TECHNOLOGY MANAGEMENT
PRACTICES IN SHRIMP CULTURE
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TECHNOLOGY MANAGEMENT IN SHRIMP CULTURE

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3.0 INTRODUCTION

As defined earlier, technology management attempts to integrate technology – which is the means to convert ideas into procedure and process realities – throughout the organisation as a source of competitive advantage. It links up the functional areas of management to formulate strategy, develop technical capabilities and use them to achieve strategic objectives.

In aquaculture management, the crucial and critical unanswered issue is sustainable development. Though success in aquaculture is seen at some parts of India during certain time spans, it could not be sustained for a period of time. The “boom – and – burst” scenario is not uncommon even in the countries identified as pioneers or giants in the field of aquaculture.

The emergence of technology as a realisation factor of the culture process emphasises a point that it is not adequate to focus the attention on the macro-level technology elements, but equally important is micro-level technologies.

The current, fourth generation technology management paradigm – an execution oriented one – finds its application in shrimp farming. This necessitates the identification of various micro-level technology elements and their practices. So many variables are encountered in the process and the critical ones are identified as follows and search for the culture practices and acceptable levels for each of the variables that may be permitted are identified in detail subsequently:
1. Species selection
2. Site selection
3. Pond engineering
4. Preparation of grow-out ponds
5. Seed
6. Stocking
7. Feed and its management
3.1 SPECIES SELECTION

The selection of species for culture has different approaches. The initial enthusiasm for rearing as many species as have biological characteristics suitable for culture was followed by the recognition that the development of a commercially viable aquatic farming system requires much more research and development efforts than the experimental raising of a few animals under controlled conditions. It was therefore considered logical to concentrate efforts on a smaller number of species and farming systems in order to have an adequate number of properly tested technologies for commercial application.

While aquaculture research per se would be concerned with developing and improving production systems, basic studies and experimentation in the various disciplines were expected to be carried out by more academically orientated institutions. This approach has, however, been somewhat counteracted by market demands created by the diminishing supply of an increasing number of over-fished and valuable species in commercial fisheries. High market demand is undoubtedly a major incentive for farming many of the species and for related research and development work. But experience so far does not in any way minimize the need for a competent inter-disciplinary research and appropriate pilot scale operations to develop commercially viable systems. This view has been more than supported by the history of efforts to establish farming of a number of species.

When considering the value of limiting the number of species for culture, a distinction has to be made between the farming (especially semi-intensive or intensive) and enhancement of natural stocks. Pillay (1994) mentions, “in farming per se the main goal is the commercially viable production of marketable species, which is in many ways similar to agriculture and animal
husbandry. The science and the industry that relate to these farming activities are concentrated on a relatively small number of species, and even after several years of concerted efforts, research and experimentation continue on an expanded scale to improve the farming system and related industries. Stock enhancement is meant mainly to revive or rehabilitate over-exploited resources or to increase or introduce new populations in natural waters. While the expected benefits, ecologically, industrially, and socio-economically, are major criteria for undertaking this activity, the main intention is to build up or maintain natural resources at sustainable levels”.

Nash and Colin (1995) identify, “the principal criterion for the selection of species for use in each system and the practice is based on market demand. Specific species suit certain markets and therefore the choice is important. Growth rates of cultured species are also important, and they are higher in the tropics than in temperate climates due to elevated water temperatures. For the most part, tropical and sub-tropical countries produce a far greater range of species than temperature countries. Temperature countries invariably confine culture to high-value marine species, because of the high level of investment and the regional markets”.

According to Alagarswami (—), “in the current decade, India embarked on development of modern brackishwater aquaculture mainly to boost the export of penaeid prawns. The private sector is entering in a big way on modern lines. The technology front of this sector remains weak and is under development. Consequently the production and productivity is low. The country has a wide spectrum of species of prawns, fin fish, and molluscs in the brackish-water regime which are suited for culture. However, prawn farming tops the priority list in view of high productivity, ready marketability and export earnings”.

Dehadrai (—) declares, “there are about 18 species of crabs, 10 of catfishers, 5 of snakeheads, 6 of tilapias, 4 of mullets, 4 of perches, 2 of clupeids and 5 of shrimps besides several others of considerable local significance which
are cultured in one or the other part of India. Lately, shrimps have gained considerable importance owing to their tremendous export value”.

Bal (1991) identifies the following species as having high growth rates and resistance to changing water conditions in brackish water ponds:

Penaeus monodon (Tiger Prawn)
P.indicus (Indian White Parwn)
P. merguiensis (Banana Prawn)
P. semisulcatus (Green Tiger Prawn)
P.japaonicus
Metapenaeus monoceros (Indian Prawn)
M.dobsoni (Flower Tail Prawn)
M.brevicornis (Yellow Prawn)
M. affinis (Indian prawn)

Silas (1978) suggests, “out of 55 species of shrimp varieties in India, 11 species of penaeid shrimps are listed as suitable for culture in the saltwater along the coast line”. The suggested list of 11 species include the species listed above excluding p.japonicus but including the following;

Parapenaeus stylifera
Parapenaeus sculptilis and
Parapenaeus hardwickii

Sundararaj, Devaraj and Prince Jayaseelan (1992) give adequate consideration to the total bioeconomic matrix of the penaeids, P. Monodon, P.Indicus and P.Semisulcatus which emerge as the most suitable species for brackishwater culture. Table 6 shows their biological and cultivable features.
### TABLE 6
**BIO-ECONOMIC MATRIX OF PENAEID SHRIMPS IN INDIA**

<table>
<thead>
<tr>
<th>Common Name</th>
<th>PENAEUS INDICUS</th>
<th>PENAEUS MONODON</th>
<th>PANAEUS SEMISULCATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability</td>
<td>East and West Coasts</td>
<td>East and West Coasts</td>
<td>East Coast</td>
</tr>
<tr>
<td>Abundance</td>
<td>Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal (W.B)</td>
<td>Bheris of W.B, Chilka lake, Orissa, Andhra Pradesh</td>
<td>T.N, Andhra Pradesh, Bheris of W.B</td>
</tr>
<tr>
<td>Feeding habit</td>
<td>Omnivorous</td>
<td>Omnivorous</td>
<td>General carnivorous</td>
</tr>
<tr>
<td>Maximum Growth</td>
<td>228 mm</td>
<td>336 mm</td>
<td>250 mm</td>
</tr>
<tr>
<td>Size at First Maturity</td>
<td>130mm</td>
<td>60 gm wt.</td>
<td>23 mm (carapace length)</td>
</tr>
<tr>
<td>Fecundity</td>
<td>68,00-731,000</td>
<td>300,000-700,000</td>
<td>67,900-660,900</td>
</tr>
<tr>
<td>Postlarval Availability</td>
<td>Near shore and brackishwater round the year</td>
<td>Near shore and brackishwater seasonal less available</td>
<td>Less availability in the coastal waters.</td>
</tr>
<tr>
<td>Induced Breeding</td>
<td>Successful-seed produced in hatcheries</td>
<td>Successful-seed produced in hatcheries</td>
<td>Successful yet to produce in hatcheries</td>
</tr>
<tr>
<td>Culture</td>
<td>Widely done</td>
<td>Next to P.indicus</td>
<td>Limited</td>
</tr>
<tr>
<td>Salinity Tolerance</td>
<td>Tolerates higher salinity (4-40% a species for summer)</td>
<td>Prefers low salinity (0.5-34% suitable for monsoon crop)</td>
<td>Good for sea water salinity (19-40%)</td>
</tr>
<tr>
<td>Maximum Yield</td>
<td>8 tons/ha/crop</td>
<td>7.5 tons/ha/crop</td>
<td>N.A</td>
</tr>
</tbody>
</table>

Ganapathy (---) mentions, "the species having the capacity to grow faster in impoundments, with higher survival rate, adjusting to farm management measures, ability to consume artificial feed with satisfactory conversion, recovering easily from the pond, and tolerant to environmental variables such as salinity, temperature etc, are considered most suitable for culture in the brackish water farms. Through the results of laboratory experiments and field experience by various agencies it has been established that prawns such as P.indicus and..."
P.monodon are most desired species for brackish water prawn farming than others due to their fast growth in confined areas, hardy and tolerant during handling, can adjust themselves to certain degrees of fluctuation in salinity and temperature in the farming area and also fetch a high price in the market. Hence among the species that are occurring in our coastal regions. P.indicus and P.monodon are considered most ideal for farming.

In Menon's [1991] view, “the most popular species for culture is P.monodon due to its high growth potential and price, inspite of its narrow salinity preference”.

Alagarswami [----] observes, “the advantages of P.monodon are outstanding growth rate, omnivorous feeding habit with relatively low dietary protein requirement, euryhaline nature and high tolerance to handling stress. Another important advantage is that India has a good source of natural seed resources”.

Boyd (1995) mentions, “the P.monodon will survive and grow well at lower salinity. He further adds that the species can tolerate fresh water for a month”.

Jory (1996) identifies, “the P.monodon as the most important farmed shrimp species that has dominated the world production for many years and it comprised 60% of all farmed shrimp in 1995”.

Fisheries World (1995) reports, “on the price front, the black tiger shrimp is showing a steady trend”. Fisheries world (1995) says, “the black tiger shrimp is moving well and the price is firm, while the prices of other counters are unsettled”.

In the economic analysis of aquaculture, especially in the review of productivity and cost per kilogram, comparisons will be impossible if the quality of a product and it’s composition differ from one to the other. To facilitate the comparisons, therefore, it is necessary to convert heterogeneous figures into a standard parameter.
Hirasawa (1992) suggests a method viz., Black tiger prawn conversion (BTC) production method. "Since black tiger prawn is the major target of shrimp culture in Asia, the weights of other species are converted into the weight of black tiger prawn. By this method, with the price of Black tiger Prawn per kilogram as 100, the conversion rate of price for other prawn or fish are taken and then multiplied by their respective weights, thus leading to the volumes of BTC production".

This analytical background justifies the selection of the shrimp specie, P.Monodon (black tiger prawn), as the species to be focused for the research.

3.2 SITE SELECTION

The success and economics of shrimp farming depends upon the selection of suitable site. It is accomplished through proper surveying. Basak (--) suggests the following as the principal criteria for site selection:

- topography
- source of water supply
- soil type
- socio-economic conditions and
- climatic and meteorological conditions.

3.2.1 TOPOGRAPHY

The objective of topographical survey is the preparation of a map with complete details. These maps are necessary and very valuable in the design and location of shrimp farm projects.

Nash (1995) identifies proximity to suitable water as the principal criterion for suitable space. There are some important secondary spatial criteria, such as the area available, gradient, geology, permeability and accessibility, but these are very site-specific characteristics.

The site selected may be:
• island or coastal areas adjacent to water,
• tidal flatlands or permanently submerged land,
• land above subterranean aquifers or
• suitable rain-fed land.

Pillay (1994) is of the view, "even though considerable knowledge has accumulated on site requirements for aquatic farming, it is very seldom that one can find a site that confirms to all the ideal physical and logistic features that are needed. Each site has its own drawbacks, and the accumulated experience can be used to rectify them. The availability of economically feasible sites was found to be a major limitation to the expansion of the industry, but technological advances have made it possible to site farms in relatively more exposed coastal areas".

Reconnaissance survey is to be conducted to have a thorough knowledge of the site to be selected. First an understanding about the site has to be done to determine the best possible arrangement of the work to be carried out at that place. Various boundaries are to be noted, apart from identifying the position of canal, bushes, road and permanent structures. A fairly accurate idea is obtained to produce a hand sketch map called index sketch or key plan showing the boundaries.

3.2.1.1 TYPES OF BRACKISHWATER AREA

Several categories of land useful for brackish water shrimp farming are called: tidal mud-flats, swamps and marshy/low lying areas and estuarine areas.

Tidal mud-flats are the areas which get covered with tidal water during high tides but are exposed in low tides. They often do not require any excavation. Construction of peripheral dyke with a master sluice would convert the area into a farm.

Swamps and marshy areas are the one with low shrubs and other vegetation partially covered with tidal water. Subsoil is always under standing
water, which could be stagnant or raising and falling with tidal water. Such areas are usually called low lying areas or swamps and marshes.

Estuarine areas; the water zone lying between the riverine stretch and open sea with distinct zonation, of tides, salinity and water flows. These areas are broadly classified into five zones as follows:

- **Head zones**: Entry of freshwater; river flow dominates the current.
- **Upper zone**: Salinity range 5-18%; muddy bottom deposit; current negligible
- **Gradient zone**: Salinity 18-25%; mud and sand present; higher tidal waves with faster current.
- **Lower zone**: Salinity 25-30%; dominating sand with some mud present; fast current prevails.
- **Mouth of the river**: Salinity naturally equal to that of adjacent sea; maximum sand content; strong tides prevail.

### 3.2.2 SOURCES OF WATER SUPPLY

Adequate supply of suitable quality water is one of the most important factors for successful shrimp farming. The water sources should be perennial so that in dry months there would not be any difficulty for replenishment of water. Utmost care is required about the quality of water to be supplied to the farm ponds. It will also be necessary to ensure proper circulation of water to retain the required level of oxygen and nutrients in water and to prevent the rise in concentration of undesirable metabolites and pollutants over certain level. Pipelines, open channels are few common means of conveyance of water supply to the ponds. Gravity flow should be used to supply water wherever possible. Each pond should have the facility of independent filling arrangement.

#### 3.2.2.1 QUALITY OF WATER:

The following components in water need to be examined before finalising the site selection.
• colour and Turbidity
• Alkalinity, Hardness, Salinity and pH
• Total dissolved gases
• Presence of heavy metals.

The impact of these components on the shrimp growth and the optimum level of each one is identified and discussed in the subsequent topics.

3.2.3 SOIL

The quality of soil of the proposed site, its texture and composition are essential to decide about the suitability in the pond construction and the natural productivity of the pond. Soils are generally composed of three main components viz., air, moisture and solids. It is broadly classified into six types – gravels, sand, silts, clay, fine grained organic soil and peaty soil. Soils having the combination of clay 8-15% by weight, sand 60-80% by weight and silt 12-25% by weight are ideal for pond construction.

Field test will indicate the soil suitability for pond construction. A handful of moist soil samples from different depths are to be collected and each sample is to be made a ball. If the ball remains intact without crumbling, the soil is cleared. A knowledge of the rate of percolation of the soil will help in determining the extent of water loss through the pond bottom or dykes. Another important test is to identify the load bearing capacity if heavy equipments are to be installed.

3.2.3.1 SOIL CHARACTERISTICS:

Bottom soil of pond is considered as the virgin area where biomedical reactions are taking place. Bottom soil plays a pivotal role in the storage and release of nutrients into the water, the mineralisation of organic bottom deposits, providing shelter and food for bottom dwelling organisms and acts as a bed for the growth of algal pasture. Soil characteristics such as its
texture, composition and fertility are the major aspects which govern the productivity of the pond.

3.2.4 SOCIAL AND ECONOMIC CONDITIONS

Accessibility of the site, cost of land, labour availability, competing uses for land and nearby waters and pollution are the major issues under this.

Accessibility by road so as to carry the construction materials to the work site and also for quicker transportation of harvested shrimps to the market. Land cost should be determined so that economic viability of the project can be evaluated. Knowing the customs, traditions and work culture of local community will help in identifying the labour. The uses of nearby land and water should be assessed to determine what impact, if any is made by the shrimp farming or the possible effect on the shrimp farming. Determine the harmful substances that are to be released into the water ways, and determine the pollution it can cause to the environment.

3.2.5 METEOROLOGICAL CONSIDERATIONS

The wind direction and velocity have important bearings on the pond design. Details of squally weather conditions may be collected from the meteorological office. The data so collected will provide guidance for pond layout so that the pond is less subjected to the destructive effect of the storms. The rainfall records for the past ten years will provide information on the trend of rainfall in the region. Evaporation, absorption, interception by vegetation on the area are called rainfall losses and are expressed as centimeter of water depth over the entire rainfall. The difference between the amount of rainfall and rainfall losses is called surface runoff or surface flow off or run off. This will help in the construction of the pond as well in the water storage and efficient management of water.

3.3 POND ENGINEERING

The success of prawn culture depends upon the proper planning and construction of ponds. In designing the layout of pond, due considerations
are to be given to some basic principles such as physical features of land, topography, properties of soil and water, hydrodynamic of the flow system, the climatic condition of the region and availability of the construction materials, which are all important to make the design economical, stable, productive and suitable for efficient management.

Sinha (---) says, "development of technically and economically feasible methods of drainage, control of seepage and silt removal would be needed. Cost-effective design and construction guidelines for new systems are needed for more efficient management and increased productivity. Rehabilitation of acid sulphate soils for brackishwater farming needs site specific treatment and development. Design and construction guidelines are needed for culture farming".

Dehadrai (---) is of the view, "the future development of aquaculture as an industry depends upon the advancements in the field of aquaculture engineering, mechanization, and energy utilization through planned research. These would provide effective management protocol for maximum profitability. Cost of infrastructure and physical inputs has considerable bearing on the profitability of aquaculture operations. Standards need to be laid down for efficient pond and farm design. Water, an expensive input involving high energy cost, is used indiscriminately in aquaculture without much knowledge on quantified requirement of specieswise biomass and quality maintenance operations. Mechanization and automation of aquaculture operations require continuous innovation and trials. Engineering research needs are varied in regard to integrated aquaculture".

Piedrahita (---) suggests, "design of production systems must be based on technical and economic considerations. Information on some of the topics described above as well as disease prevention should be used in the selection of pond or tank sizes and construction details and water distribution systems".
At present most prawn farmers utilise bheries traditionally known as Bhasa Bhada fisheries in West Bengal, and pokkali fields in Kerala for paddy-cum-prawn culture under extensive farming, where prawns are mainly dependent on natural food. Minimal improvements are adopted depending on the existing condition of these brackish-water bodies, whereas for semi-intensive operations more improvements in-depth, gate and canal system are required.

Gopal Krishna (1991) mentions, “the traditional ponds, namely, existing bheries and pokkali fields, range from 5 to 20 hectares in area. Such a large size leads to difficulties in water management, pest and predatory control, and retrieval during harvest. Hence ponds ranging from 2 to 4 hectares in area are more suitable for the extensive system. In semi-intensive ponds the stock is supplemented with artificial feed in addition to natural food; further water exchange is also provided. Hence smaller pond areas, ranging from 1 to 2 hectares are ideal”.

Basak (----) enumerates, “ponds for prawn culture are mainly of two type: i) Dug out ponds and ii) levee ponds. Dug out ponds are similar to earthen vessel for holding tidal brackishwater. Dug out ponds are constructed by excavation into the ground to a certain depth and the removed earth is utilised in building the perimetre-dykes for protecting the ponds. The levee ponds are most suitable for areas with shallow depressions, which are converted into ponds by building raised banks or levees around the area”.

So the ponds for prawn production are of various types. But whatever be the type of ponds, the success of prawn culture is very much dependent upon proper planning and construction of ponds. Well-designed and well-constructed pond is economic in construction, enhances production and facilitates efficient management. The biological and chemical investigations like the species of prawn to be reared, availability of seed, pond fertility and other parameters are important to be studied beforehand. Detailed engineering studies
on the topography of the pond site, soil properties, salt water availability, drainage and other factors are also equally important.

MPEDA Handbook on Shrimp Farming (1992) explains, “the components of shrimp farm consists of water control structures such as dykes, canals and sluice gates and support facilities such as pumps, aerators, generators, warehouses, farm houses, roads, bridges, workshops etc., Considering the size and type of the culture system, the farm is to be designed to include these components. The lay out of the ponds has to be designed properly with the help of a qualified aquaculture engineer to decide the relative position of nursery and grow-out ponds, main, and secondary drainage canals, main and secondary sluice gates, pump houses etc., for effective water management and control of predators and harvesting. Individual nursery and grow-out ponds could be of a size of 500 Sq.m. and 10,000 Sq.m. and a depth of 80 and 100 cm respectively. For semi-intensive farming smaller-size ponds with more depth is preferred. For effective water exchange, it is preferable to have square or rectangular shaped ponds with width to length ratio of 1:2. Water intake system is to be located where abundant good quality water is available throughout the year. If the elevation of the site is more, extensive excavation will be required to maintain one meter water depth in grow-out ponds. In such sites, peripheral trenches can be cut to have sufficient depth and water column in ponds. The dimensions of the main dike may vary from place to place depending upon the maximum flood level of the area, wave tidal thrust, quality of soil and the purpose it has to serve”.

The safe height of the dyke is determined on the basis of the following considerations;
1) The amount of clearance for foundation of the dyke being the ground level.
2) The maximum depth of tidal water standing on the dyke.
3) The height of free board of the dyke. The free board water surface to the crest of dyke after its consolidation.
4) Settlement allowance of dyke – A newly constructed dyke keeps on settling for sometime due to its own weight and compactness. The usual allowance for settlement is approximately 10% of the height of dyke. Rate of settlement for various soils are:

- Ordinary loose earth = $1 \frac{1}{2}''$ to $2''$ / ft height
- Compact earthfull = $1''$ to $1 \frac{1}{2}''$ / ft height
- Black cotton soil = $2''$ to $3''$ / ft height.

Basak (----) suggests, “the safe height of dyke as:

$$H = h + h_p + r + h_f + h_s$$

$h = \text{depth of foundation of dyke (m)}$

$h_p = \text{height of maximum tidal water (m)}$

$r = \text{height of wave run-up (m)}$

$h_f = \text{height of free board (m)}$

$h_s = \text{height for settlement in dyke (m)}$

The peripheral dyke should be at least 60 cms above the maximum flood level of the area and slope depends upon the seepage gradient of the soil used. Feeder canal dikes should have at least 50 cm free board above the average spring high tide water level, with a top width of 100 cm. Internal bunds between ponds can have a top width of 100 cms and height of 130 cms including 30 cms free board. A berm of 100 cm width and 15 cm free board shall be helpful to prevent erosions of dykes from wave actions. Depending upon the elevation of the site and tidal amplitude excavation may be required to maintain one metre water depth.

A water depth of 80 cms is more suitable for extensive and semi-intensive operations; if this is not met the yield is affected. A bottom trench, 3 to 8 m wide and 0.7 m deep is excavated along the dyke or across the pond to provide a deeper portion, covering 20 to 25 percent of the total area. This measure would enhance the yield of the ponds. A free board of at least 30 to 40 cm for the dykes is to be provided in both extensive and semi-intensive ponds.
A single gate and canal system to serve both as water supply and
drain are required for ponds of size 2 to 4 hectares in extensive culture systems. However, a single gate canal system is inadequate for larger ponds. In semi-intensive ponds two gate systems are essential. The supply gate and canal system should be separate from the drain gate and canal, to allow more efficient water exchange and to remove metabolites. The traditional screening facilities such as bamboo screen are to be replaced by fine mesh screen installed at the inlets either as a big net or as a circular screen.

The safe seepage gradient for various types of soil are:

<table>
<thead>
<tr>
<th>Type of soil</th>
<th>Seepage gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay</td>
<td>1 in 4</td>
</tr>
<tr>
<td>Loam</td>
<td>1 in 8</td>
</tr>
<tr>
<td>Sand</td>
<td>1 in 8 to 1 in 10</td>
</tr>
</tbody>
</table>

The seepage line must fall within the base of the dyke and can be covered by at least 90 cm of soil.

The partition dykes are of low height constructed to separate the ponds. The crest level of partition dykes should be about 0.60 metre above the pond water level.

Bensam (1990) feels, “since the strength, stability and durability of marine culture ponds depend solely upon the quality of the soil, it is essential to acquire a sound knowledge of the quality of the soil, before taking up construction. Ideal soil for pond construction is the clayey one”.

The soil for the dykes are evenly spread in layer of 15 to 20 cm stretching across the whole section, and rolled till the layers are perfectly consolidated. The rolling may start with seeps-foot-roller followed by smooth wheeled roller. This method is most suitable for compacting dry soil with low moisture contents. It is always advisable to build the whole dyke of one homogeneous material to make it water tight. Some times water percolates under the dyke when the base of dyke rests on the pressure of the head of seepage
water. A “cut-off” trench is made in the bgd under the dyke to such water. The “cut-off” trench is filled up with good clay puddle or cement concrete or brick wall with cement mortar (1:4).

To calculate the cross section area of a dyke, to determine the amount of soil needed, the following formula can be used:

\[
\text{Area of cross section} = \frac{\text{Width of the base} + \text{Width of cresh}}{2} \times \text{height}
\]

The area of the cross section is then multiplied by the length of the dyke to get the amount of soil required.

Provision of sluice gate is necessary to facilitate water exchange during the tides. The vent/width of the sluice has to be decided depending upon exchange of water required, period of tide availability for exchange and obstruction of flow through the screen in the gate. A pump is also an essential equipment for exchange of water. However, for semi-intensive or pump – fed farms, the main feeder canal has to be designed taking into consideration the water flow required for exchange. A farm is to be properly designed by an engineer to obtain maximum water area at minimum construction cost.

Figures 9 & 10 show the model layout of a shrimp farm and its cross sectional views. By giving due consideration and weightage to Indian conditions, the nodal agency for aquaculture in India – MPEDA (Marine Product Export and Development Authority) recommends this model for shrimp culture.

ECONOMIC CONSIDERATIONS OF THE SIZE AND SHAPE OF POND

The first consideration is the number of ponds. The second consideration is the expenditure while digging the top soil which is generally more fertile could be kept aside.

Increase in the number of ponds should mean increase in the number of secondary dykes, secondary sluices and increase in the management measures. The total expenditure would increase. Thirdly, the water area would decrease.
FIGURE 9
MODEL LAYOUT OF A SHRIMP FARM

MOL - MAIN OUTLET
PB - POND BED
Dph - PERIPHERAL DYKE
Dfc - FEDDER CANAL DYKE
Ddc - DRAINAGE CANAL DYKE
Dp - PARTITION DYKE
ETP - EFFLUENT TREATMENT PLANT
TOTAL AREA 13.0 ha
WATER AREA 10.0 ha
PF - PUMP SHED CUM FARM STEAD
LC - LEADING CANAL
FC - FEDDER CANAL
P - CULTURE POND
IL - CULTURE POND INLET
OL - CULTURE POND OUTLET
FIGURE 10
CROSS SECTION OF FIGURE 9

CROSS SECTION ON AA'

CROSS SECTION ON BB'

CROSS SECTION ON CC'

CROSS SECTION ON DD'
Therefore, a general formula given below can be used and modified, if necessary, to suit the individual case:

i) minimum water area of a pond considered suitable for economic management and production is 0.5 ha to 1 ha.,

ii) if larger ponds are dug general drainage of the pond, harvesting etc., would involve increase in labour and general management problems and

iii) often sufficient water might not reach the entire pond in one tidal incursion and the tail ends might be left shallow or dry.

3.4 PREPARATION OF GROW-OUT PONDS

Grow – out ponds are defined as those ponds, where the post larvae and juvenile prawns, which have been stocked there, after rearing, reach marketable size and from where they are harvested.

3.4.1 POND PREPARATION

One of the major precautionary steps in the culture operation is the proper preparation of the culture pond for receiving the stock. This involves in providing a healthy and clean environment for achieving faster growth and maximum survival of the stock which is free from pest, predators and competitors and rich in natural food which promote the growth of the prawns.

Pond culture has an advantage in that their natural productivity can be used. Especially in prawn culture it is important to improve ponds prior to culture so as to sufficiently perform water control. With pond dried and harmful fish and their eggs removed, water is put in the pond, followed by proper manuring, so that the pond becomes suitable for the growth of natural feeds. In addition, feed expense can be reduced through occurrence of natural feeds.

Hirasawa (1992) suggests, “to make the maximum use of the natural productivity potential of a pond, the pond must be kept well maintained, enabling sufficient control of water. The natural productivity of pond may be defined as the productivity of the pond obtained without supplementary feeds. In other words, it is the productivity that a pond has originally or potentially”.

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Jory (1995) explains, “there are two main elements in the management of natural productivity of shrimp pond; pond preparation between production cycles and the monitoring and quality maintenance of pond bottom soil and water parameters”. Adequate pond preparation gives shrimp, post-larval and juveniles, an environment with suitable conditions, free of predators and competitors, as stress-free as possible, and with an abundant supply of adequate feed organisms. Several procedures for pond quality monitoring maintenance assure the pond’s environmental conditions are optimal for shrimp production.

The first step involved in the preparation of pond for culture is draining the water completely wherever possible and drying the exposed bottom of the pond for a week to clear off the predators and unwanted organisms ensuring that the ponds on all the four sides of the pond and the sluice are maintained in their positions. Drying also helps in the removal of poisonous gases and adds to the fertility of the soil. Repeated raking and filling of the bottom of the pond would expose the lowest layer of the earth, and also increase the soil fertility. Burrowing animals like crabs, mollusc etc. which do not die by mere exposing and drying the surface of the pond bottom are killed by the application of toxicants like lime, tobacco dust, tea seed cake, mahua oil cake, ammonia etc. in minimum required quantum of water in the pond.

During the rainy season as Jory (1995) suggests, “it is not possible to dry pond bottoms, and many ponds do not drain completely due to defective design and/or construction. The only action feasible during the wet season is to physically remove as much sludge as possible. Sludge removal is critical because if left undisturbed, it will become anaerobic, reduced sediment which will generate toxic metabolites such as methane, hydrogen sulfide, nitrite and others, negatively affecting water quality and production during the next production cycle".
3.4.2 APPLICATION OF LIME:

CP Shrimp News (1995) recommends, “before water preparation lime application is made at 200-300 kg/rai. For new water intake ponds and the waste water canal, lime (Ca C) should be used at 300-500kg/rai”. For the lime to spread uniformly throughout the pond for destroying the predators, a minimum quantum of three inches of water column is maintained. The pH value of pond water increases and heat is also released as a result of the reaction of quick lime on water in the pond. This results in the killing of predators and other unwanted organisms. The water logged portions in the pond like ditches and depressios are treated with milk of lime for giving required results.

John Simon (—) suggests, “the dosage of lime required in those ponds which cannot be drained is approximately 1875 to 2250 kg/ha/meter deep water”. Jory (1995) mentions, “Boyd (1995) has recommended as satisfactory the following liming rates (Using calcium carbonate CaCo$_3$)

<table>
<thead>
<tr>
<th>pH Value</th>
<th>Lime Rate (Kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 5.0</td>
<td>4000</td>
</tr>
<tr>
<td>5.0 – 5.5</td>
<td>3000</td>
</tr>
<tr>
<td>5.5 – 6.0</td>
<td>2000</td>
</tr>
<tr>
<td>6.0 – 6.5</td>
<td>1000</td>
</tr>
<tr>
<td>6.5 – 7.5</td>
<td>500</td>
</tr>
</tbody>
</table>

John Simon recommends the following rate, if shell lime (slacked lime) –Ca(OH)$_2$ is used ;

<table>
<thead>
<tr>
<th>Soil pH</th>
<th>Lime Quantity (Kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>1610</td>
</tr>
<tr>
<td>4.5</td>
<td>1430</td>
</tr>
<tr>
<td>5.0</td>
<td>1050</td>
</tr>
<tr>
<td>5.5</td>
<td>730</td>
</tr>
<tr>
<td>6.0</td>
<td>410</td>
</tr>
<tr>
<td>6.5</td>
<td>200</td>
</tr>
</tbody>
</table>
"The neutralising capacity of different types of lime components vary drastically from 59% (sodium bicarbonate) to 208% (calcium magnesium oxide) Boyd (1995), provides the neutralizing values for various compounds used in liming process and is detailed in the following table"; (Jory 1995)

**TABLE 9**

<table>
<thead>
<tr>
<th>Compound</th>
<th>Neutralizing Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural Limestone</td>
<td></td>
</tr>
<tr>
<td>• Calcium carbonate</td>
<td>100</td>
</tr>
<tr>
<td>• Dolomite</td>
<td>109</td>
</tr>
<tr>
<td>Burnt Lime</td>
<td></td>
</tr>
<tr>
<td>• Calcium Oxide</td>
<td>179</td>
</tr>
<tr>
<td>• Calcium Magnesium Oxide</td>
<td>208</td>
</tr>
<tr>
<td>Hydrated Lime</td>
<td></td>
</tr>
<tr>
<td>• Calcium hydroxide</td>
<td>135</td>
</tr>
<tr>
<td>• Calcium magnesium hydroxide</td>
<td>151</td>
</tr>
<tr>
<td>Soda Ash</td>
<td></td>
</tr>
<tr>
<td>• Sodium carbonate</td>
<td>94</td>
</tr>
<tr>
<td>Baking Soda</td>
<td></td>
</tr>
<tr>
<td>• Sodium bicarbonate</td>
<td>59</td>
</tr>
<tr>
<td>Other Compounds</td>
<td></td>
</tr>
<tr>
<td>• Calcium silicate</td>
<td>86</td>
</tr>
<tr>
<td>• Calcium phosphate</td>
<td>65</td>
</tr>
</tbody>
</table>

Chattopadhyay (1995) says, "the characteristics of soils and the roles of different soil properties influence the productivity of ponds".

**3.4.3 FERTILIZATION**

Good maintenance of a pond with appropriate manuring causes the natural development of feed, thus leading to the improvement of productivity. If this productivity of a pond is called natural productivity, then how to utilize this potential will be critically important in raising the pond productivity and saving feed costs in prawn culture.

Jory (1995) explains, "a vigorous phytoplankton bloom promotes shrimp growth and survival by supplying oxygen, removing toxic metabolites, and
increasing shrimp appetite. Additionally, juvenile penaeid shrimp feed on plant material, and algae are probably a major source of carbon for penaeid shrimp through intermediate prey. Therefore, it is important to promote the establishment of a robust phytoplankton community in shrimp ponds. There is extensive scientific data about how important natural food production is in the diet of penaeid shrimp. In fact, over 50 percent of the carbon in tissue of harvested animals from semi-intensive ponds is probably derived from natural productivity and not commercial feeds”.

The most critical step in management of natural productivity is fertilization to promote a vigorous phytoplankton bloom and a healthy benthic community before stocking post-larvae, and during the cycle to maintain a robust plankton bloom.

There are several relevant aspects of pond fertilization that merit close attention. For example, there is no universally optimal N:P ratio, and each farm has to determine the most suitable fertilization regime. Also, different fertilizers perform differently depending on a pond's characteristics. In addition, in areas that have a markedly different dry and wet seasons, there are different optimal fertilization ratios for each season, as well as different optimal stocking densities and other significant management differences.

The most commonly used inorganic fertilizers are urea and sodium nitrate as nitrogen sources, and diammonium phosphate (DAP) and triple superphosphate (TSP) as phosphorus sources. A high nitrogen to phosphorus ratio has been reported to promote the development of diatom blooms. The N:P ratios used worldwide vary extensively from 1:1 up to 45:1. There is no universal N:P ratio that is optimal for every farm for every pond or time of the year; the most suitable fertilization regime has to be determined and be continually adjusted. And in regions with marked seasons (dry and wet seasons), there are certainly different optimal fertilization ratios for each season, as well as different optimal stocking densities and other management differences.
Organic fertilizers used to fertilize marine shrimp ponds include diverse compounds, including various manures (chicken, duck, cattle, and swine), rice bran, burnt rice shell, and cottonseed meal. A word of caution is in order: this practice must be carefully considered when using chicken manure because of the risk of pesticide contamination; use of insecticides sprayed on the manure to control flies and other pest insects is very common in many chicken farms.

John Simon (---) suggests the following organic and inorganic manures/fertilizers commonly used in ponds of water spread area of 1 ha.,

**TABLE 10**

**ORGANIC AND INORGANIC FERTILIZERS**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Organic Manures</th>
<th>Chemical Inorganic Fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cowdung</td>
<td>Urea</td>
</tr>
<tr>
<td></td>
<td>Poultry</td>
<td>Superphosphate</td>
</tr>
<tr>
<td>Cowdung</td>
<td>200 kg</td>
<td>100 kg</td>
</tr>
<tr>
<td>Poultry Droppings</td>
<td>500 kg</td>
<td>100 kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>200 kg</td>
<td>100 kg</td>
</tr>
<tr>
<td></td>
<td>500 kg</td>
<td>100 kg</td>
</tr>
<tr>
<td>Subsequent</td>
<td>1500 kg*</td>
<td>25 kg@</td>
</tr>
<tr>
<td>Addition</td>
<td>250 kg*</td>
<td>25 kg@</td>
</tr>
</tbody>
</table>

* - monthly,  @ - fortnightly

After applying manure and other fertilizers, the water level in the pond has to be kept at 30cm. for two days. During this period, the pond water will turn green, indicating the growth of algae and a layer of algae will form on the surface of the bottom soil. At this stage sea water is let into the pond, thereby maintaining the water column to one meter.

**3.4.4 SEA WATER PREPARATION**

C.P. Shrimp News (1995) suggests the following guidelines with regard to the sea water preparation:

- Create a separate pond called disinfection treatment pond and pump sea water until full level of 1.5 to 2.0 meters
- Use hypochlorite powder of 60 percent concentration at the rate of 30 ppm diluted in water. Throw the chlorine solution over the whole pond water
surface. The preferred time for this application is during the period with less sunshine. This is because sunshine can make chlorine evaporate easily. At the time of throwing in chlorine solution, all aerators or paddle wheels must be turned on. After two or three hours, turn off the aerators or paddle wheels. The purpose is to increase the suspension time of the chlorine in water to enhance its effectiveness.

Chlorine water reacts with oxygen reducing agents or inorganics such as hydrogen sulfide, iron, manganese, nitrite and ammonia and others both through slow action and quick action. This is called the 'side reaction', namely chlorine will react with all these substances before disinfecting and killing the disease organisms. Therefore, the chlorine application rate depends on the quantity of all the adverse substances in water.

- Two or three days after chlorine solution application, turn on the paddle wheels to evaporate chlorine. Use as many paddle wheels as you can to help speed up the evaporation process. Usually, using two paddle wheels per rai, the evaporation process will take about two or three days. Sunny days will also accelerate the evaporation.

- Check the chlorine residue in water to use titration method.

- The water will be clear after chlorine evaporation. Chlorine residues may be checked again before pumping water in the next ponds for sedimentation, as well as in the grow-out ponds.

- Reduce water salinity down to 15-20 ppt. Deep well water of five ppt will be used to decrease the salinity.

C.P. Shrimp News (1995) states, "another frequent practice is to add commercial feed to ponds at rates of 5-20 kg/ha a few days before stocking, to stimulate benthic production. In addition, this practice probably "weans" the young shrimp and gets them used to eating commercial aquafeeds sooner".
After maintaining one metre water column, the pH of soil and water as well as the water salinity have to be tested for ensuring the readiness of the pond to receive the specific.

3.5 SEED

3.5.1 SEED AVAILABILITY

Srinivasalu Reddy (1995) says, “the spectacular growth experienced by the penaeid shrimp farming industry in recent years has resulted in an increased demand for shrimp postlarvae. It has been estimated that there will be an immediate need of over a few billion penaeid seed for culture operations. Even today, prawn seed is in short supply and it will be an enormous task to meet the further demand unless proper steps are taken now itself”.

There are two ways of overcoming this problem, namely, seed collection from natural resources and establishment of modern prawn hatcheries.

The adult marine prawns breed in the open sea and the young larvae are brought into the estuaries and backwaters. These young larvae, after reaching the adult stage in the estuaries and backwaters, move to open sea in search of high saline water. These baby prawns, usually known as 'post larvae' are collected for stocking purpose.

Algarswami (—) explains, "the traditional system depends on tide-borne seed of prawns. Some farmers of West Bengal and Kerala resort to supplementary stocking by collecting Penaeus monodon and P.indicus seed, respectively, from the estuaries, canals, and surf region. The new systems developed in Andhra Pradesh, Orissa, and Tamil Nadu also depend on wild seed of prawns. Here the seed grounds have been identified. There is in fact a great demand for seed during stocking season”.

Krishi Vigyan Patrika (1980) details the seed availability calendar and distribution pattern for Indian coastal line and is given in Table 11.
<table>
<thead>
<tr>
<th>Region</th>
<th>Species</th>
<th>Season of abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gujarat</td>
<td>P. indicus</td>
<td>February – April</td>
</tr>
<tr>
<td></td>
<td>P. merguiensi</td>
<td>February – April</td>
</tr>
<tr>
<td></td>
<td>K. kutchensis</td>
<td>February – September</td>
</tr>
<tr>
<td></td>
<td>M. brevicornis</td>
<td>March - April</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>P. monerguiensis</td>
<td>October – December</td>
</tr>
<tr>
<td></td>
<td>M. monoceros</td>
<td>October – December</td>
</tr>
<tr>
<td></td>
<td>M. affinis</td>
<td>October – December</td>
</tr>
<tr>
<td>Goa</td>
<td>P. monodon</td>
<td>July – August</td>
</tr>
<tr>
<td></td>
<td>P. indicus</td>
<td>February – May</td>
</tr>
<tr>
<td></td>
<td>P. merguiensi</td>
<td>February – May</td>
</tr>
<tr>
<td></td>
<td>M. dobsoni</td>
<td>February-April-May</td>
</tr>
<tr>
<td></td>
<td>M. monoceros</td>
<td>September – December</td>
</tr>
<tr>
<td>Karnataka</td>
<td>P. monodon</td>
<td>October – April</td>
</tr>
<tr>
<td></td>
<td>P. indicus</td>
<td>December – January</td>
</tr>
<tr>
<td></td>
<td>P. merguiensi</td>
<td>December – March</td>
</tr>
<tr>
<td></td>
<td>M. dobsoni</td>
<td>October – April</td>
</tr>
<tr>
<td></td>
<td>M. monoceros</td>
<td>October – April</td>
</tr>
<tr>
<td>Kerala</td>
<td>P. indicus</td>
<td>October – May</td>
</tr>
<tr>
<td></td>
<td>M. dobsoni</td>
<td>October – January</td>
</tr>
<tr>
<td></td>
<td>M. monoceros</td>
<td>October – December</td>
</tr>
<tr>
<td></td>
<td>M. affinis</td>
<td>October – December</td>
</tr>
<tr>
<td>Tamil nadu</td>
<td>P. monodon</td>
<td>March – May</td>
</tr>
<tr>
<td></td>
<td>P. semisulcatus</td>
<td>January – April, June – October</td>
</tr>
<tr>
<td></td>
<td>P. indicus</td>
<td>February – May, August – September</td>
</tr>
<tr>
<td></td>
<td>M. Monoceros</td>
<td>March – September</td>
</tr>
<tr>
<td>Andhra pradesh</td>
<td>P. indicus</td>
<td>October – December</td>
</tr>
<tr>
<td></td>
<td>P. monodon</td>
<td>September - April</td>
</tr>
<tr>
<td>Orissa</td>
<td>P. monodon</td>
<td>April – May, November – February</td>
</tr>
<tr>
<td></td>
<td>P. indicus</td>
<td>April – July, November – January</td>
</tr>
<tr>
<td>West bengal</td>
<td>P. Monodon</td>
<td>April – May, August – September</td>
</tr>
<tr>
<td></td>
<td>P. indicus</td>
<td>February – April</td>
</tr>
<tr>
<td></td>
<td>M. brevicornis</td>
<td>July, October – December</td>
</tr>
</tbody>
</table>
Nayak Lakshman (1995) writes, "the catch of Penaeid shrimp seed is more during high tide than the low tide. The catch is also more in fullmoon days as compared with the new moon days".

3.5.2 SEED COLLECTION

Bal (1991) is of the view, "during high tide, seeds are collected from the estuaries and backwaters using different nets and amongst them the scoop net is said to be more effective".

John Simon (----) suggests, "during the spring tides, which occur about 5-6 days around full and new moon periods, large number of larvae are brought into estuaries of backwaters and they can be collected without much difficulty during this period, using any of the following methods".

a) Shooting Nets: This is the most commonly used gear. This is actually a bag net having a wide funnel shaped mouth with a detachable tail end. It is supported by the help of six bamboo posts. The mesh size varies from one eight of an inch to one-twelfth depending on water condition. Usually it is operated during high tide and at every interval of 15-20 minutes. The seeds that get accumulated at the tail end are scrapped out and the position of the net is changed as per the tide.

b) Shore Seins: These are operated just about two hours before the end of low tide. This is a small sized net with floats and sinkers operated in shallow waters. Two persons hold the net on either side and slowly drag it through the water. Another set of people heat the water and March towards the hauling net. Finally the catch is accumulated in a small area through retraction of the net and get emptied into a bucket, containing water.

c) Scooping or Pit Collection: There are small hand nets varying from 1 to 1.5 meter in dimension which may be circular, rectangular or triangular in shape and are used to catch or to scoop prawns from pits, depressions, etc., which are available in the inter-tidal zones. The pits or depressions gets filled with water and prawn or fish seeds during high tides.
d) Double stack net: A small funnel shaped net where mouth is kept opened with the help of two bamboo sticks on either side. An empty vessel is tied to the tail end of the net and prawns are collected.

e) Surf net: During the low tide, this is the usual method practised for collecting quality seeds and is operated by three persons using small meshed net of size 1.5 x 1.5 mts.

3.5.3 SEGREGATION OF QUALITY SEEDS

The species desired for culture has to be determined before going in for collection. The seeds that are collected by any one of the above mentioned methods will be a mixture of fish and prawn seeds of other species. This is due to the collection of prawn fry indiscriminately. Bal (1991) cautions, “this practice may lead to unnecessary destruction of post larvae of other species not required for culture and adversely affect their culture. Thus the collection of prawn fry should be done by experienced and trained collectors in a restricted and planned manner”.

The entire collection is transferred to a bigger vessel, having a wide mouth. The fish seeds, which are generally bigger in size are picked up with the help of small hand nets. The desired prawn seeds are to be identified, sorted and stored separately for stocking in the field. The quality young prawns can be identified only by the field experienced personnel and the seed should not be directly handled by hand and should not be allowed to remain outside the water. Now, the seed is ready for transferring.

3.5.4 DEMAND-SUPPLY GAP

Aquaculture Magazine (1997) in its status report mentions, “penaeid seedstock production is still almost completely dependent on wild broodstock. This is a global reality common to shrimp hatcheries, large and small, permanent and transient. The dependence is potentially very dangerous, as an increasing number of wild shrimp stocks around the world are testing positive for a variety of dangerous viruses for which there is no cure yet".
Jory (1996) reports, “maturation of wild-caught penaeid broodstock is routinely done in many areas, but maturation of captive broodstock over several generations and the "closing" of the life cycle has only been achieved on a consistent, dependable basis for a handful of penaeid species. Shrimp hatcheries around the world continue to be heavily dependent on wild broodstock”.

The importance of maturation is obvious, as the ability to produce seedstock on demand, consistently and in sufficient numbers to support the industry must be a major objective to maintain shrimp farming as a strong, environment friendly and viable industry. The importance of domestication and stock selection for marine shrimp culture has already been emphasised.

Shrimp farming can not depend on nature to reliably supply its raw material forever. Achieving domestication of selected species through stock selection and genetic improvement continues to be a major research objective. An integral component of this objective is the development of high health animals.

Jory (1996) explains, “common objectives include efforts to improve disease prevention, detection and control, acquisition and maintenance of good quality broodstock, synchronizing larvae production to farm demand, and improving quality of postlarvae to improve production (survival and growth) during subsequent grow-out”.

Jory further suggests various methods which are used to spawn penaeid shrimp. One way is to capture or procure from suppliers wild, sperm-bearing females that can spawn right away; this strategy normally produces high quality eggs and larvae. The second way is to obtain wild adults and mature and spawn them. The third approach is to mature and spawn adult shrimp that have been reared in captivity. The first two approaches are widely practised around the world in most shrimp farming countries. At least 26 penaeid shrimp species have been matured and spawned in captivity to produce viable eggs at
experimental and pilot scales. However, only a few species are routinely matured and spawned in captivity on a commercial (consistent, large scale) basis, and just a handful have been bred over several generations in captivity. The first two spawning strategies mentioned above imply the continuing dependence of hatcheries on wild stock and an inherent failure risk due to the known presence of various values in, and the variable availability of, wild shrimp stocks. The third strategy implemented by rearing succeeding generations in captivity is the only one that will lead to successful stock domestication, selection for commercially important traits like fast growth and disease resistance, and eventually to stock improvement.

Srinivasalu Reddy (1995) explains, "another scientific achievement to overcome constraints in meeting shortage of pure and healthy shrimp seeds is by eyestalk ablation, a procedure which had obtained perfection in the laboratory and which can be transported to aquafields for large-scale production of good healthy prawn seed".

Eyestalk ablation is a procedure widely used to induce maturation in penaeid shrimp. Since the 1940's it has been known that eyestalk ablation had a stimulating effect on reproduction, but the technique was not incorporated into shrimp culture until the 1970's. In early attempts ablation was done bilaterally (both eyestalks removed) and resulted in high mortality rates. Unilateral eyestalk ablation reduced mortalities to acceptable levels while stimulating maturation. Normally only females are ablated.

Eyestalk ablation is a relatively simple procedure and is normally done only on shrimp that are hard-shelled, not on animals that are about to molt or that have recently molted. Prospective broodstock are normally acclimatized for several weeks in maturation tanks prior to undergoing ablation. There are various procedures to perform ablation.

To reduce stress and minimize mortality the animals are immersed in cold water before and after the ablation procedure is performed. The timing of
ablation is very important, and the results can vary depending on the season and stage in the molt cycle. The best results are obtained when ablation is synchronized with the molt cycle and performed as animals are entering their reproductive peak.

3.5.5 PENEAEID LIFECYCLE

In nature the typical penaeid life cycle Figure 11 begins with adults migrating offshore, maturing and spawning up to several km offshore. Initially the eggs sink but after a few hours they hatch and the nauplii (the first stage) float to the surface. Penaeid shrimp spawning grounds are normally located in areas where favourable currents will eventually bring the developing larval stages inshore into nursery areas such as large bays, estuaries and coastal lagoons. Nursery areas typically have abundant food sources, and offer the developing shrimp adequate conditions for survival and growth. The animals remain in the nursery areas for several months, and then begin maturing and moving offshore to spawn and complete their species’ cycle.

In the hatchery, gravid female shrimp (wild or matured in captivity) spawn during the night and produce between 20,000 and 500,000 eggs each depending on several variables (species, size, water temperature, wild or captive origin, and how many times the animal has previously spawned). Eggs will hatch the next morning. Penaeid larval development from egg to postlarvae is complex and elaborate and involves three stages, nauplii, zoea and mysis; the first stage has 5-6 substages, and the last two generally have three substages each, with each substage lasting several hours. Larval development lasts around 15 days. As animals develop and finish consuming the yolk sac their diet changes beginning with microscopic algae (phytoplankton), to microscopic animals (zooplankton), and after the mysid stage is reached the diet includes a wide variety of organisms, including the brine shrimp Artemia. This varied diet – a live one – must be produced in the hatchery, in enough quantity and quality and on time. It has taken scientists many years to successfully learn to reproduce these
LIFE CYCLE OF PENAEUS MONODON

FIGURE 11
LIFE CYCLE OF PENAEUS MONODON

MYSTIS

POST-LARVA

JUVENILE

EGG

ZOEAL

ADULT

NAUPLIUS

1
2
3

1
2
3

6
5
4

2
3
natural conditions in the artificial environment of a hatchery. Recently some major advances have been made to produce artificial diets for larval shrimp. After reaching the postlarval stage the animals look like very small adult shrimp, can feed on zooplankton, detritus and commercial feeds, and molt almost daily. After several days as postlarvae the animals are ready to be stocked into nursery or growout systems.

3.5.6 HATCHERY CATEGORIES

The function of a hatchery is to simulate as close (and as cost-efficiently) as possible the natural conditions under which shrimp normally undergo their elaborate larval development to postlarvae, in order to maximise larval survival and growth, and produce postlarvae that are hardy and ready for stocking into nursery or growout ponds and tanks.

Various authors have categorized hatcheries as being small-, medium – and large-scale. Small or backyard hatcheries, also called MOM-and-POP hatcheries are typically a family operation. The setup and operating costs are relatively very low, and their approach is unsophisticated, low-tech and practical, using untreated water and low culture densities. They tend to specialize in the production of either naupulii or postlarvae, and are frequently hit by disease outbreaks and other problems like water quality. However, because of their nature and size (larval rearing tank capacity usually less than 50 tons: 1 ton = 1 m³), they can easily shutdown and restart in a relatively short time. Reported survival rates range from 0 to 90%. Backyard hatcheries are very common and have been very successful in South Eastern Asia.

Medium-scale hatcheries are usually based on the Japanese/Taiwanese (or "Eastern") design, use large larval rearing tanks and tank capacity is usually between 50 and 500 tons. They operate with low stocking rates and reduced water exchanges, and take an "ecosystem" approach by directly adding various inorganic fertilizers to encourage plankton blooms on which the developing larvae feed. Other nutrients may be added to larval tanks to
promote the establishment and growth of "good" bacteria populations or "probiotics", to the exclusion of harmful or "bad" bacteria. Reportedly, this "ecosystems" approach results in stronger seedstock and standard survival rates to postlarvae are around 50%.

Large-scale hatcheries are very expensive and rely on sophisticated technology to establish and maintain their controlled environments. They are designed to produce large numbers of nauplii and postlarvae (100 million postlarvae or more per year) under a high degree of environmental control. The larval rearing tank capacity is generally over 500 tons, with tank sizes between 1 and 10 tons. Production methods are intensive (100 or more larvae per liter) and require highly qualified and paid technicians, scientists and management. Water quality and disease problems are common in these hatcheries, and when hit by disease outbreaks, large-scale hatcheries typically take up to several months to recover and go back on line.

Survival rates in large-scale hatcheries are typically 70-80% and these hatcheries try to operate year round, although they can have problems selling their postlarvae when wild seedstock is very abundant.

Jory (1996) comments, "future success of hatcheries and the shrimp farming industry depends both on solving technical and biological problems, and improving management procedures so that the industry can co-exist with other users of common resources such as coastal land and water".

Recent developments in gene probe technology offer valuable tools to screen out animals that carry unwanted pathogens, and this technology is becoming a very important ally on the road to successful domestication and selection of disease resistant stocks. But the most promising strategy to deal with these diseases, as well as others that will undoubtedly appear in the future, is the development of pathogen - resistant stocks through stock selection programs.

Dehadrai (----) concludes: "Seed production in most of the countries is still based on hypophysation and is yet to be standardised. Despite a great
achievement in terms of the quantum of Seed produced, it still remains a hit-and-miss technique”.

3.5.7 TRANSPORTATION OF SEEDS

The collected quality prawn seeds are to be transported to the stocking pond for further growth from the site of collection. If the distance between the collection spot and stocking pond is very short, the seeds can be transported conveniently in open containers, where agitation during the transport would increase the dissolved oxygen and water can also be exchanged, if necessary when transportation is done by waterway. However, if the distance is more, the seeds are transported in air tight plastic bags, containing oxygen.

PACKING OF SEEDS: Polythene bags of thicker gauge and of the size that could be kept inside a tin container are usually used for packing seeds with oxygen. The bags are to be tested for leakage which can be done by immersing the air blown bag in water. After that, the bag has to be washed properly and filled with 5-6 litres of clear, unpolluted saline water collected from the same source where the seeds were collected so that there will be no variation in salinity. The quality prawn seeds are now introduced into this bag and the number of seeds to be packed in a bag is determined depending on the size, duration of transport and the existing temperature.

John Simon (----) recommends the concentration of seeds for packing which is given in Table 12.

TABLE 12
SEED CONCENTRATION IN OXYGEN BAGS

<table>
<thead>
<tr>
<th>Seed Size (mm)</th>
<th>Duration 1 - 12 hrs</th>
<th>12 - 24 hrs</th>
<th>24 - 48 hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 - 10</td>
<td>15000</td>
<td>12000</td>
<td>10000</td>
</tr>
<tr>
<td>10 - 12</td>
<td>10000</td>
<td>8000</td>
<td>5000</td>
</tr>
<tr>
<td>13 - 18</td>
<td>5000</td>
<td>3000</td>
<td>2000</td>
</tr>
<tr>
<td>18 - 20</td>
<td>3000</td>
<td>1000</td>
<td>500</td>
</tr>
</tbody>
</table>
Srinivasalu Reddy (1995) suggests, “through experiments that the best results have been obtained by transport of seed preferably at low temperatures between 15-20°C in insulated containers. This can be done by using folcable waxcoated cardboard boxes reinforced by 1/2 - 1 inch thick sheets of thermocode inside”.

Other practice is to keep air tight packet of ice inside the polythene bag which will help reduce the shooting temperature during transit. Narrow strips of polythene films with periphytic growth or grass when introduced inside the polythene bag shall serve as a subtraction for the larvae to sit rather than allowing them to crowd at the bottom. In order to prevent pollution, caused by the faecal matter of the larvae, no feed should be given for several hours before picking. Sufficient quantity of screened plankton may be added as feed during the transit.

The bag is now closed to expell the air and pure oxygen is bubbled into the water till the bag is well inflated. The mouth is firmly tied and kept inside the container whose inner side is provided with thermocole insulation to check temperature. Now the container is ready for transit and for large scale transport, refrigerated or insulated trucks with facilities for controlled temperature provide solution and better results.

Now, the prawn seeds are ready for stocking.

3.6 STOCKING

The bearing capacity or stocking density of any culture system vary based on many factors. They are identified under two categories viz. technical and management.

3.6.1 TECHNICAL FACTORS

- Culture technology, whether it is under extensive, semi-intensive, intensive or super-intensive.
- Research on experimental culture system.
- Accumulated knowledge through extensive lab and field experiments.
- Species selection.
- Culture system - a Semi-closed or closed one, which is decided on whether water exchange is resorted to or not.
- Physical portion, viz. pond structure.
- Seed - through natural collection (or) through hatcheries.
- Diversity of seed brought in by the tidal waves.
- Quality of broodstock/larvae.
- Hatchery technology adopted.
- Seedling cost.
- Control of predators.
- Feed requirements - whether it is fed artificially or not.
- Feed quality, (i.e.,) drug contamination.
- Water quality - whether brackish water or freshwater.
- Water quality monitoring possibilities like test/lab facilities.
- Prawn stress is based as numerous factors and they are:
  - Natural Productivity of Pond (NPP) which is based on natural productivity.
  - Pond bottom quality, which depends on earlier usage of land.
  - Pond preparation for grow-out.
  - Fertilisation, at the beginning and during grow-out.
  - Dissolved oxygen content which depends on stocking density and volume of feed.
  - Growth of prawn which decides the oxygen requirement in pond.
  - Widespread practice of overstocking.
  - Excess stocking will result in dissolved oxygen depletion.
  - Water salinity.
  - Aeration methods.
  - Pond carrying capacity and productivity.
  - Stocking density, if decided on optimal yield will reduce the stress as the specie.
- Environment is stressed due to the not-so-good practices followed in the aquaculture industry. They are:
  - Research on disease.
  - Disease can come in through improper selection of seed, feed.
  - Mid course corrections are not carried out during the growout cycle for healthier environment.
  - Disease control procedures are not developed.
  - In the cases of mass mortality, the effluents are sent to the ocean without any treatment.
  - Non-availability of treatment avenues in joint sector.
- Cost of establishing the treatment plants.

3.6.2 MANAGERIAL FACTORS

- Organisational objective.
- Market price of the species selected and its variation.
- Type of culture adopted - Monoculture or Polyculture.
- Culture duration which depends on growth and market price.
- Number of harvests planned per year.
- Cost intensiveness of the project.
- Cost of the post - Capital and Operating costs.
- Players in the industry - government or private.
- Regulatory mechanism prevailing.
- Consultancy - both technical and managerial.
- R&D support from government and industry.
- Criteria for species selection
- Pond type which decides on the amount of feed required for culture.
- Cost-benefit analysis on seed and its' availability.
- Feed availability and management.
- Screening/testing facilities for imported feed.
- Decision on the rate of water exchange, which depends on the intensity of culture. In ultra high density cultures, upto 400 percent water exchange is practised.
- Providing and maintaining the hygenic conditions throughout the grow-out cycle.
- Extrapolation of results of small pond experiment to bigger projects.
- Availability of speciality manpower at the right time.
- Training facilities for various type of personnel.
- Level of government and other departments' intervention in securing balance in the industry.
- Option of pursuing rational and sustainable farming practices.

3.6.3 ACCLIMATISATION

The candidate species, P.Monodon is selected on the basis of the economic value of it. This is especially identified for cultivation in brackish water. As already discussed, the seeds are to be obtained either from natural resources or from the hatcheries after proper rearing. In the case of the seeds procured from natural sources, there is ample chance that the size of the seed may vary widely. Though experienced personnel are engaged in identifying and picking the seeds, uniformity can rarely be maintained. This again depends on the season. The time periods when seeds are abundantly available, it is easy to pick the uniformed ones whereas in other times, it is a difficult task. Hatchery production eliminates such kind of problem to some extent. During seasons, when many farms require seeds from the same hatchery, tendency is to mix various batches of hatchery produced post larvae and supply to the required.

John Simon (----) suggests, "stocking should be done with uniform size seeds, otherwise there will be a possibility of cannibalisation. Prawn seeds procured either from natural collection or from hatcheries are to be acclimatised before stocking for reducing cannibalisation".
The polythene bags, packed with quality prawn seeds with oxygen, when brought to the pond for releasing are immersed in the pond water for some time to get acclimatised with the temperature. The polythene bags are then opened one by one and gradual addition of pond water into the bag is done at several intervals to get the seeds acclimatised with the existing biological parameters of the pond water. After each addition of the pond water, the bag is kept undisturbed for 15-20 minutes. When the water in the polythene bags are fully exchanged with the pond water, the seeds are then released into a happa net placed inside the pond. It is better and preferable that the seeds are transported to the pond during the evening time for releasing. After the seeds are released into the happa net, the dead specimens, if any, are to be removed and kept overnight. Specified feed depending upon the size may be placed inside the net at various places for feeding. Care is to be taken that the net is not cut by the crabs at night. Next day early morning, the seeds are to be counted properly and are released direct into the pond for stocking.

3.6.4 PARTIAL HARVEST

Eventhough the stocking is done with uniform sized group of shrimps, there is a tendency for some individuals to grow faster, while others remain stunted thereby resulting in the formulations of different size group.

Verghese (----) mentions, “the carrying capacity of the culture system will start working against further growth at certain stage. The stock is then to be harvested or else thinned through partial harvest”.

The prawns which attained the marketable size are identified and harvested. This will stimulate others to grow, resulting in higher yield. Periodic sampling of prawns will help study the growth rate and survival and decision of partial harvesting can be taken.
3.6.5 RELATIONSHIP BETWEEN STOCKING DENSITY AND SURVIVAL RATE

Prawn fry stocked in ponds should be of juvenile stage for higher survival rate and shorter cropping period. Stocking density is dependent on the culture system including food availability and water management suitable for the pond and the intensity of the technology adopted.

Gopal Krishna (1991) recommends "the stocking rate for extensive culture as 10,000 to 15,000 per hectare when natural food is abundant. In semi-intensive culture system the stocking density ranges from 30,000 to 50,000 per hectare. The growth and survival depend on water management, depth of the pond and finally the quality of the supplementary food. Based on these management procedures a survival of 70 to 80 percent can be obtained".

Jory (1995) suggests, "natural productivity as a source of growth has considerably more importance in semi-intensive ponds than in intensive ponds. The natural productivity in semi-intensive ponds can support the stocked shrimp upto about 30 days (approximately 20-30 percent of the grow-out cycle), depending on the stocking density (10-20 animals stocked/m²)".

SEAFDEC Aquaculture department (1985) recommends that "the semi-intensive culture system adopt a higher stocking density upto 50,000 individuals per hectare".

Menasveta, Worawattanamateekul, Latscha and Clark (1993) inform that, "the intensive culture of P.Monodon is usually carried out at a very high stocking density, i.e. 40-60 prawns/m²".

Avault (1996) reports, "intensive culture involving high-density stocking, feeding and aeration has produced as much as 25 mt/ha (11 tons/acre) per year".

Jamandre (----) expects, "a harvest of 2.5 to 6 tonnes per year from a stocking rate of 5-10 prawns/m² in semi-intensive culture. Stocking rate is high in the case of intensive culture and is in the range of 100 to 200 thousand
animals per hectare. In this, yield is high and typically fall in the range of 1.5 to 4 tonnes/ha/crop. Hirasawa (1992) says, “in practice an increase in the productivity influences the survival rate of prawn, which depends on the intensity of culture”.

John Simon (----) based on his experiments, projects an expected survival rate based on the stocking density and proposed culture period over an area of 1 ha. The projections are given in Table 13.

**TABLE 13**

**CULTURE PERIOD – DENSITY – SURVIVAL MATRIX**

<table>
<thead>
<tr>
<th>Culture Period (months)</th>
<th>Stocking density (nos)</th>
<th>Expected Survival rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>30,000</td>
<td>70</td>
</tr>
<tr>
<td>4 - 5</td>
<td>25,000</td>
<td>60</td>
</tr>
</tbody>
</table>

Ganapathy (1982) gives a comparison amongst the technologies adopted on the stocking density and survival rate, which is presented in Table 14.

**TABLE 14**

**TECHNOLOGY TYPE – DENSITY – SURVIVAL MATRIX**

<table>
<thead>
<tr>
<th>Details</th>
<th>Technology Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Extensive</td>
</tr>
<tr>
<td>Stocking density (No. per m²)</td>
<td>1 – 10</td>
</tr>
<tr>
<td>Survival rate (%)</td>
<td>55 - 60</td>
</tr>
</tbody>
</table>

**3.6.6 TRADE-OFF**

Hirasawa (1992) mentions, “organisms have different demands for oxygen depending upon their sizes. The volume demanded is proportional to their body size. Therefore, in a pond with a certain area, small prawn can be raised in a great number. It cannot be done so in case of large-sized prawn. The
greatest care to be taken in culture should be of the rapid growth stage of the
cultured prawn”.

He suggests the formula for determining the output of culture:
\[
\text{Output} = (\text{Number of Seedling} \times \text{Survival Rate} \times \text{Prawn Weight})
\]

Rao (1995) suggests, “the stocking of seed should be made
according to the carrying capacity and productivity of the pond. Excess stocking
leads to dissolved oxygen depletion in the latter days of the culture period”.

SEAFDEC Aquaculture department (1985) classifies the culture
systems and recommends the adoption which is given in Table:15.

**TABLE 15**

<table>
<thead>
<tr>
<th>Item</th>
<th>Culture Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Extensive</td>
</tr>
<tr>
<td>Stocking rate (Pcs/ha)</td>
<td>4000</td>
</tr>
<tr>
<td>Survival rate (%)</td>
<td>50</td>
</tr>
<tr>
<td>Harvest size (gms)</td>
<td>40</td>
</tr>
</tbody>
</table>

Sundararaj, Devaraj and Prince Jayaseelan (1992) characterise the
prawn species under reference, viz., P.Monodon, to grow upto a maximum size
of 336 mm. The prawn size at first maturity is 60 gram weight.

Hirasawa (1992) outlines the weight of the harvested prawn for the
market with respect to two other countries viz., Indonesia and Thailand. The
details are in Table 16.

**TABLE 16**

<table>
<thead>
<tr>
<th>Culture Technology</th>
<th>Indonesia</th>
<th>Thailand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extensive</td>
<td>30 – 40 gms</td>
<td>25 gms</td>
</tr>
<tr>
<td>Semi-intensive</td>
<td>40 gms</td>
<td>28 gms</td>
</tr>
<tr>
<td>Intensive</td>
<td>28 – 35 gms</td>
<td>28 gms</td>
</tr>
</tbody>
</table>
John Simon (----) projects the growth of the prawn on a time scale which also takes into account the survival rate. The projection is for a culture in an area of 1 ha and is given in Table 17.

**TABLE 17**

<table>
<thead>
<tr>
<th>Culture Period (months)</th>
<th>Stocking density (pcs)</th>
<th>Survival rate (%)</th>
<th>Harvest (pcs)</th>
<th>Projected growth (gms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>30000</td>
<td>70</td>
<td>21000</td>
<td>29</td>
</tr>
<tr>
<td>4 – 5</td>
<td>25000</td>
<td>60</td>
<td>15000</td>
<td>40</td>
</tr>
</tbody>
</table>

Changes in the pond environment will have a bearing on the growth of the prawn. During culture, the prawn growing in the same pond remain stunted after a period of time and if these prawns are released into another pond, the growth will be faster.

The size of the prawn does matter, as the bigger ones fetch a higher market price. However, the stocking density and survival rate will decide the number of species grown and harvested.

3.7 FEED

Feed is an important input in prawn culture for increasing production. It should be easily digestible with high conversion value, readily acceptable and available in large quantities at low cost. Appropriate feed management practices can significantly contribute to a healthy pond environment and consequently improve production.

Jory (1995) identifies five primary factors which are intimately inter-related and each one is critical for success, that will determine the success of an aquafeed. The factors are:

- natural food availability
- feed formulation and nutrient content
- feed manufacture and physical characteristics
• feed handling and storage
• feed application method and feeding regime

The successful use of a feed clearly requires a thorough understanding of the aquatic environment, natural food production and management of pond water and bottom, as well as feed handling, application methods and feeding regime.

Feeds are one of the most critical components of successful shrimp farming, and certainly the most expensive element in the operating costs of a farm. Therefore, optimizing feed management and maximising use of natural food production is crucial for economic survival of the farms.

3.7.1 FEEDING OPTION

Shrimp feeding practices can be broadly classified into four food management options depending upon the level of technology deployed, form of nutrient input required and the level to be supplied. Options are:

• natural food in pond
• application of fertilizers to improve natural productivity of pond
• Supplementary diet feeding and
• complete diet feeding

3.7.1.1 NATURAL FOOD IN POND

This is the basic system where prawn shrimp growth is totally dependent upon natural productivity of the water body. Since prawns are omnivorous in feeding habit they eat both living and non-living matter. But it prefers to feed on tiny plants/animals otherwise called food organisms present in the pond.

In the natural habitat, shrimps feed on other small crustaceans, finfish, molluscs, polychaetes, ophlufolds and other slow-moving benthic organisms. They catch food with their pereiopods, take to their buccalcavity and nibble slowly. They are omnivorous but cannibalise if food is insufficient or of
poor quality. They also feed on any kind of decaying matter available in the habitat.

Natural food organisms are allowed to grow in well prepared pond fertilised with organic or inorganic fertilisers. These food organisms in the form of benthic blue-green algae, diatoms green algae and various species of microscopic zooplankton and microbenthos serve as the natural food of the cultured shrimp.

The different types of food organisms that are present in the natural habitat of prawn ponds are described below:

a) Lab-Lab: This is a kind of microbenthos composed of blue-green algae, diatoms and other microscopic plants and animals. This might be a suitable food for juvenile prawns measuring upto 100 mm in total length.

Pond soil preparation is important for growing lab-lab. Pond bottom is to be leveled to ensure a uniform growth of algae. By drying the pond bottom for a week, the required pond bottom quality may be achieved to facilitate the algae growth. Chicken manure is applied to the dry pond bottom at 350 kg/ha. If this is not available, 18-46-0 inorganic fertiliser is applied at 100 kg/ha. After fertilization, 3 to 5 cm water is let into the pond and after one week, same amount of fertilization is done and water level in the pond is raised to 10-15 cms. Same procedure is repeated during second week and water level is increased to 20-25 cms. This procedure will give better ‘lab-lab’ growth.

Varghese (----) establishes a relationship between lab-lab growth and soil texture and the organic matter present in the soil. This relationships are shown in Table 18.
TABLE 18
SOIL TEXTURE & ITS USEFULNESS

<table>
<thead>
<tr>
<th>Growth of lab-lab</th>
<th>Soil texture</th>
<th>Organic matter present in soil (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very abundant</td>
<td>Clay</td>
<td>Above 16</td>
</tr>
<tr>
<td>Abundant</td>
<td>Silty clay loam</td>
<td>9 – 15</td>
</tr>
<tr>
<td>Few</td>
<td>Sandy clay loam</td>
<td>7 – 8</td>
</tr>
<tr>
<td>Very few</td>
<td>Sandy loam</td>
<td>6</td>
</tr>
</tbody>
</table>

Rao (1994) mentions, “growth of lab-lab requires higher salinity which is not conducive for the growth of tiger shrimp. In fact best growth of lab-lab is reported to be at salinities above 25 ppt. However, lab-lab is used as natural food for the post-larvae and juveniles in the first two months after stocking”.

b) Lumat: This is composed primarily of grass green algae. Soft mud bottom with pH 6.8 to 7.5 favour the growth of lumat. For the growth, the pond bottom may be dried but only for 3 days. After drying, water is let in just sufficient to moisten the soil and the pond bottom is seeded. Then the pond is filled upto 20 cms. Three to seven days after seeding, the pond is fertilized with 16-20-0 at 18-20 gms/m³ of water. After one week, the water level is raised to 40 cms and weekly application of fertilizers 8-10 gms/m³ is done. The lumat can be grown in low salinity i.e., below 25 ppt. compatible with the growing conditions for shrimps.

Phytoplankton: This is composed of small plants which float in the water. They are the primary producers which serve as food of zooplankton and other organisms which in turn become food for shrimps. Most types of phytoplankton are normally found in deeper water where temperature does not get as high as it does in shallow ponds. If water temperature is too high the growth will be retarded. By applying fertilizers in required quantity, phytoplankton can also be grown. The application of fertilizer should be of
small quantity at a time and the frequency can be increased. Gopal Krishna (1991) is of the view, “yellow-green or brownish pond water indicate the presence of phytoplankton in good quantity. The growth is recorded in deep waters with low and medium salinities (10 to 30 ppt).

c) Zooplankton: The tiny animals that float on the water with little moving ability is called zooplankton. To get a good growth of this, there should be plenty of phytoplankton which is the chief food as stated earlier. Therefore the fertilization practice followed will not only generate phytoplanktons but also zooplankton.

d) Benthic animals: Small animals that live on the pond bed soil are called benthic animals. They are real food organisms that are liked by prawns. These animals feed on organic matter available in the pond soil and lab-lab. To get good growth of benthic fauna, soil should be rich in organic matter and debris.

Detritus: This is yet another natural feed available in the pond. If there are no food organisms present in the pond bed, prawns then consume detritus as food. When organic and/or inorganic fertilizers are used in the pond, detritus is formed in a short period of time. Detritus is a conglomeration of substances, dead and decaying matters.

3.7.1.2 APPLICATION OF FERTILIZERS

The production capacity of the culture system is increased by the application of chemicals or organic manures as a source of nutrients to enhance the production of live food organism within the water body and this management option is typical of a semi-intensive or improved extensive farming. The prescribed fertilization referred to above, if adhered, will improve production.

Jory (1995) suggests, “in semi-intensive ponds natural productivity can support the stocked shrimp for upto about 30 days (approximately 20-30% of the duration of the typical grow-out cycle), depending on the stocking density (10-20 animals stocked/m²), until a critical shrimp bio-mass (generally between 100
and 300 kg/ha) is reached and additional subsidies – in the form of added aquafeeds – are needed to sustain shrimp growth”.

3.7.1.3 SUPPLEMENTARY DIET FEEDING

As the prawns grow the food requirement will increase substantially and if they do not get sufficient food, cannibalism will take place leading to heavy mortality. The dietary nutritional requirement of the aquaculture species are supplied by a combination of live food organisms and supplementary feed which consists of low-cost locally available agricultural materials and byproducts and may include live or fresh natural food items.

Rao (1994) identifies the following as commonly used supplementary feeds:
- rice bran with trash fish
- Carabao and cattle hides, house discards/leftovers
- chopped toads and frogs
- snails with shells crushed
- mussel and clam meat.

Gupta Jancy (1994) comments, “technology related to prawn supplementary feed production is one which has to be developed based on the needs i.e. from farm-to-lab rather than from lab-to-farm. It is suggested that the supplementary feed prepared approximately should contain 35-45% protein from animal and vegetable sources, 10% fats and 25% carbohydrates with fibre content not exceeding 6%”.

Sridhar Manpal (1994) says, “few of the farmers use farm-made feeds and hence the quality and composition vary depending on the availability of raw materials”.

Vergheese mentions in his article that the most favoured food given to shrimp in Japan is fresh meat of clams or squids. About 10 kg of meat is reported to be required to add one kg. weight of shrimp. However, providing fresh meat in the commercial culture will pose several problems. The main problem is
that the fresh meat will create pollution hazards if regularly used. The animal wastes are given to the shrimps either raw or after boiling to remove excess fat. The feed is given in baskets suspended in water. The feed in meat form are to be given after soaking in water so as to prevent floating.

Srinath (1996) mentions, “the practice of supplementary feeding as followed at present by small farmers is not based on any rationale in the quantity and method of feeding. The tendency to mimic intensive farming resulted in stress and premature harvest. Only about 20-30% survival is generally reported through the culture period in the fields following supplementary stocking and feeding practices. In the absence of facilities for soil and water quality testing and monitoring disease, farmers very rarely get technical advice in this regard. The stock is often harvested by farmer in small quantities, when they require the money, even before the completion of the culture period”.

Supplementary diet feeding strategies generally allow higher stocking densities when used in conjunction with pond fertilization and are typical within semi-intensive farming systems.

**3.7.1.4 COMPLETE DIET FEEDING**

This employs the use of an external feed as a complete source of dietary nutrients for direct consumption by the cultured shrimp, which meets the nutritional requirements of the species. Traditionally, complete diets have taken the form of dry or moist pelleted feed consisting of a combination of different processed feed ingredients, the nutrient profile of which approximates as far as possible to the known dietary requirements of the cultured species. Complete feeds may consist of the continuous use of single, natural food items with a high nutritive value such as ‘trash fish’ or hatchery cultured live food organisms. Complete diet feeding is employed within intensive farming systems and because of the high stocking densities employed no nutritional benefit is assumed to be gained by the cultured species from the natural food organisms present in the waterbody.
3.7.2 FEED MANAGEMENT

The objective of feed management is to make available to the shrimps the best quality artificial feed, in the required quantity, and at the right times and places. Satisfying this objective requires experience and knowledge of shrimp behaviour and feeding habits and a continuous pond sampling program that provides accurate and timely data on pond environmental parameters, and shrimp biomass, size distribution and individual mean size.

Management of artificial feed is a sequential process, only as strong as its weakest link. It includes feed selection, handling and storage, feed application methods, feeding regimes and feed rate adjustments.

3.7.2.1 FEED CHARACTERISTICS

A feed may be nutritionally balanced, but unless acceptable to the shrimp is of little value if not consumed. To facilitate easy identification and pick up of feed, it is highly essential that feed ingredients should be in a particular shape, size and consistency. Shrimp feed by smell and not by sight and hence colour is not a significant one. When feed is mixed with attractants (amino acids), shrimps are attracted towards it and they start eating them up. Attractability and palatability are both important and should be observed while making the feed. The particles of feed should not be large but of the size which can be ingested by the shrimps. The texture should be uniform as any cracks result in poor water stability and variations show poor processing. Clumping of pellets indicate improper drying before bagging leading to poor shelf-life. Feeds should not contain more than 2% dust or fines, as excess indicates poor processing and handling and is a waste leading to water pollution. Shrimps are slow and continuous feeders and a minimum stability of 2 to 2 1/2 hours is sufficient. Feed which are not stable and disintegrate rapidly result in feed waste, poor food conservation ratio (FCR) and water pollution.
3.7.2.2 FEED SELECTION

In selecting an artificial feed it is critical to ensure it meets several criteria. The feed chosen must fulfill the known nutritional requirements of shrimp. It must be fresh and free of pesticides and have low pollution potential. The feed should include attractants and natural foods to improve palatability. The addition of enzymes and highly digestible ingredients in feed formulation increases nutrient assimilation and reduces excreted materials. Pellet size must be appropriate to shrimp size and feed must be sufficiently stable after immersion in water.

Sanhotra Manpal and Mohamed Peer (1994) recommends the protein and lipid levels in commercial shrimp feeds (as fed basis) as in Table 19.

**TABLE 19**

**SHRIMP SIZE Vs NUTRIENT REQUIREMENT**

<table>
<thead>
<tr>
<th>Shrimp Size (gms)</th>
<th>Nutrient Level (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Protein</td>
</tr>
<tr>
<td>0 - 0.5</td>
<td>45</td>
</tr>
<tr>
<td>0.5 - 3</td>
<td>40</td>
</tr>
<tr>
<td>3 - 15</td>
<td>38</td>
</tr>
<tr>
<td>15 - 40</td>
<td>36</td>
</tr>
</tbody>
</table>

Cuzon, Hew, Cogne and Solechnik (1982) report the nutrient loss from a pelleted shrimp feed after one hour immersion in sea water. The details are in Table 20.
TABLE 20

FEED NUTRIENT LOSS

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Initial level</th>
<th>Lever after one hour</th>
<th>Loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (%)</td>
<td>100</td>
<td>81</td>
<td>19</td>
</tr>
<tr>
<td>Crude protein (%)</td>
<td>52</td>
<td>41</td>
<td>21</td>
</tr>
<tr>
<td>Carbohydrate (%)</td>
<td>16</td>
<td>8</td>
<td>50</td>
</tr>
<tr>
<td>Vitamin – C (mg/kg)</td>
<td>3089</td>
<td>332</td>
<td>89</td>
</tr>
<tr>
<td>Thiamine (mg/kg)</td>
<td>29.5</td>
<td>0.7</td>
<td>98</td>
</tr>
<tr>
<td>Riboflavin (mg/kg)</td>
<td>55</td>
<td>7.5</td>
<td>86</td>
</tr>
<tr>
<td>Choline (mg/kg)</td>
<td>3368</td>
<td>1835</td>
<td>45</td>
</tr>
<tr>
<td>Pyridoxine (mg/kg)</td>
<td>14</td>
<td>1</td>
<td>93</td>
</tr>
</tbody>
</table>

3.7.2.3 HANDLING AND STORAGE

Feed management at the farm level intensifies with the arrival of feed shipment. Adequate handling and storage of feed and proper quality control have immediate and significant consequences for shrimp production. Poor storage and handling of feed will result in product deterioration, reduced feed attractability and palatability, nutritional deficiencies and disease outbreaks and lower growth rates and overall production.

The first step is to evaluate feed quality. Each farm develops its own requirements, and there are several quality criteria used to evaluate artificial shrimp feeds. Common criteria including pellet size, uniform appearance, physical integrity and density, humidity, protein and lipid content, water stability, attractability and smell. Twice a year feed samples should be collected from newly received shipments and analysed for proximate composition, mycotoxins and selected pesticides if pertinent.

Aquafeeds are made of highly perishable ingredients, and it is critical to handle and store them properly till usage.
Markey (---) has discussed four major problems associated with handling and storing aquafeeds. They are: nutrient losses, growth of microorganisms, insect and rodent infestations and rancidity.

Jory (1996) suggests the guidelines for handling and storage of shrimp artificial feeds which is presented in Table 21.

**TABLE 21**

**GUIDELINES FOR FEED HANDLING & STORAGE**

<table>
<thead>
<tr>
<th>1. Check manufacture date and follow manufacturer's use guidelines.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. During transit to farm, floor of vehicle or boat must be dry and clean. Cover bags with plastic or water proof material. Reject deliveries of wet or moldy feed shipments.</td>
</tr>
<tr>
<td>3. Store feed in safe, dry, shaded and well ventilated areas, and in as cool a temperature as possible (difficult in tropical areas).</td>
</tr>
<tr>
<td>4. Avoid feed contact with polluting sources such as dust, paint, oil, gasoline, pesticides and other chemicals.</td>
</tr>
<tr>
<td>5. Storage area should be kept clean of spilled feed, which attracts pests. Avoid areas with poor drainage and where water pools (breeding ground for many insects). Windows should have mosquito mesh. Spray with approved pesticides and equipment (by qualified personnel).</td>
</tr>
<tr>
<td>6. Calculate feed needs in advance and only purchase amounts to be used within 2 months. Maintain accurate inventory control. Keep new shipments separate from other batches. Do not store new bags on top of older ones. Do not stack more than 9-10 bags, and maintain a minimum distance of 30 cm between stacks to allow for sufficient air flow.</td>
</tr>
<tr>
<td>7. Use farm-made, moist feeds within 2-3 hours after preparation, or promptly sun-dry or store frozen.</td>
</tr>
<tr>
<td>8. Rotate Stock: feed should be used according to “first-in, first-out” (older bags are used first). Feeds from the same manufacturer but different age (time in storage) can result in significantly different yields in shrimp growth. Maintain different feeds separately, not only by shipment but also by type (medicated, protein content, manufacturer).</td>
</tr>
<tr>
<td>9. When handling feed bags, do not drop but carry and put bags down gently. Stack bags nearly on pallets and avoid direct contact with damp walls and floor. Do not walk on stacked bags to prevent physical damage to pellets.</td>
</tr>
</tbody>
</table>

**3.7.2.4 FEED APPLICATION METHODS**

In larger ponds, artificial feeds are applied by manual broadcasting or mechanically by blowers from dykes, platforms and boats. In small, intensive
ponds, automatic feeders with timing mechanisms can be used. However, high pressure, blower-type feeders can be ineffective because pellets usually will become pulverized, and these devices usually do not reach beyond 25 mts. Automatic feeders can be a useful alternative to manual feed broadcasting, but should not replace regular observation and visual assessment by trained personnel.

Early in the grow-out cycle it is important to distribute the feed evenly throughout the pond. At many ponds feeding is done from boats. As shrimps grow, they avoid areas where anaerobic sediments accumulate like internal drainage canals and areas adjacent to drain gates. Many shrimps relocate to deeper areas within the pond during the day. Therefore, very shallow areas or those with sediments should not receive any feed during the daylight hours, because the fate of this feed will be to become expensive fertilizer and lower water quality.

Size of pellets: The size of pellets is not related to the mouth size. As shrimp carry the pellets and swim around in the water, they should be small enough to be carried to the mouth and swim around in the water. Not more than 3 sizes are recommended viz. 1mm crumbles for post larvae: 2mm x 4 mm pellets for juveniles and 2.5mm x 5mm pellets for adult shrimp. However, the smaller the particle size the more per unit weight would be available feeding a greater number of shrimp.

Feeding Method: They are used in two ways. Trays have long been used to monitor feed consumption and make adjustments to feed rates. Another way is to use trays as the only means to provide feed to a pond. The recommended number of trays is 15-20 units/ha. for intensive ponds, and 10-12 units/ha. for semi-intensive ponds. For a stocking density of 10-15 animals/m² the suggested number of trays are 10-20 units/ha. and more units are added if stocking density is higher.
3.7.2.5 FEEDING REGIMES AND PERIODICITY

Every artificial feed has an ideal feeding rate range which optimises growth and feed efficiency, and this range will change depending on animal age and weight, density, water quality, and availability of natural foods. The optimal feeding rate and frequency must be determined at each farm and for different feeds by testing and comparing results in growth, survival and feed efficiency for several growth cycles, to account for seasonal variability in environmental factors.

Increasing the frequency of feeding generally produces immediate benefits, including reduced nutrient and feed loss and increased growth and feed utilization efficiency. Shrimp should be fed several times a day with the major portion of the ration being administered at night when they are most active. As dissolved oxygen concentrations are very low during midnight, it is advisable not to feed between 10 PM to 6 AM next day.

Sanhotra Manpal and Mohamed Peer (1994) suggest the time and ration to be fed daily which are given in Table 22.

TABLE 22

<table>
<thead>
<tr>
<th>Time</th>
<th>Feed Ration %</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 AM</td>
<td>20</td>
</tr>
<tr>
<td>10 AM</td>
<td>10</td>
</tr>
<tr>
<td>2 PM</td>
<td>10</td>
</tr>
<tr>
<td>6 PM</td>
<td>30</td>
</tr>
<tr>
<td>10 PM</td>
<td>30</td>
</tr>
</tbody>
</table>

Abesamis (1989) recommends a more realistic feeding schedule, as given in Table 23, taking into consideration of the growth of shrimp.
**TABLE 23**

INTEGRATED FEEDING SCHEDULE

<table>
<thead>
<tr>
<th>Shrimp Size (g)</th>
<th>Days</th>
<th>Feeding Times (h)</th>
<th>Percent Ration</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL-3.0</td>
<td>0-30</td>
<td>700</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1700</td>
<td>50</td>
</tr>
<tr>
<td>3.0-6.5</td>
<td>31-45</td>
<td>700</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1700</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2200</td>
<td>30</td>
</tr>
<tr>
<td>6.5-11.0</td>
<td>46-60</td>
<td>700</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1100</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1700</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2200</td>
<td>25</td>
</tr>
<tr>
<td>&gt;11.0</td>
<td>61 - harvest</td>
<td>700</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1100</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1400</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1800</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2200</td>
<td>25</td>
</tr>
</tbody>
</table>

Jory (1996) maintains that, "feeding periodicity in penaeid shrimp species over diet cycles is a complex and unresolved subject. It is generally agreed that most penaeid shrimp spend the day buried in the bottom and emerge at night to forage and feed, but there is also evidence for the opposite".

Supplementary feeding calculations are based on feed and survival percent tables. These tables vary by species, geographic area, age of animals, target mean size, intensity level of culture, water temperature and dissolved oxygen, feed attractability and water stability, frequency and times of feeding, and other factors. Daily ration is calculated based on estimates of density, mean individual weight of animals and survival percent, and percent body weight to
feed daily. Each farm develops its own in-house survival and feeding tables over time.

The major drawback of these feed calculations is the difficulty of accurately estimating survival rates, particularly when dealing with small animals in large (> 5 ha) ponds. Several factors affect feeding rates, including poor water quality (low dissolved oxygen levels, temperature extremes, sudden pH fluctuations, increasing concentration of toxic gasses from decaying bottom conditions, plankton, population changes and others) and molting cycles. Feed consumption changes due to these as well as other stressors that can be detected by the proper use of monitoring feed trays.

3.7.2.6 FEED RATE ADJUSTMENTS

Feeding rates are adjusted based on population sampling and monitoring of environmental parameters such as water temperature, dissolved oxygen and other water parameters, the use of feed trays and experience. Rates are adjusted periodically (usually weekly) based on sampling estimates for individual average body weight, population size distribution and pond shrimp biomass. As animals grow the feed amounts used decrease as a percentage of the total shrimp biomass, but the total amount of feed increases proportionally with increasing shrimp biomass.

Sampling: Gopal Krishna (----) suggests, “a simple sampling procedure to arrive at the total weight of shrimp available in the pond at any point of time. Regular sampling of prawns by the use of a cast net gives good estimates of the total biomass as well as the condition of prawns.

\[
\text{Total weight} = \frac{\text{Total sample wt (g)}}{\text{Area of the net (m}^2\text{)}} \times \text{Total pond area (m}^2\text{)}
\]

The best time for sampling is at night or early morning during which time prawns are active and uniformly dispersed in the pond".
Feeding Trays: Feeding trays are the best option to adjust feed inputs into shrimp ponds and avoid under and overfeeding, and are also very useful for monitoring daily feed consumption and for making adjustments aimed at improving efficiency of feed utilization. When trays are brought to the surface they usually have some shrimp. This is an excellent opportunity for experienced personnel to inspect a sample of animals (for fullness of digestive tract, bacterial lesions, molting). Trays must be placed throughout the pond (avoiding areas of sludge deposition) and in enough numbers to be representative, from 1-2 trays/ha in large ( > 5 ha) semi-intensive ponds, to 10-15 tray/ha in intensive ponds ( < 1 ha). The principle behind the use of trays is to place a known amount of feed in the tray (1-2 percent of the scheduled feeding ration) and then to examine the tray after 2-4 hours and estimate how much is left (if any). Interpreting amounts left in trays can be subjective, and whenever possible the same people should be used for this task. The same criterion applies to operations like cast netting to collect animals during periodic population assessments. When using feed trays to adjust feed rations, there are many criteria that can be used to interpret the amount of feed left and what action to take.

Clifford (1992) and Salame (1993) suggest a standard table which could be used to make adjustments to feeding rates based on the average of feed left on feeding trays and is presented in Table 24.

**TABLE 24**

<table>
<thead>
<tr>
<th>Average Amount (%) of Feed Remaining in Tray</th>
<th>Feeding Rate Adjustments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Increase 5%</td>
</tr>
<tr>
<td>&lt; 5%</td>
<td>Maintain same rate</td>
</tr>
<tr>
<td>5-10%</td>
<td>Reduce 5%</td>
</tr>
<tr>
<td>10-25%</td>
<td>Reduce 10%</td>
</tr>
<tr>
<td>&gt; 25%</td>
<td>Suspend two rations and restart with 10% less amount</td>
</tr>
</tbody>
</table>
Feed management continuously strives to provide the best quality feed at an economical cost. This also helps in maintaining proper environment which results in higher production. Experience and knowledge of shrimp behaviour and feeding habits and a continuous feedback on pond environmental parameters and shrimp population are factors critical for successful feed management. The best artificial feed will become useless if not managed properly.

3.8 WATER QUALITY MANAGEMENT

One of the prime factors for a successful brackishwater aquaculture is maintenance of healthy aquatic environment. This can be provided with concentration on bottom soil of the pond and water used for culture. Production of shrimp is limited by degradation of water quality. The impounded brackishwater become organically polluted due to productive processes and presence of aquatic organisms. A clear understanding of the three factors, viz., physical, chemical and biological will help in identifying the required environmental conditions that have to be necessarily ensured for healthy development of shrimp.

Purushan (1995) affirms that "the rate of water exchange is the most important single factor determining the success/failure of a farming endeavour. The daily rate of exchange may vary depending upon the stocking density".

3.8.1. A) PHYSICAL FACTORS :

Depth, temperature and turbidity are the three important physical factors to be focussed for providing the required environment for shrimps.

3.8.1.1 DEPTH :

Sunlight penetration into the pond water column is very significant as the shrimps go deep into the bottom during day time. It also influences water circulation in the brackishwater impoundments. The optimum depth should be between 90-120 cms. If the depth is low, during summer season, the pond water
temperature will increase resulting in death of shrimps. As mentioned in the feed management practices, the water column should be gradually increased before seedling to allow the growth of various benthic organisms.

3.8.1.2. TEMPERATURE :

This accelerates the metabolic and physiological activity in the pond. This attains optimum when temperature is favorable and this level is upset when unusually low or high temperature prevails. The optimum temperature required for growth ranges from 26°C to 32°C and is considered as best in terms of yield. Shrimp may survive up to 35°C but extremes – both high, and low, temperatures – are unfavourable.

3.8.1.3. TURBIDITY :

Water in its pure form is quite transparent. But due to the admixture of various living and non-living components the transparency is lost. The degree of transparency is measured to determine turbidity. The turbidity restricts the penetration of solar energy into the water due to suspended particles thereby restricting photosynthesis and inhibiting plant growth. Rain and flood may also cause turbidity of temporary nature. The crawling activities of the shrimps themselves make the water turbid. The turbidity due to this cause is taken as an indication of the quantity of shrimps available in the pond. In a well managed pond the traditional Secchi disc visibility will be up to 25 to 35 cm.

3.8.2 B) CHEMICAL FACTORS :

Dissolved oxygen, alkalinity, pH, salinity, other dissolved gases, salts etc., are concentrated as part of chemical factors responsible for providing the required quality environment.

3.8.2.1. DISSOLVED OXYGEN :

The D.O. is used by aquatic organisms for respiration. Maintenance of adequate levels of D.O. in the pond water is very important. The D.O. is the single most important parameter in aquatic environment, which
influences metabolic activity on which the growth, survival and health of the animal depends.

The sources of D.O. in water are air and photosynthesis by phytoplankton and submerged aqua weeds. The volume of D.O. will be usually minimum before sunrise and reaches maximum at mid day.

There are several factors that affect the solubility of oxygen. They are: temperature, salinity, accumulation of detritus and organic matter on the pond bottom, cloudiness and thermal stratification.

Rao (1995) explains that the capacity of water to hold oxygen in dissolved state increases with decreasing temperature. Table 25 gives the details regarding the solubility of oxygen at different temperatures in pure water at 1 atm.

**TABLE 25**

**SOLUBILITY OF OXYGEN AT DIFFERENT TEMPERATURES**

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>O₂ (mg/lit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>14.16</td>
</tr>
<tr>
<td>5</td>
<td>12.37</td>
</tr>
<tr>
<td>10</td>
<td>10.92</td>
</tr>
<tr>
<td>15</td>
<td>9.76</td>
</tr>
<tr>
<td>20</td>
<td>8.84</td>
</tr>
<tr>
<td>25</td>
<td>8.11</td>
</tr>
<tr>
<td>30</td>
<td>7.53</td>
</tr>
<tr>
<td>35</td>
<td>7.04</td>
</tr>
</tbody>
</table>

Salinity inversely affects the solubility of oxygen. At higher salinities, solubility of oxygen is less. At temperatures of 20-35°C solubility of oxygen decreases by about 0.007 mg/per litre for each 210 ppm. increase in salinity. The solubility of oxygen in water (mg/litre at 1 atm) at different salinities and temperatures is given in Table 26.
<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Salinity</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td></td>
<td>11.3</td>
<td>10.6</td>
<td>9.9</td>
<td>9.3</td>
<td>9.0</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>10.7</td>
<td>10.1</td>
<td>9.5</td>
<td>8.9</td>
<td>8.7</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>10.3</td>
<td>9.7</td>
<td>9.1</td>
<td>8.6</td>
<td>8.3</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>9.9</td>
<td>9.3</td>
<td>8.7</td>
<td>8.2</td>
<td>8.0</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>9.5</td>
<td>8.9</td>
<td>8.4</td>
<td>7.9</td>
<td>7.7</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>9.1</td>
<td>8.6</td>
<td>8.1</td>
<td>7.6</td>
<td>7.4</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td>8.7</td>
<td>8.2</td>
<td>7.8</td>
<td>7.3</td>
<td>7.1</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td>8.4</td>
<td>7.9</td>
<td>7.5</td>
<td>7.1</td>
<td>6.9</td>
</tr>
<tr>
<td>26</td>
<td></td>
<td>8.1</td>
<td>7.7</td>
<td>7.2</td>
<td>6.8</td>
<td>6.6</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td>7.8</td>
<td>7.4</td>
<td>7.0</td>
<td>6.6</td>
<td>6.4</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>7.6</td>
<td>7.1</td>
<td>6.8</td>
<td>6.4</td>
<td>6.2</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td>7.3</td>
<td>6.9</td>
<td>6.5</td>
<td>6.2</td>
<td>6.0</td>
</tr>
<tr>
<td>34</td>
<td></td>
<td>7.0</td>
<td>6.7</td>
<td>6.2</td>
<td>6.0</td>
<td>5.8</td>
</tr>
</tbody>
</table>

The non-living organic matter (detritus) normally accumulates due to addition of organic manures, overfeeding, and phytoplankton die-off. During night times, especially if it is warm and calm, there is not enough oxygen production due to the absence of photosynthesis, and thus leading to D.O. depletion.

Cloudiness will reduce the photosynthesis of the phytoplankton leading to D.O. depletion during nights. In summer, ponds with 2 to 2.5 mts of depth normally undergoes thermal stratification. The thermolime formed prevents circulation of water from surface to bottom. This results in low D.O. levels.
D.O. in a culture pond should not go below 4 ppm during any part of the day. During early morning hours, the D.O. should not be below 4 ppm and in healthy ponds, 5-8 ppm of oxygen is generally dissolved. When oxygen deficiency arises, it should be attended immediately either by mechanical aeration or by exchange of water or by adding potassium permanganate at 4 kg/ha. Addition of lime at 250kg/ha. will also help in rectifying oxygen depletion.

3.8.2.2 CARBON DIOXIDE:

This is highly soluble in water and its concentration controls vital activities of the pond water like buffering against rapid shifts in acidity-alkalinity states, regulating many biological processes in aquatic communities and supplying the element carbon for the formation of various compounds essential for the life of the shrimps. Carbon di-oxide in the pond is derived from a number of sources such as bacterial decomposition of organic matters, respiration of animals, certain chemical reactions. The concentration depends upon the salinity and temperature. The solubility decreases as the other two factors increase.

3.8.2.3 ALKALINITY:

Total alkalinity is defined as the total concentration of titratable bases in water. Carbonate, bicarbonate or hydroxide are collectively known as total alkalinity in otherwords. This is also defined as the index of potential carbon-dioxide and all the above mentioned forms cannot exist at the same time. The productivity improves as the alkalinity increases. Total alkalinity will vary upto 1000 ppm but the optimum range is 50-300 ppm. Higher the alkalinity the more stable is the pH.
3.8.2.4 pH:

The term 'pH' refers to the hydrogen ion concentration in water, more generally, pH refers to how acidic or basic the water is. For practical purposes, water with a pH of 7 is considered neither acidic nor basic; it is said to be neutral. When the pH is below 7, water is said to be acidic. If it is above 7 it is basic. The pH scale extends from 0 to 14; the greater the departure of pH from 7, the more acidic or basic the water is. Alkaline medium is required for the growth of shrimps as acidic condition reduces the appetite and decreases the tolerance capacity to toxic substances. The stability or variability of pH is of great importance in culture, for most of the aquatic organisms are adapted to an average pH value and do not easily withstand sudden and strong variations. The increase in pH value is accompanied by a marked risk in total alkalinity and decrease in carbon dioxide. The frequent flushing and water exchange keep the pH at the required level.

Boyd (1995) generalizes the effect of pH on shrimp which is shown in Table 27.

<table>
<thead>
<tr>
<th>pH Value</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Acid death point</td>
</tr>
<tr>
<td>4 - 6</td>
<td>Slow growth</td>
</tr>
<tr>
<td>6 - 9</td>
<td>Best for growth</td>
</tr>
<tr>
<td>9 - 11</td>
<td>Slow growth</td>
</tr>
<tr>
<td>11</td>
<td>Alkaline death point</td>
</tr>
</tbody>
</table>

3.8.2.5 SALINITY:

Brackishwater is essentially a diluted sea water. The weight in grams of the numerous salts that have gone in 1 kg. of water is known as salinity. In other words, it is the total concentration of dissolved ions in water and is generally expressed in parts per thousands (ppt). Depending on the degree of admixture of sea water and fresh water, the salinity of brackishwater fluctuates from time to time. This emphasises the essential requirement of good drinking
It is brought from nearby wells in adequate quantity. Salinity affects the water density, increases buoyancy, regulates osmotic pressure and solubility of gases. Oxygen dissolves 20% less in sea water than in fresh water under the same conditions of pressure and temperature. Survival and growth of shrimps are affected at very high and low ranges of salinity. The productivity of ponds, growth and abundance of food organisms, and the rate of growth and survival of cultural shrimp are very much related to the ambient salinity. The salinity tolerance capacity of shrimps vary much and therefore changes in salinity should be gradual which should be acclimatized at each change. Depending upon the salinity and temperature the productive period can be classified as favourable, less favourable and harmful. Verghese (——) identifies "the favourable period as the one when salinity remains more or less stable within the range of 10-30 ppt with temperature at 25° to 32°C. The harmful effects are manifest in the rainy season when salinity and temperatures register a sudden fall from the highest summer level".

3. 8.2.6. OTHER DISSOLVED CHEMICAL FACTORS:

John Simon (——) identifies, "nitrogen, phosphorus and hydrogen sulphide as three important dissolved items which call for attention. In brackishwater medium, NH3 is used mainly by algae; whereas diatoms prefer nitrates. Dissolved nitrogen above 0.2 ppm is advisable for culture purpose. The availability of the second item-phosphorus in aquatic medium is a limiting factor for the productivity of phytoplankton. The last item, hydrogen sulphide, is poisonous to prawns, resulting in death. It gets accumulated in the pond bed as a result of chemical reaction and affects respiration of the shrimps. For larger water area, frequent water exchange is a must to remove the accumulated hydrogen sulphide. Treating Ferrous oxide at the rate of 1 kg/m² also prevents this formation to some extent.

3. 8.3 BIOLOGICAL FACTORS

The organically polluted ambient water of the pond has to be replenished with unpolluted clear tidal water. This intake may lead to the entry of larvae and post larvae of predators into the brackishwater impoundment which has been prepared with pesticides, fertilizers etc., and the entry of predators can
be prevented by filtering the water through a velon screen of smallest mesh size, placed in front of the inlet sluice.

3.8.4 WATER EXCHANGE

The water exchange is done during each fortnight preferably during the lunar phase when the tidal amplitude will be higher. When changing the water, one third of the pond water to be drained at low tide and replenished during the high tide of each day for 3 to 5 days, preferably either during the early morning or late evening hours.

Water exchange frequency is linked with technology adopted for cultivation. The exchange rate goes up from semi-intensive to intensive to super-intensive method of culturing. The natural productivity of the pond will take care of the juvenile requirements for first few weeks as stated earlier. The rate of water exchange goes up as culture time progresses.

Nageshwara Rao (1995) suggests a scheme of water exchange per day linking it with the culture period. Table 28 gives the details:

<table>
<thead>
<tr>
<th>Culture Period</th>
<th>Rate of Water Exchange per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>From 1st to 20th day</td>
<td>Less water exchange; depends on water quality; add water to maintain water level.</td>
</tr>
<tr>
<td>From 21st to 60th day</td>
<td>5 to 10 percent</td>
</tr>
<tr>
<td>From 61st to 90th day</td>
<td>10 to 20 percent</td>
</tr>
<tr>
<td>From 91st to 120th day</td>
<td>20 to 30 percent</td>
</tr>
<tr>
<td>From 121st to harvesting</td>
<td>30 to 40 percent</td>
</tr>
</tbody>
</table>

3.9 DISEASE CONTROL

Karunasagar and Indrani (1995) write, "shrimp culture has been a traditional activity in some parts of the world for centuries. With the development of the aquaculture as an industry, disease has come to pose a major threat. This situation can be seen in all the countries where shrimps are being cultured on an industrial scale. During 1987, Taiwan was a leading producer of shrimp in the world. However, in 1988 the disaster by diseases struck and production dropped
by 70%. During 1991, China emerged as a leading producer of cultured shrimp, but a sharp decline in production occurred as a result of the outbreak of the disease during 92-93. India experienced huge losses estimated at 10,000mt of shrimp during 1994-95 due to disease outbreaks. These examples illustrate the havoc diseases can play in aquaculture systems.

3 9.1 ENVIRONMENT AS A FACTOR

At this juncture when the industry has suffered so much it is necessary to have a radical change in our concepts. Let us redefine the white spot as an environmental disease or a disease caused by the presence or absence of certain environmental factors. Studying it as a viral disease would lead us to genetic probes and would produce an extremely valuable literature in molecular biology, which would be useful only to scientists. As there is no real cure for any viral disease, only an ounce of prevention is worth much more than a pound of cure. Prevention is possible in near future mainly through the manipulation of environmental factors and not just through genetic engineering.

Kaleemur Rahman Md. (1996) writes, "it is widely accepted that there are some environmental factors which activate the SEMB virus (probably present in all culture systems) and favour its multiplication. At the same time it is very difficult to pin down the environmental factors which trigger its multiplication in a aquaculture system". Firstly because many of the environmental and water quality parameters like phosphate, silicate, nitrate, ammonia, hydrogen sulphate etc., are not recorded in most of the farms. Some farmers do not even bother to record the pH and DO (Dissolved Oxygen). They are just satisfied with salinity. Secondly, the data recorded are not correct. There are either errors in the measuring instruments, or in the methodology and sampling procedure adopted in farms due to lack of trained manpower. Presently there are no studies on the input and output of N:P:K in shrimp farms in India. No information is available on the soil and water interaction in shrimp farms. No scientific data published on the effect of turbidity and there are major lacunae in the literature of micro nutrients in water that remained to be bridged. Unless more empirical evidences on the environmental factors triggering the multiplication of the virus are published, it is
very difficult to analyse and come to a definite conclusion. However, certain analyses are possible through the first mentioned factor.

3.9.2 MICROORGANISMS CAUSING DISEASE IN SHRIMP

a) Viral Disease: Viruses are tiny microorganisms which can multiply only in a living cell. When they are released into the environment from infected hosts, they may survive for a while but they need to enter new hosts to replicate. Viral diseases are suspected to be involved in large scale shrimp mortalities that took place in Taiwan, China and India.

P. Monodon baculoviruses (MBV)

Karunasagar and Indrani (1995) write, “this virus was first identified by Dr. Lightner and his group when it caused large scale mortalities in P. monodon in Mexico during 1980. This virus has been found in P. monodon from many countries including Taiwan, Thailand, The Philippines, Malaysia, Indonesia, Singapore, and India. The virus affects the post larvae, juvenile and adults. Presence of MBV in a large percentage of healthy (70-100%) larvae in many countries of Southeast Asia led on Lightner to propose that MBV is well tolerated by P. monodon. Most cases of MBV related mortality are triggered by poor environmental conditions”.

Since the virus is enzootic in hatcheries using wild-caught brood stock, Feral P. monodon are thought to be the reservoir of infection. The infected shrimps shed the viruses and these contained in “Occlusion bodies” may remain infectious for years. The presence of MBV can be detected by direct examination of wet mounts of infected tissue stained with 0.1% aqueous solution of malachite green. A more sensitive method, especially for post larvae would be examination of tissues from animals with enhanced infections. Enhancement can be accomplished by crowding in small tanks. Recently, techniques based on antibodies and DNA probes are also being developed to detect the virus in infected shrimps.

MBV infections can be prevented only through avoidance i.e., by using MBV free brood stock and larvae. It is also suggested that the incidence of MBV in hatchery can be substantially reduced by using clean sea water to wash eggs or nauplii before transferring them to rearing tanks.
Infesetous Hypoderma and Necrosis Virus (IHHNV)

This has been reported from USA, South America and South East Asia. The virus appears to be highly virulent in P. stryloristris causing 80 – 90% cumulative mortality within two weeks particularly in the post larvae and juveniles. IHHNV can be recognised through histological sections having cowdry type – A intranuclear inclusion bodies. However, this virus does not seem to be a problem in South East Asia.

The transmission of the virus is via parental infection, direct contact, indirect contact through contaminated water. P. monodon can carry IHHNV as a latent carrier.

Systemic Ectodermal and mesodermal Baculovirus (SEMBV)

Karunasagar and Indrani (1995) add, “this is a new Baculovirus which caused serious mortalities (upto 80 – 100%) in shrimp farms in China during 92-93. This virus is suspected to be the major cause of mass mortalities of cultured shrimp in India during 94-95”. This virus seems to have a wide host range (P.monodon, P.indicus, P.chinensis) and affects all ages causing 80-100% mortality. The affected shrimp develop white spots of variable size on carapace and other parts of exoskeleton. The virus can be confirmed using a DNA probe.

Presently SEMBV disease can be countered only through avoidance i.e., by preventing introduction of SEMBV infected shrimp into the culture area. The virus infected stock should be destroyed and contaminated areas disinfected.

Hepatopancreatic parvolike virus (HPV)

The shrimp infected by the virus show poor growth rate, anorexia, reduced preening activity and increased surface fouling. The virus may also be found in shrimp which show no outward sign of disease. The significance of HPV is difficult to assess because this virus is generally present along with others in epizootics with high mortality rates.

Yellow head disease

This disease is characterised by pale body colour with yellowish gills and hepatopancreas. It is most commonly seen 50-70 days of post stocking. The virus affects a number of organs and tissue. Diagnosis is made based on
degradative changes. Cumulative mortalities may reach 100% within 3-5 days. Initially the virus was thought to be a baculovirus, but recent evidence indicates that it is a RNA virus. No treatment is available like for any other viral disease. Outbreaks of yellow head disease in Thailand have led to introduction of closed system where direct intake of seawater is involved. However, there are reports of outbreak of disease even in closed systems.

b) **Bacterial Disease:** Among the various bacterial agents known to cause problems in shrimp culture, *Vibrio* spp. are the most common. These bacteria are predominant flora of the marine environment and several species such as *V. alginolyticus*, *V. patahaemolyticus*, *V. harveyi*, *V. vulnificus*, *V. splendidus* etc. have been involved in shrimp mortalities. Vibrios may be a problem both in hatcheries as well as grow out ponds. In hatcheries, sudden mortalities may be observed which may reach 80-100%. Luminiscent vibrios, *V. harveyi* and *V. splendidus* are common, in juveniles or adults.

The filamentous bacterial such as *Leucothrix* may be found on body surface of shrimp particularly in ponds with poor water quality. These bacteria may cause mortality due to hypoxia and impairment of molting process.

c) **Fungal pathogens:** Among fungal pathogens of shrimp, *Lagenidium* seems to be most prevalent in larval and early post larval stages. It may also affect eggs which subsequently fail to hatch. Infected larva may become weak to lose equilibrium and appear whitish. Mortality may reach 100%. Another fungus *Sirolpidium* may cause similar infections. *Haliphthoros*, *Fusarium*, *Saprolegnia*, *Leptolegnia* are other fungal pathogens of *P. monodon*.

d) **Protozoan disease:** There are two types of protozoan pathogens (i) ecocommensals (ii) endoparasites. Microsporidians may cause sterility, weakness and greater susceptibility to other environmental stresses.

### 3.9.3 OCCURRENCE AND DIAGNOSIS OF SHRIMP DISEASES

All over the world, early and proper diagnosis of shrimp diseases to minimise the economic losses suffered by the farmers has been engaging the attention of scientists. But, shrimp farming being a multi-disciplinary industry, many specialists like marine biologists, fishery scientists, water management engineers, microbiologists, pathologists, toxicologists and lastly pharmacologists
will have to be involved as a team, if we have to quickly diagnose the diseases and initiate measures for their prevention and control. But, unfortunately such a team of scientists is very difficult to build and much more difficult to sustain particularly in our country, because of obvious reasons. Secondly no regulatory authority exists in India for the standardisation and implementation of diagnostic and treatment procedures as in U.K. and U.S.A. This has resulted in mushrooming of many psuedo-consultants ill-equipped as they are, much to the detriment of the farmer and the industry. This is to be discouraged by all concerned in the best interests of the industry and its future growth.

**Clinical Symptoms of the Diseases**

Infected tiger prawn displayed lethargy, weakness, anorexia, and cessation of feeding. Infected prawns initially gathered in shallow waters adjacent to pond embankments and within 4 days infection became acute and mass mortality has been observed. Externally there is no focal damage to the shell. There are no ulcers of black spots on the body.

Body colour became dull and pale-white circular spots in the shell, were observed. As the disease progressed, the white spots were also noticed on the abdominal and tail region. In some ponds one or both the antennae of the infected shrimps were damaged. In the infected shrimps, delayed molting resulted in slow-growth or cessation of growth. Improper mineralisation has caused softening of the shell.

The most important disease character observed is the gradual liquification of the hepatopancreas. In affected specimens alimentary canal is empty and often filled with clear fluid. Haemocoel is cloudy, blood vessels damaged and blood cells are aggregated in some areas. The disease has caused muscle necrosis in the juveniles and young prawns and the dead muscles gradually turned into brick-red colour.

**Causative Pathogen**

Gopal Rao (1995) writes, "microbiological tests of the haemocoel, muscle, hepatopancreas have clearly indicated that the primary causative pathogen is the bacteria, Vibrio parahaemolyticus. In some shrimp in addition to Vibrio Spp., Aeromonas Spp and Pseudomonas Spp., have also been identified
causing mixed infection. Mixed infection is resulting in the red discolouration of the body of the infected prawn. The Vibrio Spp., Aeromonas Spp., and Pseudomonas Spp., are gram-negative and opportunistic pathogens. They became virulent due to the prevailing stress factors particularly low temperature, decreased water salinity and poor water quality and feeding management methods.

**Bacterial Count**

The extreme stress factors cause rapid multiplication of the Vibrio spp and bacterial count in the haemocoel ranged between $10^5$ - $10^8$. High concentration of the Vibrio bacteria spreading to all the vital organs, damaged the cellular level functions of all the organs resulting in acute 'Septicaemia' and rapid death of the infected prawns.

The pathogenic bacterial Vibrio sps, which are a common flora in the sea and coastal waters, is multiplied at a faster rate in creeks, canals due to prevailing environmental conditions, presence of high organic load with decaying water hyacinth and grasses and mixing with drainage water from agricultural fields with pesticides. With the letting out of the infected pond water into common drain/creek from which water is pumped into other ponds depending on the same creek has resulted in rapid multiplication and the spread of disease to different areas.

**3.9.4 PREVENTION AND CONTROL OF DISEASES**

Reddy (1995) explains, "it is well known that it is always better, easier and economical to try to prevent diseases rather than waiting for the diseases to strike and then initiate control measures. This is even more true in dealing with aquatic animal like shrimp under modern farming conditions as they are always surrounded in a medium hostile to them for their proper growth and development and have to co-exist with millions of other organisms often living at the cost of the shrimp".

**Control:** At best it should be the last resort to the farmer but, in reality it is perhaps the only weapon available to him when a disease strikes. But, it is costly and most often ineffective.
Reddy further adds that many drugs and chemicals have been
developed and are in use in our country as elsewhere in the world. In fact, more
number of such drugs and chemicals are freely available because of utter lack of
regulatory bodies for licensing of their production or availability to farmers without
any 'prescription ' from the competent authority. Some of them are listed below:
A. Drugs: (ingested along with feed and act systematically in the body )
1. Penicillins; Amoxycillin\Ampicillin. Broad spectrum . Bactericidal, short acting
   and less residues. Shorter with drawal period.
2. Tetracyclines; Oxytetracyclines : Oxytetracycline/Doxycycline. Broad
   spectrum. Bacteriostatic slow acting, more residues and longer withdrawal
   periods.
3. Potentiated sulphanilamides : Sulphamethoxazole with Trimethoprim. Broad
   spectrum. Antibacterial, Bacteriostatic, retards growth, more residues and
   longer withdrawal periods.
4. Quinolones  : Flumaquine. Norfloxacin, Enrofloxacin etc., Synthetic Anti-
   bacterials, Broad spectrum, Bactericidal. Quickacting, shorter withdrawal
   periods.
   Bacterio-static, slowacting and problem of drug resistance.
B. Chemicals: (Used for external application for purification of water and killing
   of bacteria, viruses and Protozea but outside the body of shrimp)
1. Copper compounds; Copper sulphate and and its chelated compounds.
2. Iodophores: Povidone Iodine (Iodine with carrier) etc.,
3. Quanterinary Ammonium Compounds: Benzalkonium Chloride etc.,
4. Chlorine Compounds: Sodium Hypochloride (Bleaching Powder)
5. Other Compounds: Formalin, Malachite green and potassium permanganate.
6. Ectoparasiticides: Dichlorovis, Parathion etc.,

Route of Application

Chemicals: Sold as liquids or powders are to be dissolved in water and sprayed
over water surface uniformly. Care must be taken to ensure that the chemical
dissolves and spreads uniformly throughout the depth and width of the water. It
will be helpful in many cases to switch on the paddle wheel aerators to help in uniform mixing of the chemical with water.

**Drugs:** Most drugs including antibiotics are usually mixed with feed and given to shrimp continuously for at least 5 to 7 days or till the disease is controlled fully. If already compounded feed is used, it is suggested that the feed is soaked for 10 to 15 minutes in a solution of the drug and then the feed may be used. Withdrawal of medication before 5 to 7 days may result in a relapse often with more serious consequences.

All drugs and chemicals are metabolised in the body or degraded in water depending upon the condition of water, the state of the shrimp and many other chemical characters of the medium (water). There are many countries to which our shrimp is exported, which impose severe restrictions on antibiotic residues present in the exported shrimp. So, it is advisable to observe a 'safe' withdrawal period of 15 days of all drugs (particularly antibiotics) before the crop is harvested as no pharmacokinetic studies have so far been conducted on usage of antibiotics and other drugs on shrimp whereas full data are available on the usage of such antibiotics, responsibility and human being.

**Problem of Drug Resistance**

It is commonly observed in all species of animals that continuous usage of one antibiotic over a period or time will make the pathogens in such animal more resistant to the same antibiotic for further treatment. Hence, to guard against such development of bacterial drug resistance in the pathogenic bacteria, it is advisable to periodically change the type of antibiotic used in shrimp farming.

**3.9.5 INTEGRATED METHOD OF CONTROL**

Gopal Rao (1995) adds, "in order to achieve full control an integrated approach comprising the following methods are essentially required;"

- Reduction of stress factors.
- Therapy with antibiotics.
Reduction of Stress Factors

- In order to minimise the stress factors, exchange of pond water is to be done initially to remove the toxic grasses, and to reduce the organic load in the pond.
- Fill up the pond up to one meter depth and clean the pond water by applying iodophores and other sanitizers. This controls the fluctuation in water temperature, dissolved oxygen level and bacterial load in the pond water.
- At this stage farmers should not frequently exchange the pond water as the water in supply canals is contaminated with pathogenic organisms. Whenever the water is exchanged, water cleaning with iodophores has to be carried out.
- Do not apply any manures or add decayed meat into the pond.

THERAPY WITH ANTIBIOTICS

Sensitivity tests conducted have shown that the pathogenic bacteria vibrio and other bacteria collected from the infected shrimp are found to be sensitive to antibiotics viz., Tetracycline, Terramycin, Aueromycin, Chloramphenicol, Co-trimaxazole, Nitrofurazone, Furaxone Nalidixic acid and Kanamycin. All the pathogenic bacteria are resistant to pencillin, gentamycin, streptomycin and sulfonamides.

- Recent field tests indicate that Nifurpirinol is able to control the infection. Use of mixed antibiotics are also yielding positive results in controlling the disease.
- The antibiotics have to be applied in higher dosage for example 3 to 4 g/1Kg of feed. Antibiotics should never be used in low dosages as they may create resistance.
- Major difficulty in the therapy with antibiotics is that required dosage of medicine is not entering into the body of infected shrimp because of the cessation of feeding by the diseased shrimp. Method of antibiotics application to feed pellets through mixing with egg albumin or any binder is also not efficient. Control of Vibrio septicaemia needs quality medicines and efficient application.
3.10 HARVESTING

Purushan (1995) is of the view, "maintenance of quality water within the system will give added stimulus to the growth of shrimps. As such, it is necessary to assess the growth rate of shrimps periodically by random sampling. Statistical procedures are followed to sample the representative group of specimens for determining the correct mean weight. It is on the basis of this periodic growth assessment alone that the feed ration is changed at weekly intervals. In a well maintained system, the P.monodan will acquire 30-40g within a favourable period of 3-4 months".

Harvesting and marketing are the final stage of the prawn culture operation. The economy of the culture operation depends on the size, quantity and quality of shrimp harvested and the returns obtained through proper marketing. Prawns normally have the habit of burying themselves in the soft slushy pond bottom during day time and become active and move about during night hours. In other words, it is nocturnal in habit and more active during dusk and dawn periods. They are attracted towards light during dark nights. Prawns are also stimulated by the movement of fresh sea water. They become active and swim around in the pond and often gather near the sluice when fresh high tide water is let into the pond. They have the tendency to move along the periphery of the pond during night hours. Older prawns have the stimulation to migrate back to the offshore to complete its life cycle. This behaviour can be noticed as they try to swim out of the pond when the water is drained during low tide. These behaviours of the prawn are suitably taken into advantages for harvesting the cultured prawns. All types of gears that are designed for the harvest had been on the basis of these behaviours of the prawns. Many types of gears and devices are in operation for harvesting the cultured prawns. But most of these devices are effective only for practical harvest from the pond. Total harvest is possible only by hand picking after complete draining of the pond either by gravitational force or by pumping. Before going into the details of the various gears in operation for harvesting the cultivated prawn, it is necessary to understand the marketable size of the prawn and time for harvest.
3.10.1 SIZE AND TIME FOR HARVEST

The size of prawns at harvest is an important factor which determines the price of the prawns. Among the species considered for culture, Penaeus monodon is known to grow up to a size of 337mm. In culture operation, the growth of the prawn normally depends upon the environmental condition, the natural fertility of the pond and the method of pond management practices followed. In semi intensive culture practice where pond management is practiced and supplementary feeding is applied, P. Monodon grows to 150-170mm (40-45gm) in 5 to 6 months. Although the prawns can be grown to still bigger size by lengthening the rearing period it may not be feasible as the cost for its management will be more in comparison to the production rate for these extended period. P. Monodon can be harvested at the end of 6th month, when it reaches the size of 40-45gms. Many prawn moult during full moon period. Soft shelled animals fetch lower price. It is therefore necessary to assess the quality of prawn before starting the harvest.

Krishna Srinath (1996) adds, “survey results of the farming practices followed by farmers show that only 25 percent of the farmers follow the recommended practice of harvest after the prescribed period”.

3.10.2 METHOD OF HARVEST

Ganapathy (---) writes, “various methods and devices are employed for harvesting the cultured prawn. These devices can be grouped under two categories, namely partial harvest and total harvest”.

3.10.2.1 PARTIAL HARVEST

Partial harvest is widely practised in the pond where differential growth of the prawns are observed. Prawns show different growth rates, that is some individuals grow much faster than the others. In such ponds complete harvest, irrespective of size, will be uneconomical. Therefore partial harvesting is resorted to catch only the bigger prawns. If bigger prawns are removed the smaller ones will grow faster. The nets that are used for partial harvest is as follows:
(i) **Cast Net**

Cast net is a simple type of gear, conical in shape and operated by a single person to catch prawns and fishes. There are two types of cast nets, namely stringed and stringless. Stringless cast net is efficient in catching the prawns from the slushy pond bed, but it will take more time to retrieve the prawns from the net. It is easy to release prawn from the stringed type of cast net. To attract the prawn, and improve the catching efficiency a strong source of light is kept on the dyke while operating this net during night hours. As the prawns are caught alive in this type of operation, the young undamaged ones could be released back for further growth. However, this process of operation is time consuming.

(ii) **Drag Net**

Drag net, of convenient size, provided with float and sinker is normally operated by two persons to catch the cultured prawns. Even by repeated operation of this type of net we can harvest only 70-80% of the stock of the pond.

(iii) **Traps**

Traps made of bamboo screen are also used to catch the prawn from the pond. The swimming behaviour of the prawn along the periphery of the pond during night hours is suitably utilised for trap operation for catching the prawn. This type of operation consists of a guide screen or leader line and the catching traps. The leader line or the guide screen is staked and oriented perpendicularly or diagonally form the pond dyke. At the end of the screen the traps are placed. The traps are provided with 2-4cm openings. The prawns that move along the peripheral dyke during night hours and guided by the screen towards traps where it enters through the opening in each trap. A small kerosene lamp is placed on the top of the trap to attract more prawns. If the number of prawns are more in the pond the trap has to be emptied periodically to avoid spoilage.

3.10.2.2 TOTAL HARVEST

Purushan (1995) adds, "a successful and complete harvest entails capturing of all the specimens after attaining optimum size with minimum effort."
Usually harvest is planned at a time when the shrimps remain utmost healthy with hard shells coupled with high demand. In a well managed farm there may not be any undesirable size variation of shrimps. Provisions for potable water, enough quantity of ice, other chilling facilities and transportation are to be arranged well before hand to avoid spoilage after harvest. By lowering the water level by draining, majority of shrimps can be caught employing cast net and drag nets. After complete draining, the remaining ones can be hand picked. With scientific, extensive and semi-intensive farming techniques, it is quite possible to attain a production level 2-5 tonnes/ha/crop in respect of P.Monodon within a reasonable survival rate of 60-80%.

Following are the methods followed for total harvest:

1. Big Net Operation

Conical shape bag net is one of the gear employed for harvesting the cultured prawn. It measures 6 to 9 meter in length with a mesh size of 5 to 12 mm and fixed to the mouth of the sluice gate by means of a rectangular frame. The net is operated during low tide, when the water is let out through the sluice gate in night time. A light is installed near the mouth of the sluice to attract more prawns. The prawns that move along the out-flowing waters are trapped at the cod end of the net which are removed periodically with the help of ‘lazy line’. This type of gear is extensively used in the traditional paddy-cum-prawn cultivation fields of Kerala around the lunar phases.

2. Harvest by partial draining

Harvesting the prawns like P.Monodon is difficult due to its tendency to remain in the pond without moving along with the outgoing water when it is released during low tide. When the water reduces, it moves to the deeper areas of the pond where it can be caught with suitable net such as drag net or cast net. When the new tidal water is allowed to come in as the tide rises, it stimulates the prawns to swim against the current, during that time it can be harvested by using the traps.

3. Harvest by complete draining

Total harvest by complete draining is practised only after the harvest of more than 80% of the stock in the pond by anyone of the methods.
explained above. In order to have the total harvest, the pond water is completely
drained and the rest of prawns are hand picked. Prawns trapped in the small
pools or deeper portions of the pond bed are scooped out with small hand nets.

4. **Pump equipped drag net**

In places like Japan pump equipped drag net is operated to catch
the prawns from the culture ponds. This type of net has two parts, a frame and a
drag net. The frame is square in shape, made of metal rod and fitted with a
water pipe (60 mm dia.) at the bottom of the frame on which a number of
nozzles are fixed. Water from the board is let in at high pressure through a hose
to the water pipe. The other part of the gear is the conical shaped drag net
which is connected to the frame. The net is provided with a tickler chain (9 mm.
long) at the bottom to be drawn in front of the ground rope. During operation, the
net is towed by a boat at a speed of 20-30 m/minute and the pump in the boat
presses the water at high pressure (4 kg/cm.) at the rate of 0.3 cubic meter per
minute to the water pipe attached to the frame. Due to the pressure the water is
jetted out through the nozzles vertically to stir up the pond bottom. The prawns
are scared out and eventually trapped in the net. This type of gear is normally
operated during day time when the prawns tend to burrow and remain inactive.

5. **Electric fishing**

Electric fishing gear is similar to the pump equipped drag net in
having a metal frame and a drag net. But instead of the nozzled pipe there are
brass bars (12cm long and 12 mm wide) situated 20 cm apart from the bottom of
the frame. The brass rods are positively and negatively charged electrodes and
arranged alternatively. The wiring is insulated against water. The battery
voltmeter, ampere meter and switch board are all kept in the boat. During
operation, the current from the battery charged in the electrodes in the frame,
creates an electric field in between and shocks the prawns to jump out from the
bottom and trapped in the drag nets. This type of operation is prevalent in Japan.

Gopal Krishna (---) further adds, "in ponds which are dependent of
tidal exchange, harvest has to be synchronised with tide, either new moon or full
moon, so long as the prawns are not moulting. The harvested prawns are
washed thoroughly in pond water and immediately released in chilled fresh water
in live condition. After 15 to 20 minutes in chilled water, the prawns are placed on a platform for segregation as per the size and weight and grouped into three categories namely large 21 to 30, medium 31 to 40 and small 41 to 50 per kg.

Ice must be used in large quantities to preserve the quality of the product. Transport must be made in insulated containers or vehicles to maintain temperature. Once frozen the product should be stored below 0°C.