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Comparative Evaluation of *Penaeus monodon* (Fabricius, 1798) Culture in Different Saline Grow-Out Systems in India

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Abstract: Present study was conducted for a period of 156 days (February to July, 2010) in three earthen ponds of each 10000 m^2 area in different salinities. *P. monodon* seeds were stocked at a density of 15 nos m^{-2} in all the ponds. The water quality parameters, such as temperature, salinity, hydrogen ion concentration (pH), dissolved oxygen and alkalinity were monitored. The alkalinity at pond 1-3 showed a significantly value (60-130, 180-230 and 220-260 ppm) at 86 DOC. The pond 2 showed higher survival rate than that of pond 1 and 3. The survival at the time of harvest was 86.6% for pond 1, 95.6% for pond 2 and 72.6% for pond 3 at 142, 114 and 156 DOC, respectively. The Average Body Weight (ABW) gained during the 114 DOC was 33.16±0.83, 23.44±0.62 and 17.83±0.28 g for pond 2, 1 and 3, respectively. The Average Daily Growth (ADG) at the time of harvest was 0.23 g for pond 1, 0.29 g for pond 2 and 0.17 g for pond 3 at 142, 114 and 156 DOC, respectively. Among the ponds, Feed Conversion Ratio (FCR) was found to be lower in pond 2, followed by pond 1 and 3. A similar trend was observed for Specific Growth Rate (SGR), also in which pond 2 showed 37% higher SGR than pond 3 and 29.31% higher than pond 1. Pond 2 obtained higher harvested biomass of shrimps at lesser DOC (4928 kg in 114 DOC) than pond 1 (4390 kg in 142 DOC) and pond 3 (3150 kg in 156 DOC). The Revenue Over Investment (ROI) was maximum for pond 2 (99%), followed by a moderate ROI at pond 1 (60%) and the least was for pond 3 (10%), respectively.

Key words: *Penaeus monodon*, salinity, water quality, growth, cost analysis

INTRODUCTION

Aquaculture is one of the fastest growing sectors that ensure a mammoth role in satisfying the protein requirements of the burgeoning populace. It is rapidly expanding in developing countries and is generally regarded, as an efficient means of increasing protein production and income generation (Pullin, 1993). Shrimp farming in India developed at a phenomenal rate in the last decade. Congenial conditions, such as availability of unutilized coastal land, successful transfer of hatchery and grow-out technology, increased export demand and opening up of the economy in 1990s paved way to the rapid expansion of commercial intensive shrimp aquaculture. *Penaeus monodon* are widely cultured crustacean species around the world. Shrimp culture contributing to a significant portion of national income through export earnings. India stands as the 5th highest producer of farmed shrimps (Felix *et al*., 2007).

India is bestowed with an extensive coast line and brackishwater area with vast potential for coastal aquaculture activities. The saline wetlands in India are estimated to the tune of 70,00000 ha (Agarwal *et al*., 1982). The Godavari delta in Andhrapradesh is having significant high saline alkaline area and this could be effectively utilized for aquaculture activities by making use of the fresh water resources during the flood or by using low saline ground water. Physico-chemical parameters of water plays a very vital role that determines the fate of culture. Among this, salinity is one of the most important abiotic factors in aquaculture, though many crustacean species exhibit some degree of euryhalinity (Pequeux, 1995). Salinity is a masking factor that modifies numerous physiological responses, such as metabolism, growth, life cycle, nutrition and intra-and inerspecific relationships (Venkataramiah *et al*., 1974). Salinity is said to be a prime factor that plays a very vital role in the physiology and growth of shrimps that ultimately decides the fate of culture. The physiological responses are believed to be essential to assess the animal performance at different environmental conditions (Menezes *et al*., 2006). Staples and Heales (1991) emphasized that salinity influence the food consumption and conversion efficiency thereby affects the growth and survival of

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cultured penaeid shrimps. Understanding the importance, several studies have been conducted to determine effects of salinity alone or in conjunction with other abiotic factors on the osmoregulatory ability of commercially important penaeid species.

Mair (1980) conducted salinity tolerance experiments in penaeid shrimps suggested that salinity preference changed with size in such a fashion that postlarvae adapted quickly to lower salinities than the other age groups. The age of tolerance to wide salinity fluctuations for most penaeidpostlarvae is between PL10 and 40 (Tsuzuki *et al*., 2000) during this period farmer can subject them for acclimatizing to low-saline well waters. The postlarvae and juveniles of most of the penaeid species adapt and osmoregulates well at lower salinities than their adults. Studies conducted by Parado-Estepa (1998).

Although, few studies addressed the impact of salinity on survival (Ogle *et al*., 1992) and growth (Ponce-Palafox *et al*., 1997) of *P. vannamei*, the estimation of optimal salinity for the growth of white shrimps is still controversial. Farming of shrimp in inland low saline water has been undertaken in many parts of the world. Particularly, the culture of white shrimp, *P. vannamei* has become a rapidly growing industry in low saline areas due to its wide tolerance to salinities ranging from 1-50 psu (McGraw *et al*., 2002). The ability of *P. vannamei* to grow at high salinities has also been demonstrated for aquaculture purposes in dry regions (Martinez-Cordova *et al*., 1997).

Earlier researches on this line suggested that the optimum salinity for the culture of *P. monodon* ranges from 15-25 psu (Chen, 1984). A thorough and careful investigation on the role of salinity and its aftermath on the survival and growth of *P. monodon* is found wanting. The present study is framed in this backdrop with the objective of analyzing the semi-intensive culture of *P. monodon* in low, medium and high salinities in Godavari delta region of Andhrapradesh. Present study has been directed so as to generate information pertain to various biological and economic factors, such as survival, Average Body Weight (ABW), Average Daily Growth (ADG), Specific Growth Rate (SGR), Food Conversion Ratio (FCR) and cost analysis in different salinities.

MATERIALS AND METHODS

Description of the study area: The present study was conducted in three growout ponds with pronounced salinity variation each of 1 ha water spread area. The pond 1 is a low saline (2-5 psu) culture pond and is located at Kumaragiri (Lat. 16°35'40.9"N; Long. 82°17'35.8"E). The pond 2 is a medium saline (15-20 psu) culture pond and is located at Yedhurlanka (Lat. 16°40'55.41"N; Long. 82°5'47.67"E). The pond 3 is a high saline culture pond where the water salinity ranges from 30-40 psu and is located at Antervedi (Lat. 16°21'37.71"N; Long. 81°45'19.6"E). The present study was conducted for a period of 156 days (February to July, 2010) in 3 earthen ponds of each 10000 m^2 area.

Stocking: Healthy and WSSV negative (PCR tested) *P. monodon* seeds were procured from a commercial hatchery near Kakinada. Post Larvae (PL-20) with an average initial weight of 0.02 g were selected and acclimatized to pond water temperature and salinity and stocked at a density of 15 shrimps m^{-2} in all the ponds. All the three experiments were conducted concurrently under semi-intensive production conditions. The shrimps were fed with CP feed (Charoen Pokhpond Aquaculture India Pvt. Ltd.). Feeding rate ranged between 2.5 and 10% of body weight per day. The feed ratio was divided in to 4 times a day (06:00, 11:00, 16:00 and 21:00 h).

Water quality parameters: The water quality parameters in the pond are strictly monitored in the morning hours daily at different corners of the pond. Temperature, salinity, hydrogen ion concentration (pH), dissolved oxygen and alkalinity were monitored *in situ*. Water temperature and dissolved oxygen were measured with the aid of portable electronic meter (Lutron, Model No. DO-5510). The water salinity was measured by using a hand refractometer (Atago, Japan, Model No. 440449) pH and alkalinity were measured using test kits (Advance Pharma Co., Ltd. method-colorimetry). For the sake of convenience in interpretation, the data were pooled up in 14 days interval. The harvest was conducted at 142 DOC in pond 1, 114 DOC in pond 2 and 156 DOC in pond 3.

Assessment of survival, growth and Food Conversion Ratio (FCR): Shrimps in each pond were sampled at every 7 days interval to assess the growth. The survival, Average Body Weight (ABW), Average Daily Growth (ADG), Specific Growth Rate (SGR) and Food Conversion Ratio (FCR) were calculated using the equation mentioned as.

Average Body Weight (ABW):

$$\text{ABW}(\text{g}) = \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial weight}} \times 100$$

Survival:

$$\text{Survival}(\%) = \frac{\begin{array}{c}\text{No. of shrimps survived at}\\ \text{the end of the experiment}\end{array}}{\begin{array}{c}\text{No. of shrimps survived at}\\ \text{the begining of the experiment}\end{array}} \times 100$$

Estimated survival (based on feeding rate):

$$\text{Survival}(\%)=\frac{\text{Biomass}(\text{kg})}{\text{Average Body Weight}(\text{ABW})}\times 1000$$

$$\text{Biomass}(\text{kg})=\frac{\text{Total feed}(\text{kg})\text{ used on the day of estimation}}{\text{Percantage of feed }(\text{based on fed chart})}$$

Average Daily Growth (ADG):

$$\text{ADG}(\text{g})=\frac{\text{Aerage final weight}}{\text{No. of days of culture}}$$

Food Conversion Ratio (FCR):

$$\text{FCR}=\frac{\text{Total feed consumed}(\text{Dry weight basis})}{\text{Wet weight of shrimps produced}}$$

Specific Growth Rate (SGR):

$$\text{SGR}(\%)=\frac{\text{Final mean weight}-\text{Initial mean weight}}{\text{Duration of the experiment}}\times 100$$

Statistical analysis: The results of survival, ABW, ADG, SGR and FCR were arranged in 14 days interval for the sake of easy interpretation. The results are statistically treated with the help of computer package (MS-Excel and SPSS Software, version 10.0). To maintain uniformity and for the sake of comparison, the graph, tables so also the statistical treatments were represented evenly for 114 DOC only. The results are presented as mean±SD (Standard Deviation). Differences between mean values of growth parameters were analysed by two-way Analysis of Variance (ANOVA) followed by testing for multiple range comparisons between means (Duncan's multiple range test) and the differences between means were checked for significance at level $p<0.05$. The cost analysis was worked out individually for each pond covering all factors pertain to expenditure. The production cost per kg of shrimp against all major expenditure was calculated with special emphasis on profit and Revenue Over Investment (ROI) so as to get a clear picture of economics.

RESULTS

Water quality parameters: Water quality parameters were recorded from all the ponds daily and the results are pooled up in 15 days interval and are portrayed in graphs.

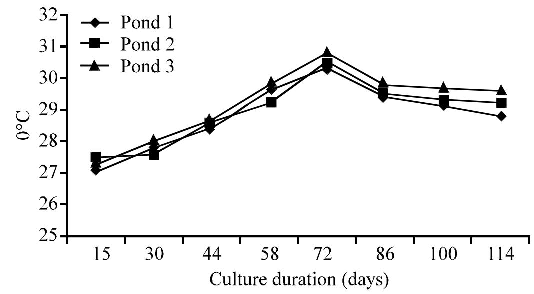

Fig. 1: Water temperature (°C) recorded in all the ponds (1-3) during the study period

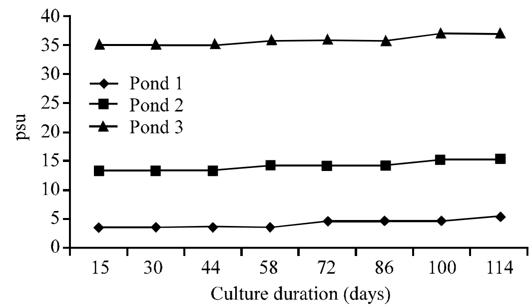

Fig. 2: Salinity (psu) recorded in all the ponds (1-3) during the study period

Water temperature: The results of water temperatureare depicted in Fig. 1. The temperature in all the three ponds varied from 27-30.7°C. No pronounced variation in temperature was found between the ponds. Among all the ponds, the minimum was recorded during the 15 DOC and the maximum was recorded during 72 DOC.

Salinity: The results of salinity are detailed in Fig. 2. The salinity in pond 1 was ranged between 4-6 psu, in pond 2 between 14-16 psu and in pond 3 between 34-36 psu throughout the study period.

Hydrogen ion concentration (pH): The details of pH are portrayed in Fig. 3. The pH was ranged between 7.5 and 8.2. The pH displayed an optimum range at all the experimental ponds during the culture period. In pond 1 and 2, the pH ranged between 7.8-8.2 whereas in pond 3 it ranged from 7.5-8.2, respectively.

Dissolved oxygen: The variation in dissolved oxygen levels between the grow-out ponds during the entire days of culture are pooled up in Fig. 4. In general, high dissolved oxygen levels were recorded during the early days of culture. In pond 1, the level varied from 4-6.5 mL L^{-1}, in pond 2 it was 4-6.5 mg L^{-1} and in pond 3 the dissolved oxygen level varied from 4-5.5 mL L^{-1}, respectively.

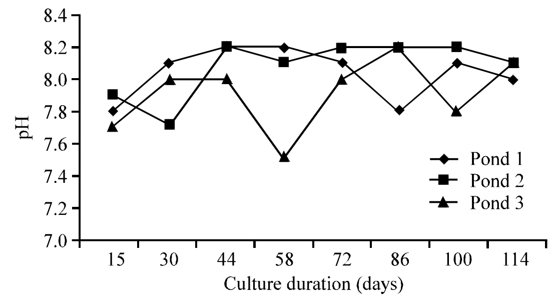

Fig. 3: pH recorded in all the ponds (1-3) during the study period

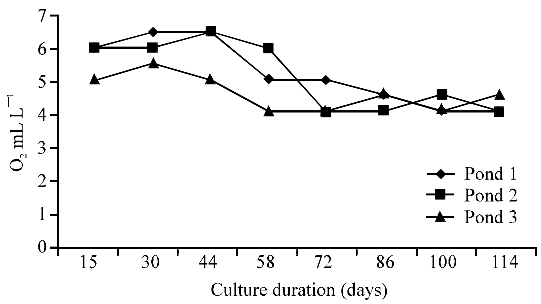

Fig. 4: Dissolved oxygen (O_2 mL L^{-1}) recorded in all the ponds (1-3) during the study period

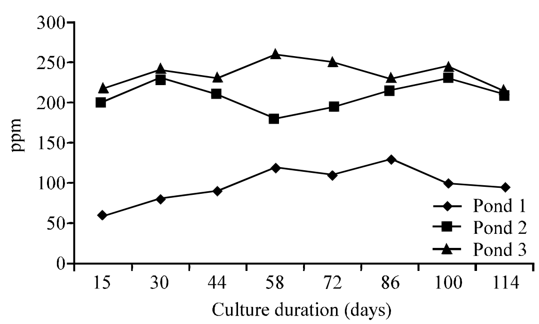

Fig. 5: Alkalinity (ppm) recorded in all the ponds (1-3) during the study period

Alkalinity: The results of alkalinity are detailed in Fig. 5. The alkalinity at pond 1 showed a significantly lower value (60 ppm) during the initial days of culture and had a gradual increase as the culture proceeds with the maximum level (130 ppm) during 86 days of culture. In pond 2 and 3, the alkalinity showed a higher range (180-230 ppm in pond 2 and 220-260 ppm in pond 3, respectively).

Growth parameters *P. monodon* postlarvae were checked for survival in happa after 48 h of stocking. Pond 1 and 2 observed higher survival (90 and 95%) than pond 3 (80%), respectively. Based on the happa survival, the feeding was adjusted in each experimental pond. The shrimps were fed with CP feed (Charoen Pokhpond Aquaculture India Pvt. Ltd.). The feeding schedule was based on the feed chart given by the CP company. Blind feeding was done for the first 25 days. Later the feeding ration was adjusted based on the check tray observation and periodic sampling.

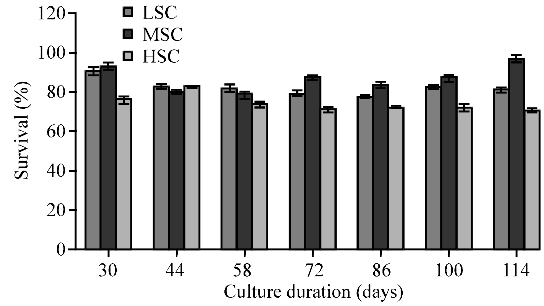

Fig. 6: Survival (%) of *P. monodon* cultured in ponds 1-3 upto 114 days of culture

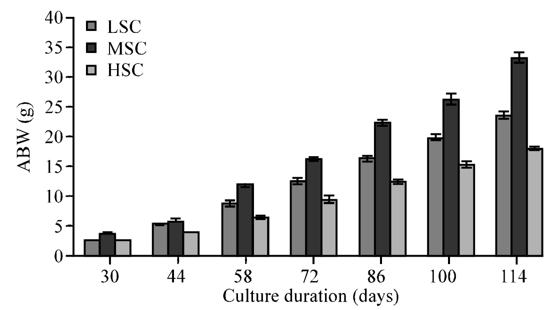

Fig. 7: Average Body Weight (ABW) (g) of *P. monodon* cultured in ponds 1-3 upto 114 days of culture

Survival: The results of the survival rate are depicted in Fig. 6. The survival at 30 DOC was 90.33±2.08% in pond 1, 92.33±2.08% in pond 2 which showed significance ($p\leq 0.05$) with each other. But, pond 3 showed the least survival of 76±1%. The survival at pond 1 was 80.67%, in pond 2 was 95.67% and in pond 3 was 70.67% at 114 days. The survival at the time of harvest was 86.6% for pond 1, 95.6% for pond 2 and 72.6% for pond 3 at 142, 114 and 156 DOC, respectively. Except for the significance between pond 1 and 2 during 30 days, all other duration showed a varied significance between the ponds. The analysis of variance (two-way) showed significant difference in survival between the days of culture and also between the culture ponds ($p\leq 0.05$).

Average Body Weight (ABW): The results of growth performance based on Average Body Weight (ABW) are detailed in Fig. 7. The average body weight of shrimps at 30 DOC was 2.33 ±0.05g in pond 1, 3.64±0.09 g in pond 2 and 2.26±0.06 g in pond 3. The ABW in all the three ponds varied significantly ($p \leq 0.05$) from the beginning of the culture to 114 DOC and harvest. The average weight gained during 114 DOC in pond 1, 23.44±0.62 g and in pond 3 was 17.83±0.28 g which showed significantly lower values ($p \leq 0.05$) than pond 2 (33.16±0.83 g).

The pond 2 exhibited fastest growth (33.14 g) in 114 days and was harvested 28 days before pond 1 and 42 days before pond 3. In general, the shrimps grown at pond 3 showed poor growth performance from the beginning of the culture and attained a harvestable size of 28.58 g only at 156 days. The analysis of variance (two-way) showed significant difference in average body weight between the days of culture and also between the culture ponds ($p \leq 0.05$)

Average Daily Growth (ADG): The results of growth performance based on Average Daily growth (ADG) are depicted in Fig. 8. The ADG at 30 DOC for pond 1 (0.07±0.00 g) was significant with pond 3 whereas pond 2 showed fairly higher ADG value (0.12±0.01 g). The average daily growth at 114 days for pond 2 was recorded to be the maximum (0.29±0.01 g) compared to pond 1 (0.20±0.01 g) and pond 3 (0.15±0.00 g), respectively. There was continues increment in ADG as the culture days proceeds. Comparatively, pond 2 revealed higher ADG followed by pond 1 while pond 3 showed lesser values throughout the culture period. The Average Daily Growth (ADG) at the time of harvest was 0.23 g for pond 1, 0.29 g for pond 2 and 0.17 g for pond 3 at 142, 114 and 156 DOC, respectively.

The analysis of variance (two-way) showed significant difference in average daily growth between the days of culture and also between the culture ponds ($p \leq 0.05$).

Food Conversion Ratio (FCR): The results of the food conversion ratio are detailed in Fig. 9. The FCR in all the three ponds varied significantly ($p \leq 0.05$) from the beginning of the culture up to the harvest. The FCR of shrimps at 30 DOC was 1.06±0.07 in pond 1, 1.17±0.07 in pond 3 and the lowest was 0.83±0.03 in pond 2, respectively. The FCR widely ranged from 1.57±0.02 to 2.06±0.06 at 100 days and varied significantly ($p \leq 0.05$) at all ponds. The final FCR for pond 2 at 114 days was 60.83% less than pond 3 and 34.26% less than pond 1. At harvest, the pond 3 showed higher FCR (2.4) than pond 2 (1.42) and pond 1 (1.89), respectively.

The analysis of variance (two-way) showed significant difference in FCR between the days of culture and also between the culture ponds ($p \leq 0.05$).

Specific Growth Rate (SGR): The results of the SGR at different salinities are presented in Fig. 10. The SGR of shrimps at 30 DOC was 7.69±0.15% in pond 1, 7.45±0.22% in pond 3 and 12.06±0.3% in pond 2, respectively. At 100 days, the SGR varied greatly between pond 1 (19.71±0.23%), pond 2 (26.09±1.02%) and pond 3 (15.21±0.48%), respectively. The SGR at 114 days for pond 2 was recorded to be the maximum (29.06±0.73%) compared to pond 1 (20.54±0.54%) and pond 3 (15.62±0.25%). Throughout the culture period, higher SGR was observed at pond 2, followed by pond 1 and 3. At harvest, pond 2 showed 37% higher SGR than pond 3 and 29.31% higher than pond 1, respectively. Pond 3 showed a lesser SGR compared with pond 1 (-20.98%) and pond 2 (-37%), respectively.

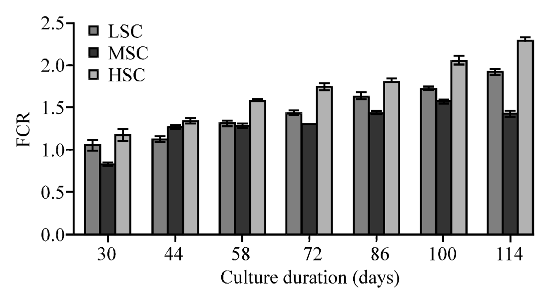

Fig. 9: Food Conversion Ratio (FCR) (g) of *P. monodon* cultured in ponds 1-3 upto 114 days of culture

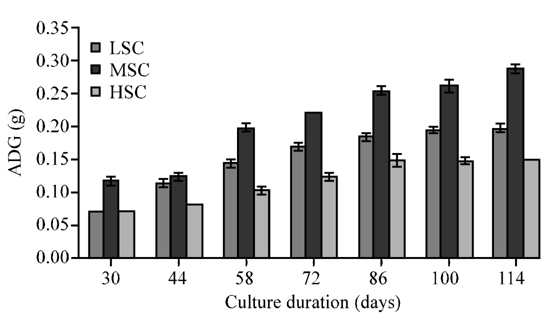

Fig. 8: Average Daily Growth (ADG) (g) of *P. monodon* cultured in ponds 1-3 upto 114 days of culture

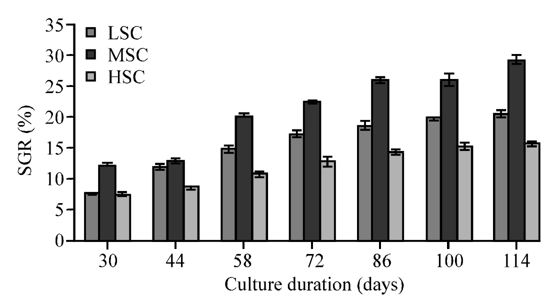

Fig. 10: Specific Growth Rate (SGR) (%) of *P. monodon* cultured in ponds 1-3 upto 114 days of culture

The analysis of variance (two-way) showed significant difference in SGR between the days of culture and also between the culture ponds ($p \leq 0.05$).

Cost analysis: The details of harvested shrimp biomass is detailed in Table 1 and Fig. 11. Pond 2 obtained comparatively good harvest in shorter time (4928 kg at 114 DOC) than other ponds. The culture period for pond 1-3 had a varied duration (142, 114 and 156 days, respectively) and diffrent biomass production (4390, 4928 and 3150 kg, respectively).

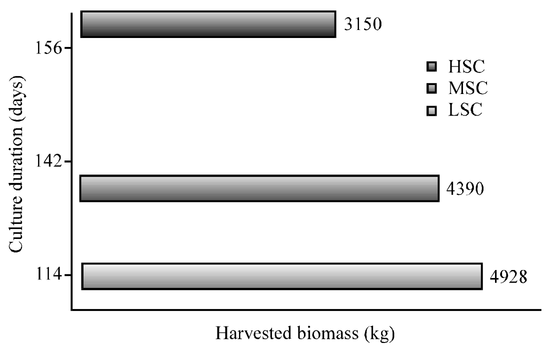

Fig. 11: Total harvested biomass of *P. monodon* at end of the culture a pond 1-3

Table 1: Pond wise summary of semi-intensive shrimp farming pertain to stocking, harvest and growth

Culture details	Pond 1	Pond 2	Pond 3
Pond area (m^2)	10,000 m^2	10,000 m^2	10,000 m^2
Initial stocking (Nos.)	1,50,000	1,50,000	1,50,000
Density (Nos. m^{-2})	15	15	15
Stocking date	10/02/2010	12/02/2010	18/02/2010
Days Of Culture (DOC)	142	114	156
Date of harvest	01/07/2010	05/06/2010	23/07/2010
Biomass harvested (kg)	4390	4928	3150
Total feed consumed (kg)	8311	6992	7597
FCR	1.89	1.42	2.4
ABW (g)	33.14	33.14	28.58
ADG (g)	0.23	0.29	0.18
SGR (%)	23.3	29.06	18.3
Survival (%)	86.6	95.6	72.6

The production cost analysis was worked out individually and are given in Table 2. The feed cost of accounted to the maximum expenditure in all the three experimental culture. The cost of feed per kilogram of shrimp in pond 3 was maximum (Rs. 120.59) whereas the pond 1 recorded 21.55% less (Rs. 94.60 kg^{-1}) and pond 2 recorded 41.17% (Rs. 70.94 kg^{-1}) less expenditure than the pond 3. The next major expenditure was the energy cost. The pond 3 showed the maximum power cost per kg shrimp (Rs. 27.99), followed by pond 1 (Rs. 19.74 kg^{-1}) showing a reduced cost by 41.99% than pond 3. The least expenditure was obtained by pond 2 (Rs. 13.22 kg^{-1}) which was comparatively 111.72% less than pond 3 and 49.31% less than pond 1, respectively. The lease cost includes lease for land, generator and aerators for a single crop (6 months), respectively. The probiotics used for soil, water and feed accounted for 6% of the total expenditure at pond 1 whereas pond 2 showed 7.06% and pond 3, 4.26%, respectively. The seed cost in pond 3 were high (Rs. 11.43 kg^{-1} shrimp) when compared to pond 1 (Rs. 8.20 kg^{-1} shrimp) and pond 2 (Rs. 7.305 kg^{-1} shrimp). The labour cost per crop in pond 3 was 1.99 fold more than the pond 2 and 1.56 fold more than the pond 1.

The overall production cost per kg of shrimp was minimum for pond 2 (Rs. 130.31), followed by pond 1 (Rs. 161.88 kg^{-1} shrimp) whereas the highest production cost was observed in pond 3 (Rs. 208.58 kg^{-1} shrimp), respectively. For pond 3, the production cost per kg of shrimp increased by 37.5 and 22.3% when compared to pond 2 and 1, respectively. The profit per kg of shrimps for pond 2 (Rs. 129.64) showed six fold increase

Table 2: Economics and profit analysis (pond wise) of the semi intensive shrimp farming

	Low saline culture (pond 1)		Moderate saline culture (pond 2)		High saline culture (pond 3)	
Cost details per crop	Total cost	Cost/kg shrimp	Total cost	Cost/kg shrimp	Total cost	Cost/kg shrimp
Feed (Rs.)	4,15,550	94.60	3,49,600	70.94	3,79,850	120.59
Seed (Rs.)	36,000	8.20	36,000	7.30	36,000	11.42
Electricity (Rs.)	86,640	19.74	65,136	13.22	88,176	27.99
Bleaching (Rs.)	13,050	2.64	13,050	2.97	13,050	4.14
Lime (Rs.)	Nil	Nil	7,500	1.52	6,250	1.98
Probiotics (Rs.)	42,825	9.76	45,375	9.21	28,200	8.95
Chemicals (Rs.)	6,000	1.37	10,500	0.47	2,000	0.63
Labour (Rs.)	25,000	5.69	22,000	4.46	28,000	8.89
Lease (Rs.)	62,500	14.24	70,000	14.20	62,500	19.84
Fencing (Rs.)	3,000	0.68	3,000	0.60	3,000	0.95
Others (Rs.)	20,000	4.56	20,000	4.06	10,000	3.17
Total expenditure (Rs.)	7,10,565	161.88	6,42,161	130.31	6,57,026	208.58
Total income(Rs.)	11,41,400	260.00	12,81,280	260.00	7,24,500	230.00
Profit (Rs.)	4,30,835	98.14	6,39,119	129.69	67,474	21.42
Revenue over Investment (ROI, %)	60	-	99	-	10	-

than pond 3 and 1.32 fold increase than pond 1. Likewise the profit per kg of shrimp for pond 1 (Rs. 98.14) increased to 4.58 fold than pond 3 and decreased to 0.32 fold than pond 2. The Revenue Over Investment (ROI) was maximum for pond 2 (99%). A moderate ROI was seen for pond 1 (60%) whereas the ROI (10%) was least for pond 3.

DISCUSSION

Water quality parameters: The water quality parameters play a very vital role in the successful culture of aquatic organisms. In *P. monodon* culture the hydrological parameters, such as salinity, pH, dissolved oxygen and alkalinity levels ranks a crucial role in the fate of the growth and survival of shrimps especially in semi intensive systems. The variations of dissolved oxygen, temperature and salinity are the key factors in the culture system which plays an important role in keeping the prawn in good condition (Shiqueno, 1972).

Water temperature is probably the most important environment variables in shrimp culture because it directly affects metabolism, oxygen consumption, growth, moulting and survival. Boyd (1992) opined that the optimum temperature range in culture ponds is between 25-30°C that accelerates the growth of shrimps and the level greater than this range is lethal to the cultured organisms. The temperature in all the three ponds varied from 27-30.7°C with no pronounced variation was found between the ponds. Boyd (1992) opined that the optimum temperature range in culture ponds is between 25-30°C that accelerates the growth of shrimps and the level greater than this range is lethal to the cultured organisms.

Salinity is one of the most prime environmental parameter in shrimp culture that decides the fate of culture. In the present study, the salinity ranged from 4-6 psu in pond 1, 14-16 psu in pond 2 and 35-37 psu in pond 3. The salinity closer to isosmotic point (14-16 psu) resulted in increased growth in pond 2 than other ponds. The growth of *Peneaus monodon* will be at optimum in salinities of 15 and 20 psu (Cheng and Liao, 1986).

In the present study, the pH range flanked within the optimum level for penaeid shrimp culture. Ramakrishna (2000) recommended an optimum pH of 7.5-8.5 for *P. monodon* culture. The dissolved oxygen level was maintained at 4-6.5 mg L^{-1} during the culture period in all the ponds which is proved to be an optimum range in the semi intensive culture of shrimps. Even, the lowest level of dissolved oxygen observed (4 mL L^{-1}) was also suitable for high survival and growth rate of *P. monodon*. This was attained probably due to continuous aeration in the pond. A similar observation was made in the study of McGraw *et al.* (2001).

Growth performances: The estimation of preliminary survival was based on the assessment of postlarvae stocked in happa. Poor survival and lack of accurate prediction in the early phase of grow-out are the major obstacles during the culture. However after 30 DOC, the response of shrimps to the feeding trays is more legible and this will gave a clear idea of survival for the successive phase of culture. Thus, the use of feeding trays is considered inevitable in shrimp farming. Postlarvae of *P. monodon* aged between PL 7 and 22 proved better survival and growth at 20 and 25 psu than at high salinities (40 ppt) indicates that their optimal salinity is in the lower range. This is in accordance with the research of Raj and Raj (1982) whom studied the salinity preference of postlarvae and juveniles of *P. indicus*. The results of survival obtained in the present study revealed that shrimps in pond 2 exhibited fairly higher survival (96%) than that of pond 1 (81%) whereas in pond 3 which is a high saline culture, showed comparatively poor survival (71%). It is also clear from the present investigation that shrimp production increased significantly with the stocking density and survival, this is in agreement with the report of Allan and Maguire. Michael opined that poor shrimp survival leads to less yield though the growth rate and shrimp size at harvest were good.

In the present study, shrimps grown at medium salinity (pond 2) had better growth performance when compared with shrimps cultured either in low (pond 1) or high salinity levels (pond 3), suggesting that the best productivity of *P. monodon* is in the moderate salinity level of 15-20 psu. The growth of *P. monodon* will be at optimum in salinities of 15 and 20 psu and at high or low salinities affects the molting frequency. Similarly Huang (1983), reported that *P. vannamei* performed better growth at salinities of about 20 psu and poorest at 5 and 45 psu, respectively.

The Standard Growth Rate (SGR) and the Average Daily Growth (ADG) was also influenced by the salinity in such a fashion that pond 2 showed an increased ADG and SGR during all the sampling intervals. The final mean ADG is to the tune of 0.23, 0.29, 0.18 g and SGR is about 23.3, 29.06 and 18.3% in pond 2, 1 and 3, respectively. The results of the present findings are comparable to the SGR reported by Bautista-Teruel *et al.* (2003). Parado-Estepa (1998) reported that food consumption and conversion ratio is correlated with water temperature and salinity of the grow-out. In the present study, it was observed that food consumption of shrimps reared at pond 2 was much lower in comparison with those cultured in pond 1 and 3, respectively. Since, the temperature was nearly constant between the culture ponds, variation in food consumption was mainly related to salinity (Kumlu *et al*., 1999).

Sandifer *et al*. (1991) reported that intensive shrimp culture typically has a Feed Conversion Ratio (FCR) of 2.0 or earliar. But, the FCR value observed in this study showed promising results. Pond 1 (1.89) and 2 (1.42) showed a better FCR which might be attributed to the favorable salinity conditions whereas pond 3 exhibited feed conversion ratio of about 2.4 which might be due to the influence of high salinity. Therefore, it is safe to vouch that salinity plays a decisive role in increased survival rate and enhanced shrimp growth that will significantly improve the profitability of shrimp farming, Yu *et al*. (2006) suggested that either high growth rate or high survival rate would imply a high biomass. Low-saline groundwater is an abundant source of many aridregions which has great potential for aquaculture (McIntosh and Fitzsimmons, 2003). Commercial and viable culture of *P. vannamei* (Samocha *et al*., 1998) and *P. monodon* (Cawthorne *et al*., 1983) has been successfully carried out in moderate saline inland groundwater. No pronounced problems have been reported in culturing shrimps in the saline ground waters of inland or coastal low-lying saline-alkaline areas. China has been exploiting and ameliorating the saline-alkaline wetland by using the fish pond-agricultural terrace system in the yellow river delta for decades. It is prominent that this type of aquaculture could not only reduce the salinization of the soil around the pond area but also be a good way for the sustainable development of the agricultural economy (Cheng, 1993).

Cost analysis: Feed is the most important expensive item for a semi-intensive shrimp culture practice. Pond 3 showed high FCR (1:2.4) which might be attributed to less survival and slow growth rate. Concurrent to this, the cost of feed/kg shrimp increased exponentially in pond 3 (Rs. 120.59), compared to pond 1 (Rs. 94.60) and pond 2 (Rs. 70.94).

Overfeeding results in higher cost of feed per unit shrimp produced (Rothlisberg, 1998). Besides Wyban *et al*. (1995), opined that excess feeding can cause deterioration of water quality that leads to poor growth and survival with a consequent reduction in production and economic return. The proper assessment of check trays are treated as a guide for adjusting feeding rates (Allan *et al*., 2006). The second major expenditure accounting to the production cost is the power cost. The slow growth rate increased the duration of culture in pond 3 (156 days) and pond 1 (142 days), resulted in increased utilization of electricity which inturn increase the power cost/kg shrimp by Rs. 27.99 and 9.74, respectively. However, pond 2 with least culture period (114 days), showed the economical (Rs. 13.22) power cost per kg shrimp.

Seed is another major expenditure item all the experimental ponds were stocked with the same stocking density but the harvest results showed that the lowest seed cost/kg of shrimp produced was achieved in pond 2 (Rs. 7.30) compared to pond 3 (Rs. 11.45) and pond 1 (Rs. 8.20). The might be credited to the good productivity (in terms of harvested biomass) in pond 2 (4928 kg ha^{-1}), compared to pond 3 (3150 kg ha^{-1}) and pond 1 (4390 kg ha^{-1}), respectively. Because of good survival (95%) in pond 2, the frequency of probiotic application so to improve soil condition was doubled (weekly once), compared to pond 1 (once in 2 weeks) and pond 3 (once in 10 days). Though the quantity of probiotic applied was comparatively higher for pond 2 but the cost of probiotics per kg of shrimp was still lesser (Rs. 9.2) compared to pond 1 (Rs. 9.76) and pond 3 (Rs. 8.95). A similar trend was observed for the cost of chemicals applied and for manpower. Because of the saline and alkaline soil nature of pond 1, little expenditure were made for liming whereas in pond 2 (Rs. 1.52) and pond 3 (Rs. 1.98), expenditure were made for liming but accounted only a smaller proportion compared to the total expenditure. The profit per kg of shrimp was worked out which showed that pond 2 exhibited 6 fold increase than pond 3 and 1.32 fold increase than pond 1, respectively. Correspondingly, results of economic evaluation indicated that the Revenue Over Investment (ROI) was maximum for pond 2 (99%), followed by pond 1 (10%) and the least was observed at pond 3 (10%).

The results of the present study revealed that by utilization of the fresh water sources of Godavari and low saline ground water from saline and alkaline area gave more ROI in pond 1 than the culture in pond 3. There are no pronounced environmental and economical problems in culturing shrimps by utilising saline ground waters in the inland or coastal low lying saline-alkaline areas. Shrimp species, such as *P. vannamei* (Samocha *et al*., 1998) and *P. monodon* (Flaherty and Vandergeest, 1998) have been commercially reared in grow-outs using the saline inlandgroundwater in arid and semi arid regions. China has beenexploiting and ameliorating the saline-alkaline wetland by using the fish pond-agricultural terrace system in the yellow river delta fo decades. In some places of New South Wales, Australia, utilization of saline alkaline area for aquaculture purpose is very successful.

CONCLUSION

From the present study, it is clear that the survival, growth performance, carrying capacity of the pond and the maximum profitability was found good in moderate salinity culture (pond 2). Because of the minimum ROI in high saline culture, it is observed that the effort made in the high saline culture area (pond 3) to produce *P. monodon* should be diverted towards low saline and moderate saline ponds to get the maximum productivity and ROI.

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