Introduction

Bangladesh is considered one of the most suitable countries in the world for giant freshwater prawn (M. rosenbergii) (De Man 1879) farming, because of its favorable resources and agro climatic conditions. M. rosenbergii has significant aquaculture potential and is commercially cultured (Akand and Hasan 1992; Ahmed 2001; Muir, 2003). Freshwater prawn (M. rosenbergii) farming is currently one of the most important sectors of the national economy and during the last two decades, its development has attracted considerable attention because of its export potential. The prawn and shrimp sector as a whole is the second largest export industry after readymade garments. Five biggest producers of galda (M. rosenbergii) are China (48%), Bangladesh (37%), Taiwan (6%), Thailand (6%) and India (1%) (Khondaker, 2008). According to FAO (2000), cited by Valenti (2002), world production of freshwater prawn between 1990 and 2000 increased from 21,000 to 118,500 tons per year, which corresponds to an increase of about 500%. In the late 1980s, this farming practice began to be adopted widely in the original location in Khulna area, where prawns were grown along with carps and rice (Kamp and Brand, 1994). The expansion of prawn cultivation has been dramatic, and since 1990 adoption has accelerated, spreading to other southwest districts such as Khulna, Satkhira and Jessore. Since the early 1990s prawn farming has become one of the financially most attractive investment opportunities in these areas (Ahmed, 2001). Bangladesh has huge fresh water areas where galda (M. rosenbergii) can be cultured in ponds under polyculture system or with fish and rice in gher system. In year 2002-2003, galda (M. rosenbergii) contributed 18% in export income but in 2006-2007 it was increased to 24% (Khondaker, 2008). In 2006-2007, Bangladesh earned 6.25 crore dollar by exporting galda (DoF, 2008). A recent estimate has shown that 6,00,000 ha fresh water area can be used for galda farming in Bangladesh (Khondaker, 2008). Extensive production typically use slightly modified versions of traditional methods and are called low-density (10,000 to 18,000 post larvae ha.year\(^{-1}\) and low-input system. The system relies mainly on natural productivity (e.g., planktons and benthos) of the pond, but organic and inorganic fertilizers and feeds are used to promote the growth of prawn. Extensive feeding practices generally use supplementary diets consisting of a mixture of locally available feed ingredients, such as rice bran, wheat bran, oil cake and fish meal. Semi-intensive operations practice intermediate levels of stocking (18,000-30,000 post larvae ha./year) and other inputs. Farms with semi-intensive feeding practices depend on commercially manufactured pelleted feeds. The main objectives in this study were to evaluate the growth, production, economic returns under different levels of stocking densities for sustainable M. rosenbergii culture in south-west coastal region of Bangladesh.

Methodology

Time and location of the study

The experiment was conducted for a period of six months (April’2012 to September’2012) in the farm of M. rosenbergii at Tarokhada upazilla is Khulna, Bangladesh. The culture practice was mainly started in April and saline water was introduced from the river.
Experimental design
The current research was carried out under three treatments (T1, T2, and T3), each with three replications. In each treatment, the stocking density of M. rosenbergii juvenile was varied in different farms. T1: The farm size was 50 decimal and stocking density was 10/m². T2: The farm size was 50 decimal and stocking density was 12/m². T3: The farm size was 50 decimal and stocking density was 14/m².

Pond preparation
The ponds used in the present study are located at Terokhada upazilla of Khulna district which is located in south-west coastal region of Bangladesh. Initially the farms of the present study were allowed to dry and crack to increase the capacity of oxidation of hydrogen supplied and to eliminate the fish eggs, crab larvae, other predators and undesirable organisms. Then farm bottom was scraped 2 to 4 cm by using a tractor blade to avoid topsoil. Subsequently the farm bottom was ploughed horizontally and vertically a depth of 30 cm to remove the obnoxious gases, to oxygenate the bottom soil and to increase the fertility. The average pH was calculated and required amount of lime was applied to maintain the optimum pH after three days the water color turned to light green. Healthy M. rosenbergii seeds were purchased from a commercial hatchery and stocked in the farm.

Stocking
Fry are normally transported in plastic bags and filled up with oxygenated water and then placed inside the boxes. Five days after fertilization seeds were stocked. Stocking density of prawn in culture was 10, 12 and 14/m² for treatments T1, T2 and T3 respectively.

Post stocking management
The pond was fertilized with Urea, T.S.P. and Cow dung at the rate of 100g, 50g and 3kg/dec. respectively as periodical dose and it was done once in month. During the culture period, small amount of supplementary feeds- mustard oil cake (20%), wheat bran (20%), rice bran (20%) and fish meal (25%) and maize bran (15%) were used at a regular basis. For maintaining the suitable water depth for fish in the pond, water was supplied regularly from the deep tube well.

Table 1. Composition of the formulated diet

| Name of ingredient | % of ingredient |
|--------------------|----------------|
| Fish meal          | 25.0           |
| Mustard oil cake   | 20.0           |
| Maize bran         | 15.0           |
| Rice bran          | 20.0           |
| Wheat bran         | 20.0           |

Feed ingredients were mixed to make ball and then fish were feed with ball twice a day at the rate of 5% of the total body weight.

Table 2. Proximate composition of feed used in the experiment

| Components | Diets |
|------------|-------|
| Moisture   | 9.6%  |
| Crude protein | 28.5% |
| Crude lipid | 13.6% |
| Crude fiber | 14.5% |
| Ash        | 7.55% |
| NFE        | 26.25% |

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

Study of water quality (physico-chemical) parameters
A series of physico-chemical parameters viz., water temperature, water transparency, hydrogen ion concentration (pH), dissolved Oxygen (DO), were determined twice a week.

Growth performance
The growth performance was calculated through the following equations-
Mean weight gain (g) =Mean final weight- Mean initial weight
Weight gain (g) = Mean final weight (g) - Mean initial weight (g)

SGR (% bwd⁻¹) = \( \frac{\text{In final weight} - \text{In initial weight}}{\text{Culture period in days}} \times 100 \) (Brown, 1957)

Survival rate (%) = \( \frac{\text{Number of fish harvested}}{\text{Number of fish stocked}} \times 100 \)

Production= No. of fish harvested x final weight of fish.

Economical analysis
The net benefit was calculated by using the following formula-
Net benefit = total return — total cost

Cost benefit ratio was calculated as- \( \frac{\text{Net benefit}}{\text{Total investment}} \)

Statistical analysis
Water quality, fish production, and economic parameters were subjected to one way ANOVA (Analysis of Variance) using computer software SPSS (Statistical Package for Social Science, version-15). The mean values were also compared to see the significant difference from the Duncan Multiple Range Test (Zar, 1984).

Results and Discussion

Water quality parameters
The mean values of different water quality parameters in different months are presented in table- 3. The mean value of water temperature during the study period was found to be ranged from 28.88±0.16 (T1) to 32.32±0.97 (T3) °C. Water temperature of 25 to 32°C is considered suitable for culture (Boyd and Zimmermann, 2000). Therefore, the mean water temperature found during the study was similar with the recommended values by
Boyd (1998); Hossain and Bhuiyan (2007) stated that water temperature for prawn culture were 29.72±30.49 °C and 20.4±33.2 °C, respectively which are more or less similar to the present findings.

The mean value of water transparency was differed from 29.3±0.345 (T1) to 32.7±0.28 (T3) cm. Rai and Rathore (1993) stated that low values of water transparency which could be attributed to rich phytoplankton density and higher budgets of suspended and particulate matter. This finding range of secchi disc reading were found favorable for culture and this was strongly agreed with Wahab et al. (1995) who recommended the secchi disc readings between 26 to 50 cm for pond.

The mean value of dissolved oxygen during the study period was varied from 5.33±0.184 (T1) to 6.17±0.13 (T2) mg l\(^{-1}\). This value is more or less similar to the findings of Hossain and Bhuiyan (2007), who recorded the DO value of 3.87 to 5.85mg l\(^{-1}\) Chakraborty and Mirza (2007) recorded DO value 3.88 to 5.22 mg l\(^{-1}\) while Kohinoor (2000) measured dissolved oxygen 2 to 7.4 mg l\(^{-1}\) in nursery pond. So, the level of dissolved oxygen (DO) was within the acceptable range in all the experimental ponds for prawn culture.

The mean value of pH during the study period was varied from 6.52±0.205 (T2) to 6.79±0.025 (T1). pH values ranging from 6.5 to 9.0 were observed for pond culture (Swingle, 1967). The pH values of the present study are also agreed with the findings of Kohinoor et al. (1994); Chakraborty and Mirza (2007); Hossain et al. (2013). Salinity is the important physico-chemical factor of the prawn farm. This study showed that the salinity varied from 13.75±0.16 (T2) to 15.22±0.20 (T1). The optimum salinity range (13-15%) for M. rosenbergii larvae (Fujimura and Okamoto, 1972; Ling, 1969). Goodwin and Hanson (1975) who indicated that juvenile M. rosenbergii grows more rapidly in fresh water or slightly brackish water (≤5 %) when compared to more brackish water of up to 15 %. So, the level of salinity was within the acceptable range in all the experimental ponds.

**Growth performance**

Mean growth performance of prawn (Juvenile) of three different treatments after 6 months are presented in table-4. Initial weights of three different treatments of M. rosenbergii were 0.129 ± 0.014g, 0.130 ± 0.005g and 0.129 ± 0.014g respectively. Daniels et al. (1998) stated that freshwater prawn (M. rosenbergii) Juvenile stocked in the nursery was about 0.11±0.058g and upper size population are 0.25±0.086g. Smith et al. (2009) reported that the stocked prawn initial weight is 0.006 to 2.66 g. So, these findings are more or less similar of the present study.

Final weight of present study of three treatments of M. rosenberri were 59.93±1.45g, 51.30±1.76g and 48.93±1.45g respectively. Abramo et al. (2007) reported that weight at harvest range from 15.0 to 44.3g and decrease with increasing stocking density. The final weight of the present study of different treatments are more than these findings. Similar type study was conducted by Nabil et al. (2013) who observed that increasing the stocking density 50 to 100 animalm\(^{-2}\) decreased the final weight of M. rosenbergii. Weight gain of three treatments of Macrobrachium rosenbergii were 59.79±0.15g, 50.68±0.14 and 48.78±0.12 respectively shown in table-4. Willis et al. (2009) stated that Juvenile grew to a weight of 43.25g after 6 months if it stocked 5.10 and 20m\(^{2}\). Hossain and Akteruzzaman (2007) found that the weight gain of prawn was 88.1g in polyculture. Here, the weight gain of M. rosenbergii are more than their findings, though here we stocked 10,12 and 14m\(^{2}\).

SGR (%. bwd\(^{-1}\)) of M. rosenbergii were 3.39±0.4, 3.16±0.9 and 3.26±0.16% in T1, T2 and T3 respectively. Hossain and Akteruzzaman (2007) found that the SGR (%. bwd\(^{-1}\)) of prawn was 2.0% in polyculture. Here, the SGR (%. bwd\(^{-1}\)) of M. rosenbergii are more than their findings, though here stocked 10,12 and 14m\(^{2}\). Similar type study was conducted by Nabil et al. (2013) who observed that increasing the stocking density 50 to 100 animal/m\(^{2}\) decreased the SGR (%. bwd\(^{-1}\)) 3.287±0.15 to 2.753±0.12 respectively of M. brachium which is closely similar to the present study.

Survival rate of present study of three treatments of M. rosenbergii was 75.02±0.577, 66.66±0.88 and 61.01±0.577 respectively. Abramo et al. (2007) reported that after grow out periods survival rate ranging from 54.3 to 89.9%. Rouse et al. (2007) reported that survival rate of prawn in tilapia fry ponds was 65% compared to 75% and 91% respectively. Similar type study was conducted by Nabil et al. (2013) who observed that increasing the stocking density 50 to 100 animal/m\(^{2}\) decreased survival rate 77 to 57% respectively of M. brachium. Survival rate also increased in low density culture ponds in coastal region. Production of M. rosenbergii of present study in three treatments were 2302.04 (kg ha\(^{-1}\)month\(^{-1}\)) 1768.52 (kg ha\(^{-1}\)6months\(^{-1}\) ) and 1393.08 (kg ha\(^{-1}\)6months\(^{-1}\) ) respectively where stocked Juvenile 10, 12, 14m\(^{2}\) of T1, T2 and T3 treatment. Siddiqui et al. (2007) reported that total yield increased low density per m\(^{2}\) and decreased high densities respectively. These findings similar to the present study. Willis et al. (2009) reported that the production of 2278.61 kg ha\(^{-1}\) occurred in ponds stocked with 20m\(^{2}\). But present research result shows that maximum yield comes from T1 treatment where stocked with 10m\(^{2}\).

The economics of different treatments are shown in table-5. A simple economics analysis was performed to estimate the net profit derived from a monoculture of M. rosenbergii at different stocking densities using a feed for 6 months. The major variable input costs were mainly due to feed, fertilizer, seed, labour and irrigation. The highest net profit was estimated in treatment T1 (801900±37340) while the moderate was found in treatment T2 (494000±5930).
Table 3. Variation in the mean values of water quality parameters in different treatment during the study period (T₁, T₂, T₃)

| Parameter          | T₁            | T₂            | T₃            |
|--------------------|---------------|---------------|---------------|
| Temperature (°C)   | 31.32±0.97a   | 28.88±0.161a  | 30.10±0.35a   |
| DO (mg/l)          | 6.17±0.13a    | 5.66±0.141b   | 5.33±0.184b   |
| Salinity           | 15.22±0.20a   | 13.75±0.16b   | 13.96±0.21b   |
| pH                 | 6.79±0.18a    | 6.52±0.205a   | 6.79±0.23a    |
| Transparency (cm)  | 29.73±0.34b   | 32.70±0.28a   | 32.68±0.35a   |

P< 0.05; figures in a row bearing common letter do not differ significantly.

Table 4. Mean growth performance of prawn (Juvenile) of three different treatments after 6 months.

| Growth Parameter | T₁            | T₂            | T₃            |
|------------------|---------------|---------------|---------------|
| Initial weight   | 0.129±0.014a  | 0.130±0.005a  | 0.129±0.014a  |
| Final weight     | 59.93±1.45a   | 51.03±1.7a    | 48.93±1.45a   |
| Weight gain (g)  | 59.79±0.15a   | 50.86±0.11a   | 48.78±0.12a   |
| SGR (%)          | 3.39±0.4a     | 3.16±0.94a    | 3.26±0.16a    |
| Survival rate (%)| 72±3.4a       | 66.66±0.08a   | 61.01±0.57a   |
| Yield (kg/50dec./6month) | 466±3.21a | 358±404b | 282±1.52c |
| Yield (kg/hac/6month) | 2302.04 | 1768.52 | 1393.808 |

P< 0.05; figures in a row bearing common letter do not differ significantly.

Table 5. Economics of different treatments during the study period (T₁, T₂, T₃)

| Parameter          | T₁            | T₂            | T₃            |
|--------------------|---------------|---------------|---------------|
| Total cost (Tk/ha) | 656000±174    | 596120±452    | 549100±94     |
| Total Returns (Tk/ha) | 1492400±12  | 1078200±11   | 806480±91    |
| Net benefit (Tk/ha) | 801900±734   | 494000±593   | 288600±1320  |
| Cost benefit ratio | 1 : 1.8a     | 1 : 0.83a    | 1 : 0.49a    |

P< 0.05; figures in a row bearing common letter do not differ significantly.

Conclusions

This study was conducted on the growth performance of the most valuable export commodity, the freshwater prawn *Macrobrachium rosenbergii*. The maximum production was found in treatment T₁. This study indicates using less stocking density can be the important strategy to improve the *Macrobrachium rosenbergii* yield in fertilizer and feed based culture in ponds.

Acknowledgements

We express our gratitude to Department of Fisheries, Rajshahi University, Bangladesh for the facilities provided to carry out this research work.

References

Ahmed, N. 2001. Socio-economic aspects of freshwater prawn culture development in Bangladesh. PhD Thesis, Institute of Aquaculture, University of Stirling, Scotland, UK:41-61pp.

Akand, A. M. and Hasan M. R. 1992. Status of freshwater prawn (*Macrobrachium spp.*) culture in Bangladesh. In: Freshwater Prawns (ed. by E.G. Silas):33-41pp.

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

Boyd, C. and Zimmermann, S. 2000. Grow-out systems-water quality and soil management. *Blackwell Science*, Oxford, UK, PP. 221-238.

Bramo, J. M. H.; Randall, R. and Jeffrey, S. C. 2007. Production of the *Macrobrachium rosenbergii* stocked as Juveniles at different densities in temperate zone ponds. *World Aquaculture society*, (20):81-89pp.

Brown, M. E. 1957. Experimental studies on growth. In: *The physiology of fishes.* (Brown, M. E. edn.) 1. Academic press, New York, 361-400pp.

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

Danials, W. H. R.; Abramo, R. W.; Fondren, D. and Duran, 1998. Effects of stocking density and feed on pond production characteristics and revenue of harvested fresh water prawn *M. Rosenbergii*. *World Aquaculture society*, (26):38-47pp.

DoF. 2008. Report on Export Fishery Products in 2007. Fisheries Resources Suey System, Department of Fisheries (DoF), Ministry of Fisheries and Livestock, Dhaka, Bangladesh.

DoF. 2009. Development of Prawn: an attempt of Catalyst. Department of Fisheries (DoF), Ministry of Fisheries and Livestock, Dhaka, Bangladesh: 120pp.

FAO. 2000. Cultured Aquatic Species information *Macrobrachium rosenbergii* (De Man, 1879). Food and Agriculture Organization of the United Nation. On-line document, Retrieval with Windows Explorer Version 5.5, retrieved on January 15, 2009.

Fujimura, T. and Okamoto, H. 1972. Notes on progress made in developing a mass culturing technique for *Macrobrachium rosenbergii* in Hawaii. IN: *Coastal aquaculture in the Indo-Pacific Region*, edited by
T. V. R. Pillay. West Byfleet, England, Fishing News Books Ltd. for IPFC/FAO, pp. 313-27.

Goodwin, H. L. and Hanson, J. A. 1975. Aquaculture of the freshwater prawn Macrobrachium species. The Oceanic Institute, Waimanalo. Hawaii.

Hossain, M. A. and Akhteruzzaman, M. 2007. Effect of stocking density on the growth performance of prawn (Macrobrachium rosenbergii) and carp under polyculture system in Northern Bangladesh. Mt. J. Sustain. Agric. Tech., 3(5):18-22.

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

Hossain, M. I.; Ahmed, S.; Reza, M. S.; Hossain, M. Y.; Islam, M. N.; Ara, J. and Islam, R. 2013. Effects of organic fertilizer and supplementary feeds on growth performance of silver carp (Hypophthalmichthys molitrix) and bata (Cirrhinus reba) fry in nursery ponds. International Journal of Research in Applied, Natural and Social Sciences, 1:117-124.

Kamp, K. and Brand, E. 1994. Greater options for local development through aquaculture. CARE GOLDA Project, Dhaka, Bangladesh pp 56.

Khondakar, H. R. 2008. Freshwater Prawn Culture Extenuation Project. Prawn Hatchery Fish Seed Multiplication Farm, Gallamari, Khulna, Bangladesh. Training program under the Department of Fisheries, 25th May- 30th June, 2008. pp 104.

Kohinoor, A. H. M.; Haque, M. Z.; Hussain, M. G. and Gupta, M. V. 1994. Growth and survival of Thai punti, Puntius gonionotus (Bleeker) spawn in nursery ponds at different stocking densities. J. Asiat. Soc. Bangladesh, Sci., 20:65–72.

Ling, S. W. 1969. The general biology and development of Macrobrachium rosenbergii (de Man). FAO Fish. Rep., (57):3:589–606

Muir, J. F. 2003. The future for fisheries: economic performance. Fisheries Sector Review and future development study. Commissioned with the association of the World Bank, DANIDA, USAID, FAO, DFID with the cooperation of the Bangladesh Ministry of Fisheries and Livestock and the department of fisheries. Dhaka, 172pp.

Nabil, F.; Abdel-Hakim; Al-Desoki, A.; Al-Azab; Hasan, Y.; Allam and Ahmed, G. A. Gewida. 2013. Effect of stocking density and probiotic dietary supplementation on growth performance, feed conversion and survival of postlarvae of the freshwater prawn (Macrobrachium rosenbergii). Egypt. J. Aquat. Biol. and Fish, 17(1):81-90.

New, M. B. and Singholkia, S. 1982. Freshwater prawn farming. A manual for the culture of Macrobrachium rosenbergii. FAQ Fisheries Technical Paper No. 225. Food and agriculture organization of the united nation, Rome, Italy.

Rouse, D. B.; Naggar, G. O. E. and Mulla, M. A. 2007. Effects of stocking size and density of tilapia on Macrobrachium rosenbergii in polyculture, World mariculture society, 18:57-60pp.

Siddiqui, A. Q.; Yousef, S. A. H.; Ahmed, H. A. H. and seikh, A. H. 2007. Effects of stocking density and monosex culture of M. rosenbergii on growth and production in concrete tanks in saudi Arabia. World Aquaculture society, 28:106-112 pp.

Smith, T. I. J.; Sandifer, P. A. and Trimble, W. C. 2009. Pond culture of the Malaysian prawn, Macrobrachium rosenbergii (de Man), In South Carolina .World Aquaculture society, 7:625-644 pp.

Swingle, H. S. 1967. Relation of pH of pond water to shrimp suitability for fish culture. Proc. Pacific Sd. Congre., 9(10):72-75.

Valenti, W. C. 2002. Situacao atual, perspectivas e novas tecnologias para producao de camaroes de agua. In. Anais do XII Simposio Brasileiro de Aquicultura, junho de 2002, Goiania, PP. 90-109pp. (Publish in Portuguese).

Wahab, M. A.; Ahmed, Z. F.; Islam, A. and Rahmatullah, S. M. 1995. Effect of introduction of common carp (Cyprinus carpio L) on the pond ecology and growth of fish in polyculture. Aquacult. Res., 26:619-628.

Willis, S. A. and Berrigan, E. 2009. Effects of stocking size and density on growth and survival of M. rosenbergii (De man) in ponds. World Aquaculture Society, 8:251-264pp.

Zar, J. H. 1984. Biological Analysis. 2nd edition, Prentice Hall, Inc., Englewood Cliffs, New Jersey, USA.