INTRODUCTION

Shrimp is a valuable aquatic food resource high in protein and commands good export markets. It has become the main target commodity for aqua-farming in recent years.

Traditionally, shrimp fry are trapped and held in ponds and later collected by shrimp gatherers for stocking in grow-out ponds. With increasing demand for shrimp, supply of wild fry for the increasing number of shrimp farms has become insufficient and inconsistent. The breakthrough in the completion of the life cycle of commercially important shrimps in captivity, such as the tiger shrimp (*Penaeus monodon*), the Japanese kuruma ebi (*P. japonicus*) and the eastern shrimp (*P. orientalis*), has greatly enhanced mass production of shrimp fry under hatchery conditions. The excellent growth performance of these hatchery-bred fry in grow-out ponds strongly shows that the shrimp hatchery can answer the industry needs for ample supply of shrimp fry for farming.

From many years of accumulated experience and research findings, the success of a shrimp hatchery depends on:

- the choice of a suitable site
- effectiveness and efficiency of the hatchery design
- experience of hatchery technicians
- efficiency of operational management

SELECTING SUITABLE SITES FOR A HATCHERY

Prior to the establishment of any shrimp hatchery, it is of primary importance to carry out a thorough feasibility study to determine the suitability of the proposed site. The main criteria followed are water quality, availability of spawners and site accessibility.

For establishing large-scale modern hatcheries, the criteria for hatchery site selection must be rigidly followed because it is costly to change site when high financial inputs have already been committed. However, site selection for smaller hatcheries are less rigid than the bigger ones.

Criteria in the selection of a suitable site for a hatchery

Sea water supply
The sea water used in a hatchery should be clean, clear and relatively free from silt. The water quality should be stable with minimal fluctuation in salinity. Suitable sites are usually found in sandy and rocky shore ecosystem where there is clean, clear and good quality sea water all year round. Sites not suitable for hatchery are swamps and muddy shores where the water becomes turbid during heavy rains or due to turbulence. Avoid river mouths where abrupt lowering of salinity often occurs during heavy rainfall. An added advantage of rocky and sandy shores is that good quality sea water is relatively near the shoreline thus reducing the cost of piping installation and pumping cost. The hatchery site should also be free from possible impact from any inland water discharges containing agricultural or industrial waste.

Availability of spawners

Presence of spawners at the vicinity of the proposed site is of considerable advantage in ensuring consistent supply of spawners, reducing the cost of transportation which could affect the rate of spawning.

Availability of power source

Electricity is essential to provide the necessary power to run equipment and other life support systems in the hatchery. Although some marine pumps and aerators can be driven directly by handy generators, the shrimp hatchery can therefore be operated in areas without electricity supply. However, it is more economical to operate it in areas where there is a reliable source of electricity. Installation of an on-site standby generator is absolutely necessary especially in areas where there are frequent lengthy power failures and fluctuations.

Freshwater supply

Freshwater is essential for daily hatchery operation such as salinity adjustment, equipment maintenance and for domestic use.

Accessibility

Ideally, a hatchery should be sited in areas where there are active shrimp farming operations so that the shrimp larvae produced can be easily transported and distributed to the grow-out ponds. Hence, the site chosen
for hatchery establishment must be easily accessible to facilitate communication and transportation.

Climatic conditions

A hatchery can be established in any climatical condition as long as the required rearing conditions can be adequately provided. However, all the commercial hatcheries take full advantage of nature in terms of energy source and supply of good quality water. Sunlight is the basic requirement for hatchery operations especially in the mass production of natural food used as feeds for the growing shrimp larvae. In the temperate region where adequate sunlight is only available in certain periods of the year, hatchery operations are usually confined to a certain suitable season. This is especially so in the case of some marine shrimps such as *Penaeus japonicus* and *P. orientalis* which have a single pronounced spawning season. In such situations, hatchery production is relatively limited to a short period of time. On the other hand, the tropics are endowed with warmer climate with adequate sunlight all year round and has ideal climatic conditions for hatchery operation especially for many warm water species such as the tiger shrimp, *Penaeus monodon*, the white shrimp, *P.indicus* which spawn all year round. The optimal temperature for hatchery design may be necessary in areas where there are pronounced long period of rainfalls which often reduces the intensity of light, cause turbidity in water supply and lowering of water temperature.
Mysis and post larval stages

a. MYSIS 1
b. MYSIS 2
c. MYSIS 3
d. POSTLARVAE 1

HATCHERY DESIGN AND CONSTRUCTION

Basically, there are two hatchery systems being adopted. The large-tank hatchery which was developed in Japan is still the popular system applied in many Asian countries such as Taiwan, Thailand, Philippines and Indonesia. The small tank hatchery which originated from Galveston USA, has been applied in the Philippines and to some extent in Malaysia and Thailand. Recently a modification of the above systems has been developed (also in India) which combined the beneficial characteristics of both systems taking into consideration the limitation of spawner supply.

There are three determinants in designing a hatchery viz: target species, production target and level of financial inputs. In any case, the target species must be clearly identified before designing the hatchery.
Production target can be determined based on a market demand and financial input. In the case of species such as *Penaeus monodon* at which the production of fry depends on the availability of spawners from the wild, production target is limited by the supply of spawners. This limits the production capacity of the hatchery. Whereas in *P. japonicus* and white shrimps at which spawners are easily available, production capacity is unlimited. Tank capacity up to 2500 cubic meters can be seen in many large-scale hatcheries in Japan where *P. japonicus* is the primary species grown. However, in most Southeast Asian countries where tiger shrimp (*P. monodon*) forms the target species for hatchery production, tank capacity is considerably reduced due to limited spawner supply from the wild.

Hatchery design is aimed at achieving the production target which determines the size of the hatchery. The tank capacity is based on an approximate ratio between algal culture tank and larval rearing and nursery tanks. Desirable algal tank capacity is 10–20% of the larval rearing tank capacity. The capacity of maturation tank depends on the number of spawners needed. Method of estimation of tank capacity for various rearing and holding tanks are given in the following examples:

**Size of hatchery**

Generally, the size of a hatchery should be based on its functional requirements and economic efficiency. Based on the level of operation, production output and financial investment, hatchery practice can be broadly grouped into three categories viz: small-scale, medium-scale and large-scale hatchery.

**Small-scale hatchery**

This is a “backyard” hatchery usually owned and managed by the shrimp grower himself using family members or immediate relatives for additional labour. The main goal is to supply his own shrimp farm with the required number of fry and the excess may be sold to neighboring growers. Usually the hatchery site is an extension of the farm house with floor space ranging from a few square meters up to about 1000 square meters. In such hatchery operation, the total production capability seldom exceed 5 million postlarvae per annum and the hatchery is operated by not more than 2 technical personnel.

**Medium-scale hatchery**
This type of hatchery is relatively larger than the small-scale hatchery in terms of capital investment, hatchery size, production capability and scale of operation. While hatchery management is somewhat similar to that of small-scale hatchery, the production capability range between 10–20 million postlarvae per annum and is operated by about 3 technical personnel and 3–4 labourers. This type of hatchery is usually put up by small cooperatives to supply the required shrimp fry to its member growers. Private entrepreneurs or government agencies may also establish hatchery of such operational scale to produce fry of sale or distribution to the growers.

Large-scale hatchery

This scale of hatchery is commercially run by big corporations, national agencies or cooperative projects. While the capital and operational investment far exceed that of the medium-scale hatchery, production capability of such hatchery usually exceeds 20 million postlarvae per annum. Such hatchery is centrally and systematically managed and is supported by a pool of not less than 6 technical personnel and 6–10 labourers

Hatchery facilities

In designing a hatchery, ample space should be provided for the rearing and support facilities needed in the operation. A functional hatchery should have the following essential components:

Maturation tanks

The major constraint in hatchery operation of tiger shrimp is the limited supply of spawners from the wild. Hence, eyestalk ablation techniques can be used to augment the scarcity of spawner supply. Thus, maintaining ablated shrimp in maturation tanks would ensure a constant supply of gravid females. The shape of maturation tanks can either be circular, rectangular or oval. The tank capacity may vary from 5 to 40 tons with depth ranging from 1.2 to 2 meters. If the shrimps are kept for less than 5 weeks, bottom substrate is not needed in the tank.

Spawning tanks
Spawning tanks should be circular with a flat or conical-shaped bottom. Water holding capacity may vary from 50 liters to 1.5 tons. The tank can be made of fiberglass, Plexiglass, plastic or marine plywood. The tanks are used to temporarily hold the gravid females until spawning.

**Larval rearing tanks**

Two types of rearing tanks are being used to rear the newly hatched larvae. In Japan and Taiwan, larger tanks with a capacity of more than 50 tons are being used. In Southeast Asia, most of the hatcheries use smaller larval rearing tanks of about 3 tons capacity.

**Small Tank System**

The larval rearing tank may be circular, rectangular or oval in shape with tank capacity ranging from 0.8 to 3 tons. The bottom of circular tanks may either be flat or conical. Rectangular or oval-shaped tanks always have flat bottom. The circular tank is usually 1.8 m in diameter and 1.2 m in depth. The drainage pipe is set at the side of the tank. The drainage pipe is also used for harvesting. In all types of tanks, sea water is delivered into the tank through an inlet pipe installed at the top of the tank.

**Big Tank System**

The tanks used are rectangular or square in shape with capacity varying from 50 to 2000 tons or more (5 × 5 × 2m or 20 × 50 × 2m). The tanks can either be located outdoors or if located indoors, transparent roofing should be provided to allow for sources of sunlight (**Fig.4**). In a big tank system, spawning, hatching and larval rearing operations are done in the same tank. The larvae are reared for 35–40 days (PL25-PL30).

**Live food culture tanks**

In mass cultivation of live food organisms, size of tanks used usually ranges from 1 to 20 tons. The tanks can be made of either fiberglass, polyethylene, marine plywood or concrete. On the average, the total tank capacity for live food culture is about 20% of the total tank capacity for larval rearing.

**Water storage and filtration tank**
The water storage tank is normally elevated to effectively distribute water by gravity to the hatchery. The water storage tank capacity should be at least 20% of the larval rearing tanks. Storage tanks are normally constructed out of reinforced concrete to withstand the water pressure. When the water is turbid, installation of a filtering screen and sand filter unit becomes necessary. The filter chamber may be constructed adjoining the holding tank. The filter chamber usually contains either white sand, charcoal, gravel, or all the three as filter material.

**Aeration**

Aeration is essential during the entire larval rearing process in maintaining sufficient dissolved oxygen concentration in the water, ensuring even water temperature throughout the water column through turbulence and also help reduce the ammonia content in the water.

Aeration may be provided with a roots blower, rotary blower or an air compressor. A blower provides large volume of low pressure air while an air compressor provides small volume of high pressure air. An air blower runs continuously while a compressor which is equipped with the pressure tank runs whenever the pressure is low. The compressor automatically switches on when pressure drops below a pre-determined level. In a hatchery, low pressure air available at large volume is more desirable than high pressure air at small volume. Moreover, the hatchery tanks are seldom more than two meters deep. Rotary air blowers are not designed for oil free operation and have a tendency to blow oil particles into the air line producing oil slicks on the surface of the water. Air filters at the inlet and outlet pipes are therefore needed. Since continuous aeration is essential to the survival of larvae in high density, any prolonged power interruption would seriously affect the culture organisms in the tank. Thus, it is essential to install an automatic switch which starts a standby generator whenever there is a power failure. A battery operated warning device to signal the crisis and the required operation of the standby generator can also be used.

**Seawater supply and piping system**

Seawater can be drawn directly from the sea or from a sump pit. If the course of the water is relatively clear, the water can be pumped directly into the overhead filter tank and stored in the reservoir or storage tank. Water is
then gravity-fed to various culture tanks through its delivery pipes. However, it the water is turbid and contains a high concentration of suspended solids, the water is pumped first into a sedimentation tank where the suspended solids are allowed to settle down and the clearer water on the top is pumped into the filter tank. Sometimes when the water source is far from the shore due to low tide and if large quantity of water is needed continuously, the intake pipe should be laid horizontally from the littoral zone to the underground sump pit and the filter tank. Whenever possible, the seawater should be drawn directly from a tube well. Water from the tube well is usually clear and clean water is needed, it can be pumped directly into the filter tank.

Lay-out and construction

Once the project site is selected and production target defined as an aerial survey of the proposed site will help to determine the perimeter of the area. An aerial view would show the important topographic characteristics such as rivers, shoreline, mountain and low lying plains. A master plan of the hatchery is then made. Lay-out of the hatchery should provide a schematic design of the location and integration of various facilities such as buildings, broodstock tanks, larval rearing tanks, nursery tanks, spawning tanks, pump house, air supply and power house, laboratory, staff house, piping for water supply and drainage canal. The lay-out plan should include the exact dimension, locality, shape and size of said facility.

PREPARATION OF BROODSTOCK FOR SPAWNING

Conditioning of broodstock

Upon arrival in the hatchery, the broodstock are first acclimatized in holding tanks for 4–7 days. The holding tanks should be big enough to provide proper space and aeration. 60% of the water in the tanks is changed daily. Once the animals have recovered from transport stress, they are induced to molt by manipulating salinity of water in the holding tank. The salinity is decreased by about 4–5 ppt for two days and then increased to the normal salinity of the seawater. Majority of shrimps will molt after changing salinity. Mating occurs during this time when the females are newly molted. The shrimps are then ablated 2–3 days after molting or when the shell is completely hardened.

Induced maturation
Only suitable broodstocks are used for eyestalk ablation. The criteria are:

   a. complete appendages
   b. presence of spermatophore in the thelycum of females
   c. size should at least be 100 gm.

Presently, the most practical way of inducing maturation is by unilateral ablation of either right or left eyestalk of the female. Ablation is done by using a razor blade to cut/open the eye, then squeezing out the eyestalk from the base to the tip with the thumb and forefinger or using the fingers alone to break and squeeze the eye or by using electrocautery apparatus. The ablated animals are stocked in maturation tanks at a density of 5–6 per square meter and a sex ratio of one male to one female.

**Maintenance of broodstock in maturation tanks**

The broodstocks are fed with squid, mussel or cockle meat or pellet feeds at the rate of 10% of total biomass. The water in the tank is allowed to flow through continuously or changed daily at 60–70% of total capacity.

**Sampling**

Gonadal development of an ablated female is checked 3–5 days after ablation while checking for gravid females is carried out every other day.

Sampling and checking are done at night or at any time if the tanks are sufficiently covered and kept dark. During sampling, an underwater flashlight, tied to a pole is held close to the shrimp so that the light strikes perpendicularly on the dorsal part of the body where the ovaries are located. Water in the maturation tank can be lowered to 30 cm to allow the worker to get inside for closer observation. Only gravid females with stages III or IV ovaries are collected and transferred to spawning tanks.

**SELECTION OF SPAWNERS AND EGG COLLECTION**

Although spawning occurs throughout the year among tropical species of shrimps, there are distinct periods of the year when majority of the shrimps spawn. In the case of *P. monodon* and *P. indicus* in India spawn during November to April. While spawners of these species of shrimps are supposedly available all year round, they are abundantly caught during the spawning season.
A gravid female can be easily recognized by the presence of a very large and distinct diamond-shaped dark green mass of ovary between the first and second abdominal segment below the dorsal shell. Selection of spawners can be easily done by holding the animal with its ventral body facing a light source.

The criteria used for selecting spawners from the wild are:

a. stage IV ovary  
b. complete appendages  
c. the back is not broken  
d. presence of spermatophore underneath the thylecum; and  
e. the color of the shrimp especially *P. monodon* should be pink with a faint greenish tint. Spawners which are slightly reddish could be due to stress caused by abrupt lowering of the water temperature during transportation by fishermen who try to delay spawning. Stressed spawners give very low spawning rates.

![Stage 3](image1.png)  
![Stage 4](image2.png)

**Spawner with mature gonad**

**Treatment of spawners**
Upon arrival, each spawner is normally placed directly in a spawning tank without any further treatments. However, during winter or when there is known spread of disease, spawners are usually treated with either (a) Treflan (trade name), 0.5–1 ppm (b) KMnO₄, 3ppm or (c) Formalin, 25 ppm for 10–15 minutes.

**Spawning activity**

Spawning usually occurs between 0200 to 0300 hours at water temperature and salinity ranging from 25 to 30°C and 28 to 32 ppt, respectively.

**Egg collection and treatment**

After spawning, the animal is removed from the tank the following morning. The eggs are then cleaned by siphoning into egg collectors. During the cold season, fungus and bacteria are likely to infect the eggs during incubation. Preventive treatment normally consists of dipping the eggs in 1 ppm of methylene blue or 0.5 ppm of malachite green for 10 minutes or 3 ppm KMnO₄ for 30 minutes. After that, the eggs are transferred to a cleaner tank for further incubation and subsequent hatching. From the incubation/hatching tank, samples of eggs are counted to determine the number of eggs spawned per female.

**HATCHING**

Eggs of most species of shrimps hatch within 12–18 hours after fertilization at temperature and salinity range of 26–30°C and 30–23 ppt, respectively.

**Determination of hatching rate**

The density of nauplii is estimated a day after hatching. Nauplii from three 100 ml water samples taken from the spawning tank are counted and averaged. The total number of nauplii in the tank is then obtained by multiplying the volume by the average density.

To determine the hatching rate, the following formula is employed:

\[
\text{Hatching rate (\%)} = \frac{\text{No. of nauplii counts}}{\text{No. of egg count}} \times 100
\]
Nauplii are then directly transferred to larval rearing tanks.

**Transportation of nauplii**

At the nauplii stage, the larvae hardly feeds and thus depends on its yolk for development. This stage is easy to transport even for long durations. In some cases, where the site of the established hatchery is far from the spawner collecting areas, it is more advantageous to transport the nauplii instead of the spawners which are more prone to stress.

plastic bags - Each bag containing about 6–8 liters of water can be stocked with 200,000 nauplii. The water in the bags are oxygenated and the open end is closed with rubber bands. The survival rate is about 80–90% if transport takes about 4–6 hours (Fig. 30).

**LARVAL REARING**

From the spawning tank, sample of eggs are counted to determine the number of eggs spawned per female. In normal condition, fertilized eggs hatched within 12–15 hours. The hatching rate is measured by assessing the number of hatched nauplii.

**Larval rearing in small indoor tanks**

After hatching, the newly hatched nauplii are stocked at a density of 100–150 nauplii per liter in the 2.5-ton larval rearing tanks with fresh filtered seawater filling up to 3/4 of tank capacity. No feed is required at the nauplii stage since the nauplius still utilizes its yolk as food. However, diatom are inoculated immediately after stocking to ensure availability of feed when the nauplii molt into the protozoea stage.

**Protozoea stage**

This is a critical stage of larval rearing. The larvae at this stage start feeding on external food and feed on minute and easily digested microscopic algae such as *Skeletonema costatum*, *Chaetoceros* sp. and *Tetraselmis* sp. The optimal feeding of phytoplankton in the rank is 50,000 cells/ml for *Skeletonema* or *Chaetoceros* and 10,000 cells/ml for *Tetraselmis*. 
On the other hand, there is a bright prospect in the use of wet or dry processed invertebrates tissue or encapsulated or microencapsulate feeds in shrimp hatchery feeding strategy. The feeding scheme advocated is based either on the exclusive use of a marine invertebrate wet or dry processed tissue as feed for all the shrimp larval stages or the exclusive use of microencapsulated. The use of these types of feed can reduce production cost as well as make the feeding regime of shrimp larvae more convenient especially for small-scale or backyard hatcheries which can not afford to have a phycology laboratory. The use of marine invertebrates as food organisms can be purchased at low prices and in large quantities since these are available locally. The commonly used food organisms are paste shrimp (Acetes sp.), rock shrimp (Metapenaeus sp.), stomatopod (Oratosquilla sp.) blood cockle (Anadara sp.) and mussel (Perna sp.).

The shrimp larvae are fed with either wet or dried processed crustacean tissue during protozoea stage. However, the time of metamorphosis is usually uncertain. Thus, feeding must start one day ahead of the expected time of metamorphosis, that is, feeding starts from nauplii four. The quantity of feed given is 10 μg/larva/day and 50 μg/larva/day for dry and wet processed crustacean tissue respectively. The amount of feed given is increased by 20% daily. The particle size used are 50>125μ, 125>250μ and 250>350μ for protozoea, mysis and early postlarvae, respectively. Based on observations, feeding in outdoor tanks appears to be better than that in indoor tanks.

Schematic diagram of prawn production from hatchery to grow-out ponds.
Microencapsulate diets on the other hand is the latest research product in feeding strategy. However, studies using this type of feed are still in progress. The recommended feeding rate is 16 μg/larva/day and increased daily by 20%.

Mysis stage

The larvae at this stage will start feeding on rotifers (Brachionus plicatilis) or the brine shrimp nauplii required depends on the density of shrimp larvae being reared. Each mysis larvae consumes about 100–200 rotifers or about 20–50 artemia nauplii per day or a standard ratio of about 5 grams dry Artemia cysts is required per cubic meter of rearing water.

During this stage, the tank bottom is already filled with dead organisms and must be siphoned out daily. Once the larvae reaches the first day of postlarval stage (P1), they can be transferred to the bigger nursery tanks.

One day before transferring the postlarvae to the outdoor tanks, the nursery tanks should be first filled up with fresh filtered seawater to allow adequate blooming of diatom. The postlarvae is stocked at a density of 15–20 larvae/liter.

ROUTINE HATCHERY MANAGEMENT

The maintenance of optimal environmental conditions is necessary for maxima growth and survival of the cultured organisms.

Maintenance of water quality

a. Salinity - Biologically, most penaeid shrimps do not breed in brackishwater while mating, spawning and even hatching of eggs take place only in the open sea. Salinity in spawning grounds normally ranges from 30 to 36 ppt. Thus, seawater salinity in spawning tanks should be maintained at 30–32 ppt to ensure good hatching rates. Moreover, low salinity affects larval growth during the first 15 days of rearing. Though abrupt or extreme variations in salinity may adversely affect larval survival, slight variations in salinity is not detrimental.

b. Temperature - Temperature directly affects the metabolic system of any given species. In penaeid shrimps, eggs do not hatch at temperatures lower than 24°C. Larvae usually grow and molt faster at
higher temperature. The optimum temperature is 26–31°C. Below this level, larvae do not grow well and molting may be delayed. The protozoea of *P. monodon*, for instance, molt to mysis stage within 4 days at temperatures ranging from 28°C to 31°C, however, molting takes 6 days when temperature drops to 24–26°C. Slight increase in water temperature above threshold may be lethal in the tropic species. Gradual variations in temperature throughout the day is not critical, however, sudden changes even as narrow as 2°C can cause high mortalities due to stress and temperature stock.

c. Dissolved oxygen - Dissolved oxygen is a critical factor in larval rearing. High mortalities can occur if aeration stops even for only one hour.

d. pH and nitrogenous compound - Normal pH of seawater ranges from 7.5 to 8.5. The pH value is a key indicator of changes in the water environment of the rearing tank relative to ionized and un-ionized ammonia. This is so because NH₃ and NH₄ ratio in water is pH dependent. If pH value is high, this signifies increased levels of un-ionized ammonia (NH₃) which is toxic to larvae. Ionized ammonia (NH₄⁺) however, is not toxic because it is unable to pass through the gill membrane of the larvae. Safe ammonia concentrations in water should not exceed 1.5 ppm for NH₄⁺ and 0.1 ppm for NH₃. 4

**Feeds and feeding schemes**

Shrimp larvae at the first protozoan stage cannot efficiently seek food as the swimming appendages have yet to develop. Hence, the feeds must be present in sufficient quantity. On the other hand, diatoms often overbloom in the rearing tank especially those in the outdoor hatchery. This causes high mortality due to attachment of diatom on the appendages of the larvae which makes them unable to move and molt properly. In addition, overblooming of diatom collapses easily the next day and this results in water fouling. Therefore, programming of natural food culture and maintaining feeds at sufficient levels only is an important operational strategy.

To monitor if the feed is sufficient in the rearing tank, the density of diatoms is counted daily before and after water management. Diatoms are counted by using a haemacytometer while *Brachionus* and *Artemia* densities are established by head count. Once diatoms in the larval rearing tank become brown, new diatom cultures are added to meet the density requirement of
the larvae. The approximate density sufficient for larvae in the rearing tank is 50,000/ml for Chaetoceros sp. or Skeletonema costatum and 10,000/ml for Tetraselmis sp. Brachionus must be maintained at 20 individuals/ml and Artemia at 50 grams for every 100,000 postlarvae. Overblooming of diatoms during summer days is controlled by shading the larval rearing tank or by draining out a portion of the water and replenishing with fresh filtered seawater.

Monitoring

Environmental parameters such as water temperature, salinity and pH should be checked twice daily. Meanwhile, the estimated number of larvae at each stage of development should also be recorded. Count larvae in three 1-liter samples for small tanks and 10 times for big tanks. The average number of larvae per liter will give an idea of total amount of larvae. However, larval estimates can be done until P₄ only because the larvae changes to demersal feeding habit after this stage. The precise number of larvae will be known during harvest when head counts are done.

NURSERY OF POST LARVAE

Since small tank nurseries normally produce up to P₅ - P₆ postlarvae only, such stages cannot be stocked directly in grow-out ponds. Therefore, nursing of postlarvae from the small hatchery is still necessary. Nursing of postlarvae can be done in concrete tank. Concrete tanks are prepared by filling up with filtered seawater provided with aeration and pure cultures of diatom added to preserve water in good condition and make it less transparent. Ideal stocking density of the larvae is about 25 - 50/liter of water. It is advisable to use substrates to increase surface area in the nursery tank, because postlarvae have a habit of clinging to the wall and tank bottom. Polyethylene nettings can be used and being synthetic, they do not decompose in water and can last longer without deterioration.

The early stages of larvae are fed with Artemia, while the older ones are given chopped mussel or cockle meat. Young and adult Artemia may also be added to the diet throughout the nursery period. Water is changed daily at 50% of the total capacity. Flow-through system is permitted in the nursery tank as this results in good growth and survival rates.
HARVEST AND TRANSPORT OF POST-LARVAE

$P_{21}-P_{25}$ is suitable for harvesting from nursery tanks because this size can be stocked directly to the pond and easily be transferred. The larvae in nursery tanks can be harvested by first reducing the water level to about 1/3 of its depth and then can be collected from the bag net positioned at the tip of the drained pipe. This method is efficient enough to collect all the larvae.

The postlarvae can also be harvested with a scoop net, dip net or seine net after 2/3 of the tank water has been drained. This method however, is time-consuming.

The number of harvested postlarvae is estimated from a single water basin of known volume from which animals within have been individually counted. This basin serves as a constant where visual comparisons are made with the rest of the harvest in similar basins. This method is reliable especially if the size of the larvae is uniform.

Plastic bag - Very often, postlarvae are transported in polyethylene bags provided with oxygen. The bag (60 cm × 40 cm) is first filled with 6–8 liters of fresh seawater and then packed with 3000–5000 postlarvae. The density may be reduced if the expected transport time is longer. After properly tightening the mouths of the bags, they are placed in styrofoam boxes or plastic buckets. Temperature is reduced to about 22–25°C by crushed ice mixed with sawdust on the bottom, side and top of the styrofoam box. Under these conditions, postlarvae may be kept alive for more than 12 hours during transport.

LARVAL FEED
Under natural conditions, penaeid shrimps are either omnivorous scavengers or detritus feeders. In general, shrimp larvae feed on phytoplankton, detritus, polychaete and small crustaceans and their food preference changes with age. They start feeding at protozoea stage. Protozooe and early mysis stages prefer phytoplankton (although the digestive system is not yet fully developed). At mysis and early postlarvae, food preference changes to zooplankton such as rotifer or brine shrimp. As the larvae grow older than P₆, feeding habit changes again to that of a bottom feeder. Polychaetes, chopped mussels or cockle meat are fed during these stages.

Large-scale production of phytoplankton for larval rearing can be obtained in two ways: by direct fertilization of seawater in the rearing tanks or from pure culture. Many workers in the field rely partly on mixed populations of phytoplankton present in rearing water. In the past, fertilization of tank water was done directly with the resultant algal population from the “blooms” utilized for feeding purposes. The method, however, has its disadvantages. Using direct fertilization techniques, heavy “blooms” of undesirable species often occur. Such circumstances have led to the development of techniques for screening different algal species suitable for larval culture and isolation techniques for pure culture of specific types of phytoplankton.

In addition, many other types of feed have been developed and tested as part of penaeid shrimp larval rearing strategies. These feed may either be frozen or dry material from molluscs, crustacean tissue, soy bean cake, soy bean curd, egg mustard and fertilized eggs or oyster. Other types are available as formulated diet or the newly-developed microparticulate and microencapsulated diets. However, the choice of a particular feed used should be properly evaluated based on the following criteria:

a. availability and ease of handling (including technical support);
b. feed performance; and
c. feed cost and rate of return on capital.

The basic feeding strategies regarding the type of larval feed in penaeid shrimp hatchery employed to date are summarized as follows:

a. use of mixed diatoms through direct fertilization in combination with dry or fresh feed material such as soybean curd, soy bean cake,
fertilized oyster eggs followed by live food organisms such as rotifer, artemia nauplii.
b. use of mixed diatoms through direct fertilization and/or pure culture diatom followed by rotifer and Artemia nauplii.
c. use of mixed diatoms through fertilization and/or pure culture of diatoms in conjunction with fresh/frozen mollusc and crustacean tissue.
d. use of mixed diatom through direct fertilization and/or pure culture of diatoms in conjunction with other dry feed materials or formulated diet.
e. exclusive use of microencapsulated or microparticulate larval feed.
f. exclusive use of wet or dry product of crustacean tissue.

Preparation of larval feed

Phytoplankton culture

The more popular phytoplankton species found to be suitable as food for the early larval stages of shrimp are Chaetoceros calcitrans, Skeletonema costatum, Tetraselmis sp. These plant component of the oceans usually require certain environmental conditions for growth. In the wild, phytoplankton abundance is easily affected by fluctuations in temperatures, day length, presence of grazers, availability of nutrients, water depth and turbidity as well as the seasons of the year. Manipulations, however, of the above-mentioned factors is possible under laboratory conditions or controlled rooms.

Phytoplankton culture is usually carried out by subjecting a known amount of phytoplankton to an environment suitable for its growth.

Water

Primary consideration must be given to water quality which serve as base of the culture media. The water must be clear and free of any toxic material. Offshore water is ideal because it is unpolluted and contains less sediments. This type of water can be filtered easily.

Glassware

Absolute care must be taken to ensure that all glassware are clean and sterilized in autoclaves or drying ovens prior to use.
All culture vessels must be covered after sterilization. Non-absorbent cotton plugs or sterile surgical gauze can be used to plug sterilized test tube or bottles. Dilute acid solutions can be used to disinfect plastic carboys or other large culture containers as sterilization may be omitted for mass-scale production.

**Nutrients**

Phytoplankton require certain nutrients for growth. Reagent grade chemicals must be used for stock cultures while technical and agricultural grade fertilizers may be used for mass-scale propagation of algae. These nutrients enrich the sea water media thereby allowing faster growth of phytoplankton in shorter periods of time.

Chemicals must be kept in a cool dry room and containers closed tightly after use.

**Brine shrimps as larval feed**

Many hatcheries depend largely on brine shrimps to feed their growing shrimp and fish larvae. In most cases, it is the nauplii that are used to feed the larvae probably because of its small size and relatively slow moving habits. They can be easily preyed upon by the predatory fish or shrimp larvae.

Brine shrimp (*Artemia*) eggs are sold commercially but the quality varies with the trade brand representing different strains, geographical origin and processing methods. In purchasing brine shrimp eggs, it is essential to know the trade brand so that the quality of eggs or cysts can be assessed. Percentage of hatching of eggs or cysts varies with the brand of eggs (*Table 9*). However, the method of incubation and hatching is the same.

**Incubation and hatching of Artemia cysts (eggs)**

Incubation of *Artemia* eggs or cysts takes about 24–36 hours depending on the source of the eggs. The eggs should be thoroughly washed with clean fresh seawater for about 15–20 minutes before incubation. This is to remove dirt and other minute particles attached to the eggs. Often times, the eggs have a certain peculiar odor. By washing the eggs, this smell can be removed.