Optimization of stocking rates of tiger shrimp under modified improved culture system

M.L. Islam and M.J. Alam
Bangladesh Fisheries Research Institute, Brackishwater Station, Paikgacha, Khulna- 9280, Bangladesh

Abstract

With the target of increasing the shrimp (*Penaeus monodon*) production through farm development and improved grow out management, an experiment was conducted with three different stocking densities *viz.* $5/m^2$ (T1), $7/m^2$ (T2) and $9/m^2$ (T3). Results of the experiment revealed that, among the water quality parameters, values of dissolved oxygen and transparency were lower in the higher stocking densities with significant difference ($p<0.05$) among the treatments. Other water quality parameters were similar in all the treatments. Bacterial load in bottom sediment had the trend to increase with increasing culture period and showed significant difference ($p<0.05$) among the treatments with the highest in the higher stocking density. Soil pH in the end sample reduced a little bit in all the treatments than the initial. Deposition of organic matter, phosphorus and nitrogen was related to the respective stocking densities. Final weight gain and survival rate of shrimp were significantly ($p<0.05$) higher in T1 than in T2 and T3. Stocking density of $5/m^2$ showed the highest production of 759.14 ± 19.002 kg/ha, which was significantly ($P<0.05$) higher than that of 670.77 ± 16.078 kg/ha obtained in T2, but similar to 701.24 ± 33.507 kg/ha obtained in T3. The net economic return and BCR was also significantly higher ($p<0.05$) in the same stocking density ($5/m^2$) compared to others. Whereas, FCR value was significantly lower ($p<0.05$) in T1 than the other two treatments. However, pond ecological conditions were more congenial for shrimp culture in lower stocking density ($5/m^2$), which minimized the risk of disease outbreak in the respective stocking density, keeping the culture environment favorable.

Key words: Stocking density, Tiger shrimp, Modified improved culture

Introduction

Most of the traditional shrimp farmers in Bangladesh only stock shrimp post-larvae indiscriminately and selectively harvest the adult shrimp, with minimum recovery rate and production (Roy *et al.,* 1997). Optimum stocking density in aquaculture is the triggering factor for maximizing the survival rate and production. Stocking density of shrimp mainly depends on the condition of the culture tank and management practice followed. Optimum stocking density of shrimp plays a vital role minimizing the environmental risk and maximizing per unit production. There have available information regarding the high tech shrimp culture system like semi-intensive to intensive in the world (semi-intensive ponds in Mexico by Guererro-Galvin *et al.,* 1998-1999; intensive ponds in Thailand by Briggs and Funge-Smith 1994, 1998; intensive ponds in Australia by Burford *et al.*, 2003a; intensive tanks in Brazil by Thompson *et al.*, 2002). But, the information obtained from these studies on culture system of shrimp never reflects the situation of the coastal farms in Bangladesh. The infrastructural facilities of the coastal areas, the land pattern and ability of the resource poor marginal farmers never permitted to adopt such high tech practice of shrimp farming over the farming areas. Few literatures on the monitoring of water quality and nutrient dynamics of extensive shrimp farms are also available (Alongi *et al* 2000; Wahab, *et al*, 2001 and 2003; Islam, *et al*, 2004). But information regarding a moderate stocking density of shrimp with synchronized culture technique, which might be environment friendly, economically viable and socially acceptable is scarce to nil. The information presented in this paper reflected a moderate stocking density of shrimp under modified improved culture system for promoting per unit production than the existing level in the South-west coastal areas in Bangladesh.

Materials and Methods

To optimize the stocking density of shrimp under modified improved culture system and to have its effect on the culture environment; trial was conducted in earthen ponds (each 0.2 ha) of the Brackishwater Station of Bangladesh Fisheries Research Institute. The experiment was conducted with three different stocking densities *viz.* 5/m^2 (T1), 7/m^2 (T2) and 9/m^2 (T3) each with three replications. Data were analyzed using Completely Randomized Design (CRD) protocol.

About 200 m^2 (10%) area of each pond was enclosed with nylon net fastened with bamboo frame for in-pond nursery of shrimp post larvae (PL). Bamboo sticks were provided within the nursery enclosure at a density of 3-4/m^2 as shelter for the PL and also for the development of periphytonic films as initial feed for shrimp PL. The ponds under the trial were prepared through drying and liming the bottom-soil with agricultural lime @250 kg/ha. The ponds were fed with tidal water up to a depth of 65-75 cm and the water was treated with 20 ppm bleaching powder. Then the ponds were fertilized with urea @2.0-2.5 ppm, TSP @ 3.0-3.5 ppm, MP @0.6-0.8 ppm and then left over for 7 days for the growth of available primary producer.

After 7 days of fertilization, the post larvae (ABW, 0.007 g) of *P. monodon* were stocked in each in-pond nursery enclosure according to the design. Shrimps in all ponds were fed with commercial nursery feed @ 100%, 60%, and 30% of the estimated shrimp biomass for the 1st, 2nd, and 3rd week, respectively. After 14 days of rearing within the in-pond nursery enclosure the juveniles were allowed to spread over the culture pond by up folding the nets. Afterwards, grow out pellet feed was supplied @ 3–5 % of the estimated shrimp biomass twice a day for the rest of the culture period. Like that of the traditional *ghers*, there was no practice of regular water exchange in each lunar cycle, except occasional addition to replenish any loss due to evaporation or seepage. As post stocking management, all ponds were limed @ 10–12 ppm with an equal mixture of $CaCO_3$ and $CaMg(CO_3)_2$, fortnightly during the entire culture period. Additional liming was also done at the same rate after every heavy rainfall. The ponds were fertilized with urea, TSP and MP @ 0.5-0.8 ppm, 1.0-1.20 ppm and 0.3-0.4 ppm, respectively at fortnight interval up to 60 days of culture.

During the entire culture period, pond ecological parameters like, temperature, transparency, water depth, pH, Dissolved oxygen and salinity were monitored bi-weekly intervals. Bacteriological load (Total Heterotrophic Colony Forming Unit) in bottom sediment was monitored on initial, mid and at the end of the culture cycle. Whereas, bottom sediment sample was collected at initial and end of the culture cycle, processed and analyzed. Analysis of water quality, bacterial load and soil sample was done following the methods of (APHA, 1992).

After 90 days of rearing, a jumping growth of some shrimp in each pond was observed. At that time selective harvesting was started using cast net and shrimp trap. The harvesting was continued and ended at 120 days by dewatering the ponds. Then growth, survival rate, FCR and production were estimated. Economic analysis was done considering all variable costs to the expenditure and respective shrimp sales of the treatment to the gross return. ANOVA was done to observe the differences in growth, survival rate, production, FCR values and economic return among different treatments. But in case of bacterial load and observed soil characteristics ANOVA was carried out between different sampling periods.

Results and Discussion

Results on water quality parameters during the entire culture period have been presented in Table 1. However, pH of water in all the ponds lies between 7.7 and 8.4, which was alkaline in condition. Alkaline water is more suitable for aquaculture rather than neutral or acidic.

Acidic water restricted the growth of primary producer and also reduced feeding affinity of aquatic organisms (Boyd, 1989). Variation in pH in the present trial was within an optimum range (7.7-8.4) and congenial for shrimp culture for the entire period avoiding any unionized NH_3-N toxicity for prawn (New, 1995). Water temperature was almost similar in all the treatments and the highest level (39.60 ^{o}C) was found during prolonged draught after 55 days of culture in June (Fig. 1). At that time, dissolved oxygen (DO) decreased in all the treatments (Fig. 2) and dropped to its minimum level of 4.0 mg/l.
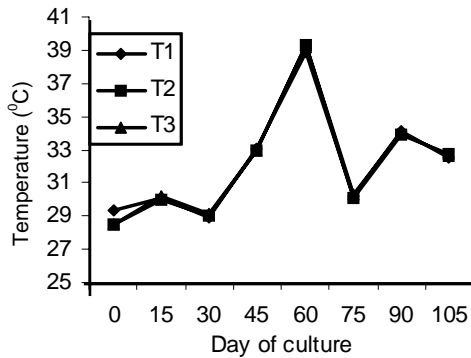

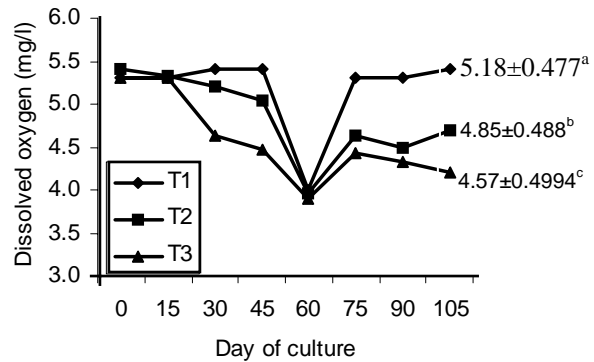Fig. 1. Temperature regime during the culture period under different stocking densities

Fig. 2. Trend in dissolved oxygen during the culture period under different stocking densities

Dissolved oxygen in aquaculture inversely related to temperature (Boyd, 1989). Dissolved oxygen in aquatic environment might be decreased due to restrictions in photosynthesis during long term cloudy weather by crushing of primary producers. It might also be decreased for decay and subsequent mineralization of organic matter by bacterial activity on the aquatic ecosystem at higher temperature (Schroeder, 1974). So, the lower level in dissolved oxygen in the present trial might be due to utilization of considerable amount of DO for stabilization of uneaten feed, molted shell and excreta by bacterial activity in the sediment-water interface. However, the DO values remained above sub-optimal levels (>4 mg/l), avoiding environmental stress for shrimp (Chanratchakool *et al*, 1995). Initially the transparency of water was similar in all the treatments and was congenial (25 – 35 cm) for aqua-farming (Boyd, 1989), but it subsequently decreased in all the treatments with the progress of culture period (Fig. 3).
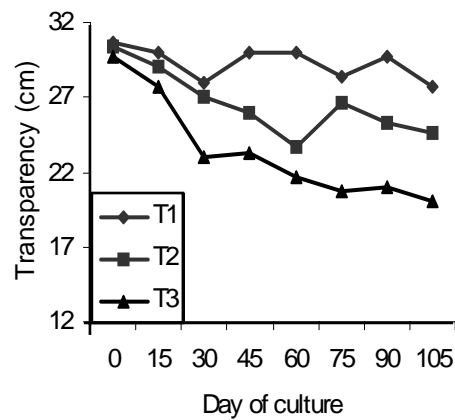

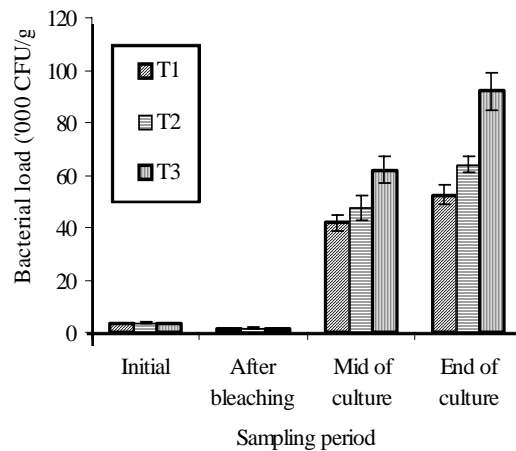Fig. 3. Status in water transparency under different stocking densities

Fig. 4. Status and dynamics in sediment bacteria under different stocking densities

Transparency showed significant difference among the treatments with the preferable level in lower stocking density. Higher stocking density may lead higher influx of organic matter onto the bottom sediment (Paez-Osuna *et al*, 1997). Bacterial activity on organic matter released available primary nutrient in water, which is preferable source of nutrient to the primary producer (Saha, 2000) that stimulated the growth of primary producer in the respective ponds might cause lowered transparency level in the respective treatments.

As shown in Fig. 4, bacterial load in bottom sediment was found low at initial sample and decreased to almost zero after application of bleaching, but increased further with the increase in culture duration. The concentration of bacterial load was higher in the end sample and it was highest in higher stocking density at the end of culture period. However, intensification of stocking density of shrimp might lead excessive influx of uneaten feed, faeces and molted shell on to the bottom sediment, which may have increased the bacterial load and activity onto the sediment-water interface. The observation of the present trial was strongly supported by the observation of Saha (2000). Similar bacterial dynamics was also reported by Burford, *et al*, (2003b) under zero exchanged and highly intensified shrimp ponds. Besides, other water quality parameters were congenial for shrimp culture in all the ponds (Table 1) and the differences of other water quality among the different treatments were insignificant.

Table 1. Ranges in water quality parameters of the ponds under different stocking densities

Parameters	Treatments		
	T1	T2	T3
Depth (cm)	63.0-93.5	65.0-95.8	65.0-100.0
Salinity (ppt)	8.5-11.0	8.5-11.0	8.5-11.0
pH	7.8-8.4	7.7-8.1	7.8-8.2

Soil profile indicated that initially the soil was moderate in pH, but pH level in the end sample reduced in all the treatments than the initial. The reduction of soil pH between initial and end sample was significant ($p < 0.05$) in T2 and T3 (Fig. 5).
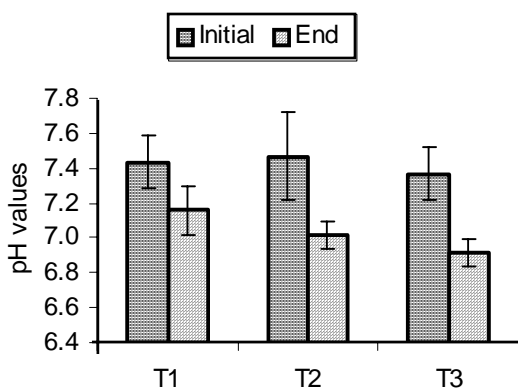
Fig. 5. Status in soil pH under different treatments and samplings
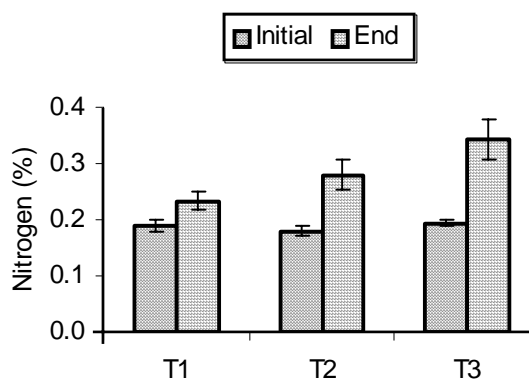
Fig. 6. Status in nitrogen under different treatments and samplings

The presence of nutrient (Nitrogen and phosphorus) and organic matter in soil was very low in the initial sample, but increased significantly ($p < 0.05$) with culture duration and with the increment of stocking densities (Fig. 6-8). Whereas, in their studies on rotational rice-shrimp farming by traditional method in the same agro-ecological zone, Wahab *et al*, (2001) and Chakraborti *et al*, (1985) reported that the percentage of organic matter did not increase significantly and the different parameters monitored did not show extreme value. The findings of present study on soil profile differ with the observation of above mentioned authors.
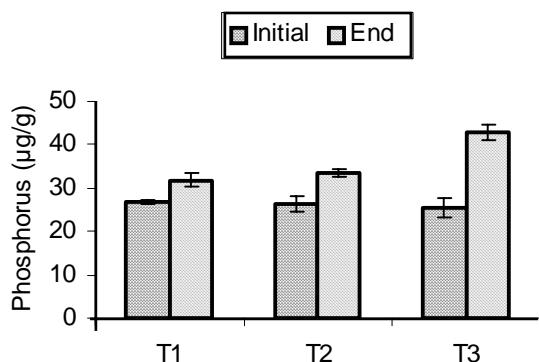

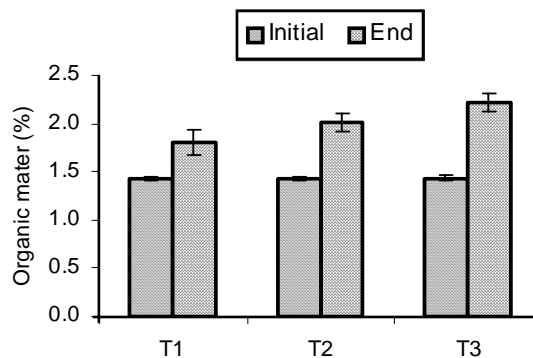Fig. 7. Dynamics in sediment phosphorus under different treatments

Fig. 8. Dynamics in soil organic matter under different treatments

Optimum stocking density played a vital role in providing better environmental condition. Stocking density of shrimp could be increased to intensive level by increasing the management practices. But such type of stocking densities enhances the accumulation of huge amount of nutrient enriched organic matter into the bottom (Paez-Osuna *et al,* 1997; Briggs and Funge-Smith, 1994; Briggs and Funge-Smith, 1998; Smith, 1996), which needs to be reduced or excavated after every culture cycle. Hence, the observation of the present trial on soil profile coincided with the observation of above mentioned authors. However, in this experiment though an increased accumulation of nutrient on the bottom sediment was found, but the amount did not exceed the extreme level for aquaculture (Adhikari, 2003) for a single culture cycle of shrimp.

As shown in Table 2, after 120 days of rearing, average weight gain (26.33±1.697 g) of shrimp was significantly ($p < 0.05$) higher in T1 than in T2 (21.33±0.789 g) and T3 (20.34±0.846 g). The survival rate of 57.76±2.451% with the lowest stocking density (5/m^2) was significantly higher ($p < 0.05$) than that of T2 (44.98±2.075%) and T3 (38.32±1.385%). Stocking density of 5/m^2 performed the highest production of 759.14±19.002 kg/ha, which was significantly ($P < 0.05$) higher than that of 670.77±16.078 kg/ha obtained in T2, but similar to 701.24±33.507 kg/ha obtained in T3. However, production of shrimp between T2 and T3 was insignificant ($p > 0.05$), indicated higher production in lower stocking densities. The FCR value (2.15±0.082) was significantly lower ($p < 0.05$) in T1 than the other two treatments.

Table 2. Details of production performance and economic analysis of shrimp (*Penaeus monodon*) under different stocking densities

Particulars	Treatments		
	T1	T2	T3
Final weight (g)	26.33±1.697[a]	21.33±0.789 [b]	20.34±0.846 [cb]
Survival rate (%)	57.76±2.451 [a]	44.98±2.075 [b]	38.32±1.385 [c]
Production (kg/ha)	759.14±19.002 [a]	670.77±16.078 [cb]	701.24±33.507 [ba]
FCR	2.15±0.082 [c]	2.4±0.075 [a]	2.35±0.026 [ba]
Variable cost ('000 Tk/ha)	151.09±0.695 [c]	160.57±1.689 [b]	171.40±2.318 [a]
Gross return ('000 Tk/ha)	303.66±7.601 [a]	251.54±6.03 [b]	245.43±11.73 [c]
Net return ('000 Tk/ha)	152.56±8.077 [a]	90.96±4.95 [b]	74.04±9.41 [c]
BCR	2.01±0.057 [a]	1.57±0.03 [b]	1.43±0.0 [c]

*Figures with different superscript in the same row differs significantly

Stocking density of shrimp mainly depends on the condition of the culture tank and management practice followed. Shofiquzzoha and Ahmed (2001) found a stocking density of 1-2 under extensive traditional culture system in multiple stocking and harvesting, which provided the production of 156-228 kg/ha. Shofiquzzoha *et al*, (2001) suggested a stocking density of 1.0 - 1.5/m^2 for shrimp in shrimp-mullet polyculture. Average production of shrimp obtained in the present experiment was much higher than that of Apud *et al*, (1984), who reported an average yield of 340 kg/ha/125 days of crop at stocking rate of 4 – 5/m^2 in monoculture with supplemental feed and improved water management. While reporting on the dynamics and diversity of extensive to improved extensive shrimp farming, Nuruzzaman *et al*, (2001) attributed an yield range of 74 – 221 kg/ha, Islam *et al*, (2005) also reported a similar average production of 83 - 204 kg/ha with a density of 2 – 3/m^2, following partial stocking and harvesting pattern for an extended culture period of about 180 - 200 days. However, the average production of shrimp obtained in the present study in a culture period of 120 days seemed to be approximately 3-4 folds higher than those reported by the above mentioned authors for the shrimp farms located in the same agro-ecological region.

The net economic return of Tk.152.56 thousand/ha in T1 was significantly higher (p<0.05) than in T2 (Tk. 90.96 thousand/ha) and T3 (Tk. 74.04 thousand/ha). The BCR was also significantly higher (p<0.05) in the same stocking density than the others. The reasons behind this might be the additional price for seed and feed for the higher stocking densities. It also might be due to the higher market price of shrimp harvested from the lower stocking density. Market price of shrimp generally depends on the quality of product, size of shrimp and international demand. In lower stocking density (5/m^2) shrimp attained an average body weight of 26.33±1.697 g within the experimental period of 120 days, which provided better market price than the shrimp harvested from the higher stocking densities.

However, the over all finding of the present trial focused that, among the tested stocking densities higher density (9/m^2) caused lower growth increment of shrimp and more time needed to reach marketable size. This caused more investment of input, increased the chance of environment degradation leading to disease outbreak. Whereas, lower stocking density (5/m^2) provided the highest production and economic output, but provided lowest stress to the culture environment than the others. Considering the culture practice, infrastructural facilities and environmental condition of the farms of the South-west Bangladesh, it could be concluded that stocking density of 5/m^2 might be considered as optimum with relevant culture practice to boost up the production few folds than the existing level, minimizing environmental stress and production risk.

Acknowledgement

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