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Feeding management and waste production in semi-intensive farming of *penaeus monodon* (fab.) at different stocking densities

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Abstract. Studies on waste production and feeding management of *Penaeus monodon* in semi-intensive culture system were carried out for four successive crops at a commercial farm (M/S Suryo Udyog Ltd.) at Chandipur Coast of Orissa, India, at six different stocking densities. The prescribed feeding programme of C.P. Group, Thailand (NOVO-shrimp feed) were adopted and standardized during first two crops and the standardized feeding scheme was evaluated in the last two crops. Influence of standardized feeding programme on average feed conversion ratio (FCR) of *P. monodon* was highly significant ($p < 0.001$) against that of manufacturer's (NOVO-feed) prescribed feeding programme. A feeding frequency of more than four times a day showed no improvement in growth rate and there was no change in diurnal feeding habit probably due to the fact that, in scientific farming, aquatic environment is artificially controlled. It was also observed that, as the age and weight of shrimp increases, feed % decreases from 8.8 to 1.9% and lift net (LN)% increases from 2.4 to 4.3% for 1–40 g mean body weight of *P. monodon* respectively. The higher the stocking density, the higher was the FCR and sedimentation rate. In the present experiment, the sedimentation rate was estimated to be 49.5 m^3 (dry volume)/1000.0 kg of shrimp biomass. The average quantity of waste matter production was only 571.4 kg of organic matter, 10.21 kg of nitrogen and 0.527 kg of phosphorus at an average FCR of 1.437 and stocking density of 22.5 pcs m^{-2} during the four crop experimental period.

Introduction

Scientific shrimp farming depends largely upon commercially formulated high-energy balanced feed, which constitutes nearly 55% of the total operation costs. Supplemental feed is provided especially in commercial shrimp farming due to insufficient availability of natural feed. However, both the feed quality and management play important role in governing production and feed conversion efficiency as well as minimizing pond bottom and water quality deterioration due to over feeding. As feed intake pattern and consumption rate of shrimp varies under different agro-climatic conditions, a site-specific standardized feeding programme is essential for effective feeding management. As shrimp feeding is affected by several other factors such as feed attractant quality, feeding practice, pellet size, moulting, water and bottom quality, disease and availability of natural food (Mohanty 1996), strategic feeding management in combination with a site-specific feeding programme is highly essential, as it only improves growth and FCR but also reduce production cost per kg shrimp.

Pond bottom sediment quality and quantity reflect pond output and play an important role in mineralization process of organic matter, absorption and release of nutrients to water, influencing water quality and eventually survival of shrimp. The physico-chemical properties of pond water are more or less a reflection of the properties of bottom sediment. The nutrient status, chemical and biochemical process in shrimp pond depend largely on the quantity and quality of bottom sediment. While the latter (quality) has been investigated in great details (NACA 1994; Boyd 1995), the former (quantity) inspite of its importance, has not received much attention in the Indian sub-continent. Therefore, the present study on scientific feeding management and quantification of sediment settlement rates, as well as waste production at different stocking density was carried out.

Material and methods

The present study was carried out at "Shrimp Culture Pilot Project" at Chandipur Coast of Orissa, India, during 1997–1998. Three ponds of 7500 m^2 each (P_1, P_2 and P_3) and three ponds of 6000 m^2 each(P_4,P_5 and P_6) were selected for the proposed study. Stocking density (pcs m^{-2}) of *P. monodon* was 35, 25, 15, 30, 20 and 10 for pond no. P_1, P_2, P_3, P_4, P_5 and P_6 respectively, through out the four crop experimental periods. Semi-intensive culture methodology was adopted. Artificial high energy supplemental feed (NOVO feed of C.P. Group, Thailand) was used through out the experimental periods, while periodic water exchange (2–30%), liming, fertilization and pond aeration using paddle wheel aerator was a regular practice. The recommended feeding schedule by the feed manufacturer i.e; % feed (5.5–2.3 for 6–36 g MBW), % lift net (2.6–4.1 for 6–36 g MBW), checking time (2 hour through out the culture) and feeding frequency (4 up to 12 g MBW, 5 upto 24 g MBW and 6 up to 36 g MBW) was modified as given in Table 1. Feeding management was mainly based on site-specific approach. Standardization of feeding programme for proper utilization of feed, minimal wastage and better growth of shrimp was done (Table 1) and adopted in the third and fourth crop after observing the meal to meal check tray performance of prescribed feeding scheme of C.P. Group, Thailand, the manufacturer of NOVO-shrimp feed, during the first two crops. Standardization of feeding programme was carried out on the basis of shrimp feeding behavior, meal to meal check tray report, time control in relation to shrimp age and weight, feed quality and stocking density. Keeping the size of pond and position of aerator in view, six check trays per ha (one check tray approximately for every 1650 m^2) were used.

Physico-chemical parameters of pond water, e.g., dissolved oxygen (DO), temperature, pH, turbidity, CO_2 and salinity were monitored in-situ every day between

Table 1. Standardised Feeding Programme for *Penaeus monodon* at Stocking Density of 10–30 pcs m^{-2}.

(A) Blind Feeding Programme (Initial 30 days)

Days of Culture	Feed Increase/ Day/100000 PL	Feed/Day/100000 PL	Feed Code
1	–	1.2 kg	Starter-1
2–10	200g	1.4–3.0 kg	Starter-1 & 2
11–20	250 g	3.25–5.5 kg	Grower
21–30	300 g	5.8–8.5 kg	Grower

(B) Detailed Feeding Programme

DOC	MBW (g)	ADG (g)	% Feed	Feed Type	Frequency	% Lift Net	Time Control
1–30	0.02–2.0	0.006	60–8.0	Starter-1,2	4	2.4–2.5	2.5 h
30–50	2.0–6.0	0.2	8.0–5.4	Starter-2	4	2.5–2.6	2.5 h
50–75	6.0–11.5	0.22	5.4–4.3	Grower	4	2.6–2.9	2.0 h
75–90	11.5–16.5	0.33	4.3–3.8	Grower	4	2.9–3.3	2.0 h
90–100	16.5–20.0	0.35	3.8–3.4	Grower	4	3.3–3.7	2.0 h
100–110	20.0–24.0	0.4	3.4–3.0	Grower	4	3.7–3.9	1.5 h
110–120	24.0–28.5	0.45	3.0–2.4	Finisher	4	3.9–4.0	1.5 h
120–140	28.5–37.0	0.42	2.4–2.0	Finisher	4	4.0–4.2	1.0 h

N.B.: From 25th day, check trays are immersed in to the ponds with some amount of feed for every meal upto 30th day, so that baby shrimps are made to learn their check tray feeding habit. From 31st day onwards till harvesting meal to meal feed adjustment is done on the basis of check tray feed consumption.

DOC: days of culture, MBW: mean body weight, ADG: average daily growth.

0700–0800 hours and 1500–1600 hours. Weekly analysis of other physico-chemical parameters of pond water, discharge water and monthly analysis of pond soil and sediment sample were carried out using standard methods (APHA, American Public Health Association 1989; Biswas 1993; Dash and Pattanaik 1994). Soil samples from each experimental pond were collected from 0.3m depth profile and 10 samples from each pond were collected from different locations, twice in a crop (beginning of each crop after removal of black soil and immediately after harvesting, before flushing). However, sediment samples were collected once per crop after harvesting. Standard methods were used for analysis of soil and sediment pH, sodium chloride, H_2S, ammonia, EC, organic carbon, organic matter, available nitrogen, $CaCO_3$ and phosphorous (Biswas 1993). Estimation of sedimentation rate was done by fixing graduated scales at different locations after proper compaction and before water filling in the ponds. Before water filling the initial scale reading parallel to the bottom surface was taken. After harvesting, the final scale reading parallel to the bottom surface was taken. The immediate difference between the two readings was the wet thickness of sediment while, after 3 weeks of sun drying, the difference between the two readings was taken as dry thickness of sediment. Readings for plankton and benthic fauna (Dash and Pattanaik 1994) were also carried out for each pond during the four crop experimental periods.

Weekly growth study was carried out by sampling prior to feeding, so that complete evacuation of gut was ensured. Growth performance and factors affecting growth were statistically (ANOVA) analyzed. Weekly condition factor, mean body weight (MBW), average daily growth (ADG), survival rate (SR%), biomass (kg), feed requirement, % feed used, amount of check tray feed, feed increment per day and FCR was estimated using formulas as described by Mohanty (1997, 1999).

Results

The site-specific standardized feeding program (Table 1), which was evaluated during the last two crops, showed encouraging results (Table 4) with higher percentage survival rate, low FCR, high ADG and productivity (t ha^{-1}) in comparison to the first two crops of similar stocking density (crop-III, summer crop vs. crop-I, summer crop and crop-IV, monsoon crop vs. crop-II, monsoon crop). The influence of a standardized feeding programme on average feed conversion ratio of *P. monodon* was highly significant ($p < 0.001$) against the feed manufacturer's feeding programme (Table 3). Meal-wise as well as month-wise feed consumption rate in percentage of total feed consumed per crop was evaluated on the basis of check tray assessment and daily feed consumption. Meal-wise average feed consumption was 25.9%, 24.7%, 28.0% and 21.4% for morning, afternoon, evening and night meals respectively, while month-wise average feed consumption rate was 3.5%, 11.7%, 34.2% and 50.6% for 1st, 2nd, 3rd and 4th month to harvesting respectively.

The study also revels that as the age and weight of shrimp increases, the feed % decreases from 8.8–1.9% and lift net % increases from 2.4–4.3% for 1–40g mean

Table 2. Feed Percentage and Lift Net Percentage in Relation to Average Body Weight (g) of *Penaeus monodon*.

MBW (g)	FEED %	LN %	MBW (g)	FEED %	LN %
1	8.8	2.4	21	3.3	3.7
2	8.0	2.5	22	3.2	3.8
3	7.3	2.5	23	3.1	3.8
4	6.6	2.5	24	3.0	3.9
5	6.0	2.6	25	3.0	3.9
6	5.4	2.6	26	2.8	3.9
7	5.2	2.7	27	2.6	3.9
8	5.0	2.7	28	2.4	4.0
9	4.8	2.8	29	2.4	4.0
10	4.6	2.8	30	2.3	4.0
11	4.4	2.9	31	2.3	4.1
12	4.2	2.9	32	2.2	4.1
13	4.1	3.0	33	2.2	4.1
14	4.0	3.1	34	2.1	4.1
15	3.9	3.2	35	2.1	4.2
16	3.8	3.3	36	2.0	4.2
17	3.7	3.4	37	2.0	4.2
18	3.6	3.5	38	1.9	4.2
19	3.5	2.6	39	1.9	4.2
20	3.4	3.7	40	1.9	4.3

MBW: mean body weight, LN: lift net

body weight respectively, while the check tray checking time (time control) decreases from 2.5–1.0 h for 1–37 g mean body weight of *P. monodon* respectively (Tables 1 and 2). If longer monitoring time are used, shrimp will be overfed and will increase FCR. A feeding frequency of more than four times a day showed no improvement in growth rate and there was no change in diurnal feeding habit of *P. monodon*.

In the present experiment the organic content of the sediment was low and ranged from 1.88–4.03 mg/kg of ammonia, 175.6–431.2 mg/kg of nitrogen, 9.7–21.4 mg/kg of phosphorous and 1.07–2.11 mg/kg of H_2S probably due to the adoption of site-specific feeding programme (strictly based on standing biomass and meal to meal check tray monitoring), moderate stocking density (avg. SD = 22.5 pcs m^{-2}), periodic liming, water exchange and aeration. The average sedimentation rate in grow-out ponds (after harvesting) was 170–370, 169–301, 160–330, 150–268, 152–300 and 140–240 m^3/ha/crop (dry volume) at stocking density of 35, 30, 25, 20, 15 and 10 pcs m^{-2} respectively in four crops. The sedimentation rate was estimated to be 49.5 m^3 (dry volume)/1000.0 kg of shrimp biomass, as the total build up sediment was 3504.0 m^3 (dry volume) during the four crop experimental period against the total shrimp production of 70788.47 kg. The maximum and minimum FCR was 1.649 and 1.286 for P_1 (crop-II) and P_6 (crop-IV) respectively and the average quantity of waste matter (Table 6) was only 571.4 kg (organic matter), 10.21 kg (nitrogen) and 0.527 kg (phosphorus) at average FCR of 1.437. It is also estimated that an average 1 pcs m^{-2} increase in stocking density would increase sediment content (dry weight) @ 3.12 t/ha/crop in a semi-intensive culture system.

Discussion

Feeding management

P. monodon is a nocturnal continuous-intermittent feeders. This feeding behavior dictates the feed management strategy. Akiyama and Chwang (1995) reported that, shrimp should be fed several times a day with the major portion of the daily feed allotment to be administrated at night when shrimp are most active. However, the present study showed poor feed consumption during night times (last meal of the day) due to low dissolved oxygen, pH and temperature. Feed management should therefore be regulated by feed consumption and demand as shrimp appetite vary with the environmental conditions, i.e, weather, water quality, physiological conditions such as moulting, stress, disease and gut evacuation rate (Dall 1967). It is generally acknowledged that multiple feeding improves growth and FCR (Sedgewick 1979) and minimize accumulation of uneaten feed. Juvenile and adult shrimp ingest what they can effectively assimilate at one time and stop feeding once their cardiac chamber (fore gut) is filled (Lovett and Felder 1990). Gut evacuation rate of *P. penaeid* shrimp are in the order of 1–5 hours (Dall 1967) and therefore, infrequent feeding obligates the animal to forage on other food items. Akiyama and Chwang (1989) reported that a higher feeding frequency resulted in higher growth. However, in the present study a, feeding frequency of more than four times a day showed no improvement in growth, which is also supported by Robertson et al. (1992). The diurnal feeding habit may change in relation to the age of shrimp (Raymond and Lagardere 1988), but during this study no such changes were observed, probably due to the fact that in scientific farming the aquatic environment is artificially controlled (Mc Tigue and Feller 1989).

Approximately, 1–3% of the total feed provided per meal are given on each check tray (Abesamis 1989) and all the feed in tray should be consumed within 1–1.5 hours after feeding for the larger shrimp and within 2 hour for smaller shrimp (Akiyama and Chwang 1995). However, the present study revealed that as the age and weight of shrimp increased the feed % decreased and lift net % increased for 1–40 g mean body weight of *P. monodon* respectively (Tables 1 and 2). As feed consumption may during the day due to changing environmental/hydrobiological factor, feed consumption should be monitored at each feeding using check trays.

Additional daily feeding has no effect on growth (Robertson et al. 1992) and a little underfeeding is better than overfeeding (Anonymous 1994), as much of the uneaten food particles act as substrate for the growth of benthic fauna and contrib-

Table 3. Influence of Different Feeding Progamme on Average Feed Conversion Ratio of *Penaeus monodon* at Different Stocking Densities.

Source of variation	Degree of freedom	Sum of squares	Mean square	Calculated F-value	Tabulated F-value	P-value	Significance level
Between stocking density	5	0.011	0.002	8.212	5.1	< 0.05	*
Between feeding programme	1	0.034	0.034	125.093	47.2	< 0.001	*
Error	5	0.001	0.000	–	–	–	–

CV = 1.15%, standard error of treatment mean = 0.017, standard error of difference of two means = 0.023, critical difference value = 0.060.

Table 4. Results of Standardised Feeding Programme

Results of Feeding Programme of C.P. Feed, Thailand (Average of Crop-I & Crop-II)					
POND NO.	SD (pcs m^{-2})	ADG (g)	FCR	Production (t/ha)	SR %
1	35	0.232	1.55	4.98	42.2
2	25	0.232	1.5	4.26	57.87
3	15	0.24	1.48	2.39	50.79
4	30	0.235	1.47	4.85	48.93
5	20	0.235	1.47	3.28	59.41
6	10	0.231	1.46	1.47	59.43
Result of Standardised Feeding Programme (Average of Crop-III & Crop-IV)					
POND NO.	SD (pcs m^{-2})	ADG (g)	FCR	Production (t/ha)	SR %
1	35	0.25	1.45	7.22	68.99
2	25	0.261	1.36	5.9	73.49
3	15	0.259	1.36	3.37	72.66
4	30	0.254	1.4	7.05	74.81
5	20	0.261	1.37	4.77	68.39
6	10	0.274	1.35	2.33	66.55

SD: Stocking Density; ADG: Average Daily Growth; FCR: Feed Conversion Ratio; SR: Survival Rate.

ute to a deterioration of the water and bottom quality of the pond. Feed should be dispersed uniformly through out the pond and feeding zone and not in the scouring path of aerators. Improving FCR is a significant means of cost reduction. In most of the cases it was observed that the higher the stocking density the higher the FCR (Table 4). The relative feeding rate decreases as the days of rearing increases. In order to accelerate growth and to reduce cannibalism, a little overfeeding during the initial phase of rearing is recommended as it showed a negligible effect on FCR.

The observed results of feeding management in the present study also suggests that, about 20–25% of feed can be reduced during high turbidity (< 20 cm), partial moulting (20–30%), bad weather, low dissolved oxygen (< 3.0 ppm), low temperature (< 24 °C) and about 50% of total feed can be reduced during mass moulting, continuous bad weather, plankton crash and low temperature (< 14 °C). Since different size group normally do not feed together, split feeding technique can be adopted to avoid size variation. As shrimp feed consumption is also affected by changing feed code/size, the current feed and subsequent feed can be mixed @ 75:25, 50:50, 25:75 and finally 100%. The mixture can be fed for three days, thereby, gradually weaning the shrimp from one feed code/size to another.

Sedimentation rate

Shrimp pond sediments are characterised by a high organic matter content due to increased feed input, excretion, suspended solids, plankton die-off and manuring. Mounds of sediment in well aerated ponds usually do not contain large amount of organic matter as commonly thought. They consist primarily of mineral soil (95–98%) and only a little organic matter of 2.5% (Boyd 1995). As reported by NACA (1994), for scientific shrimp culture system for a period of 120 days, the content of sediment was 13.9–102.4 mg/kg of ammonia, 7.45–19.45 mg/kg of H_2S, 0.1–0.21 mg/kg of nitrite, 0.31–0.47 mg/kg of nitrate, 0.01–2.71 mg/kg of phosphate and 3.1% of organic matter. However, in the present experiment the content of sediment was much less which ranged between 1.88–4.03 mg/kg of ammonia, 175.6–431.2 mg/kg of nitrogen, 9.7–21.4 mg/kg of phosphorous and 1.07–2.11 mg/kg of H_2S probably due to the adoption of site-specific feeding programme (strictly based on standing biomass and meal to meal check tray monitoring), moderate stocking density (avg. SD = 22.5 pcs m^{-2}), periodic liming, water exchange and aeration.

The average sedimentation rate in grow-out ponds (after harvesting) was 307–330 m^3/ha/cycle (Banchong 1995), where as in the present study it was 170–370, 169–301, 160–330, 150–268, 152–300 and 140–240 m^3/ha/crop (dry volume) at stocking density of 35, 30, 25, 20, 15 and 10 pcs m^{-2} respectively in four crops. The sedimentation rate was estimated to be 49.5 m^3 (dry volume) / 1000.0 kg of shrimp biomass, as the total build up sediment was 3504.0 m^3 (dry volume) during the four crop experimental period against the total shrimp production of 70788.47 kg. The quantity and quality of sediment produced by the experimental ponds in the present study was variable, depending on the days of culture, farm management,source of water, stocking density, FCR and water exchange rate. In most cases, it was observed that the higher the stocking density, the higher the FCR giving a higher sedimentation rate (Table 5). A good FCR however, helps in maintaining good pond bottom and minimizes the sediment quantity. At FCR 1.0–1.5, estimated waste production (Anonymous 1991) ranges between 500–875 kg (organic matter), 26–56 kg (nitrogen) and 13–21 kg (phosphorus). However, in the present study the estimated values were much less than the values reported (Table 6), probably due to moderate stocking density (< 35 pcs m^{-2}) and adoption of site-specific management practices. Variation in pond management also affects rate of sedimentation. Wyban and Sweeney (1989) reported that organic sedimentation rate in scientific shrimp culture ponds can exceed 0.8 kg dry matter m^{-2}/day. However, the present study disagrees with this high rate of sedimentation, as in the present experiment,

Table 5. Sediment Quantity in Relation to Stocking Density and Feed Conversion Ratio of Penaeus Monodon (Average of four crops).

Pond No	Area	SD	Yield	FCR	Average Quantity of Sediment	
	(m^2)	(pcs m^{-2})	(kg)		m^3/m^2/crop	Dry weight (t/ha/crop)
1	7500	35	4579.9	1.503	0.024	56.5
2	7500	25	3816.0	1.432	0.0225	45.0
3	7500	15	2166.5	1.420	0.0205	31.6
4	6000	30	3572.2	1.438	0.0227	65.0
5	6000	20	2417.3	1.422	0.0217	61.8
6	6000	10	1145.2	1.406	0.0185	29.0

SD: Stocking Density; FCR: Feed Conversion Ratio.

Table 6. Quantification of Waste Production in Relation to Feed Conversion Ratio of *Penaeus monodon* and Biomass.

Pond No	Average	Quantity of waste matter (kg)			Waste matter (kg) / t of shrimp produced		
	FCR	OM	N	P	OM	N	P
1	1.503	987.3	18.27	0.907	215.60	3.99	0.20
2	1.432	492.7	14.11	0.648	129.10	3.7	0.17
3	1.420	258.3	6.37	0.434	119.20	2.94	0.20
4	1.438	1076.4	12.11	0.640	301.30	3.4	0.18
5	1.422	415.3	7.36	0.360	171.80	3.05	0.15
6	1.406	198.4	3.06	0.176	173.20	2.67	0.15
Average:	1.437	571.4	10.21	0.527	185.03	3.29	0.18

FCR: Feed Conversion Ratio, OM: Organic Matter.

the average sedimentation rate was 4.82 kg m^{-2}/crop at average stocking density and FCR of 22.5 pcs m^{-2} and 1.437 respectively (Table 5).

Although several factors like water exchange, source water, organic and inorganic inputs etc. are responsible for sedimentation process, stocking density and feeding management play the key role. Therefore it is recommended to avoid over stocking (ideal SD = 20–30 pcs m^{-2}), overfeeding and over-fertilization. A sufficient number of aerators (1 hp aerator per 1650m^2 at the minimum) in the right position for sediment accumulation at the centre and timely water exchange (preferably bottom drainage) should be carried out to minimize the sedimentation process.

These above findings and information on shrimp feeding behaviour and intake pattern should help aquaculturists in managing their shrimp ponds more scientifically and effectively. By adopting site-specific feeding schedule, economically viable FCR can easily be achieved without hampering the growth performance of shrimp. This would also reduce the stress on pond ecology and sedimentation rate which ultimately reflects in better pond output.

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