# BIO-ECONOMIC EVALUATION OF SEMI-INTENSIVE SHRIMP FARMING IN KERALA

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## Certificate

This is to certify that this thesis entitled "BIO-ECONOMIC EVALUATION OF SEMI-INTENSIVE SHRIMP FARMING IN KERALA" is a bona fide research work carried out by Mr. G. Prasad, under my supervision and guidance. I further certify that no part of this thesis has previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title or recognition.

Cochin
January, 1995

(K. ALAGARAJA)
Supervising Teacher

# DECLARATION

*I hereby declare that this thesis entitled "Bioeconomic Evaluation of Semi-intensive Shrimp Farming in Kerala", is a record of original and bona fide research work carried out by me under the supervision and guidance of Dr. K. Alagaraja, Principal Scientist and Head, FRA Division, Central Marine Fisheries Research Institute, Cochin, and that no part thereof has been presented for the award of any other degree, diploma, Associateship, Fellowship or other similar title or recognition.*

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# CHAPTER I

## GENERAL INTRODUCTION

Penaeid shrimps are, perhaps, the most important fishery resource of the coastal waters of our country. Their exceptionally tasty, protein-rich flesh tops any seafood in foreign exchange earnings. No wonder, the demand of shrimp, the "Pinkish Gold of the Sea" (MPEDA, 1992), is increasing in the world market. The high demand of shrimp in the developed countries, especially USA and Japan, since the beginning of the sixties, has been a strong incentive for developing countries with good shrimp fishery grounds, to concentrate on this fishery. Although penaeid species are found in all the seas of the world upto subpolar latitudes, their distribution is mainly tropical and subtropical (Wickins, 1976a). Most of the species of high commercial value, and their most productive fishing grounds, are distributed between the tropics (Pedini, 1981).

The high demand and the high price of shrimp in the international market have led to a rapid increase in the number of shrimp trawlers in the fishing fleets of the developing countries, resulting in intensive exploitation, rather overexploitation, of this resource; shrimp fishery of many of the countries, thus, has been depleted, is fast dwindling, or has reached the maximum sustainable yield. The global production of shrimp by capture had already levelled off in 1985 at 1.9–2.0 million mt. The average annual growth from 1985 to 1990 was only 0.02%; indeed negligible by all standards (Csavas, 1993). Since the capture shrimp fishery in terms of CPUE has been stagnating for the last several years, any further increase to close the supply-demand gap can be achieved only through aquaculture; shrimp culture has already gained considerable momentum in many parts of the world.

> The author wishes to add a note of clarification at this juncture, regarding the distinction between the two terms—shrimp and prawn—, which are still loosely and arbitrarily used in literature, so that often they appear as synonyms, despite the consensus arrived at the World Conference on the Biology and Culture of Shrimps and Prawns held in Mexico City in 1967, to restrict the term 'prawn' to freshwater forms and 'shrimp' to their marine and brackishwater counterparts. Throughout this text, these two terms are used as recommended by the said world conference and later emphasised by Csavas (1988).

By virture of the ideal conditions for pond construction, seed availability, favourable climate and above all, the inclination of the Asian people, fish culture has long been practised in Asia, right from the time of Wen Wang, the founder of the Chou Dynasty (1135-1122 B.C.). Fish culture first emerged as a profitable business by 460 B.C. in China. Large-scale brackishwater pond culture of fish and shrimp had its beginning in southeast Asia (Fast, 1991). By 1400 A.D. itself, milkfish (*Chanos chanos*) and several other species of brackishwater fishes began to be cultured in Indonesia (Ling, 1977). According to Padlan (1987), traditional brackishwater shrimp farming might have started about three centuries ago, in the Far East. Extensive system of shrimp farming in paddy fields around lagoons and backwaters in Kerala and West Bengal in India has been existing from historical times (Padlan, 1987). This extensive system of farming is the forerunner of the present-day improved, but low technology practice involving trapping, growing, and finally, capturing the animals. It would appear that very high intensive shrimp farming operation, with the aid of sophisticated technology, is rather a very recent development, barely 20–30 years old.

The pioneering works in shrimp culture research were carried out in the 1930s; the most important aspect studied was larval rearing. In 1934, Dr. Fujinaga, the father of shrimp culture, had successfully spawned and partially reared, for the first time, the larvae of *Penaeus japonicus* (Hudinaga, 1942). Later, Hudinga and co-workers also achieved success with the rearing of *P. japonicus* larva (Hudinaga and Kittaka, 1967). A succeeding breakthrough—the artificial rearing of *P. monodon*—was achieved in 1968 (Liao *et al.,* 1969). Larval rearing techniques for *P. vannamei* were developed in the early 1980s (Liao, 1990). Another important development that, in fact, revolutionised the field of shrimp culture was the commercial production of formulated feed; preliminary breakthrough in feed formulation technology occurred in the mid seventies. The dramatic increase in the share of cultured shrimp in the total world production of shrimp, from a paltry 2.1% in

1981 to a significant 22% in 1988, stands testimony to the impact formulated feed has had in shrimp culture (Liao, 1990).

Notwithstanding these developments, intensification of production from the extensive grow-out system was severely impeded for quite some time because of the severe shortage of post-larvae and juveniles for stocking. By the late 1960s and early 1970s, however, many of the constraints in captive reproduction of shrimp and seed availability were reduced or eliminated. This, in turn, resulted in the development of more intensive shrimp culture systems. The average shrimp production from the traditional extensive system is well under 500 kg/ha/year, whereas that from intensive culture may be ten times higher. Ultra-intensive culture systems can even produce more than 30,000 kg/ha/year. It is technically possible to produce a very high quantity of shrimps from a small area, but the profit margins are the highest in the semi-intensive production range of 500 to 2500 kg/ha/year (Fast, 1991).

Ecuador was the leading country in shrimp culture in the mid 1980s. But it lost this status in 1987, when Taiwan came to the forefront. In 1988, there occurred a mass mortality crisis of cultured shrimps in Taiwan, which enabled China to become the new world leader in 1988; China retrained the position till 1991. In 1992 Thailand became the world leader; China finished second, Indonesia third and Ecuador fourth.

According to the latest statistics (Anon, 1994), the total world production of shrimp from farming, which clocked at 721,000 mt in 1992, declined to 609,000 mt in 1993. The eastern hemisphere contributed to 78% of the world production and the western, 22%. In 1993, 25% of the shrimp placed in the world market came from farms. Thailand still retains the first place, contributing 155,000 mt of farm-produced shrimp. Ecuador has improved its position, finishing second (90,000 mt) and Indonesia held the third place (80,000 mt), but China went down to the fifth place (50,000 mt). As of 1993, India holds the fourth position, with a contribution of 60,000 mt of farm-raised shrimp to the world market.

As of ever, in 1993 also the tiger shrimp (*Penaeus monodon*) is the major produce contributing to 56% of the world farm-raised shrimp; *P. vannamei* forms 19% and *P. chinensis*, 16%.

Today, shrimp culture is most flourishing in the tropics, particularly in Asia and Latin America. The world production of shrimp from culture in 1992 was $7.21 \times 10^5$ mt—about 28% of the total world production (Rosenberry, 1992). Over 48,500 shrimp farms currently exist in more than 40 countries. The number of hatcheries is estimated to be about 3,000. The total area used for shrimp culture is 1,001,147 ha and the average production, 720 kg/ha/year (Rosenberry, 1992). The projected estimate of marine shrimp production from culture for 2000 A.D. is about $1.1 \times 10^6$ mt (Fast, 1991).

Shrimp culture will probably continue to expand in the late 1990s, but may be at a slower pace. Asia's production seems to have reached peak levels, and China's has already registered a decline from 1991 to 1993 (Rosenberry, 1994). Even though shrimp farming activity in the Asian region continues to increase, as indicated by the increase both in the number of entrepreneurs and the area brought under farming, this region faces major constraints by way of insufficient infrastructure facilities and expertise, pollution, disease and market fluctuations. Such constraints are very likely to impede the progress of shrimp farming all over the world in the coming years.

Shrimp has been the *prima donna* of the Indian fishery exports since early 1970s (MPEDA, 1992); it continues to be so. Till 1987, India was the world's largest shrimp producing and exporting country. Landings from capture fisheries were between 175,000 and 200,000 mt during 1973-87. It seems that production from this sector may not increase further, as the inshore waters are nearly fully exploited. Deep sea exploitation of shrimp resources is not only highly capital intensive, but its results are unpredictable as well; it is not likely to make any substantial additional contribution to the shrimp production of this country. However, the consumer demand for shrimp continues to increase world over. In this situation, aquaculture is the only way out for India to augment its shrimp production and to maintain its position as one of the leading shrimp producing and exporting countries of the world.

India is one of the few countries blessed with rich natural resources for fish and shrimp farming. It has 7,500 km coastline. The brackishwater area available for aquaculture in the country is about 1.4 million ha, of which only 80,000 ha are now under shrimp farming though; in 70% of this area traditional extensive method of culture alone is practised even now. In 1993, India produced 60,000 mt of cultured shrimp; from 4,000 farms at an average production of 750 kg/ha/year The Indian shrimp farming scenario of 1993 was as follows (after Rosenberry, 1994).

Total area under farming : 80,000 ha

Total production : 60,000 mt live wt.

Mean production : 750 kg live wt./ha

Number of farms : 4,000

| Extensive | Semi-intensive | Intensive |
|---|---|---|
| 70% | 25% | 5% |

Number of hatcheries : 30

| Small-scale | Medium-scale | Large-scale |
|---|---|---|
| 55% | 35% | 10% |

Species cultured :

| *P. monodon* | *P. indicus* | Others |
|---|---|---|
| 60% | 20% | 20% |

There is great scope for expanding shrimp culture in India. Even with the extensive type of culture, if the as yet unused acreage is brought under shrimp cultivation, the annual production could be easily increased to 100,000 mt (Muthu, 1978). As the shrimp industry is export-oriented, the additional yield from aquaculture of shrimp will bring in more foreign exchange and will also improve the rural economy of the country. Today, shrimp farming is one of the most profitable enterprises; no wonder, many national and multi-national corporate as well as other companies are trying to wake this "sleeping giant" by profusely investing in this industry in the maritime States of India, such as Andhra Pradesh, Tamil Nadu and West Bengal.

It is Kerala, the small southwest State of the Indian sub-continent, that put India on the map of shrimp exporting countries of the world. The waterspread of brackishwater lakes and the adjacent low lying fields and mangrove swamps in this State is estimated at about 242,000 ha (Tharakan, 1991). A traditional system of shrimp farming in paddy fields, popularly known as "prawn filtration", is practised in more than 4,500 ha of the low lying coastal brackishwater fields adjoining the Vembanad Lake. These fields, ranging in size from less than 0.5 ha to more than 10 ha, lying mainly in the coastal villages of Alleppey, Ernakulam and Trichur districts, and confluent with the Vembanad Lake through canals, are subjected to tidal influence. The farming system involves entrapment of juvenile shrimps brought in by the tidewater in the fields and catching them by filtration at regular intervals. These fields are used for growing paddy during the southwest monsoon season (June–September) and shrimps during the rest of the year. During the southwest monsoon, the heavy precipitation makes the waters of the Vembanad Lake almost fresh, and the paddy fields are inundated by freshwater. During this period, a special variety of paddy called "Pokkali", which is tolerant to salinities upto 8 ppt, is grown in these fields.

After the paddy is harvested, the fields are leased out to shrimp farmers from October to April. During this period, the salinity of the water in the feeder canals increases so that paddy cannot be grown. The bunds and sluices are repaired. The decaying paddy stalks provide a good substratum for the growth of periphyton. The juveniles of shrimps and fish that are natural inhabitants of the backwater system, enter the fields along with the tidewater. They feed on the rich detritus, periphyton and plankton and grow rapidly. During low tide, the shrimps and fish are prevented from escaping from the fields by placing nylon screens in the sluices. Fishing starts in December and continues till April. Fishing is done at night or in the early morning, during low tide, for 6–8 days about the new- and full moon phases. The average shrimp catch from these fields is around 300 kg/ha for a period of five months (Tharakan, 1991). At the end of the lease period, the fields are handed back to the owners for paddy cultivation.

There are some disadvantages for this type of culture. It is not possible to control the species composition or the density of the population of shrimps. The natural supply of seed fluctuates widely both in species composition and abundance from year to year and, therefore, the yield is highly variable. Of late, the production of shrimp from these fields is declining mainly because of the decline in larval recruitment of shrimps consequent on pollution and other types of human interference such as reclamation of backwaters, deforestation of mangroves, indiscriminate exploitation of juveniles with stake nets etc. Yet another factor is predators; they enter into the fields along with shrimp seed, prey upon the seed and thus drastically curtail the yield.

To overcome these difficulties and to get more profit from shrimp culture, monoculture of desirable species of shrimps has been started recently in Kerala. This small-scale, semi-intensive form of culture involves controlled stocking with known number of shrimp larvae collected from the wild or produced artificially in hatcheries. Supplementary feed is given to enhance the growth rate. The yield is highly variable depending on the nature of the ponds, the fertilizers used, the stocking density, the food given and the species cultivated. In Kerala this type of culture has been taken up by a few enthusiastic farmers mainly in Alleppey and Ernakulam districts. They are stocking the ponds with *Penaeus monodon* seed obtained mainly from hatcheries in other States.

The tiger shrimp, *P. monodon*, is universally recognised as one of the most important cultured species, particularly in the tropical southeast Asian countries. It is a fast growing, euryhaline, omnivorous and hardy species well known for its delicious flesh and high commercial value. Reaching a maximum length of about 330–340 mm, it is the largest and the fastest growing farm-raised shrimp species and it contributes to the major share of shrimp production from farming. This species contributed to about 56% of the world farm-raised shrimp in 1993 and 60% of the total cultured shrimp produced in India in 1993 (Rosenberry, 1994).

Semi-intensive shrimp farming is being widely practised in many parts of the southeast Asian countries. In India, in Nellore (Andhra Pradesh) and in Tuticorin (Tamil Nadu) the activity is hectic. But this system of farming shrimp is still in its infancy in Kerala State. However, some farmers have taken to monoculture of the tiger shrimp, though in a semi-scientific way. Of late, the number of such farmers is also increasing. Nevertheless, a perusal of the literature will reveal that, so far, there has been no serious attempts to study the various aspects of this small-scale, semi-intensive *P. monodon* culture practice in this State. This lack of information prompted the present study which was an attempt at making a detailed study on,

(i) the physico-chemical characteristics of the small-scale, semi-intensive tiger shrimp culture systems,

(ii) the growth and survival of tiger shrimp in selected semi-intensive, monoculture systems,

(iii) the efficacy of certain supplementary feeds, both natural and formulated, that are being used by shrimp farmers of the State, on the overall performance of shrimp in these systems, and

(iv) the economics of the small-scale, semi-intensive tiger shrimp culture in this State.

## Culture Systems Selected

In Kerala, shrimp farming is very popular in the two central districts—Alleppey and Ernakulam. The names and addresses of shrimp farmers in these two districts were procured from The Marine Products Export Development Authority (MPEDA), Cochin. First, a survey was conducted to evaluate the shrimp farming practices in the two districts. Based on this, three regions (Pallithode in Alleppey and Chellanam and Kannamaly in Ernakulam), where shrimp farming is done in a more or less scientific way, were selected (Fig. 1). From each region, three ponds which have somewhat similar management practices, were chosen. Altogether, nine ponds were selected for the study: three each from Pallithode, Chellanam and Kannamaly.

The general features of the nine ponds selected are shown in Table 1. In the selected regions sufficient salinity prevails for 8-10 months in an year and, therefore, two cultures per year are done in these regions. The study was conducted during 1991-92; altogether, 36 culture operations were studied. The period of the culture operations were as shown in Table 2. For the sake of convenience, the 36 culture operations studied were designated as shown in Table 3.

According to Fast (1991), the general characteristics of the semi-intensive shrimp culture systems are the following.

Semi-intensive culture is conducted above the high tide level. Ponds are generally smaller than those in extensive systems and they tend to be more regular in shape. Fertilization is done in most cases. The stocking rates range from 25,000 to 200,000 post-larvae/ha, with the stock coming both from the wild and from hatcheries. Since there is more competition for natural food in semi-intensive systems, supplementary feed is provided. Pumps, generally diesel pumps, exchange 5-20% of the water every day. In some cases the post-larvae are held in special nursery ponds for 1-2 months before they are stocked in the grow-out ponds. Artificial aeration by mechanical means, such as paddle wheel, is sometimes done. Shrimp production from such semi-intensive culture systems ranges from 500 to 2,500 kg/ha/year.

The characteristics of the small-scale, semi-intensive monoculture systems of *Penaeus monodon* practised in Kerala are almost similar to those described above. However, artificial aeration is not common in Kerala at present; in none of the ponds selected for the present study, artificial aeration was given.

The general culture practices of the farms selected were the following.

1. The area of the ponds ranged from 0.5 ha to 1.0 ha. The dykes and sluices were repaired and maintained throughout the culture period.

2. Drying the pond bottom, eradication of pests and predators, pond fertilization and water management were carried out in all the farms.
3. The undrainable portions of the ponds, if any, were usually treated with mahua oil cake, or ammonia gas. (Instead of ammonia as such, some farmers used lime in combination with ammonium sulphate).
4. After preparing the dykes and eradicating pests/predators, the ponds were limed (100–600 kg/ha). After this, the ponds were fertilized with organic and inorganic fertilizers. The organic fertilizer used was cattle manure (200–500 kg/ha) and the inorganic fertilizers used were superphosphate, musooriphos, ammonium sulphate or urea, either solitarily or in combination of two or more of these (20–75 kg/ha).
5. Hatchery-reared *P. monodon* post-larvae (PL 20), mainly obtained from other States, were used by all farmers. Two to three weeks after fertilization, stocking was done. A small portion of the pond was maintained as nursery by some farmers, whereas others initially stocked the material in hapas made of nylon net.
6. For the first two days of stocking shrimps were not fed. After that, clam meat, chopped or ground in a mixer/grinder, was given dialy during the nursery raring period.
7. After 10–15 days of nursery raring, the juveniles were released into the grow-out ponds.

8. In the grow-out ponds, clam meat, clam meat + compounded feed (dough ball), in ratios varying from 1 : 1 to 8 : 1, or pelleted feed was given as supplementary feed.The feeding schedule in the grow-out phase was as follows.

Feeding was done twice daily from the third day of stocking onwards till the end of the culture period. Of the feed for a day, 40% was given in the morning (6 a.m.) and the rest 60% in the evening (6 p.m.). A part of the feed was given in check trays (75 cm x 75 cm) for monitoring the feed consumption by the shrimps; the rest was broadcast over the ponds. For ponds of 1 ha area 6 check trays, of 0.8 and 0.75 ha area 5 and of 0.5 ha area 3 check trays were used. In a pond, 2-6% of feed/day (depending on the days of culture as shown below) was equally distributed in the check trays. After 2 hours of feeding, the trays were retrieved and examined for feed consumption by shrimps.

Feed for the morning or the evening session of feeding for a day was given as shown below.

| Days of culture | Distribution of feed | |
|---|---|---|
| | In check tray | By broadcasting |
| 3 - 60 | 6% | 94% |
| 61 - 90 | 4% | 96% |
| 91 - 120 | 2% | 98% |

9. Water exchange rate was about 5-10% per day during the early days of rearing and, towards the end of the culture operation, it was increased to nearly 20%.
10. The culture period was 120 days.

The quantity of lime and fertilizers used, the type of feed given and the estimated production of shrimp per hactre in the 36 culture operations studied are shown in Table 4.

## TABLE 1

General features of the nine ponds selected for the study

| Sl. No. | Location | | Pond number | Area (ha) | Shape | Depth (cm) | Source of water | Soil type |
|---|---|---|---|---|---|---|---|---|
| | District | Region | | | | | | |
| 1. | Alleppey | Pallithode | 1 | 0.50 | Rectangular | 90 | Backwater | Clay-loam |
| 2. | | | 2 | 0.75 | ,, | 80 | ,, | ,, |
| 3. | | | 3 | 1.00 | ,, | 80 | ,, | ,, |
| 4. | Ernakulam | Chellanam | 1 | 0.80 | ,, | 80 | ,, | ,, |
| 5. | | | 2 | 1.00 | ,, | 80 | ,, | ,, |
| 6. | | | 3 | 0.80 | ,, | 80 | ,, | ,, |
| 7. | | Kannamaly | 1 | 1.00 | ,, | 120 | ,, | ,, |
| 8. | | | 2 | 1.00 | ,, | 120 | ,, | ,, |
| 9. | | | 3 | 1.00 | ,, | 120 | ,, | ,, |

## TABLE 2

Period of shrimp culture in Pallithode, Chellanam and Kannamaly during 1991-1992

| Region | Year | I Culture | II Culture |
|---|---|---|---|
| Pallithode | 1991 | 4.1.91 to 4.5.91 | 12.8.91 to 12.12.91 |
| Chellanam | | 15.1.91 to 15.5.91 | 4.8.91 to 4.12.91 |
| Kannamaly | | 2.1.91 to 2.5.91 | 3.7.91 to 3.11.91 |
| Pallithode | 1992 | 18.1.92 to 18.5.92 | 4.7.92 to 4.11.92 |
| Chellanam | | 10.1.92 to 10.5.92 | 3.8.92 to 3.12.92 |
| Kannamaly | | 4.1.92 to 4.5.92 | 2.7.92 to 2.11.92 |

TABLE 3

Designation of the 36 culture operations studied

| Sl. No. | District | Region | Pond number | Year of culture | First or second culture | Designation of culture number * |
|---|---|---|---|---|---|---|
| 1. | Alleppey | Pallithode | 1 | 1991 | I | P.1. I/91 |
| 2. | | | 2 | | | P.2. I/91 |
| 3. | | | 3 | | | P.3. I/91 |
| 4. | | | 1 | | II | P.1.II/91 |
| 5. | | | 2 | | | P.2.II/91 |
| 6. | | | 3 | | | P.3.II/91 |
| 7. | | | 1 | 1992 | I | P.1. I/92 |
| 8. | | | 2 | | | P.2. I/92 |
| 9. | | | 3 | | | P.3. I/92 |
| 10. | | | 1 | | II | P.1.II/92 |
| 11. | | | 2 | | | P.2.II/92 |
| 12. | | | 3 | | | P.3.II/92 |
| 13. | Ernakulam | Chellanam | 1 | 1991 | I | C.1. I/91 |
| 14. | | | 2 | | | C.2. I/91 |
| 15. | | | 3 | | | C.3. I/91 |
| 16. | | | 1 | | II | C.1.II/91 |
| 17. | | | 2 | | | C.2.II/91 |
| 18. | | | 3 | | | C.3.II/91 |
| 19. | | | 1 | 1992 | I | C.1. I/92 |
| 20. | | | 2 | | | C.2. I/92 |
| 21. | | | 3 | | | C.3. I/92 |
| 22. | | | 1 | | II | C.1.II/92 |
| 23. | | | 2 | | | C.2.II/92 |
| 24. | | | 3 | | | C.3.II/92 |
| 25. | | Kannamaly | 1 | 1991 | I | K.1. I/91 |
| 26. | | | 2 | | | K.2. I/91 |
| 27. | | | 3 | | | K.3. I/91 |
| 28. | | | 1 | | II | K.1.II/91 |
| 29. | | | 2 | | | K.2.II/91 |
| 30. | | | 3 | | | K.3.II/91 |
| 31. | | | 1 | 1992 | I | K.1. I/92 |
| 32. | | | 2 | | | K.2. I/92 |
| 33. | | | 3 | | | K.3. I/92 |
| 34. | | | 1 | | II | K.1.II/92 |
| 35. | | | 2 | | | K.2.II/92 |
| 36. | | | 3 | | | K.3.II/92 |

* Region.Pond number.Culture number/year

P = Pallithode; C = Chellanam; K = Kannamaly

## TABLE 4

Quantity of lime and fertilizers used, the feed type given and the estimated production/ha in nine ponds (3 each from three regions; total 36 cultures in two years) from the three regions (Pallithode, Chellanam and Kannamaly) in Alleppey and Ernakulam districts

| Sl. No. | Culture number * | Lime (kg/ha) | Fertilizer (kg/ha) | | Feed type ** | Production/ha (kg) |
|---|---|---|---|---|---|---|
| | | | Organic | Inorganic | | |
| 1. | P.1. I/91 | 300 | 300 | 20 | F3 | 768 |
| 2. | P.2. I/91 | 267 | 260 | 25 | F1 | 821 |
| 3. | P.3. I/91 | 200 | 300 | 20 | F1 | 576 |
| 4. | P.1.II/91 | 500 | 250 | 30 | F3 | 1154 |
| 5. | P.2.II/91 | 467 | 200 | 25 | F1 | 756 |
| 6. | P.3.II/91 | 200 | 200 | 30 | F1 | 810 |
| 7. | P.1. I/92 | 500 | 350 | 40 | F3 | 1344 |
| 8. | P.2. I/92 | 400 | 300 | 50 | F1 | 840 |
| 9. | P.3. I/92 | 300 | 250 | 40 | F1 | 848 |
| 10. | P.1.II/92 | 600 | 400 | 40 | F3 | 1536 |
| 11. | P.2.II/92 | 350 | 300 | 30 | F1 | 910 |
| 12. | P.3.II/92 | 300 | 250 | 30 | F1 | 1008 |
| Mean | | 365.33 | 280.00 | 31.67 | | 947.58 |
| 13. | C.1. I/91 | 250 | 200 | 19 | F2 | 713 |
| 14. | C.2. I/91 | 300 | 200 | 50 | F2 | 675 |
| 15. | C.3. I/91 | 375 | 200 | 75 | F1 | 675 |
| 16. | C.1.II/91 | 313 | 200 | 25 | F2 | 780 |
| 17. | C.2.II/91 | 250 | 250 | 50 | F2 | 1176 |
| 18. | C.3.II/91 | 500 | 200 | 63 | F1 | 780 |
| 19. | C.1. I/92 | 250 | 300 | 25 | F2 | 560 |
| 20. | C.2. I/92 | 100 | 250 | 60 | F2 | 750 |
| 21. | C.3. I/92 | 500 | 200 | 75 | F1 | 900 |
| 22. | C.1.II/92 | 200 | 200 | 31 | F2 | 1233 |
| 23. | C.2.II/92 | 200 | 150 | 60 | F2 | 1182 |
| 24. | C.3.II/92 | 500 | 200 | 75 | F1 | 1215 |
| Mean | | 311.50 | 212.50 | 50.67 | | 886.58 |
| 25. | K.1. I/91 | 200 | 300 | 50 | F2 | 786 |
| 26. | K.2. I/91 | 100 | 400 | 40 | F1 | 720 |
| 27. | K.3. I/91 | 100 | 350 | 30 | F1 | 735 |
| 28. | K.1.II/91 | 200 | 350 | 50 | F2 | 960 |
| 29. | K.2.II/91 | 100 | 300 | 40 | F1 | 1035 |
| 30. | K.3.II/91 | 100 | 400 | 40 | F1 | 1047 |
| 31. | K.1. I/92 | 250 | 400 | 50 | F2 | 1056 |
| 32. | K.2. I/92 | 100 | 500 | 40 | F1 | 1134 |
| 33. | K.3. I/92 | 100 | 500 | 40 | F1 | 1140 |
| 34. | K.1.II/92 | 300 | 500 | 40 | F2 | 1248 |
| 35. | K.2.II/92 | 100 | 500 | 60 | F1 | 1320 |
| 36. | K.3.II/92 | 100 | 500 | 40 | F1 | 1340 |
| Mean | | 145.83 | 416.67 | 43.33 | | 1043.42 |
| Grand Mean | | 274.22 | 303.06 | 41.89 | | 959.20 |

* Region.Pond number.Culture number/year

P = Pallithode; C = Chellanam; K = Kannamaly

** F1 = Clam meat; F2 = Clam meat + Dough ball; F3 = Pelleted feed

Fig. 1 Part of the central west coast of Kerala State, showing the three regions--Pallithode (1), Chellanam (2) and Kannamaly (3)--selected for the study

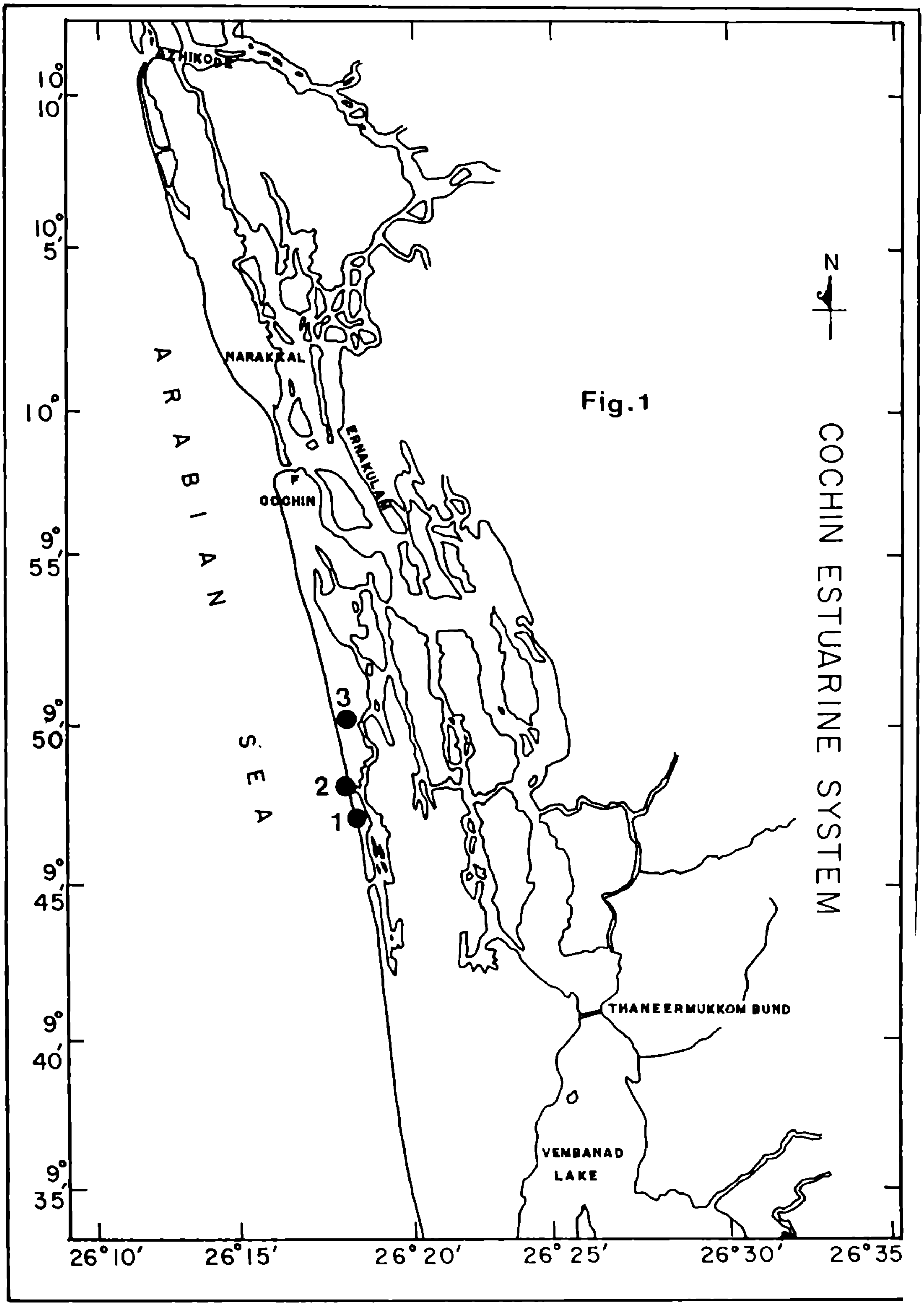


Fig.1

COCHIN ESTUARINE SYSTEM

# CHAPTER II

# PHYSICO-CHEMICAL FEATURES OF THE CULTURE SITES

## Introduction

A knowledge of the biotic and abiotic factors affecting the cultivable species of fish/shellfish is a pre-requisite for their successful culture. The culture performance of shrimps and their survival and growth are influenced by environmental conditions. Factors controlling the quality of water which determines to a great extent the success or failure of culture operations, are extremely varied; maintenance of optimum water quality is essential for the optimum survival and growth of shrimps.

Successful management of an aquaculture system depends on a constant supply of nutrients necessary for the optimal growth of the cultured species. A constant supply of nutrients depends heavily on rapid recycling, which is one of the most important factors for maximising production in pond culture. Phosphate and nitrate play a significant role in the production of aquatic organisms, especially micro- and macroplants. The supply of nutrients is also dependent on the fertility of the bottom soil and soft sediment, which form the habitats for bottom organisms, particularly shrimps.

For augmenting fish/shrimp production in pond culture, the growth of plankton and aquatic macrophytes is critical, especially because most fish/shrimp raised in warm water ponds in less developed countries are dependent largely upon natural food. Phytoplankton is used by the primary consumers (zooplankton), which serve as the major food source for a wide variety of organisms including fish. Phytoplankton growth and the associated ecological factors in fish ponds have concerned fish farmers the world over. Lin (1970) stated that carp farmers in China judge the water quality of the ponds by the colour of the water; the degree of greenness of water reflects the abundance of phytoplankton.

In brackishwater ponds with moderate or high salinity, diatoms are the dominant phytoplankton. Diatoms require fairly large amounts of nitrogen; nitrogen is often as important, or even more important than phosphorus for the growth of phytoplankton. A healthy diatom bloom will improve shrimp growth rate and survival; it shades the bottom, decreases toxic forms of ammonia and increases the appetite of shrimps (Wyban *et al.,* 1990). Feed consumption rate is greater, and growth rate double, in waters with rich phytoplankton than in clear waters. However, the exact reason for this is not understood yet.

Sick *et al.* (1972) published a research report establishing selected preliminary environmental and nutritional requirements for penaeid shrimps. Lee *et al.* (1986), and Wyban *et al.* (1987a) reported that shrimp growth was not correlated with the water quality parameters. Huang *et al.* (1990) found that the buffering capacity of pond water changed remarkably after the removal of organic matter; they suggested that the buffering capacity of pond water may be used as an index for the quantity of organic matter in pond water. Hopkins *et al.* (1991) studied the relation among feeding rate, paddle wheel aeration rate and the expected dissolved oxygen at dawn in intensive shrimp culture ponds. The results of this study indicate that the dissolved oxygen at dawn can be predicted based on the amount of feed applied per unit aeration. Visscher and Duerr (1991) studied the water quality, and the microbial dynamics in shrimp ponds receiving bagasse-based feed. In 1992, Boyd published an excellent report (Boyd, 1992) on the role of water quality and aeration in shrimp farming, which can be considered as a practical manual for water quality management of shrimp culture ponds. Hudson and Lester (1992) published the results of their study on the relation between water quality parameters and ectocommensal ciliates on cultured *P. japonicus*; they noted that as the water quality decreased, the number of *Zoothamnium* increased and the number of *Cothurnia* decreased.

Feed cost is usually the heaviest operating expense in aquaculture, often representing half of the total operating expenses of a fish farm. One effective alternative to overcome this is fertilization. It will not only simplify the whole process of fish/shrimp culture, but also will lower the labour cost and the total operating expenditure. The excellent review by Hickling (1962) on pond fertilization has emphasised the efficiency of inorganic fertilizers and organic manure for increasing the productivity of fish ponds. Bhimachar and Tripathi (1966) expressed the view that lack of adequate fish food organisms is one of the major causes of low productivity of brackishwater fish ponds. They recommended the application of fertilizers for increasing pond productivity. Importance of the use of fertilizers and manure for brackishwater fish culture has also been emphasised by Pillay (1954), Lin (1968), Chen (1972) and Djajadiredja and Poernomo (1972). Beneficial effect of combined treatment with different inorganic fertilizers has been reported by Hepher (1962), Wrobel (1962) and Singh *et al.* (1972). Blanco (1970) reported that production in brackishwater ponds can be enhanced considerably by the addition of nitrogen and phosphorus fertilizers along with organic manure. The addition of phosphorus and nitrogen to aquatic systems increases phytoplankton and zooplankton population (Boyd, 1979). Chattopadhyay and Mandal (1980) studied the influence of cow dung along with inorganic fertilizers on some chemical and biological properties of the water and soil of brackishwater ponds.

Intense organic and chemical fertilization of fish ponds can replace all the conventional feed requirements and give fish yields of 15-31 kg/ha/day, with no supplemental feeding (Tang, 1970; Yashouv and Halevi, 1972; Schroeder, 1974; Schroeder and Hepher, 1976; Moav *et al.* 1977). Such yields are similar to those attained with conventional feeds containing 25% protein and 10% fish meal. Benthic microbial activity increases in response to sedimentation of phytoplankton blooms and benthic biomass is capable of doubling because of increased microbial production (Graf *et al.*, 1982). Research done in Israel by

Schroeder (1978) on organic fertilizers in fish culture systems may have applications to shrimp culture. This study has shown that increase in the microbial community which uses manure and organic matter, is adequate to increase fish growth in earthen ponds; increase in the benthic biomass would likewise be expected to increase shrimp production. Chattopadhyay and Mandal (1982), Chakrabarti (1984) and Andarias (1990) studied the influence of organic and inorganic fertilizers on the quality of the soil and water in brackishwater culture ponds.

In semi-intensive and intensive culture, shrimps are fed artificial feed. The major part of the feed settling to the bottom is consumed by shrimps. Inorganic nutrients released into the water from shrimp excrement and from microbial decomposition of uneaten feed, stimulate phytoplankton blooms. Phytoplankton have a short life span and they continually die and settle to the bottom. In some places water supplies contain settleable solids of appreciable organic matter content that gets deposited on the pond bottom. The net effect is that a sediment containing appreciable amounts of organic matter is accumulated over a period of time. This alters the shape of the pond bottom, reduces pond volume and provides organic substrate for microorganisms. Water currents are the weakest at the soil-water interphase. Here, since microorganisms rapidly decompose organic matter, dissolved oxygen may be exhausted faster than it is delivered by water movement (Boyd, 1993). This can result in anaerobic conditions at the bottom, even though the water above may be thoroughly oxygenated. In anaerobic soil and sediment, microorganisms can produce nitrite, ferrous iron, hydrogen sulphide, methane and other reduced compounds that can harm shrimp. Thus, even if the water quality variables of the water column are within tolerable ranges, poor soil condition can be a severe limitation to shrimp production, and this may be the prime reason for the poor growth, disease and mortality often occurring in intensive and semi-intensive ponds.

The importance of soil in brackishwater aquaculture system has been emphasised by Djajadiredja and Poernomo (1972). Soil nutrients and their role in plankton production are well studied (Banerjea, 1967; Banerjea and Ghosh, 1967; Banerjee and Banerjee, 1975; Mollah *et al.*, 1979; Chattopadhyay and Mandal, 1980, 1982, ; Singh, 1980; Chakraborti *et al.*, 1986; Pradeep and Gupta, 1986). Maguire *et al.* (1984) studied the macrobenthic fauna of brackishwater shrimp farming ponds. Simpson and Pedini (1985) investigated on the problems of acid sulphate soils in the tropics and suggested management measures which can reduce the level of acidity. Gilbert and Pillai (1986) analysed the physico-chemical parameters of the soil in aquaculture systems located around Cochin backwaters. Chien (1989) studied the sediment chemistry of tiger shrimp ponds, kurama shrimp ponds and redtail shrimp ponds. Chien and Ray (1990) have made a comprehensive study on the effects of stocking density and presence of sediment, on the survival and growth of *P. monodon* larvae. Kungvankij *et al.* (1990) have reported on the recent trends in pond design, construction and management strategy for shrimp farming in acid sulphate soil in Thailand. Aravindakshan *et al.* (1992) studied the benthos and substratum characteristics of shrimp culture fields in and around the Cochin backwaters. Boyd (1993), based on a detailed study of shrimp pond bottom soil characteristics and sediment chemistry, suggested management measures. Some other recent noteworthy publications relevant to the context are those by Gaviria *et al.* (1986), Chamberlain (1988), Fast *et al.* (1988), Gately (1990) and Ayub (1992).

Even though literature related to hydrobiological parameters of brackishwater culture systems of India is available from the sixties onwards (Varma *et al.*, 1963; Mandal, 1964), information available on the physico-chemical characteristics of shrimp culture ponds of Kerala is fragmentary and far from complete. George (1974) studied certain aspects of shrimp culture in the seasonal and perennial fields of Vypeen islands, Kerala. Gopinathan *et al.* (1982), who studied the environmental characteristics of the seasonal and perennial shrimp culture fields in Cochin, Kerala, found significant regional differences in primary productivity and in the faunistic composition of the epifauna and benthos of these fields. Chakraborti *et al.* (1985) studied the physico-chemical characteristics of brackish water ponds in Kakdwip, West Bengal, and their influence on the survival, growth and production of *P. monodon*. They found that *P. monodon* production was positively correlated with salinity and temperature in the water phase, and organic carbon, phosphorus and nitrogen in the soil phase, but not with depth, turbidity, pH, total alkalinity and primary productivity. Mathews (1992) studied the ecological characters of extensive type of shrimp culture fields in the Cochin area.

Evidently, hitherto no serious attempt seems to have been made to study the influence of the water quality parameters on the overall performance of shrimp cultured in the small-scale,semi-intensive, monoculture systems of this State. It was, therefore, thought worthwhile to study some of these aspects in the selected culture ponds in the hope of evolving as comprehensive a picture as possible of the culture system. The water quality parameters (water temperature, salinity, DO, pH, alkalinity, nitrate, nitrite, phosphate and ammonia), which are believed to be the major factors deciding production from aquaculture, were given importance in this study.

## Materials and Methods

During the culture period, fortnightly collections of water samples were taken from the selected culture ponds; collection was done between 8 and 10 a.m. Altogether five samples—four from the corners and one from the centre of the ponds--were collected from each pond. Water samples, for the estimation of pH, salinity, total alkalinity, nitrate-N, nitrite-N, ammonia-N and reactive phosphorus, from the five sites of each pond were thoroughly mixed and from the mixture a 2 litre sample was brought to the laboratory in polythene bottles. In the laboratory all the parameters were estimated in duplicate.

Air, water and soil temperatures were measured at the site itself, using a 0-50°C high precision thermometer. The pH of water was determined by using an Elico Digital pH meter, Model U-120 (Elico, India), immediately on reaching the laboratory.

Dissolved oxygen contents of the surface and bottom water were estimated by the Winkler's method with the azide modification (Anon, 1975). For this, water samples from the surface and bottom (five samples each) were collected in BOD bottles, appropriately fixed at the site itself and brought to the laboratory; DO of each set of water samples was estimated and the average was calculated which was reckoned as the DO of surface or bottom water of a pond.

Total alkalinity was estimated employing the method suggested by Boyd and Pillai (1984). The nutrients—nitrate-N, nitrite-N and reactive phosphorus--were estimated by using the method of Morris and Riley as described by Strickland and Parsons (1968). Ammonia-N was determined by using the phenol hypochlorite method (Solarzano, 1969). All the parameters are expressed in ppm.

A Secchi disc tied to one end of a nylon rope was lowered in the water column in five different parts of the pond and the depth at which the disc just disappeared was measured with a metre scale. The average of the five readings was taken as the Secchi disc visibility and was expressed in cm. The depth of the pond was measured by lowering the Secchi disc upto the bottom at five parts of the ponds, and measuring the length of the rope from the disc to the upper water surface; the five values were averaged and this value was taken as the average depth of the pond.

In addition to the aforementioned parameters, soil temperature and soil pH were also determined. For measuring the pH of soil, about 25 g soil was dried and stirred with distilled water and allowed to settle; pH of the supernatant was measured with an Elico pH meter.

For all parameters, in each pond, eight collections/measurements were made during one culture operation, the average of which was reckoned as the value of a parameter for a given pond for that culture operation. The weighted average of the averages for three ponds in one culture operation was calculated to get the value of the parameter for the I or II culture operation in a region in an year. Mean values for a year were calculated as the weighted averages of the values for the six culture operations in the relevant year. From the average values for the 12 culture operations in a region, the weighted average was calculated and this was reckoned as the mean value of the parameter for a given region. The method of calculation of the relevant means of physico-chemical parameters is shown in Chart I. The data were analysed statistically employing ANOVA and simple linear correlation analyses (Zar, 1974).

## Results

The results of the analyses of physico-chemical parameters of the culture sites are consolidated in Table 5 and Figs. 2-9.

Mean air and water temperatures ($^{o}C$) in the three regions were somewhat similar. But soil temperature registered higher mean value for Pallithode (30.06 ± 0.56) than both for Chellanam (29.10 ± 0.57) and Kannamaly (27.72 ± 1.32). Mean salinity (ppt) in Pallithode was also higher (16.30 ± 5.82) than in Chellanam (14.41 ± 4.91) and Kannamaly (13.29 ± 3.78).

Water pH in all the three regions was slightly toward the alkaline side; the highest mean value was recorded for Chellanam (7.86 ± 0.27) and the lowest for Pallithode (7.28 ± 0.11). Mean pH of soil in Chellanam (7.21 ± 0.10) and Kannamaly (7.13 ± 0.10) was also slightly alkaline. But in Pallithode mean soil pH tended to be nearly neutral or slightly acidic (6.93 ± 0.10).

Mean dissolved oxygen contents (ppm) of surface water in Pallithode (6.05 ± 0.52) and Chellanam (6.06 ± 0.23) were slightly higher than in Kannamaly (5.84 ± 0.34). A more or less similar trend was noted for mean DO of bottom water in the three regions.

Mean alkalinity (ppm) in Chellanam was as high as 92.67 ± 11.78. In Kannamaly it recorded a mean value of 72.54 ± 8.50 and in Pallithode, a comparatively low value of 65.12 ± 17.54.

Nitrate-N (ppm) had a very high mean value for Kannamaly (0.64 ± 0.09) compared to Chellanam (0.31 ± 0.07) and Pallithode (0.27 ± 0.07). But, mean nitrite-N (ppm) was strikingly similar in all the three regions (0.08 ± 0.01 - 0.02). Mean ammonia-N (ppm) values for Chellanam and Kannamaly were similar (1.89 ± 0.25 and 1.90 ± 0.30, respectively); it registered a slightly higher value for Pallithode (2.22 ± 0.59). Mean values of reactive phosphorus (ppm) were the same in Pallithode and Chellanam (0.03 ± 0.01), whereas it was as high as 0.08 ± 0.03 in Kannamaly.

Mean values of Secchi disc visibility (cm) were more or less similar for Chellanam (35.56 ± 3.15) and Kannamaly (36.36 ± 3.26); a slightly higher value was noted for Pallithode (40.35 ± 6.11).

On the whole, the results suggest that all the physico-chemical parameters tested in the three regions were conducive for shrimp culture. The mean values of most of the parameters (except salinity, alkalinity, nitrate-N and reactive-P) for the three regions were apparently more or less similar. However, in single factor ANOVA (based on the data for 12 culture operations in each region) revealed that all parameters, except air temperature, water temperature, salinity, DO of surface water, nitrite-N, ammonia-N and Secchi disc visibility, registered statically significant differences between the three regions (Table 5). Since such significant regional differences were registered, data on nine water quality parameters (temperature, salinity, pH, DO of surface water, alkalinity, nitrate-N, nitrite-N, ammonia-N and reactive-P) of ponds in which the three different feed types (clam meat alone, clam meat + compounded feed and pelleted feed) were used, were compared statistically (single factor ANOVA). The results showed that, of the nine parameters, only three (pH, alkalinity and ammonia-N) differed significantly between the three feed treatments (pH : $F = 7.501$, $P < 0.01$; alkalinity : $F = 9.210$; $P < 0.001$; ammonia-N : $F = 4.990$, $P < 0.05$).

Chart showing method of calculation of means of physico-chemical parameters relevant to the results presented in Table 5

| REGION | POND NO. | 1991 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1992 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | I Culture |  |  |  |  |  |  |  |  | II Culture |  |  |  |  |  |  |  |  | I Culture |  |  |  |  |  |  |  |  | II Culture |  |  |  |  |  |  |  |  |
|  |  | Collections/Measurements * |  |  |  |  |  |  |  |  | Collections/Measurements * |  |  |  |  |  |  |  |  | Collections/Measurements * |  |  |  |  |  |  |  |  | Collections/Measurements * |  |  |  |  |  |  |  |  |
|  |  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Mean | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Mean | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Mean | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Mean |
| Pallithode | 1 |  |  |  |  |  |  |  |  | $A_p$ |  |  |  |  |  |  |  |  | $D_p$ |  |  |  |  |  |  |  |  | $G_p$ |  |  |  |  |  |  |  |  | $J_p$ |
|  | 2 |  |  |  |  |  |  |  |  | $B_p$ |  |  |  |  |  |  |  |  | $E_p$ |  |  |  |  |  |  |  |  | $H_p$ |  |  |  |  |  |  |  |  | $K_p$ |
|  | 3 |  |  |  |  |  |  |  |  | $C_p$ |  |  |  |  |  |  |  |  | $F_p$ |  |  |  |  |  |  |  |  | $I_p$ |  |  |  |  |  |  |  |  | $L_p$ |
| Chellanam | 1 |  |  |  |  |  |  |  |  | $A_c$ |  |  |  |  |  |  |  |  | $D_c$ |  |  |  |  |  |  |  |  | $G_c$ |  |  |  |  |  |  |  |  | $J_c$ |
|  | 2 |  |  |  |  |  |  |  |  | $B_c$ |  |  |  |  |  |  |  |  | $E_c$ |  |  |  |  |  |  |  |  | $H_c$ |  |  |  |  |  |  |  |  | $K_c$ |
|  | 3 |  |  |  |  |  |  |  |  | $C_c$ |  |  |  |  |  |  |  |  | $F_c$ |  |  |  |  |  |  |  |  | $I_c$ |  |  |  |  |  |  |  |  | $L_c$ |
| Kannamaly | 1 |  |  |  |  |  |  |  |  | $A_k$ |  |  |  |  |  |  |  |  | $D_k$ |  |  |  |  |  |  |  |  | $G_k$ |  |  |  |  |  |  |  |  | $J_k$ |
|  | 2 |  |  |  |  |  |  |  |  | $B_k$ |  |  |  |  |  |  |  |  | $E_k$ |  |  |  |  |  |  |  |  | $H_k$ |  |  |  |  |  |  |  |  | $K_k$ |
|  | 3 |  |  |  |  |  |  |  |  | $C_k$ |  |  |  |  |  |  |  |  | $F_k$ |  |  |  |  |  |  |  |  | $I_k$ |  |  |  |  |  |  |  |  | $L_k$ |

* Relates to any one of the 15 parameters

Calculation of means for a region, say Pallithode

Mean for I culture of 1991 at Pallithode = $(A_p + B_p + C_p) \div 3$ = P.1-3. I/91

Mean for II culture of 1991 at Pallithode = $(D_p + E_p + F_p) \div 3$ = P.1-3.II/91

Mean for 1991 at Pallithode = $(A_p + B_p + C_p + D_p + E_p + F_p) \div 6$

Mean for I culture of 1992 at Pallithode = $(G_p + H_p + I_p) \div 3$ = P.1-3. I/92

Mean for II culture of 1992 at Pallithode = $(J_p + K_p + L_p) \div 3$ = P.1-3.II/92

Mean for 1992 at Pallithode = $(G_p + H_p + I_p + J_p + K_p + L_p) \div 6$

Mean for Pallithode = $(A + B + C + D + E + F$

## TABLE 5

Table showing the results of the analyses of the physico-chmical parameters of the culture sites in Pallithode, Chellanam and Kannamaly (Mean ±

| Region | Culture number * | Temperature (°C) | | | Salinity (ppt) | pH | | Dissolved oxygen (ppm) | | Alkalinity (ppm) | Nitrate-N (ppm) | Nitrite-N (ppm) | Ammonia-<br>(ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Air | Water | Soil | | Water | Soil | Surface | Bottom | | | | | |
| PALLITHODE | P.1-3. I/91 | 31.89 ± 0.08 | 31.98 ± 0.05 | 30.49 ± 0.72 | 21.02 ± 0.14 | 7.31 ± 0.10 | 7.00 ± 0.11 | 6.29 ± 0.24 | 3.87 ± 0.49 | 73.81 ± 13.07 | 0.21 ± 0.01 | 0.08 ± 0.01 | 1.80 ± 0.0 | |
| | P.1-3.II/91 | 31.15 ± 0.66 | 30.94 ± 0.09 | 29.91 ± 0.77 | 13.71 ± 0.08 | 7.28 ± 0.06 | 6.94 ± 0.05 | 5.69 ± 0.34 | 3.58 ± 0.49 | 46.57 ± 15.39 | 0.31.± 0.01 | 0.09 ± 0.03 | 2.35 ± 0.6 | |
| | Mean for 1991 | 30.78 ± 0.58 | 31.46 ± 0.58 | 30.20 ± 0.74 | 17.37 ± 4.00 | 7.29 ± 0.08 | 6.97 ± 0.08 | 5.99 ± 0.42 | 3.73 ± 0.47 | 60.19 ± 19.64 | 0.26 ± 0.06 | 0.09 ± 0.02 | 2.08 ± 0.5 | |
| | P.1-3. I/92 | 30.62 ± 0.13 | 30.73 ± 0.13 | 30.09 ± 0.26 | 23.16 ± 0.07 | 7.39 ± 0.12 | 6.97 ± 0.05 | 6.63 ± 0.50 | 4.01 ± 0.44 | 80.15 ± 15.90 | 0.22 ± 0.02 | 0.07 ± 0.03 | 2.02 ± 0.6 | |
| | P.1-3.II/92 | 30.05 ± 0.09 | 30.35 ± 0.22 | 29.75 ± 0.25 | 9.30 ± 0.11 | 7.16 ± 0.14 | 6.81 ± 0.08 | 5.61 ± 0.16 | 3.51 ± 0.37 | 59.97 ± 4.79 | 0.36 ± 0.06 | 0.08 ± 0.01 | 2.72 ± 0.4 | |
| | Mean for 1992 | 30.34 ± 0.32 | 30.54 ± 0.26 | 29.92 ± 0.30 | 16.23 ± 7.59 | 7.28 ± 0.14 | 6.81 ± 0.08 | 6.12 ± 0.65 | 3.76 ± 0.46 | 70.06 ± 15.25 | 0.29 ± 0.09 | 0.08 ± 0.02 | 2.37 ± 0.61 | |
| | Mean for Pallithode | 30.93 ± 0.76 | 31.00 ± 0.64 | 30.06 ± 0.56 | 16.30 ± 5.82 | 7.28 ± 0.11 | 6.93 ± 0.10 | 6.05 ± 0.52 | 3.74 ± 0.44 | 65.12 ± 17.54 | 0.27 ± 0.07 | 0.08 ± 0.02 | 2.22 ± 0.59 | |
| CHELLANAM | C.1-3. I/91 | 30.28 ± 0.11 | 30.49 ± 0.16 | 29.52 ± 0.59 | 16.48 ± 0.13 | 8.09 ± 0.39 | 7.26 ± 0.09 | 6.21 ± 0.26 | 4.21 ± 0.16 | 98.04 ± 14.80 | 0.29 ± 0.09 | 0.08 ± 0.01 | 1.65 ± 0.20 | |
| | C.1-3.II/91 | 30.65 ± 0.05 | 30.76 ± 0.05 | 28.66 ± 0.60 | 9.52 ± 0.00 | 7.78 ± 0.20 | 7.18 ± 0.09 | 5.84 ± 0.21 | 3.87 ± 0.20 | 91.40 ± 9.70 | 0.36 ± 0.07 | 0.09 ± 0.01 | 1.90 ± 0.07 | |
| | Mean for 1991 | 30.46 ± 0.22 | 30.63 ± 0.18 | 29.09 ± 0.71 | 13.00 ± 3.81 | 7.94 ± 0.33 | 7.22 ± 0.09 | 6.02 ± 0.29 | 4.04 ± 0.24 | 94.72 ± 11.77 | 0.32 ± 0.08 | 0.08 ± 0.01 | 1.78 ± 0.19 | |
| | C.1-3. I/92 | 30.41 ± 0.02 | 30.60 ± 0.02 | 29.52 ± 0.10 | 21.13 ± 0.00 | 7.90 ± 0.16 | 7.30 ± 0.06 | 6.16 ± 0.19 | 4.19 ± 0.39 | 94.44 ± 16.37 | 0.25 ± 0.05 | 0.08 ± 0.01 | 1.84 ± 0.28 | |
| | C.1-3.II/92 | 30.30 ± 0.10 | 30.51 ± 0.29 | 28.68 ± 0.02 | 10.52 ± 0.01 | 7.66 ± 0.21 | 7.10 ± 0.05 | 6.03 ± 0.12 | 3.86 ± 0.09 | 86.78 ± 8.95 | 0.32 ± 0.03 | 0.09 ± 0.03 | 2.15 ± 0.19 | |
| | Mean for 1992 | 30.35 ± 0.09 | 30.55 ± 0.19 | 29.10 ± 0.46 | 15.82 ± 5.81 | 7.78 ± 0.21 | 7.20 ± 0.12 | 6.10 ± 0.16 | 4.03 ± 0.31 | 90.61 ± 12.52 | 0.29 ± 0.05 | 0.08 ± 0.02 | 2.00 ± 0.27 | |
| | Mean for Chellanam | 30.41 ± 0.17 | 30.59 ± 0.18 | 29.10 ± 0.57 | 14.41 ± 4.91 | 7.86 ± 0.27 | 7.21 ± 0.10 | 6.06 ± 0.23 | 4.03 ± 0.27 | 92.67 ± 11.78 | 0.31 ± 0.07 | 0.08 ± 0.01 | 1.89 ± 0.25 | |
| KANNAMALY | K.1-3. I/91 | 30.28 ± 0.05 | 30.36 ± 0.07 | 28.61 ± 0.11 | 16.88 ± 0.01 | 7.81 ± 0.13 | 7.19 ± 0.09 | 6.20 ± 0.17 | 3.55 ± 0.09 | 80.88 ± 1.22 | 0.65 ± 0.12 | 0.09 ± 0.01 | 2.17 ± 0.18 | |
| | K.1-3.II/91 | 30.18 ± 0.01 | 30.31 ± 0.02 | 25.95 ± 0.07 | 9.64 ± 0.09 | 7.32 ± 0.03 | 7.04 ± 0.01 | 5.44 ± 0.28 | 3.49 ± 0.35 | 62.39 ± 0.77 | 0.59 ± 0.09 | 0.08 ± 0.01 | 1.61 ± 0.33 | |
| | Mean for 1991 | 30.23 ± 0.07 | 30.34 ± 0.05 | 27.28 ± 1.46 | 13.26 ± 3.97 | 7.57 ± 0.29 | 7.11 ± 0.10 | 5.82 ± 0.46 | 3.52 ± 0.23 | 71.64 ± 10.16 | 0.62 ± 0.10 | 0.08 ± 0.01 | 1.89 ± 0.39 | |
| | K.1-3. I/92 | 30.28 ± 0.00 | 30.44 ± 0.03 | 29.14 ± 0.06 | 16.92 ± 0.01 | 7.76 ± 0.27 | 7.22 ± 0.08 | 5.85 ± 0.32 | 3.37 ± 0.12 | 77.71 ± 7.78 | 0.61 ± 0.06 | 0.06 ± 0.02 | 1.85 ± 0.30 | 0 |
| | K.1-3.II/92 | 29.91 ± 0.01 | 30.07 ± 0.10 | 27.17 ± 0.48 | 9.71 ± 0.01 | 7.44 ± 0.12 | 7.08 ± 0.06 | 5.88 ± 0.06 | 3.20 ± 0.25 | 69.16 ± 4.30 | 0.71 ± 0.06 | 0.08 ± 0.01 | 1.98 ± 0.12 | 0 |
| | Mean for 1992 | 30.10 ± 0.20 | 30.25 ± 0.21 | 28.15 ± 1.12 | 13.32 ± 3.95 | 7.60 ± 0.25 | 7.15 ± 0.10 | 5.86 ± 0.20 | 3.29 ± 0.20 | 73.44 ± 7.31 | 0.66 ± 0.07 | 0.07 ± 0.02 | 1.92 ± 0.21 | 0 |
| | Mean for Kannamaly | 30.16 ± 0.16 | 30.30 ± 0.15 | 27.72 ± 1.32 | 13.29 ± 3.78 | 7.58 ± 0.26 | 7.13 ± 0.10 | 5.84 ± 0.34 | 3.41 ± 0.24 | 72.54 ± 8.50 | 0.64 ± 0.09 | 0.08 ± 0.01 | 1.90 ± 0.30 | 0. |
| Inference of one factor ANOVA testing difference in parameters between the three regions | | Not Significant | Not Significant | F = 6.861<br>P < 0.05 | Not Significant | F = 9.760<br>P < 0.01 | F = 12.391<br>P < 0.01 | Not Significant | F = 10.283<br>P < 0.01 | F = 7.688<br>P < 0.05 | F = 48.304<br>P < 0.001 | Not Significant | Not Significant | F<br>P |

*Results are presented as average of the values for three ponds for the I or II culture of 1991 or 1992. Thus, P.1-3.I/91 = Average value for three ponds in Pallithode for
Mean for any year is the average of the values for six cultures in the relevant year
Mean for any Region is the average of the values for twelve cultures in 1991 and 1992 for the relevant region

| | |
|---|---|
| **Fig. 2** | Air, water and soil temperature in the culture sites of the three regions |
| **Fig. 3** | Salinity of water in the culture ponds of the three regions |
| **Fig. 4** | Water and soil pH in the culture ponds of the three regions |

Regions :
P - Pallithode
C - Chellanam
K - Kannamaly

**Fig. 5** Dissolved oxygen content (DO) of surface and bottom water in the culture ponds of the three regions

**Fig. 6** Total alkalinity of water in the culture ponds of the three regions

**Fig. 7** Nitate nitrogen ($NO_3$-N), nitrite nitrogen ($NO_2$-N) and ammonia nitrogen ($NH_3$-N) content of water in the culture ponds of the three regions

Regions:
P - Pallithode
C - Chellanam
K - Kannamaly

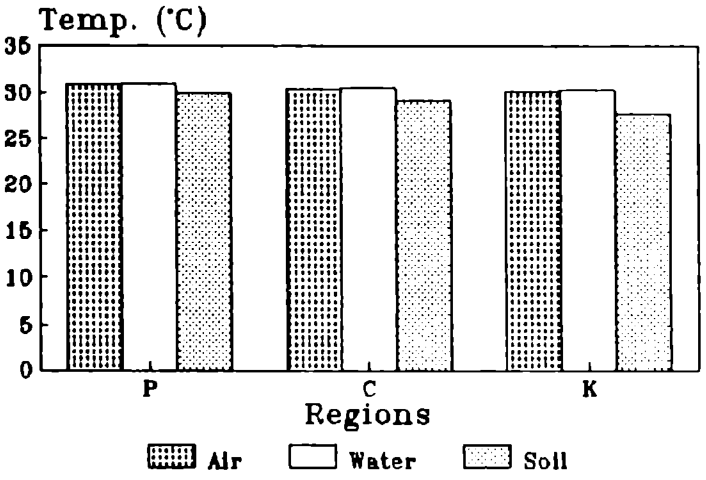


Fig. 2

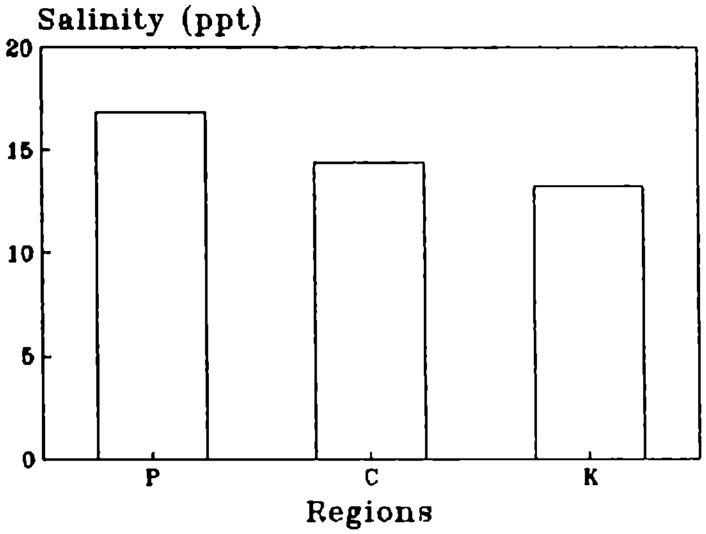


Fig. 3

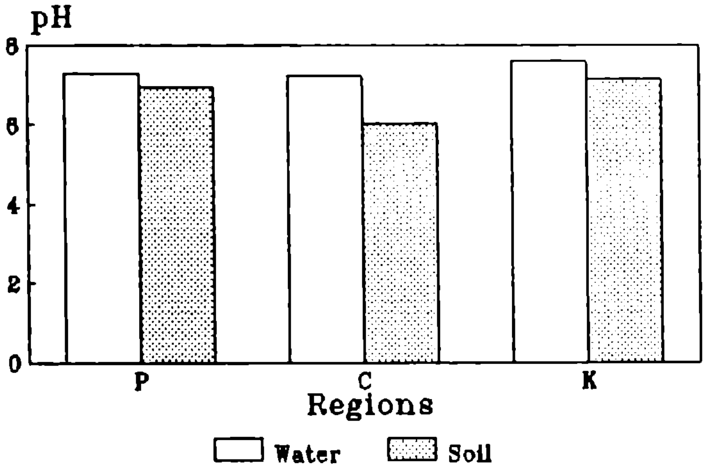


Fig. 4

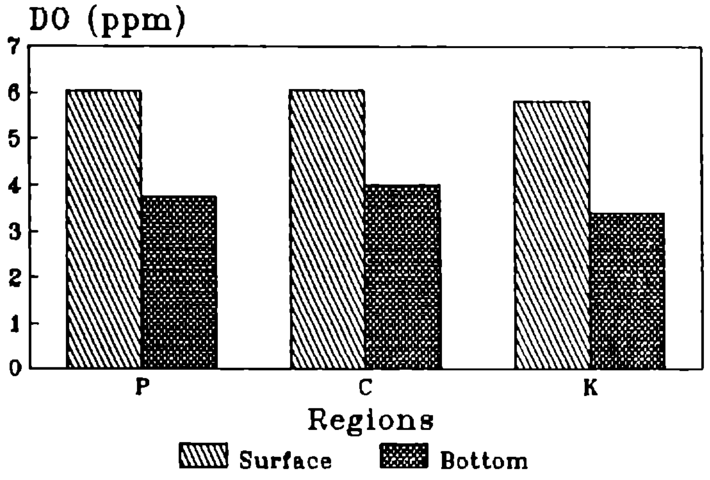


Fig. 5

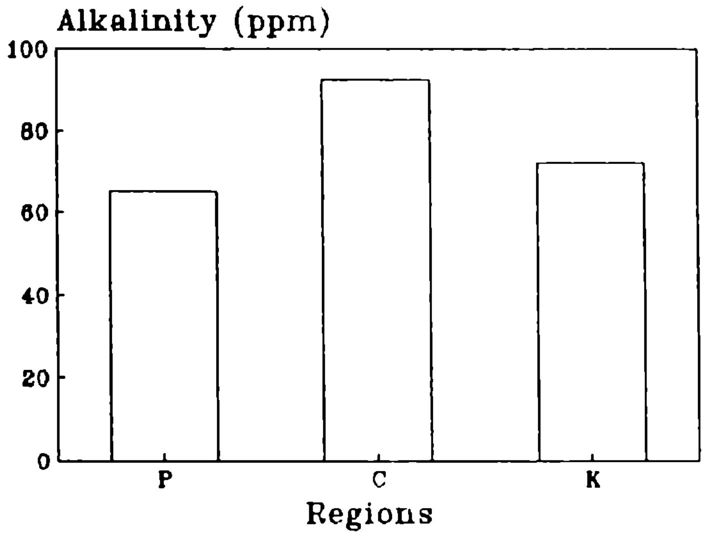


Fig. 6

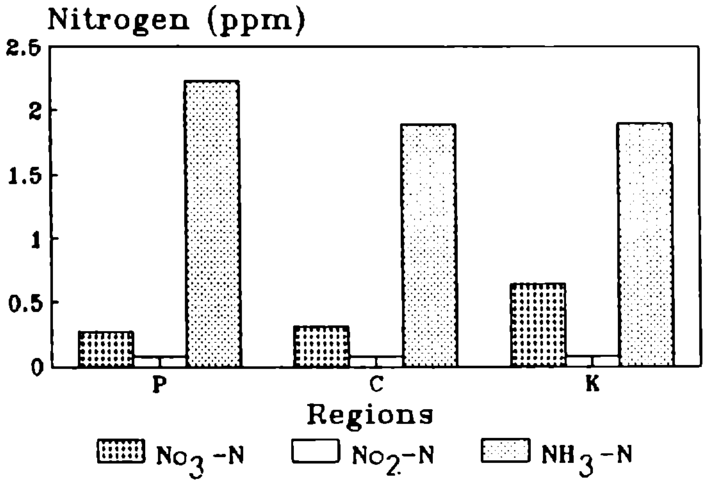


Fig. 7

**Fig. 8** Reactive phosphorus content of water in the culture ponds of the three regions

**Fig. 9** Secchi disc visibility in the culture ponds of the three regions

**Regions:**

P - Pallithode
C - Chellanam
K - Kannamaly

Fig. 8

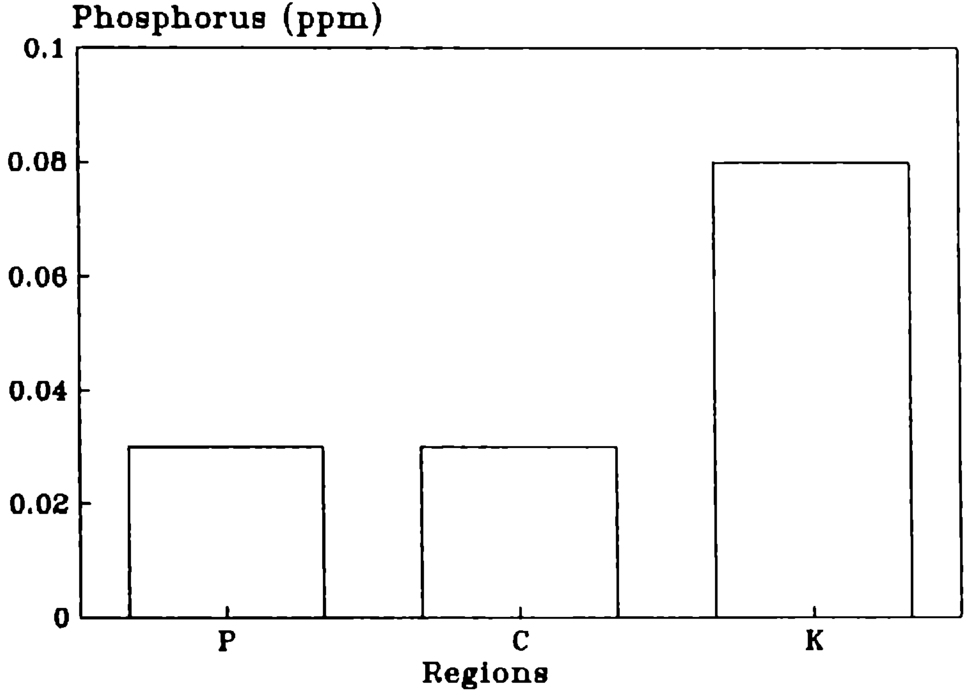
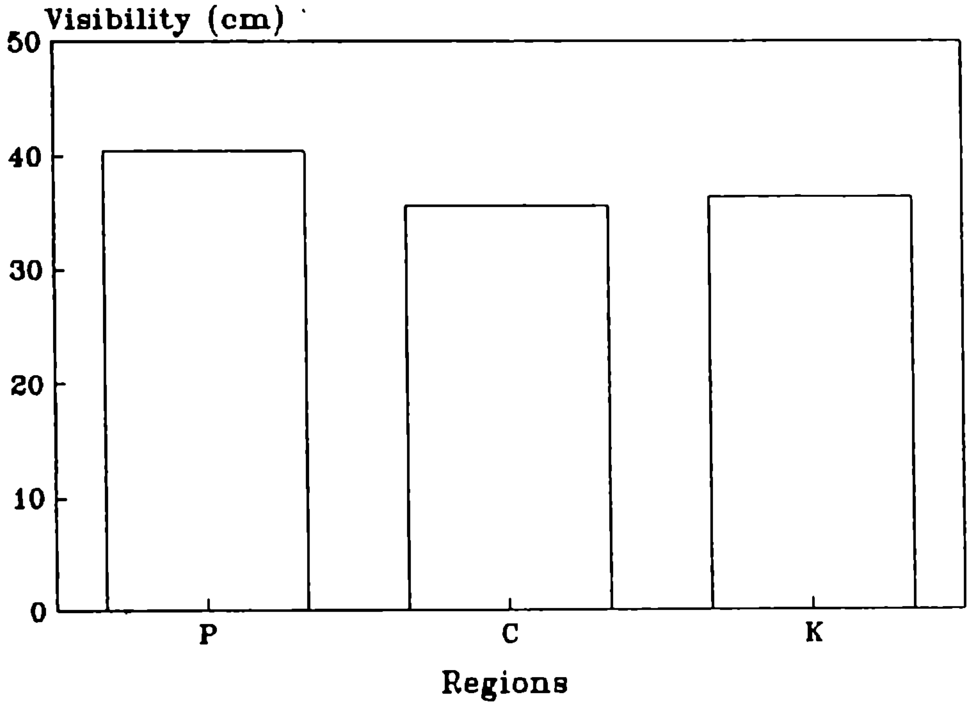

Phosphorus (ppm)
0.1
0.08
0.06
0.04
0.02
0
P
C
K
Regions

Fig. 9


Visibility (cm)
50
40
30
20
10
0
P
C
K
Regions

## Discussion

Chakraborti *et al.* (1985) studied the physico-chemical characteristics of brackishwater ponds in Kakdwip and their influence on the survival, growth and production of *P. monodon*. They found that shrimp production was dependent on salinity and temperature of the water phase and organic carbon, available phosphorus and available nitrogen in the soil phase, but not on depth, turbidity, pH, total alkalinity and primary productivity. However, many earlier and later workers disagree with Chakraborti and co-workers.

Furness and Aldrich (1979) reported that no relation existed between the growth of brown shrimp and dissolved oxygen or pH levels of pond water. Rubright *et al.* (1981) also reported similar results; they emphasised that, because of the complexity of biological communities in ponds, it is rather difficult to identify specific factors responsible for the increased shrimp yield. In fact, no experimental evidence exists to relate weight gain of shrimp with the primary poroductivity. Lee and Shleser (1984) found no correlation between growth rate of *P. vannamei* and water quality parameters. Garson *et al.* (1986) concluded that low survival of *P. stylirostris* and *P. vannamei* was not correlated with low dissolved oxygen. Lee *et al.* (1986), who studied the growth and production of *P. vannamei* in manure fertilized systems, reported that shrimp growth was not correlated with any water quality parameter.

The results of the present study also did not reveal any statistically significant correlation (simple linear correlation analysis) between water quality parameters and shrimp survival or growth. It would appear from the results that, the physico-chemical parameters of the ponds had only minimal influence on the growth and production of shrimps in the culture systems. However, it would be too premature to arrive at such a conclusion particularly in regard to poikilotherms, which are intimately associated with their milieu, so that even a minor alteration in the milieu may have significant effects on the life of these organisms (see Wedemayer, 1970).

The culture performance of shrimp are undoubtedly influenced by environmental conditions which are very complex, and extremely varied as shown by Chiang *et al.* (1990) (see Fig. 10). It is obviously the inadequacy of the methodology that conceals the interrelations between the physico-chemical parameters and the performance of shrimp in culture; we still attempt to correlate the performance of a poikilotherm in a given ecosystem with individual ecological parameters, forgetting or rather ignoring the complexity of the ecological cycles existing in that ecosystem. Evolving appropriate models that will account for the several ecological characteristics as well as their interrelations, alone is the remedy. And, until such models are evolved, fool-proof management measures in shrimp culture systems would remain elusive.

Analyses to find out correlations, if any, between the nine water quality parameters and the mean final weight of shrimp, biomass increase per day and production per hectare in culture operations with three feed types revealed that water temperature and biomass increase per day alone were consistently correlated (negatively) in the three feed treatments (Table 6).

Simple linear correlation analysis of the data for 36 culture operations revealed that survival rate was not correlated with salinity, water pH and DO of surface water. Similarly, salinity and production were also not correlated.

It may be concluded from the results that, the overall performance of shrimp in the 36 culture operations in the three regions studied were not consistently correlated with the physico-chemical features, as also reported by many earlier workers.

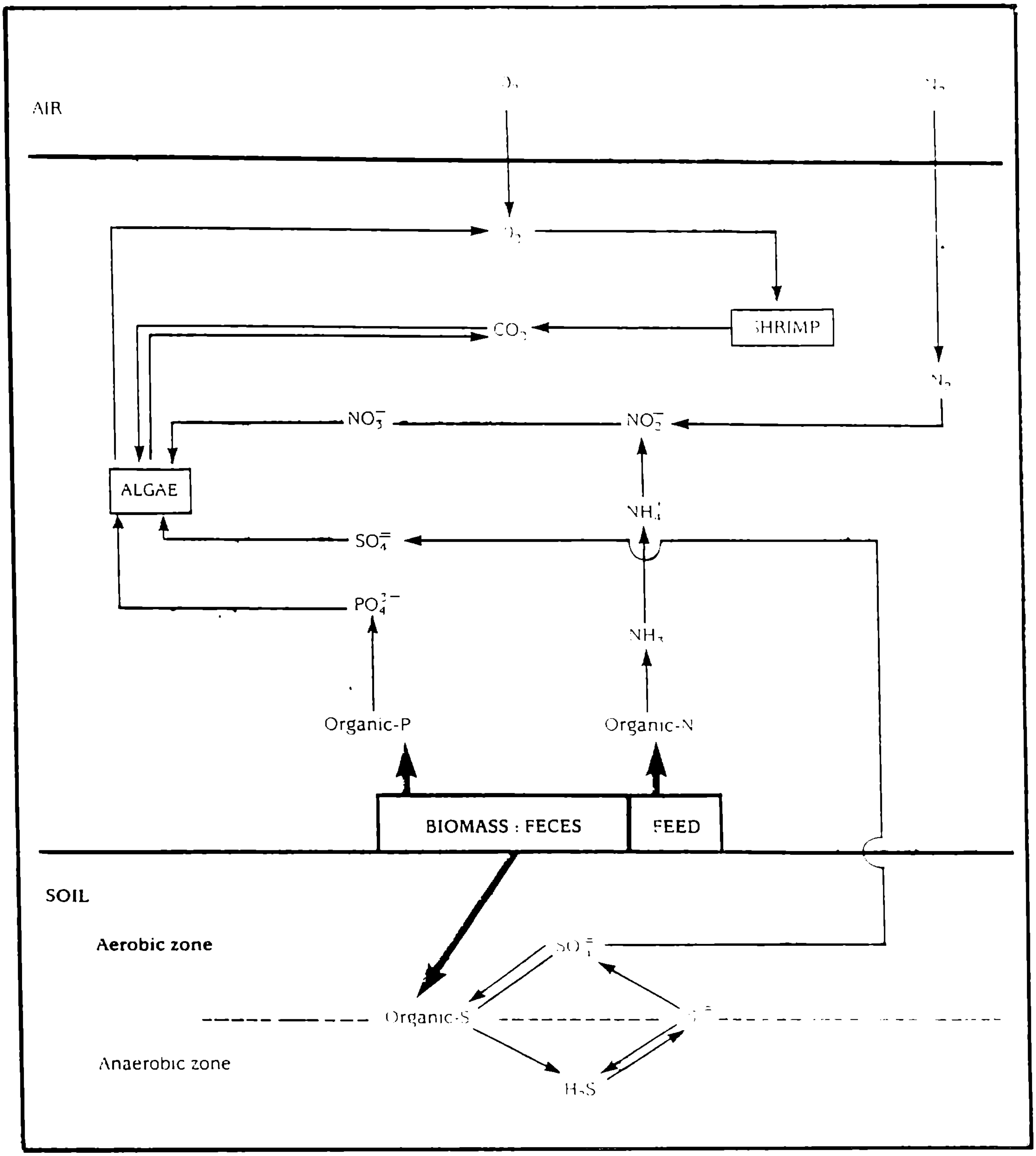
# TABLE 6

Results of simple linear correlation analyses (r values) between selected water quality parameters and three culture parameters in relation to the three feed types

| Feed types : | Clam meat | | | Clam meat + Dough ball | | | Pelleted feed | | |
|---|---|---|---|---|---|---|---|---|---|
| Culture parameters / Water quality parameters | Mean final weight | Biomass increase per day | Production per ha | Mean final weight | Biomass increase per day | Production per ha | Mean final weight | Biomass increase per day | Production per ha |
| Temperature | -0.158 | -0.510* | -0.238** | -0.031 | -0.696* | -0.414** | -0.074 | -1.000*** | -1.000*** |
| Salinity | -0.725*** | -0.356 | -0.178 | -0.005 | -0 109 | -0.594* | 0.319 | -0.518 | -0.517 |
| pH | 0.058 | -0.166 | -0.617** | 0.013 | -0.362 | -0.572 | 0.236 | -0.060 | -0.059 |
| DO - surface | -0.082 | -0.372 | 0.197 | -0.002 | 0.297 | -0.720** | 0.669 | -0.104 | -0.139 |
| Total alkalinity | -0.053 | -0.217 | -0.109 | -0.001 | -0.424 | -0.651* | 0.923 | -0.001 | 0.001 |
| Nitrate-N | -0.094 | 0.553* | -0.567** | 0.013 | 0.198 | 0.333 | -0.436 | 0.817 | 0.816 |
| Nitrite-N | -0.247 | -0.057 | -0.087 | 0.050 | -0.028 | -0.154 | -0.645 | -0.225 | -0.224 |
| Ammonia-N | -0.603** | -0.049 | 0.248 | 0.052 | 0.327 | 0.391 | 0.069 | 0.961* | 0.961* |
| Reactive phosphorus | 0.375 | 0.514* | -0.430 | 0.011 | 0.417 | 0.535 | -0.058 | 0.511 | 0.509 |

* P < 0.05
** P < 0.01
*** P < 0.001

·Fig. 10 Organic cycles in pond ecosystem
(after Chiang *et al.*, 1990)



AIR
O₂
N₂
O₂
SHRIMP
CO₂
N₂
NO₃⁻
NO₂⁻
ALGAE
NH₄⁺
SO₄⁼
PO₄³⁻
NH₃
Organic-P
Organic-N
BIOMASS : FECES
FEED
SOIL
Aerobic zone
SO₄⁼
Organic-S
S⁼
Anaerobic zone
H₂S

Fig.10

# CHAPTER III

# GROWTH AND PRODUCTION OF SHRIMP

## Introduction

The study of the growth of an organism is important in understanding the conditions under which optimum growth occurs. It is also important in getting an insight into the various factors that influence growth. Studies on the growth pattern of commercially important species of shrimp and of the factors that influence their growth rate are essential for the successful cultivation of shrimps.

The length-weight relations of cultured organisms is useful to culturists in estimating the number of organisms in bulk-weighed samples, in setting feeding rates based on the percentage of body weight and in determining the time of harvest of organisms of market size. Length-weight data can also be used as a basis of comparison in calculating the relative condition factor (LeCren, 1951; Swingle and Shell, 1971; Grover and Juliano, 1976). Anderson and Linder (1958), Chin (1960), Kutkuhn (1962), McCoy (1968) and Fontaine and Neal (1971) have reported on the length-weight relations of several species of penaeid shrimps in the natural populations. Hutchins *et al.* (1979) studied the length-weight relations of different species of shrimps in culture systems.

Lee and Shleser (1984) reported on rapid growth of shrimp in ponds fertilized with cattle manure. Some workers have, on the other hand, found a negative growth response to fertilization (Rubright *et al.*, 1981; Garson *et al.*, 1986). Wyban *et al.* (1987a) studied the growth of *P. vannamei* in manure-fertilized ponds; they reported negative correlation between stocking density and growth. Further, there was no correlation between shrimp growth and water quality. Furness and Aldrich (1979) found positive correlation between shrimp growth and pond bottom softness. They also found that there was no correlation between shrimp growth and chlorophyll-*a* levels, dissolved oxygen or pH. Rubright *et al.* (1981) attributed the increase in shrimp production in fertilized ponds with supplementary feeding to the abundant occurrence of polychaetes, copepods and nematodes. This was implicitly corroborated by Anderson *et al.* (1987), who showed that when natural foods are abundant, 53 to 77% of the growth of *P. vannamei* were because of grazing on pond biota, whereas 23 to 47% were due to supplementary feed.

Several workers have studied the growth rate of different species of shrimps in culture (Delmondo and Rabanal, 1956; Kubo, 1956; Poernomo, 1968; Subrahmanyam, 1973; Forster and Beard, 1974; Verghese *et al.*, 1975; Kungvankij *et al.*, 1976; Gundermann and Popper, 1977; Liao, 1977; Sundararajan *et al.*, 1979; Sebastian *et al.*, 1980; Liu and Mancebo, 1983; Chakraborti *et al.*, 1985, 1986; Tiro *et al.*, 1986; Chen *et al.*, 1989a, b; Haran *et al.*, 1992). The correlation between growth (daily or monthly weight gain/mean final weight) and factors such as stocking density, fertilization, aeration, and salinity has been worked out by some of these workers, but they have come up with proof either in support of or against the influence of the factors on the growth of shrimps. The major general conclusion that may be deduced from the results of these studies is that, in semi-intensive monoculture systems, *P. monodon* reaches marketable size, with a body weight of about 30 g, in about 120 days of rearing.

Biomass increase in cultured shrimps is more or less positively correlated with survival rate, as evidenced from the results of the studies conducted by Deshimaru and Shigueno (1972), Sick *et al.* (1972), Sick and Andrews (1973). Other relevant contributions on this aspect have come from Gundermann and Popper (1977), Eldani and Primavera (1981), Lee *et al.* (1986), Sandifer *et al.* (1987), Wyban *et al.* (1987a) and Subosa (1992).

Survival rate of shrimps in culture is highly variable; from 10 to 90% (Delmondo and Rabanal, 1956; Caces-Borja and Rasalan, 1958; Eldani and Primavera, 1981; Badapanda *et al.*, 1985; Chakraborti *et al.*, 1986; Pillai *et al.*, 1987; Chen *et al.*, 1989a, b; Trino *et al.*, 1992). On an average, the survival rate of cultured shrimps is as low as about 50%. Factors such as DO, pH, salinity changes, physiological stress, disease, pollution, transportation stress etc., are responsible for this low survival rate of shrimps. Notwithstanding this, survival rate as high as 92% (Deshimaru and Shigueno, 1972) and 100% (Subosa, 1992) are also reported in literature. Generally, survival rate in culture systems is inversely related to stocking density (Chamberlain *et al.*, 1981). However, several workers have reported that there is no significant correlation between stocking density and survival rate of shrimps (Garson *et al.*, 1986; Wyban *et al.*, 1987a; Goxe *et al.*, 1988; Sivakami, 1988; Chen and Wang, 1990; Allan and Maguire, 1992; Hernandez-Llamas *et al.*, 1992). As Cuzon *et al.* (1994) has rightly pointed out, the bearing of stocking density on the survival of shrimp is but a matter of conjecture yet.

The growth and production of farmed fish and shrimp are dependent on 40 or more essential dietary nutrients, derivable from either endoganeously produced live food organisms or exogeneously supplied artificially compounded diets (Tacon, 1993). Supplementary feed is highly necessary in shrimp culture because the natural food supply in a small pond is very inadequate to support the high density of shrimp stocked in mariculture ponds. Supplemental feed is commercially formulated in most cases to satisfy the nutritional requirements of shrimp. The importance of supplementary feed in shrimp culture systems has already been established (Sick *et al.*, 1972; Balazs *et al.*, 1973; Rajyalakshmi *et al.*, 1979, 1982; Sedgewick, 1979; Ali, 1982, 1988; Liu and Mancebo, 1983; Gosh *et al.*, 1987; Cruz-Suarez *et al.*, 1992).

Natural diets based on *Tapes philippinarum* or *Mytilus crassitida* are successful for the culture of *P. japonicus* (Shigueno, 1979), but procurement of large quantities of fresh molluscs has obvious constraints. Dietary requirements of penaeid shrimps, particularly *P. japonicus,* have been well studied by Japanese workers (Kanazawa *et al.,* 1970, 1984; Kitabayashi *et al.,* 1971; Deshimaru and Shigueno, 1972; Deshimaru and Yone, 1978; Deshimaru *et al.,* 1985). In recent years, researchers in the United States have carried out nutritional studies on *P. vannamei* and *P. stylirostris* (Chamberlain and Lawrence, 1981; Wilkinfeld *et al.,* 1984). Yet, only relatively little is known of the nutritional requirements of shrimps (Courtney, 1989). With a view to finding out a diet which could be used to study the nutritional requirements of shrimps, Kanazawa *et al.* (1970) formulated four artificial feeds and compared their effect on growth with the results of the studies on shrimps fed on fresh mollusc, *Tapes philippinarum.* These artificial diets were derived from silk worms, chinook salmon and brine shrimp. The average growth rates for all the four diets ranged from 20 to 72% of the growth rate of shrimps fed the short-necked clam, *T. philippinarum.*

Protein requirements not only differ between penaeid species, but also within species, at different stages of development. Post-larvae appear to require more protein than juveniles and juveniles require more protein than the older stages (Bhaskar and Ali, 1981). Bages and Sloane (1981) have found that the growth of post-larvae of *P. monodon* was proportional to the level of protein in the diet (ranging from 25 to 55%). Smith *et al.* (1985) concluded that small *P. vannamei* appeared to be more influenced by protein level in the diet, whereas growth of medium-sized and large *P. vannamei* appeared to be more influenced by the protein source.

Protein being the most important ingredient in formulated diets, there has been much interest in ensuring its correct proportion in manufactured feeds. Although there is a lot known of the optimum protein levels and growth rates of penaeids. Wickins (1976a) pointed out that comparisons cannot be made because of the differences in the source of proteins used. It is generally accepted that dietary proteins with an aminoacid composition similar to that of the shrimp are of better nutritional value (Deshimaru and Shigueno, 1972; Wickins, 1976a; Tseng and Cheng, 1981). In a feeding experiment on *P. japonicus*, Deshimaru and Shigueno (1972) found that the highest growth rate was achieved with shrimp fed on short-necked clam, *Tapes philippinarum*, and also that this food had the greatest similarity, both in the quantity and profile of aminoacids, with those in brown shrimp.

Food conversion of shrimps is a fairly well studied area in shrimp culture. The early grow out trails carried out in the mid 1960s in Japan on *P. japonicus* yielded feed conversion ratios in the order of 12 : 1, with feed combinations of clam, fish and non-commercial red shrimps (Shigueno, 1979). In earler experiments juveniles yielded feed conversions of about 5 : 1. Deshimaru and Shigueno (1972) showed that younger *P. japonicus* were more efficient feeders than the older. Smith *et al.* (1985) found that younger shrimps grew at a faster rate than older ones. Not only do the younger shrimps utilise food more efficiently, but their higher growth rate demands that they also feed more frequently than older shrimps.

Compounded diets, presented in different forms (gels, pastes, steam-compressed pellets, flakes, capsules, and dried, spaghetti-like extrusions), are acceptable to shrimp (New, 1976).

A perusal of the literature revealed that a fairly large quantum of information is available on the various aspects of the biology and culture of the common penaeid shrimps of India. But, quite noticeably, information on the growth of shrimps in field conditions is much restricted and is based mainly on length frequency studies. Information on the combined effect of fertilization and supplementary feeding on shrimp growth in semi-intensive systems is also scant, except that from the preliminary studies by Rajyalakshmi *et al.* (1982), Chakraborti *et al.* (1986), Pillai *et al.* (1987), Chakrabarti and Das (1988), Sivakami (1988) and Haran *et al.* (1992). This chapter deals with the results of the studies on the growth of *P. monodon*, in fertilized farming systems of Kerala, fed three different supplementary feeds: clam meat, compounded feed (dough ball)and farm-made pelleted feed.

## Materials and Methods

It was practically impossible to procure post-larvae for length and weight measurements at the time of stocking. To circumvent this, 120 *P. monodon* post-larvae (PL20) were collected from a hatchery and their mean length and weight were determined. These were reckoned as the size at stocking for all culture operations. On the 30th day of stocking,and thereafter, after every 15 days, specimens were collected from the ponds with small-meshed (*ca.* 5 mm) castnet; 40 specimens were callected at random and placed in a plastic bucket or basin containing pond water. Average length and weight after blotting off as much water from the shell as possible, were found out. All live specimens were returned to the ponds after the measurements.

The average growth (average weight at harvest), and the average production in relation to the stocking density, survival rate and three different feed types (clam meat alone, clam meat + dough ball and pelleted feed) were estimated. The other relevant parameters analysed are the following.

1. Average daily weight/length gain

$$\text{Average daily weight gain} = \frac{W_f - W_i}{d} \text{ g/day}$$

where, $W_f$ = average final weight (g)

$W_i$ = average initial weight (g)

d = length of the culture period (days)

$$\text{Average daily length gain} = \frac{L_f - L_i}{d} \text{ cm/day}$$

where, $L_f$ = average final length (cm)

$L_i$ = average initial length (cm)

d = length of the culture period (days)

2. Instantaneous growth

It was calculated by using the following formula, as suggested by Hopkins (1992).

$$G = \frac{(\text{Ln Wt} - \text{Ln Wo})}{t}$$

where, G = instantaneous growth

Ln Wt = natural logarithm of the weight at time t and

Ln Wo = natural logarithm of the initial weight

3. **Biomass increase per day** ($g/m^2/day$)

Biomass increase per day was calculated following New (1976), as

$$\frac{c}{x}$$

where, c = biomass increase ($g/m^2$) and

x = length of the culture period (days)

$$c = \frac{azy}{100} - bz$$

where, a = average final weight (g)

z = initial stocking density ($No./m^2$)

y = survival rate (%)

b = average initial weight (g)

4. **Apparent Feed Conversion Ratio (AFCR)***

AFCR was estimated by using the following formula (New, 1987).

$$\text{AFCR} = \frac{\text{Total amount of feed given (kg dry wt.)}}{\text{Total production (kg wet wt. of heads on shrimps)}}$$

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* According to New (1987), feed conversion ratio under natural and farming conditions is more appropriately designated as Apparent Feed Conversion Ratio (AFCR), rather than Feed Conversion Ratio (FCR), to indicate the inter ference of natural foods. Some of the earlier workers who have actually determined the AFCR in their studies, have inadvertently designated it as FCR in their publications. In this text, on all such occasions including those in previous works cited herein, the usage AFCR is adopted.

(The ratio of wet weight to dry weight of fresh clam meat was 4 : 1, and of dough ball, 2 : 1)

### 5. Feed Conversion Efficiency (FCE)

FCE was calculated by using the formula suggested by New (1987)

$$\text{FCE} = \frac{\text{Total production (wet wt. of heads-on shrimps)}}{\text{Total amount of feed given (kg dry wt.)}}$$

### 6. Survival Rate

The mean shrimp weight at harvest was determined from a random sample of 40 shrimps. Survival rate was then calculated by using the following formula (Rubright *et al.*, 1981)

$$s = \frac{h}{gb} \times 100$$

where, $s$ = survival rate (%)

$h$ = total harvest (g)

$g$ = mean weight of shrimp (g) at harvest and

$b$ = initial number stocked

Correlations of average final weight, biomass increase per day and average total production with stocking density and survival rate, were analysed by simple linear correlation analysis. Bearing of feed types on the final weight and total production was analysed employing one-way ANOVA. When in this analysis, ANOVA implied significant difference, Newman-Keuls multiple range test (SNK) was done to find out which of the three treatments (feed types) was significantly different from the others in realising better final weight/production.

Length-weight relation of shrimp in relation to the three feed types were worked out by using the simple linear regression. Significant differences if any, between the regression lines were tested by analysis of covariance procedure. For length-weight studies, the linear form of the relation $W \propto L^n$ was used.

$$\log W = \log a + n \log L$$

where $W$ = weight (g), $L$ = length (cm) and $a$ and $n$ = calculated constants. Relevant statistical methods were adopted from Zar (1974).

The protein, fat and carbohydrate contents of the three feeds were estimated based on the methods of AOAC (1975). From these results the gross energy and the protein to energy ratio (P/E ratio) were computed following the procedure suggested by ADCP (1983).

## Results

The overall results of the study on shrimp culture in 36 culture operations during 1991-92, each extending for 120 days, in three ponds each from Pallithode in Alleppey district and Chellanam and Kannamaly in Ernakulam district are consolidated in Table 7. The mean length of PL 20 at stocking was 1.40 cm and the mean weight, 0.060g

### General Features

The stocking density ranged from 4 to 10 PL/$m^2$ (mean = 6.31 PL/$m^2$). The average survival rate was 50.21% (range : 38-58%). The shrimps registered a mean final length of 15.10 cm and a mean final weight of 30.23 g. Average final length ranged from 14.20 to 16.40 cm and final weight, from 26 to 34 g. The mean length gain per day was 0.128 cm and the mean daily weight gain, 0.252 g. Biomass increase per day registered a mean of 0.795 $g/m^2/day$ (range: 0.478–1.275 $g/m^2/day$). The total production in the 36 ponds ranged from 560 to 1,536 kg/ha, with an average of 959.20 kg/ha.

The survival rate and the average final weight were not correlated with stocking density. But, biomass increase per day ($r = 0.884$; $P < 0.001$) and total production ($r = 0.459$; $P < 0.01$) registered significant positive correlation with stocking density. The average final weight of shrimps was not correlated with survival rate. Similarly, total production also was not correlated with survival rate.

## Culture Operation in the Three Regions

As noticeable from Table 4, the major difference in the culture operations in the three regions was in regard to the supplementary feed. In each region, two types of feed were used: fresh clam meat (F1) and clam meat + dough ball (F2) in Chellanam and Kannamaly and fresh clam meat and pelleted feed (F3) in Pallithode. In Pallithode, for eight culture operations fresh clam meat and for four, pelleted feed were used. In Chellanam fresh clam meat was used for four cultures and clam meat + dough ball for the remaining eight cultures. In Kannamaly clam meat + dough ball was used in four cultures, whereas fresh clam meat was used for the rest eight cultures. In spite of the said difference, the average final weight, biomass increase per day and the total production of the three regions did not show any significant differences.

## Feed Types and Growth of Shrimps

The three feeds used for the culture operations had the following composition.

Feed - 1 : Fresh meat of *Vellorita cyprenoides* var. *cochinensis*

Feed - 2 : Feed-1 + Dough ball

Composition of the dough ball was the following.

| Ingredients | Parts per hundred |
|---|---|
| Ground nut oil cake | 45 |
| Wheat flour | 25 |
| Rice bran | 20 |
| Tapioca flour | 10 |
| Fish oil | 2 ml/kg |

All the ingredients, except fish oil, were mixed thoroughly and cooked well in an aluminium container. After cooling, fish oil was added and mixed well.

Feed - 3 : Pelleted feed

This feed contained the following ingredients.

| Ingredients | Parts per hundred |
|---|---|
| Squilla powder | 54 |
| Rice bran | 10 |
| Shrimp head waste | 10 |
| Ground nut oil cake | 10 |
| Wheat flour | 10 |
| Tapioca flour | 5 |
| Vitamin mix + mineral mix | 1 |
| Cod liver oil | 2 ml/kg |
| Palm oil | 2 ml/kg |

All the ingredients, except oils and vitamin mix were ground and mixed in a mixer/mincer machine and steam cooked. After cooling, oils and vitamin mix were added and mixed well. The mixture was pelleted with a hand pelletiser. The pellets were sun-dried to less than 10% moisture.

The quantity of the feeds used in the culture operations is shown in Table 8. Feed-1 (clam meat alone) was fed at 8-10% body weight/day. In Feed-2 clam meat and dough ball were mixed in proportions ranging from about 1 : 1 to 8 : 1 and fed at 5-6% body weight/day. Pelleted feed (Feed-3) was given at 3-4% body weight/day. The exact feeding schedule was as described earlier (page 15; Chapter I).

The protein, fat and carbohydrate contents of the three feed types are given in Table 9. The nutritional indices of the three feeding systems are shown in Table 10.

Apparent feed conversion ratio for Feed-1 ranged from 1.49 to 2.55 (mean = 1.70) in the 20 culture operations in which it was used. AFCR of Feed-2 ranged from 1.29 to 2.62 (mean = 1.59; in eight cultures) and of Feed-3 ranged from 1.52 to 1.56 (mean = 1.55; in four cultures) (Table 8). The AFCRs of the three feed types did not differ significantly. The growth of shrimp (g body wt. *vs* days of culture) achieved with the three feed types is shown in Table 11; Fig. 11. As noticeable from the results, with pelleted feed the growth was greater than with the other two feeds; with Feed-1 and Feed-2, the growth was more or less the same.

The mean total production with the three feed types did not differ significantly. Biomass increase/day was also not significantly influenced by the feed types. However, the final average weight of shrimps for the three feed types differed significantly ($F = 3.817$; $P < 0.05$). SNK multiple range test (modified for unequal group sizes; Zar, 1974) to test the differences between mean final weight of shrimps with the three feed types gave the following results.

| | Feed type | | |
|---|---|---|---|
| | F1 | F2 | F3 |
| Mean final body weight (g) | 30.00 | 30.18 | 31.60 |
| Rank of means | 1 | 2 | 3 |

| Comparison | Difference in mean | SE | $q$ | $p$ | $q_{0.05,21,p}$ | Conclusion |
|---|---|---|---|---|---|---|
| 3 *vs* 1 | 1.60 | 0.4117 | 3.886 | 3 | 3.566 | $\mu_3 \neq \mu_1$ |
| 3 *vs* 2 | 1.42 | 0.4367 | 3.252 | 2 | 2.942 | $\mu_3 \neq \mu_2$ |
| 2 *vs* 1 | 0.18 | 0.3255 | 0.553 | 2 | 2.942 | $\mu_2 = \mu_1$ |

Overall conclusion : $\mu_1 = \mu_2 \neq \mu_3$

i.e., mean final weight with feed types F1, F2 and F3 F1 = F2 ≠ F3

The results show that with pelleted feed (F3) a higher mean final weight of shrimp is possible or that pelleted feed is superior to both fresh clam meat (F1) and clam meat + dough ball (F2) in realising growth of shrimps.

## Length-weight Relations of Shrimps

The length-weight relations of shrimps raised using the three feed types were worked out (simple linear regression analysis; log W = log *a* + *n* log L).

Fresh clam meat was used in all the three regions studied and hence, the length-weight relations of shrimps fed this feed were worked out for the three regions separately. The regression equations derived are the following.

**Pallithode:** $\log W = \log 0.0332 + 2.4573 \log L$ ($t = 36.833$; $P < 0.001$)

**Chellanam:** $\log W = \log 0.0183 + 2.7172 \log L$ ($t = 38.253$; $P < 0.001$)

**Kannamaly:** $\log W = \log 0.0061 + 3.0311 \log L$ ($t = 21.940$; $P < 0.001$)

The slopes of the three regression lines differed significantly (analysis of covariance: $F = 7.604$; $P < 0.001$). The results of multiple range test (SNK) showed that the length-weight relations of shrimps fed clam meat alone in the three regions were significantly different from each other.

Fresh clam meat + dough ball was used both in Chellanam and Kannamaly. The regression equations derived for these two regions are the following,

**Chellanam:** $\log W = \log 0.0216 + 2.6531 \log L$ ($t = 56.242$; $P < 0.001$)

**Kannamaly:** $\log W = \log 0.0040 + 3.2234 \log L$ ($t = 14.902$; $P < 0.001$)

The slopes of these two regression lines were significantly different ($F = 2665.879$; $P < 0.001$).

Pelleted feed was used in Pallithode only. The length-weight relation of shrimps fed this feed is,

$$\log W = \log 0.0159 + 2.7664 \log L \quad (t = 44.322;\ P < 0.001)$$

In all the foregoing six cases, the dependence of weight on length was statistically highly significant.

Since three different supplementary feeds were used by the shrimp farmers, an attempt was made to study the length-weight relations of shrimps fed the three feeds, ignoring the regional differences within the treatments (feed types). Multiple range test (SNK) revealed that the slopes of the three population regression lines were similar; their elevations were also not significantly different. Since the three regression lines were coincident, the common or weighted regression coefficient ( $b_c$ ) was calculated; $b_c = 2.7387$.

If the regional differences in the length-weight relations within the feed types are ignored, the common regression equation for the length-weight relation of the shrimps cultured in the small-scale, semi-intensive, monoculture systems of Kerala is,

$$\log W = \log 0.0154 + 2.7399 \log L \quad (t = 53.586;\ P < 0.001)$$

This relation is illustrated in Fig. 12.

The 95% confidence interval for the regression coefficient was 2.7399 ± 0.1006 and the standard error for the Y intercept was, log 0.0154 ± log 0.0523

TABLE 7

e showing the results of the study on shrimp culture in nine ponds (3 each from three regions; total 36 cultures in two years) from the thre regions (Pallithode, Chellanam and Kannamaly) in Alleppey and Ernakulam districts

[ Average initial length ($L_i$) = 1.40 cm; Average initial weight ($W_i$) = 0.060 g; Total number of days of culture (d) = 120 days ]

| ure er * | Average final length (cm) ($L_f$) | Increase in average length (cm) ($L_f$ - $L_i$) | Average daily length gain (cm) ($L_f$-$L_i$) ÷ d | Average final weight (g) ($W_f$) | Increase in average weight (g) ($W_f$ - $W_i$) | Average daily weight gain ($W_f$-$W_i$) ÷ d | Instantaneous growth (g) | Stocking density (No/$m^2$) | Survival rate (%) | Biomass increase (g/$m^2$) | Biomass increase per day (g) | Production per ha (kg) | I |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I/91 | 16.20 | 14.80 | 0.135 | 32.00 | 31.94 | 0.266 | 0.052 | 6.00 | 40.00 | 76.44 | 0.637 | 768.00 | |
| I/91 | 15.60 | 14.20 | 0.130 | 28.00 | 27.94 | 0.233 | 0.051 | 5.30 | 55.00 | 81.30 | 0.677 | 821.00 | |
| I/91 | 15.60 | 14.20 | 0.130 | 30.00 | 29.94 | 0.250 | 0.052 | 4.00 | 48.00 | 57.36 | 0.478 | 576.00 | |
| II/91 | 16.40 | 15.00 | 0.137 | 30.40 | 30.34 | 0.253 | 0.052 | 10.00 | 38.00 | 114.92 | 0.958 | 1154.00 | |
| II/91 | 15.20 | 13.80 | 0.127 | 30.00 | 29.94 | 0.250 | 0.052 | 5.60 | 45.00 | 75.26 | 0.627 | 756.00 | |
| II/91 | 16.20 | 13.80 | 0.127 | 30.00 | 29.94 | 0.250 | 0.052 | 5.00 | 52.00 | 77.70 | 0.647 | 810.00 | |
| I/92 | 16.00 | 14.60 | 0.133 | 32.00 | 31.94 | 0.266 | 0.052 | 10.00 | 42.00 | 133.80 | 1.115 | 1344.00 | |
| I/92 | 16.20 | 14.80 | 0.135 | 30.00 | 29.94 | 0.250 | 0.052 | 6.66 | 42.00 | 83.52 | 0.696 | 840.00 | |
| . I/92 | 15.00 | 13.60 | 0.125 | 32.00 | 31.94 | 0.266 | 0.052 | 5.00 | 53.00 | 84.50 | 0.704 | 848.00 | |
| .II/92 | 16.00 | 14.60 | 0.133 | 32.00 | 31.94 | 0.266 | 0.052 | 10.00 | 48.00 | 153.00 | 1.275 | 1536.00 | |
| .II/92 | 14.20 | 12.80 | 0.118 | 26.00 | 25.94 | 0.216 | 0.050 | 6.66 | 52.00 | 89.64 | 0.747 | 910.00 | |
| .II/92 | 15.00 | 13.60 | 0.125 | 30.00 | 29.94 | 0.250 | 0.052 | 6.00 | 56.00 | 100.44 | 0.837 | 1008.00 | |
| ean | 15.55 | 14.15 | 0.130 | 30.18 | 30.12 | 0.251 | 0.052 | 6.69 | 47.58 | 93.99 | 0.783 | 947.58 | |
| 1. I/91 | 16.00 | 14.60 | 0.133 | 30.00 | 29.94 | 0.250 | 0.052 | 4.75 | 50.00 | 70.97 | 0.591 | 713.00 | |
| 2. I/91 | 14.80 | 13.40 | 0.123 | 28.00 | 27.94 | 0.233 | 0.051 | 5.00 | 48.20 | 67.18 | 0.560 | 675.00 | |
| 3. I/91 | 14.60 | 13.20 | 0.122 | 30.00 | 29.94 | 0.250 | 0.052 | 5.00 | 45.00 | 67.20 | 0.560 | 675.00 | |
| 1.II/91 | 14.20 | 12.80 | 0.188 | 28.00 | 27.94 | 0.233 | 0.052 | 5.00 | 40.00 | 55.70 | 0.464 | 780.00 | |
| 2.II/91 | 14.60 | 13.20 | 0.122 | 30.00 | 29.94 | 0.250 | 0.052 | 5.00 | 50.00 | 74.70 | 0.622 | 1176.00 | |
| 3.II/91 | 14.70 | 13.30 | 0.123 | 30.00 | 29.94 | 0.250 | 0.052 | 5.00 | 52.00 | 77.70 | 0.647 | 780.00 | |
| 1. I/92 | 14.80 | 13.40 | 0.123 | 30.00 | 29.94 | 0.250 | 0.052 | 5.00 | 52.00 | 77.70 | 0.647 | 560.00 | |
| .2. I/92 | 14.60 | 13.20 | 0.122 | 30.00 | 29.94 | 0.250 | 0.052 | 7.00 | 56.00 | 117.18 | 0.976 | 750.00 | |
| .3. I/92 | 14.80 | 13.40 | 0.123 | 30.00 | 29.94 | 0.250 | 0.053 | 6.25 | 48.00 | 89.63 | 0.747 | 900.00 | |
| .1.II/92 | 15.40 | 14.00 | 0.128 | 34.00 | 33.94 | 0.283 | 0.053 | 6.25 | 58.00 | 122.88 | 1.024 | 1233.00 | |
| .2.II/92 | 14.80 | 13.40 | 0.123 | 30.00 | 29.94 | 0.250 | 0.052 | 7.00 | 54.20 | 113.40 | 0.945 | 1182.00 | |
| .3.II/92 | 14.80 | 13.40 | 0.123 | 30.00 | 29.94 | 0.250 | 0.052 | 7.50 | 54.00 | 121.05 | 1.009 | 1215.00 | |
| Mean | 14.84 | 13.44 | 0.129 | 30.00 | 29.94 | 0.250 | 0.052 | 5.73 | 50.62 | 87.94 | 0.733 | 886.58 | |
| K.1. I/91 | 14.80 | 13.40 | 0.123 | 30.00 | 29.94 | 0.250 | 0.052 | 5.00 | 52.40 | 78.30 | 0.652 | 786.0 | |
| K.2. I/91 | 14.80 | 13.40 | 0.123 | 30.00 | 29.94 | 0.250 | 0.052 | 5.00 | 48.00 | 71.70 | 0.597 | 720.0 | |
| K.3. I/91 | 14.60 | 13.20 | 0.122 | 30.00 | 29.94 | 0.250 | 0.052 | 5.00 | 49.00 | 73.50 | 0.612 | 735.0 | |
| K.1.II/91 | 14.80 | 13.40 | 0.123 | 30.00 | 29.94 | 0.250 | 0.052 | 6.00 | 54.00 | 96.84 | 0.807 | 960.0 | |
| K.2.II/91 | 15.20 | 13.80 | 0.127 | 32.00 | 31.94 | 0.266 | 0.052 | 6.20 | 52.20 | 103.19 | 0.860 | 1035.0 | |
| K.3.II/91 | 15.20 | 13.80 | 0.127 | 32.00 | 31.94 | 0.266 | 0.052 | 6.00 | 54.20 | 103.70 | 0.864 | 1047.0 | |
| K.1. I/92 | 15.20 | 13.80 | 0.127 | 32.00 | 31.94 | 0.266 | 0.052 | 7.00 | 48.00 | 107.10 | 0.892 | 1056. | |
| K.2. I/92 | 14.60 | 13.20 | 0.122 | 30.00 | 29.94 | 0.250 | 0.052 | 7.00 | 54.00 | 112.98 | 0.941 | 1134. | |
| K.3. I/92 | 14.80 | 13.40 | 0.123 | 30.00 | 29.94 | 0.250 | 0.052 | 7.00 | 54.30 | 113.61 | 0.947 | 1140. | |
| K.1.II/92 | 14.80 | 13.40 | 0.123 | 30.20 | 30.14 | 0.250 | 0.052 | 8.00 | 52.00 | 124.32 | 1.036 | 1248. | |
| K.2.II/92 | 15.00 | 13.60 | 0.125 | 30.00 | 29.94 | 0.250 | 0.052 | 8.00 | 55.00 | 131.52 | 1.096 | 1320. | |
| K.3.II/92 | 15.10 | 13.70 | 0.126 | 30.00 | 29.94 | 0.250 | 0.052 | 8.00 | 56.00 | 133.92 | 1.116 | 1340. | |
| Mean | 14.90 | 13.50 | 0.124 | 30.52 | 30.46 | 0.254 | 0.052 | 6.52 | 52.43 | 104.22 | 0.868 | 1043. | |
| Grand mean | 15.10 | 13.70 | 0.128 | 30.23 | 30.17 | 0.252 | 0.052 | 6.31 | 50.21 | 95.38 | 0.795 | 959 | |
| Range | 14.2-16.4 | 12.8-15.0 | 0.118-0.188 | 26-34 | 25.94-31.94 | 0.216-0.283 | 0.050-0.052 | 4 - 10 | 38 - 58 | 55.7-153.00 | 0.478-1.275 | 560- | |

* Region.Pond number.Culture number/year

P = Pallithode; C = Chellanam; K = Kannamaly

F1 = Clam meat; F2 = Clam meat + Dough ball; F3 = Pelleted feed

# TABLE 8

Quantity of feed used, total production, the apparent feed conversion ratio (AFCR) and feed conversion efficiency (FCE) in 36 culture operations using three different feeds

| Sl. No. | Feed type | Feed type (wet weight-kg) | | Total dry weight (kg/ha) | Production (kg/ha) | AFCR | FCE | Culture number |
|---|---|---|---|---|---|---|---|---|
| | | Clam meat | Dough ball | | | | | |
| 1. | Clam meat | 5120.00 | | 1280.00 | 821.00 | 1.56 | 64.14 | P.2. I/91 |
| 2. | | 5880.00 | | 1470.00 | 576.00 | 2.55 | 39.18 | P.3. I/91 |
| 3. | | 5120.00 | | 1280.00 | 756.00 | 1.69 | 59.06 | P.2.II/91 |
| 4. | | 5412.00 | | 1353.00 | 810.00 | 1.67 | 59.87 | P.3.II/91 |
| 5. | | 5545.00 | | 1386.25 | 840.00 | 1.65 | 60.60 | P.2. I/92 |
| 6. | | 5565.00 | | 1391.25 | 848.00 | 1.64 | 60.95 | P.3. I/92 |
| 7. | | 5860.00 | | 1465.00 | 910.00 | 1.61 | 62.12 | P.2.II/92 |
| 8. | | 6000.00 | | 1500.00 | 1008.00 | 1.49 | 67.20 | P.3.II/92 |
| 9. | | 4620.00 | | 1155.00 | 675.00 | 1.71 | 58.44 | C.3. I/91 |
| 10. | | 5240.00 | | 1310.00 | 780.00 | 1.68 | 59.54 | C.3.II/91 |
| 11. | | 6265.00 | | 1566.25 | 900.00 | 1.74 | 57.46 | C.3. I/92 |
| 12. | | 8000.00 | | 2000.00 | 1215.00 | 1.65 | 60.75 | C.3.II/92 |
| 13. | | 4665.00 | | 1166.25 | 720.00 | 1.62 | 61.75 | K.2. I/91 |
| 14. | | 5120.00 | | 1280.00 | 735.00 | 1.74 | 57.41 | K.3. I/91 |
| 15. | | 7290.00 | | 1822.50 | 1035.00 | 1.76 | 56.81 | K.2.II/91 |
| 16. | | 7372.00 | | 1843.00 | 1047.00 | 1.76 | 56.81 | K.3.II/91 |
| 17. | | 7210.00 | | 1802.50 | 1134.00 | 1.59 | 62.91 | K.2. I/92 |
| 18. | | 7520.00 | | 1880.00 | 1140.00 | 1.65 | 60.61 | K.3. I/92 |
| 19. | | 8760.00 | | 2190.00 | 1320.00 | 1.66 | 60.27 | K.2.II/92 |
| 20. | | 8630.00 | | 2157.50 | 1340.00 | 1.61 | 62.11 | K.3.II/92 |
| Mean | | 6259.70 | | 1564.90 | 930.50 | 1.70 | 59.40 | |
| 21. | Clam meat + Dough ball | 2750.00 | 625.00 | 1000.00 | 713.00 | 1.40 | 71.30 | C.1. I/91 |
| 22. | | 2500.00 | 750.00 | 1000.00 | 675.00 | 1.48 | 67.50 | C.2. I/91 |
| 23. | | 1870.00 | 2000.00 | 1467.50 | 560.00 | 2.62 | 38.16 | C.1. I/92 |
| 24. | | 3000.00 | 750.00 | 1125.00 | 750.00 | 1.50 | 66.67 | C.2. I/92 |
| 25. | | 3120.00 | 1030.00 | 1295.00 | 780.00 | 1.66 | 60.23 | C.1.II/91 |
| 26. | | 5000.00 | 1500.00 | 2000.00 | 1176.00 | 1.70 | 58.80 | C.2.II/91 |
| 27. | | 3750.00 | 1875.00 | 1875.00 | 1233.00 | 1.52 | 65.76 | C.1.II/92 |
| 28. | | 4700.00 | 2075.00 | 2212.50 | 1182.00 | 1.87 | 53.42 | C.2.II/92 |
| 29. | | 3000.00 | 600.00 | 1050.00 | 786.00 | 1.34 | 74.86 | K.1. I/91 |
| 30. | | 4000.00 | 500.00 | 1250.00 | 960.00 | 1.29 | 76.80 | K.1.II/91 |
| 31. | | 4000.00 | 800.00 | 1400.00 | 1056.00 | 1.33 | 75.43 | K.1. I/92 |
| 32. | | 4500.00 | 1300.00 | 1775.00 | 1248.00 | 1.42 | 70.31 | K.1.II/92 |
| Mean | | 3515.83 | 1150.42 | 1454.17 | 926.58 | 1.59 | 64.94 | |
| 33. | Pelleted feed | | | 1200.00 | 768.00 | 1.56 | 64.00 | P.1. I/91 |
| 34. | | | | 1800.00 | 1154.00 | 1.56 | 64.11 | P.1.II/91 |
| 35. | | | | 2100.00 | 1344.00 | 1.56 | 64.00 | P.1. I/92 |
| 36. | | | | 2330.00 | 1536.00 | 1.52 | 65.92 | P.1.II/92 |
| Mean | | | | 1857.50 | 1200.50 | 1.55 | 64.51 | |

TABLE 9

The protein, fat and carbohydrate contents (%) of the three feed types

| Feed type | Protein | Fat | Carbohydrate |
|---|---|---|---|
| Clam meat | 52.60 | 10.63 | 28.46 |
| Clam meat + * Dough ball | 40.75-49.79 | 8.61-10.17 | 25.47-27.77 |
| Pelleted feed | 35.27 | 6.79 | 9.79 |

* Represent values for clam meat to dough ball ratios ranging 1 : 1 to 8 : 1

TABLE 10

Nutritional indices of the three feed types

| Indices | Feed types | | |
|---|---|---|---|
| | Clam meat | Clam meat + dough ball | Pelleted feed |
| Crude protein (%) | 52.60 | 40.15-49.79@ | 35.27 |
| Gross energy * (kcal/100g feed) | 502.72 | 403.69-480.24@ | 295.91 |
| P/E ratio # (mg protein/kcal) | 104.63 | 99.48-103.68@ | 119.24 |
| AFCR | 1.70 | 1.59 | 1.55 |
| FCE | 59.40 | 64.94 | 64.51 |

* Calculated based on 4.1 kcal/g for carbohydrates, 9.1 kcal/g for fat and 5.5 kcal/g for protein (ADCP 1983)

# Protein to energy ratio

@ Represent values for clam meat + dough ball ratios ranging 1 : 1 to 8 : 1

TABLE 11

Mean length (cm) and weight (g) of shrimps raised using three different feed types, at 15 days interval from 30 days post-stocking

| Feed type | | Days post-stocking | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 30 | 45 | 60 | 75 | 90 | 105 | 120 |
| Clam meat | Length | 5.17 | 7.99 | 10.06 | 11.93 | 13.09 | 14.14 | 15.01 |
| | Weight | 1.73 | 3.97 | 6.70 | 12.65 | 18.46 | 24.36 | 30.00 |
| Clam meat + Dough ball | Length | 4.73 | 6.93 | 8.98 | 11.01 | 12.64 | 13.88 | 14.90 |
| | Weight | 1.22 | 2.62 | 4.95 | 11.03 | 18.23 | 14.22 | 30.18 |
| Pelleted feed | Length | 5.98 | 8.45 | 10.50 | 12.38 | 13.78 | 15.00 | 16.15 |
| | Weight | 2.03 | 6.10 | 11.65 | 18.38 | 23.25 | 27.30 | 31.60 |

Fig. 11 Mean final weight of tiger shrimps fed the three feed types—clam meat alone, clam meat + compounded feed (dough ball) and pelleted feed--at 15 days interval from 30 days post-stocking to end of culture period (120 days)

(mean weight of PL 20 at stocking = 0.060 g)

Fig. 11

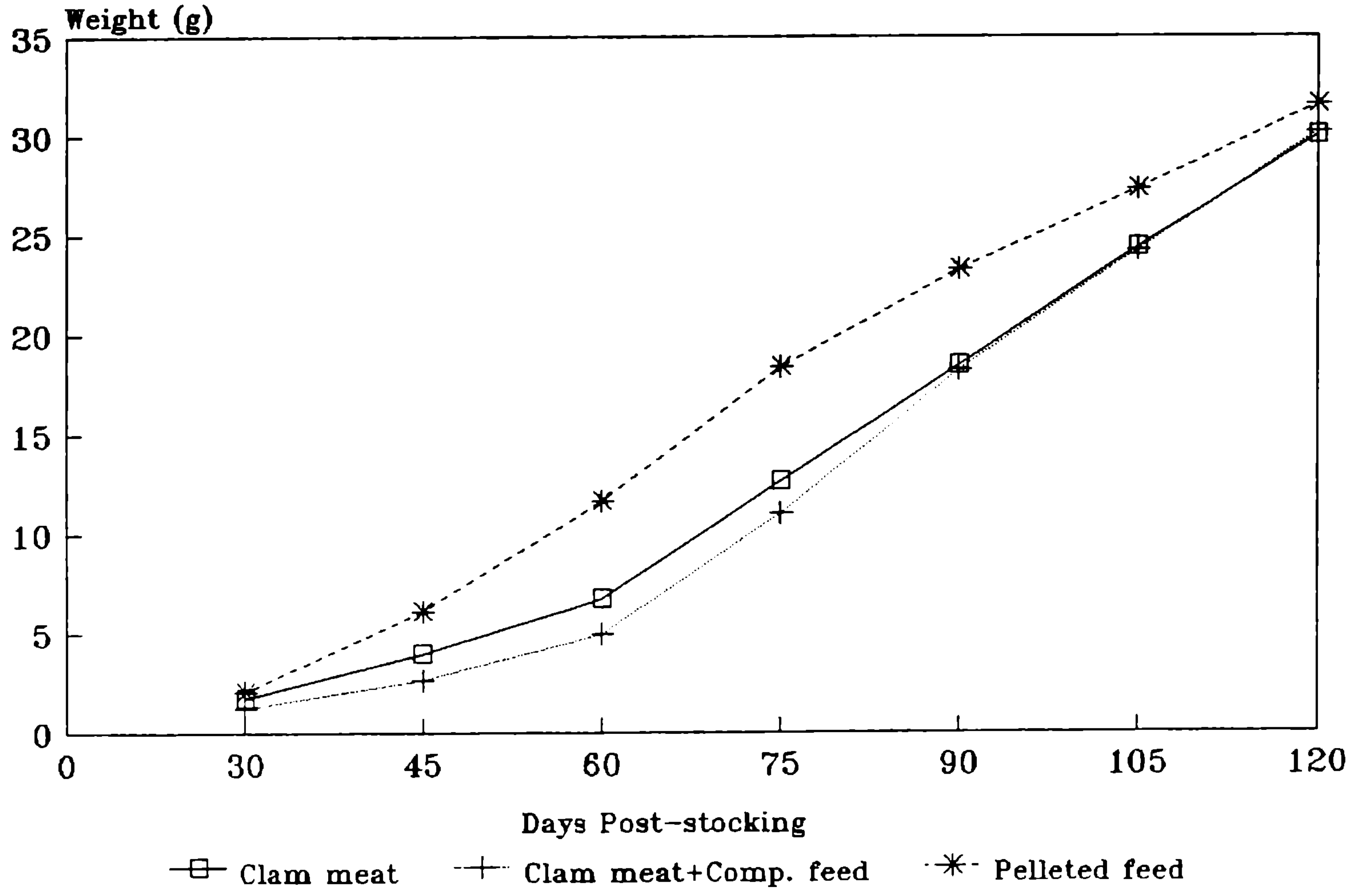
Weight (g)
35
30
25
20
15
10
5
0
0
30
45
60
75
90
105
120
Days Post-stocking
Clam meat
Clam meat+Comp. feed
Pelleted feed

**Fig. 12** Regression line showing the length-weight relation of tiger shrimp in small-scale, semi-intensive, monoculture systems on the backwaters of Kerala State

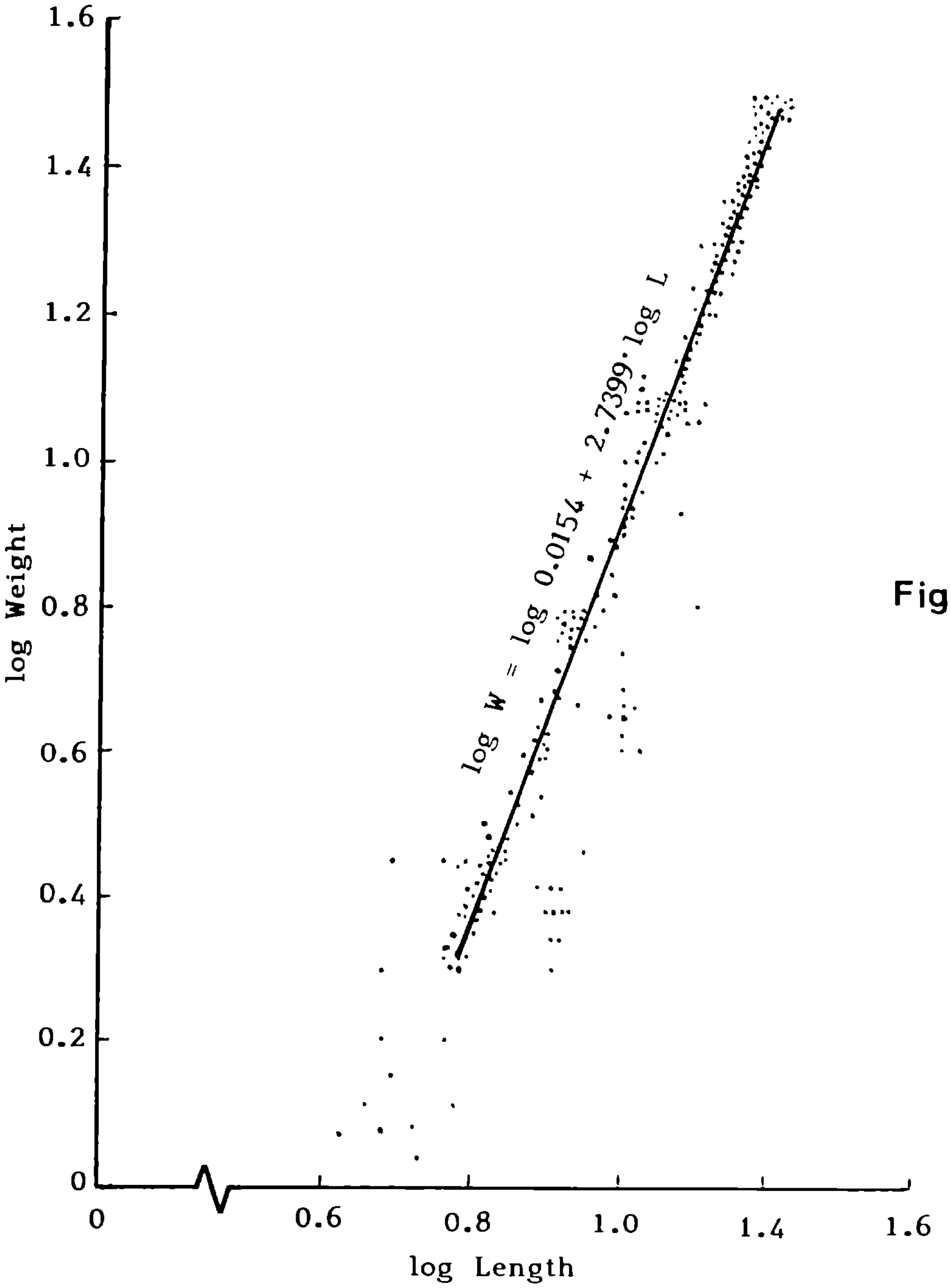
log W = log 0.0154 + 2.7399·log L
log Weight
log Length
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0
0.6
0.8
1.0
1.4
1.6

**Fig. 12**

## Discussion

It is well documented that *Penaeus monodon* and *P. japonicus* can be cultured at high densities (Liao, 1977; Liu and Mancebo, 1983; Shigueno, 1985). However, arious factors such as salinity, temperature, oxygen, food supply, disease, physiological stress, density of population and consequent availability of space for individuals and competition for the same ecological resources, all influence the growth of shrimps.

Sriraman *et al.* (1989) reported that the growth rate of *P. monodon* is high; this shrimp attains larger size in culture systems than in natural conditions. For this species, Subrahmanyam (1973) reported a growth rate of 25 to 30 mm/month in the natural conditions and 5 to 26 mm/month in aquaria and tanks. Forster and Beard (1974) reported fast growth rates for *P. monodon* and *P. orientalis*; at low stocking density they reach the mean live weights of 25.43 and 22.80 g, respectively, in 16 weeks rearing. These workers concluded that "both species grew very quickly, and at the low stocking density, reached an acceptable market size within eight weeks from an initial weight of 150 mg."

In the present study, the average daily increment in length was 1.28 mm and in weight, 0.252 g at an average stocking density of 6.31 PL/m$^2$. Gundermann and Popper (1977) reported a growth rate of 0.300 g/day for *P. monodon*, which is slightly higher than that obtained in the present study. The stocking density was low in the former study (1.5 PL/m$^2$) and that might be the reason for the higher growth rate.

Sundararajan *et al.* (1979) also reported high growth rate for tiger shrimp (1.59 mm/day; 0.390 g/day), and an average weight of 32.26 g in 80 days rearing. Here the stocking density was as low as 20,000/ha (= $0.2/m^2$) and the ponds were fertilized with urea and superphosphate. Sebastian *et al.* (1980) observed an average growth rate of 38.4 mm/month at a stocking density of 7,000/ha. The growth rate observed by Sundararajan *et al.* (1979) in the salinity range of 10.9 to 22.4 ppt was 47.7 mm/month. The average growth rates reported by Delmondo and Rabanal (1956), Kubo (1956), Poernomo (1968) and Verghese *et al.* (1975) vary between 13.8 and 17.5 mm/month. Chakraborti *et al.* (1986) observed steady growth of *P. monodon* for the first two months of rearing, as also the occurrence of two size groups at the end of this period. With formulated feed and a stocking density of 1.58 shrimps/$m^2$ *(P. monodon)*, and with paddle wheel aerators and water exchange, Liu and Mancebo (1983) obtained an average final weight of 31.4 g after 106 days rearing. In the present study, the final average weights after 120 days rearing without aeration, but with three different feeds were, 30.00 g (clam meat), 30.18 g (clam meat + dough ball) and 31.60 g (pelleted feed). As observed in the present study, an average harvest weight between 30–32 g in 120 days culture with supplemental feeding, for this species is reported by several workers (Kungvankij *et al.*, 1976; Liao, 1977; Liu and Mancebo, 1983; Tiro *et al.*, 1986).

For *P. monodon*, Sebastian *et al.* (1980) reported very fast growth rate during the first 30 days of rearing. Chakraborti *et al.* (1986) noted a fall in growth rate after two months. Pillai *et al.* (1987) also reported on fast growth of *P. monodon* in the early period of culture. AQUACOP (1984) reported that *P. monodon* grows slowly upto 3-4 g body weight and thereafter at an accelerated rate. Gundermann and Popper (1977) also observed very slow growth in the earlier days (first 40 days) of culture for *P. monodon*; the growth rate was maximum between 70 and 120 days. Chen *et al.* (1989a) reported that the growth rate of *P. monodon* was the fastest from 94 mm to 161 mm and the slowest thereafter. The present results are in agreement with those of AQUACOP, Gundermann and Popper and Chen *et al.*, mentioned above; here the growth rate was fast after about 60 days of rearing (*ca.* 9-10 cm length; 5-6 g weight), till 120 days.

In 1992, Haran and coworkers reported that the growth of *P. monodon* in semi-intensive systems in Andhra Pradesh, is about 25 g in 120 days rearing, with Hanaqua feed and paddle wheel aerators; the mean stocking density was 26-28 shrimps/$m^2$. In comparison, the standard growth rate of *P. monodon* fed Hanaqua feed is 29.0 g in 120 days. In the present study, the growth of *P. monodon* was 30 g, or a little more, in 120 days.

Even though some studies suggest that shrimp growth is inversely related to stocking density, there was no evidence in the present study to corroborate this, as also reported by AQUACOP (1984) and Wyban *et* *al.* (1987a). The high growth rate obtained in the present study may be because of the combined effect of feed and fertilizer applied to the culture system. The addition of phosphorus and nitrogen to aquatic systems increases phytoplankton populations (Boyd, 1979). Benthic microbial activity increases in response to sedimentation of phytoplankton blooms, and benthic biomass is capable of doubling because of increased microbial production (Graf *et al.*, 1982). Research done in Israel with organic fertilizers in fish culture may have application to shrimp culture. This research has shown that increased production of the microbial community which utilises manure and organic matter, greatly enhances fish growth in earthen ponds (Schroeder, 1978). An increase in the benthic biomass would likewise be expected to increase shrimp production. The application of fertilizer in shrimp grow-out ponds is to stimulate phytoplankton production. This increase in primary production, propagating through the trophic chain, leads to an increase in the food available for shrimps and, therefore, it supports a greater crustacean biomass.

Rubright *et al.* (1981) attributed the increase in shrimp production in ponds in which fertilizers and feed are added, to the abundant occurrence of polychaetes, copepods and nematodes. This was implicitly corroborated by Anderson *et al.* (1987), who showed that, when natural foods are abundant, 53 to 77% of the growth of *P. vannamei* are due to grazing on pond biota, whereas 23 to 47% were contributed by the feed added. Crustaceans, polychaetes and nematodes are the main diet of *Penaeus* species (Wassenberg and Hill, 1987) and their importance as nutritious food sources for marine invertebrates, from a stand point of energy, protein and essential nutrient requirements, was pointed out by Phillips (1984). The usefulness of fertilization in fish/shrimp culture systems is its beneficial effects on autotrophic and heterotrophic productivity and on the detrital cycle (Buck *et al.*, 1981; Rubright *et al.*, 1981; Wohlfarth *et al.*, 1985).

Deshimaru and Shigueno (1972) reported a total biomass increase of 897.60 g/m$^2$ for 60 days at the rate of 14.96 g/m$^2$/day for *P. japonicus*, at a stocking density of 17 shrimps/m$^2$ and 92% survival. Sick *et al.* (1972) for *P. setiferus* reported 47.4 g/m$^2$ (0.680 g/m$^2$/day) as biomass increase at a stocking rate of 12.7 shrimps/m$^2$ and a survival of 83%. Sick and Andrews (1973) observed 77.2 g/m$^2$ as biomass increase (0.920 g/m$^2$/day) for *P. duorarum* at 23.6 shrimps/m$^2$ stocking density and 87% survival. In the present study the mean biomass increase was 95.33 g/m$^2$ for 120 days at the rate of 0.795 g/m$^2$/day at an average stocking density of 6.31 shrimps/m$^2$ and a survival rate of 50.21%.

Gundermann and Popper (1977) reported a biomass increase of 603.8 g/day/ha for *P. monodon* in a polyculture system with fertilizer alone (at a stocking density of 0.75 shrimps/m$^2$ and a survival of 90%). Eldani and Primavera (1981) reported a biomass increase of 2.34 kg/ha/day, in monoculture of tiger shrimp, with fertilizer alone and 2,000 shrimps/ha stocking density. With chicken manure fertilizer and with 100% survival, a biomass increase of 1.18 kg/ha/day for this species is reported by Subosa (1992). In the present study the biomass increase was higher than that obtained in any of these studies. The high biomass increase may be due to the high stocking density (and probably because of the addition of fertilizers and supplementary feed). A significant positive correlation ($r = 0.884$, $P < 0.001$) between stocking density and biomass increase per day was observed in this study. Similar results are reported for *P. vannamei* by Lee *et al.* (1986), Sandifer *et al.* (1987) and Wyban *et al.* (1987a).

The survival rate of shrimps in the present study varied between 38% and 58% (mean = 50.21%). A survival rate of 50%, even though comparatively low, is consistent with figures reported in commercial shrimp culture. Shrimps grown in brackishwater ponds in Philippines have a survival rate of 10–50% (Delmondo and Rabanal, 1956) and 20% (Caces-Borja and Rasalan, 1958; Eldani and Primavera, 1981) after of 5-8 months rearing. In monoculture of tiger shrimp, Badapanda *et al.* (1985) obtained 32.7%, Chakraborti *et al.* (1985), 25.8% in nursery ponds, and Pillai *et al.* (1987), 34.6%. Chakraborti *et al.* (1986) obtained 25.2% to 33% survival at a stocking rate of 4 PL/$m^2$ and Chen *et al.* (1989a) observed a survival rate of 40–67.7% in highly intensive systems (124 to 143 PL/$m^2$). Trino *et al.* (1992) obtained 51.4% to 73.6% survival in feed and fertilized systems.

The exact reason for this low survival rate is still a matter of speculation. Wickins (1976b) reported that shrimps are stressed when dissolved oxygen falls below 2.0 ppm. The same author reported that *P. monodon* post-larvae are however, unaffected by a pH as low as 6.45. It seems that adverse dissolved oxygen or pH were not the reasons for the low survival rate noted in the present study, in which both these parameters were well within the tolerance limits. It is not known whether shrimps were already weakened by diseases or physiological malfunction, or, if otherwise healthy, succumbed to the aggressiveness of their fellows in the crowded conditions.

It is reported that survival of *P. monodon* post-larvae is directly influenced by the organic content and dissolved oxygen in the water. The detrimental effects of organic pollution are high BOD, low dissolved oxygen, high ammonia and $NO_2$-N. At sublethal levels, a combination of these adverse environmental conditions can induce stress and result in decreased survival (Millamena, 1990). In the present study mortality was high in the larval stages. As the shrimp post-larvae were mostly transported from other States, transportation stress (combined with the other stress factors stated above) might have induced high mortality. From Andhra Pradesh and Orissa hatcheries, shrimp post-larvae are packed at a density of 3,000/5 litres (one packet). An average 36 h transportation time is required for bringing the larvae to the culture site. It should be evaluated whether this packing density is safe enough for the shrimp larvae to withstand the long transportation time.

Another reason for high mortality could be the salinity change. High mortality and poor growth rates of *P. monodon* juveniles occur at salinities lower than 10 ppt (Cawthorne *et al.*, 1983). Some workers have reported that *P. monodon* larvae survived and grew well at lower salinities (Musig and Ruttanagosrigit, 1982). Moulting at extremely high or low salinities requires more time and this renders shrimps more vulnerable to predation (where predators are inadvertently introduced in the culture ponds) and cannibalism, and prolongs their inability to forage for food (Chien, 1993). Rapid changes in salinity also usually cause high mortality of *P. monodon* (Tseng, 1987). Transferring shrimp directly into grow-out ponds is always detrimental.

In the present study there was no significant correlation between salinity and survival rate of shrimps. Further, post-larvae from hatcheries were directly introduced into the grow-out ponds (either into hapas in the grow-out ponds or into a delineated nursery section in the grow-out ponds). Thus, transportation stress and stress induced by sudden transfer of post-larvae into the grow-out ponds might also have contributed to the low survival rate noted in the present study.

Though survival rate in culture system is inversely related to stocking density (Chamberlain *et al.*, 1981), in the present study, with moderate survival at all stocking densities, such a correlation was not found. Chen and Wang (1990) for *P. monodon* and Garson *et al.* (1986), Sandifer *et al.* (1987), Wyban *et al.* (1987a), Goxe *et al.* (1988), Sivakami (1988) and Hernandez-Llamas *et al.* (1992) for other penaeid species, also did not find any significant correlation between stocking density and survival rate.

Different types of conventional feed are used in aquaculture. Ghittino (1972) had reported on the use of selected slaughter house byproducts as supplementary diet in the culture of salmonid fish. In Japan meat of short-necked clam (*Tapes philippinarum*) and mussel (*Mytilus edulis*) is used as supplementary feed for the culture of *P. japonicus* (Deshimaru and Shigueno, 1972). Jhingran and Gopalakrishnan (1973) used mustard oil cake as supplementary feed in the monoculture of mullets. Qasim (1975) described the use of oil cakes as direct manure in polyculture ponds of fish and shrimps in many southeast Asian countries. Maguire *et al.* (1981) reported that Sydney rock oyster (*Crassostrea commercialis*) improves the meat condition of cultured shrimp. According to Maguire and Leedow (1983), Pipi flesh (*Plebidona deltoides*) can sustain very high growth and survival rate even at high stocking densities of the school prawn, *Metapenaeus mecleayi*.

In the shrimp farms selected for the present study three types feeds were used by farmers. The conventional feed used was fresh clam meat. A compounded feed (dough ball) along with clam meat and a farm-made pelleted feed were the other two feeds used. The mean AFCR for clam meat was 1.70, for clam meat + dough ball, 1.59 and for the pelleted feed, 1.55. The AFCR for the three feeds were not significantly different.

Fresh clam meat is conventionally used as supplemental feed in shrimp culture. Kanazawa *et al.* (1970) reported that for *Penaeus japonicus*, a diet of fresh meat of the short-necked clam, *Tapes philippinarum*, gave better growth than compounded feed. Forster and Beard (1973, 1974) obtained fast growth for *Palaemon serratus* fed fresh mussel meat. But, according to Villegas (1978), the growth and survival of *Penaeus monodon* larvae fed with the meat of *T. philippinarum* were only next to those fed compounded diets. Colvin (1976a) used a diet of fresh mussel meat and prawn meat (50 : 50) as control diet for *P. indicus* and found remarkably slow growth with this diet. Ali (1982), who used fresh meat of *Sunetta scripta* as control diet for evaluating the efficacy of certain protein sources in the growth of *P. indicus*, found not only inferior performance but also heavy mortality of the prawns fed fresh clam meat. Even though there is a difference of opinion as to the efficacy of fresh clam meat as supplementary diet for prawn/shrimp, it would appear that the available information does not weigh in favour of fresh clam meat as the ideal feed for realising better growth in prawn/shrimp. This poor performance of fresh clam meat may be because of the high rate of chitinoclastic bacterial infection of the animals fed fresh clam meat (Venkataramaiah *et al.*, 1975b). Ali (1982) also emphasised this point, and he reported that the growth was high, and the food conversion ratio the best, in juvenile *P. indicus* fed dry, powdered meat of *Vellorita cyprenoides*.

The gross energy (502.72 kcal/100 g) as well as the protein content (52.60%) were higher for clam meat than for the other two feeds. The protein to energy ratio (P/E ratio) for this feed was 104.63 mg protein/kcal. Shrimps, like all other animals, feed primarily to satisfy their energy requirements (Cho and Kaushik, 1985). If the feed has an excess of dietary energy, it may result in decreased feed intake, and consequently, the intake of other essential nutrients may also be lowered. Both these can adversely affect the growth. On the other hand, if the dietary energy is too low, the shirmp utilises other nutrients such as protein for fulfilling its energy requirements rather than for growth. Therefore, P/E ratio of the feed is crucial and there is an optimum P/E ratio at which the growth will be the maximum. Hajra *et al.* (1988) found that the most efficient dietary energy for *P. monodon* was 412.60 kcal/100 g feed. It should be noted that various factors such as water temperature and quality and the size and physiological state of the animal, affect its energy requirements. The energy in clam meat used by farmers in Kerala was higher than the optimum recommended by Hajra *et al.* (1988) and therefore, this feed might have been underutilised by the shrimp.

In the present study the AFCR for fresh clam meat was 1.70, which is lower than that reported by many earlier workers for clam meat used by them : 9.45-11.70 (Mohammad Sultan *et al.*, 1982), 2.70 (Ahamad Ali, 1988), 1.79 (Kungvankij *et al.*, 1990) and 3.4 (Jayagopal, 1991). This was quite appreciable as, on wet weight basis, 6.80 kg of clam meat produced 1 kg of shrimp. Deshimaru and Shigueno (1972) reported that the profiles of conjugated amino acids of *P. japonicus* and the short-necked clam, *Tapes philippinarum*, are very similar. Whether this is true for *P. monodon* and *Vellorita cyprenoides* var. *cochinensis* also is not known, but this traditional feed had a low AFCR and it yielded high average final weight and comparatively high production, even in spite of the presumed under utilisation of this feed because of its high energy level.

Dough ball (compounded feed) is widely used for shrimp farming in India and abroad. In India at the Kakdwip Brackishwater Research Centre, West Bengal, a supplementary feed consisting of soya bean flour, brewer's yeast, maize powder, wheat flour, calcium phosphate, vitamins and algin was formulated for feeding the post-larvae of *P. monodon.* Another feed consisting of goat offal, yeast, algal powder, wheat flour, and terramycin was used in this Centre for feeding the post-larvae of *P. indicus.* This Centre has also conducted feeding trials on *P. monodon* in cement cisterns with three feeds: a mixture of fish meal, ground nut oil cake and rice bran; fish meal alone and flesh of trash fish alone. It was reported that the flesh of trash fish gave the highest growth and the best AFCR (AICRP 1978). Mohammad Sultan *et al.* (1982) formulated feeds with frog flesh waste and reported AFCRs between 3.01 and 4.06 for *P. indicus* and 5.87 and 8.21 for *P. monodon.* In semi-intensive culture systems of *P. japonicus* in Italy (with fertilization and pelleted feed), Lumare *et al.* (1985) reported that the AFCR ranged from 1.60 to 3.90. Kungvankij *et al.* (1990) reported an AFCR of 1.53 (at stocking density 40 PL/$m^2$ of *P. monodon*) for a feed consisting of trash fish and rice bran. Bostock (1991) reported an AFCR of 3.3 for dough ball (27% protein) and 2.9 for pelleted feed (34% protein) for *P. monodon* cultured in Andhra Pradesh. The ingredients of the dough ball were wheat flour, soya meal, rice bran, trash fish, beef and dried fish. Wood *et al.* (1992) reported an AFCR of 3.3 for dough ball in *P. monodon* farming systems of West Bengal. They reported an AFCR of 4.4 for pelleted feed and 7.0 for powder-based dough ball. With the dough ball, a surprising yield of 1410 kg/ha of *P. monodon* was achieved by Wood *et al.* (1992). The AFCR of this dough ball was 5.6 and the crude protein content, 26%.

In the present study, the moist dough ball used had a protein content of 27.71%. In combination with clam meat, the ratio of clam meat to dough ball varying from 1 : 1 to 8 : 1 in this combined feed, the protein content ranged from 40.15% to 49.79%. This combined feed had a low AFCR (1.59). This improved AFCR could be due to the presence of more than one protein source in the feed, as also reported by Alava and Lim (1983). However, the performance of shrimp fed dough ball in combination with clam meat was not significantly different from those fed fresh clam meat alone. Three plausible explanations may be put forth for the inefficacy of this feed.

1. The dough ball had a high moisture content, about 50%. This high moisture content could have resulted in fast physical disintegration of the feed leading to rapid leaching out of the nutrients thereby making them unavailable to the shrimps.
2. The feed (nutrient) input (on dry weight basis) into the system where clam meat alone was fed was more than in the feeding regime in which dough ball was fed along with clam meat (see Table 8).
3. Except on one occasion when clam meat and dough ball were mixed in nearly 1:1 ratio (see Table 8, Sl. No. 23), on all other occasions clam meat was the dominant component in this feeding regime. It is also noticeable that in this culture (C.1.I/92) the AFCR was as high as 2.62 and the production, as low as 560 kg/ha; the FCE was only 38.16%. This suggests that, increasing the proportion of the dough ball in the feed combination tends to lower the efficacy of the combined feed. Alternatively, it may be that, in the feed combination, it is the clam meat component that is more responsible for the supply of nutrients. Detailed studies are needed to evaluate the efficacy of the dough ball used by the shrimp farmers in Kerala. Notwithstanding, it is nearly unequivocal that, in the present form and manner in which it is used, the clam meat-dough ball combination is only as efficient as clam meat alone.

The present results, even though speak of the inefficacy of supplementing a conventional feed with an unscientifically formulated and prepared dough ball in the hope of realising better production of shrimp, suggest that, in the context of the shortage of sufficient quantity of fresh clam meat, and consequently of the increasing cost of this feed, using a combination of clam meat and dough ball can help the farmers save, though only marginally, on feed cost. In the present study the input cost of fresh clam meat was higher (36.04% of the total imput cost) than that for clam meat + dough ball (34.31% of total input cost).

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 gross energy calculated for this feed containing 35.2% protein, was 295.91 kcal/100 g and the protein/energy ratio was 119.24 mg protein/kcal. Ali (1982) reported AFCR values ranging between 1.46 and 4.20 for compounded feeds prepared with ground nut oil cake and shrimp waste as the major ingredients. Mohammed Sultan *et al.* (1982) reported an AFCR of 8.21 for pelleted feed used in *P. monodon* rearing. Raman *et al.* (1982) conducted feeding trials on *P. indicus* using different combinations of feed ingredients such as fish meal, prawn processing waste, ground nut oil cake, gingelly cake, black gram husk, bengal gram husk, bajra, wheat flour, wheat bran, rice bran and tapioca. Among the feed combinations tested, fish meal, rice bran and tapioca in the ratio of 1:1:1 and 2:2:1 gave satisfactory results; the AFCR obtained with the first feed combination was 1.69 and with the second, 3.21.

Venkataramaiah *et al.* (1972a,b; 1975a,b) while studying the effects of feeding levels and salinity on the growth and AFCR in *P. aztecus*, reported that the AFCR of a standard shrimp feed varied from 1.25 to 3.73. The AFCR for the pelleted feed used in the present study is within this range. Elam and Green (1974) conducted feeding experiments on *P. setiferus* with different formula feeds and obtained AFCRs ranging from 1.8 to 2.3, which are slightly higher than the AFCR for the pelleted feed in the present study.

Forster and Beard (1973) observed that the growth of *Palaemon serratus* was high when the diet contained more than one protein source. Zein-Eldin and Corliss (1976), who obtained similar results for the same specie,s reported that inclusion of rice bran in shrimp feed improved the growth. For *Macrobrachium rosenbergii* the results were much superior when the diet contained fish meal, soya bean and shrimp meal compared to a diet having only soya bean meal, (Balazs *et al.*, 1973). Subsequently, Balazs *et al.* (1974) found that the diet containing soya bean meal and tuna meal yielded significantly greater growth than the diets containing only soya bean, tuna meal or shrimp meal. These authors concluded that by using different protein sources, the possibility of approaching optimum amino acid balance in the diet was greater.

The pelleted feed was superior to the other two in realising better average final weight and growth rate of *P. monodon* in semi-intensive systems of Kerala backwaters. This may be because of the better amino acid balance in the pelleted feeds by virtue of the four different protein sources incorporated in the feed (mixed sources of protein provide better amino acid balance - Balazs *et al.*, 1973, 1974). Alava and Lim (1983) reported that diets containing two or more protein sources are better utilised by shrimp than those containing a single protein source. This could be the reason for the higher mean final weight realised with pelleted feed in the present study.

The second feed type (F2 = clam meat + dough ball) also contained more than one protein source. However, the growth of shrimp fed this feed was not significantly different from that fed clam meat alone. Moreover, the results obtained with F2 were significantly inferior to that realised with pelleted feed. The poor performance of F2 compared to pelleted feed is attributable to the lack of any other marine protein source, other than clam meat, in F2. The pelleted feed contained two sources of marine protein: shrimp head waste and squilla powder. Further it is now proven that penaeid shrimps have a dietary requirement of native chitin (Fox, 1993). The odour of the feed (by virtue of chitin present in it) may be attracting the animals and making the feed more palatable (Ahamad Ali, 1988). Shrimp head meal is not only a good source of chitin, but also of protein, cerotenoid pigments, fatty acids and fibre (Meyers, 1986). Deshimaru and Shigueno (1972) reported that the amino acid composition of the rations that give the best growth performance of shrimp, most closely approximate the amino acid composition of the shrimp. Shrimp meal in the pelleted feed, therefore, would have ensured a desirable amino acid balance in the formulation. Besides, shrimp meal would meet the substrate requirement of chitin and provide the requisite amount of calcium needed for rapid growth of shrimps.

According to Cuzon *et al.* (1994) shrimp meal can be used at fairly high levels and this generally helps to sustain good growth rate. When correctly prepared and preserved, shrimp meal provides a substantial amount of essential nutrients. It is an excellent source of protein because its amino acid composition is similar to that of the whole animal. This is especially true when the product comes from local fisheries.

Cod liver oil is rich in w-3 poly unsaturated fatty acids (PUFA), whereas terrestrial plant oils (palm oil) are rich in w-6 fatty acids (Hajra *et al.*, 1988). The presence of both w-3 and w-6 PUFAs helps in the synthesis of essential fatty acids (EFA) that are needed for rapid growth and normal moulting of penaeids (Colvin, 1976b; Guary *et al.*, 1976). In the pelleted feed used here, cod liver oil and palm oil were incorporated.

The protein/energy ratio was the highest for pelleted feed (119.24 mg protein/kcal. This value is in agreement with that reported by Hajra *et al.* (1988) (107.70–120.80) and Shaiu and Chou (1990) (96-96-118.21 ) for the feeds they used for *P. monodon*.

Several authors have reported that shrimps require relatively high content of protein in their diet. The diets used by Deshimaru and Shigueno (1972) for *P. japonicus* contained over 60% protein. Lee (1972) reported optimum growth of *P. monodon* at 40% protein level and the same level was established as optimum for *P. aztecus* by Venkataramaiah *et al.* (1972a). According to Andrews *et al.* (1972), *P. setiferus* require an optimum protein level of 28-32%. Zein-Eldin and Corliss (1976) reported that 30% protein is the optimum for *P. aztecus.* Balazs *et al.* (1973) obtained the best growth performance of *P. aztecus* at 25-40% protein level. The feed used by Alikunhi *et al.* (1975) for *P. monodon* contained 20% protein. Rajyalakshmi *et al.* (1979) reported that a protein level in the range of 20-40% in the diet is sufficient to ensure good growth in penaeid shrimps, especially in tropical waters. The present results corroborate the above mentioned observations. The best growth was realised with pelleted feed containing about 35% protein. According to Rajyalakshmi (1982) fast growth and remarkable size of *P. monodon* are obtained with diets containing less than 40% protein.

Even though the protein content of clam meat + dough ball (1 : 1) was about 40%, this feed was not as efficient as the pelleted feed. The reasons for the inefficacy of this combined feed have already been discussed. It is to be emphasised on the basis of the present results that the protein content of a feed is not the sole criterion to assess its efficacy.

The AFCRs for the three feed types used in the present study were low compared to earlier reports on the AFCR for feeds used in shrimp cultures. This low AFCR could have been due to the better feed management with check trays and probably because of the good primary productivity prevailing in the culture ponds. It is to be noted here that, according to Gopinathan *et al.* (1982), the culture ponds connected to the Cochin backwater system are highly productive. The physico-chemical features of the ponds selected in the present study were well within the limits for systems showing good productivity. The application of fertilizers and use of supplementary feed to the ponds under study had an enhancing effect on primary productivity of these ponds.

In the present study fresh clam meat as a supplementary feed was used in all the three regions (Pallithode, Chellanam and Kannamaly). But the production achieved with clam meat was higher in Kannamaly than in the other two regions. The higher production is attributable to the following two reasons.

1. Ihe higher amount of organic fertilizer used in Kannamaly (350–500 kg/ha; mean = 431.25 kg/ha) than in Pallithode (200–300 kg/ha; mean = 275.5 kg/ha) and Chellanam (200 kg/ha in all four cultures).
2. The higher nitrate and phosphate contents of the waters of Kannamaly ponds (see Table 5).

The high nitrate and phosphate contents could have resulted in high primary as well as secondary productivity. The organic manure, since after its disintegration forms food for the detritus feeders including shrimp, might have helped in augmenting productivity of the ponds and better survival and growth of shrimps. Another point deserves mention especial in this context. Sathiadas *et al.* (1989) reported that the distance of the culture ponds from the 'bar-mouth', and the production are inversely related. Kannamaly is closer to the Cochin 'bar-mouth'; this proximity of Kannamaly ponds to the 'bar-mouth' obviously seems to have had a positive influence on the production for these ponds.

Probably, the slightly higher survival rate in Kannamaly region (52.8%) than in Pallithode (50.4%) and Chellanam (49.5%) also might have contributed towards this end, though survival rate and production in the present study were not significantly correlated.

As evident from the observations made during the present study, the age-old practice of feeding clam meat as the sole supplementary food source in shrimp culture is still in vogue in Kerala State; of the 36 culture operations studied, in 20 this was practised. Even though this practice is conducive and recommendable to the areas where the clam (*Vellorita cyprenoides*) is available in plenty, it is to be remembered that this clam is a delicacy for human beings also. Yet, the clam is farmed neither for the purpose of human consumption nor for the requirement of shrimp culture. In fact, both these needs are at present met by the wild or natural populations of the clam. With a boom in shrimp farming along the east coast of India, aquaculture feed manufactures have also started exploiting the wild populations of the clam for incorporation of its meat in compounded feeds. It is but only a matter of time before the natural resource of *V. cyprenoides* was over exploited. In this scenario, presumably with the impending acute shortage of the clam, and the consequent hike in the cost of clam meat, the practice of using clam meat as a sole supplementary feed for shrimp would, and should, gradually phase out. However, the whole-someness of this feed cannot be given a go by.

In this study, the overall performance of shrimp weighs strongly in favour of the use of pelleted feed. In terms of economics also the same holds good because, of the total production cost, 36.04% and 34.31% were accounted respectively for the cost of clam meat and clam meat + dough ball, whereas only 30.37% of the total production cost were accountable for pelleted feed. The performance of the pelleted feed in terms of growth and economy was mainly because of its quality and nutritional value. Shrimps being slow feeders, require a water-stable pellet. Further, uniformity in the particles compacted into a pellet, the nutrient density in the feeds in terms of macronutrients and micronutrients, all add to the qualities of the feed. The pelleted feed used in this study had all these qualities.

Further, this feed was made in the farm itself adopting an appropriate feed technology with maximum utilisation of locally available conventional and non-conventional ingredients. It was all these factors, which New (1992) also emphasized, that added up to advocate on-farm feed making for the small-scale, semi-intensive, monoculture systems *P. monodon*, particularly in holdings of less than one hectare, on the backwaters of Kerala State.

# CHAPTER IV

# ECONOMICS

## Introduction

Aquaculture research has been, and it is by and large even today, mostly addressing biological and technical problems with a view to overcoming the constraints to production and to modifying and/or intensifying the traditional culture practices; it would seem that researchers are least concerned about studying the economics of aquaculture of various modes (Shang, 1990). As rightly observed and pronounced by the IDRC, Canada, more than a decade ago, the true viability of any aquaculture technology rests mainly on its economic viability, not simply on the biological and technological viability (IDRC, 1982). Even though a little late, the importance of aquaculture economics research is gradually being recognised. Economic analysis is essential to evaluate the viability of investment in aquaculture, to determine the efficiency of resource allocation, to improve the existing management practices, to evaluate new culture technology, to assess market potential and to intensify areas in which research success would have high potential payoff (Shang, 1990). Economics research in aquaculture can provide a basis not only for decision making for farmers, but also for identifying research priorities and formulating public aquaculture policies.

The output from an aquaculture system is mainly a function of the inputs applied in the production process; it depends upon such inputs as stocking density, supplementary feed, labour, managerial expertise, and the underlying technology used. The relation between inputs and outputs is referred to as, in the economics jargon, the 'production function'. The economics of an aquaculture system mainly rests on the production function. Further, the study of production function can contribute to improved farm management. An understanding of the existing social, cultural and economic interactions and the extent of resource allocation in a society is important in the introduction and development of aquaculture technology.

As in any other industry, in aquaculture also the aquaculturist is an entrepreneur, and his business activity is mostly guided by the net economic yield, which is the difference between the costs of inputs and the output. However, in many developing countries, both interest and capacity for conducting economic studies are lacking, which make it difficult for the development of sound policies. The shortage of reliable data on aquaculture economics and the lack of understanding of the importance of such data impede economic analysis.

Shang (1986) spoke of the following constraints in the study of aquaculture economics.

1. Lack of reliable economics data: In many cases, the information available is from the laboratory, and not from the field. Laboratory results require supplemental information from

the existing commercial farms. Unfortunately, the data base on commercial aquaculture is not only poor, but also difficult to obtain because of the proprietary and nascent nature of an operation.

2. Lack of cooperative research among aquaculture experts: In many areas aquaculture experts, including economists, conduct their studies with no or only very little interaction with each other. Therefore, the necessary data for economics analysis are either not available or are quiet often fragmentary.
3. Lack of interest of economists in aquaculture research.
4. Inappropriate data and/or methods for analysis: This ends up in results that are not meaningful, if not erroneous.
5. Finally, the diverse forms and species cultured and the variety of aquaculture modes make economic comparisons difficult.

Since aquaculture is a multidisciplinary science that includes such diverse disciplines as biology, engineering, hydrology and hydrography, nutrition and feed technology, genetics, economics, and even pathology and pharmacology, collaborative research is needed to develop efficient operating systems and to improve the existing management practices. As mentioned earlier, the lack of sufficient data for economics analysis in aquaculture is a major problem, but this problem may be overcome by cooperative efforts, locally and internationally, among relevant aquaculture specialists, as suggested by Shang (1986).

Even though a lot of information is available on even such special aspects as physiology, nutrition, diseases etc., of culturable/ cultured shrimp species, that on the economics of shrimp culture is rather scanty. Anderson and Tabb (1970) studied some economic aspects of pink shrimp farming in Florida. Ford and Amant (1971) put forth the management guidelines for predicting the production of the brown shrimp, *P. aztecus*, in Louisiana. Greenfield (1975) studied the economics of the production and marketing of shrimp. Shang and Fujimura (1977) showed that prawn farming in a tropical area such as Hawaii, is profitable; their analysis of the economics of production suggests that there is great potential for the culture of *Macrobrachium* sp. in this area. Bloomstein *et al.* (1977) provided a guideline for profitable investment in shrimp farming. Roberts and Bouer (1978) discussed the economics of *Macrobrachium* production in grow-out ponds in South Carolina; they concluded that even though net returns were small, it was too early to predict on the feasibility. According to Klemetson and Rogers (1985), additional investigation is needed to determine the viability of prawn culture in temperate areas. Godifriaux *et al.* (1978) investigated on the potential for culturing both *Macrobrachium* and rainbow trout in power plant waste water. Some other noteworthy publications regarding *Macrobrachium* farming, which have applicability in shrimp farming, are those of Sandifer *et al.* (1982), Shang (1982) and Liao and Smith (1983).

Allen and Johnston (1976) developed a model to predict the feasibility of lobster culture. However, the model when applied to the data from prawn farms in Hawaii, was not successful. The "mystique of the pond" or the poor understanding of the processes occurring in the pond, was suggested as the reason for the inefficiency of the application of the computer model for freshwater prawn production (Klemetson and Rogers, 1985). Computer simulation models have been developed for estimating the number of prawns in culture systems (Huang *et al.*, 1976), modelling of prawn production in ponds (Morita, 1977) and for management economics for shrimp farming (Stamp, 1978). The application of computer studies in aquaculture has distinct advantages in the design of aquaculture facilities that will benefit management, reduce operational costs and eliminate trial-and-error pond management (Orth, 1980).

Madewell (1971) and Walker and Baaker-Arkema (1975) have considered the economics of catfish production in the United States, the techniques and parameters discussed by them are applicable to shrimp production in grow-out ponds. Hirasawa and Walford (1979) studied the economics of *Penaeus japonicus* farming. Pond preparation strategies and budget analysis for penaeid shrimps have been discussed by Johns *et al.* (1981). The model developed by Klemetson and Rogers (1981) on the maintenance of aquaculture pond temperature (MAPT) provides information on the relation between climatic conditions, heat inputs and prawn productivity potential. Pardy *et al.* (1983) made a preliminary analysis of stocking strategies for penaeid shrimp culture and they reported that the growth of *P. stylirostris* was more sensitive to stocking density than that of *P. vannamei.* A preliminary economic analysis of polyculture in shrimp ponds has been conducted by Sadeh *et al.* (1983).

Hirasawa (1985, 1988) published extensive reports regarding the economics of shrimp culture in Asia. Wyban *et al.* (1987b) reported on the design, operation and comparative financial analysis of shrimp farms in Hawaii and Texas; they suggested that producers should work towards increasing shrimp survival, number of crops per year, stocking density and market price, rather than trying to save on cost items. Wyban *et al.* (1988) who studied the shrimp yield and economic potential of round ponds, reported that the round pond design and management yield high shrimp growth rates and production. Smith and Lawrence (1990) reported on the economic feasibility of penaeid shrimp culture in inland saline groundwater-fed ponds in Texas; the results of this study suggest that saline groundwater in southern Texas can be used for the culture of *P. vannamei.* Yahaya (1990) analysed the economics of brackishwater shrimp culture in Peninsular Malaysia. He concluded from the results of this study that increased production from the farms could be achieved through improved culture techniques, efficient management practices and cost-cutting strategies. Lambregts *et al.* (1991) compared semi-intensive, intensive and very intensive production strategies for shrimp farms of various sizes in Texas; they concluded that the semi-intensive strategy is clearly a better choice than the other two. DeSilva and Jayasinghe (1993) studied the technology and economics of small-scale shrimp farms in Sri Lanka; they suggested that more careful considerations in site selection, improvements in pond preparation and management procedures and substitution of imported feeds with low cost feeds are important for better economic returns and future viability of small-scale shrimp culture industry in Sri Lanka.

Some other noteworthy studies in the field of shrimp culture economics are those by Huang *et al.* (1984), Griffin *et al.* (1985), Hanson *et al.* (1985), Israel *et al.* (1985), Sandifer and Bauer (1985), Hatch *et al.* (1987), Posadas (1988), Primavera (1989) and Fast *et al.* (1990).

Models in aquaculture try to provide answers to the questions of economic feasibility, optimal system design, optimal method of operations and research directions. Like many other biological production systems, aquaculture is a dynamic and probabilistic process. During the production process, the growth and survival rate of an animal depend primarily on management inputs and environmental conditions. Profitable operations can be only achieved through better understanding of the relevant elements, as well as their interrelations, in the entire production process. This is not an easy task for any producer to perform without the assistance of a proper tool. A system analysis that can integrate all these important elements and help the producer locate the optimal course of action will contribute to the success of the operation. In the endeavour to develop such an integrated analysis, collaborative efforts of biologists and economists have erected a new class of analysis called bio-economic modelling (Shang 1990). Basically, it integrates a biological model into an economic analysis.

Several system models have been developed for operational management and system design of shrimp culture facilities. Barbieri and Cuzon (1980) used linear programming to determine the optimal nutritional level of *P. japonicus.* The Texas A & M group has developed a rather extensive shrimp simulation model for the purpose of providing year to year financial situations of a proposed facility (Adams *et al.* 1980a, b; Griffin *et al.*, 1981, 1984). An excellent aquaculture modelling text was written by Allen *et al* (1984). Karp *et al.* (1986) used a dynamic programming model to determine the optimal stocking and harvest rates of *P. stylirostris.* Leung *et al.* (1989) and Hochman *et al.* (1990) extended the stochastic growing inventory model to analyse the optimal harvesting schedule for penaeid shrimp production in Hawaii. Leung and Rowland (1989) developed an electronic spread-sheet model for financial evaluation of shrimp production. This model provides a comprehensive analysis of the major phases of shrimp production including maturation, hatchery, nursery and grow-out ponds. Leung and Shang (1989) developed a computer operational bio-economic model for assessing the economics of alternative pond management and marketing strategies for prawn production in Hawaii. Cacho (1990) reported on bio-economic simulation programme (AQUASIM) for catfish production. Condrey (1991) made a review of shrimp population models and management, and recommended strategies for enhancing the yields.

There are only very few studies on the economics of aquaculture systems in India. Dhondyal and Singh (1968) studied the cost-benefit ratio in inland fish culture. Raje and Ranade (1980) studied the economic implications of shrimp farming. They showed that two crops/year are possible with *P. merguiensis* and recommended the establishment of more hatcheries. Reddi (1980) worked out the economics of shrimp farming in Karnataka State. He reported a production of 260 kg shrimp/ha/year and suggested that using artificial feed may further increase production. Gopalan *et al.* (1980) studied the economics of an improved method of paddy field shrimp culture in Vypeen Islands, Kerala. The results of this study showed that the improved method of operation is economically more advantageous than the traditional one, even though the farmer has to incur more initial investment. An overall review of the economics of traditional shrimp culture in coastal Karnataka was made by Pai *et al.* (1982). These workers reported that the traditional shrimp farming in this State is highly profitable. Srivastava *et al.* (1983) reported on the economics of brackishwater aquaculture in India. Jayarajan *et al.* (1987) analysed the economics of shrimp farming in Andhra Pradesh. They suggested that a well-knit and co-ordinated approach ensuring timely and adequate availability of inputs such as quality seed feed, equipment, credit, chemicals etc., is needed to enhance the production. Jose *et al.* (1987) studied the feasibility and economic viability of selective culture of *P. indicus* in Kerala. The results of the study showed that selective culture of *P. indicus* in 'pokkali' fields is much more profitable than the traditional method of prawn filtration, both in terms of yield and economy. Purushan (1987) reported on the economics of traditional shrimp farming in Kerala. According to him, to realise more poroduction and monetary returns, the farmars must shift from the traditional farming practice to monoculture of desirable species. In 1989, Sathiadas and coworkers evaluated the economics of paddy integrated prawn farming in Kerala. They reported that the total prawn production decreased as the distance of the farm from the 'bar-mouth' increased. Ajithkumar (1990) who evaluated the economics of semi-intensive *P. indicus* farming in Maradu, Kerala, reported that by increasing the application of certain inputs, the net profit can be maximised. Jayagopal (1991) revealed that the production of *P. monodon* in semi-intensive systems of Kannamaly area of Kerala is influenced by the inputs such as seed, feed, labour and the area of culture ponds. The input-output relation indicated that the use of all inputs should be increased to maximise the profit. Nasser and Noble (1992) reported on the economics of extensive prawn culture systems in Vypeen Islands, Kerala, with emphasis on some little-known facts, mainly soft-shell disease and predation problems among the farmed shrimps. Usharani *et al.* (1993) analysed the economics of semi-intensive shrimp farming in coastal Andhra Pradesh and reported that the resource utilisation is not optimal and there is further scope for increasing the resource utilisation efficiency.

The general procedure for discussing the economics of production is similar, though each study is unique and based on criteria for a given geographical location. The economic feasibility reported in the studies varies since some are round-the-year culture systems, whereas the growing season in temperate areas may be around six months. In addition, the methods of harvesting, market prices, feed conversion ratios and other factors may vary from location to location. These make meaningful comparison of the results reported by various workers difficult, if not impossible.

This part of the present study aims at analysing the economics of the small-scale semi-intensive shrimp farming being practised in Kerala by using the Cobb-Douglas production function analysis, and to providing feed back information on the profitability of field situations of the culture practice and on the allocation efficiency of inputs used in this shrimp farming system.

## Materials and Methods

The data on 36 culture operations were collected with suitably structured and pretested schedules (Annexure) The values were calculated on per hectare basis. The influence of six major inputs (area of pond, stocking density, feed cost, labour charges, cost of eradication and amount of fertilization) on the production of shrimp was worked out by regression analysis.

Input-output ratio was estimated as follows

$$\text{Input-output ratio} = \frac{\text{Gross returns (Rs.)}}{\text{Total costs (Rs.)}}$$

**Feed and operating cost ratio:** This ratio shows the contribution of the cost of all types of feeds used in the farm to the total farm operating cost.

$$\text{Feed and operating cost ratio} = \frac{\text{Feed costs (Rs.)}}{\text{Operating cost (Rs.)}}$$

**Seed and operating cost ratio:** How much the cost of the stocking materials add to the total cost of operating the shrimp farms, is indicated by the ratio.

$$\text{Seed and operating cost ratio} = \frac{\text{Cost of stocking material (Rs.)}}{\text{Operating cost (Rs.)}}$$

**Labour charge and operating cost ratio:** This was calculated as follows.

$$\text{Labour charge and operating cost ratio} = \frac{\text{Labour charges (Rs.)}}{\text{Operating cost (Rs.)}}$$

Cobb-Douglas production function was worked out to find out the bio-economic relation of various inputs on the output. The production function is algebraically expressed as,

$$Y = a\, X_1^{b_1}\, X_2^{b_2}\, X_3^{b_3}\, X_4^{b_4}\, X_5^{b_5}\, X_6^{b_6}$$

where Y = the average production in kg (or output), a = a constant and $X_1$ ... $X_6$ = the six input variables:

$X_1$ = Water area in hectare
$X_2$ = Stocking density (No./ha)
$X_3$ = Cost of feed (Rs./ha)
$X_4$ = Labour charges (Rs./ha)
$X_5$ = Cost of eradication (Rs./ha)
$X_6$ = Fertilization (kg/ha),

$b_1$ ... $b_6$ = the elasticities of production inputs $X_1$ to $X_6$.

The coefficient of each variable was tested to find out the level of significance employing the t-test. The mean value for output and the economics of scale was worked out.

Economic optima can be calculated by using the estimated production function by comparing the benefits of adding units of inputs to the additional cost of these inputs. The marginal physical product (MPP) represents the additional yield and it is expressed mathematically as the partial derivative of the production function with respect to one particular independent variable, or

$$MPP_x = \frac{\bar{y}}{\bar{x}} b$$

where, $\bar{y}$ = geometric mean of output

$\bar{x}$ = geomatric mean of input X

b = partial elasticity of input X

The value of the marginal product (MVP) of an input variable is calculated by multiplying MPP of that input by the unit price of the product,

$$MVP_x = (MPP_x)(P_y)$$

where, $MVP_x$ = value of marginal product of input variable X and $p_y$ = unit price of output.

$MVP_x$, when compared with the unit cost of input X (= $P_x$) indicates whether the level of input use is at that level which maximises profit. If the $MVP_x$ exceeds $P_x$ then profit can be increased by additional input use. The profit maximising level of input usage is reached when $MVP_x = P_x$.

An alternative formulation of the condition for profit-maximising input use is $MPP_x = \frac{P_x}{Py}$, which explicitly indicates the importance of the relative input-output prices. This equation states that as long as the additional input is increasing yield faster than the ratio of its price to the price of output, further intensification will increase profit.

The relevant methods for the analysis of economics were adopted from Shang (1990).

## Results

The general economics variables relating to the small-scale semi-intensive shrimp farming in backwater systems of Kerala State are summarised in Table 12.

On an average, the total cost of production per hectare was Rs. 72,420.00. The largest component of the operational cost was feed cost (35%), the next major items being the labour charges (27%) followed by seed cost (20%). On an average, the yield obtained per hectare was 959.20 kg shrimp. The gross and net incomes were Rs. 1,40,026.00 and Rs. 67,606.00. The production cost per kg of shrimp was Rs.75.50; the price realisation of the product was Rs.146.44 per kg. The input-output ratio ( $\equiv$ cost-benefit ratio) was 1.93. This means that, for every rupee invested on shrimp production, the additional returns realised was Rs. 0.93.

The results of the production function analysis are given in Table 13.

The Cobb-Douglas production function was,

$$Y = 0.006036\ X_1^{0.14}\ X_2^{0.82}\ X_3^{0.26}\ X_4^{0.14}\ X_5^{0.009}\ X_6^{0.07}$$

An examination of the elasticity coefficients revealed that three variables--stocking density, cost of feed and labour charges--were statistically significant and positive at 0.1%, 1% and 5% levels, respectively. The effect of eradication charges, area of the pond and the amount of fertilizer applied on yield were not significant. The $R^2$ was 0.91 suggesting that the selected six variables in regression indicated a good fit and explained upto 91% of the variation in the production. Cobb-Douglas production function was analysed with the three significant variables (stocking density, feed cost and labour charges) and the $R^2$ obtained was 0.88. The results of this analysis suggest that these three significant inputs explained upto 88% of the variation in the output..

There was significant positive correlation between stocking density and production ($r = 0.88$; $P < 0.001$). The coefficient of this variable was 0.82 which indicates that, when the other inputs are held constant, 10% increase in stocking density would result in 8.2% increase in yield. The positive value of all the coefficients itself is an indication that increase in production is achievable by increasing the inputs included in the model.

The other two significant variables were feed cost and labour charges. The coefficient of feed cost was 0.26 implying that 10% increase in feed cost would make 2.6% increase in total output. The coefficient of labour charges suggested that 10% increase of the labour charges would increase the production by 1.4%. The other three variables—area of the pond, cost of eradication and the amount of fertilization—did not have any significant bearing on production.

The overall economics characteristics of the three significant inputs identified in the study are summarised in Table 14.

TABLE 12

The general economics variables of the small-scale, semi-intensive, monoculture of tiger shrimp in brackishwater ponds of Kerala State

| | | |
|---|---|---|
| Average pond area (ha) | = | 0.87 |
| Average stocking density (No./ha) | = | 63,116 |
| Average survival rate (%) | = | 50.20 |
| Average feed cost (Rs./ha) | = | 25,626.00 |
| Average seed cost (Rs./ha) | = | 14,803.00 |
| Average labour charge (Rs./ha) | = | 19,720.00 |
| Average production (kg/ha) | = | 959.20 |
| Average gross income (Rs./ha) | = | 1,40,026.00 |
| Average operating cost (Rs./ha) | = | 72,420.00 |
| Average net income (Rs./ha) | = | 67,606.00 |
| Average cost of production (Rs./kg) | = | 75.50 |
| Average cost of product (Rs./kg) | = | 146.44 |
| Average cost of seed (Rs./1000) | = | 234.50 |
| Average cost of feed (Rs./kg) | = | 16.42 |
| Input-output ratio | = | 1.93 |
| Feed and operating cost ratio | = | 0.35 |
| Seed and operating cost ratio | = | 0.20 |
| Labour charge and operating cost ratio | = | 0.27 |

## TABLE 13

Estimated Cobb-Douglas production function for tiger shrimp production in small-scale, semi-intensive, monoculture, brackishwater systems of Kerala State

Intercept = 0.006036

$R^2 = 0.91$

Net production = 959.20 (kg/ha)

| | Inputs | | | | | |
|---|---|---|---|---|---|---|
| | Area (ha) | Stocking density (No./ha) | Cost of feed (Rs./ha) | Labour charges (Rs./ha) | Eradication charges (Rs./ha) | Amount of fertilization (kg/ha) |
| Production coefficient | 0.14 | 0.82 | 0.26 | 0.14 | 0.009 | 0.07 |
| Standard error | 0.098 | 0.224 | 0.086 | 0.066 | 0.005 | 0.072 |
| t-value | 1.43 | 3.67 | 3.02 | 2.12 | 1.8 | 0.10 |
| Significance level | NS | $P < 0.001$ | $P < 0.01$ | $P < 0.05$ | NS | NS |
| Input means | 0.87 | 63,116 | 25,626 | 19,720 | 696.50 | 344.95 |

NS = Not significant

## TABLE 14

The overall economics characteristics of the three significant inputs, cost of seeds, cost of feed and labour charges, in the small-scale, semi-intensive, monoculture of tiger shrimp being practised in Kerala State

{Unit price of output ($P_y$) = Rs.146.44/kg}

| Input | $P_x$ (Rs.) | $P_x/P_y$ (Rs.) | MPP | MVP (Rs.) | Recommendation* |
|---|---|---|---|---|---|
| Seed cost | 234.50/1000 | 1.60 | 12.36 | 1810.00/1000 | I |
| Feed cost | 16.42/kg | 0.11 | 0.16 | 23.43/kg | I |
| Labour charges | 50.00/man-day | 0.341 | 0.3415 | 50.01/man-day | S |

* I = Increase input to increase production

S = Stop input increase; profit maximising level reached

MPP - Marginal Physical Product (see text)

MVP - Value of Marginal Product (MPP x $P_y$)

$P_x$ - Unit price of input

## Discussion

The tiger shrimp, *Penaeus monodon*, is one of the most suitable species of shrimp for semi-intensive and intensive cultivation because it is a euryhaline omnivore that has a relatively fast growth rate and tolerance for a wide range of temperatures (Chen *et al.*, 1989a).

Chen *et al.* (1989b) reported 8.7-21 tonnes/ha/crop for *P. monodon* in intensive systems in Taiwan, and Yahaya (1990), 2.58 tonnes/ha/crop in intensive systems and 1.71 tonnes/ha/crop in semi-intensive systems in Malaysia. Bombeo-Tuburan *et al.* (1993) reported a production of 59 to 124 kg/ha/crop for *P. monodon* in extensive culture systems of Philippines.

In India Sundararajan *et al.* (1979) achieved an average weight of 32.2 g and a production of 514 kg/ha in 80 days at a stocking density of 20,000 PL/ha. Venketesan and Bose (1982), in the same farm, obtained an average final weight of 24.6 g and production of 498.2 kg/ha in 90 days at a survival rate of 81% and an initial stocking density of 25,000 PL/ha. In pen culture of *P. monodon* at Killai, Tamil Nadu, Kasim and Bose (1985) obtained an average production of 435 kg/ha in 100 days at a stocking density of 20,000 PL/ha. Chakraborti *et al.* (1986) used lime, poultry manure and fertilizers, adopted a stocking density of 40,000 PL/ha and fed the shrimp with pelleted feed with a protein content of 46%; they realised a production of 250-329.3 kg/ha/crop and a harvest size of 21.6 to 26.1 g. In Andhra Pradesh, a stocking rate of 75,000 seed/ha of *P. monodon* has yielded a production of 1,400 kg/ha/crop (Anon, 1989). Surendran *et al.* (1991) reported a maximum production of 6 tonnes/ha/crop of *P. monodon* in Nellore District of Andhra Pradesh. Usharani *et al.* (1993) reported 943.97, 1,232.97 and 1,161.21 kg/ha/crop for *P. monodon* cultured in small, medium and large farms in Andhra Pradesh, India.

Mathews (1986), who studied the comparative economics of the traditional and semi-intensive shrimp culture systems in Kerala, based on an experimental culture, reported that although much difference in production was not observed between the two systems, the profit per hectare was substantially high in semi-intensive culture. Jose *et al.* (1987) reported on a production of 552 kg/ha of the white shrimp, *P. indicus*, in 83 days in certain selected culture systems of Kerala. Ajithkumar (1990) has reported a production of 820.6 kg/ha/crop in the semi-intensive culture farms of central Kerala. An average production of 738 kg/ha/crop has been reported from Kannamaly, Kerala, by Jayagopal (1991).

In the present study the average production was 959.20 kg/ha, which is higher than the values reported from Kerala by Ajithkumar (1990) in Maradu and Jayagopal (1992) in Kannamaly and from small-scale semi-intensive farms in Nellore, Andhra Pradesh, by Usharani *et al.* (1993).

Usharani *et al.* (1993), based on their studies on shrimp farming in Nellore, Andhra Pradesh, reported a cost-benefit ratio of 1.28 for small semi-intensive farms. In the present study a higher ratio (1.93) was obtained suggesting that the present system of semi-intensive shrimp farming in Kerala is highly profitable. Usharani *et al.* (1993) further reported the average cost of production per kg of shrimp as Rs. 93.66 in small farms in Nellore. But in the present study this was as low as Rs. 75.50. The total cost of production per hectare in Nellore, reported by Usharani and coworkers is also considerably higher (Rs. 88,411.24) than in the present sutdy (Rs. 72,420.00). Evidently, the small-scale semi-intensive farming of *P. monodon* in Andhra Pradesh is more capital intensive than in Kerala; conversely, the profit realisation in shrimp culture is high in Kerala.

The largest component of the operational costs was feed in the present study (35%). In Andhra Pradesh this component formed 56.89% of the total operational cost. Posadas (1988) reported a feed and operating cost ratio of 0.60 (60%) for semi-intensive shrimp farming in Philippines. This item accounted for 29% and 22% of the operating costs of tiger shrimps farming in Taiwan and U.S., respectively (Fast *et al.* 1990).

The next major item was labour charge in Kerala (27%), but in Andhra Pradesh it was seed cost; in Andhra Pradesh the human labour component was only 4.78% of the operational cost. Labour and operating cost ratio was as low as 0.03 (3% of the total cost) in Philippines

(Posadas, 1988). In Hawaii the labour cost was 22% of the total operating costs. The gross and net incomes on an average were Rs.1,13,276.40 and Rs. 24,865.16, respectively for small farms in Andhra Pradesh. In the present study, the respective values were Rs. 1,40,026.00 and Rs. 67,606.00. In Andhra Pradesh farmers are using imported pelleted feed which is costlier than the indigenous (both natural and formulated) feeds used in Kerala.

The results of the production function analysis showed that three inputs—stocking density (= seed cost), feed cost and labour charges--were significant, and that increasing the application of these three inputs could substantially increase production.

These results are similar to those reported by Ajithkumar (1990) in Maradu and Jayagopal (1991) in Kannamaly for semi-intensive shrimp farming in this State; in these studies also the significant inputs were the costs of seed, feed and labour.

The feed cost ($r = 0.86$; $P < 0.001$) and labour charges ($r = 0.78$; $P < 0.001$) were significantly correlated with production. This result is in agreement with that obtained by Chen *et al.* (1989b) and Jayagopal (1991) for the production of *P. monodon.* In the present study the sum of the coefficients of the input variables was 1.439, which is more than unity. This high value implies that doubling all the inputs will increase the output more than twice.

Although seed production is no longer considered a technical constraint in shrimp culture, seed still is a major operation cost. The seed and operating cost ratio was 0.22 (22%) in semi-intensive shrimp culture systems in Philippines (Posadas, 1988). It formed 35% and 27% of the operating costs in Taiwan and Hawaii, respectively (Fast *et al.*, 1990). Usharani *et al.* (1993) reported that the cost of seed is 10.78% for the semi-intensive farms in Andhra Pradesh. But in the present study the cost of seed was much higher--20% of the total production cost—, which is attributable to the fact that shrimp seed for farming in Kerala mainly comes from other States unlike in Andhra Pradesh where it is available locally, both from hatcheries and from the wild. Wild seed is much cheaper than the hatchery produced ones, especially when it is locally available at or around the farm site as it is in Andhra Pradesh. Further, since hatchery produced seed is also available locally in Andhra Pradesh, cost of transportation of seed is substantially less in that State. Evidently, cost of transportation of seed and non-availability of wild seed in Kerala State are the factors that added heavily to this input in tiger shrimp farming in this State. Further, the transportation stress might be contributing to mortality of seed. Thus there is an urgent need for establishing more shrimp hatcheries in the State for making semi-intensive shrimp farming in Kerala, economically more rewarding.

Comparison of the MVP and the unit prices of cost of seed, and cost of feed suggest that increasing these two inputs will yield better production. These results corroborate those reported by Ajithkumar (1990), Jayagopal (1991) and Usharani *et al.* (1993). A similar comparison on labour charge implied that the labour is in the optimum level in the semi-intensive shrimp farming sector of Kerala and it is not profitable to increase the man-days to obtain more production.

The percentage of feed cost in the total production cost, of pelleted feed was 30.37%; for clam meat and for clam meat + dough ball it was 36.04% and 34.31%, respectively. This clearly shows that the farm-made pelleted feed is economically more profitable than the conventional feeds in the semi-intensive shrimp culture in Kerala. Further, from the nutritional point of view also the pelleted feed was found to be much superior to the other two feeds (see Chapter III). Promotion of the commercial production of this pelleted feed is recommended. Further, this is expected to cut down the cost of this feed.

It may be concluded from the results of the present study that the small-scale semi-intensive farming of *P. monodon* is highly profitable in Kerala and much more profitable than in similar systems in Andhra Pradesh. The inputs have a positive correlation with the output and by increasing the two significant inputs (seed and feed), production can be substantially increased. But the labour shows an optimum level. Compared to similar production systems in Andhra

Pradesh, labour charge and seed cost are higher in Kerala. But feed cost is much less, mainly because of the indigenous nature of the feeds used in Kerala. The farm-made pelleted feed seems to have more economical and nutritional value than the conventional feed (clam meat) and the conventional feed in combination with compounded dough ball. The popularisation of the use of the pelleted feed among entrepreneurs is recommended to make the small-scale semi-intensive shrimp farming in backwater ponds in Kerala a more economically feasible endeavour than it is at present.

# SUMMARY

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 $g/m^2$ for 120 days at the rate of $0.795/m^2/day$ at an average stocking density of 6.31 $PL/m^2$. 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.

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

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 ± log 0.0523).

10 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.

11. 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,

$$Y = 0.006036\ X_1^{0.14}\ X_2^{0.82}\ X_3^{0.26}\ X_4^{0.14}\ X_5^{0.009}\ X_6^{0.07}$$

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.

12 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 *Vellorita 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.

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* Originals not referred

## ANNEXURE

## SCHEDULE

Code No.

Date of Enumeration

I. Name of the farmer :

2. Address

3. Area of pond with location :

4. Ownership of pond - owned/leased :

Value of land :

If leased, lease amount . . . . . . . length of lease . . . . . . .

5. Duration of culture

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

6. Year of construction of pond :

7. Average depth of pond (cm) :

8. Nature of soil . . . . . . . . . . . . . . . . . . .

9. Experience in shrimp farming :

10. Annual income from shrimp farming :

II. Inventory of assets:-

|  | Acquisition year | Unit cost | Economic life | Prevailing market value |
|---|---|---|---|---|
| 1. Pond |  |  |  |  |
| 2. Sluice gates |  |  |  |  |
| 3. Pond excavation |  |  |  |  |
| 4. Water canals |  |  |  |  |
| 5. Others if any |  |  |  |  |

III. Equipments:

| | Purchase value | Lease amount/crop | Working charges |
|---|---|---|---|
| 1. Pump | | | |
| 2. Generator | | | |
| 3. Feeding equipments | | | |
| 4. Compressor | | | |
| 5. Nets | | | |
| 6. Other (if any) | | | |

IVa Labour requirements/crop:

| Particulars | Family members | Hired | Wage/day | Total wages |
|---|---|---|---|---|
| 1. Pond preparation | | | | |
| 2. Stocking | | | | |
| 3. Feeding | | | | |
| 4. Weeding | | | | |
| 5. Fertilization | | | | |
| 6. Repair and maintenance | | | | |
| 7. Harvesting | | | | |
| 8. Processing | | | | |
| 9. Marketing | | | | |
| 10. Others if any | | | | |

b. Monthly salary
Watchman -
Others if any -
Total labour charge -

Va Stocking

1. Source of seed
2. Average size at stocking: Length......... Weight..........
3. Date of stocking
4. Nursery rearing : Yes/No
5. Type of nursery : Hapa/nursery pond
6. Stocking Density in grow out ponds:
7. Others, if any :

b. Feeding
1. Feed material used :
2. Ingredients of feed :
3. Feeding schedule :

4. Others if any :

### VI Major inputs costs

| | Qty./crop | Unit cost | Total Cost |
|---|---|---|---|
| 1. Seed | | | |
| 2. Toxicants | | | |
| 3. Fertilizers | | | |
| Organic | | | |
| Inorganic | | | |
| 4. Feed | | | |
| 5. Other if any | | | |
| | | Total: | |

### VII Harvest:

| 1. Species | Counts | Unit price | Qty. sold | Value |
|---|---|---|---|---|

2. Survival rate
3. Duration of culture
4. Method of harvesting
5. Qty. harvested : Total number Total weight
6. Average size: Length (cm) Weight (g)

### VIII Other expenditure if any:

1. Fuel and oil
2. Electricity
3. Water supply
4. Insurance
5. Taxes
6. Others (if any)

| IX | Source of finance | Amount | Rate of interest | Subsidy | Repayment |
|---|---|---|---|---|---|

X 1. Gross Income -
2. Expenses -
3. Net Income -