated using a computer program, Microsoft Office Professional Plus 2016. Furthermore, some statistical tests were executed by Statistical Product and Service Solutions (SPSS) ver. 25. One-way ANOVA and Duncan's Multiple Range Test (Duncan 1955) were employed to observe the differences in growth parameters and survival rates of fingerlings among the treatments. The analyzed data are presented in tabular and graphical forms to describe them elaborately for extracting the information accurately.

Results

Water quality parameters: The documented water quality parameters *viz.* temperature, salinity, pH, dissolved oxygen concentration, alkalinity and total ammonia concentration of water during the nursery period in this study are presented in Table I. Interestingly, all the physico-chemical parameters of the experimental ponds were within the suitable ranges for brackishwater nursery management of spotted scats. Temperature is one of the crucial physical regulators that affects the growth, energy flow and biological effects of marine organisms specially finfishes like spotted scats. There were very little temperature fluctuations in experimental ponds. The temperature of the experimental ponds ranged between 27 ^{o}C and 33 ^{o}C. Salinity is considered as one of the most important factors that affects the survival and development of *S. argus*. The salinity level in different experimental ponds varied between 5 ppt and 20 ppt. The recorded pH of this study ranged from 7.52 to 8.73. Dissolved oxygen concentration, alkalinity and total ammonia levels of the experimental ponds ranged between 4.75-7.48, 96-178 and 0.00-0.50 ppm, respectively.

Table I. Ranges of different water quality parameters during the study period

Variables	Treatments			Optimum Level [†](Khanh *et al.* 2018)
	T1	T2	T3	
Temperature (°C)	28-33	27-32	27-33	25-32
Salinity (ppt)	5-18	6-20	6-19	5-25
pH	7.55-8.65	7.61-8.53	7.52-8.73	6.50-9.00
DO (ppm)	5.25-7.42	5.18-7.48	4.75-7.36	4.00-8.00
Alkalinity (ppm)	102-178	98-168	96-172	80-200
TAN (ppm)	0.00-0.25	0.00-0.25	0.00-0.50	0.00-1.00

Note: [†]denotes source

Growth performance of spotted scats: The growth performance of spotted scats in term of ABW (Average Body Weight) at each fortnightly sampling under different stocking densities were plotted to show the growth curves in Fig. 1. The average gained weight was quite slow in the first 60 days after stocking for all the treatments. Thereafter, the growth appeared speedy till the complete culture period. The average initial weight of scats in different treatments was 0.1±0.03 g for all treatments. During first 15 days of rearing, the scats fry raised up to 0.62±0.10 g, 0.79±0.16 g and 0.48±0.24 g in T1, T2 and T3, respectively. On 30th day, the final average weight was recorded as 1.23±0.16 g, 1.54±0.23 g and 1.15±0.24 g in T1, T2 and T3, respectively. On 45th day, the final average weight was recorded as 1.68±0.22 g, 2.13±0.19 g and 1.54±0.32 g in T1, T2 and T3, respectively. On 60th day, the final average weight was recorded as 2.21±0.34 g, 2.97±0.37 g and 2.03±0.39 g in T1, T2 and T3, respectively.

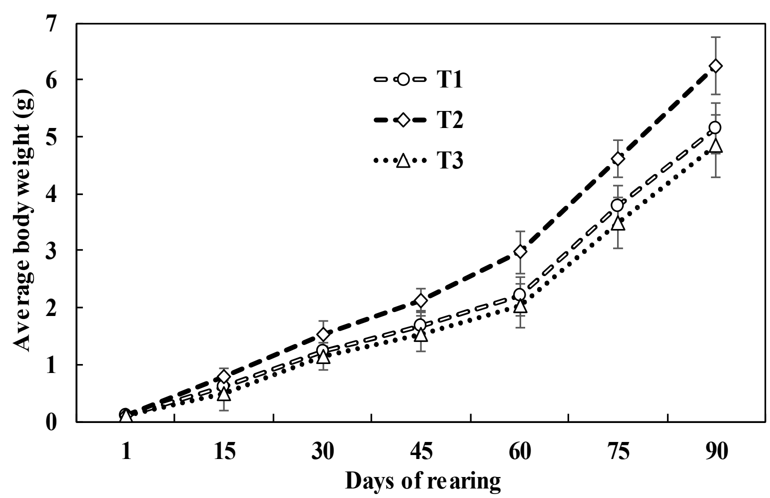

Fig. 1. Growth curves of spotted scats (*S. argus*) grown in brackishwater ponds under different stocking densities.

Thereafter, the growth appears faster and the scats attains average weight as 3.79±0.35 g, 4.62±0.32 g and 3.49±0.45 g in T1, T2 and T3, respectively in the 75th days of culture. Finally, after 90 days of culture period the recorded final average weight of scats were 5.15±0.45 g, 6.24±0.51 g and 4.84±0.56 g in T1, T2 and T3, respectively. Moreover, T2 performed significantly (p<0.05) better in growth than other two treatments from the 45th day of nursery rearing. In general, the growth values of T2 was found higher than the growth value of T1 and T3.

Production performance of spotted scats: The different production parameters of spotted scats were presented in Table II. The findings of the ANOVA test revealed that stocking density was significantly influenced the production parameters like final body weight, NWG, RGR, SGR, SR and production ($p<0.05$). The recorded final weight was 5.15±0.45 g, 6.24±0.51 g and 4.84±0.56 g in T1, T2 and T3, respectively. The net weight gain was calculated as 5.05±0.35 g, 6.14±0.42 g and 4.74±0.43 g in T1, T2 and T3, respectively. The final weight and net weight gain was significantly ($p<0.05$) higher in T2 compared to T1 and T3.

Table II. Production performance of spotted scats (*S. argus*) under different stocking densities

Parameters	Treatments		
	T1	T2	T3
Stocking density (fry.m^{-2})	50	100	150
Initial body weight (g)	0.1±0.03[a]	0.1±0.03[a]	0.1±0.03[a]
Final body weight (g)	5.15±0.45[b]	6.24±0.51[a]	4.84±0.56[b]
Net weight gain (g)	5.05±0.35[b]	6.14±0.42[a]	4.74±0.43[b]
Relative growth rate (g.day^{-1})	5.61±0.39[b]	6.82±0.46[a]	5.27±0.48[b]
Specific growth rate (%.day^{-1})	4.27±0.12[b]	4.62±0.16[a]	4.21±0.13[b]
Survival rate (%)	67.67±2.05[b]	73.33±1.70[a]	60.33±2.49[b]
Production (g.m^{-2})	174.02±10.08[b]	457.43±30.24[a]	436.34±23.82[a]

Note: Different letter superscripts in the same column indicate significant difference (p<0.05)

Similarly, in terms of RGR and SGR, T2 with a stocking density of 100 fry.m^{-2} showed significantly ($p<0.05$) better result in comparison with T1 (50 fry.m^{-2}) and T3 (150 fry.m^{-2}). The recorded RGR was 5.61±0.39 g.day^{-1}, 6.82±0.46 g.day^{-1} and 5.27±0.48 g.day^{-1} in T1, T2 and T3, respectively. The SGR in T1, T2 and T3 was calculated as 4.27±0.12 %.day^{-1}, 4.62±0.16 %.day^{-1} and 4.21±0.13 %.day^{-1}, respectively. Likewise, highest survival rate (73.33±1.70 %) was also recorded in T2 followed by T1 (67.67±2.05 %) and T3 (60.33±2.49 %). Furthermore, highest total production was also achieved in T2 (457.43±30.24 g.m^{-2}) at 100 fry.m^{-2} stocking density which is significantly higher than T1 (174.02±10.08 g.m^{-2}), but indifferent with T3 (436.34±23.82 g.m^{-2}).

Discussion

Nursery rearing is the critical stage in farming of spotted scat (*S. argus*), which produce fish fingerlings as an input for grow-out farming. To determine the optimum stocking density for better growth performance and production, a nursery rearing experiment was carried out. In order to feed cultured fish species phytoplankton, zooplankton and other arthropods must grow, and ideal water quality characteristics offer all the essential nutrients. In fact, high growth and lower mortality are ensured by proper nutrition in the waterbody. Consequently, having appropriate water quality is crucial for fish farming (Ojwala *et al.* 2018). In this investigation, the water's temperature ranged between 27-33 ^{o}C. Salinity levels in the research varied from 5 ppt to 20 ppt. The experiment was started in the late winter when the salinity was quite low around 5 ppt and ended in the summer season when salinity rises around 20 ppt. Meanwhile, there was a large variation of salinity among the treatments due to seasonal changes. Notably, the fry of *S. argus* capitulate better growth and survival rate in the lower range of salinity from 5-20 ppt compared to 25-30 ppt salinity range and there by indicated the ideal range for fry rearing (Mookkan *et al.* 2014). Therefore, the salinity ranging from 5-20 ppt in the present study confirmed the desirability of estuarine habitat for the rearing of the scat fry. The recorded water pH and dissolved oxygen (DO) were within a range of 7.52-8.73 and 4.75-7.48 ppm, respectively. Additionally, during the trials, alkalinity (96-178 ppm) and total ammonia (0.00-0.50 ppm) were noted. In spotted scats nursery rearing, all water quality parameters were found within the standard range in accordance with Khanh *et al.* (2018).

In the present study, the recorded final weight in T1, T2 and T3 were 5.15±0.45 g, 6.24±0.51 g and 4.84±0.56 g, respectively. The net weight gain was estimated as 5.05±0.35 g, 6.14±0.42 g and 4.74±0.43 g in T1, T2 and T3, respectively. A similar trend of weight gain (3.48±1.20 g) was also observed during the outdoor fry rearing phase (30–60 days) at the stocking density of 80 scats.m^{-2} (Mandal *et al.* 2021). Similarly, T2 with a stocking density of 100 fry.m^{-2} showed a considerably higher (p<0.05) performance in terms of RGR and SGR. The SGR of *S. argus* was recorded as 4.31±0.18 %.day^{-1} in the lower salinities with a stocking density of 400 fry.m^{-2} in a 30 days experiment (Mookkan *et al.* 2014). The highest SGR (3.21±0.01 %.day^{-1}) of *Clarias gariepinus* was studied by (Oke and Goosen 2019) with a stocking density of 80 nos.m^{-2}. These values of SGR are comparable with the present study. There are very scant previous studies comparing the effects of *S. argus* density on its growth performance and survival during the nursery rearing in aquaculture ponds. However, the observations are consistent with the outcomes of other brackishwater fishes obtained by Bombeo *et al.* (2002); Siddiky *et al.* (2015); Sontakke and Haridas (2018). Likewise, highest survival rate was recorded in T2 (73.33±1.70 %) followed by T1 (67.67±2.05 %) and T3 (60.33±2.49 %). During the outdoor rearing phase, the highest survival rate of 78.94±2.78 % was recorded in a stocking density of 80 fry.m^{-2} (Mandal *et al.* 2021) which resembles the results of the present study. The survival rate of *S. argus* at 25 ppt salinity with a stocking density of 400 fry.m^{-2} in a 30 days experiment was recorded as 76.67±2.89 % (Mookkan *et al.* 2014). As the experimental duration in the present study was for 90 days so the findings is in line with the findings of Mookkan *et al.* (2014). Furthermore, highest total production was also achieved in T2 (457.43±30.24 g.m^{-2}) which is significantly higher than T1 (174.02±10.08 g.m^{-2}), but indifferent with T3 (436.34±23.82 g.m^{-2}). The effect of stocking densities on the growth and production performance of several commercial fish species has been studied in many research such as African catfish, *Clarias gariepinus* (Oke and Goosen 2019), Red porgy, *Pagrus pagrus* (Laiz-Carrión *et al.* 2012), Senegalese sole, *Solea senegalensis* (Andrade *et al.* 2015), Atlantic salmon, *Salmo salar* (Hosfeld *et al.* 2009), European seabass, *Dicentrarchus labrax* (Lupatsch *et al.* 2010). These studies have shown that high stocking densities have an adverse effect on both survival and production. The observations reported on other brackishwater fishes are compatible with the findings of the present study (Mandal *et al.* 2020; El-Dahhar *et al.* 2021).The difference in feed quality and feed stability between this study and other studies may account for the discrepancy in the results.

Spotted scat is a commercially important finfish species for coastal aquaculture on the southwest region of Bangladesh. However, lower survival and slow growth are the major threats to the nursery rearing of *S. argus*. Hence, optimizing the stocking density for better growth of juvenile scats, minimize mortality and improving the production during the nursery rearing were the main goals of the study. To sum up, spotted scats nursery a stocking density of 100 fry.m^{-2} brought a positive effect to enhance the growth, survival and production in farming of juvenile *S. argus*.

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