3. **DISCUSSION**

3.1 **IN SEARCH OF AN APPROPRIATE TECHNOLOGY**

3.1.1 Site selection with reference to species, technology, eco-characteristics such as Tidal Range, Soil, Topography, Water, Environmental aspects and infrastructure

To a certain extent shrimp farming is site specific due to its peculiar requirements. It is an accepted well known fact that the right selection of site is probably the most important factor that determines the feasibility of viable operations. Poor selection of sites leads to enormous loss of money. In addition, most problems associated with shrimp farming are location specific. There is considerable area to area variation in the physico-chemical parameters, such as those related to the soil and water characteristics, climate and other infrastructural facilities. Also, the success of production depends upon the cumulative effect of all the inputs made available in adequate quantity at appropriate time. Hence the production problems in different areas of the country are dissimilar and non-comparable. So the practical problems faced by Kerala farmers are entirely different from those in Gujarat/Andhra Pradesh/Goa/Karnataka/Orissa/ West Bengal etc.

In general ideal sites with 100% favourable natural conditions may not be available due to various interacting environmental factors. Unfortunately a lot of coastal area is reclaimed for unproductive agricultural crops and the return is low. The best land use policy to get maximum output has not yet been evolved. Since coastal aquaculture has emerged as a new science/profession with high return, it requires a major change in the policy of government.

Given an opportunity to select an ideal site, it shall depend upon the species to be cultured, nature of environment and the
technology to be employed and marketing opportunities. Limitation in any of the three factors namely, site characteristics, species selection and appropriate technology obviously restrict choice of the others. The species to be selected for culture and the technology to be adopted depend on the characteristics of site selected as noticed in the study area.

Some of the factors which have to be taken into consideration before the site selection is done are agroclimatic conditions and support facilities like communication, protection from natural disasters, public utilities, security, skilled and unskilled labour, access to markets and extension sources which can seriously affect profitability.

The criteria for the selection of a brackishwater farm site for shrimp culture have been discussed by Hora and Pillay (1962), Jhingran, et al. (1970), Sengupta (1976), Muthu (1980) and Purushan (1986).

The assessment of suitability necessitates critical examination of meteorological and environmental information especially the existing and future sources of pollution and the type of pollutants. Satyadas et al. (1989) analysing the cost and return structure of shrimp filtration have noted wide variation in net returns among the fields in three areas namely Rs. 2080 in Vypeen, Rs. 830 in Parur and a loss of Rs. 1400 in Varapuzha on account of the effect of pollution emanating from the nearby Eloor industrial belt resulting in the low productivity and absence of *P. indicus*.

However, in the present study, the average net return from three different traditional fields between Nayarambalam and Thrikkadakapilly in Vypeen island varied from Rs. 804 to 4436/ha where as at Pooyapilly (Parur) it was Rs. 2847/ha (Table 9).

It is worth noting that the figures given are not comparable with that of Sathidas et al. (1989) because of the time gap and the
method of selection of observational units.

Mangrove vegetation is often considered as a positive indicator of soil types, elevation and salinity for field development (Plate XVIII B) as it is very much influenced by the soil particle size, topography, tidal range, flooding and the extent of fresh and marine water mixing. Sandy soil and acidic soil which has a reddish hue should be avoided. It is also wiser to avoid excessively low areas and conversely areas with high elevation.

Thus the soil characteristics, the quantity and quality of water and the draining facility by gravity are important. Unrestricted availability of good quality water and tube wells, springs etc. will be an added advantage as the level of intensification goes up.

In the study area, the coastal ponds and paddy field farms (Group A and Group B) are situated in protected tidal areas near river estuaries. So the most economical method of water management in this area is through tidal flow. Hence it is necessary to know the tidal amplitude and its fluctuations in the site.

The relationship between tidal levels and ground elevation at the pond site is decisive. A tidal fluctuation of around 3 m is considered ideal for coastal ponds against the range of 0.3 - 0.75 m being experienced in the fields investigated (Group A). The southern fields at Nayarambalam and Narakkal were influenced by the tidal processes of Cochin barmouth where as the northern fields from Kuzhipilly to Thrkkadakapilly and Pooyapilly were under the influence of Munambam barmouth. The distance from the barmouth was 10-12 Km in the former case where as it was within 5-8 Km in the latter. Therefore, the tidal amplitude was more towards the northern fields ranging from 50-75 cm against the fairly low range of 30-40 cm experienced at the southern fields. Even though physico-chemical properties of tidal water of both barmouths were more or less similar, relatively high values of transparency and salinity were
characteristics of tidal water of Munambam barmouth on account of the lack of harbour development activities and its nearness to the sites.

On the contrary, the site selected for the semi-intensive farming of *P. monodon* at Mundapuram (Group E) was elevated above mean sea level. Nevertheless, it was also under the tidal influence of Mattol estuary fed from Azhikode barmouth.

Gopinathan et al. (1982) studying the environmental characteristics of the shrimp culture fields in the estuarine systems of Cochin from Azhikode to Kumarakom during 1977-78, noted significant variation in the composition of epifauna and benthos, chemical composition of the mud and primary production. Accordingly areas of high (> 1500), moderate (500 - 1500) and low productivity (< 500 mg c/m²/day) were delineated as observed during the present studies.

High productivity fields are located in the dynamic environments such as Cochin barmouth areas and Azhikode barmouth areas where there is constant incursion of sea water and influx of river water resulting always in new water due to high replenishments. The presence of two barmouths for sea water entry within a short distance along with freshwater discharge from Periyar river contribute to definite ecological advantages. The moderate fields are present in between Cherai and Vallarpadom. This substantiates the earlier observations (George et al. 1968; George, 1974 and Gopinathan, et al., 1982).

Because of the influence of soil on productivity and its suitability for dyke construction, its quality is decisive in paddy field/ponds/farms. The characteristics of the soil also greatly determines its ability to retain the overlying water in required level. The nature of soil stratification may also necessitate adoption of appropriate measures to prevent seepage. Preference is given to dominant clayey silt mixture (45-60%) type with good water retention capacity with soil pH of 7.0 - 8.5 and good nutrient contents. Several
new methods developed to arrest seepage are expensive (Bhakta, 1987).

Simple visual and tactile inspection to detailed subsurface exploration and laboratory tests are necessary to study the soil suitability. Two important physical properties of the soil are its porosity and texture. The soil texture which can be determined roughly by touch and feel, depends on the relative proposition of particles of sand, silt and clay. Clay and organic fractions will facilitate aggregation of sand particles and encourage crumb structure formation, the most desirable structural form. This will improve water and nutrient holding capacity, reduce excessive drainage and losses of nutrients through leaching, regulate soil aeration and temperature and prevent erosion (Kumaraswami, 1991). The nature of bottom soil is of great importance in brackish water aquaculture (Hickling, 1971). It has been observed that in Taiwan highly productive fish ponds were distributed in regions having silty loam soils.

In general, estuarine sediment composition expressed as percentage on a dry weight basis indicated sand as a major constituent followed by clay and silt. The type of sediment appeared sandy clay loam or sandy clay. Organic carbon expressed as mg c/g varied from 1.5 to 7%.

Subramanian (1981) noted significant correlations between the abundance of shrimp seed populations and mud organic carbon and salinity values. The soft organically rich sedimentary substratum (texture) of the inshore region preferred by penaeid shrimps is brought about by the filtering effect of the estuary (Nair and Hashimi, 1986). The shrimp population in relation to substratum was discussed by Williams (1958), Grady (1971) and Ruello (1973). Williams (1958) through laboratory experiments showed that while the pink shrimp selected most often the comparatively hard substrate of mixed shell and sand, the brown and white shrimps occurred most frequently on softer bottom composed of loose peat, sandy mud or muddy sand. The primary attractant appeared to be protective cover rather than food content.
One may assume that a gross exchange in substrate composition arising due to increased silt load or a reversal in circulation pattern with attendant changes in scouring action and rate of sediment deposition, could alter estuarine carrying capacity.

Sandy clay to clayey loam soils are found suitable for pond construction. The fine textured soil, because of their cohesive properties are more suitable for fish ponds than light textured soils which can cause high seepage and percolation. The average loss of water due to evaporation and seepage can be as much as 2.5 cm. per day in tropics compared to 0.4 to 0.8 cm. per day in Europe.

Eswara Prasad and Pillai (1984) studied on soils of some shrimp culture fields around Cochin. The results showed Pokkali fields ranking first in the fertility status of the soil in respect of all the soil parameters monitored except soil texture. This can be attributed to the predominance of clay and silt in the soil composition.

The fields and ponds selected (Group A, B & C) for the study were low lying and the soil was composed of silt and clay. But the farm was elevated at Mundapuram (E) where the ratio of mud was more than the clay. Vypeen soils in general are fine textured, black silty clayey loam soils occurring along the long land portions in the coastal belt. Being developed in areas with relatively high ground water table, these soils showed aquatic properties. In some areas of pokkali fields, undecomposed organic matter is observed in lower layers causing problems of acidity (Anon, 1989). The pond bottom was more firm in the deeper fields, but southern fields were seen usually more muddy. All fields were seasonably operated for shrimp culture alternating with paddy except for the one at Thrikkadakapilly (Cherai) which was perennial since five years.

Silas (1987) estimated that there are some 3,90,000 ha. of acid sulphate soil in India which are on the increase with poor management. Analysis revealed that development of acid sulphate soils is one of the
major factors involved in the failure of old style aquaculture farms in Indonesia and Philippines. The pokkali fields along the mangrove backwaters of Cochin are another example of low productivity caused by excessive soil acidity, the condition leads to the occurrence of "soft shrimps" in affected ponds and frequently results in the loss of the entire stock. This is a matter of alarm for the shrimp farmers in this area. Rao (1987) also observed "soft prawn" syndrome generally in summer months both from the seasonal and traditional fields in Kerala. Rajamani (1982) based on biochemical studies on soft prawns concluded that the soft condition caused by the higher non protein nitrogen fraction (NPN) compared to that of healthy ones with high protein content (PN) is the after effect of protein starvation in the adverse ecological conditions. Acid sulphate soil may be acting as an adverse factor.

Nevertheless, the potentiality of this system to generate food is quite well known. Alternating paddy and shrimp culture in the pokkali fields of Ernakulam district is the most traditional, advantageous and economic method of crop raising. Hari Eswaran (1991) commented this age old practice as the proper, stable and correct method of farming having significance even in the present era of novel farming practices. It is advantageous in the sense that it enables exploitation of fertile organic resource less expensively in the form of rice and fish depending upon season.

In the case of owner operated grow-out ponds (B1-B7) the tidal exchange was accomplished through canals linked to Vembanad lake and Anthakaranazhi. The tidal amplitude varied between 30 and 60 cm. The tidal water was more turbid at Puduvaypu due to its proximity to the Cochin harbour with increased dredging activities than that at Narakkal. However, the tidal water available in the ponds at Cherthala taluk was relatively silt free, since they were located far away from the Cochin barmouth. Probably the silt load in the tidal water will gradually get deposited enroute to long distances.
The substratum was more firm at Narakkal with soil composed of fine silt and clay where as at Puduveypu it was muddy with loose consistency. A firm substratum consisting of sand and clay containing acid sulphate soil was noticed at Chalippuram. In ponds at Karumancheri and Cherungal the substratum was composed of saline hydromorphic soils. Undecomposed organic matter was also observed in the lower layers at Pallithode causing problems of acidity at times. The soils in general were brownish, deep and imperfectly drained. The firm substratum containing mud and clay at Mundapuram (E) was only slightly acidic (pH 6.5 - 6.8) without doing any harm to the associated fauna.

The prevalence of acid sulphate soils/cat-clays is a major constraint in site selection for coastal paddy field/pond farms in the brackish water areas of the tropics.

This state can be defined as one in which toxic quantities of iron and aluminium are released, rendering phosphorus not available for algal growth leading to sudden fish kill during rain soon after dry spell. Acid sulphate soil results from the formation of pyrite especially in the mangrove swamps.

While sodium chloride is the dominant salt of the soil in most of the maritime states, the largely sandy loam - loam to sandy loam - clay loam soil in Kerala makes out an exception where sodium sulphate is the dominant salt which is reflected in low soil pH (3.5 - 5.5) (Natarajan, 1988). The acid soil types, high monsoon precipitation, low tidal amplitude are some of the major environmental constraints that restrict culture period of shrimp in Kerala.

Though it is possible to minimise the harmful effects of acid soils, it is expensive and time consuming. However in the tropics, especially in the study area, there may be only little choice to have sites with good soil. The only alternative is to choose sites that can be reclaimed readily by removing the source of acidity by oxidising the
pyrite from the pond bottom and flushing it out of the 10-15 cm. deep surface soil and preventing further diffusion of acids, aluminium and iron salts from the subsoil. This way, the farm can be made suitable for aquaculture within 5 years.

The construction of ponds in areas reached only by the high spring tides would require excavation leading to higher construction costs. The drainage may be affected by excavation. Further, the removal of fertile top soil which is important to induce the growth and maintenance of benthic organisms in coastal ponds, will result in the loss of much time in reconditioning the pond bottom to stimulate such growth. Gedrey et al. (1984) estimated that the construction and operation of a farm with a pump water supply system can be more economical than that of a tidal water farm. Bhakta (1987) while commenting on the economic aspects on investment and operation of tide fed, pumpfed and tide cum pump fed farms categorised the last type as more expensive. As is the case in the study area, tidal movements related to its elevation and ranges are depended on, for filling and draining the ponds and also for leaching out toxic elements. However, by virtue of elevated nature only pumping was resorted for filling in water in the semi-intensive farm at Mundapuram (E). But, draining was accomplished during low tide through the exit gate.

If pumping is to be substituted for tidal flow, the cost of construction of dykes and sluice gates would be minimised and the ponds could be constructed and operated without disturbing the acid soils, allowing a non acidic layer of sediment to deposit on the bottom. On a long run this can be economical especially in paddy fields when paddy crop rotates with that of shrimp crop.

Depending on season, shrimp culture was practised during summer months as a single crop in all cases except at Karumancheri where two crops were raised within a year. Because of prevalence of higher salinity in all months except during intense monsoon, chances of raising more crops at Mundapuram (E) also seem very bright.
Temperature and salinity of water also are important in site selection as they are species specific, *P. monodon* preferring an optimal salinity of 10 to 25\% and *P. indicus* at the range of 15 to 40\%. However in the present study, the level of salinity while stocking *P. monodon* was less than 5\% at Chalippuram. Therefore, the post larvae were acclimatised to the prevailing salinity levels by a gradual and prolonged process to avoid the ill effects of mortality. But in the case of *P. indicus* culture, the level of salinity in all farms remained within the range required. The higher temperature (26-35°C) and salinity (32-36\%) prevailing at Mundapuram (E) was favourable for the culture of *P. monodon*. But when the salinity dropped to 23\% during June, the culture was terminated.

Due to decreased light penetration into high turbidity water column caused by suspended solids (about 4% or more), the productivity will be reduced considerably, naturally affecting shrimp production. Often increased turbidity was found responsible for oxygen deficiency in water. The turbid water situations at Puduvype due to high sediment load also contributed to low organic productivity and low levels of oxygen having its effect on the shrimp growth and production. The exclusively traditional field operated at Nayarambalam was also affected by these characteristics having its impact on shrimp growth and yield.

In the study area it has become necessary to select sites with highly turbid water with all its characteristics especially at Puduvype - the recently emerged wetland ecosystem. Owing to higher operational costs, it was not possible to adopt methods of reducing turbidity such as repeated applications of gypsum, settling tanks and filters. However, maximum care was taken to reduce sediment load by settling before tidal water was drawn to ponds at Puduvype. The filtration devices followed before filling experimental tanks by pumped water was also not efficient to prevent the ill effects of colloids and other microparticles present in the medium. Even by using filter beds during filtration only particle above 50 micron were retained; those
particles less than 50 micron size being visible with the medium, their intensity was capable of causing stress to the shrimps grown in the tanks. The continued prevalence of such stressful factors and also lack of proper aeration of the medium did not provide suitable living conditions to the stock resulting in stunted growth and survival of shrimps during pilot studies in the miniponds and experimental culture in tanks. Since filtered pumped water was used at Mundapuram, turbidity range at no time affected the growth of *P. monodon*.

A pH of 6.7 to 8.0 measured before day break is considered as the most suitable medium for shrimp culture as values below and above this leads to reduced growth and production. While the above range was commonly seen in all fields and ponds at Vypeen island, there were fluctuations in the range at southern ponds of Cherthala taluk selected for the study. Therefore it has become necessary to maintain the correct pH adding lime to neutralise the acidity during the study period. In the semi-intensive farm at Mundapuram, the pH was maintained more alkaline (8.2 - 8.5) by the periodic application of lime and health stone in order to promote growth of *P. monodon*.

The likelihood of discharges from facilities used for intensive culture polluting public water bodies and spreading communicable diseases from farm stocks to wild stocks should be considered, as this can lead to social conflicts. Hence there arises the need to select sites avoiding conflicts. Conflicts may also arise when paddy fields are totally converted as shrimp farms. Also indiscriminate conversion and reclamation of mangroves impairing the ecosystem may be avoided during site selection.

Fortunately, none of the above problems affected the shrimp culture fields and ponds selected for the study. However, reduction in the general water column and concomitant impairment of quality were noticed during the flag end of operation, i.e., beyond the end of March in the study area. The situation created troubles especially to the seasonal shrimp farms with shallow depth. Also at Chalippuram, the
restricted tidal water entry since the middle of February as the rule of land was strict, accelerated water quality deterioration endangering the *P. monodon* culture. Again, the *P. monodon* culture carried out at Pullithode during the fall end of summer (April - May) had to tide over the adverse environmental situations. Thus the inability of farmers to take full advantage of the growth potential of the shrimp species, on account of the drastic and undesirable changes in the water medium, continues to remain as a hurdle for enhanced shrimp yields from culture systems in terms of quality and quantity. However, even with relatively low water column of 75 cm and lack of proper living space for shrimps due to high stocking density, highest yield of quality *P. monodon* @ 2390.4 kg/ha/4 months was attained at Mundapuram on account of the management aspects attended to, maintaining the system healthy.

3.1.2 **Design, layout and construction; and size and shape of fields/grow outs/farms/ponds**

The design and construction of a farm in ensuring both technical and economic success of shrimp culture are equally important as that of site selection. Kotoh (1982) has suggested the general standards for the design and construction planning of aquaculture ponds for maintenance of water quality inside. Also Miyamaru and Kotoh (1986) have described the fundamentals of planning and designing of aquaculture ponds, particularly on essential points of the planning of penaeid shrimp ponds and giving emphasis on the effective and defective factors. Sengupta (1980) and Reddy (1980) have dealt with the salient features of construction and maintenance of shrimp farms for commercial production in 'bheris' of West Bengal and Kakkinada respectively. Often farm design and construction are controlled by financial constraints. However, in the traditional fields of the study area (Group A) this has no relevance as shrimp culture rotates with paddy culture and the ownership rests with the agriculturists. Any change in the structural design was strongly objected by the owners of the field.
However, in the owner operated extensive farms (Group B) where only shrimp farming was practised, design could be accomplished in the most desired manner.

In the traditional field at Nayarambalam, the bed was left almost undisturbed. But, maximum silt was removed from the extensive field at Kuzhupilly along with clearing of canals. In the other four cases, the bottom was levelled and canals of different dimensions were excavated to the extent agreed upon by the owners to traverse the entire area for increasing the water holding and life carrying capacities of the fields.

The design and layout of the six traditional fields (Group A) had slight deviations in their disposition. All fields were compact units with rectangular shape except the large and extensive one at Kuzhupilly with rhombus shape. All fields were lying below the low tide level with bottom elevation towards the main sluice gate. Even bottom prevailed in all, but for the extensive one at Kuzhupilly.

The main and subsidiary canals of all fields drained towards the main sluice pit. The perimeter dyke was wider and stronger where as the partition dykes were narrower and shorter depending upon the size and shape of respective fields. Compared to others, the fields at Thrikkadakapilly and Kuzhupilly were fairly deep. The main sluice gate of the fields opened directly towards the main water body at Thrikkadakapilly, Pooyapilly and Kuzhupilly where as at Ayyampilly, Nayarambalam and Narakkal it opened into feeder canals. The water supply and drain gates were separate in all places except at Thrikkadakapilly and Pooyapilly. At Kuzhupilly extensive field, the water entry and exit gates were located in opposite directions where as both the gates were fixed on the same side at Nayarambalam and Narakkal fields. However, at Ayyampilly improved field, they were fixed at right angles to open at different points to the feeder canal. Nurseries were set up in the improved fields at Ayyampilly and Narakkal.

Mukherjee (1977, 1980), Hickling (1971), Pillay (1948,
1954), Hora and Nair (1944) and Hora & Pillay (1962) have described various aspects of sluices.

Screens made of bamboo slats and nylon meshes were used at respective sluice gates to prevent the entry of predators and the escape of stocked shrimps. Neither any pumps nor any aeration pipes were used except at Kuzhupilly extensive field where draining of water was possible only with the help of an electrical axial pump.

The owner operated extensive 7 farms (Group B) located from Narakkal in the north to Pallithode in the south, were rectangular shaped and compact. Similarities were seen in the nature of elevation with slope towards the main sluice gate and in the installation of sluice gates. Differences were noticed in their disposition, size and physical facilities available.

Four, rectangular shaped small compartments within an 8 ha shrimp field with three sluice gates formed the unit at Narakkal. Each of the four compartments was connected to the central median canal of the field through respective openings in the dyke fitted with screens made of bamboo slats and nylon mesh. 4 rectangular, small and independent ponds with separate sluice gates made up the unit at Puduvuypu.

A 0.24 ha rectangular pond comprising of two longitudinal and unequal compartments connected each other and opening with the bund canal with a single sluice gate formed the culture system at Narakkal Harijan farm. Though generally with even bottom, the depth varied between 70 and 90 cm. in the small and large compartments respectively.

The one ha rectangular farm at Cherungal was well designed with a central drain inclined towards the main sluice gate. Also other subsidiary canals traversing the farm were merging with the main canal coalesced with the sluice pit where pumping system was erected. The well defined nursery comprising an area of 0.08 ha with suitable inlet
and outlet set within the farm accomplished the purpose in the most efficient manner.

At Chalippuram, the 1.1 ha paddy field transformed coconut grove was divided into three dissimilar compartments containing 32 interconnected longitudinal canals of 4-6 m width and 1.5 m depth each inclined towards the main gate. Coconut trees were planted on the wider and strongest bunds.

The L shaped pond with three rectangular, dissimilar compartments connected one another and inclined towards the sluice gate constituted the 0.4 ha culture field at Karumanchuri. The shallow pond having even bottom maintained a water level between 60 and 70 cm.

At Pallithode 13 longitudinal and 3 horizontal canals each of 50 x 3 x 1m size constituted the 0.61 ha water body. All these were interconnected and set inclined towards the sluice gate.

While one sluice gate each served at the Narakkal Harijan farm, Puduvayypu, Karumanchuri and Pallithode, two gates each installed at right angles functioned at Chalippuram and Cherungal and three gates at the Narakkal 8 ha field. A suitably designed, electrical 5 HP axial pumping system was permanently installed at Cherungal. At Chalippuram 2 diesel engines of 5 and 6 HP and in other places one 5 HP diesel engine each were at times made use of. Nurseries within the farm with appropriate screens fitted, facilitating efficient water exchange were set up at Chalippuram, Cherungal and Pallithode. The above improvements were incorporated for better water management leading to high production.

In contrast to the above, the semi-intensive farm at Mundapuram (Group E) was sloping towards the cylindrical drain gate set at the opposite corner. Though with even bottom, canals of any kind were peculiarly absent within the farm. Further, there was no entry gate for admitting tidal water. Since the farm was elevated, the water
filling upto 75 cm level was always accomplished using a suitable 5 HP axial pump with accessories (Fig. 11).

Eventhough separate feeder and drainage canals as well as inlets and outlets located on opposite sides of ponds are advisable for operational efficiency and safety, in the study area, the same canals were used both for drainage and feeding in order to economise on space and construction costs. This continues to be a serious draw back in the study area. In the case of tide fed ponds, water supply is controlled by the size of feeder canals and the size and number of water gates. Also the duration of low tides and their amplitude determined the quantity of water that could be drained.

From the angle of feed distribution and waste removal, elongated or rectangular ponds with central drains are preferable for a round one. According to Malca (1983) ponds should have a rectangular shape in order to aid water flow during exchange. At the same time the pond bottom should possess an inclination of 0.3 to 0.5% towards the drain structures so as to facilitate harvest and correct exchange of bottom water in order to maintain optimum oxygen levels. Failure to drain the ponds completely makes, harvest and competitor and predator control difficult.

In the existing conditions of the study area, the above modifications remained out of reach.

The commonly used water control device in Asian coastal farms is the wooden type open sluice, although its economical life will be less than that of concrete structures. In this connection the ferrocement gates and dykes developed at SEAFDEC Aquaculture department was found to reduce the cost minimising routine maintenance work and providing safety to the stock. The circular movement of water created by paddle wheels were able to concentrate waste products towards the central drain from where the waste could be flushed out as the need arises (Anon, 1987). Incorporation of above was beyond the reach of
For proper water management in tide fed ponds, it is necessary to determine the ground elevation which actually approximate the tidal levels of mean lower high water or of mean high water at neaptides. Otherwise, resorting to pumping for water management will be uneconomical.

The size of a farm has to be determined on the basis of various factors such as level of technology, production and income anticipated to make it viable economically, extent of available land and water. The size of an ideal pond was found to be 0.05 - 2.0 ha for nursery and 0.25 to 10 ha for grow outs. For greater control, intensive ponds should be small ranging from 1 to 5 ha, whereas extensive can be up to 10 ha (Yap et al., 1979). Square shaped ponds are considered preferable from the point of view of cost of construction. The shape of the traditional fields in the study area largely followed the land contours, many of them having irregular shapes.

The disadvantage of a small pond is that it has a high dyke area to surface area ratio. Concrete dykes can solve this problem of higher run off of water. It is recommended that small ponds be located if topography permits with their long axis parallel to the prevailing winds in order to provide maximum aeration (Plate XVIII B). Some times larger ponds may have the long axis at right angles to the prevailing winds as the winds blowing over a long stretch of water may create higher waves and greater erosion of the dykes. But all the fields and ponds selected in the present case were in agreement to the general rule in this regard.

Depending on the culture practices and on climatic conditions, the depth of water to be maintained in a pond varies between 0.8 and 3.0 m for grow outs. In this respect also, all culture systems of the study region were within the range mentioned recording the maximum depth of 1.5 m at Chalippuram.
The traditional culture pond should be large, otherwise it is not economical and wastes much man power, facilities and money. On the other hand management will be very difficult if the ponds are too large. The optimum area will vary from place to place. Most of the traditional shrimp filtration fields in central Kerala come under this category including the ones studied at Kuzhupilly and Narakkal.

Since all the owner operated farms (Group B) selected for the study were compact and small (area varying between 0.24 and 1.1 ha) their management was effective throughout the operation. So also, the small size and shape of mini ponds (Group C) and experimental tanks (Group D) facilitated adequate control of system management. Similarly, it was on account of the handy shape and small size (1.2 ha) that the efficient management of the pumpfed farm at Mundapuram (E) was feasible.

Nevertheless, small ponds have a preference with the high level of intensity of culture. Regarding the question, what can be the maximum size of a pond for optimal production determined by its shape, water circulation and feed distribution efficiency, the answer is that no differences in production rates were correlated with pond size either in the study area nor in other areas/part of the world. However in India - Orissa and West Bengal - size has a bearing on economic viability as ponds upto 0.5 ha are given singly or in clusters to marginal farmers and landless labourers.

Central Institute of Coastal Engineering for Fishery, Bangalore categorised brackish water shrimp farms into three types (a) tide fed (b) tide cum pump fed and (c) pump fed (Bhakta, 1987). Invariably the tide fed farm required a main sluice gate on the periphery dyke to prevent the farm from flooding during astronomical tides or floods and every pond required an individual sluice for exchanging filling and draining the pond, as and when required through the supply cum drainage channels. All fields in Group A belonged to this category.
In tidal cum pump fed farms where spring tide range is smaller and exchange of water will not be possible at times, supplementary water supply using diesel pumps was required as was the case with Group B & C ponds.

Pump fed farms are seen in places where the mean spring tide range is too small (less than 0.8 m) or too big (more than 2.0 m). A pump fed farm would not require the main big sluice or expensive individual sluices for the ponds. There would be plenty of savings in the formation of periphery bunds internal bunds and sluices, though partly this would be offset against the installation of pump and pump house. The earthern tank (C6) and all other cement & fibre glass tanks of Group D and the semi-intensive farm at Mundapuram (Group E) belonged to this category.

While tide fed farms proved expensive on investment, but economical in operation, pump fed farms proved economical on investment but expensive on operation. In a comparative study to assess the costs and benefits of tidal versus pumped aquaculture systems in Malaysia, the latter was found economically more successful (Gedrey et al., 1984).

To sum up, in the traditional shrimp fields, use of pumps was seldom required where as in the extensive culture ponds, proper water management was accomplished using pumps in addition to tidal effect in all cases studied. The successful culture of P. monodon was made possible at Chalippuram and Pallithode because of the added advantage of pumping alone. So also the added advantage of pumping in water management contributed much to the enhanced production of P. indicus at Karunancheri and Cherumal. Of all the series studied, the highest rate of production in respect of P. monodon was resulted at Mundapuram (E), where pumping was resorted exclusively for water management, although other aspects were also equally important for the success. However, the cost benefit return was too low (16.9%) when compared with that of Chalippuram (76.87%) where relatively low production rate was
achieved.

3.1.3 **Pond preparation**

In pond preparation, the requirements are drying of pond beds (Plate XIX A) to eliminate pests and predators, release toxic gases, disinfect harmful wastes and mineralise part of the organic matter making nutrients available (Hickling, 1962).

Pond conditioning can be done by tilling, enabling light penetration through loosening of soil. Lime is added to neutralise acidic nature, sterilize soil and control disease. Depending on the initial pH, hydrated lime can be added at a rate of 1-2 tonnes per ha to raise the pH to 7.0. Also the application of hydrated lime (calcium hydroxide) at the rate of 20 to 40 Kg. per surface acre (0.84 ppm lime for every 1 ppm of CO₂) was found good as a remedy for low dissolved oxygen for years. CO₂ in the presence of Ca(OH)₂ is converted to calcium bicarbonate enabling the shrimps to utilise the available oxygen better. Expensive sodium carbonate may be used in lieu of lime to avoid the rise of pH above 11 and the accompanying ammonia problems.

According to Norfolk et al. (1981) ammonium sulphate (21-0-0) can be added to lime at a rate of 1:5 in the watered portion of the ponds to eradicate pests and predators during pond preparation. The use of organic pesticides such as derris root, tea seed cake and tobacco dust has been encouraged by Seafdoc AQD (Apud et al., 1983).

In short the main objectives of pond preparation are (1) to maintain stability of pond conditions at a level conducive to growth and survival of the shrimp crop by preventing or minimising fluctuations, (2) to eliminate or atleast minimise competition between the shrimp stock and other organisms and (3) to install shrimps as the top consumers by eliminating any organisms that may prey on them.

The nature of pond preparation varied according to the type of
operation in all the six traditional fields (Group A) selected for the study. Raising of peripheral dykes and inner dykes and partial removal of paddy stumps from main canals (Plate V A) were commonly practised in all cases along with sluice fixation. Nothing more was done at Nayarambalam, where as at Pooyapilly and Thrikkadakapilly fields, mechanical removal of macroalgal vegetation and use of proper bamboo screens and nylon nets at the sluice gate during tidal water entry and exit were also attended to. In addition at Thrikkadakapilly, all the three main canals and cross canals were properly dug out to reach the extremities apart from clearing the sluice basin. Drawing of water using a 40 HP axial pump, removal of accumulated silt from sluice pits and basins, excavation of canals to proper dimensions, bottom levelling, slopping of canals towards main sluice gate, dyke repair and predator elimination by drying were the aspects given emphasis during preparation in the extensive field (Plate V A) at Kuzhupilly with a view to increase the water holding capacity. So also in the improved fields at Ayyampilly and Narakkal, adequate attention was bestowed to enhance the life carrying capacity of the fields by way of desilting the sluice basins and canal systems and also by ramifying the canals to reach every nook and corner. Since minimum water level was maintained while preparation, the repeated dragging and cast netting practised in these fields could eliminate all the predatory species.

No application of lime, manures or fish poisons was applied in any of the cases during preparation.

On account of small size of holdings, the extensive shrimp farms (Group B) selected could be dewatered completely. Hence bottom levelling and silt removal from the basins and canals could be carried out satisfactorily. Peripheral bunds and inner dykes leaving appropriate gaps for traversing canals were strengthened. A suitable nursery each was set up adjoining the supply channel within the farms at Chalippuram, Cherungal (Plate XII A) and Pallithode.

Since hour long sundrying of ponds (Plate XIX A) was not
possible in the compartments at Narakkal farm and canals at Pallithode, on account of seepage problem, mahua oil cake (Plate II B) @ 200 ppm was applied to eradicate predators. In both these cases water exchange was permitted through screens only after a fortnight. Except for drying the pond bottom till cracking, no other predator eradication measure was followed in Harijan farm at Narakkal and at Puduvypepu. Since there was no problem with acidity at Vypeen island, no application of lime was required in farms at Narakkal and Puduvypepu.

However, basal dose of lime as a precaution to resist acid sulphate problem and cow dung as a manure were applied (Plate XIX B) in farms at Chalippuram, Karumancheri, Chorungal and Pallithode. In addition, fertilising with required quantities of superphosphate and urea was done at Karumancheri. In all these farms, dried twigs were planted (Plate XIII B) to generate periphyton and to offer protection to the stock as well. Further, they helped to provide the natural habitat for shrimps. The sluice gates and gaps of nursery of all farms were fitted with appropriate screens made of bamboo slats and nylon mesh (Plate X B) to control the predators and pests during water supply and draining.

The same procedure as adopted in Group B2 was repeated in the preparation of Group C mini ponds except in C6 wherein earthen tank (Plate XIV A) above tidal marks was excavated afresh. Thick plastering with mud and clay was given to the bottom of earthen tank in order to remove its broken nature owing to sun drying. Since the substratum of group C ponds was loose, a layer of sand was used at the bottom to facilitate the shrimps to bury as practised in Japan.

No preparations were required for the cement and fibre glass tanks (Plate XVI A&B) of Group D experiments, but for the conditioning of tanks. However, a sand bed of 8-10 cm. thickness was provided in the circular cement tanks (Group D) to facilitate burying of shrimps. The oval screen made of dry twigs kept immersed (Plate XIV B) in the fibre glass tanks functioned as a false bottom and provided resting
place for shrimps.

Compared with others, the method of preparation was peculiar in the semi-intensive farm (E). Timely application of required quantities of inputs and precautionary measures adopted thereafter were effective in the predator elimination and in improving the organic productivity of the farm. The unique supply of health stone and BN$_{10}$ helped to maintain alkaline conditions and reduce bacterial load, respectively. Elevated nature and use of a pump (Fig. 11) accelerated the preparatory process in time.

3.1.4 Pond ecosystem: Physico-chemical and biological factors governing the natural and enhanced production

Role of environmental parameters on benthic and pelagic populations is well known. Environmental parameters such as temperature and salinity of water determine the distribution, spread and abundance of estuarine organisms (Kinne, 1967). Thorson (1966) stated that factors such as salinity, dissolved oxygen, temperature, turbidity, availability of food etc. exert their influences individually or collectively on the distribution pattern of pelagic and benthic organisms. The tidal influence on the physico-chemical conditions in the backwaters, connected canals and adjacent paddy fields along Cochin estuary had been pointed out (Sankaramarayanan et al., 1986).

The estuaries and backwaters feeding the shrimp farms are specialised ecosystems as they are in a state of perpetual flux due to the conglomerate influence of marine, terrestrial and fresh water elements. However, estuaries are not self contained ecological systems. The salinity of the estuaries is regulated by the differential exchange of waters from the open sea on one side and from the extensive freshwater sheds on the otherside (Pritchard, 1967). Same way, the fertility is controlled by allochthonous nutrients from
the sea and from the land.

The rainfall of peninsular India, depends on 2 monsoons, viz south west and the north east. The profound effect of the monsoon is reflected on the physico-chemical parameters of the shallow estuarine environment, variations depending to a large extent on the time of the year and the place of observation (Qasim, 1980). The summer maximum of salinity values were recorded by Ganapati and Murthy (1955) in Visakhapatnam, Jayaraman (1951) in Madras, Krishnamurthy (1966) and Subramanian (1981) in Portonovo waters. Salinity showed positive correlations with temperature, registering the peak values in summer season in Vellar estuary (Subramanian, 1981).

The semi-catadromous, cyclic life of most of the penaeids involving the sea and low saline coastal ecosystems has been well established and salinity has been considered as one of the important abiotic factors influencing their survival, growth (food intake and FCR) and production of tropical penaeids. The inter-relations between tidal cycle and shrimp distributions have been recorded by Subramanyam (1965), Hughes (1969), Young (1975) and Clark and Caillouct (1975). The distribution of shrimps based on salinity and temperature was well documented by Gunter (1950), Williams (1958), Gunter et al. (1964), Aldrich et al. (1968), Pullen and Trent (1969) and Rao (1973). The importance of temperature and salinity on the survival and growth of shrimp post larvae and juveniles was discussed by Williams (1960), Zein-Eldin (1963), Zein-Eldin and Griffith (1969) and Venkataramiah et al. (1972).

Nair and Krishnankutty (1975) experimenting on the influence of salinity on the growth of juveniles of the shrimp (Penaeus indicus) at different periods of their stay in backwaters noticed significantly high growth rate in low salinity for the post larval specimens; where as the larger juveniles showed a significantly high growth rate in high saline waters.
Paul Raj and Sanjeeva Raj (1982) elucidating the effect of different salinity levels on the growth and survival of _P. indicus_ and _P. monodon_ noted their preference for low salinity levels (15-25%) for better growth. Paul Raj (1976) noted higher population density in low saline areas. Nair and Krishnan Kutty (1975) reported high growth for postlarval stages in 10%, and for juveniles in 30% salinity. Venkataramaiah et al. (1974) stated that although the young shrimp can survive a wide salinity range, the best growth and survival rates were obtained in optimum salinities of 8.5 and 17%. Kinne (1970) stated that "in most of the euryhaline invertebrates, growth is restricted to a narrow range than survival is".

Shrimps, at one life history stage or another have been observed in waters ranging in salinity from less than 1% (Gunter 1956, 1961) to more than 60% (Gunter et al., 1964). The interaction between shrimp population and algal vegetation was reported by Strawn (1954), Allen and Inglis (1958), Hughes (1966), Rajyalakshmi (1973), Young (1975), Kannan and Krishnamurthy (1978) and Subramanian et al. (1980).

In recognition of the importance of benthos in sustaining the productivity of the culture ponds, Srinivasan and Rao (1984) studied on benthos in prawn culture fields of Vypeen island, in relation to environmental parameters. The results showed the main factors which limited the abundance and distribution of macrofauna as salinity followed by organic carbon, redox potential and nitrite - nitrogen in the perennial fields, nitrite followed by organic carbon, salinity and redox potential in the pokkali fields and redox potential in one coconut grove.

Studies on the physical and biological aspects of Cochin backwaters mainly centred around the Cochin harbour have been made by Sankaranarayanan and Qasim, (1969), Ramaraju et al. (1979) and Qasim et al. (1969). Sankaranarayanan et al. (1986) found that during SW monsoon season, due to influx of freshwater, longitudinal salinity
gradient could be noticed only up to short distance. During post monsoon (shrimp culture season) the partially mixed estuary with the saline intrusion extended further upstream up to 17 km whereas in the pre-monsoon season the extension was beyond 21 km.

Depending upon seasonal changes from monsoon to post monsoon and pre monsoon the longitudinal salinity gradient of Cochin estuary gradually extended up to 21 km upstream, thus providing estuarine water suitable for shrimp culture.

Laxmanan et al. (1982) observed seasonal variation in temperature (25.2 - 33.8 °C) and salinity (0-30% o) in Cochin estuary.

Ramaraju et al. (1979) noted at the Cochin barmouth highly stratified saline conditions existing during the monsoon season, gradually changing to partially mixed and homogeneous conditions of the post and pre monsoon periods apparently due to decreasing river flows and increasing tidal influence.

Shynamma and Balakrishnan (1973) and Balakrishnan and Shynamma (1976) have reported seasonal dial variations in hydrographic conditions in Cochin backwater.

The hydrobiological conditions of Cochin backwater have been studied by Haridas et al. (1973). Pollution of the Cochin backwaters by the effluents of FACT and the coconut husk rotting in some places was noted by Shetty (1963).

Vijayan et al. (1976) reported that organic pollution has significant effects on dissolved oxygen, BOD, and sulphate content of waters in Cochin estuary, while the temperature and salinity are not significantly affected. The effects of pollution on benthos have been studied by Remani (1979) and Saraladevi (1986).

Estuarine temperature showed diurnal/tidal variations with
increased temperature during ebb and reduced temperature during flood especially in monsoon months. But during warmer weather, solar radiation overshadowed these changes. In the Cochin backwaters, the temperature varied from 23 to 34°C; with maximum value during premonsoon months. From May onwards temperature falls. Intrusion of cold upwelled water from the sea was usually noticed during May. Cochin backwater as is the case with Vellar estuary is always confluent with sea waters, there being no complete closure of the mouth and thus may be said to be a true estuary.

Salinity of estuarine waters also showed diurnal and seasonal variations varying from place to place depending on the fresh water intrusion. While isohaline features were common during premonsoon, vertical salinity gradients were predominant during the monsoon months. One of its most variable yet easily measured attributes, salinity more so than any other property, characterised the estuary (Pritchard, 1967).

Norfolk et al. (1981) found at pH above 9 ammonia becoming toxic to animals. Same time, the water pH reaching below 6.5, usually influenced by potentially high acidic soil, reduced the production considerably.

The pokkali fields along the mangrove backwaters of Cochin are another example of low productivity caused by excessive soil acidity. The condition leads to the occurrence of "soft prawns" in affected ponds and frequently results in the loss of the entire stock (Silas, 1987). The water quality can be high with proper pH.

Turbidity as measured by the vertical distribution of luminous energy in any water body depends upon the quality, density and aerial extent of the suspended organic and inorganic matter it contains. According to Flint (1956), Darnell (1958) and Hall (1962), such detrital material may serve in the dual capacity of nutritive food in suspension and protective for the transient shrimp from predation. A
gradual reduction of light at all levels of the water column, due to a steadily increasing silt load could be expected to suppress algal productivity in open bay waters (Ragotzkie, 1959) and thereby indirectly inhibit the development of shrimp.

Gilbert and Pillai (1987) collected soil samples from different seasonal and perennial shrimp culture fields around Cochin backwaters during the premonsoon and monsoon season for estimating their lime requirement ie, the amount of liming material needed to neutralise the acidity of bottom muds and increase the total hardness and alkalinity to at least 20 mg./litre. The statistical analysis of their data showed no relationship between pH and the liming rate indicating the high potential acidity in soil samples even with normal pH necessitating higher liming rate.

In Cochin backwaters, siltation is the major factor contributing to the progressive shallowing by 35% during the past 50 years. The siltation occurs as a result of river discharge and tidal inflow. This has been accelerated by man made alterations (Gopalan et al., 1983). The magnitude of siltation is reflected in the removal of 2.5 million cubic yards of silt by dredging every year in order to maintain the Cochin harbour shipping channel. The rate of silting is 180 cm/year (Kurup, 1971). The resultant reduction in volume together with effluent discharge has considerably reduced the carrying capacity of system affecting fisheries. The carrying capacity of a natural ecosystem is the maximum production of fish species which can be maintained by naturally available food resources (Rosenthal et al., 1988).

Rangarajan (1958) observed the lowest oxygen values in Vellar estuary during dawn hours and noted their increase as the day progressed. Often, the low oxygen levels in estuaries could be linked to the presence of higher silt composition too in the area.

Subramanian (1981) showed significant negative correlation for
the dissolved oxygen values with salinity. In general, the rate of oxygen consumption increased with decrease in salinity of the medium indicating that *P. indicus* spends least energy as the salinity goes up and the maximum in low salinity.

Tidal flow and diesel pumps are the means adopted to circulate water in shrimp culture ponds. The exchange brings freshly oxygenated water and flushes wastes out of the pond. Water exchange by flushing with water of lower oxygen demand (less bacteria, algae, NO₂, NH₃ and H₂S) is a relatively expensive means of simply increasing oxygen levels. Instead aeration can reduce pumping costs. But as the intensity of production increases, aeration alone becomes inadequate to avoid accumulation of metabolic wastes such as NO₂, NH₃ and H₂S. Consequently increasing levels of water exchanges are required. Normally, the tidal water exchange is 2% of about 5-10% per day in extensive farms while it is 2% 10-20% and 20-30% per day in the semi-intensive and intensive farms respectively. But in the intensive ponds of U.S.A., the daily rate is increased from 1% to 15% in step, with increasing biomass of shrimps in the pond (30 nos/m²) in 90 days. Also for effective removal of wastes during water exchange, the use of a central drain has been highly successful (Anon, 1987).

Often the 2 functions of water exchange namely gas exchange and circulation are performed by the use of paddle wheels or a combination of air lifts (a blower connected to submerged diffuser strips to increase oxygen concentration at nights by gas exchange) and submerged low speed propeller (to prevent day time stratification and maintain anaerobic pond bottom). Shrimps flourish in the currents created by aeration.

The most important requirement in aquaculture is unpolluted water. Biochemically the shrimp body consists of 80% water ie 72% oxygen. Water is the 'life blood' of aquaculture industry since it forms the medium of transport of oxygen and food to the culture organisms. Also oxygen is the primary factor limiting productivity
(Sakthivel, 1988). The water control system has to achieve and sustain complete reliability under all extremes of weather. It has been pointed out that in seasonal paddy cum shrimp fields low oxygen values usually prevail due to decomposition of organic matter present at the bottom and the increased microbial activity during summer period between December and April (Nair et al., 1988). Accumulation of waste products on the bottom of the pond appears to be a limiting factor especially in intensive culture systems. This waste consuming oxygen creates an anaerobic zone on the bottom where the shrimps live. Therefore it is very important to maintain clean bottoms free from waste products (Sakthivel, 1988).

Water quality problem is found mainly around centres of population, due to lack of adequate sewage treatment systems and lack of any treatment after use by coastal industries including petro-chemicals and run off containing pesticides from agricultural lands. In addition to the above problems, the concentration of shrimp ponds also leads to very high organic loadings in the water nearby, a result of the large water exchanges taking place daily from the ponds especially towards the end of the seasonal operation in central Kerala. High BOD (5) values (6.21 to 280.40 mg/L), low dissolved oxygen values (0.05 to 3.081 mg/L) and high sulphide content in the bottom water have been reported from some localities in the Cochin backwater (Unnithan et al., 1975).

As a result of increased rate of inflow of industrial (260 million litres/day) and domestic effluents (80 million litres/day) in the Cochin region (Anon, 1982) its adverse effect has been reflected in the incidence of mass fish kills and the increased bacterial activity (Unnithan et al., 1975, 1977; Venugopal et al., 1980).

Gesamp (1991) has brought out a document on the need for reducing environmental impacts of coastal aquaculture. Coastal wet lands are amongst the most productive ecosystems and are important in sustaining the ecological integrity and productivity of adjacent
coastal waters. Mangrove areas for example, are important nursery grounds for many commercial fish and shrimp species (Linden, 1990). Therefore, mangrove swamps form excellent areas for extensive shrimp farming with minimal negative ecological impacts utilising tidal energy, for water exchange and shrimp larval supply (Purushan, 1991). They also prevent erosion and reduce turbidity by trapping sediments and binding nutrients.

The craze for intensive shrimp farming at the expense of mangrove areas and such other natural environs have disrupted the equilibrium of ecosystems in Ecuador and many other southeast Asian countries. This in turn has considerably affected the livelihood of poor traditional rural communities who depend on it and produced other negative social consequences in tapping the organic food source (Bailey, 1988). Therefore, it is apparent that mangrove areas should be protected and no further development of shrimp farms allowed in these areas.

More often, the imbalances taking place in the ecosystem can be attributed to the averacious human activities. The pumping of enormous quantity of ground water for intensive shrimp and eel farming in Taiwan has promoted land subsidence and salt water intrusion creating impediments to agriculture activities and fresh water supply apart from causing many other damages (Huang, 1990).

Most of the shrimp farming countries in Southeast Asia face environmental problems and farmers attain low profit or no profit from the endeavour. Therefore, it is important to mitigate or minimise the environmental degradation, emanating from intensive farming methods. The effluents from semi-intensive and intensive ponds located adjoining small estuaries contain waste products, nutrients from disintegrating foods and fertilizers which along with sewage and remnants of industries cause unhealthy conditions to the aquatic ecosystem. The results are disastrous - stunted growth and mortality to the stock. In the deteriorated water quality conditions with stress, usually
burgeoning population of Vibrio bacteria, virus, protozoa, fungi and other microbes thrive well resulting in out break of diseases damaging farmed fish/shrimp species. Because of the failure to maintain clean water in the systems, the shrimp farming industries collapsed in China, Thailand, Indonesia and Taiwan at one time or another during 1988-89 owing to disease problems (Anon, 1990). Consequently, farmers have to endure heavy loss and they learnt to space their farms and balance their demand for water. It is also reported that public health consequences resulted in red tide out breaks in areas where shell fish are grown (Maclean, 1989).

The processes that occur beneath the waters of a pond/field could indicate the difference between profit or loss to a shrimp farmer. To enable the pond operator to manage the pond/field in a manner that will ensure maintenance of conditions conducive to better growth and survival of shrimps stock and therefore better production, it is important to understand well the factors contributing to pond ecosystem processes. Functional role of the environment aims at the evaluation of cause - effect relationships and the probable results of short and long term changes.

There is constant interaction among soil, water, air, sunlight, weather conditions and the living organisms in the field/pond.

Some of the physical and chemical factors to be reckoned with during shrimp farming are as enumerated below.

1. Water as a universal solvent can dissolve/contain both beneficial as well as harmful substances.
2. The oxygen used by organisms for breathing to sustain life is the one in the gaseous state dissolved in water and in so doing oxygen content in the pond is lowered to the point of depletion.
3. Decomposing organic matter produce harmful products such as \( \text{NH}_3 \) and \( \text{H}_2\text{S} \).
4. Amount of $O_2$ can be increased by letting new water, bubbling air or agitating.

5. Salinity and temperature affect dissolved oxygen content; saltier and warmer waters holding less oxygen.

6. As the temperature increases, the density is lowered, allowing warm water to float over cold water.

7. The denser and heavier sea waters allow fresh water to float over it.

8. The free or dissolved hydrogen and hydroxyl ions present in water measured as pH in a scale from 1-14 are decisive factors for maintenance of life. The water pH is determined by soil pH and the amount of $CO_2$ in the water.

9. The transparency of the water is decreased by the increased presence of particles.

In the light of the above, it is appropriate to examine the various ecobiological factors prevalent during the present study.

In the contractor operated traditional fields (Group A), shrimp culture operations were carried out during the favourable season - November to April except the one at Thrikkadakupilly (Cherai) where perennial culture was practised from June 87 to April 88.

Pooyapilly, Nayarambalam and Narakkal fields were operated during the same season, ie between November 88 and April 89. In the other three fields, culture operations were carried out separately during three consecutive seasons between November 86 and April 88.

In the owner operated extensive shrimp culture ponds (Group B) shrimp farming was done during the summer season between November and June except at Karumancheri (Ezhupunna) where an additional crop of $P$. monodon was raised during rainy season between June and October.

The pilot studies on $P$. indicus in mini ponds (Group C) were also carried out during the summer period between November and June in
different seasons without being affected by the influence of monsoon. However, the *P. monodon* culture being extended between February and September could tide over the hazards of extreme summer and intense monsoon.

In the case of experimental tank culture of *P. indicus* (Group D) carried out between November and June under controlled water conditions, the ill effects of ecobiological variations were minimal.

The ecobiological variation in the semi-intensive farming at Mundapuram (E) was also negligible, since the farming was conducted during summer months of 1992. However, the monsoonal influx and consequent dilution during June, partially affected the culture during the fag end.

The water quality parameters, in respect of Group A fields, fluctuated within tolerable limits. The pH of water remained alkaline (7.0 - 8.4). So also, the water temperature ranged between 28.0 and 31.5°C. The salinity varied between 14 and 30.2%. Owing to the relatively higher depth maintained at Thrikkadakapilly wherein saline waters always prevailed, shrimp culture started in June could tide over the ill effects of monsoonal influx.

The dissolved oxygen values fluctuated between 2.6 and 7.3 ml/L, the lowest values being noticed during the fag end of operation ie, during the end of March to April. The diurnal variations in O₂ values were noticed in all fields at one time or other. During certain occasions values between 1 and 2 ml/L prevailed during 3-6 AM especially when there were difficulties for intake of water due to tidal effect during such time. However, in no case, any mortality level was encountered.

On account of suspended particles in the medium, the transparency was generally low ranging between 28 and 58 cm. However, at Thrikkadakapilly and Kuzhupilly, transparency was higher ranging
between 35 and 70 cm probably because of the absence of disintegrating paddy stumps and partly due to their increased depth. The meio and macrofaunal diversity were illustrative of conducive biological factors prevalent in these fields. The present data also enunciated the observations of earlier workers (Nair et al., 1988) that environmental conditions highly suited for prawn culture prevail in seasonal fields of Vypeen island during summer months.

In group B ponds, the water quality parameters such as pH, temperature, salinity and dissolved oxygen fluctuated between 6.5-9.0, 28.5-34.5°C, 4.0-32.0‰ and 2.75-5.30 ml/L respectively. The lowest salinity (4.0‰) was at Chalippuram during November 90 which gradually picked up to 30‰ during the terminal period of operation in March. Of all, the two ponds selected at Narakkal and one at Puduvoypu in Vypeen island were within the tidal influence of Cochin barmouth whereas the other four ponds had the additional effect of Anthakaranazhi. However, at Karumancheri (Ezhupunna) even though the level of salinity was less than 8‰ during June-October period, it was possible to raise an additional crop using P. monodon. So also at Chalippuram, a successful crop of P. monodon was raised taking advantage of the wide range of salinity 4-30‰ prevailed during the culture period. At Chorungal, as the salinity was less than 5‰ up to January on account of the influx of fresh water from the eastern source, P. indicus culture was possible only after February. The increase in the level of salinity continued even during rainy season up to August (Table 15a) on account of the tidal influence of nearby pozhi connected with Anthakaranazhi and also due to the unique saline water intrusion through the holes of sea wall all along the beaches from Maruvakkad to Chellanum. Since a large volume of sea water was thus emptied into the pozhi along with the abundance of penaeid shrimp post larvae, P. indicus culture could be made possible in the surrounding farms during the rainy season.

The coconut groves at Pallithode often encountered general water reduction, increased water temperature, impairment in water quality and algal blooming during the culture period. Hence water
management was done with extreme caution and pumping was resorted to maintain stability of the medium.

The usual benthic faunal groups similar to that of traditional fields occurred in both ponds at Narakkal. At Puduveypu, *Apseudes chilkeusis*, *Corophium sp* and certain polychaete worms were represented. While at Chalippuram, the benthic fauna comprised of tanacids (amphipods was more abundant and diverse), it was very scarce at Karumancheri and Cherungal. At Pallithode, lamobilibranchs and gastropods were noticed occasionally. It is to be pointed out at this juncture that except for the compartmental farm at Narakkal, all other farms were kept sundried (Plate XIX A) for 3-7 days during the preparation time without giving any considerations for benthic faunal generation.

In the semi-intensive farm at Mundapurum (E), the firm bottom characteristics and alkaline conditions of the medium remained favourable for shrimp growth. The diurnal fluctuations of water quality parameters were within tolerable limits. The regular pumping resorted to retain 70-75 cm water column and use of paddle wheel aerators (Fig. 11 and Plate XVII B) ensuring adequate water circulation in addition to increasing dissolved oxygen content were advantageous to maintain suitable water quality. The summer salinity maximum (36‰) occurred at the beginning of farming operations, gradually lowered, remaining at congenial levels (30-32‰) during the period of farming. The successful crop was harvested without any damage at the time when the salinity was dropped considerably (<23‰) with the advancement of monsoon showers. Eventhough the substratum was fertile, no much regard was given to the benthic fauna, since the shrimps were grown on nutritious supplementary feed.

Thus the analyses of data from the various regions of the study clearly indicated that the physico-chemical and biological factors of culture systems are decisive for the success of shrimp farming. Of course, the dynamic processes taking place in the estuarine environment
and the capacity of the ecosystem to maintain a conducive environment contribute very much for the sustenance of shrimp culture.

The significance of the above informations is best appreciated when one speculates on the fate of estuary depended shrimps, in the event they are deprived of estuarine habitat. But the basic question being advocated by those engaged in development of estuaries, at the expense of the living resources is that 'can't shrimp adjust to the new conditions wrought by human activity? and if not, why'?

It stands to reason, from the material available, that any unusual disturbance of the physical and chemical constitution of an estuarine system, would almost certainly be manifested in subtle changes. Accordingly in each species, the capacity to achieve a biomass (equivalent to that attained under environmental conditions characterising the ecological niche into which the species has evolved) will be subjected to the alterations in the habitat. Abrupt modifications of their respective niches would, superficially speaking, affect every species to a different degree.

With the imminent changes of estuarine biotope whether the shrimp species can adapt or gradually disappear is a logical one.

The fertile estuary, from the ontogenic point of view, constitutes an irreplaceable factor in the survival strategy of major shrimp resources. The perpetuation of such resources at commercial levels of productivity, (apart from their continued existence per se) will be contingent of our ability to minimize disturbance of the shrimp's estuarine habitat.

Environmental conditions may become increasingly severe for shrimp growth. The use of fertilizer supports the growth of other organisms, one of which is a protozoa which infects the gills of the shrimps. This alters shrimp's normal negative phototropism and causes individuals to surface more frequently than normal, making them more
vulnerable to seagull predation. Further oil spills are causing problems for both farmers and hatchery operators. Losses of wild larvae and other ecological damage were substantially larger.

Shrimp farmers in some areas also complained of losses resulting from the over burdening of the ecosystem with organic material, sewage and agricultural run off. The reducing conditions of the bottom substrate associated with water stagnation at times caused unhealthy situations in the experimental tanks. Surfacing of shrimps during early hours of the day was not uncommon.

Based on above factors among a number of uncertain others, one is forced to accept their interactive roles in controlling the distribution, survival and growth of juveniles during their estuarine occupancy. Still much remains to be done to know the extent to which above environmental factors control the productivity of shrimp resources. The ecological observations made in all the areas renowned as shrimp farms during this study could give only general feature of the habitat environment.

Experimental studies by Panikkar (1951), Williams (1960), McFarland and Leo (1963), Dobkin and Manning (1964), Rao (1958), Zein-Eldin (1963) etc. have provided the needed direction for meaningful pursuit of ecological (cause-effect) relationships, by which we can defend the maintenance of our estuaries as a necessary environment for biological resources as shrimps.

Still more, the shallow estuaries and the biological populations are prone to the consequences of unpredictable natural adversities like droughts, floods, freezes, tropical storms etc. leading to abrupt changes in the environmental properties.

Hildebrand and Gunter (1953), Gunter and Hildebrand (1954), Parker (1955), Viosca (1958) and Thomson (1956) have related the annual production of shrimps to extended drought and floods. Effect of
tropical storms has been studied by Kutkuhn (1962).

Java, the major shrimp producing area in Indonesia was hardest hit from the drought in 1991 damaging the grow out ponds and reducing hatchery production.

The unusually long cold spell during November 91 to January 92 in Thailand resulted in farm failures of over 70%, also delaying production out-put by one month.

The grow outs in South America (Ecuador and Peru) were heavily flooded due to rainfall attributed to the 'El Nino current' (Anon, 1991).

To conclude, most of man's activities in coastal lands - change in basin configuration, protective works, change in volume and seasonal distribution of fresh water inflow, domestic, industrial and agricultural pollution and development of mineral resources - generally affect the shrimp habitat, restricting economic levels of productiveness.

It is against the unabated distribution of estuarine habitat by a rapidly advancing civilization that the culture of shrimps on a commercial scale has received wide attention. The process aims at greatly improving the carrying capacity of a comparatively smaller area of estuarine habitat through manipulation of the numbers of juvenile shrimps involved and by the control of biological and environmental factors. The farming according to Allsopp (1960), Hall (1962) and Fujinaga (1963) depends primarily on local tides of sufficient height to permit alternate flooding and draining of diked off areas of swamp, bay and estuary. Hudinaga (1942), Delmendo and Rabanal (1956), Kesteven and Job (1957) and Allen (1963) have reviewed shrimp culture practices of the world. Lack of adequate tide differential, difficulty in leasing or acquiring title to submerged lands and problems to growth in semi-natural conditions are some of the problems encountered
What ails shrimp farming in Kerala?

A matter of concern is the question of continued productivity and perpetuation of shrimp stocks in the face of man's steady incursion of estuaries. This situation has evolved specifically as a result of the rapid urban and industrial development along our estuary rich Kerala coast. The most serious anthropogenic environmental alteration taken place in the estuaries of Kerala is its alarming rate of reduction in extent. The largest Vembanad kaylor which had an area of 36500 ha in the last century is predicted to have only 17% left as open brackish water by the dawn of 21st century for aquaculture purposes (Gopalan et al., 1983). Hence it is necessary to analyse the functional relationships between the estuarine environment and commercial shrimp sources and suggest measures to be adopted to offset the untoward effect of civilization.

It is almost centuries, since we recognised the multifaceted uses of our estuaries. The wetlands were reclaimed for farming, urbanizing and industrialization by the expanding society. Our manifold wastes were dumped in these readymade pools. Waters were deepened in some areas for waterborne transportation. Underlining sand mud and shell deposits were extracted. Natural areas were used for recreational purposes. The fresh water flow was directed for municipal, agricultural and industrial uses.

The above activities in turn have posed an ever increasing threat to those species of high economic value as food for man, harboured by the estuaries. The shrimp is a single constituent of the distinctive ecosystem of each estuary composed of communities of biological elements exhibiting different gradients of tolerance to each other as well as to an infinity of combinations of the physical and chemical factors that characterize it.
Most of the penaeid shrimps of commerce have a distinctive life history characterised by a period of more or less predictable length which it passes in an estuary or comparable brackish water environment (Mohamed & Rao, 1971). In each of the species so evolved, the parent population breeding in the sea at various distances from the mainland, produces seasonally large numbers of microscopic semi buoyant eggs which almost immediately hatch into small, planktonic nauplii. Development proceeds rapidly through the protozoal and mysis stages, the larval shrimp all the while moving or being transported landward in a still not fully explained manner towards the mouth of the river or to passages into broad and shallow estuaries. The amount of time lapsing between hatching off shore and entry of the small shrimp into brackish waters inshore may vary from a few days to several weeks, again depending on the species as well as on the prevailing oceanic conditions.

**Mangroves as food godowns**

It is worth utilising the otherwise unused wetlands - mangrove swamps - as the most valuable coastal resources. The importance of mangrove can be viewed as a buffer zone against wave and wind erosion; as a silt trap; as a spawning and nursing ground for aquatic organisms; as an organic food factory which exceeds 10 tonnes/ha of dry matter/year. Hence it is very much important to conserve such resources without its conversion as low productive culture ponds. The significance of mangrove ecosystems has been well documented (Snedaker and Snedaker, 1984).

The natural, valuable habitats such as shore areas and mangrove waters of several commercial shrimps such as *P. monodon* and *P. indicus* are under destruction in many areas. Therefore it is important to propagate their fry and adult artificially (Motoh, 1984).

The paradox of mangrove clearance is that the natural shrimp population uses mangrove backwaters to spawning; the removal of such areas is in itself important for the farming industry as they rely on wild seed to provide larvae for production.
Many of the perceived environmental problems of the shrimp industry of India including the study area are those associated with loss of mangrove areas in the estuaries of rivers in order to use for multivariable activities (Purushan, 1991).

Ecuador endowed with great diversity of potential environments for aquaculture ranging from sea weed culture to bull dog farming could produce 70000 MT tonnes of shrimp biomass from an area covering 90000 ha covering 80% of potential area during 1990. However, in Kerala 90% of the potential area is yet to be utilised for shrimp farming. Hence it is all the more important to conserve the estuarine environment without any further deterioration by way of reclamation effluent dumping, lime shell extraction and mangrove clearance for the sustenance of estuarine dependent fisheries, especially shrimps.

3.1.5 **Seed management - Species, larval habitat and abundance, autostocking and supplemental (wild and hatchery)**

Seed management is centred mainly around availability of quality seed in time. One of the pre-requisites of this is the development of hatchery technique which is slowly taking up in Kerala. From the production and economic point of view, the question to be considered is the type of species to be cultured, whether in mono or polyculture.

The science of shrimp farming as distinct from traditional shrimp culture is relatively new. The traditional shrimp culture remained as a polyculture system because of the inability to control the composition of the seed. The long traditional experience and scientific research, so far, is yet to succeed in domesticating shrimp culture in the sense of animal husbandry practices for large scale commercial aquaculture. Species have to be selected according to the objectives of culture, for example increased protein supplies to poor, export to earn foreign exchange etc.
Biological characteristics of aquaculture shrimp species include a) a faster growth rate to attain marketable size in a short time before it attains first maturity b) breeding easily with high fecundity and spawning frequently under captive conditions in hatcheries to ensure seed availability c) species with larval preference for artificial diet than live ones d) species low in food chain and also preferring artificial diet e) species that can tolerate/resist unfavourable conditions and f) behaviour pattern in confinement for intensive purposes.

But, to an aquaculturist/shrimp culturist economical considerations are more important than biological factors in the selection of a species for culture. They are a) availability of proven technologies of culture backed by economic viability b) consumer acceptance and c) availability of markets for the species.

The above considerations even demand introduction of exotic species for which established culture technologies exist and the economics of production and marketability have been demonstrated.

Jhingran and Gopalakrishnan (1974) have catalogued 465 species belonging to 28 floral families and 107 faunal families. Of the 32 shrimp species that have been investigated and cultured through out the world, seven species including P. monodon (Plate XX A) and P. indicus (Plate XX B) are most commonly cultured in south east Asia (Liao, 1987). Tropical waters of India, both sea and inland are abound in a variety of shrimps, contributed by 55 species. Of these 8 penaeids and 6 non penaeids are of considerable significance. Of the 7 cultivable species P. indicus, P. monodon and M. monoceros are widely distributed and the other 4 are of local importance only (Rajyalakshmi, 1980; George, 1967).

The largest (336 mm) and fastest growing P. monodon contributes to 43% of world production of farm raised shrimps (Plate XXI A) in the south east Asia where as P. chinensis from China growing upto 183 mm
accounts for 18%. The preferred species in western Asia and Ecuador is the tough _Penaeus vannamei_ (17%) growing to a maximum of 230 mm. Rest of the culture shrimp species (22%) include a number of species (World Shrimp Farming, 1991), _P. indicus_ being the preferred one in the extensive farms through out south east Asia, especially India.

In our country depending on export demand and value realization, _Penaeus sp_ which grow to large size is preferred. Even though _P. monodon_ is the most preferred owing to its outstanding growth rates, omnivorous feeding habit (leading to a relatively low dietary protein requirement), its euryhaline nature (which results in normal growth from 5 to 25% salinity) and its high tolerance against handling stesses, _P. indicus_ has also better farming prospects, in view of its faster growth rate, shorter duration of culture in grow out ponds and easy availability of seed. Recently, the record production of _P. monodon_ (Plate XXI A) in hyper saline conditions (45 to 47%) reported from a farm at Radhanallur, Tamil Nadu has over-ruled the earlier belief that it can be farmed only within the salinity range of 15 to 25% (MPEDA, 1991). Efforts should also be made to augment their production by culture as well as by improving the existing traditional farming practices by adopting scientific methods (Mohamed, 1969., Gopalakrishnan, 1973). Furthermore, the significant drawbacks associated with _P. monodon_ culture are high price of its seed and insufficient availability of fry due to shortage of mother shrimp. The growth rate of _P. indicus_ is similar up to a body length of 12-13 cm in 89-90 days rearing. Cheap cost and a large supply of seed will easily compensate for the small size. In the commercial view point it is very significant to note that _P. indicus_ will continue to grow in prolonged confinement and attain bigger size in the brackish water conditions (Subramanian and Rao, 1968, Mohanty, 1974 and George, 1974). It is therefore important to expand _P. indicus_ culture in Kerala due to its relatively low production cost compared to _P. monodon_.

A considerable body of information is available on the shrimp larval recruitment as well as on the distribution of their adult
counterparts and their fishery from geographically different regions in India (Menon, 1952 and George 1962 in the west coast and Evangeline and Sudhakar, 1973 in the east coast of India).

Also studies have been made on the occurrence of juvenile shrimps in the inland waters and their prospects in a culture undertaking (George et al., 1968; George and Sebastian, 1970 and Selvakumar et al., 1972) from the west coast of India, and Gopalakrishnan (1952, 1968), Chacko et al. (1954), Pillay (1954), Evangeline (1969), Jhingran and Natarajan (1969), Ghosh et al. (1973), Sampson Manickam and Srinivasagam (1973), Evangeline et al. (1975), Victor Chandra Bose et al. (1980) and Subramanian et al. (1980) on the east coast of India.

A comparative study on penaeid shrimp juvenile abundance in Indian brackish water bodies has been carried out by Gopalakrishnan (1973), Muthu (1973) and Rajjalakshmi (1973), Rao (1980) and Rao (1983). Relative occurrences in quantitative term and size distribution with regard to estuarine shrimps were done by Subramanian (1981) and George and Suselan (1982).

Such a detailed survey on the availability of penaeid shrimp juvenile resources of an area is a sine qua non to practise their culture (Mhaswade, 1980; Alikunhi, 1980). The surveys conducted on availability and abundance of seed of cultivable species in different brackishwater bodies stand as a milestone in this direction (Rao, 1983; Ghosh, 1985).

India with a brackish water hinterland of coastal localities has an area of 2.2 million ha available for coastal aquaculture. The vast inland and brackish water localities hold promise to solve the problem of quantitative procurement of required species for undertaking shrimp culture (Silas, 1980). Nevertheless, proper conservation and maintenance of brackish water shrimp seed resources is very essential for a sound management and promotion of aquaculture ventures.
The availability of epibenthic shrimp juveniles in dynamic brackish water ecosystems could show fluctuations (George, 1973; Pillai, 1978; Alikunhi, 1980). From the information on pattern of distribution of penaeid shrimp juveniles in Vellar estuary, it has become evident that most of the species are perennial, while some showed seasonal and a few others sporadic distribution. Also considerable year to year variation in their abundance (P. monodon and P. indicus) was noticed as their life span would last more than a year. Also biological (predator-prey relations) and ecological stresses would exert their influences for fluctuations (Walker, 1975; Palaniappan et al., 1978; Krishna Murthy et al., 1978).

George (1962) has observed that the larvae of P. indicus would enter into backwaters of south west coast of India (Kerala) during November - December. P. indicus post larvae were abundantly recruited to the Cochin backwaters along with tidal current during September and January and May to July (Rao, 1973). The size of recruits was less than 10 mm total length (Panikkar and Menon, 1956). In Cochin estuary, eventhough a lot of shrimp/fish seed are available from the Puduvoypu locality (Plate XXI B) during season, a great majority undergo stress due to the turbulent water conditions (Purushan, 1989). This in turn affects the survival of shrimps and fishes in culture systems of that region apart from creating problems of efficient pond management.

The presence of vegetation would provide shelter for the moulting shrimps (Plate XXI B) and it also provides rich organic debris as a fresh food source (Rajyalakshmi, 1973; Young, 1975). Total organic carbon forms the base of the detrital food system. Hoese (1960) related the abundance of juveniles in Gulf of Mexico to the sea grass beds. Allen and Inglis (1958) reported on the habitations of the post larval and juvenile penaeid shrimps among salt grass. Similar reports have been made on turtle grass (Strawn, 1954) and upon Cymodocea isoetifoliums (Kannan and Krishna Murthy, 1978 and Subramanian et al., 1980). Young (1975) reported the marked occurrence of juvenile shrimps on sea grasses than on bare exposed substrate. The
sea grass containing Philippine meadows are considered as preferred substrata for the large scale recruitment of *P. monodon* post larvae. The conspicuous absence of such a habitat along Vembanad lake especially in the study area might be the reason for the low level of recruitment of *P. monodon* post larvae.

Young shrimps, irrespective of species prefer phytoplankton, mainly diatoms as their staple food. These diatoms were found to occur upon periphyta, on the stalk of the submerged vegetation and were voraciously preyed upon by the juvenile shrimps (Ghosh et al., 1973). Mohanty (1975) and Evangeline (1973) observed the presence of *Enteromorpha* sp and *Chaetomorpha* sp in the stomachs of post larval and early juvenile shrimps. In places like Portonovo, presence of low lying areas like mud flats along side was found to help trap and retain the nutrients of the nutritive estuarine waters for eventual growth of sea grass and algal vegetation. These were also found to harbour characteristic fauna. Hence, the shrimps in such areas were found to prefer algal vegetation for their food and shelter.

In the Cochin back water, in the case of commercial shrimp larval recruitment, it is believed that usually 4 to 6 weeks might have elapsed by the time, the young begins to arrive as 5-10 mm post larvae, which no longer be classified as true plankters. Once in the estuarine waters, the post larvae quickly transform into juveniles. Over the subsequent 90-150 days, they grow rapidly and reach commercially acceptable size shortly before their return to the sea where the life cycle is completed.

Appreciable variations occur among the commercial penaeaeidae of the world, both in the degree to which each species utilizes an estuarine type environment during its life history and in the distribution of its parent population along the brackish-marine gradient of the littoral zone at the sea's edge.

Thus a species completes its life cycle wholly within the
confines of an estuary (Morris and Bonnet, 1951), while another undergoes entire development in the ocean at depths approaching 900 metres (Maurin, 1965). In between may be noted all shades of difference in the ontogenetic-estuarine relationship.

In the light of the above background it will be interesting to analyse the seed management methods adopted in the farming systems selected for the study.

In all the contractor operated traditional fields (Group A) shrimp larvae were autostocked by regular tidal processes. All efforts were made to concentrate maximum larvae by skilful techniques. The intake of tidal water and its draining through appropriate screens taking full advantage of all high and low tidal processes especially during dusk and dawn hours was followed. Therefore no conditioning or acclimation of any sort, of larvae was necessitated as the environmental conditions were quite similar both inside and outside. The confluent nature of the general field system also enabled the fry to enjoy the entire niche from the very moment of their entry. So also, there was no known method to assess the shrimp larval density within, by the process of autostocking. Nevertheless, experienced shrimp farmers derived satisfaction when they observed juvenile shrimps getting buried profusely in the bottom with eyes projected. These countless objects discernible during day and dusk hours on close observations of the shrimp fields were indicative of the satisfactory level of shrimp juveniles recruitment.

In the aforesaid aspect, the ideal site location and the extent of tidal amplitude played significant role in the shrimp production capacity of traditional fields. Eventhough all fields selected from Thrikkadakapilly (Cherai) to Narakkal were situated advantageously in this regard, fields at Thrikkadakapilly and Pooyapilly were situated in strategic positions having all the advantages for close proximity with main water body and maximum tidal gradient. In contrast, the field at Nayarambalam was located quite interior from the main feeder source and
with minimum tidal amplitude. The autostocking of shrimp larvae in fields at Ayyampilly, Kuzhupilly and Narakkal was also satisfactory, since they were able to draw high tidal water with fair gradient being influenced by Munambam and Cochin barmouths respectively.

Apart from autostocking, supplemental seed induction was done in improved fields at Ayyampilly and Narakkal where adequate arrangements to increase the carrying capacity were made during preparations. One lakh each of _P. indicus_ healthy juveniles (Plate I A) procured from natural sources with a mean size of 25-30 mm were additionally released into the appropriate compartments within the field earmarked as nurseries upto 2 months. Since these young ones were collected from the nearby back waters and kept under hapa rearing (Plate I B) in the same environment, no further acclimation was required while introducing them into the fields. However, injured, unhealthy and undersized ones were avoided while transferring. The induted shrimp larval densities were 3.3 nos/m³ and 4.4 nos/m³ at Ayyampilly and Narakkal respectively.

The method of seed management varied very much in the owner operated extensive farms (Group B). Both _P. monodon_ (Plate XX A) and _P. indicus_ (Plate XX B) were farmed in respective growouts depending upon season and seed availability. Of the eight operations carried out in 7 farms, sequential farming of _P. monodon_ and _P. indicus_ was carried out only in the farm at Karumancheri. _P. monodon_ farming was done at Chalippuram and Pallithode. In other four farms - Narakkal (two) Puduvoypu and Cherungal - _P. indicus_ was cultured.

There were much differences in the procurement, size, stocking density and other management aspects of seed of both _P. monodon_ and _P. indicus_. Only hatchery (Plate XXII A) fry were made use of in the case of _P. monodon_, the fry size being PL10, PL12 and PL22 at Karumancheri, Pallithode and Chalippuram respectively. Also, the stocking densities in order were 12350, 24700 and 68100/ha. While the fry after acclimatization (Plate XXII B) were directly released at Karumancheri,
there was two to three weeks nursery rearing in the other two systems.

In the case of _P. indicus_, both hatchery (Plate XXII A) fry and wild (Plate XXI B) seed were made use of. Tiny PL5 and PL12 hatchery fry were released at Cherungal (Plate XII A) and Karumancheri respectively at stocking densities of 1.5 lakhs and 75000/ha. While uniform sized (0.041 g/19.4 mm) wild seed were stocked @ 50,000/ha both in the compartments at Narakkal and ponds at Puduveypu, fairly advanced juveniles (0.258 g/34.5 mm) @ 1,17325/ha were released in the Harijan farm at Narakkal. No nursery rearing was done in the case of _P. indicus_ except at Cherungal.

Even by using fry from different sources and treatments, no incidence of disease was noticed at any time, despite the stocking densities ranged between 12350 and 1.5 lakh/ha comprising both species.

Of the 8 experimental series under group C, 6 were carried out using _P. indicus_ and the other 2 with _P. monodon_. In the 5 series of experiments in the miniponds with _P. indicus_, uniform sized wild fry kept under hapa rearing (Plate XXII B) were made use of. The size of fry and stocking density varied from one experiment to another. Though with uniform stocking size, the stocking density of fry also varied from 1 to 2.5 lakh/ha in different treatments of the same series. The mean size (length/weight) at stocking was 16.2 mm/0.029 g; 53 mm/0.848 g; 28.0 mm/0.155 g; 39.8 mm/0.388 g and 17.7 mm/0.030 g respectively in the series of experiments 1 to 5. All fry were introduced into the miniponds after proper conditioning.

In the C6 experiment PL6 fry of _P. indicus_ obtained from Govt. Prawn hatchery (Plate XXII A) Azhikode were conditioned and released @ 4 lakh/ha into the pump fed earthern tank (Plate XIV A).

Uniform sized _P. monodon_ wild fry (PL10) and similar sized ones procured from MPEDA hatchery at Vallarpadam were separately stocked @ 2.5 lakh/ha after conditioning (C7) in the respective earthern pools.
(Plate XV A). In C8 nursery reared and mean sized (2.211 g/68.4 mm) _P. monodon_ juveniles after conditioning were stocked @ 27000/ha in the minipond.

In all cases, fry remained in stagnant water conditions mostly except during the time of water exchange.

Under group D, _P. indicus_ fry were stocked in 4 series of circular cement tanks (Plate XVI A) and one series of fibre glass tanks (Plate XVI B). The mean size of wild fry stocked was 27.4 mm (0.112 g); 32 mm (0.196 g); 49.2 mm (0.789 g) and 24.2 mm (0.128 g) respectively in the series of experiments 1 to 4. The corresponding fry stocking densities were 50,85,100 and 800/m$^3$.

In the fibre glass tanks, the mean size of wild fry was 17.7 mm (0.030 g). The stocking densities varied in each tank @ 20,40,60 and 80/m$^3$ respectively. All fry were conditioned before stocking in both set of tanks.

3 lakh, PL$_{20}$ _P. monodon_ fry were brought from TASPARC, Visak in 22% saline medium. During the transport around 10% mortality was noticed. The fry were transferred in batches after 4 hours of acclimatisation to the semi-intensive farm at Mundapuram (group E) having a salinity of 36%, at a stocking density of 2.25 lakh/ha. The entire operation lasted for 10 hours. Subsequent mortalities observed in the vicinity of the transfer points might be indicative of the stress conditions experienced by the fry owing to the short duration acclimatisation. Various researchers (Rao, 1973; Subramanian, 1981 and Pillai, 1991) have indicated the importance of optimal salinity for greater survival and growth of prawn larvae.

The limiting factor in the large scale adaption of shrimp farming is the non availability of seed from natural sources.

So the success of brackish water culture depends upon one basic

As noted above the natural shrimp seed supply is periodical, unreliable and most important of all, limited. Also seed collection is rather destructive method as usually not more than 10% of the collected seed is belonging to the preferred species (the rest is destroyed) and similarly a low percentage of the selected seed reach the grow out ponds and have a chance of survival.

Most highly priced and expensive is the wild caught seed, reputed to produce much more hardy shrimp with better growth characteristics as observed in Ecuadorian shrimp industry (Liam Kelly, 1991). However, supply is erratic dependent on the current of the coastal waters and the natural abundance of the spawning shrimps.

While *P. indicus* seed are available throughout Indian coasts, *P. monodon* seed are confined to certain localities only. Compared to Tamil Nadu, Orissa and West Bengal, the seasonal abundance of *P. indicus* is low in the Cochin backwaters and Vembanad lake areas of Kerala.

Auto stocking of post larvae and juveniles by natural ingress along with rising tide, being subjected to unpredictable fluctuations, is not a dependable procedure. Also it has the disadvantage of bringing in predators too. Further, the back waters in Kerala show a predominance of slow growing shrimp species. *Metapenaeus dobsoni* is plentiful throughout the year with peak in October - January where as *M. monoceros* occurs during October - December.

The alternative to tide over the above is to make use of the
PLATE XV

A - Earthen pools

B - Minipond under *P. monodon* rearing at Puduveypu
PLATE XVI

A - Conditioned circular cement tanks

B - Conditioned fibre-glass tanks
PLATE XVII

A — Fringe of mangrove vegetation at Mundapuram farm

B — Paddle wheel aerated semi-intensive farming at Mundapuram
PLATE XVIII

A - Test feed trays suspended from platform

B - Pond excavated amongst mangroves and exposed to wind aeration
PLATE XIX

A — Pond preparation — drying

B — Manuring
PLATE XX

A - *Penaeus monodon*

B - *Penaeus indicus*
seed of the growth potential species selected from the natural environment or the establishment of enough hatcheries.


But, Dwivedi (1985) estimated the seed requirement to be 256 billions ($10^9$) with a stocking density of 1,50,000/ha in a potential area covering 1.711 million ha ($10^6$). This can be made possible by raising the stocking material by profusely breeding shrimp under controlled conditions as in Japan (Furukuwa, 1972), Taiwan (Chen, 1972) and Philippines (Villaluz, 1974).

As early as 1942, Hudinaga successfully spawned wild spawns of *P. japonicus*. Since then, *P. indicus* and *P. monodon* are among the 24 penaeid species for which commercial scale propagation methods are available. *P. monodon* was spawned using unilateral eye-stalk ablation.

Japan and Taiwan virtually produced all the required seed in hatcheries. The requirement for setting up hatcheries are 1) brood shrimps from sea 2) spawning and rearing of eggs to post larval stages, 3) availability of suitable feed depending on larval stages and 4) setting up and management of the controlled systems.

However in recent years, with the functioning of about 18 viable shrimp hatcheries of different capacities both in public and private sector throughout the country (MPEDA, 1992), almost 200 million shrimp seed PL4 to PL25 are annually supplied against the present requirement of about 5000 million.

Throughout the experiment it was noticed that the over pampered fry obtained from hatcheries are not able to adapt easily to the more harsh field environment leading to high mortalities and low growth rates in grow out phase as observed at Puduveypu and Pallithode.
Percentage survival of shrimps and their yields are often interlinked by a linear relationship, provided the seeds are of good quality. Also better survival rates could be ensured by controlling cannibalism, using uniform sized hatchery bred seed which moult synchronously. However, by virtue of their sturdiness and lower prices, the natural/wild seeds are preferred for extensive management.

Kurata and Shigueno (1976) observed higher survival rate in *P. japonicus* if large fry of 1.10 to 6.08 g weight were stocked in the culture ponds. Mohanty (1974) recorded higher rate of survival in the experiment when advanced juveniles of *P. indicus* were stocked and lower rates of survival when early juveniles were stocked in the ponds. Above observations enlighten the importance of stocking of advanced fry.

Alikunhi et al. (1980) noted the percentage survival as 96, 75, 78 and 55 when *S. merguiensis* advanced post larvae were stocked at a rate of 1000, 2000, 3000 and 4000/m² respectively without aeration, but with artificial feeding and water exchange.

One of the most important problems encountered in shrimp culture is the large scale and unaccounted mortality of the stocked shrimps in the grow outs/ponds. According to Rajyalakshmi (1982), 70 to 80% mortality of *P. monodon* in the culture ponds is caused by cannibalism, inadequate feed and its relationship with salinity, temperature and oxygen content of the medium controlled by exchange of water. Nandakumar (1982) found higher survival rate for *P. indicus* when fed with supplementary feed.

### 3.1.6 Feed and feed management

Aquaculture is one of the fields where opportunities to increase food production in a relatively short time and at a reasonable cost, seems very promising. Also world-demand for shrimp is on the increase, since last decade. It is estimated that currently around 0.7
Million tonne of shrimps are produced annually by world aquaculture and is projected to double by 2000 A.D. (World Shrimp Farming, 1991). One way to achieve this target is by optimal feeding coupled with improved water quality after selective stocking. This is possible only by developing one of the pressing strategies namely feed, which is one of the essential inputs in shrimp farming.

A point to remember is that as the shrimps grow to marketable/harvestable size of 20-30 g, their nutritional (dietary) requirements vary. Also, as they grow, undergoing several molts, a change in the size of feed particles is warranted in relation to the different growth phases. Therefore, the search for a suitable, high quality water stable food for the post larval stages, juveniles and adults of _P. indicus_ (Plate XX B) and _P. monodon_ (Plate XX A) is one of the important areas of study in the production. The feed for shrimp growout are broadly classified as (1) post larval (2) starter (3) grower and (4) finisher feed.

As the feed cost constitutes over 60% of the overall cost of production, it has an important decisive role in the economics of farming. Feed quality, quantity and the manner in which feed is given would influence the shrimp yield. Hence the need arises for selection/production of a cost effective feed with high feed conversion ratio (FCR 1.2:1) among the various raw materials available locally or at least within the country.

The Feed conversion ratio (FCR) - the value which measures the efficiency of feed utilization for growth can be defined as "the dry weight of feed offered to shrimp during a certain period of time divided by the wet weight gain of shrimp during the same period of time". A primary use of the FCR is to evaluate nutritional quality of feeds, more nutritious feeds yielding lower FCR values. A ratio between the quantities of feed applied and shrimp produced will be very close in the case of good quality feed where as a distant ratio between the two will denote a poor quality feed (Purushan, 1991).
Poor FCR means considerable loss of feed to pond bottom in the form of undigested wastes polluting the water thereby incurring reduced products and profits.

According to Asian Shrimp News, 1st quarter 1992, FCR performance is related to shrimp size, with the smaller sized shrimp having the lower FCR and the larger sized shrimp, the higher FCR (1.15 for 20 g size raised to 1.65 for 50 g size in the case of P. monodon). Furthermore, the Thailand farmers were successful to achieve an FCR of even 1:1 due to the increased reliance on natural feed availability in the environment along with optimum supplemental feeding in a semi-intensive culture system with a stocking density of 10-20/m² (Asian Shrimp News, Issue No. 8, 1991).

As on today, the 5000 farmers engaged in the shrimp farming in about 50,000 ha in our country, following traditional culture with a production ranging from 200-500 kg/ha, do not apply feed.

In brackishwater shrimp culture, the natural productivity of the estuarine water which is rich in nutrient elements and food organisms, is being utilised to the extent possible by exchanging water under impoundments with the tide water (Hickling, 1971).

The basic organic productivity of the seasonal paddy fields is seen to be of a higher order which in turn reflects in the shrimp production (George, 1974). The disintegrating paddy stalk releases required nutrients for generating optimum plankton growth which promotes the favourable growth of shrimps resulting in higher production. The debris and detritus accumulated in the paddy field shrimp culture system are also consumed by shrimps which enhances the production to a great extent. In a densely populated shrimp ground large food masses may be insufficient to support a healthy population and this deficiency is likely to be made up by feeding on the epifauna and epiflora of the mud surface (Dall, 1968).
Studies by Sugunan and Parameswaran Pillai (1984) on vertical distribution of the meiofauna of the sediment in selected culture fields around Cochin showed 85% of the population occupying the upper 2 cm layer indicating the role of salinity, dissolved oxygen, available phosphorus and temperature as controlling factors.

The composition of the epifauna comprised of rotifers 50%, copepodites, copepods like Oithona spp, Acartia spp, Pseudodiaptomus spp, Acartiella spp, Diaptomus spp, nauplii of crustaceans, bivalve larvae, nematodes, polychaetes, fish eggs, Cladocerans, tintinnids and harpacticoid copepods. The dominant benthic fauna included bivalves, molluscs, polychaetes, amphipods, isopods and cumaceans.

Shrimps graze on the soft parts of the plants associated with small animals and particularly on the decaying remains of the plants in the pond bottom (Primavera and Gacutan, 1985). In general, shrimps move around the perimeter of the pond in the late afternoon and evening and even though they feed at anytime during the day, they prefer to bottom feed when there is light (Apud et al., 1980). Strangely benthic algal control was necessitated to avoid trapping of post larvae.

George (1972) analysed the food contents of shrimps of the backwaters of Cochin and found that in juveniles, small crustaceans formed the major food item, and only a small portion consisted of unidentified objects and debris. There is an indication of varying food differences to some extent.

Kuttyamma (1974) has made a study of the feeding habits of M. dobsoni, M. affinis, M. monoceros, P. monodon and P. indicus in the Cochin area. The food in general consisted of varying amounts of organic matter mixed with sand and mud. Gut content analysis of P. indicus from various fields showed crustaceans as the major constituent in the stomach (21.11%) followed by detritus (19.64%), vegetable matter (18.41%) and polychaetes (16.49%). There was no significant variation in the gut contents between ponds. Hence it may be concluded that the
seasonal availability of food organisms in the environment determines their selectivity.

Benthic (fauna) food items of shrimps identified in the mud samples of the study area consisted of polychaetes - Prionospio sp and Heteromastides sp, nereidae, tanaidaecids such as Apseudes chilkensis and A. gymnophobium. Amphipods like Corophium sp, Gammarus sp and Melita sp, mysids of decapods, bivalve Pandora flexuosa and gastropod Littorina sp were represented apart from unidentified objects and debris. Quantitative and qualitative differences were also observed in different months.

**Plankton management**

According to Chen (1987), the production potential of farms is related to the pond water colour depending on the type and extent of plankton bloom. Rubright et al. (1981) observed the influence of adequate pond fertilization on shrimp growth and production possibly (via) plankton - detritus food chain. Kongkeo (1990) has highlighted the important role of plankton production and its regulated supply to grow out ponds practised in Thailand. Even though the technology of preferential blooming of the proper phyto-plankton and its regulated supply to grow outs is yet to be tried in India, the author has successfully bloomed phytoplankton in the study farms by proper broadcasting of fertilizers and manures.

The role of natural productivity in earthen ponds in the study area is highly significant. The growth of natural food in ponds is enhanced by fertilization, which is a standard practice in pond preparation for extensive and semi-intensive farming. This is done by normally applying organic manure @ 1 - 2 tonnes/ha. Also inorganic fertilizers such as ammonium phosphate (16-20-0) and urea (46-0-0) at 75-150 and 25-50 kg/ha respectively are in use. Generally fertilization is not done in intensive ponds. Subosa (1986) demonstrated the feasibility of producing shrimp stocked at 7500 per ha.
(P. monodon) reaching marketable size in 120 days through the use of 1 tonne chicken manure/ha.

In general feeds control production in ponds, as inadequate feeds reduces production. As the stocking density is increased to progressively more intensive levels, the contribution of food chain organisms to the diet, diminishes. This necessitates increase in quantity and quality of feed to maintain good nutrition and growth.

Studies have indicated that supplemental feed is required in densities higher than 15000/ha for P. monodon and 30000/ha for P. indicus.

The shrimp being cultured are receiving part of their nutrient required from natural sources and part from the artificial feed being added to the pond. Supplementary feeds are cheaper than complete feeds. Moist feeds are normally proportionately cheaper than the equivalent dry feeds, if made at the farm site.

The Chinese shrimp farmers rely on live feeds (primarily crushed clams and mussels) supplemented with pelleted feeds consisting of agricultural byproducts (soy bean meal, pea nut meal and corn). Japanese shrimp culture depends mainly on feeding with short necked clam and the mussel (Mytilus edulis). Formulated moist and dry feeds are also used very widely.

Supplemental feeds generally used consisted of chicken entrails, frog meat, mussel meat, trash fish, worms, snails, clams, slaughter house waste etc. But to get an enhanced production of 1 tonne/ha, the problems encountered were their mass production, storage, free availability and quality. Hence the need arose for the development of commercial feed/dry pellets.

Supplementary feed is basic to intensification and the highest recurring cost in intensified practices is attributed to the feed cost.
Usually high protein formulated diets are used in intensive culture.

Despite higher cost, most intensive farms used balanced diet formulations with 35-40% protein, an effective binder for underwater stability and a complete mix of vitamins and minerals. However in the laboratory experimental series, formulated compounded feed were used and good results obtained.

Commercial feeds are available in the form of water stable pellets of different shapes and sizes (worm like or crumbles) prepared using finely ground ingredients and different kinds of binders, by cooking - extrusion or dry or wet pelleting.

The manual on "Feed and Feeding of Fish and Shrimp" (FAO, ADCP/REP/87/26) is an easy to read guide to the choice, manufacture, storage and use of feed in small scale aquaculture.

Feeding has a most significant potential role to play in increasing the revenue and profitability of any aquaculture unit (New, 1987). According to Shang (1981) the cost of feed in aquaculture often exceeds 50% of total production cost, rising to as high as 75%. But, the higher feed costs might be a disadvantage.

The status of shrimp nutrition and feed development in SE Asia has been extensively reviewed by Pascual (1989). Accordingly formulated feed constitutes around 50-60% of the operational costs in shrimp culture and hence there is a need to develop, low cost effective feeds. However, owing to limited information on feeding habits and nutritional requirements, development of feeds of P. monodon has been dependent on data derived from other penaeid species.

Shrimp culture can be promoted by producing feed in pellet form economically by utilizing locally available inexpensive raw materials like rice bran, ground nut oil cake and cotton seed oil cake. This vegetarian diet has to be fortified with animal protein to accelerate
the shrimp growth. In the absence of a standard reliable shrimp feed, formulated feeds prepared from locally available and cheap materials were made use of in different culture systems (Purushan, 1991).

Rarely few fed shrimps with imported feed to get a production of 2 to 4 tonnes/ha. Supplemental feeding is done in about 15000 ha (Andhra Pradesh 6000, Maharashtra 1800, Tamil Nadu 250 and Orissa 7100 ha) where extensive farming methods are followed. Farmers in Andhra Pradesh generally used farm made feed and as the name indicates, the quality and composition of feed varied considerably. Goc, brocken rice, soybean cake, rice bran and dried fish formed the ingredients in the feed meant for extensive farms. Sametime, the farmers opting for improved extensive farms used fish meal, shrimp head meal, squilla, soyacake, goc, rice bran, wheat flour, meat, bone, vitamin and mineral mixes. According to Ponnuchamy et al. (1990), few chose lecithin too. Only less than 200 ha located in Tamil Nadu and Andhra Pradesh are under semi-intensive system. Intensive system was able to produce upto 8 tonnes/ha/yr at Nellore in Andhra Pradesh and Paradeep in Orissa.

But, for the success of production, one major limiting factor is the nonavailability of appropriate quality feed in time. This necessitates development of local substitute feeds economising import costs.

Based on above facts, it is estimated that in the coming 5 years, the annual requirement of feed may go up to 30000 tonnes from the present 5000 tonnes. The annual feed requirement by 2000 AD may touch 2,50,000 tonnes (MPEDA, 1992). In this context, the functional feed mills like the one being set up at Cochin have to play predominant roles for the development of shrimp farming. The six functional feed mills set up in Andhra Pradesh possessed capacity to produce 20,000 m.t./annum.

According to Chiu (1989), the composition of diets and feeding management should provide for maximum growth. Both feeding rate and
feeding efficiency contribute to differences in growth response and feed efficiency.

Proper feeding management is important for the attainment of maximum growth and feed efficiency. Both parameters vary with many factors including the species and size of shrimp, water temperature and dietary energy level and the physiological status of the shrimp. Growth and feed frequency are positively related. Shrimps at the higher feeding regime naturally grow faster.

However, there is a maximum limit to extensive feeding at which the increase is negligible when considering the amount of food given (Chua and Teng, 1978) and this is defined as the optimal feeding frequency which varies among different species. Semi-intensive culture requires regular supplementary feeding in addition to natural food. In contrast, intensive farming necessitate supply of formulated feed 3-6 times per day.

It has been reported that the changes in temperature, salinity, dissolved oxygen etc. have a profound influence over the appetite of shrimps. So feeding rates can be adjusted 5 to 10% up or down on a daily basis. The feed rations generally found varying from farm to farm, decreased from 25% in the early juvenile stage to 2-4% before harvest.

Improvements in feed efficiencies can be done in three ways. One way is to maximise production of free food chain organisms as practised in the present experimental investigations. According to Moriarty (1986), most of the feed supplied to shrimp ponds is actually being utilised first by bacteria. In the extensive paddy field traditional system, the left over paddy stumps are devoured by shrimps in the same manner. The meiofauna eaten by shrimps feed on these bacteria. A limiting factor in this process is availability of dissolved oxygen for growth of the aerobic bacteria. According to Moriarty, aeration can be an effective tool to accelerate the
conversion of wastes into nutritious food organisms. Also aeration is found capable of increasing plankton growth which serves as forage for shrimps with a conversion ratio of 1.5. Usual biweekly fertilization with urea, superphosphate, calcium silicate etc. increased diatom population considerably.

A second method of improving feed efficiency is to feed several times per day rather than just once, because shrimp forage for small quantities of food continuously. Also multiple frequent feedings reduce the deterioration and waste that occurs when pellets are not eaten immediately. This careful feed management could lead to a conversion efficiency of 1.7. Also frequency can be increased towards the end of growing season. This kind of feeding could be adopted in the experimental culture tanks where as only one time supplemental feed could be provided in the extensive grow outs. In the improved extensive farms at Andhra Pradesh, farmers divide the daily feed into two portions and broadcasting is done during the dawn and dusk hours.

The third method is to avoid over feeding or under feeding keeping pace with weekly growth rates and survival rate. This can be done by looking at the residual feed left on the feeding trays which can be an active indicator of feeding also. This necessitates close monitoring of feed off-take. This practice was followed in all experimental tanks and mini ponds. Very similar method of feed supply also proved successful in the extensive grow outs at Chalippuram (B5) and Cherungal (B6) and in the semi-intensive farm at Mandapuram (E).

In the extensive farm in Andhra Pradesh, feed is supplied from the 31st day of stocking @ 10% of the daily estimated biomass. But the feed ration is reduced to 4% after 90 days. Often better survival rates and yields are contributed by the pelletised feed compared to the wet dough balls.

The papers presented during the Third Asian Fish Nutrition, Network meeting held at Philippines (De Silva, 1989) have dealt with,
in detail various aspects of basic nutritional requirements of fish and shrimps.

What is lacking still is information on the nutritional requirements of the shrimps and the conversion ratio of the existing conventional feeds. Artificial dry feed pellets containing essential components for growth were used in experimental shrimp culture at Puduveypu. Application of nutritious and cheap feed of relevant quality helped very much to increase production. However, shrimp being slow eaters, the feed stuffs used in ponds should not leach easily to avoid water quality deterioration in the culture system. Therefore feed application in suitable containers will help to maintain water quality conditions apart from minimising feed wastage. The ability to correctly judge and positively respond to the requirements of the culture medium does promote production success (Purushan, 1991). All precautions taken in this regard while supplying feed in all the owner operated farms, especially at Chalippuram produced commendable results.

On comparison with other systems, where indigenous feeds were only used, the strategy adopted at Mundapuram (E) was different. Recognising the importance of nutrient rich high quality feeds in the semi-intensive farming, 7 brands of imported feeds (Plate II A) were made use of. However, owing to the delay caused during import, the sequence of feed supply in the order - starter, grower and finisher - could not be adhered to, leading to topsyturvy nature of distribution. The scarcity of feed was compensated with clam meat. In addition, corresponding to the increase in mean size, feeding frequency was raised giving emphasis to feed adjustments as judged from test trays and distribution techniques. The supply of prawn stronger as appetizer was an exception in this case. However, the culture resulted in an enhanced production of _P. monodon_ (♂ 2.4 tonnes/ha/4 months) with the highest record in Kerala, eventhough the FCR was 1.4:1. This rate did not commensurate the highly nutrient rich quality of imported feed owing to the reasons mentioned.
In 1986, SEAFDEC (Vol 8 (27) demonstrated that with supplemental feeding of commercial pellet (Plate II A) and trash fish added to the natural food in the pond, a record production of 843.35 kg/ha was feasible at a nominal (+10%) stocking rate of 25,000 fry of _P. monodon/_ha. During the 124 days of operation, the fry grew from 0.57 g to 31.42 g with an estimated survival rate of 97.6%.

But, in the present series, still amazing was the results achieved at Chalippuram. The PL22 fry of _P. monodon_ cultured @ 68100/ha grew to an average size of 28 g (155 mm) and attained a production @ 1170.5 kg/ha after 107 days with a survival rate of 75.39%. This stands as the most shining example to indicate the significance of feed and water management among the whole set of investigations made in a variety of culture systems.

In addition to the live feed generation, the feeding technique employed at Chalippuram was quite peculiar both in nutritive contents and method of supply. The _P. monodon_ post larvae were fed ad libitum by a suspension containing ground clam meat, boiled egg and cod liver oil from the very moment of its acclimatisation and conditioning which practice was not followed in any other case. Further, the same feed @ 10% of body weight was supplied once daily during the 2 week nursery rearing. Subsequently, the shrimp juveniles were fed with specially cooked and vitaminised nutritious feed containing clam meat, g.o.c. and rice bran in 6:1:1 ratio.

The use of 250 numbers of wide mouthed earthen trays (Plate VIII A) suspended at fixed points and 3 suitable canoes (Plate XI A) facilitated proper feed distribution in the entire system without disturbing the bottom. The daily feed ration @ 10% body weight and the manner of its application helped to promote efficient utilization without leading to any wastage and associated water quality problems. Because of the systematic approach adopted, no difficulties were encountered or any stress noticed at any time, even when the feed ration was around 100 kg/day towards the fag end of operation. The
freshly prepared palatable feed with better conversion rate induced faster shrimp growth thereby tremendously enhancing quality and quantity of yield within the short culture duration. The quality of feed ingredients, the care and attention bestowed in its preparation, the frugal quantity distribution etc. were the important aspects of management stood unique in the system at Chalippuram when compared with other places.

Artificial feeds/diets can be developed based on nutritional/dietary requirements obtained from food intake studies in the natural habitat/in the wild and in ponds. In the present series, such studies have been pursued in the traditional shrimp culture fields, grow out ponds, miniponds and experimental tanks.

Feed strategies adopted in the contractor operated fields (Group A), showed much similarities than differences among one another. Except for the large amount of organic detritus resulted from the decay of paddy stumps and the usual forage available in the paddy fields, no other feed source was available to the shrimps in the traditional and modified fields at Nayarambalam and Pooyapilly. But, in addition to natural forage, pulversied feed composed of rice bran, ground nut oil cake and shrimp head meal (Plate XXIII A) in equal ratios was supplied in the modified traditional and perennial field at Thrikkadakapilly during the interphase period of filtration. The feed supply ranged from 5 to 8 kg/day during the prolonged culture period of 7 months from August to February.

So also in the improved fields at Ayyampilly and Narakkal, similar type of pulversised feed was supplied daily @ 5-10% of body weight in the additional shrimp seed stocked compartments while distributing only lower doses of feed in other areas. Only after ascertaining considerable advancement in the mean size of shrimps by virtue of the frugal feeding followed in these compartments that the juveniles were permitted to move out to graze in the general system. Both being paddy cultivated fields for decades, there was no shortage
PLATE XXIII

A - Feed ingredients - shrimp head meal

B - Fish meal
of decaying paddy stumps during the ensuing shrimp culture season. Therefore a surplus quantity of natural forage was always available.

On the contrary, no decaying paddy stumps were present in the large and extensive field (Plate V A) at Kuzhupilly where in, the paddy cultivation had been stopped for many years. Nevertheless, other natural forage was available in the vast and perennial water body. Further, considering the magnitude of the extent and the chances of recruitment of enough shrimp seed in the system, supplemental feeding with a pulverised diet made of powdered tapioca, ground nut oil cake and fish meal (Ambassis sp) (Plate XXIII B) in equal ratios was done. Even though the stocking density was not known, a feed ration @ 5-8 kg/day was broadcast during dusk hours altogether providing a quantity of about 700 kg feed during 4 months between December and March.

In the owner operated extensive farms (Group B), though considerable variations in feed and water management occurred between farms, much emphasis was given to generate live feed within. Ever since the time of preparation, this aspect has been well cared. Dry twigs were planted (Plate XIII B) before hand in the farms with a view to generate periphyton for shrimps. Subsequent to shrimp seed stocking, calculated quantity of cowdung as weekly doses @ 2.5 tonne/ha/yr was regularly applied in all farms except at Cherungal and Pallithode. Besides, at Karumancheri, fertilizing with urea was also done at regular weekly intervals in addition to cowdung manuring. These applications were helpful to evolve live feed organisms in the farming systems.

Since known and higher stocking densities of shrimps were employed, supplementary feeding was done in all farms although the type of feed and feed ingredients varied greatly depending on the place and season of farming. More or less similar type of feed in the form of different treatments was supplied in the farms at Narakkal and Puduveypu. The effect of cowdung manuring @ 2.5 tonnes/ha/yr as
fortnightly doses, application of commercial feed pellets (Plate II A) @ 3-5% of mean body weight/day and supply of pulverised feed comprising of rice bran + goc + clam meat @ 5-8% of body weight/day on growth of shrimps was demonstrated at Narakkal and Puduveypu.

During the initial rearing of shrimps in nurseries and ponds, pulverised feed comprising of rice bran and goc in required doses was broadcast at Karumancheri and Pallithode. But in the nurseries at Cherungal (Plate XII A), ground clam meat as ad libitum doses was supplied during the earlier stages. Crushed clam meat @ 5-10% of body weight was supplied during daily evening in farms at Karumancheri, Cherungal and Pallithode and also in the excavated farm at Narakkal. However, in the latter case, the application of feed was not regular on account of short supply of clam meat. But, the daily application of crushed clam meat @ 8-10% of body weight in farm at Karumancheri and steamed clam meat @ 5% of body weight in Pallithode was quite regular throughout the period of farming. However, at Cherungal, apart from supplying clam meat @ 5-8% of body weight regularly, another feed in the form of a half cooked mash comprising goc, rice bran and shrimp head meal incorporated with clotted blood from butcher house was given alternately @ 3-5% of body weight. Thus the type of feed supply and management at Cherungal was more or less similar to that at Chalippuram but, considerably different from that of other farms.

Since suitable containers (Plate XVIII A) and earthen pots (Plate VIII A) were used while applying manures and feeds, necessary control could be effected depending on the response of shrimps in the farming units. As the feed was supplied as ration/day and frugal measures adopted in its application, no water quality problem arose at any time during the farming period. Except for the frequent removal of algal mat developed in the farm at Karumancheri on account of periodic manuring and fertilization, no other side effects were noticed in any other farming systems.

In an experimental series under group C it was observed that
use of organic manures such as poultry droppings and cow dung in calculated quantity was highly effective to promote the growth of P. indicus than buffalo dung. Positively the increased energy contents of the former might have contributed to enhanced fertility resulting in better growth increments of shrimps.

Formulated and compounded feeds prepared from locally available and cheap materials in definite ratios and combinations when applied in specified doses had their clear influence on the growth of P. indicus and P. monodon as demonstrated in similar series of experiments. In general, shrimp growth was seen highly promoted with the application of ground and fresh clam meat exclusively or other diets containing clam meat or shrimp meal (Plate XXIII A) or fish meal (Plate XXIII B) as one of the major ingredients. The quality P. indicus realised in comparatively large numbers from C5 indicated that ingredients of formulated feed such as shrimp meal and mangrove detritus (Plate XXIV A&B) contained required composition to promote shrimp growth with better conversion rate than other feeds with low conversion rate.

In group D experiments, in tanks using natural turbid water, application of increased doses of quality commercial pellet feed (Plate II A) was not effective to obtain satisfactory growth and production of P. indicus. However, better growth was resulted when ground clam meat was fed as observed in the earlier series.

Rapid growth of cultured organism is possible only through a balanced diet. This shows the importance of proper feed and feeding techniques. This can be done in the form of supplemental feed or complete diet. Therefore, it is important to have an insight into the development of feed techniques based on basic nutritional concepts in order to increase production.

The following factors are to be taken into consideration in the formulation of a feed.
PLATE XXIV

A - Detritus - *Avicennia* spp.

B - *Rhizophora* spp.
a) for good agrowth adequate nutrition is essential
b) the dynamic equilibrium of the nutrients in the body must be
   maintained without over/under supply of one
c) nutrient needs are controlled by age, physical activity, body
   size, state of health, growth, reproduction and pathological
   disorder.
d) the feed must have nutrients similar to those found in natural
   feed
e) nutrient requirement of each species must be identified
   separately
f) a variety of feed stuffs may be preferred to one source.

Feed composition

To ensure proper growth, a standard shrimp feed require about
40 dietary ingredients and nutrients grouped under protein and energy
concentrates, roughages, (crude fibre > 18%), minerals, vitamins and

Owing to the slow feeding rate of shrimps, the feed has to be
in the water for 4 to 6 hours. To avoid leaching of nutrients into
water, one of the 8 available binders is often used in preparing feed.
In addition, pigment improvers, chemo-attractants and preservatives are
added. In general 11 formulae are widely accepted.

Pandian (1989) reviewing protein requirements of fish and
prawns cultured in Asia, observed prawns as poor converters than fish
in general. He noted the dietary protein requirement of *Penaeus spp* as
nearly two times higher than the maximum required among fish.
According to him prawns lose over 20% of the converted body substance
at moulting. So prawns receiving low protein diet (< 25%) almost
exhaust the converted energy on exuvia production. According to
Castell and Budson (1974) protein acts both as structural component and
as an energy source in decapods.
Studies on protein requirement for growth (Alava and Lim, 1983; Millamena et al., 1986; Bautista, 1986; Nezaki, 1986) revealed a protein content of 50% as optimal.

There exists considerable differences in dietary requirements of protein between species. Much of the information on nutritional requirements is not readily available as they are proprietary in nature. According to New (1987), a higher protein level (48-60%) is required for *P. japonicus* compared to a low level (35-39%) of *P. monodon*. However, Pandian (1989) has reported a still wider ranges of protein level requirement viz 60-76%, 25-60% and 21-53% for *P. japonicus*, *P. monodon* and *P. indicus* respectively. Studies on amino acid pattern in the diet by Deshimaru and Kuraki (1974) showed the need for 10 amino acids varying with species pattern. Highest percentage weight gain and feed efficiency was found when fed with a diet having closest similarity of amino acid with the particular species; closer the amino acid pattern of the diet, the more effective is the growth.

Alawa and Lim (1983) and Pascual (1989) used squid meal, fish meal, shrimp meal, casein, soybean meal and earth worm meal as protein source in diet with protein content varying from 25 to 60% and found best growth rate with 40% protein diet.

According to Hameed Ali et al. (1982) crustacean wet tissue suspension is reported to be used as larval feed successfully in small scale hatchery operations in India. Thus Mysis and Acetes blended into a fine particulate suspension and graded by fine meshed sieves have been used as the only feed during the entire larval phase and an average larval survival of 44% has been reported.

Both quality and quantity of protein is known to have a significant effect on the growth of shrimp. The weight gain of the shrimps fed with meat may be attributed to the quality of the protein. Alava (1979) found that 40-45% protein is optimal for the growth of *P. monodon* juveniles where as Bages and Sloane (1981) reported 55% protein
level requirement for the early larval stages.

During the present studies, the growth responses of *P. monodon* and *P. indicus* fed with various diets (treatments) were found significantly different. Often weight gain had no relevance with survival rate. Among all feeds clam meat promoted higher growth gains in shrimps irrespective of its supply either alone or in combination with other items. Hence it also served as a substitute for high energy imported feed during semi-intensive farming at Mundapuram (E).

There were considerable variations in the biochemical composition of the different formulated feeds used. In all cases, the percentage carbohydrate level was considerably higher than that of proteins. But, the fat content was very low in all, except in the case of a pulverised feed. The energy content of the feeds ranged between 2771 and 3233 K.cal/kg. The relatively high energy content of formulated feeds prepared from locally available and cheap materials speak well for their large scale use in production systems, although their performance depends upon several other water quality factors.

*P. monodon* post larvae (P/ml) fed to excess with a diet of finely ground cooked mussel meat (Mytilus) had significantly lower weight gain ($P < 0.05$) than those fed with live preadult Artemia (Yashiro, 1987). But survival rate was highest (47%) for P/ml fed with mussel meat than Artemia.

Aside from the nutritional value of feed, other factors could have caused the difference in survival rate. Low survival rate can be attributed to over feeding causing severe fouling and stress as noted by Gopalakrishnan (1976) for *P. merginatus* larvae.

Another cause of mortality was the "jumping" behaviour of the shrimps which resulted in escape or being trapped on the side of the tanks.
Physico-chemical conditions of the water are also important factors affecting the survival of shrimps.

The importance of carbohydrates in the diet was found to be their binding properties in addition to their energy value and protein sparing function.

Lipids and fatty acids were required for the energy value and vitamin value. Millamena and Quinitio (1985) have demonstrated the importance of poly unsaturated fatty acids (PUFA) for larvae for growth and metamorphosis. Mendoza (1982) and Bautista (1986) showed a 10 to 12% lipid content in the diet as optimal and effective in getting good growth and survival.

3.1.7 Water management

The very concept of water quality management is based on the fact that "all other things being equal, a pond with 'good' water quality will produce more and healthier shrimp than one with 'poor' water quality". But one of the major constraints in shrimp farming is inadequate water replenishment leading to reduced stocking density. Supply of vital requirements like oxygen, optimal temperature and salinity, calcium content etc. are closely linked with water management. According to Shigueno (1975), for increasing production, it is imperative to ensure effective water management in ponds. In this connection, it is worth noting that the shrimp body, consists of about 80% water. The importance of water management is (1) it provides living space (b) helps to maintain optimal physico-chemical qualities required for the growth and survival (c) acts as carrier of required feed items (d) helps to eliminate metabolic wastes and (e) promotes fry distribution. In the traditional shrimp culture practices, autostocking of fry is exclusively depended upon tidal processes. It also appears to be the cheapest way of water renewal and hence its significance in the prevailing ecological conditions of the study area. The most inexpensive method of water replenishment for culture ponds is
to make use of the tidal amplitude prevailing in the area. In India, second half of the year usually experiences higher amplitudes. While the amplitude is more than 1 to 1.5 m towards north of 14° Latitude, it is less towards south. Effective water exchange depends upon topography of the site selected. Also deep ponds can hold more water. However, often pumping was necessitated in extensive farming systems to supplement water exchange maintaining optimal water level. But water management exclusively depended on pumping was required in the case of semi-intensive farming at Mundapuram (E).

An alternative to above is to make use of ground water supply involving sophisticated techniques at huge expenditure. Prabhakara Rao and Raghavulu (1982) attempted culture of P. monodon in saline ground waters used for salt manufacture at Kakinada in Andhra Pradesh, after allowing it to flow through shallow evaporation channels. Though the shrimps attained an average size of 123.4 mm (16.7 g) in 135 days, the outcome was not satisfactory.

Basavakumar et al. (1992) based on their studies on the culture of P. monodon in sea water (33 to 40%) at Ankola, Karnataka, brought out the importance of daily water exchange by pumping in addition to tidal intake as an enhancer of profitability in shrimp farming. However, in the study area, on account of socio-economic problems including land lease policy and inability to take advantage of engineering innovations, it was not found feasible. Yet, area to area modifications to a certain extent were made possible in the series of studies as enumerated below in order to maintain optimal conditions so that they were within a desirable range for increased shrimp production from unit area. Often, the water supply to the farms was maintained through a feeder canal. The intake and outflow of water was controlled through one or more sluice gates.

In all shrimp fields (Group A) water management was one exclusively depended on the tidal processes. Except for the exclusively traditional field at Nayarambālam, the life carrying
capacity in all other fields was very much increased by the modifications made in the field structure. The disposition of sluice gates in appropriate and strategic locations was a noteworthy feature in all cases to accomplish the purpose of seed and live feed intake through exchange. But, the number of sluice gates varied according to the size of extent, the larger fields always having more than one sluice gate.

By virtue of the general inclination of the fields towards the main sluice gate and the planned orientation of the dug out canals coalescing with the main sluice pit, it was possible to exchange 15-20% of water daily in all fields taking full advantage of tidal processes. Further increase in water exchange could be achieved at Thrikkadakapilly and Pooyapilly on account of the higher gradient, ranging between 50 - 80 cm. present in the area. Fairly high gradient ranging between 40 and 60 cm. prevailed in all other areas except at Nayarambalam. The traditional field at Nayarambalam was located quite interior and far away from the main feeder source. Hence relatively low tidal amplitude (30-40 cm) occurred in the area with the result that the extent of water exchange was less than 15% per day.

Among group B series, the farms at Narakkal and Puduveypu were suitably located along feeder canals emerging from main water body under the influence of Cochin barmouth. Therefore, the tidal gradient was fairly high and fluctuated between 40 and 60 cm. depending on lunar periodicity. But the tidal rise and fall was relatively low (25-35 cm) at Karumancheri as the farm was situated far interior being connected through a feeder canal with the backwater fed from Cochin barmouth. The farm at Cherungal and the canals at Pallithode were located adjoining a brackishwater lagoon (pozhí) connected to Anthakaranazhi where the tidal oscillation remained between 30 and 50 cm.

The normal water level within the farms varied between 50 and 80 cm. The water entry and exit was through the single sluice gates in the Harijan farm at Narakkal and other farms at Puduveypu,
Karumanncheri and Pallithode. But in the 4 compartments set inside large (8 ha) farm at Narakkal, there were 3 suitably installed sluice gates functioning separately towards the entry and exit of tidal water. So also in the farm at Cherungal, ingress and egress of water was accomplished through separate sluice gates fixed in almost opposite directions. In addition, the permanently fixed 5 HP axial pumping unit (Plate XI B) was a unique facility in this farm for efficient water management. The daily water exchange to the tune of 15-30% could be achieved through tidal processes in all farms depending on the phase of the moon. At times when difficulties were encountered to growing shrimps due to scarcity of water, pumping of water was arranged in all farms. Since diesel engine pump sets were frequently functioning at Narakkal Harijan farm and canals at Pallithode, quality water could be supplied at remote ends maintaining the farming units healthy. But at Cherungal, owing to the unique facility of permanent pumping arrangements, water management in the farm could be accomplished to any level irrespective of the tidal rise and fall. Therefore, taking advantage of this facility, it was quite easy to make water always in motion getting rid of problems of stagnation and enhancing the rate of growth of shrimps. Further, it was also quite easy to raise short duration crops of shrimps in the farm.

The farm at Chalippuram (Fig. 9) being located at a distance of about 12 km. away from Cochin barmouth and the feeder source connected the main backwater body only indirectly, the tidal amplitude was not up to the mark in the area, the gradient oscillated between 40 and 60 cm. Yet, the peculiar design of canals and favourable position of sluice gates helped to maintain a satisfactory tidal flow during exchange. However, frequent pumping was necessary to retain sufficient water level in the fairly deep (1-1.5 m) farm. Eventhough pumping could only build up 7-8 cm. more increase in water level owing to the higher depths, it facilitated circulation of more oxygenated water especially during critical period between 2.00 A.M. and 6.00 A.M. -- the most important single aspect in shrimp pond management. Furthermore, daily replenishment of 30% water by tidal and pumping processes was quite
efficient in removing metabolites considerably, getting rid of stress factors associated with it. Thus the synergistic effect of all the above aspects resulted in the enhanced shrimp production @ 1170 kg/ha/crop which was a record in the present series of investigations.

However, at Mundapuram (E), the water intake and exit functioned at diametrically opposite points (Fig. 11). Further, the continual use of the 9 paddle wheels for aeration (Plate XVII B) which was never used in other cases also enhanced the water in motion. With these perfections, the most successful crop of P. monodon @ 2.4 tonne/ha was achieved during high density farming eventhough water column was maintained only at 70-75 cm with a daily exchange rate of < 25%.

Nandakumar (1982) noted, 25% of water level in coastal ponds, going down per day due to seepage and evaporation and hence pumping of sea water was necessary to maintain the pond water level around 0.75 m.

One way to prevent seepage is by excavation of ponds in such a manner that the pond bottom is at a level lower than the substratum of the source from where water is drawn. Alternately polythene film lined ponds can be used (Lal Mohan and Nandakumaran, 1982).

Optimal level of oxygen can be maintained in the pond water by the development of indigenous contrivances for aeration.

Atmospheric oxygen can be diffused into the water in windy areas by planning the lay out in such a way that the pond water is exposed to maximum wind action (Plate XVIII B).

One of the pre-requisites, for efficient water management at minimal expense, is regular monitoring of various parameters.

Proper water management warrants maintenance of optimal level for dissolved oxygen in the medium, taking into consideration all
aspects leading to oxygen depletion. *P. indicus* has been found to tolerate as low as 1.49 ml oxygen per litre.

In the extensive grow outs where small quantities of feed are used due to low stocking rate, management of water qualities is made easy by regular water exchange. Daily feeding rates of 40 or 50 kg/ha would result in unacceptably low dissolved oxygen in pond water (Boyd, 1989). This may even lead to mortality, diseases, poor growth rates and low FCR. This can be overcome by the use of artificial aeration devices.

**Aeration**

Shrimp farmers use tidal flow and diesel pump (Fig. 9&10) to circulate freshly oxygenated water and to flush out wastes from their extensive and semi-intensive ponds respectively. In addition, all the intensive farmers and semi-intensive farmers use paddle wheel (Fig. 11) (low cost) and aspirating aerators (high cost) and electromechanical devices that add oxygen to the water. Also, simple, non mechanical systems that can be maintained with unskilled labour and which can break up temperature stratification are in use. These blower type aeration deliver air to the bottom of the pond through a network of pipes and tubes.

Ghosh et al. (1987) have confirmed the advantage of installing simple indigenously developed aeration devices in farms for maintaining optimal dissolved oxygen level aimed at increased yields.

As the level of culture intensifies, water management becomes critical with waste accumulation. To a certain extent, an efficient plankton and feed management can reduce the level of waste production. Yet measures for reducing the balance waste and resuspension of sediments are required. Aerators or circulators can help in the resuspension of sediments for removal through water exchange.
3.1.8 Harvest and post harvest technologies

Successful shrimp culture is planned in such a manner that harvest period tunes with high market prevalence for the product. Usually, a sample of shrimp is checked before harvest for synchronous moulting to avoid tainted flavour. If a high proportion of the sample is soft shelled, harvest should be delayed for a day or two to avoid this fragile stage when the product is easily damaged.

In general, shrimps are selectively harvested in our country using a large mesh seine (Plate XXV A) by which method most of the large shrimps are caught. Similar selective harvesting is practised by Japanese also when more than one age group is stocked into the same pond. However, Japanese stocked the pond with additional small shrimps. But, at the traditional filtration fields, this was not usually done resulting in availability of more natural food for the remaining stock. According to Hirasawa (1985), selective harvest of large shrimps allows additional room for smaller shrimps. Probably, this can be the reason for the success of shrimp filtration fields in Kerala.

Multiple harvesting was the method adopted in all the traditional shrimp fields. In the seasonal shrimp filtration fields eventhough operations started during November, initial filtration began at different periods between November and January depending on the location of the field and nature of management. In all cases, sluice gate filtration using suitable bagnets (Plate IV A) was the main harvesting method employed during thakkoms. In general, filtration was usually restricted to only one or two favourable days adjoining the full moon or new moon days as the case may be especially during earlier thakkoms.

In the perennial field at Thrikkadakapilly filtration was carried out during all the 21 thakkoms comprising 154 days within 10 months culture period, where as filtration was restricted to 10
PLATE XXV

A - Harvest - use of seine

B - Cast netting for sampling
thakkoms in the modified traditional fields at Pooyapilly and Kuzhupilly. Since the traditional field at Nayarambalam was far away from the mainstream leading to poor seed recruitment, the filtration was practised during the last 7 thakkoms occurring between January and April months.

In the case of improved fields, owing to the delayed induction of seed, filtration was carried out only on minimum number of days limited to 6 thakkoms between January and April at Ayyampilly and 9 thakkoms between December 88 and April 89 at Narakkal.

Filtration was the only method of harvest practised at Thrikkadakapilly, Pooyapilly and Nayarambalam where as other methods such as cast netting (Plate XXV B) and hand picking (Plate XXVI A) were also employed in the extensive field at Kuzhupilly and improved fields at Ayyampilly and Narakkal. Filtration process could catch the entire shrimp yield at the former three places. However, only part of shrimp yield accounting to 53.02, 58.83 and 76.01% was obtained in the latter three fields respectively. In general, shallow fields of the former series showed better performance in the filtration process. With increasing depth, a dwindling trend in shrimp catch by filtration was quite evident with the notable exception at Thrikkadakapilly. Positively, this field being fairly deep and perennial, all shrimps could be collected by way of filtration, only because of the prolonged nature of operation lasting for 10 months. Moreover, the tidal gradient prevailing in the area being very high, it was possible to entrap all shrimps in the filter bag nets at one time or another during the almost year round operation.

Besides, in the latter three fields, the share of shrimps obtained by cast netting (Plate XXVI B) was 35.76, 31.36 and 16.65% respectively against the corresponding figures of 11.22, 9.81 and 7.34% attained during hand picking.

The quality of shrimps obtained through filtration was superior
to those of other methods. Lesser quality shrimps were collected by cast netting where as medium quality shrimps were available through hand picking in all cases.

Perennial and extensive fields at Thrikkadakapilly and Kuzhupilly produced a sizeable quantity of shrimps of large size (> 15g). This can be due to the relative increase in the depth of fields and also the prolonged culture duration promoting the shrimps to acquire better sizes. Above factors are given due significance while leasing out the fields for commercial shrimp farming.

In the traditional and modified fields, metapenaeids and small ones dominated over that of _P. indicus_ (Plate XXVII A). On the contrary, the selective seed induction adopted could enhance the share of _P. indicus_ production to the level of 92.7% at Ayyampilly and 70.7% at Narakkal leaving only negligible percentages for low prized shrimps. A matter of concern is the premature sacrifice of a large number of undersized ones owing to the strictly restricted farming season in the traditional fields.

In Kerala, due to relatively low tidal gradient, no impairment of quality was noticed after filtration while in Malaysia a large number of shrimps are damaged or killed by high water pressure.

In the group B, experimental culture ponds, harvesting was done both by cast netting and hand picking (Plate XXVI A). Filtration was not practised.

Complete harvest was accomplished in different manners such as - 'on a single day', 'continuously for three days', 'on two days at an interval of 4 weeks' and 'daily harvesting continued during the last two weeks'. Cast netting (Plate XXVI B) was done after retaining minimum water level by ebbing. Water was completely drained by pumping for hand picking.
PLATE XXVI

A - Harvest - Hand picking

B - Harvest - Cast netting
Harvesting was done in a day in all compartments at Narakkal on 80th day, in the ponds at Puduveypu on 85th day and canals at Pallithode on the 89th day.

At Narakkal Harijan farm harvesting was done on two occasions by cast netting at an interval of 4 weeks. First harvest after 10 weeks realised 82.5% and 2nd harvest after 14 weeks collected 17.5%.

Cast netting by 4 persons at Chalippuram catching 1273 kg (98.87%) of *P. monodon* (Plate XXVII B) in 4 days was the most efficient technique, leaving only 14.5 kg (1.13%) for hand picking. Complete draining accomplished within a fortnight also enabled to pick up the negligible percentage of intruder shrimps such as *P. indicus* and metapenaeids from the farm.

Selective harvesting by cast netting of *P. indicus* > 5g was practised daily at Cherungal from 45th to 60th day taking care to return the younger ones into the farm. During the first week, while the quantity of shrimps collected was 15-20 kg/day, it was gradually raised to 25-35 kg/day during 2nd week thereby collecting 52.44%. Rest was harvested on the 60th day by cast netting followed by hand picking. In all, 77.22% of the yield was collected by cast netting and 22.78% by hand picking.

At Karumancheri, two crops were raised in the same farm in two different seasons in an year. During the first crop, *P. monodon* raised within 115 days was harvested by cast netting for three days followed by hand picking after complete draining of water. The second crop of *P. indicus* (Plate XXVII A) was harvested in a single day after 87 days. Cast netting followed by hand picking was employed as above.

Planned and nonselective harvest was accomplished within 5 days at Mundapuram (Group E) after 120 days of farming. Since water management was at will in this semi-intensive farm, 95% of the *P. monodon* (Plate XXVII B) was bagged through drain gate during
PLATE I

A - Shrimp post-larvae

B - Post-larvae under hapa rearing
favourable ebbing time. The rest was collected by cast netting (Plate XXVI B) and hand picking (Plate XXVI A) along with complete draining.

The continuous harvesting Indian method as opposed to the batch method of foreign countries mainly warranted additional harvesting labour adding to variable cost. However, the method of selective harvesting is very much important in temperate countries where they have to keep post larvae in small ponds until favourable temperature conditions set in.

On account of the differences in handling after harvest, there occurs a price advantage of farm raised shrimps over ocean caught ones. Further, disposal of shrimps after harvest was not a problem at any time owing to the evergrowing export demand.

Since many bidders came forward in search of shrimps during harvest time, the need for post harvest technology is limited at the farm gate. In all cases, the harvested shrimps were cleaned, categorised and graded according to prevailing market trend. At times, shrimps obtained through filtration during odd horus at night were properly iced and kept ready for disposal. All categories of shrimps were sold at competitive rates on per kg. basis at farm gate itself realising maximum unit price. Nevertheless, the rate of shrimps varied much, depending on the season of operation and also location of the farm. Since shrimps of better quality and facilities for post-harvest processing were easily available, relatively high rates for shrimps were realised at farms in Vypeen island than at other places.

3.1.9 Growth studies

The ultimate aim of studies carried out by way of a series of experiments (Group A to E) is enhanced production of shrimps from unit area. This in essence means increased growth rate by length and weight on a per day basis with least mortality which is the cumulative effect of a number of biotic and abiotic factors. Any shortfall in the
interaction of above factors is likely to be detrimental to the desired output as happened in the 'E' series of the present investigations. Hence the growth measurements are of significance in any sort of studies pertaining to culture systems.

A critical review of the literature indicates paucity of comparable data due to their diversified nature, even though many deal with growth aspects. Also majority has not made any attempt to relate growth increment with that of production. Hence in the present series of growth studies, the growth increment data are correlated with respect to the culture systems, as well with that of other studies.

Shrimp culture studies in the traditional fields (Group A1-A6) indicated occurrence of quality _P. indicus_ with higher mean growths (15.44 g/129.5 mm) and (15.25 g/130.5 mm) in the deep and extensive fields at Kuzhupilly and Thrikkadakapilly where as the lowest mean growth (12.58 g/121.1 mm) was noticed at the exclusive traditional field at Nayarambalam. Rest three fields designated as modified traditional and improved exhibited a mean growth of 13.65 g/122.5 mm to 14.08 g/123.1 mm (Table 9). The present data based on the 'unique' filtration technique practised in the study area are not comparable with data from other areas owing to the autostocking process adopted in seed recruitment. Also, studies on _P. indicus_ indicated that growth rate varied considerably in the estuarine waters from place to place and in different environments, probably depending on the food availability and prevalence of favourable environmental factors.

George (1974) recorded a model size of 126-130 mm for _P. indicus_ from seasonal fields and 136-140 mm from the perennial fields of the study area. George (1975) recorded a monthly mean growth of 15 mm for _P. indicus_ in a paddy field where as Paulinose et al. (1981) obtained 19.0 to 30.4 mm during January - February period in cage culture at Cochin. In the traditional pokkali fields of Vypeen, Gopalan et al. (1982) recorded a growth rate of 1.71, 1.02 and 1.13 mm/day when harvested at the end of 4, 8 and 12 weeks attaining a model
length of 84 mm (3.76 g), 93 mm (5.35 g) and 117 mm (11.22 g) respectively from an initial mean size of 36 mm (0.272 g).

The experimental growth studies of _P. indicus_ (Table 18) carried out in 5 grow outs (Group B) revealed that the highest growth rate in terms of length and weight was associated with the pokkali fields at Narakkal (0.166 g/1.31 mm) and Karumancheri (0.155 g/1.356 mm) where as the lowest (0.088 g/0.7 mm) was at the newly excavated farm, Narakkal. But even following the same stocking density, feed and other management aspects, the growth rate of 0.108 g/0.8 mm attained at Puduveypu was very much inferior when compared with the pokkali fields at Narakkal. However, at Cherungal, the higher growth rate (0.11 g/1.61 mm) per day noticed was on account of the shorter culture duration limited to 60 days.

Nandakumar (1982) carried out three experiments in the culture ponds at Mandapam during 1978-79. _P. indicus_ at a stocking rate of 5 nos/m², with supplementary feed (clam meat and minced fresh trash fish @ 10% of body weight) showed a growth rate of 0.62 mm/day for 158 days where as those fed with natural food elements produced by application of inorganic fertilizers (urea and superphosphate in the ratio of 4:1 @ 100 kg/ha) grew 0.64 mm/day for 78 days. At the end of 158 days, the mean was 0.30 mm. These rates are higher than those observed by Hall (1962), Subrahmanyam (1968) and George (1975) for _P. indicus_ and compare well with the growth rate of _P. monodon_ in the culture ponds at Philippines (Delmendo and Rahanal, 1956) and of _P. indicus_ in cage culture (Rajendran and Sampath, 1975) and at Narakkal (CMFRI, 1978). Sampath and Menon (1975) noted a growth rate of 0.99 mm/day in _P. indicus_ during the 95 days of cage culture with artificial feed. George (1961) recorded a faster daily growth rate of 1.39 mm in the brown shrimp _P. azetecus_ from the estuaries of Louisiana (USA). Nandakumar (1982) recorded a growth rate of 0.482 mm/day for _P. semisulcatus_ on par with _P. indicus_ as observed by George (1975).

Kunju (1978) observed a direct relationship between growth of
shrimps and the amount and quality of feed required. Slower growth rate due to non availability of proper food after 60 days was reported for _P. indicus_ (Sampath and Menon, 1975). Rajendran and Sampath (1975) noticed better survival and growth rates and Sampath and Menon (1975) found faster growth in _P. indicus_ which were given artificial feed in cage culture in Kovalam. Nandakumar (1982) noted reduced growth rate after 78 days for _P. indicus_ without supplementary feed. Siddharaju and Ramachandra Menon (1982) estimated average growth of _P. indicus_ during cage culture at Kovalam, to be 18.5 mm/month and 29.8 mm/month in 120 and 90 days rearing respectively, where as in the natural environment of Kovalam backwaters, monthly growth ranged from 15 mm to 28 mm (CMFRI, 1975). _P. indicus_ recorded a highest growth rate of 24 mm/month in the backwaters of Madras.

_P. indicus_ post larvae with an average length of 42 mm when stocked @ 100/m² in Adyar estuary, grew to an average length of 81.4 mm on the 110th day resulting in a yield of 400 g/m² (Natarajan and Jalaluddin, 1982).

Jose et al. (1987) observed that _P. indicus_ post larvae of initial size 15 mm when stocked in Vytilla pokkali fields at a density of 3/m² grew to a mean size of 93 mm (4.5 g) in 36 days with 74% retrieval. Similarly, when post larvae of 14 mm (11 mg) size, stocked @ 6/m² in the pokkali fields at Narakkal and Edavannakkad in Vypeen island attained mean size of 130 mm (14.2 g) and 126 mm (13.5 g) in 83 and 90 days respectively.

Comparative studies on the growth of _P. indicus_ (Table 33a) in 6 sets (Group C) carried out at Puduveypu exhibited differential growth gains with respect to treatments. The salient observations are presented below.

Two different sets of experiments (C1&C2) with varying stocking densities showed that stocking @ 1 lakh/ha was satisfactory for the production of quality _P. indicus_ (6.494 g/83.9 mm and 7.74 g/55.5 mm).
<table>
<thead>
<tr>
<th>Type of No. culture system</th>
<th>Stocking density g/sm²</th>
<th>Initial size g/sm²</th>
<th>Growth gain g/sm²</th>
<th>Type of feed</th>
<th>Type of water management</th>
<th>Cultureduration days</th>
<th>Production rate kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1. Mini pond (10)</td>
<td>0.029/16.2</td>
<td>6.494/83.9</td>
<td>Commercial pellet</td>
<td>Tidal + pumping (25-30% exchange)</td>
<td>93</td>
<td>430.95</td>
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<td></td>
<td>1.50,000</td>
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<td>2.50,000</td>
<td>4.826/77.6</td>
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<td>513.36</td>
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<td>C2 Mini pond (10)</td>
<td>0.848/53.0</td>
<td>7.74/55.5</td>
<td>Cowdung manure and pulv. feed containing fish meal detritus, goc and tapioca flour in 4:3:2:1 ratio</td>
<td>Tidal + pumping (25-30% exchange)</td>
<td>70</td>
<td>516.00</td>
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<td></td>
<td>1.50,000</td>
<td>3.424/32.5</td>
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<td>432.00</td>
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<td></td>
<td>2.00,000</td>
<td>2.074/21.7</td>
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<td>373.00</td>
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<td>C3 Mini pond (10)</td>
<td>0.155/28.0</td>
<td>2.179/42.3</td>
<td>Buffalo dung</td>
<td>Tidal + pumping (25-30% exchange)</td>
<td>60</td>
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<td></td>
<td>1.00,000</td>
<td>3.145/50.8</td>
<td>Cowdung manure</td>
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<td></td>
<td>4.226/49.4</td>
<td>3.287/52.3</td>
<td>Poultry droppings</td>
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<td></td>
<td>3.822/50.8</td>
<td>2.259/47.2</td>
<td>Control</td>
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<td>-</td>
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<td>C4 Mini pond (10)</td>
<td>0.385/39.8</td>
<td>3.631/44.0</td>
<td>Feed 1</td>
<td>Tidal + pumping (25-30% exchange)</td>
<td>42</td>
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<td></td>
<td>5.145/58.0</td>
<td>3.145/50.8</td>
<td>Feed 2</td>
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<td>4.226/49.4</td>
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<td>Feed 3</td>
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<td>3.822/50.8</td>
<td>2.259/47.2</td>
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<td>C5 Mini pond (10)</td>
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<td>12.67/104.5</td>
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<td>11.721/99.6</td>
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<td>11.721/99.6</td>
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<td>3.466/41.5</td>
<td>3.466/41.5</td>
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<td>C6 Pumped pond (40)</td>
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<td>3.466/41.5</td>
<td>Crushed clam meat</td>
<td>Pump fed (70% exchange)</td>
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<td>2.050/10.0</td>
<td>1.498/11.0</td>
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<td>Seepage water oscillating between 30-50 cm level</td>
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Table 33 b

<table>
<thead>
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<th>Type of No. culture system</th>
<th>Stocking density g/sm²</th>
<th>Initial size g/sm²</th>
<th>Growth gain g/sm²</th>
<th>Type of feed</th>
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<th>Cultureduration days</th>
<th>Production rate kg/ha</th>
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<td>C7 Eastern pool (25)</td>
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<td>1.498/11.0</td>
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<td>0.010/10.0</td>
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<td>Seepage water oscillating between 30-50 cm level</td>
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<td>C8 Mini pond (2)</td>
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<td>41.92/103.6</td>
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<td>Tidal + pumping (30% exchange)</td>
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</tbody>
</table>
Of the two types of feed used in the culture of *P. indicus*, formulated feed (C2) was found superior to the commercial feed (C1) at a stocking density of 10 per m².

Of the three manures used (C3), poultry droppings and cow dung were seen highly effective to promote *P. indicus* growth (3.287 g/52.3 mm and 3.145 g/50.8 mm) compared to buffalo dung (2.179 g/42.3 mm).

Among the different feeds with varying energy contents (C4&C5), the feeds consisting of fish meal or shrimp meal along with other ingredients having high energy contents (Feed 1&4 in C5) were found best to promote the growth of *P. indicus*.

Experimental studies at Puduveypu demonstrated a higher yield of *P. indicus* (800 kg/ha) in the pump fed pond (C6) over that of tidal ponds (241.0 kg/ha).

Similarly, the following inferences were drawn from the results of pilot studies on *P. monodon* (Table 33b) undertaken in mini ponds under natural turbid water conditions at Puduveypu.

Experimental studies on *P. monodon* at Puduveypu (C7) indicated superiority of wild fry over that of hatchery fry.

Clam meat when fed to *P. monodon* juvenile (C8), the growth size achieved was remarkable.

Further, as presented in Table 34, the comparative analysis of the experimental studies on *P. indicus* in tanks (D1-D5) brought out the following conclusions.

In the experimental studies in cement tanks (D1), clam meat fed *P. indicus* showed better growth.
<table>
<thead>
<tr>
<th>S1. No.</th>
<th>Type of culture</th>
<th>Stocking density</th>
<th>Initial size</th>
<th>Growth gain</th>
<th>Type of feed</th>
<th>Type of water</th>
<th>Culture duration</th>
<th>Management days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>no/ha(no/m³)</td>
<td>g/m²</td>
<td>g/cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D1</td>
<td>Circular cement tanks</td>
<td>5,00,000 (50)</td>
<td>0.112/27.4</td>
<td>3.36/55.6</td>
<td>Crushed clam meat</td>
<td>Pumped water filtered through 100 μm sieve (70% exchange)</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.20/53.2</td>
<td>Pellets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.56/48.2</td>
<td>Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D2</td>
<td>Circular cement tanks</td>
<td>8,50,000 (85)</td>
<td>0.196/32.2</td>
<td>1.50/31.9</td>
<td>Pellets @5% of body wt.</td>
<td>Pumped water filtered through 100 μm sieve (70% exchange)</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.93/36.9</td>
<td>Pellets @10% of body wt.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.94/23.5</td>
<td>Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D3</td>
<td>Oval shaped fibre glass tanks</td>
<td>2,00,000 (20)</td>
<td>0.03/17.7</td>
<td>3.74/66.9</td>
<td>Locally made compounded feed @ 5-10% of body weight (50% exchange)</td>
<td>Pumped water filtered through 100 μm sieve (50% exchange)</td>
<td>42</td>
<td></td>
</tr>
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<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>4.00/50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.38/57.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.00/60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.72/46.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.00/80</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.23/41.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D4</td>
<td>Circular cement tank</td>
<td>10,00,000 (100)</td>
<td>0.789/49.2</td>
<td>2.46/32.8</td>
<td>Crushed clam meat @ 8-10% of body wt.</td>
<td>Pumped water filtered through 100 μm sieve (70% exchange)</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D5</td>
<td>Circular cement tank</td>
<td>80,00,000 (800)</td>
<td>0.128/24.2</td>
<td>0.72/26.5</td>
<td>Crushed clam meat @ 8-10% of body wt.</td>
<td>Pumped water filtered through 100 μm sieve (70% exchange)</td>
<td>55</td>
<td></td>
</tr>
</tbody>
</table>
P. indicus when fed with pellets @ 10% of body weight grew better than @ 5% (D2).

The growth rate of P. indicus cultured in the fibre glass tanks (D3) was inversely proportional to the stocking density.

Experimental stocking of 100 juveniles/m$^3$ and 800 fry/m$^3$ of P. indicus (D4&D5) was not proved successful since the mortality in either case was exceeding 70%.

It is generally believed that using high density stocking (100/m$^3$), the lower survival rate can be balanced. But during the present study series (Group C & D), after scrutiny of the data, it is found that lower density helps for higher yields. Similar study in Thailand showed maximum profitability in intensive shrimp culture at a stocking rate of 20-30/m$^2$ with an average daily gain of 0.27 g (Asian Shrimp News, 1st Quarter, 1992).

The P. monodon shrimps grown in brackish water ponds at Madras (Venketesan and Bose, 1982) attained an average size of 154.5 mm and a weight of 25.7 g in 90 days at a stocking density of 25000/ha and 129.5 mm and 14.4 g in 90 days at a density of 40,000/ha. The results indicate high growth rate at low stocking densities. Sundararajan et al. (1979) suggested an optimal density of 20,000 P. monodon as optimum when they obtained an average weight of 32.26 g in 80 days. Chen (1976) reported a growth rate of 40 g in 90 days rearing at lower stocking densities of 5000 to 8000/ha in Taiwan when shrimp and chanos were cultivated.

P. monodon showed a rapid growth rate of 25 mm/month in the younger stage, but the growth rate slowed down considerably as the animal attained adulthood (CMFRI, 1975).

But, 15 mm (20 mg) post larvae of P. monodon stocked @ 22.5/m$^2$ in the semi-intensive culture farm at Mundapuram (Group E) attained a
mean size of 150 mm (28.0 g) within 120 days registering a mean growth rate of 34 mm (7.0 g) per month. Also _P. monodon_ post larvae (22 mm/0.030 g) when stocked @ 6.8/m² at Chalippuram attained a mean size of 155 mm (28.0 g) in 107 days, the monthly mean growth being 37.3 mm (7.842 g). Thus Chalippuram growout presented the best growth rate among the studies carried out.

3.1.10 **Economics of shrimp farming as revealed through case studies**

One of the serious constraints in the studies regarding economics of shrimp farming is that comparisons and conclusions are made difficult due to the wide variations in culture practices, shrimp species selected and the regional variations in climate. Quite often, the rate of production in an area is given as metric tonne/ha/yr without specifying whether it is a seasonal farm where only one crop is possible or a perennial/scientific farm where more than one crop/year is feasible. Also reliable economic data on actual commercial production are scarce.

Hirasawa (1985) analysed in detail the economics of shrimp culture in Asia, based on the type of production systems, investment costs and the present and expected future markets. He suggested the need to reduce the cost of cultured shrimps because of severe competition in the market. According to him, the intensive pond system will face extinction, since it is difficult to cut production cost, in case the cost of shrimp falls down. Hence, he has advocated the extensive and semi-intensive farming methods by which shrimps can be produced at low cost.

Shang (1983) made a general survey of shrimp farming in Asian countries, Ecuador and USA to show the variation in costs and returns. According to him, the average gross revenue per unit area of monoculture farms growing tiger shrimps is about double that of polyculture farms growing the same shrimps together with milksfish and crab. He further
reported that the average return on operating costs ranges from 11 to 118% indicating that all farms were profitable. The lowest returns were from places where labour costs, capital investments and management costs were high. This was confirmed by Griffin et al. (1985) who found the internal rate of return from a 200 ha farm in Ecuador to be 2.8 times that of similar one in the USA with high variable costs.

Jhingran (1977) working out the cost of production and projected unit economics by experimental culture operations observed that a net return of Rs.30000/- was feasible through shrimp culture in brackishwater ponds in West Bengal.

Shrimp culture and its economics were dealt with through 16 papers presented during the first National symposium on shrimp farming (MPEDA, 1980). The results were found sufficiently realistic and indicative, but not perfect owing to variations in capital investment from place to place. Based on their studies at Ratnagiri, Raje and Ranade (1980) indicated that the lowest rate of profit @ 30 to 35% was quite attractive.

Reddi (1980) demonstrated the economic viability of fish and prawn culture in the salt pans in Kakkinada area. The economics of a 0.78 ha farm with a single wooden sluice gate, located in the vast "gazani" areas of N. Kanara district (Karnataka) following the traditional practice of trapping and holding, in stocking the farm was worked by Pai et al. (1982). The entrepreneur, with proprietary rights over the farm, even assuming that rent, 15% interest on capital investment and recoupment of capital were allowed, got a net profit of 80% return on the capital. George (1980) observed in the Pokkali fields of Vypeen, Kerala that it is possible to have 2 harvests in the seasonal fields and 3 in the perennial fields thus making it more remunerative.

The author in an earlier case study (Gopalan et al., 1980) on the economics of an improved method of paddy field shrimp culture in
Vypeen island found that the amount of profit was directly proportional to the quality of shrimps like _P. indicus_ and inversely proportional to the quantity of other species realised. Further the results showed that the improved method of operation incurring more initial expenditure was economically more advantages than the traditional one.

Jose et al. (1987) working out the feasibility and economic viability of selective culture of _P. indicus_ in pokkali fields, recorded a production of 552 kg/ha/83 days and 382 kg/ha/90 days at Narakkal and Edavanakkad, yielding a net profit of Rs. 3958 and Rs.8250 respectively.

The author in a recent study (Purushan, 1987) concluded that by structural modifications of the traditional farms and inductions of healthy fry at large, quality shrimp can be produced, thereby raising economic returns.

Economics studies on semi-intensive shrimp farming at Nellure, TASPARC farm and certain other farms in Andhra Pradesh (Surendran et al., 1991; Haran et al., 1992 and Viswakumar, 1992) are the latest in this series.

All the above studies have confirmed the wide variability of investment and production costs in different areas.

In all the 6 case studies carried out by the author in the traditional fields (Group A) there were variations in the average lease value per unit area. The lowest lease value @ Rs.4,370.37/ha was at the modified traditional field at Kuzhupilly and the highest rate of Rs.14,450/ha at the improved field at Ayyampilly. The lease amount was the major cost component in all cases ranging from 35.29% at Narakkal to 55.32% at Nayarambalam (Table 35a). The next cost component was that of labour which was highest (41.42%) in the modified traditional field at Kuzhupilly and lowest (23.96%) in the traditional field at Nayarambalam. The expenditure components of seed induction in respect
of improved fields at Ayyampilly and Narakkal were 4.65 and 14.31% respectively, where as other four fields were devoid of additional expenses on seed component, since they were run by autostocking processes alone. The expenditure component towards operation was the lowest (4.97%) at the improved field at Ayyampilly against higher figures above 10% incurred in modified traditional fields at Thrikkadakapilly and Kuzhupilly and in the traditional field at Nayarambalam. The cost component towards sluice gates constituted between 3 and 8% with the low and high figures seen at Kuzhupilly and Pooyapilly. The expenditure of net items also varied similarly within the range of 2.8 and 6.4%. The feed and sundry items were the lowest cost component in all the 6 cases.

The cost of shrimp production/kg. was the lowest (Rs.16.25) in the modified field at Pooyapilly (A2) and the highest (Rs.30.95) in the improved field at Ayyampilly (A5), the respective values in other places remaining in between. In general, along with increase in quality shrimp yields, the cost of shrimp production was higher at improved fields than at modified traditional fields with low production costs. In this context, it is worth pointing out that being poly culture systems, the substantial amount realised through disposal of fishes and other components has helped to reduce the production cost of shrimps. But on account of high demand of the field and concomittant increase in lease amount, the cost of shrimp production at the traditional field (A1) was also higher with out much difference from that of improved fields. However, a moderate cost of production prevailed at the large extensive field at Kuzhupilly in spite of spending huge amount towards labour. It is evident from the study that relatively low lease rate and large size were factors favouring low cost in production of shrimps.

The level of profit was seen related to the extent of modification adopted in the farming practice. In the present studies, only marginal profit of 5.84% was realised at the exclusively traditional field (A1) against a fairly good margin of 31.79% and
19.25% attained in the improved farming practices at Narakkal (A6) and Ayyampilly (A5) respectively. Absence of quality shrimps and the low productivity rate generally lead to low profit in traditional field (A1). The margin of 26.53% obtained from the modified field at Kuzhupilly (A4) was indicative of the worthiness of the larger size of field in the extensive practices, eventhough there was slight increase in the cost of shrimp production. However, the generally improved quality of the produce could surpass the increase in cost of production on comparison with fields at Thrikkadakapilly (A3) and Pooyapilly (A2). On the whole, it is quite clear that modifications in the structure of traditional fields and induction of seed together play an effective role in improving the quality and quantity of yield having its positive impact on economic gains in shrimp farming. Purushan (1987) in an earlier communication has pointed out the prospects of enhanced shrimp production from traditional fields.

In the case of group B series (B3 to B7), the expenditure towards seed, feed, labour and other operational aspects - the major cost components - varied very much according to the level of management technology adopted (Table 18). But in contrast to group A fields, the lease value was not accounted except for the one at Cherungal (B6). Further, the grow outs being scientifically managed, substantial cost was met towards seed and feed which was rarely required in group A. Labour constituted the highest component (25-35%). While the cost of feed varied between 13-35% that of seed ranged between 8.4 and 30.0% depending upon the species and type of feed. Among other operational aspects, the regular pumping resorted for better water management and circulation incurred added expenditure as exemplified at Chalippuram (B5) and Cherungal (B6).

The economic analysis revealed that return on investment (ROI) was related to the species and type of management technology adopted. The profit level was infinitely low in those farms where P. indicus was farmed where as huge profit margins were realized with P. monodon (Table 18). However, an exceptional performance during the farming of
P. indicus with 125.04% (R01) was seen at Karumancheri (B7b) against the very poor margin of 13.53% (R01) at Narakkal Harijan Farm (B3). Even though the relatively high profit of 38.73% (R01) realized at Cherungal was not matching with that of Karumancheri (B7b) it has indicated chances of realising more short duration crops within favourable season.

In respect of P. monodon farming, the highest profit of 236.61% (R01) was achieved at Pallithode (B4) followed by 191.61% at Karumancheri (B7a) and 76.87% at Chalippuram (B5). Even though, the former two cases were seen very much remunerative apparently, the quantum profit realization was low due to their smaller extent. On the contrary, the huge profit margin @ Rs.76649/ha realised at Chalippuram (B5) made it all the more attractive on comparison with others. This success can probably be on account of the innovative technology and the manageable size of the unit, as well.

In the semi-intensive farm at Mundappuram (Group E), highest expenditure was incurred on feed (43%) followed by wages. The seed cost constituted 12.11% against 11.5% for farm preparations. Almost 12.92% was spent on other expenses including lease value, farm maintenance and depreciation on capital expenses, where as, only 7% was incurred for fuel. However, the farming resulted in a profit of Rs.52312.79/ha which worked out to 16.9% return on investment (Table 32b).

Data collection for aquaculture economic studies

A reliable estimation of parameters warrants collection of data from a sufficient number of farms in order to explain the output variations through a production function.

Data on inputs, output, prices and costs can be obtained from:

1) many aquaculture farms for a single production cycle
2) one farm for numerous production cycles or

3) many farms over time - the most desirable but rarely available one.

These data types are respectively cross-sectional data, time series data and time series of cross section (Garrod and Aslam, 1977). But, what is done is analysis of cross sectional data collected in record keeping farms from randomly chosen production areas.

**Economic justification**

The change in trend towards more intensive management of shrimp farms is important from an economic point of view. The duration of growing season is relatively short in Kerala restricting to summer months between November and April. Cost of land or lease charges and pond construction costs are on the increase year after year (Table 35a). So to be competitive internationally, culture facilities available must be highly productive and efficient during the short growing season. In economic terms, the proportion of fixed costs relative to variable costs (ie. seed, feed and energy) must be reduced by increasing production rate. But the annoying part is that variable costs are always on the increase, making it impossible to produce beyond a certain level.

The bestway to reduce the high fixed cost is to convert the farms as intensive/semi-intensive as practised in countries like Taiwan and Ecuador. But, it has got considerable limitations in our farming situations. Usually the paddy cum shrimp filtration fields in Kerala are leased out at rates depending upon fluctuating market trend which varied from Rs.4370.37 to Rs.14,450/ha. compared to the land costs of over $2500/ha. in Ecuador and $2.5 to 5 lakh/ha in Taiwan (Anon, 1987). As a result of variations in the lease amount, it is not easy to determine standard cost for each farm in India. Eventhough on a per ha basis, expenditure is relatively low in Kerala owing to the leasing
practice, the production cost is fairly high on a per kg. basis because of the reduced yield. In fact, the unhealthy competition prevailing to take over the field on lease contribute much to the total cost of production in Kerala regardless of the factors associated in its operation. Lack of proper management aspects and general nature of impoverished back water conditions do not help to attain higher yields in traditional systems. More often the dwindling yield (Purushan and Rajendran, 1984) fluctuates from field to field and in the same field from season to season. However, owing to the high unit price, shrimp culture is found 3 to 5 times more profitable than paddy culture.

The sad part regarding intensive farming is that the variable costs are on the increase. The naturally available feed, aeration through tidal processes and good quality water made use of in extensive systems must be supplemented at higher levels of intensification of the technology. The quality and quantity of natural food organisms available in the fields/ponds is reduced with increasing density necessitating to supplementary feed of high cost. The cost of shrimp production mounted up very high at the semi-intensive farm at Mundapuram (group E) compared to the most successful extensive farm at Chalippuram (B5).

As costs of variables rise, the intensive management is less profitable per kg. but the sheer increase in number of kgs. can improve profitability on a per ha basis as seen successful in countries like Taiwan. But such hitech practices are not yet developed or found feasible in the agrarian set up of our country. But recently, a joint effort of Kingfisheries, Kollam and MPEDA, Kochi has been reported to achieve production @ 2 tonne/ha./100 days of quality P. indicus from traditional fields at Ezhupunna by way of semi-intensive farming (Anon, 1992). Still encouraging was the record production @ 2.4 tonne/ha/120 days attained in a semi-intensive farming at Kannur during 1992, the details of which are presented under 2-4-E of the study.

In the case of Taiwan/Ecuador/Kerala example, it is more
profitable to make $0.50/kg on 12000 kg/ha ($6000/ha) than $2/kg on 5000 kg/ha (Anon, 1987). The production from Indian farms remaining at an average level of 538 kg/ha through our extensive farming practices, the per ha gain can be on par with that of Ecuador, but far below from what Taiwanese have attained.

In this context, it is worth noting the significance of extensive farming of *P. indicus*, realising still higher production @ 677 kg/ha and 622.44 kg/ha at Cherungal (B6) and Karumancheri (B7b) respectively, within short duration. Still more fascinating was the record production @ 1170.45 kg/ha attained at Chalippuram (B5) in the case of *P. monodon* with high economic return.

A comparison between the most successful farms at Chalippuram (BS) and Mundapuram (E) showed that the highest profit margin was achieved at Chalippuram where indigenous farming technology using local feed dominated by clam meat and additional water circulation by pumping was practised (BS). A disadvantage of the semi-intensive farm (E) was that the exceedingly higher cost of imported feed, the avoidable managerial cost, the superfluous use of aerator devices etc. added the production cost considerably (Table 32b). Hence, even with the highest production, ie @ 2.4 tonne/ha, the semi-intensive farming technique did not cope with the highest economic returns of the indigenous technology practised at Chalippuram (BS).

The data presented in Table 35b shows that shrimp production costs went up with the level of technology followed. While Rs.126/- was spent to produce one kg *P. monodon* in semi-intensive manner (group E), it was between Rs. 27.24 and 85.19 during the extensive farming (group B4, 5 & 7a). In the case of *P. indicus* it varied between Rs.15.72 and 27.66 per kg (B3, 6 & 7b). More or less similar was the cost of production of *P. indicus* in traditional fields (group A) as already discussed (Table 35). The data clearly denoted that while the expenses due to additional feed supply and water management added up the production cost in the extensive grow outs, it was the spiralling
lease value which determined the same in traditional fields.

In a comparative study at 5 farms adopting three different practices in Andhra Pradesh, Viswakumar (1992) estimated 14 fold increase in cost of production between extensive farming with supplementary feeding and semi-intensive farming. Also the operational profit indicated a 10 fold increase while the net profit per kg of shrimps produced decreased from Rs. 50 to 24.87 correspondingly.

Experiments on intensive culture of _P. japonicus_ (123/m²) conducted by Shigueno (1975) in Japan revealed the possibility of harvesting a crop at a rate of 2.26 kg/m² in 180 days. According to Mock (1973), an intensive culture at a stocking density of 156/m² yielded a production of 0.7 kg/m² in closed race-ways in 63 days. Even in the case of "Shigueno Style" super intensive system in Japan which produced about 20,000 kg/ha/crop it had financial crisis as a result of increased energy costs. It is worth remembering that supply of shrimps are on the increase as aquaculture continues.

The aforesaid being the trend in shrimp production, it is quite likely that there may occur a price reduction of shrimps in international market proving detrimental to the hitech shrimp farming countries at high costs (Hirasawa, 1985). Even in such situations, there lies immense scope for the well managed extensive shrimp farming practices in Asia followed by India, the endeavour always keeping a positive cost-benefit margin. Cost forecast for cultured shrimps seems to indicate that extensive and semi-intensive method will become dominant in the Asian region. The present low productivity of the systems can be greatly improved by proper management techniques.

In this background, the most sensible approach for shrimp farmers of central Kerala appears to be moderate improvement from extensive production levels of 500 kg./ha/crop by way of quality seed induction, supplementary feed application and a more judicious water management in culture systems.
### TABLE 35 a

#### THE COMPARATIVE DETAILS OF OPERATIONAL ECONOMICS OF SHRIMP FARMING IN DIFFERENT LOCATIONS ALONG VYPINH. ISLAND, KOCHI

<table>
<thead>
<tr>
<th>Location/Details</th>
<th>Nayarambalam</th>
<th>Pooyapilly</th>
<th>Thrikkadakepilly</th>
<th>Kuzhipilly</th>
<th>Ayyampilly</th>
<th>Narakkal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extent of field (ha)</td>
<td>2.38</td>
<td>0.8</td>
<td>1.6</td>
<td>20.25</td>
<td>3.0</td>
<td>2.25</td>
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<tr>
<td>Lease rate/ha (Rs.)</td>
<td>7615.55</td>
<td>8125.0</td>
<td>10937.5</td>
<td>4370.37</td>
<td>14,450</td>
<td>8222.22</td>
</tr>
<tr>
<td>Labour including fishing charges</td>
<td>7,850</td>
<td>6,500</td>
<td>12,090</td>
<td>88,274</td>
<td>24,624</td>
<td>16,550</td>
</tr>
<tr>
<td>Sluice gate</td>
<td>1,450</td>
<td>1,175</td>
<td>1,250</td>
<td>6,500</td>
<td>3,975</td>
<td>4,275</td>
</tr>
<tr>
<td>Seed</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>4,000</td>
<td>Nil</td>
<td>5,000</td>
</tr>
<tr>
<td>Feed</td>
<td>Nil</td>
<td>450</td>
<td>Nil</td>
<td>1,569</td>
<td>Nil</td>
<td>1,500</td>
</tr>
<tr>
<td>Canoe, net etc</td>
<td>1,700</td>
<td>925</td>
<td>1,675</td>
<td>6,000</td>
<td>2,589</td>
<td>1,950</td>
</tr>
<tr>
<td>Operational</td>
<td>3,450</td>
<td>1,200</td>
<td>3,925</td>
<td>21,500</td>
<td>4,275</td>
<td>4275</td>
</tr>
<tr>
<td>Sundry items</td>
<td>190</td>
<td>150</td>
<td>150</td>
<td>750</td>
<td>810</td>
<td>500</td>
</tr>
<tr>
<td>Production cost of shrimps/kg (Rs.)</td>
<td>26.63</td>
<td>16.25</td>
<td>16.87</td>
<td>30.95</td>
<td>28.39</td>
<td></td>
</tr>
<tr>
<td>Income (Rs.)</td>
<td>29688.3</td>
<td>14735.3</td>
<td>14130.4</td>
<td>25088.1</td>
<td>101798.5</td>
<td>16346.5</td>
</tr>
<tr>
<td>Profit ($)</td>
<td>105.84</td>
<td>115.66</td>
<td>119.16</td>
<td>126.53</td>
<td>119.25</td>
<td>131.79</td>
</tr>
<tr>
<td>Return on Investment (%)</td>
<td>105.84</td>
<td>115.66</td>
<td>119.16</td>
<td>126.53</td>
<td>119.25</td>
<td>131.79</td>
</tr>
</tbody>
</table>

### TABLE 35 b

#### THE PRODUCTION COST AND VALUE REALIZATION OF *P. INDICUS* AND *P. MONODON* IN DIFFERENT FARMING SYSTEMS UNDER GROUP B AND E

<table>
<thead>
<tr>
<th>Farm Location</th>
<th>Penaeus indicus</th>
<th>Penaeus monodon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narakkal</td>
<td>B-3</td>
<td>B-7(b)</td>
</tr>
<tr>
<td>Cherungal</td>
<td>B-6 *</td>
<td>B-7(a)</td>
</tr>
<tr>
<td>Karumancheri</td>
<td>B-7(a)</td>
<td>E **</td>
</tr>
<tr>
<td>Palithode</td>
<td>B-4</td>
<td></td>
</tr>
<tr>
<td>Chalippuram</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Karumancheri</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mundapuram</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production cost (Rs./kg)</td>
<td>22.81</td>
<td>27.66</td>
</tr>
<tr>
<td>Value realization (Rs./kg)</td>
<td>25.21</td>
<td>33.37</td>
</tr>
<tr>
<td>Profit (Rs./kg)</td>
<td>2.40</td>
<td>5.71</td>
</tr>
</tbody>
</table>

* Pumping ** Pumping and aeration
Thus, adaption of an extensive type indigenous farming technology as found successful in the case of *P. indicus* at Cherungal (B6) and Karumancheri (B7b) and for *P. monodon* at Chalippuram (B5) for enhanced production and better economic return assumes greater significance.

With reference to an individual aquaculturist, instead of optimum input levels based on an estimated production function, he needs location specific advice. A technology package may make sense in one area where the input/output prices reveal marginal returns greater than marginal costs. In another area, it may be the reverse because of location specific differences.

Researchers have attributed the success of viable shrimp culture system to the optimum utilization of various inputs. The identification of input levels which are significant in explaining variation in the output from various culture centres are reported by Smith (1981). The significant inputs in a shrimp culture system (or the explanatory variables) are the stocking density, supplementary inputs (feed, fertilizer, pesticides etc), labour (hired and family), managerial expertise, environment factors (soil, pH, water salinity etc) and the technology used. The input-output relationship referred to as production function is of paramount importance for the cost benefit analysis of any system.

The due attention bestowed in all these aspects in the series of investigations under group A, B and E have contributed much to the production increase and better economic return. Although the production cost remained at reasonable levels in the traditional (A) and extensive (B) farming practices, it soared up high in the semi-intensive (E) farming. While in groups A and B, maximum profits were obtained at low levels of input use and output, it did not hold true in 'E' even maximising production owing to its increased reliance on costly imported feed, surplus use of aerator devices and managerial expenses.
Often low profits are the result of poor FCR due to the indiscriminate feed supply. Viswakumar (1992) analysing the impact of varying FCRs on net income per kg production in different farming practices (extensive, improved extensive and semi-intensive) showed that variation in FCR has the least influence on profits in the case of extensive farm whereas it is the maximum in the case of semi-intensive farm.

For the cost-benefit analysis of culture system, the estimation of production function identifies the inputs that influence the product yield and shows the efficiency of inputs applied.

Many production economists have expressed that these production estimation methodologies are primarily of interest to policy makers only and that it would be unwise to use production function to advise farmers on input levels. Also it is very difficult to make any sensible comparison. In this context location specific studies are more relevant as there exists wide ecological as well as input/output price differences between culture areas.

**Shrimp farm management**

Of late it was realised that the key to successful aquaculture is not just availability of adequate technical knowledge, but it depends on efficient farm management even in a small scale farm. Huguenin and Colt (1986) have defined the managerial process as the ability to organize and implement an aquaculture technology which is a complete combination of technical, economic, marketing, social and political elements towards some specific goals. In this context, the technology most appropriate to local conditions evolved, taking into consideration, various social economical and ecological aspects, stands most relevant towards fulfilling the objective. Furthermore, adoption of such an intermediate technology will enable the producer community to step into more sophisticated technology in due course.
Webber and Riodan (1979) pointed out that "new problem areas are engendered and many of the old problems become more critically significant" as small scale fish farms owned and operated by single family units primarily for subsistence or at least for a small cash crop, evolved into large scale agri-business enterprise incorporated and conducted for economic profit. Management consists of the application of scientific laws and principles to the conduct of farm activities.

Most of the present day aquaculture farms in India are too small to afford a manager. However, situations are taking new dimensions in our country with the entry of big companies in the field of aquaculture. A well beginning has been indicated in Kerala too, under the joint auspices of MPEDA and other firms (Anon, 1992). Hence, the semi-intensive farming technology worked out as part of the present investigations at Mundapuram (E) attaining a production of 2390 kg/ha/4 months for *P. monodon* with 16.91% return on investment will be a fore-runner in this direction.

3.2 SYSTEM APPRAISAL

3.2.1 Strength, prospects and opportunities

Index of successful farming and economic impact depend upon its profitability and in terms of jobs, animal protein and foreign exchange created. The significance of shrimp farming is that it can easily become the most valuable renewable protein resource (Wisely, 1975).

India is estimated to have nearly 1.4 million ha of brackishwater area all along the coast in the form of lagoons, creeks, tidal mud flats, estuaries, mangrove swamps etc. The natural ingress of tidal waters upto 1 m in these areas is really a boon to coastal aquaculture.

In general, during the last 40 years India has made some
progress in the field of brackishwater shrimp culture such as

a) breeding and propagation of commercial species.
b) study of abundance of naturally occurring seed and establishment of seed banks.
c) nursery management

d) appropriate crop sequence

e) feed formulation for intensive farming

f) survey and selection of suitable sites for farms

g) development of designs for sluices and dykes in relation to topography, tidal amplitude, tidal flow and soil types.
h) development of basic designs and lay out for farms, necessitating further refinements and improvements.
i) development of silt traps to check siltation of ponds.

In addition, the strength of the industry is contributed by the following factors.

a) availability of infrastructure facilities specific to each area

b) existence of localised talents in farming

c) profusely available and exclusively skilled low cost labour

d) scope for increased production through intensification of modern technology

e) preference of cultured shrimp over captured ones owing to improved quality

f) much export demand with high profitability

g) dynamic interest of private entrepreneurs leading to import of technology and adoption to local conditions through modification

h) keen interest shown by central and state governments for shrimp culture even by arranging financial support from foreign agencies.

i) leadership of the Indian shrimp industry backed by nodular agencies like MPEDA, BWFFDA etc.
Thus well suited climatic condition, relatively unpolluted water sources and availability of fast growing tropical species attract the involvement of different talents, since aquaculture still is "an art by itself" rather than a technology".

The first positive aspect is that because of the high price of shrimps it can become profitable at a relatively lower level of technology than for other aquatic species as fish.

Another positive aspect is that most shrimp farms can be built using marginal land for traditional aquaculture. This means that shrimp farming provides additional economic return to the country without reducing production of agricultural crops. In addition to the coastal land, the marginal land includes any land having ground water of adequate salinities (Recent developments in Nellure, Andhra Pradesh).

Kerala is blessed with 2,42,000 ha of brackishwater area suitable for shrimp culture in contrast to limitation of space in terms of water and land for the establishment/expansion of aquaculture in other countries.

The special features that render Kerala backwaters well suited for brackishwater culture are:

a) availability of extensive areas of rectangular shaped paddy cum shrimp filtration fields with firm perimeter bunds, having adequate slopes varying from 2:1 to 4:1, to aid water flow through sluice gates during tidal water exchange.

b) the large extent of coconut groves and unfertile paddy fields available can be suitably converted to farming at low cost.

c) low tidal amplitude making it possible to use relatively simple dykes and bunds.
d) low prevailing temperature and high humidity that reduce evaporation loss maintaining favourable salinity during season.

e) location outside the cyclonic belt obviating possible risk of damage to the farm dykes and bunds.

f) a tradition of filtration which has proved the commercial prospects of shrimp culture.

g) existence of established trade channels for selling the products to external markets.

h) availability of technically competent work force.

3.2.2 Weakness, threats and constraints of shrimp farming

By making an ardent survey of literature, it was possible to understand the weaknesses, threats and constraints hampering the progress of shrimp farming.

The current production constraints may be classified as technical and non technical, each category encompassing several factors.

Technical constraints

a) Limited introduction of engineering innovation in pond design and management

Though shrimp culture is seen gradually extending in the study area, it was peculiar to note that the farmers do not give much attention to this aspect. The water management - maintenance of proper exchanges - requires innovative technologies similar to those developed at IIT, Kharagpur involving huge capital investment.

Similarly absence of proper drainage especially central drains for waste removal during water exchanges adds to the above.
b) Lack of technicians

Insufficient strength of skilled staff who are able to design pens, culture cages, embankment protection devices, sluice boxes, inlet and outlet water arrangement of shrimp culture systems and feeding equipments etc. hamper the development.

c) Seed availability

Guaranteed availability in time and in required quantity of quality seed of potential species collected from wild or produced through hatcheries by bio-technological processes contributed to the success of shrimp culture in many S.E. Asian Countries, where as, insufficiency of seed continues to prevail in our country on account of the following reasons. Against the requirement of 3 billion (300 crores) shrimp seed in India for converting atleast 1 lakh ha of potential brackishwater areas as culture ponds practising culture at extensive, semi-intensive and intensive levels in 75, 20 and 5% areas respectively, only 0.5 billion (50 crores) seeds are available.

Over fishing in coastal waters resulting in depletion of spawners leading to reduced recruitment of wild fry is a factor to reckon with. Post larval and early juvenile stages of shrimps have traditionally enhanced the catches for subsistence of fishermen, but the growing trade in seed shrimp will have an adverse effect upon these catches and will also reduce recruitment of adults to the inshore fishing grounds. Further, the methods currently used for collecting seed, leave much to be desired. For every kg of *B. monodon* seed collected, as much as 10 kg of fish fry and shrimp seed of other species is discarded with a heavy mortality rate. This wanton destruction of juveniles is bound to be reflected in smaller inshore adult spawners and a reduced fishery yield.

Research carried out for improvement of culture species through genetic studies and breeding are at the infant stage.
Lack of proper breeding in captivity of potential species and non-existence of viable hatcheries coupled with high mortalities of fry remain as a critical factor.

Absolute lack of a gene pool and knowledge of artificial insemination for continuous supply of fry.

Lack of research in genetic engineering for production of disease resistant fast growing shrimps with high survival rates for better market value.

The constraints in the traditional practice of trapping cum holding are the severe limitation of low production, poor quality and growth, uneconomic varieties and above all the menace of predators.

d) Non availability of quality feed

Successful shrimp farming very much depends upon the application of efficient, complete and inexpensive feeds suitable for each stage in its life cycle. But in India non availability of such formulated feed, bestowed with required biological and physical qualities continues. Compared to a maximum production rate of 33 to 40 tonnes/ha/year achieved in many south east Asian countries, even to double the Indian average production from the present 53 kg/ha/year, we are forced to import high energy quality feed. The point here is that the cost of good quality feed (Plate II A) often accounts more than 50% of total production cost.

Even when some supplemental feeding is resorted, same type of feed is given throughout, against the normal requirement of starter, grower and finisher feeds for different phases of growth of shrimps as practised in other places.

Of late, a factory with technical assistance from Japan has been set up to produce annually 12000 tonnes of quality feed at
Kuthiathode in Kerala. Of the 20 ingredients, required for feed making five are imported (Mathrubhumi, 7.2.92).

e) Lack or inadequacy of required inputs other than feed

The lacunae noticed in the management operations due to inadequacy of inputs are the following.

Lack of studies on optimal culture conditions, Pesticides to control pests and predators, Fertilizers - organic and inorganic, Essential facilities such as water pumps, blowers and aerators, Non availability of equipments required for monitoring water quality, Non availability of infrastructure facilities for adequate water exchange and aeration leads to oxygen depletion due to metabolic waste accumulation.

The shrimp body being composed of 80% water, the role of aeration as a donor of oxygen for growth is of paramount importance.

It is reported that on an average 25% increase in crop value can be expected by the use of paddle wheels for aeration as demonstrated at Ezhupunna during February, 1992 and at Cherukunnur between February and June, 1992. Lack of aeration reduces rate of food conversion. However, this could not be practised in the study area except at Mundapuram (Group E) because of low water column, the loose nature of substratum and non availability of electricity.

f) Environmental stress

Estuaries are major coastal resources subjected to a great deal of environmental stress. Man's intervention in the environment by way of (1) construction of harbours (2) dredging for navigational purposes (3) regulating fresh water flow through construction of dams for irrigation purposes and (4) discharging waste products from industries
and cities situated in their vicinity affect the coastal estuarine system to varying degrees. As the need for the above increases, the ecosystem dynamics is adversely affected necessitating greater importance to water quality management to protect the biological resources including shrimps.

The natural ingression of high tidal water is really a boon to coastal aquaculture. Since paddy cultivation is given more importance during previous years, strong bunds and barricades have been constructed to prevent the saline water entry into the interior areas during high tide from the sea. In Kerala, the Govt. constructed the spillway at Thottapilly in 1955 and a barrier at Thanneermukkom in 1974 in Vembanad lake for checking the intrusion of saline water in order to raise 2 to 3 crops of paddy in an year. Such actions have really damaged the entire ecosystem destroying the fishery resources of the coastal area. The unscrupulous developmental activities taken place, in Cochin backwater have considerably reduced its size in area and volume having detrimental effect on survival of shrimps (Gopalan et al., 1983).

g) Impairment of water quality due to aquatic pollution

The degradation of water quality due to pollution threats consequent to discharge of domestic, agricultural and industrial wastes to backwaters used for aquaculture is on the increase as reported in the Vembanad lake during 1991 owing to lack of awareness and limitation of protection measures.

Mass mortality is caused due to lowering of habitat conditions such as low pH, oxygen deficiency, excessive turbidity, eutrophication etc. beyond the tolerance limits of cultured organisms.

As intensification leads to accumulation of micro-organisms in crowded aquaculture environment, mortalities can occur due to bacterial or viral infection. Similar conditions also occurred in the inland
ecosystems of Kerala during 1991 leading to large scale fish kill.

h) Lack or poor understanding of the suitable technology

There arises the need for applied or practical training in aquaculture practice, due to

i) inadequacy or lack of properly trained managers, technicians and skilled labourers.

ii) lack of a multipronged strategy of education, extension and financing required to transfer the research achievements to the farmers, eventhough breeding and culture techniques are being transferred to the farmers hither and thither.

iii) lack of awareness of farmers even to adapt to the indigenous technology available and

iv) lower level of understanding of management and proper execution of shrimp culture projects.

The current aquaculture practices are primarily an "art". The artisanal nature makes transfer of technology difficult, underlining the need for a base, provided by practical experience in this field. The success of development plans in Aquaculture in Asia depends upon the methodology of delivery of information properly disseminated. The expertise can be developed only through excellent co-operation between researchers and commercial producers.

1) Unpredictable yield levels

The geographical remoteness affecting availability of quality water and seed reflects on production very much.
One of the setbacks confronted with the farmers in Kerala is that irrespective of the type of farming, production varies from crop to crop or pond to pond and even from one individual site and or facility to another similar to experiences pointed out by Smith (1981) and Apud (1988). This is because of the alternating/reversing monsoonal influence. As such, it is difficult to design a standard shrimp farming method for Kerala.

j) Energy crisis

Energy crisis owing to non availability of electricity for the operation of water pumps and other installations create impediment in shrimp culture development.

The problem farmers encounter, is lack of a sufficiently strong organisational base which could undertake developmental work on long term basis. Creation of a task force to achieve this will be a welcome step.

k) Constraints in harvest

In the absence of aqua engineering information on harvest technology and post harvest handling and storage facilities, the bulk of aquaculture produce is forcibly marketed at the production centres at a very low rate sustaining loss to the farmers.

l) Financial crisis

Lack of finance to instal sophisticated equipments in different levels of operation does not favour farming community. Non availability of the high overhead expenses to be incurred by farmers on easy terms and low interest credit for development and operation.
m) Foreign technology

Over and above all, import of culture technology poses a great threat when indigenous technology is in the offing.

Non technical constraints

Extension of aquaculture activities into low lying areas inundated by tidal waters is likely to harm the paddy crop sustaining loss to agriculturists. The continued failure of crops also will throw agricultural labourers out of employment affecting their livelihood even though the endeavour is much more remunerative to other sections. Naturally conflicts between agriculturists, agricultural labourers and aquaculturists arise and continue to exist assuming different dimensions depending upon the regional situation.

Land used for aquaculture should be fertile, clayish and with good source of water on par with paddy cultivation requirements leading to conflict of interests.

Conflict in the utility of land and water resources needed in aquaculture hampers year round shrimp culture in potential paddy fields.

Legal and institutional constraints such as obtaining licences for shrimp farming.

Lack of adequate extension services by institutional agencies is a matter of concern. Although there are few specifically designated agencies as MPEDA, KVK and BMFFDA to cater to the needs of shrimp farmers, there are no statutes or laws enacted in this regard.

Socio-economic and political constraints resulting from impounding of open back water bodies depriving opportunities for fisher folk in meeting their livelihood.
Usually aquaculture areas are occupied by socially backward communities. These backward people won't be in a position to raise the needed capital for aquaculture ventures. The poor security conditions and law and order in these areas can hamper development. These require modification by government as has been successfully resolved along the Chilka lake in Orissa. The modern concept of satellite shrimp farming is a welcome step in this regard.

There are also conflicts regarding use of coastal and inland waters used for fishing with that for aquaculture.

Deadlock due to non-allotment of land to fishermen even though their life is intimately entwined with fishery activities adds to above.

3.3 THE TECHNOLOGY
(Ecological, Social and Economical considerations for indigenous technology, implications of intensive farming and the technology in detail)

3.3.1 Major Ecological considerations

Shrimp farming results of the present study showed general increase in production rates depending on management intensity, so do cost. It was found that the choice of the appropriate management system for a given farm is dependent on many site specific factors, particularly the higher lease value of the land, cost of pond preparation and other inputs. As such, extensive pond management is appropriate in Kerala owing to the vast existing impoundments where new investment is minimal. Also availability of vast areas of brackish water sites favours extensive culture in Kerala compared to Srilanka where farming sites are highly limited forcing farmers to go for intensification. A more productive management system can be thought of only when new ponds are constructed along coastal areas at high costs involving modern technology. However, it is doubtful, how far such
system can economically function against deteriorating environmental conditions of the backwater system, energy crisis etc.

In Kerala on par with Ecuador, Brazil and Thailand, one is fortunate enough to locate enough coastal property/previously constructed impoundments, i.e. the low yielding (300 kg/ha/crop), natural extensive systems as most appropriate compared to United States with relatively high costs of suitable land, also demanding highly productive management systems. It is possible to push up the yield in India by maximising production at little extra care.

Recent studies showed that the low tidal amplitude prevailing along the study area has got its limitations to support high density farming. Also, the silt laden turbid water conditions associated with clayey substratum act as decisive factors. An alternative to the above is to switch over to intensification taking advantage of the ground water resource. However, in the wake of acute scarcity of drinking water consequent to lowering of ground water level, this should be done with caution.

It is often found that intensification can be a failure as observed during 1988 in the case of better and more sophisticated technology developed by Taiwanese (Anon, 1989). Taiwanese shrimp production was reported to have gone down dramatically due to a variety of climatological and technical reasons like over crowding resulting in environmental stress which in turn weakened the shrimps making them more susceptible to diseases. The dominant virus (MBV) at times become virulent causing the hazards. What is certain is that such widespread occurrence of diseases can be avoided by resorting to low stocking rates.

A similar mortality problem hit the high-tech shrimp farm in Srilanka by a virus leading to its closure within 2 years of its operation. Similar instances were reported from Philippines also. In 1990, shrimp farming industries in Ecuador, Thailand, Indonesia and
China contributed to environmental problems (World Shrimp Farming, 1990). Same time, it is worth noting that no such instances have been recorded in the past in the study area. Hence it is advisable to opt for extensive farming with less environmental impact.

Commensurate with intensification, there arises the need for the timely supply of enormous quantity of quality shrimp fry. In the present situations, it may not be possible for the hatcheries functioning at suboptimal levels to meet the requirements.

Intensive farming demands high energy quality feed which is not locally available, but has to be imported at high cost. This situation compels the shrimp farmers to opt for an indigenous technology where supplemental feed prepared from cheap and locally available materials can serve the purpose.

3.3.2 Social considerations

The likely socio-economic benefits of biotechnology in the Third world are positive in terms of increasing productivity of tropical commodities. Despite several remarkable achievements, in India the improved methods are slow to reach the producers, primarily due to weakness in extension. Development of more intensive methods is also hampered by a contradictory land use/land lease policy. In Kerala, subject to the prevailing land rules, shrimp culture can be undertaken only after the paddy harvest, during the post monsoon period from November to April. The major constraint is regarding ownership of the field being vested with the paddy farmers mostly and the shrimp farming being practised by a different set of contract farmers who take possession of the farm by public auction on a seasonal basis. Even though there are chances of converting certain ideally located filtration fields exclusively for shrimp farming for the whole year, the existing land utilization policy of the government restricting the conversion of paddy fields to raise other crops, it would appear that round the year shrimp culture under the existing framework may not be
a practical proposal in the study area. Thus the traditional shrimp culture practices in Kerala evolved through generations having their inherent unproductive tendencies can be altered only to a limited scale in the present situations.

Also with the advent of modern innovations, it can be noticed that the traditional aquaculture fishermen who are poor and illiterate are found displaced by a set of new people (entrepreneurs). Until job guarantee is ensured by law, the modernisation can be practised with caution alone. Government of Tamil Nadu has formulated a land leasing policy to allot coastal saline lands for shrimp farming for a period of 10 years, soon after layouts and environmental clearance are obtained.

Under this policy 60% of the area available estimated at 800 ha will be allotted to target groups, 20% will be allotted to medium and small scale entrepreneurs and the remaining 20% land will be allotted to large scale entrepreneurs. The lease rent per year will be Rs. 25/ha for target groups, Rs. 100/ha for small and marginal farmers, and Rs. 250/ha for medium and large scale entrepreneurs.

A similar policy if adopted in Kerala will give opportunities to continue the extensive new technology evolved in the study by the traditional farmers where as the few large scale entrepreneurs can switch over to sophisticated technologies depending on their capabilities as demonstrated at Mundapuram (Group E) during the present study.

Large scale destruction of potential mangrove areas for pond construction resulting in impoverished coastal waters, reduced production of domestic food fish by culture, saline intrusion making agricultural lands fallow, dependence on hatchery fry for stocking against the labour intensive natural fry collection, lesser number of man power for management, monopoly of capitalists and deprival of chances of employment to farmers and fisher folk are the disadvantages associated with intensification of high-tech shrimp farming. To engulf
such negative aspects for the mere increase in the production of export earning shrimps at a lesser cost-effective ratio cannot be afforded by India in fulfilling the national goal of offering food and avocation to the teeming millions. In this situation it is doubtless to say that extensive farming with better management is the only alternative to augment shrimp production taking maximum advantage of labour and vast potential areas available in our country. In this context, the easily adaptable rural technology evolved seems to have more relevance in the socio-ecological situations prevailing in Kerala. This will also contribute much to promote social equity and environmental conservation as pointed out by Primavera (1989).

3.3.3 Economic consideration

According to Chandrasekhar (1987), the traditional culture in Kerala is advantageous from the view point of farmers, as it involves only limited investment. In the traditional system of shrimp production, the production cost is minimal when operated by the owner of the field as revealed through the case studies under group B series. However, often the field are leased from owners for shrimp growing and the value of the lease is relatively high (group A). This influences the net return from shrimps to a major extent.

From the point of view of owner himself operating the field, the income from shrimp production will be doubled as otherwise, the field will remain fallow only (group B5). In the rotational culture, this adds to the income of the farmer and is a more efficient use of land and farm resources (case study group B7).

A review by Csavas (1988), forecasted production of 8 lakh tonnes of cultured shrimp in Asia much earlier than 2000 AD if the present trend continued. The growth curve for India is expected to reach 50000 tonnes provided, the 4 basic phases of the curve - development, growth, maturity and decline follow the general rule.
In the above context, it is worth preferring a culture practice by reasoning, giving due regard to all factors. According to Hirasawa (1985), most of those who are using semi-intensive methods, can easily survive a 20% price decrease while the same decrease would drive into the red all of the intensive ventures which are operating with a high profit per unit of culture area, but, with a narrow profit margin per volume. Owing to a narrow profit margin per area often depended upon fluctuating export market prices of high density farms, in the final analysis it is preferable to accept lower production levels with lower production costs and higher quality of the product - extensive culture.

So it is worth advisable to select a particular intensity of culture whose production can be adjusted to the demand during the declining phase of industries development. The less intensive shrimp farming methods are also supported by economic considerations in addition to ecological and social causes.

After making a cost benefit analysis of various shrimp farming systems, Hirasawa (1985) has proved the advantage of extensive farming over sophisticated methods anticipating its capacity to tide over the crisis in case an economic regression takes place for shrimps in export market.

Silas et al. (1988) pointed out the importance of shrimp farming for the economic rehabilitation of the rural poor as successfully demonstrated at Chilka lake. This was possible by the political decision during 1982-83 to apportion small units of peripheral land in the Chilka lake bed for shrimp culture to the poor under the main schemes, viz. The Economic Rehabilitation of Rural Poor Programme (ERRP) and an Area Development Approach Programme (ADAP) under the overall aegis of Brackish water Fisheries Development Agency. In the absence of such promotional programmes in Kerala, farmers have to content with the extensive farming practices only.
3.3.4 The technology most appropriate to the study area - the Central Kerala - in the prevailing conditions, based on the studies undertaken.

**Importance of indigenous technology**

The importance of modified traditional/improved/scientific extensive shrimp farming is because of the social, ecological and economic trade-offs. Also this is necessitated by the national mandates of social equity and environmental conservation.

It is necessary to establish a ratio of food crop-to-cash crop area based on biological, socio-economic and ecological criteria. Shrimp production should not be at the sacrifice of paddy crops. Economic success should not take precedence over nutritional success.

As early as 1983, the Seafdec Aquaculture Department has called for a diversification of culture species and markets in anticipation of a global slump in prices (Primavera, 1983). This also substantiated the need to control the mad rush to intensify farming resorting to foreign technology when our country is facing economic crisis. According to Hirasawa (1985), many farmers are after the total profit per hectare rather than the profit per kilogram. In other words, many shrimp farmers have joined a mad race for the greatest profit in the short time, mindless of the social, environmental and economic costs.

Any genuine development must show, over and beyond economic profitability, a responsiveness to society's needs and a soundness that will not threaten environmental resources. In short, in our farming situations only the technology advocated by the author can satisfy all the three criteria of ecological, economical and social concern to fulfill the promise of sustainable development for present and future generations.
A search on the types of rural technologies available in India revealed that whatever technologies in vogue are extremely location specific and hence most difficult to be transplanted. Regarding the question on what type of technology India can ask for from the International agencies, it can be safely concluded that owing to difficulties in land leasing systems and lack of finance, no foreign technology is worth acceptable to the traditional farmers of India.

With the development of the new technology appropriate to local situations, it is possible to raise 3-4 short term crops in the growout ponds in the prevailing environmental conditions making use of the more or less disease resistant 30-50 mm size fast growing juveniles of P. indicus and P. monodon and inexpensive feed resulting in higher survival rate. Furthermore, one of the advantages of this technology is that adequate care was taken to keep the construction cost of shrimp farms as low as possible in order to make it within the reach of rural farmers.

The technology explained

Location

Site selection is the foremost ecological factor. Ideal location of the farm with respect to its proximity with open brackishwater body (direct access) or nearness to barmouth is considered well suited for shrimp farming purposes. Availability of good quality tidal water and the prevalence of a relatively sufficient tidal amplitude ranging between 50 and 80 cm will help adequate shrimp larval entry and efficient water exchange. The important physico-chemical properties of water such as pH, temperature, salinity, dissolved oxygen and alkalinity should be within the range of 6.5-8.5, 26-32.0°C, 15-28.0%, 3.0-6.0 ml/l and 30-300 mg/l respectively. Such desirable characteristics of water occur in places where the tidal water supply is direct. Soft clay - soil, rich in organic matter provided ideal substratum for the growing shrimps and forage organisms
in traditional shrimp farms. Also a firm bottom composed of sand and clay with overlying silt free and nutrient rich tidal water having a transparency level varying between 20 and 35 cm, measured with a secchi disc, will be very fertile. This can generate live feed organisms such as zoophytomatrix and benthic organisms promoting better shrimp growth and production.

Preparation of the field as a habitat and not a trap

The structural modifications carried out within the farm, without disturbing the bottom characteristics much, by way of removal of excessive silt, paddy stumps and algal assemblages and excavation of canals of various dimensions depending on farm extent, could generally increase the water holding capacity.

About 6 to 10% of the total extent can be converted as sluice/catch basin with a depth of 2 to 4 metres, depending on the size and location of the field.

Major canals radiating from sluice basin should be 2 to 3 metres deep with a net work of minor canals ranging from 0.5 to 1.5 metre deep. This also helps uniform distribution of post larvae entering to every nook and corner of the field. These canals can act as shelter from sun's heat and ensure better feeding ground.

The disposition of required compartments and other arrangements set within, could maintain steady well oxygenated water flow facilitating internal water circulation at required levels.

The increased flow rate and efficient movement of water made possible within the system during entry and exit of tidal water preferably with the help of separate sluice gates could enhance the life sustaining capacity very much. The dykes and sluice gates have to be designed, constructed and fixed depending on the area of the field, tidal range and current pattern of the vicinity. Care has also to be
taken to fix the main sluice gate and subsidiary ones facing the incoming tides. Thus, the pond system could be maintained always healthy by removing the metabolites then and there, without getting accumulated thereby avoiding chances of water quality deterioration leading to pollution.

Decaying paddy stumps can produce local anoxic condition which is often detrimental to young shrimps. Also noxious weeds like *Salvinia*_ sp, *Eichornia*_ sp and excessive growth of floating filamentous algae lead to reduced light penetration. Hence their removal to a certain extent will be desirable for improved production.

**Predator eradication**

Several methods are employed for the elimination of undesirable species of fishes and predators. Complete draining of the pond and keeping it sundrying for a week will be much beneficial. This will promote the mineralization process by which the complex molecules of organic and inorganic compounds lying at the bottom will become simpler adding to the nutrient enrichment (Hickling, 1971).

Predators, weed fish and pests can be simultaneously eradicated by the application of non selective agents. Toxins from natural products, organochlorides and organophosphates are quite effective. Application of an aqueous solution of 216 kg tea seed cake or saponin with 144 kg quicklime to the pond bottom is effective to get rid of weed and predatory fish as well as snails. Unwanted fishes can also be eliminated by using tobacco dust or nicotine @ 2 ppm. So also Rotenone or derris powder @ 1.5 ppm level will control undesirable fish in shrimp ponds, while @ 20 ppm will be quite effective to kill unwanted fish, the toxicity remaining for 8-12 days (Pillay, 1990).

By applying Mahua oil cake (*Bassia latifolia*) (Plate II B), @ 2500 kg/ha/1m, unwanted fishes and other vertebrates can be got rid of, within 3-4 hours. However, the poisonous effect of Mahua will be
gradually lost contributing to the fertility of the pond. Within a fortnight, the system will become receptive again.

Application of a mixture (1:5) containing 125 kg Ammonium sulphate and 600 kg lime will be sufficient for a hectare, retaining 20-25 cm water column to eliminate predatory fishes within 2-4 hours. The system will be left undisturbed for a fortnight when it will regain stability.

Stocking

Owing to better living conditions prevailing in such culture fields/ponds, it is possible to maintain increased stocking densities of shrimps. Eventhough in traditional systems, shrimp larvae are stocked exclusively through tidal water entry, such processes may not be efficient to entrap enough number of shrimp post larvae in the improved systems where the shrimp holding capacity is greatly increased. Furthermore, precautionary measures adopted to prevent the entry of unwanted species using appropriate screens inside the water entry gate (Plate VI B), will also restrict the autostocking of shrimps very much. Nevertheless, it is possible that some post larvae will definitely get autostocked through the nylon webbing or bamboo screens kept inside the sluice gate while allowing tidal water exchange (Purushan, 1989). A bright light preferably with a red filter fixed at the sluice gate can attract larvae better. Maximum seed can be collected at dawn and dusk hours during high tides with satisfactory gradient. But, aiming a better crop during the season, additional stocking of shrimp larvae/juveniles should be done giving due regard to the management aspects attended to and also the capacity of the farms. These larvae (Plate I A) can either be procured from hatcheries (Plate XXII A) or collected from wild environments (Plate XXI B). It is preferable to introduce uniform sized larvae as obtained from nurseries. In the case of wild post larvae suitable ones may be selected after sorting (Plate VII A), which practice is widely adopted.
Considering the nature of management, additional stocking @ 5/m² (50000/ha) in the case of P. monodon and @ 10/m² (100000/ha) in the case of P. indicus can be easily done. Post larvae are usually released to nursery compartments arranged inside or to nurseries set up within (Plate XII A). After special care and nursing assured in the nurseries, the larvae assume juvenile size quickly when they are let out to the general system.

Retrieval and conservation

Conservation and exploitation of the growth potential of the undersized juveniles can be an important step in the indigenous technology. It is a matter of fact that large number of undersized juveniles are killed during the traditional paddy field filtration process. It is possible to retrieve these undersized juveniles by frequently emptying the contents of the cod end into suitable nursery ponds for further growth. For the above, a nursery pond may be made in one corner of the field by raising temporary earthen units. This deviation from the traditional practice can be an added success.

Often, the short seasonal culture becomes a failure as the natural tidal incursion of seed into the fields is delayed or poor. This can be overcome by timely conservation of destructive juvenile shrimp fishery into a profitable seed resource for shrimp farmers thereby also averting a socio-economic problem (Gopalan et al., 1983).

Supplementary feeding

The farm being kept sundried for a week during preparation time before start of operations, speeded up the mineralization process adding the fertility status of the soil (Hickling, 1962). The basal dose of fertilizers and manures supplied and subsequent manuring practised at periodic intervals corrected the deficiency of nutrients if any in the system maintaining better organic productivity. Also, it has been reported that a very high FCR of even 1:1 can be achieved by
the increased reliance on natural feed (Asian Shrimp News, 1st Quarter 1992). Thus successful shrimp culture could be achieved by way of proper plankton management leading to reduced requirement of high cost quality feed.

However, to overcome the shortage of feed in the system on account of additional shrimp stocking, nutrient rich feed made by combining different ingredients or procured from market can be supplied daily @ 3-10% of average body weight of shrimps. Pulverised raw feed composed of vegetable matters or ground clam meat/shrimp head meal can also be supplied in required doses apart from natural forage (Purushan, 1991). In Kerala alone it is estimated that about 25,000 tonnes of supplementary feed would be required in the existing farms, the preparation of which can provide employment for about 5000 people, if it is produced at the cottage level departing from factory based production.

**Better water management**

Owing to the increased rate of shrimp stocking and consequent use of supplemental feeds, frequent exchange of water is required in addition to maintaining a sufficient water level of 70-100 cm within the culture pond. In many of our farms, desired water exchange or maintenance of sufficient water level may not be possible exclusively depending on tidal processes. This will have repercussions on the shrimp stocked ponds especially when the biomass increases considerably. Such situations will lead to stress conditions due to metabolite release, dissolved oxygen depletion, variations in pH, temperature and such other factors. If not checked properly, the variations in the physico-chemical factors beyond the limit may endanger the shrimp stock within the system. In order to avoid such casualties, it is desirable to instal and use pumping units facilitating adequate water exchange (20-30%) and also to compensate the fall in the minimum water level. Therefore, farms of compact and smaller size are considered better for efficient control and water
management.

Growth related to thakkoms

Depending on the type of farming, the growth of shrimps will vary much in the shrimp fields. Since shrimp seed stocking and filtration during thakkoms is a continuous phenomenon in traditional fields, no specific time is allowed for shrimps to grow before harvest. Therefore, size variations in the harvested shrimps can not be ruled out. But, in the semi-intensive farms, shrimps are harvested only after attaining better commercial size within specified period. In an efficiently managed farm, it is possible to grow *P. monodon* to 30-40 g size within 3-4 months whereas shorter period of 2-3 months only is required for *P. indicus* to attain 12-20 g size.

Harvest Technology

The success of shrimp farming always depends on the efficiency of harvest. The efficient harvesting is to collect the entire stock without damage at minimum cost. Different methods such as sluice gate filtration, cast netting (Plate XXVI B) and hand picking (Plate XXVI A) are employed at different stages in the farming. Usually, in semi-intensive farming most shrimps are cast netted after keeping minimum water level in the ponds with a view to avoid damage to the produce. The remaining shrimps are easily hand picked after draining the pond completely.

But in the case of traditional fields multiple harvesting technique dominated by filtration is the regular practice followed. Since, this culling process provides more living space and food to the remaining stock, it is usual to obtain grown up shrimps by this practice during each thakkom. Nevertheless, cast netting and hand picking are also employed at different stages during the prolonged operation period in order to harvest the stock completely. Because of the protracted harvesting practice and varied techniques employed,
marketable sized shrimps are always obtained during the prolonged operation.

Since shrimps produced by the above scrupulous methods of harvest are of better quality, higher unit price is realised for the product at the farm gate. Moreover, the harvest is always tuned at a time when the demand for the commodity is at its peak. These measures of maximising production and return are very much important in the economic viewpoint also, in order to make the shrimp culture a maximum profit realising enterprise in the cost-benefit ratio level.