The tiger shrimp, *Penaeus monodon* Fabricius, is a fast growing, euryhaline, eurythermic, omnivorous, hardy species well known for its delicious flesh that is not only very tasty and highly nutritious but also of very high commercial value, especially in the international market. Since the ever increasing demand of this shrimp is hardly met by the exploitation of the natural populations, this shrimp is now artificially raised in many parts of the world, particularly in the tropical southeast Asian countries. On realising the high economic potential of *P. monodon*, many entrepreneurs in India have, long back, taken to the farming of this shrimp; in Nellore in Andhra Pradesh and in Tuticorin in Tamil Nadu *P. monodon* culture is a hectic activity. In Kerala State artificial rearing of shrimp is an age-old practice. But till recently, the only shrimp farming activity of this State was the traditional system of "prawn filtration"—entrapment of juvenile shrimps, during October-April period, brought by the tide water into the low-lying 'Pokkali' rice fields adjoining the Vembanad Lake, and harvesting them at regular intervals. This crude traditional method, even though still in vogue, of late there is heightened interest and activity for farming *P. monodon* in small-scale, semi-intensive, monoculture systems connected to the extensive backwater spread, particularly in the central parts of the State. The present study was aimed at analysing the bio-economics of *P. monodon* farming now being
practised in Kerala State, as there has hitherto been no serious attempt at making such a study. Detailed analyses of the following aspects were made in this study.

1. The physico-chemical features of the small-scale, semi-intensive tiger shrimp culture systems.

2. The growth and production of tiger shrimp in selected semi-intensive, monoculture systems.

3. The evaluation of the efficacy of certain supplementary feeds, both natural and formulated, that are being used by shrimp farmers of this State, on the overall performance of shrimp in these systems.

4. The economics of the small-scale, semi-intensive, tiger shrimp farming in this State.

For the study three regions were selected from the two central districts, Alleppey and Ernakulam: Pallithode in Alleppey and Chellanam and Kannamaly in Ernakulam. From each region three ponds which had similar management practices were chosen.

In the selected three regions, sufficient salinity prevailed for 8-10 months enabling two culture operations per year. The study was conducted during 1991-92; altogether 36 culture operations, each extending for a period of 120 days were studied.

The area of the ponds selected ranged from 0.5 ha to 1.0 ha. Drying the pond bottom, eradication of pests and predators (if needed with mahua oil-cake, ammonia gas, or lime + ammonium sulphate), liming
(100-600 kg/ha) and fertilization with organic (cattle manure = 200-500 kg/ha) and inorganic fertilizers (super phosphate, musooriphos, ammonium sulphate, or urea either solitarily or in combination = 20-75 kg/ha) and water management were carried out in all the ponds. Only hatchery reared seed (PL 20), mostly transported from other States, was used for stocking. In all the three regions seed was directly introduced into the grow-out ponds, either into hapas in the ponds or in a nylon-net-secluded 'nursery' part of the pond. Three types of supplementary feeds were used by the farmers: clam meat (in all the three regions) clam meat with dough ball (in Chellanam and Kannamaly) and farm-made pelleted feed (in Pallithode alone). Water exchange rate was about 5-10% per day which was increased to about 20% towards the end of the culture period.

For the analyses of the physico-chemical parameters, fortnightly collections of water samples were taken from the ponds and the following parameters were determined. Water temperature, pH, salinity, dissolved oxygen of surface and bottom water, total alkalinity, nitrate-N, nitrite-N, ammonia-N and reactive phosphorus. In addition, air temperature, soil temperature, soil pH, Secchi disc visibility and depth of the ponds were also measured. Standard methods were employed for the determination of the physico-chemical parameters.

Because of the practical difficulties in procuring seed from all the selected ponds at the time of stocking, 120 post-larvae (PL 20) were collected from a hatchery and their average length and weight were
determined. The average length was 1.40 cm and the average weight, 0.060 g; this was reckoned as the size at stocking for all the 36 culture operations. On the 30th day of stocking, and thereafter after every 15 days, 40 specimens were collected randomly from each pond and their average length and weight were determined.

Average daily length and weight gain, instantaneous growth, biomass increase per day and survival rate were estimated by using standard procedures. Length-weight relations of shrimps fed the three supplementary feeds were worked out by simple linear regression analysis using the linear form of the relation \( W \propto L^n \), \( \log W = \log a + n \log L \).

Three supplementary feeds were used by the farmers: fresh meat of *Vellorita cyprenoides* var. *cochinensis* (clam meat), clam meat + compounded feed (dough ball) and a farm-made pelleted feed. The protein, fat and carbohydrate contents of the feeds and their gross energy and protein to energy ratio (P/E ratio) were determined. The Apparent Feed Conversion Ratio (AFCR) and the Feed Conversion Efficiency (FCE) were also determined by using standard formulae.

For the analysis of the economics of tiger shrimp farming, the following ratios were calculated. Input-output ratio, feed and operating cost ratio, seed and operating cost ratio and labour charges and operating cost ratio. Cobb-Douglas production function was worked out to find out the input-output relation. Economic optima were
calculated by using the estimated production function by comparing the benefits of adding units of inputs to the additional cost of the inputs.

The results of the study may be summarised as follows.

1. All the physico-chemical parameters in the three regions were well within the tolerance limits for the species and conducive for tiger shrimp culture. The results of ANOVA test revealed that all the parameters except air temperature, water temperature, salinity, DO of surface water, nitrite-N, ammonia-N and Secchi disc visibility differed significantly between the three regions. Therefore, the water quality parameters of the ponds in which the three different feed types were used, were compared statistically (ANOVA). The results showed that of the nine water quality parameters only pH, alkalinity and ammonia-N differed significantly between the treatments (feed types).

2. The results did not reveal any consistent correlation between water quality parameters and shrimp survival, growth, or biomass increase, suggesting that the overall performance of shrimp in the 36 culture operations in the three regions were not, or were only minimally influenced by the water quality parameters.

3. The stocking density ranged from 40,000 to 100,000 PL/ha (mean = 63,116), survival rate ranged from 38 to 58% (mean = 50.21%) and the production ranged from 560 to 1536 kg/ha per crop (mean = 959.20 kg/ha).
4. The average final length and the average final weight were 15.10 cm and 30.23 g, respectively. Mean biomass increase was 95.38 g/m² for 120 days at the rate of 0.795/m²/day at an average stocking density of 6.31 PL/m². The average growth rate was 0.252 g/day per animal.

The higher growth rate and the better overall performance of tiger shrimp noted in the present study than in most other similar studies from other regions for the same species or for other species of penaeids, are attributable to the combined effect of supplementary feed and fertilizer applied in the systems.

5. The protein content of fresh clam meat (52.60%) was higher than that of both clam meat + dough ball (40.15-49.79%) and the pelleted feed (35.27%).

The dough ball contained two protein sources (ground nut oil cake and rice bran) and the pelleted feed, four (squilla powder, rice bran, shrimp head and ground nut oil cake). All the protein sources in both the feeds were of local origin. Further, the pelleted feed contained chitin, cod liver oil and palm oil also.

The dough ball had a moisture content of about 50%. The conversion ratio of wet weight to dry weight for clam meat was 4 : 1 and for dough ball, 2 : 1.
6. Three feed types were used by the shrimp farmers in Kerala: clam meat alone, clam meat + dough ball and pelleted feed. The important nutritional indices of the three feed types were as follows.

<table>
<thead>
<tr>
<th></th>
<th>Gross energy (kcal/100 g feed)</th>
<th>P/E ratio (mg Protein/kcal)</th>
<th>AFCR</th>
<th>FCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clam meat</td>
<td>502.72</td>
<td>104.63</td>
<td>1.70</td>
<td>59.40</td>
</tr>
<tr>
<td>Clam meat + Dough ball</td>
<td>403.69-480.24</td>
<td>99.48-103.68</td>
<td>1.59</td>
<td>64.94</td>
</tr>
<tr>
<td>Pelleted feed</td>
<td>295.91</td>
<td>119.24</td>
<td>1.55</td>
<td>64.51</td>
</tr>
</tbody>
</table>

Both the AFCRs and the FCEs of the three feeds were not significantly different.

7. The production and the biomass increase per day were not significantly influenced by the feed types. However, the mean final weight of shrimp achieved with the three feed types differed significantly. The results of Newman-Keul multiple range test (SNK) showed that the pelleted feed was superior to the other two feed types in realising significantly higher mean final weight of shrimp.

Fresh clam meat, the traditional supplementary feed used by shrimp farmers in Kerala though on its own is a good supplementary feed for farm-raised shrimps, is inferior to the farm-made pelleted feed used in the present study. This is attributable to the high gross energy of fresh clam meat resulting in its under utilisation by the shrimp leading to low
intake of food and consequently, deficiency of essential nutrients.

The results of the present study also showed that the combination of clam meat and the unscientifically formulated dough ball was no better than clam meat alone as supplementary feed. However, when there is shortage of clam meat, the combined feed may come in handy not only to keep up the production at the same level as that with clam meat alone but also to help the farmer gain, though only marginally, on feed cost. Improving the quality of the dough ball by adding/changing the ingredients and reducing the present level of 50% moisture content, may improve the efficacy of the feed.

8. The lowest AFCR (1.55) as well as the highest growth (mean final weight = 31.60 g) were achieved with the pelleted feed used in this study. The P/E ratio was also the highest for pelleted feed (119.24 mg protein/kcal). The higher efficiency of this feed is because of,

(i) the better amino acid balance in the feed by virtue of the presence of four different protein sources of local origin, of which two are marine,

(ii) the presence w-3 and w-6 poly unsaturated fatty acids by virtue of the incorporation of cod liver oil and palm oil in the feed and
(iii) the presence of chitin (shrimp head and squilla powder) in the feed, which improves its palatability, fulfills the shrimps requirements of chitin substrate and supplies ample quantity of calcium for rapid growth.

9. The length-weight relations of shrimps fed each feed type in each region were worked out.

The results showed that the length-weight relations of shrimps fed clam meat alone in the three regions were significantly different from each other. The same was true for the two regions where clam meat + dough ball was fed. Pelleted feed was used only in Pallithode. In all the cases the dependence of weight on length was statistically highly significant.

The length-weight relations of shrimps fed the three feed types (ignoring the regional differences within the treatments), revealed that the slopes as well as the elevations of the three regression lines were similar. Hence, a weighted or common regression coefficient \( b_c \) was calculated \( b_c = 2.7387 \). The common regression equation derived for the length-weight relation of the shrimps cultured in the small-scale, semi-intensive, monoculture systems of Kerala is,

\[
\log W = \log 0.0154 + 2.7399 \log L
\]

(The 95% confidence interval of the regression coefficient = 2.7399 ± 0.1006; standard error of Y intercept = \( \log 0.0154 \pm \log 0.0523 \)).
Analysis of the economics revealed that the small-scale, semi-intensive, monoculture system of *P. monodon* culture being done in Kerala is highly profitable. The average cost of production was Rs.75.50/kg and the price realisation, Rs.146.44/kg. The input-output ratio was 1.93, which is a high index in this industry.

The operating cost is less (Rs.72,420.00) and the gross (Rs.1,40,026.00) and net incomes (Rs.67,606.00) on an average are higher for tiger shrimp farming in Kerala than in other similar systems in the country.

Cobb-Douglas production function worked out for the six input variables—area of pond (*X*_1), stocking density = seed cost (*X*_2), feed cost (*X*_3), labour charges (*X*_4), eradication cost (*X*_5) and fertilization (*X*_6)—is,

\[ Y = 0.006036 X_1^{0.14} X_2^{0.82} X_3^{0.28} X_4^{0.14} X_5^{0.009} X_6^{0.07} \]

with an \( R^2 \) of 0.91.

All the elasticity coefficients were positive and they added up to 1.439, implying that production can be increased substantially by increasing the inputs. However, of the six inputs, only three—seed cost, feed cost and labour charges—were significant; up to 88% of the variation in the output were attributable to these three inputs. Nevertheless, comparison of the values of marginal product of the input variables (MVP) with the unit cost of the inputs, or of the marginal physical product
of the input variables (MPP) with the ratio of the unit cost of the inputs to the unit price of the output revealed that the input, labour charges, in tiger shrimp farming in Kerala has reached the profit maximising level; stocking density and feed are yet to reach this level and increasing these inputs can substantially increase the production of tiger shrimp in the farming systems of the State.

The largest component of the operating cost of tiger shrimp culture in Kerala was feed cost (35%) followed by labour charges (27%) and cost of seed (20%).

The percentage of feed cost in total production cost, of pelleted feed was 30.37%; of clam meat + dough ball, 34.31% and of clam meat, 36.04%. Thus, the farm-made pelleted feed is economically much more profitable than the conventional feed alone, or this in combination with the unscientifically prepared compounded feed, in the semi-intensive tiger shrimp culture in Kerala. Further, from the nutritional point of view also the pelleted feed was found to be superior to the other two feed types.

The seed cost in Kerala is high. This is attributable to the non-availability of wild seed in the State and, therefore, the necessity of transportation of seed from other States because of the shortage of hatchery produced seed locally.
From the results of the present study the following major conclusions are drawn.

1. The present practice of the small-scale, semi-intensive, monoculture of *P. monodon* in brackishwater ponds of the central districts of Kerala is a highly profitable enterprise.

2. The profit margin can be substantially increased by increasing the two inputs, seed (= stocking density) and feed.

3. Establishment of *P. monodon* hatcheries to make available enough seed locally can heavily cut down the present high cost of seed and this, in turn, can increase the profit margin.

4. There is an imminent need to popularise the farm-made pelleted feed, as the one used by some farmers in the State, as this feed is superior both from the nutritional and from the economics points of view. This is particularly true because, overexploitation of the natural resources of *Vellarita cyprenoides* both for use as a supplementary feed by its own or for the commercial production of compounded feeds for use in shrimp farming and also for human consumption, will, in the near future itself, lead to acute shortage of the clam and consequently, to a drastic hike in its price.