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Density-dependent Growth of Endangered *Labeo bata* (Hamilton, 1822) in Nursery Ponds

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Abstract

The effect of stocking density on growth performance and survival rate of endangered *Labeo bata*, was conducted in nursery ponds from 14th June to 13th August, 2013. Three different stocking densities viz. 500, 600 and 700 piece^{-1} decimal were assigned as treatment T_1, T_2 and T_3 respectively. The initial average weight of *L. bata* was 0.15±008 g. Hatchlings in all the nursery ponds were fed indigenous feed (26.95% crude protein) for 8 weeks. Temperature, ammonia nitrogen, pH had no significant differences ($P<0.05$). Final weight (g) was found to be the highest (4.06±0.06) in T_1 and the lowest (3.20±0.03) in T_3. The mean values of weight gain (g) was the highest (3.91±0.06) in T_1 and the lowest (3.05±0.03) in T_3. SGR was highest (5.49±0.02) in T_1 and lowest (5.09±0.02) in T_3. Yet again, survival rate was highest (70.33±0.88) in T_1 where stocking density was the lowest among those aforementioned three treatments and lowest (61.00±0.58) in T_3 where the stocking density was the highest among the treatments. And finally production (kg^{-1}ha) was found highest (352.66±4.42) in T_1 and lowest (337.50±3.19) in T_3. Rearing of the *Labeo bata* fry in those three different stocking densities showed significant ($p<0.05$) variation both in highest survival and growth performance. Overall production of *L. bata* in treatment T_1 was significantly higher than that of the other two treatments T_2 and T_3. Despite of this, consistently higher CBR was found from treatments T_1 (1:1.78) than from treatment T_2 (1:1.25) and T_3 (1:1.06).

Key words: Economics, Endangered, Growth, *Labeo bata*, Nursery pond, Production

Introduction

During the last few years, the natural production of bata has declined considerably due to increased fishing pressure, and various anthropological activities leading to siltation, aquatic pollution, and loss of natural habitat for spawning and growth (Hussain and Mazid, 2001). These activities not only destroyed the breeding grounds but also caused havoc to the availability of brood fish including fry and fingerlings (Hussain and Mazid, 2001). Although many attempts have been made to breed this species, but due to over exploitation and various ecological changes in its natural habitat; this species is on the verge of extinction (Hussain and Mazid, 2001). Recent studies suggest that worldwide 20% of all fresh water species are extinct, endangered or vulnerable (Moyle and Leidy, 1992). International Union of Conservation of Nature (IUCN 2000), Bangladesh listed *L. bata* is one of the endangered minor carps in Bangladesh. So, it is essential to conserve and rehabilitate this fish from extinction through development of appropriate nursing and rearing technique of fry and fingerlings of *L. bata*. Development of suitable techniques of nursing and rearing of larvae is very important to ensure reliable and regular supply of fish fingerlings. Successful controlled method of fry nursing depends on a proper knowledge of nutritional and environmental requirement of the larvae in the aquatic ecosystem (Mollah, 1985). Lack of proper care and understanding about the biotic and abiotic factors in the rearing system may result in mass mortality of young fry (Jhingran and Pullin, 1985). Stocking density is an important parameter in fish cultutre operations, since it has direct effect on the growth and survial and hence production (Backeil and LeCren, 1978). Stocking density is an important indicator that determines the economic viability of the production system. Although a positive effect of stocking density on growth is reported in some species, it is well accepted that the stocking density is critical factor for many aquatic animal for their growth and survival (Weatherley 1976; Rahman and Verdegem, 2010). Stocking density is related to the volume of water or surface area per fish. Increase in stocking density results in increasing stress, which leads to higher energy requirements, causing a reduction in growth rate and food utilization. It is directly related with the competition for food and space (Rahman *et al.*, 2010; Rahman and Verdegem, 2010). Generally, fish needs to compete less for food and space in lower stocking density than the higher stocking density. For the development and rearing techniques of any fish species, stocking density might play a very important role. The present rate of fish production in Bangladesh is lesser than that of population boom. To fulfill the protein demand of the people; it is strongly felt that a huge quantity of fish production is essential. So developing culture system is one of the most important factors to increase fish production. To meet the increasing demand for protein in Bangladesh, adoption of intensive and extensive culture practices on certain selective species of fishes is very important. The present investigation was carried out to ascertain the optimum stocking density of *L. bata* in pond ecology for sustainable production and obtain rearing optimal conditions.

Materials and Method

Experimental site and set up

The experiment was carried out for a period of 60 days from 14th June to 13th August, 2013 in Rajshahi University Campus. The experiment was conducted under three treatments namely T_1, T_2 and T_3 with three replications (Table-1).

Table-1. The design of the experiment

Treatment	Species	Applications	Stocking density (piece^{-1} dec)
T_1	*Labeo bata*	Feed (Fish meal 20%, Rice bran 20%, Wheat flour 30%, Mustard oil cake 30%)	500
T_2	*Labeo bata*	Feed (Fish meal 20%, Rice bran 20%, Wheat flour 30%, Mustard oil cake 30%)	600
T_3	*Labeo bata*	Feed (Fish meal 20%, Rice bran 20%, Wheat flour 30%, Mustard oil cake 30%)	700

Preparation of pond

The experimental ponds were rectangular in shape with similar size, depth, basin configuration and bottom type. At first the bottom and sides of the selected ponds were repaired and all the aquatic weeds were removed manually by hand picking, uprooting and cutting from the nursery pond. Rotenone (18.50 kg^{-1}ha) was used for the removal of predatory and unwanted fish species. After 7 days, all ponds were treated with lime at the rate of 225.25 kg^{-1}ha to disinfect the water. Then the experimental ponds were fertilized by using cow dung-1322.33 kg^{-1}ha, urea-240.03 kg^{-1}ha, TSP-191.99 kg^{-1}ha after 7 days of liming. The source of water of experimental ponds were rainfall and deep tube-well. During the introduction of water in each experimental pond, fine mesh (2 mm) nylon net hapa was used in the mouth of the pumped water to prevent predatory fish egg, spawns, fry and adult or larvae of aquatic harmful insects to inhabit their entrance. Then natural food production was tested and the water toxicity of the experimental ponds was checked.

Collection and stocking of larvae

Larvae of bata were collected from Banga Bihary Hatchery, Balihar union under Nawgoan District. Larvae were kept inside the polythene bag with proper oxygen and the mouth of the polythene was bound tightly by rope. Then the larvae were brought and were transferred to the experimental pond and were acclimatized for about half an hour. Before releasing the larvae to the experimental pond the initial length and weight of 10 larvae were recorded with the help of 5 mm graph paper and a sensitive portable electric balance (KD300kc: 0.01g-300g). Initial weight of larvae were 0.15±00 g, respectively. Fry were acclimatized with experimental pond water in plastic bag and released in each experimental pond at 8:00 am at the rate of 500 piece^{-1}dec in Treatment T_1, 600 piece^{-1}dec in Treatment T_2 and 700 piece^{-1} dec in Treatment T_3.

Feeding management

Four ingredients which were fish meal-20%, rice bran-20%, mustard oil cake-30% and wheat flour-30% used in prepared feed. The required quantities of all ingredients mixed with hand (prepared feed) and spread it to the experimental pond surface. The supplemental feed was given to fry at the rate of 10%, 8% in 1st and 2nd Month respectively. The quantities of feed were adjusted every seven 15 days interval on the basis of increase in the average body weight of the stocked biomass. Half of the ration was supplied at 9.00 am and remaining half was supplied at 4.00 pm. The proximate composition of feed has been presented in the Table 2.

Water quality parameter

Sampling was done on every fortnight interval in the morning (08:00 am to 09:00 am hrs). After each sampling water quality parameter (temperature by using thermometer, transparency using secchi disc, pH, DO, ammonia-nitrogen and alkalinity (using Hack kit) was measured.

Growth performace

Weight gain (gm), SGR (%), survival rate (%), production (kg^{-1}ha^{-1}2 months^{-1}) and CBR in different treatment were measured by following formulae:

i. Weight gain (g)=Average final weight — Average initial weight

ii. Specific growth rate (SGR%)

$$= \frac{LnW_2 - LnW_1}{T_2 - T_1} \times 100$$

where, W_2 = Final live body weight (mg) at time T_2
W_1 = Initial live body weight (mg) at time T_1

iii. The survival rate (%) was calculated by the following formula =

$$\frac{\text{Initial number of larvae} - \text{Final number of larvae}}{\text{Initial number of larvae}} \times 100$$

iv. Production (kg/ha) = No of fish harvest × Final weight

Analytical method and statistical analysis

The proximate composition of each the feed were carried out in accordance with A.O.A.C method (1990). For the statistical analysis of data collected, one-way analysis of variance (ANOVA) was performed using the SPSS (Statistical Package for Social Science, evaluation version-15.0). Significance was assigned at the 0.05% level. The mean values were also compared to see the significant differences throw DMRT (Duncan Multiple Range Test) after Zar (1984).

Economic analysis

During the study period a simple cost return analysis was done to estimate the net profit from different treatments. The approximate cost of each diet was calculated on the basis of Rajshahi local market price (2013) of all the ingredients used. The cost of leasing ponds was not included in the total cost. Finally the total expenditure was subtracting form the total incomes and get the benefit and CBR was calculated by CBR=Benifit/Total cost.

Table 2. Proximate composition of feed used in the experiment

Components	Diets
Moisture	1.6%
Crude protein	26.95%
Crude lipid	14.5%
Crude Fiber	10.25%
Ash	5.83%
NFE	26.47%

***** Nitrogen free extruct (NFE) calculated as 100-% (Moisture + Crude protein+ Crude lipid+ Crude Fiber+ Ash)

Results and Discussion

Water quality parameter

To obtain good growth survival rate in fishes under culture condition, the water quality parameters such as water temperature (°C), DO ($mg^{-1}l$), transparency (cm), pH, NH_3-N ($mg^{-1}l$), alkalinity ($mg^{-1}l$) etc. were optimum for rearing of *Labeo bata* fry. The water quality parameters recorded in different treatments during the experimental period were found within the productive ranges and transparency, dissolved oxygen, alkalinity had statistically significant effect among the three treatments. On the other hand temperature, ammonia nitrogen, pH had no significant differences (P<0.05) are presented in Table 3.

The environmental parameters exert in immense influence on the maintenance of a healthy aquatic environment and production of food organisms. Growth, feed efficacy and feed consumption of fish are normally governed by a few environmental factors (Breet, 1979; Fry, 1971). Among the three treatments the higher and lower temperature is (T_2) 32.00±0.12°C and (T_3) 31.90±0.09 °C. The temperature of the experimental ponds was within the acceptable range for nursery ponds that agreed well with Ali *et al.,* (1982) who stated that temperature range of 20.5-36.5°C in pond water. DoF (2013) recorded temperature ranges at 26-32.44°C in pond water. The present finding strongly agreed with Ling (1969) who recommended that the water temperature ranging from 22 to 32°C is suitable for fish growth, as better weight gain and lower feed conversion ratio were recorded during this period. The mean values of transparency significantly varied and highest transparency depth was recorded in T_1, possibly due to the reduction of the plankton population by higher density of fish (Haque and Ahmed, 1994; Rahman, 2005). Boyd (1982) recommended a transparency between15-40 cm as appropriate for fish culture. The present findings also agreed with Kohinoor (2000) who reported that the water transparency was 15-58 cm in fish ponds. Transparency was consistently higher in T_3, possibly due to the reduction of the plankton population by higher density of fish Haque *et al.* (1984). Fluctuations in dissolved oxygen concentrations might be attributed to the photosynthetic activity, alteration of cloudy and sunny weather of the monsoon and variation in the rate of oxygen consumption by fish and other aquatic organisms (Boyd, 1982). The dissolved oxygen in the morning was low in ponds stocked with a high density of fish compared to ponds stocked with a low density. However the level of dissolved oxygen was within the acceptable range in all the experimental ponds. Hussain (2004) and Nirod (1997) stated that dissolved oxygen ranging from 2.0-8.0 and 3.4 to 8.97 $mg^{-1}l$ in fish culture pond which were more or less similar to the present study. The present finding more or less agreed with Boyd (1998) who suggesting to keep the ammonia nitrogen value in fish pond as less than 0.1 $mg^{-1}l$. The concentration of ammonia-nitrogen observed from the experimental ponds is lower than that was recorded by Kohinoor *et al*. (2001) and Jena *et al*. (2007). However, the present level of ammonia-nitrogen content in the experimental ponds is not toxic to the fishes (Kohinoor *et al*., 1998). During experimental period pH values of most of the ponds were slightly alkaline which indicated a good pH condition for fish culture. The acceptable range required for fish culture is 6.0-8.0 (Buttner, 1993) in ponds. DoF (2008) recorded suitable pH ranges 5.66-7.44 in pond water. The findings also strongly agreed with Boyd and Faust (1992) who reported that the optimum pH range 7.5-8.5 is suitable for fish growth. The mean value of alkalinity significantly varied and this finding strongly agreed with Hossain and Bhuiyan (2007) who reported the alkalinity of pond water as 81.25 to 147.5 $mg^{-1}l$. The mean value of alkalinity similar with Alkalinity levels in the present study indicate productivity of the ponds was medium to high (Boyd, 1982; Jhingran, 1991; Rahman *et al*., 2009). Higher total alkalinity values might be due to higher amount of lime doses during pond preparation and frequent liming during the experimental period (Boyd, 1982; Jhingran, 1991).

Growth performance

Weight gain (gm), SGR (%, bwd^{-1}), survival rate (%) and prodction ($kg^{-1}ha^{-}2\ months^{-1}$) are shown in Table 3. Sampling was done on the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} fortnightly for three treatments T_1, T_2 and T_3 respectively. At the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} fortnight the growth performance such that the highest weight gain (g) and SGR (%, bwd^{-1}) was recorded in T_1 and lowest was found in T_3 which are shown in Fig. 1 and Fig. 2.

Ellis *et al*. (2002) expressed that stocking density is an important factor for fish welfare, but cannot be seen in ratio separation from other environmental factors. To achieve desirable size fish at harvesting must regulate stocking density (Feldlite and Milstein, 2000). These factors can be easily measurable and can be useable as an indicator of population stress (Sloman and Armstrong, 2002).

Table 3. Variations in mean values of physico-chemical characteristics under different treatments during the study period

Parameters \ Treatments	T_1	T_2	T_3
Water temperature (°C)	31.95±0.09^a	32.00±0.12^a	31.90±0.09^a
Transparency (cm)	34.77±0.28^a	31.85±0.08^b	28.97±0.09^c
DO ($mg^{-1}l$)	6.30±0.12^a	5.97±0.07^b	5.45±0.08^b
pH	7.76±0.09^a	7.74±0.04^a	7.57±0.07^a
Alkalinity ($mg^{-1}l$)	120.20±0.64^a	99.36±0.45^b	96.47±0.93^c
NH_3-N ($mg^{-1}l$)	0.12±0.01^a	0.13±0.02^a	0.15±0.03^a

Figures in a row bearing common letter(s) do not differ significantly ($p<0.05$)

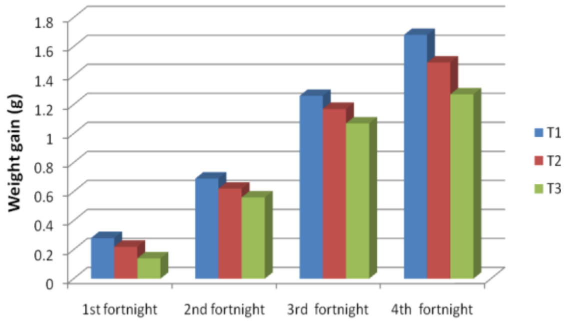

Fig. 1. Variations in the mean weight gain (g) values of fish growth performances under different treatments during study period

Growth performances (final weight, weight gain and specific growth rate) of fingerlings of *L. bata* was significantly higher in T_1 where the stocking density of fry (123,500 ha^{-1}) was low compared to those of T_2 (148,200 ha^{-1}) and T_3 (172,900 ha^{-1}) although same food was applied in all the treatments at an equal ratio. The lowest stocking densities provide more space, food and less consumption, which were reported by various authors like Ahmed (1982); Haque *et al.* (1984) and Narejo *et al.* (2005). The low growth rate of fry and fingerling in treatment T_2 and T_3 appeared to be related with higher densities and increased competition for food and space (Islam *et al.*, 2002; Rahman and Rahman, 2003). High density of fingerlings in combination with increased concentration of food in the rearing system might have produced a stressful situation and toxic substance which could be the probable cause for poor growth in treatment T_2 and T_3 (Haque *et al.*, 1984; Rahman and Rahman, 2003).

The mean values of final weight of *L. bata* significantly varied from 3.20±0.03 g (T_3) to 4.06±0.06g (T_1). Similar type study was conducted by Rahman and Rahman (2003) on calbasu *(Labeo calbasu)* spawn where they found mean final weight of 134.61±0.35, 119.83±0.17 and 99.30±0.47 mg were obtained at 6, 8 and 10 million spawn^{-1}/ha stocking densities, respectively. Chakraborty and Mirza (2007) found highest weight gain on endangered *L. bata* (6.76 ± 0.69 g) was observed in treatment T_1 (density .60 million hatchlings^{-1}/ha) and lowest (3.13 ± 0.34 g) in treatment T_3 (density 1 million hatchlings/ha). This finding more or less similar with Alim *et al.* (2003). The mean values of weight gain (g) of *L. bata* significantly varied from 3.05±0.03 (T_3 with high density) to 3.91±0.06 (T_1 with low density). Similar type study was conducted by Niazie *et al.* (2013) who found that statistically significant difference was observed between growth rate of different densities in Gold fish, as with shown significant increasing density (density of 15), growth rate was significantly lower ($p<0.05$, 15.15±0.67), but significant ($p<0.05$) difference were not found between low density of 6, 9 (control) and 12 ($p<0.05$). The mean values of SGR of *L. bata* varied from 5.98±0.2 (T_2) to 6.86±0.03 (T_1). This finding is more or less similar with the findings of Chakraborty and Mirza (2007) found endangered *L. bata* in treatment T_1 (density 0.60 million hatchlings^{-1}/ha) produced significantly higher specific growth rate (3.53 ± 0.23) than treatment T_2 (density 0.80 million hatchlings/ha) and T_3 (density 1.00 million hatchlings-^{1}/ha). The finding also strongly agreed with Niazie *et al.* (2013) that growth rate was significantly decreased with increasing the density (density of 15), on the other hand, specific growth rate was significantly increased with decreasing density (density of 6). Also, Trenzado *et al.* (2006) and Imanpoor *et al.* (2009) obtained similar results in rainbow trout (*Oncorhynchus mykiss*) and in common carp (*Cyprinus carpio*), respectively. These results are consistent to findings of Mohseni *et* *al*. (2007) on *Huso huso* fry. The mean value of survival rate of *L. bata* significantly varied from 61.00±0.58% (T_3) to 70.33±0.88 % (T_1) which is compared with the values reported by Chakraborty and Mirza (2007) who found similar survival rate (80.15 ± 0.85%) of endangered *L. bata* at lower density. Hossain *et al.* (2007) revealed that local sarpunti *(P. sarana)* larvae obtained survival rate 77.6±1.4%, 56.1±2.4% and 61.3±1.2% in T_1, T_2 and T_3 respectively and the survival rate was lower in T_2 and T_3 than that of in the present study. Samad *et al*. (2014) also found highest survival rate (75.17±0.48) and lowest survival rate (65.77±0.28) in nursery ponds for fry rearing of *L. bata*. The reasons for reduced survival rates in these treatments were probably due to higher stocking density of fry as well as competition for food and habitat in the experimental ponds (Haque *et al*., 1984; Rahman and Rahman, 2003; Rahman *et al*., 2009). Jannat *et al.*, 2012 found on *Anabas testudineus* the survivality higher in low density (350 ind. dec^{-1}) 96.57% and lower in high density (550 ind. dec^{-1}) 94.72%. Chakraborty *et al.* (2003) studied the nursery rearing of *P. sarana* in relation to varying stocking density for a period of 6 weeks in earthern ponds. The ponds were stocked at the density of 0.7 (T_1), 0.8 (T_2) and 0.9 (T_3) million individuals^{-1}ha and the highest survival and growth performances of the fry was found in T_1. Fish production in treatment T_1 (352.66±4.42 kg^{-1}ha) in the present study was higher than treatment T_2 (348.00±1.80 kg^{-1}ha) and T_3 (337.50±3.1 kg^{-1}ha). Rahman and Rahman (2003) was conducted an experiment in six nursery ponds of 40 m^2 each with 4 days old calbasu *(Labeo calbasu)* spawn at three stocking densities viz. 6, 8 and 10 million/ha where the gross and net productions of fry were higher in ponds stocked with 8 million spawn/ha. Data on economics indicated that the treatment T_1 was more profitable than that of treatment T_2 and T_3. Cost-benefit ratio (CBR) in treatment T_1 (1:1.78) in the present study was higher than T_2 (1:1.25) and T_3 (1:1.06) which was more or less similar to the findings of Khan (2003). Chakraborty and Mirza (2007) found in endangered *L. bata* the net benefits of fingerlings were obtained at a density of 0.60 million hatchlings ha^{-1}. Finally, it can be concluded that the present study revealed that the survival, growth and production of *L. bata* fingerlings were inversely related to the stocking densities of fry. Under the prevailing situation, production of quality seeds through application of our present findings might have important implications towards the protection of snakehead from extinction as well as for its conservation, stock enhancement and rehabilitation.

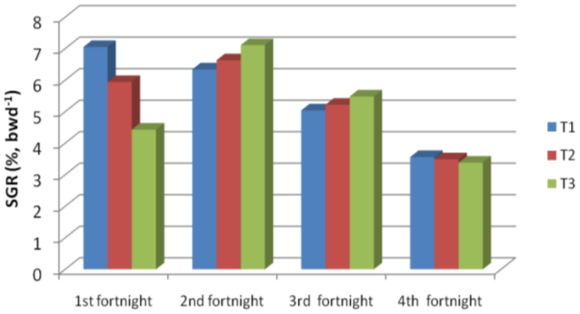

Fig. 2. Variations in SGR (%, bdw^{-1}) of fish growth performances under different treatments during study period

Variations in the mean values of fish growth performances, survival rate (%), production (kg^{-1}ha) and CBR under different treatments during the study period are presented in Table 4. The best growth performance and CBR was recorded in T_1 and lowest was found in T_3.

Table 4. Variations in the mean values of fish growth performances and survival rate, production, total cost, benefit and CBR under different treatments during the study period (60 days)

Treatments / Parameters	T_1	T_2	T_3
Mean initial weight (g)	0.15 ± 00^{a}	0.15 ± 00^{a}	0.15 ± 00^{a}
Final weight (g)	4.06 ± 0.06^{a}	3.65 ± 0.04^{b}	3.20 ± 0.03^{c}
Weight gain (g)	3.91 ± 0.06^{a}	3.49 ± 0.04^{b}	3.05 ± 0.03^{c}
SGR (%, bwd^{-1})	5.49 ± 0.02^{a}	5.32 ± 0.02^{b}	5.09 ± 0.02^{c}
Survival rate (%)	70.33 ± 0.88^{a}	64.33 ± 0.33^{b}	61.00 ± 0.58^{a}
Production (kg/ha/2 months)	352.66 ± 4.42^{a}	348.00 ± 1.80^{ab}	337.50 ± 3.1^{b}
Total cost (Tk./decimal)	1750	1880	2005
Benefit (Tk./decimal)	3115	2340	2120
CBR	$1:1.78^{a}$	$1:1.25^{b}$	$1:1.06^{c}$

Figures in a same row having same superscript have no significant different (P<0.05)

Conclusions

From the study, it is clear that the growth and survival rate of *Labeo bata* fry is faster by using low density. Based on the results of the experiment, it can be concluded that the culture of *L. bata* in nursery phase in one stage rearing with the application of appropriate density to get higher benefit in the short period of time for fingerlings production. The government of Bangladesh and NGO's needs to come forward to provide technical support as well as economic support to the nursery owners to solve their problems. If these are possible, then we can hope to get far greater fry production from nursery ponds, which increases the national economy of our country.

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References

AOAC. (Association of Official Analytical Chemists). 1990. Official methods of Analysis Association of Official Analytical Chemists. 15th edition. Ed. Helrich, K. Published by the Association Official Analytical Chemists,Inc., Suite,400, Arilington, Virginia, 2:685-1298.

Ahmed, G. U. 1982. Intensive culture of *Labeo rohita* (Hamilton) in floating ponds with special reference to different stocking .M. Sc. Thesis, Depertment of Fisheries Biology and Limnology, Bangladesh Agricultural University, Mymensingh.

Ali, S.; Rahman, A. K. A.; Patwart, A. K. and Islam, K. H. R. 1982. Studies on the diurnal variations in physicochemical factors and zooplankton in a fresh water pond. *Bangladesh. J. Fish*., 2-5 (1-2):15-23.

Alim, M. A.; Wahab, M. A.; Roy, N. C.; Raihan, A.; Mohiuddin, M. and Milstein, A. 2003. Pond dynamics in carp-small fish polyculture. In: Wahab, M.A., Thilsted, S.H. and Hoq, M.E. (eds.), Small Indigenous Species of Fish in Bangladesh. Technical Proc. of BAU-ENRECA/DANIDA Workshop on Potentials of Small Indigenous Species of Fish (SIS) in Aquaculture & Rice-field Stocking for Improved Food & Nutrition Security in Bangladesh. 30-31 October 2002, BAU, Mymensingh, Bangladesh. Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.166 p.

Boyd, C. E. 1982. Water quality management for pond fish culture. Elsevier Science Publishers, Amsterdam, The Netherlands. 318p.

Boyd, C. E. 1998. Water quality for fish pond. Aquaculture Research and Development series no. 43. Auburn University, Alabama, USA. 37p.

Boyd, C. E. and Faust, A. W. 1992. Pond monitoring and management. In: Faust A. W. and L. J. Lester (eds.). Marine Shrimp Culture: Principles and Practices. Elsevier, Amsterdam. pp. 497-508.

Brett, J. R. 1979. Environmental factors and growth. In: W. S. Hoar, D. J. Randall and J. R. Brett, eds. Fish Physiology, vol. 6, Environmental relations and behavior. Academic Press, New York. pp. 599-677.

Buttner, J. K. 1993. An Introduction to Water Chemistry in Freshwater Aquaculture. NRAC Fact Sheet No. 170-1993.4.p.

Backiel. T. and Le Cren, E. D. 1978. Some density relationship for the population parameters. In: S. D. Gerking (Editor). *Ecology of freshwater fish production*, Blackwell Scientific Publications. Oxford, pp. 279-302.

Chakraborty, B. K. and Mirza, M. J. A. 2007. Effect of stocking density on survival and growth of endangered bata, (*Labeo bata*) in nursery ponds. *Aquaculture*, 265:156-162.

Chakraborty, B. K.; Miah, M. I.; Mirza, M. J. A. and Habib, M. A. B. 2003. Rearing and nursing of local sarpunti, *P. sarana* (Hamilton) at different stocking densities. Pakistan. *J. Biol. Sci.,* 6 (9):797-800.

DoF. 2013. *Matsha Pakkah Shankalan-2013*. Department of Fisheries, Ministry of Fisheries and Livestock, Government of the Peoples Republic of Bangladesh. pp. 79–81.

Ellis, T.; B. North, A. P.; Scott, N. R.; Bromage, M. P. and Gadd, D. 2002. The relationships between stocking density and welfare in farmed rainbow trout. *J. of Fish Biol*., pp. 493-531

Feldlite, M. and Milstein, A. 2000. Effect of density on survival and growth of cyprinid fish fry. *Aquaculture International*, 7:399-411.

Fry, F. E. 1971. The Effect of environmental factors on the physiology of fish. Pages 1-98 in W.S. Hoar, D.J. Randall, and J.R. Brett, eds. Fish Physiology, vol. 6, Environmental relations and behavior. Academic Press, New York.

Haque, M. T. and. Ahmed, A. T. A. 1994. Spawning periodicity of two Indian major carps, *Labeo rohita* (Ham.) and *Cirrhina mrigala* (Ham.). *Bangladesh J. Zool*., 21(2):9–26.

Haque, M.; Islam, M. A.; Ahmed G. U. and. Haq, M. S. 1984. Intensive culture of java tilapia (*Oreochromis mossambica*) in floating pond at different stocking density. *Bangladesh J. Fish.,* (7): 55-59.

Hossain, M. A. and Bhuiyan, A. S. 2007. Study of water quality in fish pond water under the red soil zone of northern Bangladesh. *J. Subtrop. Agric. Res. Dev*., 5(5):347-351.

Hossain, M. I.; Khan, M. M. R.; Siddik, M. A. B. and Hasan, M. 2007. Effects of feed on survival and growth of local sarpunti *(P. sarana, Hamilton)* fry in glass aquaria. *J. Bangladesh Agril. Univ.,* 5(2):1-376.

Hussain, M. G. 2004. Farming of Tilapia: Breeding plans, mass seed production and aquaculture techniques. Published by Habiba Akter Hussain, Mymensingh, Bangladesh. pp. 5- 149.

Hussain, M. G. and Mazid, M. A. 2001. Genetic improvement and conservation of carp species in

Bangladesh. BFRJ and ICLARM.74.p.

Imanpoor, M. R.; Ahmadi, A. R. and Kordjazi, M. 2009. Effects of stocking density on survival and growth indices of common carp (*Cyprinus carpio*). *Iranian Scientific Fisheries Journal.,* 18(3):1-9.

Islam, M. S.; Dewan, S.; Hussain, M. G.; Hossain, M. A. and Mazid, M. A. 2002. Feed utilization and wastage in semi-intensive pond culture of mahseer, *Tor putitora* (Ham.). *Bangladesh J. Fish. Res*., 6:1-9.

IUCN, Bangladesh, 2000. Red Book to Threatened Fish of Bangladesh. The world conservation Union Appendix 1. pp. 31-61

Jannat, M. K..; Rahman, M. M.; Bashar, M. A.; Hasan, M. N.; Ahamed, F. and Hossain, M. Y. 2012. Effects of Stocking Density on Survival, Growth and Production of Thai Climbing Perch (*Anabas testudineus*) under Fed Ponds. *Sains Malaysiana,* 41(10):1205–1210

Jena, J. K.; Das, P. C.; Das, R. and Mondal, S. 2007. Performane of Olive barb, *Puntius sarana* (Hamilton) in fingerling rearing with rohu, *Labeo rohita* (Hamilton) and mrigal, *Cirrhinus mrigala* (Hamilton). *Aquaculture*, 265:305-308.

Jhingran, V. G. and Pullin. R. S. V. 1985. A Hatchery Manual for the Common, Chinese and Indian Major Carps. ICLARM Studies and reviews II. ICLARM Manila, Philippines, pp.71-191

Jhingran, V. G. 1991. A Hatchery Manual for the Common, Chinese and Indian Major Carps. ICLARM Studies and reviews II. ICLARM Manila, Philippines, pp.71-191

Khan, M. S. R. 2003. Culture of *Pangasius sutchi* (Flower) in ponds and cages. M.S. Thesis, Department of Aquaculture, Bangladesh Agricultural University, Mymensingh, 62 p.

Kohinoor, A. H. M. 2000. Development of culture technology of three small indigenous fish mola (*Amblypharyngodon mola*), punti (*Puntius sophore*) and chela (*Chela cachius*) with notes on some aspects of their biology. Ph.D. dissertation. Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh, pp. 91-102.

Kohinoor, A. H. M.; Islam, M. L.; Wahab, M. A. and Thilsted, S.H 1998. Effect of mola (*Amblypharyngodon mola* Ham.) on the growth and production of carp polyculture. *Bangladesh .J. Fish.,* 2:119-126.

Ling, S. W. 1969. Methods of rearing and culturing *Machrobrachium rosenbergii*. *FAO Fish. Rep.* 57, pp. 589-606.

Mohseni, M.; H. Pourali, F.; Sajadi, M.; and Agh Toman, V. 2007. Determine the appropriate density of culturing on *Huso huso*. *Iran Aquaculture of Journal*, 15: 129-138.

Mollah, M. F. A. 1985. Effects of stocking density and water on growth and survival of Freshwater catfish (*Clarion macrocephulus*) larvae. *Indian J. Fish.,* 32: 1-17.

Moyle, P. L. and Leidy, R. A. 1992, Loss of biodiversity in aquatic ecosystem: evidence from fish fauna. In: Fielder, P.P., Jani, H.L. (Eds.), Conservation of Biology: the Theory and Practice of Nature Conservation, Preservation and Management. Chapman and Hall, New York. p. 562

Niazie, E. H. N.; Mohamadreza I.; Vahid T. and Vahid Z. 2013. Effects of Density Stress on Growth Indices and Survival Rate of Goldfish. *Global Veterinaria*. 10 (3):365-371.

Nirod, D. B. 1997. Effect of stocking density on the growth and production of mola (*Amblypharyngodon mola*). M.S. Thesis, Department of Fisheries Management, BAU, Mymensingh, p. 75

Rahman, M. M. and Verdegem, M. C. J. 2010. Effects of intra- and interspecific competition on diet, growth and behaviour of *Labeo calbasu* (Hamilton) and *Cirrhinus cirrhosus* (Bloch). *Applied Animal Behavioural Science*, 128:103-108.

Rahman, A. K. A. 2005. Freshwater fishes of Bangladesh, 2nd ed. Zoological society of Bangladesh, Department of Zoology, University of Dhaka, 394 p.

Rahman, M. A.; Zaher, M. and Azimuddin, K. M. 2009. Development of fingerling production techniques in nursery ponds for the critically endangered reba carp, *Cirrhinus ariza* (Hamilton, 1807). *Turk. J. Fish. Aquat. Sci*., 9:165-172.

Rahman, M. M.; Kadowaki, S.; Balcombe, S. R. and Wahab, M. A. 2010. Common carp (*Cyprinus carpio* L.) alters its feeding niche in response to changing food resources: direct observations in simulated ponds. *Ecological Research*, 25:303-309.

Rahman, M. R. and Rahman, M. A. 2003. Studies on the growth, survival and production of calbasu, *Labeo calbasu* (Ham.) fry at different stocking densities in primary nursing. *Bull. Coll. Sci.*, (University of the Ryukyus) 76:245-255.

Samad, M. A.; Jasmine S.; Mosaddequr, M. R.; Jahan S.; Selim, R. M.; Istiaque, M. H. and Yeamin, M. H. 2014. Effect of Feeds and Fertilizers on Growth and Survival Rate of Threatened *Labeo bata* Fry in Earthen Nursery Ponds. *World Journal of Zoology,* 9 (4):244-249

Trenzado, C. E.; Morales, A. E. and Higuera, M. 2006. Physiological effects of crowding in rainbow trout (*Oncorhynchus mykiss*) selected for low and high stress responsiveness. *Aquaculture*, 258:583-593.

Weatherley, A. H. 1976. Factors affecting maximization of fish growth. *Journal of the Fisheries Research Board of Canada*, 22:1046-1048.

Zar, J. H. 1984. Biostatistics. Prentice–Hall, Inc. Englewwood Clitts New Jercey, USA. 718 p.