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Evaluation of Growth Performance and Survival of Wild Collected Spotted Scat, *Scatophagusargus* (Linnaeus, 1766) during Rearing of Fry to Marketable Size Juveniles for Aquarium Trade at Varied Stocking Densities

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The spotted scat, *Scatophagus argus* has a good market as ornamental fish in smaller body size and wild seeds are available for further rearing to produce marketable size. Existence of no information on rearing of spotted scatfry in low saline brackishwater (<12 ppt) offered an opportunity to conduct an 8-week trial. Wild collected scat fry (0.33±0.04 g) was reared in indoor tanks (1000 L) at three densities (100, 200 and 300 numbers m^{-3}) and comparisons were made on the resultant growth, survival, length-weight relationship and condition factor data. Results on final length and weight exhibited better growth at the lowest density (P<0.05). Accordingly, growth rates decreased as density increased, exhibiting an inverse relationship (P<0.05, R^2=0.88). Survival also decreased as density increased with differences among treatments (P<0.05). The function exponents showed that 200 numbers m^{-3} stocking density produced fish with isometric growth (b=2.989; t =0.96; P>0.05) in good condition. The fish at 100 and 300 numbers m^{-3} treatmentshad positive allometricand negative allometric growth, respectively indicating feeding and/or crowding problems. This study concludes that stocking density of 200 numbers m^{-3} could be optimum to produce spotted scat with the best length-weight relationship, an average weight of 3.84±0.28 g and a survival of 87±3%. Although, fish produced at 100 numbers m^{-3}stocking density had a better final weight (4.11±0.46 g), fish from 100 and 200 numbers m^{-3}treatments will fetch similar price in the ornamental fish market as there was nota marked difference in growth. Therefore, the stocking density of 200 numbers m^{-3} producing more numbers of healthy fish using same infrastructure is the most appropriate one from economic point of view and this system can be a viable option to the ornamental fish producers.

(***Key words:*** *Conditionfactor, Growth, Length-weight, Nursery rearing, Scatophagus argus, Stocking density*)

Scatophagus argus is a marine fish belonging to the family Scatophagidae under the order Perciformes (Kottelat, 2001). It is commonly called as spotted scat (Bardach *et al*., 1972), butterfish, Argus fish, spadefish, spotted spade fish (Barry and Fast, 1988),and widely distributed in the mudflats, mangrove swamps, harbours, upstream swamps, estuaries and marine habitats of Indo-Pacific, the Malay Archipelago, the Philippines, Australia and South and South East Asia, especially India (Sivan and Radhakrisnan, 2011). However, this fish in the ornamental fish markets of India is popularly known as “Indian discus” (Gupta, 2016). The habitats of scats are characterized by fluctuations in salinity, temperature, dissolved oxygen, tidal movements, river run-off, turbidity and turbulence. Adaptations to subsist insuch ever-changing environments endow them with several biological attributes highly desired to be possessed by a cultured finfish (Barry and Fast, 1988). The flesh quality and taste of the fish rank it as an edible fish and the spotted rhombic body places it as a fascinating aquarium fish. Scats sexually mature and breed in the sea. Advanced larvae migrate onshore, and enter estuaries and coastal wetlands during juvenile stage. Usually, seeds are collected from these areas and grown in culture ponds mostly as a component of traditional poly-farming resulting poor rearing output. Because of their favourable biological characteristics and economic importance, considerable interest exists in developing propagation and culture techniques for the spotted scat. Ornamental fish trade is one of the fastest growing fisheries sectors all over the world and the spotted scat can be maintained in freshwater, brackishwater and

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marine aquaria. Therefore, it is a suitable candidate species for promoting as an ornamental fish. Considering the potential of this species, ICAR-Central Institute of Brackishwater Aquaculture (CIBA), Chennai, India, has initiated breeding and propagation endeavours as a thrust area, and has been successful in breeding and seed production recently (Kailasam and Thirunavukkarasu, 2011). There is a recent trend among the farmers to produce scat fingerlings (40-50 mm total length) for ornamental purposes without following any established rearing protocol.

Length-weight relationship (LWR) and condition factor (*K*) are two important parameters for the management of culture systems as they provide the producer with an evaluation of the specific conditions under which organisms are growing (Araneda *et al*., 2008). LWR plays a significant role in studying the growth rate, feeding, metamorphosis, fatness, onset of maturity, gonadal development and general wellbeing of the fish population (Le Cren, 1951; Pauly, 1993), further it helps in establishing the biomass and in converting one variable to another as is often required during regular samplings for culture operation. Whereas, *K*, a quantitative parameter estimated based on length-weight data, indicates the state of well-being of the fish for determining the present and future population success by its influence on growth, reproduction and survival (Hossain *et al*., 2006). In North-East coast of India, wild seeds of this fish are available and ornamental fish producers are mostly dependent on this. During monsoon and post-monsoon when the seeds are available, brackishwater salinity drops below 10 ppt. No study has yet been conducted on the growth performance of wild collected *S. argus* fry in indoor rearing at different stocking densities. Therefore, devising a technique on indoor rearing of scat fry in low saline brackishwater would cater the need of many ornamental fish producers. Thus, the present study aims to compare the growth, survival, length-weight relationship and condition state atthree rearing densities and provides useful information towards establishing *S. argus* fry rearing protocol.

MATERIALS AND METHODS

Experimental design and protocol

The study was conducted in the indoor tank culture facility of the Kakdwip Research Centre of ICAR-Central Institute of Brackishwater Aquaculture, Kakdwip, South 24 Parganas, West Bengal, India for a period of 8 weeks in 9 equal size FRP tanks (1000L). The tanks were cleaned with bleaching powder, washed and sundried for three days to remove all unwanted organisms and residual chlorine. Wild-collected *S. argus* fry (0.33±0.04 g) were reared at three stocking densities to examine the growth and condition status based on length-weight data. The densities evaluated were 100 (D1), 200 (D2) and 300 (D3) fry $m^{-3}$and were randomly assigned to the nine tanks, with three replicates per density treatment. Water used in the experiment was taken by pumping from a creek of Mooriganga River adjacent to the experimental site, and stored in a concrete reservoir tank (5x3x2 m) and chlorinated (20 ppm) to eradicate all unwanted organisms and later dechlorinated by vigorous aeration prior to use. Before stocking, the fish seeds were acclimatized to indoor tank conditions for 7 days. The fish were fed with a commercial balanced diet containing 28% protein and 4% fat twice daily at 08:00 and 16:00 h*ad libitum*. Optimum water quality was maintained by daily siphoning out the bottom water (10%) along with faecal matters and uneaten feed, and compensating by storage tank water and continuous aeration.

Analysis of growth related and condition parameters

Gravimetric data were collected weekly throughoutthe experimental period. Total length (TL, mm)was recorded with a slide caliper, while body weight (W, g)was measured using a digital electronic balance for 30samples from each tank.

Growth rate (GR) is a function of weight and time andwas estimated for each replicate tank with the formula:

$$GR = \frac{W_f - W_i}{t}$$

Where, W_f and W_i are the averagefinal and initial weight in time *t*.

The mathematical relationship between length and weight was calculated using the conventional formula (Pauly, 1984):

$$W = a.TL^b$$

Where, W is fish weight (g), TL is total length (mm), *a* is the proportionality constant and b is the isometricexponent. The parameters *a* and b were estimated by non-linear regression analysis.

Fulton's condition equation was used to find out the condition factor (Ricker, 1975; Chow and Sandifer, 1991):

$$K = \frac{\overline{W}}{(\overline{TL})^3} \times 10^5$$

Where, K is the condition factor, $\overline{W}$ is the average weight (g) and $\overline{TL}$ is the average total length (mm).

Analysis of water quality parameters

Water samples were collected from surface of the experimental tanks between 08:00 and 09:00 h at weekly intervals to measure parameters such as temperature, pH, dissolved oxygen (DO), salinity, unionized ammonium and nitrite-nitrogen (APHA,1998).

Statistical analysis of data

Statistical significance of the isometric exponent (*b*) was analyzed to evaluate the relationship between weight and total length in each treatment using *t*-test (Snedecor and Cochran, 1967).Comparison of growth rate, condition factor, final length and weight as well as survival rate between the three treatments was made with one way analysis of variance(ANOVA). Data were expressed as mean ± standard deviation (S.D.). The analyses were performed using SPSS for Windows v. 17.0 program (SPSS Inc., Chicago, IL,USA).

RESULTS AND DISCUSSIONS

The water quality parameters of the experimental tanks under three treatments are presented in Table 1. The recorded parameters were within the optimum ranges for brackishwater aquaculture in general (Bhowmik *et al.*, 1992; Biswas *et al.*, 2011; Chakraborti *et al.*, 2002) and for spotted scat in particular (Gupta, 2016). General water quality in the experimental tanks did not exhibit any marked variations. Fry were healthy and no infection or disease was encountered during sampling. Average water quality parameters between the three treatments during the experimental period were 28.7 to 26.5°C for temperature;8.08 to 8.12 for pH; 9.48 to 11.63 ppt for salinity; 6.64 to7.39 mg $L^{-1}$for dissolved oxygen; 0.028 to 0.11 mg L^{-1} for total ammonia-nitrogen and 0.012 to 0.003 mg L^{-1} fornitrite-nitrogen. The results demonstrated the feasibility of wild collected spotted scat (*S. argus*) fry rearing in indoor tanks provided with low saline brackishwater. Although, water temperature and salinity are reported to have significantly greater effect on growth in various cultivable aquatic organisms (O'Brien, 1994; Tsuzuki *et al.*, 2000), any effect that might have occurred on growth would have been equal to allthree treatments, meaning differences in weight gain can beattributed to the varied stocking density only. However, this fish has the ability to tolerate an elevated water temperature (41.3°C) and wide range of salinity (0-40 ppt) (Gupta, 2016). Moreover, scats had a comparative high growth rate during rearing in brackishwater than in sea water (Chang *et al.*, 2005).

The highest growth was observed in the D1 treatment, with final weight of 4.11±0.46 g and the lowest in the D3 treatment with 2.87±0.33 g. Final weight achieved in D2 was 3.84±0.28 g. Weight of fish showed increasing trend throughout the culture period in all the treatments (Fig.1).The effect of density on growth performance in terms of weight differed between treatments (*F =8.05; P<0.05*) (Table 2). Similarly, the highest growth rate was observed in the D1, with an average of 0.067±0.023 g day^{-1} and the lowest in the D3 treatment with a rate of 0.045±0.015 g day^{-1} (Table2). In D2 it was 0.063±0.026 g day^{-1}. Growth rates were significantly different between treatments (*F=2.99;*

Table 1. *Water quality parameters in the experimental treatment tanks*

Water parameters	D1	D2	D3
Water temperature (ºC)	27.6 ± 1.1	27.5 ± 1.1	27.6 ± 0.9
pH	8.16 ± 0.04	8.10 ± 0.06	8.09 ± 0.01
Dissolved oxygen (mg L^{-1})	7.22 ± 0.68	7.03 ± 0.59	6.87 ± 0.40
Salinity (g L^{-1})	10.56 ± 1.08	10.48 ± 1.15	10.64 ± 0.97
Total ammonia-nitrogen (mg L^{-1})	0.062 ± 0.033	0.075 ± 0.047	0.081 ± 0.029
Nitrite-nitrogen (mg L^{-1})	0.007 ± 0.004	0.009 ± 0.002	0.010 ± 0.003

Values are mean ± S.D. of three replicate tanks; D1, D2 and D3 indicate stocking densities of 100, 200 and 300 nos. m^{-3}, respectively.

Table 2. *Comparison of spotted scat performance parameters at different stocking densities*

reatments	Days of rearing	Final length (mm)	Final weight (g)	Growth rate (g day^{-1})	Survival (%)	Condition factor (K)	Isometric exponent (b)
D1	56	49.16 ± 8.65^{a}	4.11 ± 0.46^{a}	0.067 ± 0.023^{a}	96.3 ± 1.5^{a}	3.46 ± 0.98^{a}	3.071^{a}
D2	56	47.98 ± 4.32^{b}	3.84 ± 0.28^{b}	0.063 ± 0.026^{b}	87.0 ± 2.8^{b}	3.32 ± 0.77^{b}	2.989^{b}
D3	56	44.53 ± 6.98^{c}	2.87 ± 0.33^{c}	0.045 ± 0.015^{c}	83.9 ± 6.7^{c}	3.29 ± 0.73^{c}	2.951^{c}

Means bearing different superscripts indicate statistically significant differences in a column (*P*<0.05); values are expressed as mean ± S.D.; D1, D2 and D3 indicate stocking densities of 100, 200 and 300 nos. m^{-3}, respectively.

$P<0.05$) and there was an inverse relationship ($P<0.05$, $R^2=0.881$) between higher density and weight gain (g day^{-1}) (Fig. 2). Survival was different ($F=7.18$; $P<0.05$) between the treatments with the highest in D1 (96.3±1.5%), followed by D2 (87.0±2.8%) and D3 (83.9±6.7%) treatments (Table 2). The determination coefficient (r^2) values explained the proper fit of the model for growth and potential tendency according to the variability observed in each treatment. The observed decrease in growth and survival rates with the increased rearing density and biomass coincides with other studies involving various shrimp and fish species at different salinities and densities (Appelbaum *et al.*, 2002; Biswas *et al.*, 2013; Richard *et al.*, 2010; Samocha *et al.*, 2004). This decrease is probably due to crowding at high densities, leading to stress in the organisms (Foster and Bread, 1974). Previously, a reduction of yield with increment of the stocking density was reported in scats fed with methyl testosterone in earthen ponds (Biona *et al.*, 1988).

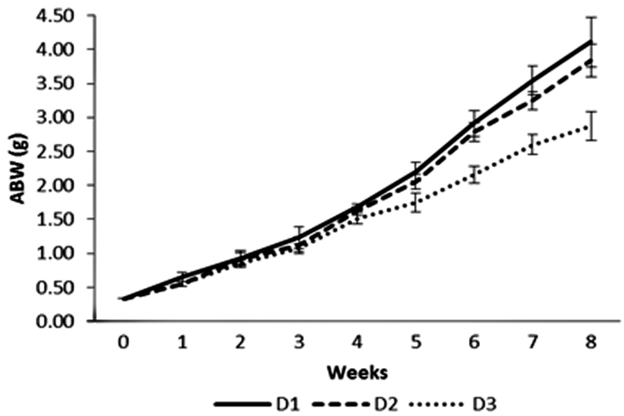

Fig. 1.Weekly increment of average body weight (ABW; mean±S.D.) of Scatophagusargusreared at three stocking densities (D1= 100, D2= 200 and D3= 300 nos. m^{-3})

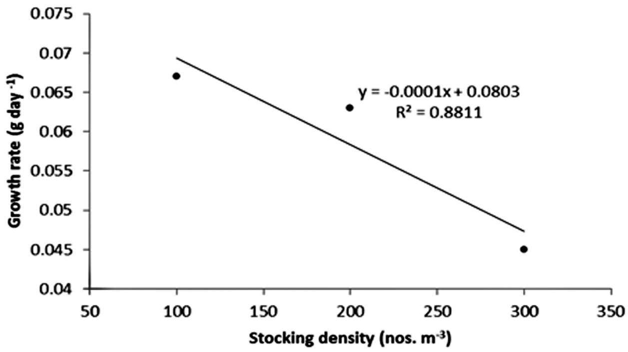

Fig. 2. Growth rate versus culture density in Scatophagusargusfry indoor rearing showing significant inverse relationship (R^2=0.881, P<0.05)

Slope (b) values were inverse to rearing densities with the highest density having the lowest value and the lowest density showing the highest value (Figs. 3-5). The highest condition factor value (3.46±0.98) was recorded in the D1treatment, followed by the D2 (3.32±0.77) and D3(3.29±0.73) treatments. According to the slope value ($b=2.989$), growth in D2 treatment was isometric, and, based on t, it was not different from 3 ($t=0.96$; $P>0.05$). The slopes for D3($b=2.951$) and D1($b=3.071$) differed from 3 ($t=3.82$ and $t=7.35$, respectively; $P<0.05$) and were therefore allometric. For the length-weight relationship and potential fit, the a and b parameters in the three studied densities are similar to those reported for different fish species (Biswas *et al.*, 2011). Enin (1994) stated that when the parameter b is equal to 3, growth is isometric and when it is less than or greater than 3, it is allometric. Wootton (1992) was more specific and stated growth to be positive allometric when organism weight increases more than length ($b>3$), and negative allometric when length increases more than weight ($b<3$). Of the three studied densities, only the 200 fish m^{-3} (D2) treatment had a t indicating isometric growth that indicates proportionate increase in length and weight (Fig. 4). Although close to 3, as per t, growth in the 300 fish m^{-3} (D3) treatment ($b=2.989$) was negative allometric (Fig. 5) and that in the 100 fish m^{-3}treatment ($b=3.072$) was positive allometric. In other words, weight was not symmetrical with length at the highestdensity and vice-versa at the lowest density. Despite being allometric,D1 is apparently the most appropriate under the studied rearing conditions because it produced organisms significantly higher in length and weight compared to the other treatments. Density conditions clearly affected the length-weight relationship of individual organisms, which is in the line with reports stating slopes less than 3can indicate density and/or feeding problems in a culture system (Murphy *et al.*, 1991). In the present study, the greater competition for feed at the 300 fish m^{-3}density would have affected this parameter, in addition to the stress of crowding. In cases of isometric growth (b=3), the a (intercept) parameter maybe considered as an indicator of good physiological condition in a population given the conditions in a certain environment; if it is allometric, however, a cannot be interpreted this way (Pauly, 1984). Condition factor and potential relation parameter data can be vital to culture system management because they provide the producer with an evaluation of the specific conditions under which organisms are developing. The present data emphasize that factors such as density can affect isometry in growth stage of organisms. The 200 fish m^{-3}density allowed the organisms to remain healthy, which was reflected in a good length-weight relationship. The 100 fish m^{-3} density produced positive allometric

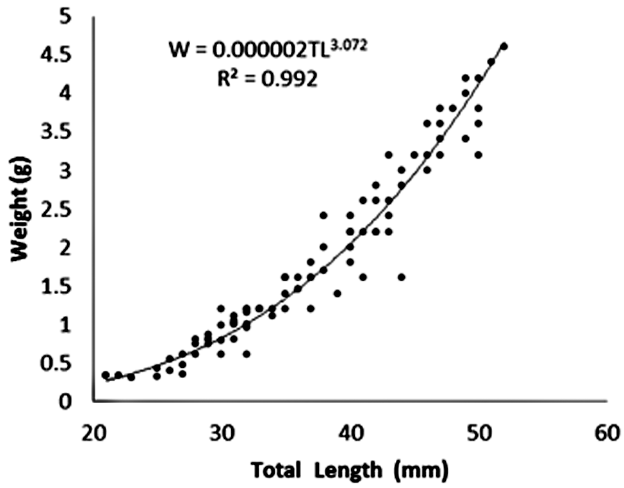

Fig. 3. *Length-weight relationship of Scatophagusargus (n=750) fry reared at 100 nos. m^{-3} stocking density*

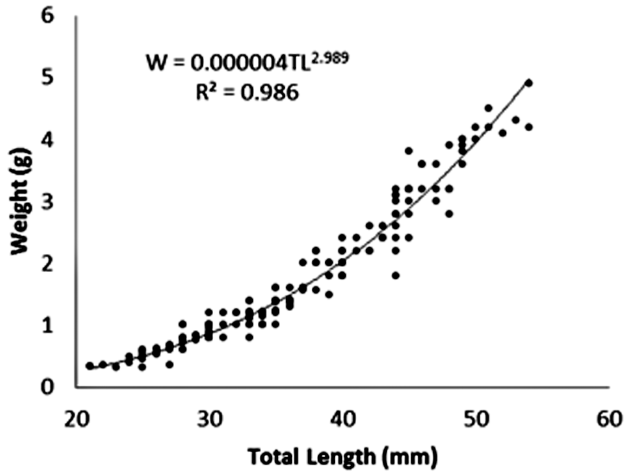

Fig. 4. *Length-weight relationship of Scatophagusargus (n=750) fry reared at 200 nos. m^{-3} stocking density*

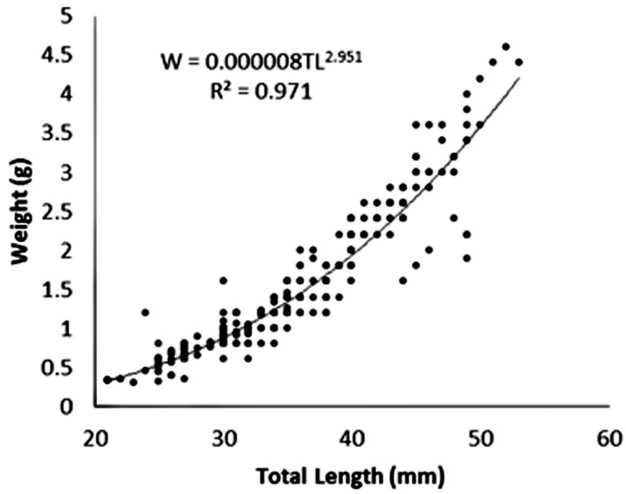

Fig. 5. *Length-weight relationship of Scatophagusargus (n=750) fry reared at 300 nos. m^{-3} stocking density.*

organisms, which are also healthy and have the added advantage of growing more in weight than in length. The 300 fish m^{-3}density produced negative allometric organisms. Condition factor is used to compare the 'condition', 'fatness' or 'well-being' of fish and based on the hypothesis that the heavier fish of a given length arein a better condition. Higher condition factor value at low rearing density and vice-versa indicate that culture condition became poorer in terms of availability of food material and space as rearing density increased. However, in bigger sized fish captured from Cochin estuary, relative condition factor was low (0.91-1.3) compared to our results and dependent on the physiological factors like maturity and spawning along with food availability in natural habitat (Sivan and Radhakrishnan, 2011).

CONCLUSION

The wild-collected spotted scat (*S. argus*) could survive and grow well in indoor tank condition at intensive densities in low saline brackishwater (<12 ppt). At the lowest studied density (100 fish m^{-3}), it was possible to raise organisms with higher growth and survival in 8 weeks. The reduction in growth and survival rates as density increased is probably due to competition for space and feed, and negative social interactions creating an inhibitory effect. Only the fish in treatment with 200 nos. m^{-3} attained isometric growth, indicating that organisms had a good length-weight relationship and were, therefore, in good condition. Fish produced in both the treatments will fetch similar price in the ornamental fish market as there is not a marked difference in size. Hence, the latter density rearing is the most profitable one which produces more number of healthy fish using same infrastructure. The findings of the current study have practical significance as an important step for establishing *S. argus* fry rearing practice in low saline brackishwater. Moreover, when rearing systems are established in rural areas, they could provide livelihood opportunities to ornamental fish producers and aid in diversifying aquaculture production systems.

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