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EFFECT OF STOCKING DENSITIES ON PRODUCTION AND ECONOMIC RETURN FROM THE SHRIMP, *PENAEUS MONODON* (FABRICIUS) UNDER SEMI-INTENSIVE CULTURE SYSTEM IN BANGLADESH

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Abstract: A study on production and economic return from the semi-intensive culture of *Penaeus monodon* (Fabricius) in relation to the stocking densities of 12, 15, 18 and 21 PL/ m² of 112 days culture period is presented. The study was conducted to determine the suitable stocking density for maximum economic return. The results of the four treatments, T1 (12 PL/m²), T2 (15 PL/m²), T3 (18 PL/m²) and T4 (21 PL/m²) show that during the culture period, average weight gain of the species was significant ($p < 0.02$) where the highest (27.53 ± 0.28 g) and the lowest (22.16 ± 0.44 g) weight was gained by the stocking density 12 PL/m² (T1) and 21 PL/m² (T4) respectively. The growth rate of the species also varied significantly ($p < 0.003$). The results also showed that with the increasing of stocking density, the growth and survival rate of the species decreased although the total production (Kg/ha) increased. Simultaneously, with the increasing of total production in different treatments (with increased stocking density) the production costs also increased. It was observed that the highest (3327.5 ± 121.5 kg/ha) and the lowest (2920.5 ± 114.5 kg/ha) production was gained by the stocking density of 21 PL/ m² (T4) and 12 PL/m² (T1) respectively. However, the economic analysis showed that the trial with the stocking density 15 PL/m² (T2) gained the highest (TK. 333701/ha/yr) economic return followed by the stocking 12 PL/m² (T1) while the lowest return (TK. 280788/ha/yr) came from the highest stocking density, 21 PL/m² (T4). This result indicated that increasing of stocking density may earn higher production but may not be suitable for increased economic return. Moreover, it could be a cause of economic loss.

Key words: Tiger shrimp; *Penaeus monodon*; Semi-intensive; Stocking density; Economic return

Introduction

Shrimp farming in Bangladesh has attracted considerable attention not only because of its value as food supply but also of its high potential as a foreign exchange earner. The success in the production of hatchery-bred shrimp fry in the 1980's has accelerated shrimp farming development in the country. With improve pond culture techniques, yield from traditional shrimp ponds has been raised to 500-800 Kg/ha/yr without supplementary feeding (Mahmood, 1990). Very recently with the advancement of culture management system, the culture industry of the species has shifted from traditional culture method to semi-intensive culture system and over 40,000 hectare area has been included under the practice of semi-intensive culture system (Khan and Hossain, 1996).

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The pond yield has been increased to 2-3 tons through supplementary feeding and intensive pond management with increased stocking density (Khan and Hossain, 1996).

Increasing the stocking density of fish or crustaceans in ponds usually exacerbates problems with water quality and sediment deterioration causing low growth and production of the culture species (Avnimelech *et al.*, 1981; Emmerson and Andrews, 1981; Chien and Lai, 1988; Hopkins *et al.*, 1988; Wyban and Sweeney, 1989). In addition, increasing the density raises pressure on natural food resources (Hopkins *et al.*, 1988) and as food conversion efficiency is often reduced (Sandifer *et al.*, 1987), the total food costs rise (New, 1987). Conversely, optimum returns on capital and labour depend upon using the highest possible stocking densities which are consistent with good survival and growth (Hanson and Goodwin, 1977). Generally the stocking rate of 2-10 and 10-50 individuals/m² are considered ideal for the semi-intensive and intensive culture systems respectively (Kongkeo, 1990).

However, very little information is available on semi-intensive culture of *Penaeus monodon* in Bangladesh (Hossain *et al.*, 1992) although there are reasons to believe that shrimp production level in the country will continue to rise as a result of the gradual introduction of more intensive practice. One of the major constraints to the future growth of the shrimp farm industry in Bangladesh is likely to be the ignorance of the proper culture strategy suitable for the region. In order to develop appropriate culture techniques and improve management practice for a shrimp farm under semi-intensive culture system in the region, the present study has been undertaken to investigate the economics of *Penaeus monodon* when maintained on an artificial feeding and improved pond management system for over 112 days of culture period. Generally, it is observed that, with increasing production (with increased stocking density) the production costs also increase. Therefore, the present study was conducted with the view to find out the optimum stocking density that can give the maximum economic return.

Materials and Methods

The data for the present study was collected from a semi-intensive culture farm, "Chokoria Shrimp Culture Farm", Cox's Bazar under the Shrimp Culture Project of Grameen Bank, Bangladesh.

Experimental Ponds: Eight ponds of the farm were selected for the study. The size of the ponds were approximately 01 (one) hectare. All the selected ponds were prepared scientifically with same procedure. Each pond contained outlets, inlets, pumps, paddle wheels and other facilities for the maintenance of water quality required for semi-intensive culture. Fries collected from both the nature and hatchery were stocked in randomly selected ponds with four stocking densities, 12, 15, 18 and 21 PL/ m². Two replicates were used for each density. The four treatments, T1 (12 PL/m²), T2 (15 PL/m²), T3 (18 PL/m²) and T4 (21 PL/m²) were conducted for 112 days. A commercial pelleted feed, "Saudi Bangla Shrimp Feed" was used to feed the shrimps in all the ponds.

Estimation of Growth, Survival and Production: Regular sampling of shrimps was carried at 14 days intervals by using cast net and tray sampling to monitor shrimp growth and survival. The shrimp from each sample were weighed individually to estimate the growth rate. The final survival, average weight and production was estimated by complete harvesting (by draining out the whole pond water through sluice gates) of the entire crop at the end of the culture period. Calculation for final survival, growth rate and production per hectare was made separately for each stocking density. The growth rate (GR) was calculated by using the following formula (Bagenal, 1978):

$$\text{Growth Rate (GR)} = \frac{\text{Weight (g) gained on 'n}^{\text{th}} \text{ day}}{\text{Total culture days (up to 'n}^{\text{th}} \text{ day)}}$$

Where, “n” represent the shrimp age.

Calculation for Economics: The economic analysis was carried out on the basis of production costs (operation costs) and value of the harvested crop to calculate and compare the economic return in different treatments.

Post Larvae (PL): The postlarvae were collected both from the nature and hatchery and were bought for an average price of Tk. 500 per thousand. The costs for post larvae per hectare stocked have been calculated for each treatment.

Feed: The price of used feed (Saudi Bangla Shrimp Feed) varies with the types of feed (starter to finisher). The average price of the feeds was close to Tk. 30/Kg. This value has been assumed for the present calculation. The costs of feed has been calculated for the production of shrimp/ha separately for different treatments.

Labour: Yearly salary for pond associated personnel has been calculated to estimate the costs for labour for the production per hectare per year.

Power: Power costs include costs for pumping, aeration and lightening. Water exchange through pumping and aeration by paddle wheel was provided equally in all the ponds. The total costs for fuel used in generators and pumps during the culture period was recorded. Calculation has been made to estimate the power costs for production per hectare.

Value of the Crop: At harvest, the selling price for the head-on shrimp was determined based on the offered price for each market category. The breakdown of market categories and the price offered for each size class are represented in the following Table 1.

Table 1. Weight categories and market value for head-on shrimp (*Penaeus monodon*) on June 22, 1998.

Count (No./Lb.)	Weight range (g/individual)	Selling price (Tk./Kg)
<15	>30	350
15 – 20	30 - 22.7	300
20 – 30	22.6- 15.13	250
>30	<15.13	200

The total price value of shrimp produced per hectare in different treatments has been calculated separately.

Estimation of Economic Return: Finally, calculation has been made to estimate the economic return by deducting the production cost/ha from the value of the produced shrimp/ha in different treatments. Percentage of economic return in different treatments also has been calculated by using the following formula:

$$\text{Economic Return/ha} = (\text{crop value/ha}) - (\text{production cost/ha})$$

$$\% \text{ of Economic Return} = \frac{\text{Economic return/ha}}{\text{Production cost/ha}} \times 100$$

Result and Discussion

Growth, Survival and Production: Table 2 shows the growth, survival and production performances gained for the four treatments (T1, T2, T3 and T4). The growth rate of the shrimp among the different trials was observed significant ($p < 0.003$). The highest average growth rate was 0.24 ± 0.003 g/day for T1 (12 PL/m²) while the lowest was 0.198 ± 0.004 g/day for T4 (21 PL/m²). The growth rates observed in the present study for *Penaeus monodon* at four stocking densities were found similar with the findings of Liao (1977) and Chen *et al.* (1989). However, the results were not inconsistent with the findings of Allan (1989) and Geoff *et al.* (1992). During the present study, as stocking density increased from 12 to 21 PL/m², average individual gained weight declined from 27.53 ± 0.28 g (T1) to 22.16 ± 0.44 g (T4). The differences in individual average growth gained for different stocking densities was found to be significant ($p < 0.02$). This result is supported by other penaeid studies (Apud *et al.*, 1981; Maguire and Leedow, 1983; Sandifer *et al.*, 1987; Wyban *et al.*, 1987). The differences in the shrimp survival was also found to significantly vary ($p < 0.01$). The highest ($86.13 \pm 0.97\%$) and the lowest ($69.18 \pm 0.88\%$) survival was found at the stocking density 12PL/m² (T1) and 21PL/m² (T4) respectively. But the height production (3327.5 ± 121.5 Kg/ha) was found with the stocking density of 21 PL/m² (T4) while the lowest production (2920.5 ± 114.5 Kg/ha) was with 12 PL/m² (T1) (Table 2). Apud *et al.* (1981) reported that increasing density of *Penaeus monodon* resulted in slight but significant ($p < 0.05$) reduction in survival. They were able to demonstrate production of 1,264 Kg/ha in 118 days at a stocking rate of 20 PL/m². However, Liao's report (1981) of a maximum 6000 Kg/ha yield in 105-120 days in Taiwan under semi-intensive system suggested that the present yields could still be increased.

Table 2. Average growth, survival and production of *Penaeus monodon* in different treatments under four stocking densities.

Treatment No.	Fry stocking (No./m ²)	Average growth rate (g/day) Mean±SD	Average weight gained (g) Mean±SD	Survivability (%) Mean±SD	Production (Kg/ha) Mean±SD
T1	12	0.246 ± 0.003	27.53 ± 0.28	86.13 ± 0.97	2920.5 ± 114.5
T2	15	0.230 ± 0.005	25.71 ± 0.58	80.14 ± 2.43	3132 ± 262
T3	18	0.208 ± 0.001	23.30 ± 0.05	70.07 ± 1.93	3202 ± 178

T4	21	0.198±0.004	22.16±0.44	69.18±0.88	3327.5±121.5
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Production Cost: Table 3 shows the costs for post larvae, feed, labour, power and, transport and miscellaneous. The calculated costs for the post larvae per hectare per year for the treatments T1 (12 PL/m²), T2 (15 PL/m²), T3 (18 PL/m²) and T4 (21 PL/m²) has been presented. Due to the variations at stocking density, the total costs for the post larvae varied in different treatments where the costs was the highest (Tk. 105000) for T4 and the lowest (Tk. 60000) for T1. The total costs for “Saudi Bangla Shrimp Feed” varied as the feed consumption ratio (FCR) and the stocking density was different in different treatments. The highest (Tk. 184676) and the lowest (Tk. 152387) costs/ha/yr for feed was paid for treatment T4 and T1 respectively. The annual salary for pond associated personnel (6 persons) was Tk. 261216. It is estimated that this manpower can effectively manage a total of sixteen hectare area ponds. According to this, the calculated salary for labour/ha/yr is Tk. 1632 which is same for all the treatments. The average costs for fuel (for pumping, aeration and lightening) per hectare per year has been calculated as Tk. 167102. Transport and miscellaneous (lime, fertilizer, predator control, repairing etc.) costs has been estimated as 20% of other costs. The costs increased with the increasing of total production costs (Table 3).

The total production costs/ha/yr varied in different treatments (Table 3). Treatment 4 (T4) shows the highest (Tk. 567725) production costs where T1 shows the lowest (Tk. 474978). The costs varied mainly due to the differences in the amount of used postlarvae and feed.

Table 3. Summary of production costs for *Penaeus monodon* culture.

Treatment No.	Items.	Amount used	Costs (Tk./ha/yr)	Total costs (Tk./ha/yr)
T1	Postlarvae	120000 Nos./ha	60,000	4,74,978
	Feed	4994 Kg/ha	1,52,387	
	Labour	6 personnel	16,326	
	Power	Not noted	1,67,102	
	Transport & miscellaneous	20% of other costs	79,163	
T2	Postlarvae	150000 Nos./ha	75,000	5,11,939
	Feed	5606 Kg/ha	1,68,188	
	Labour	6 personnel	16,326	
	Power	Not noted	1,67,102	
	Transport & miscellaneous	20% of other costs	85,323	
T3	Postlarvae	180000 Nos./ha	90,000	5,40,214
	Feed	5892 Kg/ha	1,76,750	
	Labour	6 personnel	16,326	
	Power	Not noted	1,67,102	
	Transport & miscellaneous	20% of other costs	90,036	
T4	Postlarvae	210000 Nos./ha	1,05,000	5,67,725
	Feed	6156 Kg/ha	1,84,676	
	Labour	6 personnel	16,326	
	Power	Not noted	1,67,102	
	Transport & miscellaneous	20% of other costs	94,621	

Crop Value: The crop value and the results of economic return have been presented in the table 4. The crop value was dependent on the basis of size distribution of the cultured species. As the average highest size (27.53 g) was produced by T1, it earned highest average selling price, Tk. 275/Kg while the lowest average selling was gained by T4 (average individual weight 22.16g), Tk. 255/Kg. However, the table shows that the highest crop value (Tk. 848513/ha/yr) was gained by T4 (21 PL/m²) while it was the lowest (Tk. 803137/ha/yr) for T1 (12 PL/m²).

Economic Return: The result of economic return indicates that the highest economic return/ha/yr was gained by the treatment T2 (Tk. 333701/ha/yr) while it was the lowest (Tk. 280788/ha/yr) for T4 although the highest crop value/ha/yr was earned by T4 (Table 4). Treatment T1 and T3 placed 2nd and 3rd position respectively. However, the highest (69%) and the lowest (49%) percentage of economic return was gained by T1 (12 PL/m²) and T4 (21 PL/m²) respectively.

Table 4. Summary of the crop value and economic return of *Penaeus monodon*.

Treatment no.	Average selling price (Tk./Kg)	Crop value (Tk./ha/yr)	Economic return (Tk./ha/yr)	Percentage of economic return
T1	275	8,03,137	3,28,159	69
T2	270	8,45,640	3,33,701	65
T3	260	8,32,520	2,92,306	54
T4	255	8,48,513	2,80,788	49

The maximum economic return recorded at 15 PL/m² (T2) followed by 12 PL/m² (T1) where the lowest was recorded at 21 PL/m² (T4) is in agreement with Pardy *et al.* (1983) who found that economic returns above selected costs (RASC) were greatest at lower densities. Maximum RASC were obtained at approximately 9.9 shrimps/ m² for *Penaeus stylirostris* and 13.6 shrimps/m² for *Penaeus vannamei*. Chiang *et al.* (1986) analyzed the economics of *Penaeus monodon* culture in Taiwan and conversely found that maximum return on investment was predicted at 30 to 40 shrimps/m². Maguire and Leedow (1983) found that for *Metapenaeus macleayi*, economic return increase with density up to 18.2 shrimps/m² followed by a slight but non significant (p>0.05) reduction at 21.2 shrimps/m². Geoff *et al.* (1992) have recommended that the stocking densities of *Penaeus monodon* under semi-intensive culture system would be 15-25 shrimps/m² for higher economic return. The choice of optimum stocking density will, however, also depend upon the intended market size of shimps and on the number of crops per year which the shrimp farmer intends to grow (Tiro *et al.*, 1986).

From the present study it is evident that the economic return at the higher densities deteriorated due to lower growth rates. In addition, as maintaining water quality is more difficult in ponds stocked at higher densities (Sandifer *et al.*, 1987; Hopkins *et al.*, 1988), and disease risk is likely to increase (Hanson and Goodwin, 1977) the suitable optimum stocking densities for *Penaeus monodon* grown under similar condition to those described here, would be around 15 shrimps/ m² for maximum economic return. The economic analysis described above has been based on direct or variable costs for producing the present crop and its value. For these data to be pertinent, a grower must

already have existing fishponds as well as necessary permanent infrastructure and equipments (office, store, generator, pumps, aerators, nets etc.).

Conclusion

The present study indicates that the culture environment of *Penaeus monodon* in Bangladesh is very suitable as growth, survival and production of the species show good performances in comparison with the results of other regions of the world. The results also showed that, with the increasing of stocking density, the growth and survival of the species decreased although total production (Kg/ha) increased. However, with increasing production (with increased stocking density) the production costs also increased. Therefore, in the present study, the economic analysis has been conducted to determine the optimum stocking density for maximum economic return that could make the farmers aware of increased economic return from semi-intensive practice. The result of the present study will be valuable to initiate the farmers to shrimp culture through semi-intensive system and as well as to promote the culture technology in the country.

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References

- Allan, G.L., 1989. NSW prawn production up. *Austasia Aquaculture Magazine*, 4(5): 23-25.
- Apud, F.D., Gonzales, K., and Deatras, N., 1981. Survival, growth and production of *Penaeus monodon* (Fab.) at different stocking densities in earthen ponds with flow through system and supplementary feeding. *Fisheries Research Journal of Philippines*, 6: 1-9.
- Avnimelech, Y., Lacher, M., Raveh, A. and Zur, O., 1981. A method for the evaluation of conditions in a fish pond. *Aquaculture*, 23: 361-365.
- Bagenal, T., 1978. Methods of assessment of fish population in fresh waters. *Blackwell Sci. Publication*, Oxford, London, 365 pp.
- Chen, J.C., Liu, P.C. and Lin, Y.T., 1989. Culture of *Penaeus monodon* in an intensified system in Taiwan. In: J.L. Maclean, L.B. Dizon and L.V. Hossillos (eds.), *The First Asian Fisheries Forum*. Asian Fisheries Society, Manila, Philippines, pp. 25-29.
- Chiang, P. and Liao, I.C., 1986. The practices of grass prawn (*Penaeus monodon*) culture in Taiwan from 1968 to 1984. *Journal of the World Mariculture Society*, 16: 297-315.
- Chien, Y.H., and Lai, H.T., 1988. The effects of aged sediment and stocking densities on the fresh water prawn *Macrobrachium rosenbergii* culture. *Journal of the World Aquaculture Society*, 19(1): 22A-23A.
- Emmerson, W.D. and Andrews, B., 1981. The effect of stocking density on growth, development and survival of *Penaeus indicus* Milne Edwards larvae. *Aquaculture*, 23: 45-57.
- Geoff, L. and Greg, B.M., 1992. Effects of stocking density on production of *Penaeus monodon* (Fabricius) in model farming ponds. *Aquaculture*, 107: 49 – 66.
- Hanson, J.E. and Goodwin, H.L., 1977. *Shrimp and Prawn Farming in the Western Hemisphere*. Dowden, Hutchinson and Ross, Stroudsburg PA, 439 pp.
- Hopkins, J.S., Baird, M.L., Grados, O.G., Maier, P., Sandifer, P.A. and Stokes, A.D., 1988. Impacts of intensive shrimp production on the culture pond ecosystem. *Journal of the World Aquaculture Society*, 19(1): 37.

Mostafa, M., Elliott, M. and Rahman, M., 2000. Effect of stocking densities on production and economic return from the shrimp, *Penaeus monodon* (Fabricius) under semi intensive culture system in Bangladesh

- Hossain, S.M.Z., Corre, Jr.V. and Toledo, C.E., 1992. Effects of stocking densities on the growth, survival and production of *Penaeus monodon* (Fabricius). *Bangladesh Journal of Zoology*, 20(1): 35-42.
- Khan, Y.S.A. and Hossain, M.S., 1996. Impacts of shrimp culture on the coastal environment of Bangladesh. *International Journal of Ecology and Environmental Sciences*, 22: 145-158.
- Kongkeo, H., 1990. Pond management and operation. In: M.B. New, H. de Saram and T. Singh (eds.), Proceedings of the Aquatech '90 Conference on Economic Aspect of Shrimp Farming. Kuala Lumpur, Malaysia, pp. 56 - 65.
- Liao, I.C., 1977. A Culture study on grass prawn *Penaeus monodon* in Taiwan - the patterns, the problems and the prospects. *Journal of the Fisheries Society of Taiwan*, 5: 11 -29.
- Liao, I.C., 1981. Status and problems of grass prawn culture in Taiwan. Paper presented at the ROC - Japan Symposium on Mariculture, Taipei, Taiwan, R.O.C., 35 pp.
- Maguire, G.B. and Leedow, M.I., 1983. A study of the optimum stocking density and feed rate for school prawn *Metapenaeus macleayi* (Haswell) in some Australian brackishwater farming ponds. *Aquaculture*, 30: 285-297.
- Mahmood, N., 1990. An assessment of the quantum damage caused to zooplankton while fishing bagda shrimp (*Penaeus monodon*) fry in Bangladesh estuaries. In: Proceedings, 7th National Zoological Conference of Bangladesh, pp. 87-97.
- New, M.B., 1987. *Feed and Feeding of Fish and Shrimp*. A Manual on the Preparation and Presentation of Compound Feeds for Shrimp and Fish in Aquaculture. Report ADCP/REP/87/26. United Nations Development Program, Food and Agriculture Organization of the United Nations, Rome, Italy, 275 pp.
- Pardy, C.R., Griffin, W.L., Johns, M.A. and Lawrence, A.L., 1983. A preliminary economic analysis of stocking strategies for penaeid shrimp culture. *Journal of the World Mariculture Society*, 14: 49-63.
- Sandifer, P.A., Hopkins J.S. and Stokes, A.D., 1987. Intensive culture potential of *Penaeus vannamei*. *Journal of the World Aquaculture Society*, 18 (2): 94-100.
- Tiro, L.B., Pudadera, B.J., Potestas, I.O. and Kungvankij, P., 1986. Intensification techniques in extensive culture of *Penaeus monodon* (Fabricius). In: J.L. Maclean, L.B. Dizon and L.V. Hosillos (eds.), *The First Asian Fisheries Forum*. Asian Fisheries Society, Manila, Philippines, pp. 93-95.
- Wyban, J.A., Lee, C.S., Sato, V.T., Sweeney, J.N. and Richards, W.K.Jr., 1987. Effect of stocking density on shrimp growth rate in manure - fertilized ponds. *Aquaculture*, 61: 23 - 32.
- Wyban, J.A. and Sweeney, J.N., 1989. Intensive shrimp grow out trials in a round pond. *Aquaculture*, 76:215-225.