Marine Aquaculture 9

PhD. student

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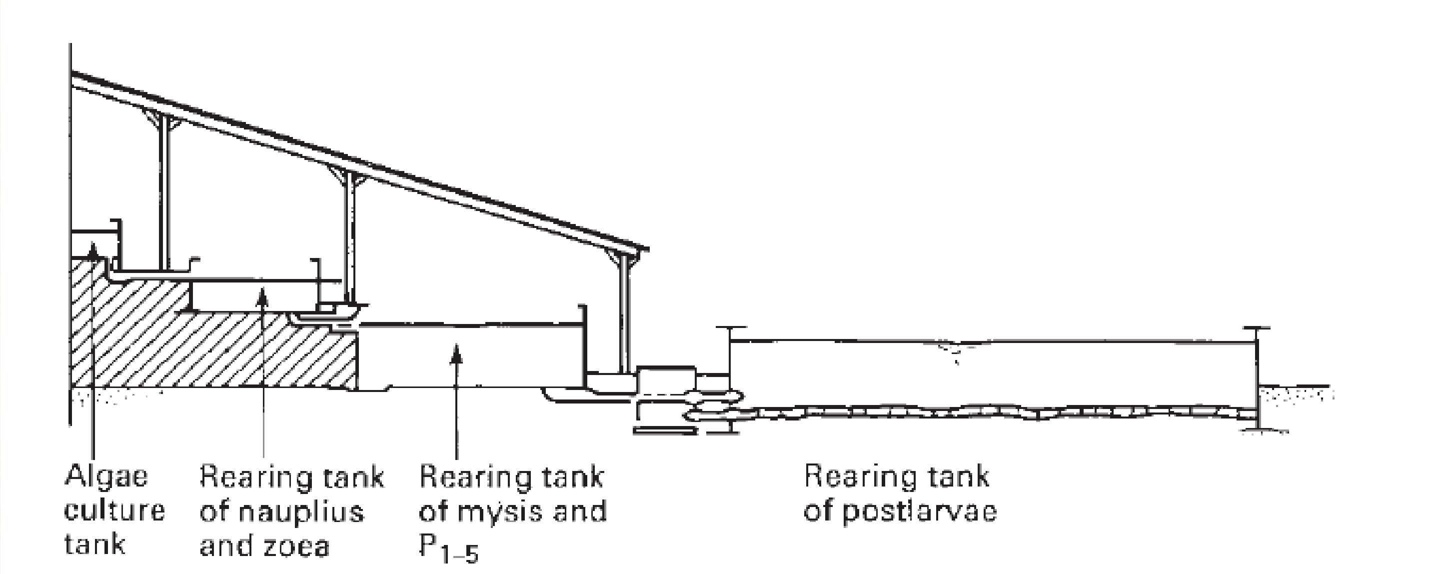


A ladder system hatchery in Taiwan.

3 Spawning and larval rearing

The minimum age of spawning females varies between species and according to the environmental conditions, as can be seen from the following:

P. aztecus	8–9 months
P. indicus	4–8 months (weight 6–8 g)
P. japonicus	7–12 months
P. merguiensis	4–8 months (weight 6–8 g)
P. monodon	9–15 months (weight 32–45 g)
wild spawners	18 months (weight 75 g)
P. orientalis	8–9 months
P. stylirostris	8–9 months (mean length 176 mm, weight 40–50 g)
P. vannamei	8–9 months (mean length 157.9 mm, weight above 30 g)

In general, spawners from captive brood stock are smaller than those from the wild. Farmers usually believe that spawners from wild stock are superior to captive ablated spawners, and that the quality and quantity of their eggs are higher.

The maturity of the males can be determined by examination of the petasma on the first pair of pleopods. In mature males these accessory organs are joined together by means of interlocking hooks. Swelling and whitish coloration of the terminal ampoules near the fifth pair of pereiopods indicate gonadal maturity.

The spawning season in nature varies according to species and location. When larvae have to be collected from the wild, or when wild spawners are used for spawning and larval rearing, it is essential to know beforehand the period and locations of their occurrence. On the other hand, captive stocks can be matured and spawned almost throughout the year under controlled conditions. Though tropical species spawn throughout the year, most Penaeids have peak periods of spawning.

In closed thelycum species (i.e. species with lateral plates that lead to a seminal receptacle, where the spermatophores can be inserted), the mating occurs soon after the females have moulted. In species with an open thelycum (with only ridges and protuberances for spermatophore attachment) mating can occur soon after the eggs become mature. In the latter group of species, spermatophores can easily be lost or fail to be affixed before spawning. The spermatophores deposited during a single moulting are generally enough, irrespective of the moult cycle, to fertilize up to three successive spawns.

For controlled spawning, gravid females and males in advanced stages of maturity are stocked in spawning tanks. Spawners obtained from commercial catches during the winter are likely to be infected and are therefore usually treated with 3 ppm $KMnO_4$, 25 ppm formalin or the commercial product Treflan®(trifuralin) at concentrations of 3–5 ppm. In large tank systems used for community culture, several spawners are introduced into the community tank, whereas in the other systems individual spawners or batches of spawners are placed in separate spawning tanks each time. In large tanks, the density of spawners are generally:

P. japonicus:	1 spawner/2 m^3
P. monodon:	1 spawner/5 m^3
P. indicus:	1 spawner/1 m^3
P. merguiensis:	1 spawner/1 m^3

Generally a 1:1 sex ratio is maintained in spawning tanks, but a ratio of two females to one male has produced higher spawning rates and egg production. There is usually a time lag between mating and spawning, as the eggs may still not be fully mature at the time of mating. *Penaeus japonicus* and *P. indicus* females have been observed to eat their own spawned eggs and so it is advisable to install mesh trays or plates on the bottom of the spawning tanks to protect the eggs. The salinity in the tanks generally ranges from 28 to 35 ppt and the temperature from 23 to 33°C. Spawning usually takes place at night. Fertilization is external and at the above temperature range the embryonic development is rapid.

The nauplius passes through three to six substages (N_1–N_6) and subsists on its own yolk material. In about two to three days it metamorphoses into protozoea with three substages (PZ_1–PZ_3) during which period the larva starts feeding on unicellular algae. This stage, which lasts for three to six days is succeeded by the mysis stage with three sub-stages (M_1–M_3).

During this stage the larva retains the filtering mechanism for feeding on algal cells. The mysis metamorphoses into post-larva in about three to five days. At this stage it ceases to be a filter-feeder and becomes capable of capturing and eating zooplankton. Development from the post-larval stage to the juvenile stage is very gradual and a PL_5 (P_1–P_5 or PL_1–PL_5 denotes the post-larval age in days) may take 15–20 days to reach a size of 20–25 mm, suitable for stocking production ponds.

In larval culture of most Penaeids, the main difficulty is in rearing the protozoeal stage when they start feeding. At this stage the larva is highly light-sensitive, and so the tanks should be properly covered to ensure darkness. The key to the success of the pioneer experiments of Hudinaga in Japan was the method developed for the culture of the diatom *Skeletonema costatum*, which formed a suitable food for the larvae. Since then several other types of live foods and feedstuffs have been tried, but cultured phytoplankton appears to be still the most efficient food for larvae at this stage.

Since the size of larvae of different species of Penaeids are not the same, they require phytoplankton of different sizes. They start feeding on zooplankton when they reach the last sub-stage of protozoea. Both mysis and post-larvae up to the fifth day prefer zooplankton, but after that stage they will consume larger food and may feed at the bottom. They can then be fed on polychaetes, chopped mussels, clams, cockles and artificial compound diets.

The more important phytoplankters suitable as food for shrimp larvae are species of *Chaetoceros*, *Skeletonema* and *Tetraselmis*. Algal culture methods have been described in Chapter 7. Among the zooplanktonic organisms, the rotifer *Brachionus plicatilis* is probably the most important as larval food. Many hatcheries depend largely on the brine shrimp, *Artemia salina*, the nauplii of which form excellent food for shrimp larvae.]

Hatcheries that produce only P_5 or P_6 stage post-larvae use concrete tanks, earthen ponds or net cages for larval rearing. Small tanks with a filtered sea-water supply and aeration are stocked at a density of up to 150/l. Diatom cultures are introduced to feed the larvae and often a substrate such as polyethylene netting is provided for the larvae to rest on. Early post-larvae are fed with chopped mussel and cockle meat together with young and adult *Artemia*. Daily exchange of water is maintained for the duration of culture (about 30 days).

Earthen nursery ponds range in area from 500 to 2000 m^2 with an average depth of 40–70 cm. The larvae are stocked at the P_9–P_{10} stage at densities of 100–150 per m^2. The ponds are prepared by eradicating predators and fertilizing with a combination of organic manures (such as 1000 kg/ha of chicken manure) and inorganic fertilizer (such as 50 kg/ha of ammonium sulphate). Supplementary feeding is done with chopped mussel or cockle meat, at about 10 per cent of the total biomass. The larvae can be reared in such ponds up to the P_{40} or P_{60} stages.

Twenty-one- to twenty-five-day-old post-larvae are suitable for stocking grow-out ponds. In some farms, particularly in Ecuador and Taiwan, post-larvae are grown (sometimes referred to as pre-growing) for 30–60 days at densities of 50–200 per m^2. With daily exchange of water (10–40 per cent) and supplementary feeding with compound feeds, they reach a mean weight of 0.5–2 g, with a survival of 80 per cent depending on species and pond conditions. These fry are then stocked in grow-out facilities.

Nursery cages are used only rarely, as the very small mesh sizes required can become rapidly choked by bio-fouling. The cages, when used, are rectangular in shape (1–2 m × 5 m × 1 m) and are of the floating or stationary type installed in protected bays, lagoons or ponds. Post larvae (P_6–P_7) are stocked at higher densities of 1000–2000 per m^3. Feeding is carried out in the same manner as in earthen ponds.

4 Grow-out of shrimps

As stated earlier, pond culture is the most common grow-out system, and extensive culture methods are gradually giving way to semi-intensive production, in both Asia and South America. The traditional coastal shrimp ponds of Asia, which were stocked with wild seed stock that gains entrance during tidal water exchange, are now being stocked with sorted fry collected from the wild or bought from fry collectors. The stocking rate is still at a low level of 3000–5000 fry/ha. During the rearing period of about two months, water exchange is maintained using tidal flow. In improved systems, the ponds are carefully prepared before stocking.

The extensive system of rice field culture of shrimps in India has also undergone some changes, such as the introduction of controlled stocking of fry and enhanced production of food organisms through better water management and manuring by rice stubble. Production may now reach 400 kg/ha per crop under very favourable conditions, but on an average it is around 200 kg/ha per crop.

Modern large-scale shrimp farming is carried out in specially designed pond farms (figs 25.12 and 25.13) following mainly semi-intensive forms of culture, which have generally proved to be more economical. Such farms usually have a hatchery and nursery and rearing ponds. Some pond layouts also include a set of transition ponds, to enable the progression method of culture, involving transfer of stocks from one pond to another as the food resources decrease and the biomass increases. The sluice gates are so located as to create a good circulation with the incoming water. The ponds are usually rectangular and about 1–3 ha in area, with a depth of 0.8–1.2 m. Ponds in Central and South American shrimp farms are sometimes larger, up to 20 ha in area. Stocking rates vary considerably between 28 000 and 50 000 fry/ha. Natural food is produced by fertilization as mentioned above, and supplementary feeding with either fresh feedstuffs or formulated feeds is performed from one to five times daily.

rations vary between farms, but generally decrease from 25 per cent in the early juvenile stage to 2–4 per cent before harvest. Some farms in South America do not fertilize the ponds either at the nursery or production stage, and depend entirely on artificial feeding. Japanese shrimp culture has depended very considerably on feeding with the short-necked clam (*Ruditapes* (= *Venerupis*) *philippinarum*) and the mussel (*Mytilus edulis*). Formulated moist and dry feeds are also used very widely.

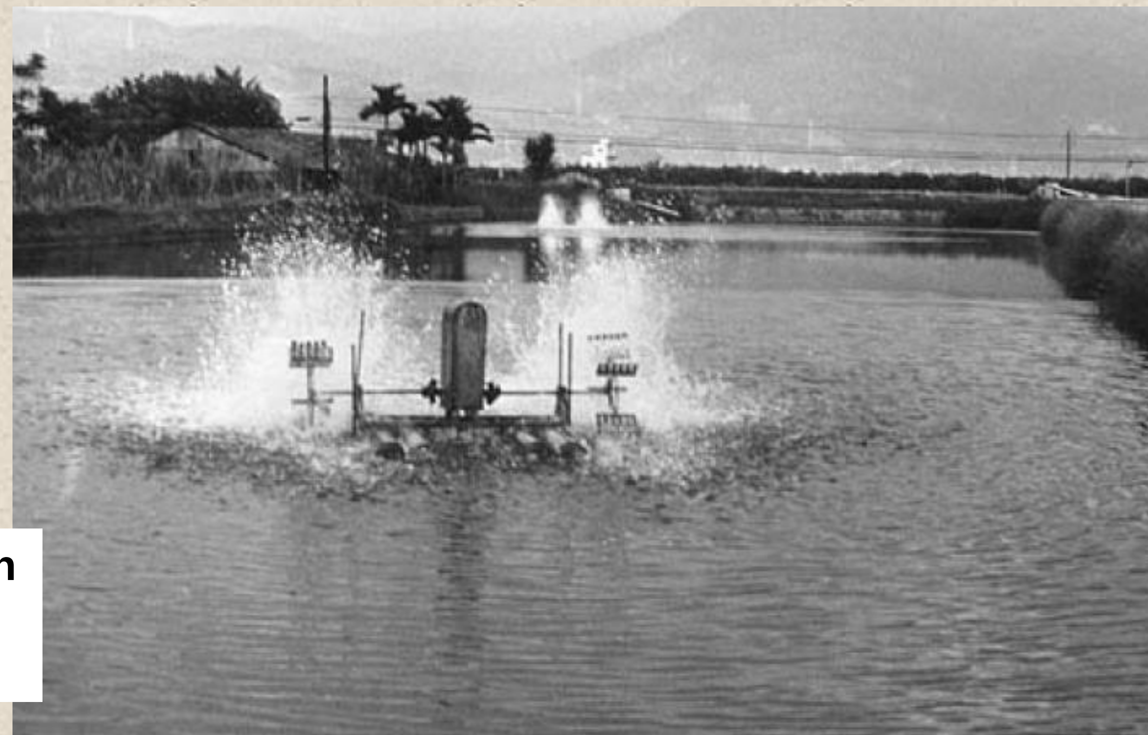
Many farms, particularly those in Central and South America, use diesel pumps to supply water. Farms in Thailand often use 'push pumps'. Though pumping increases the cost of production, regular water exchange and maintenance of good water quality are greatly facilitated. A large water exchange is required in culture ponds from time to time to accelerate and synchronize the moulting cycle of the stock. Yields in this type of culture can be 1.5–2 tons/ha per crop.

Intensive types of culture generally utilize cement tanks, although smaller earthen ponds of 0.5–1 ha size and 60–150 cm depth are also used. Inlets and outlets are arranged in such a way as to effect proper water circulation. Many pond farm designs have a drainage system radiating to a central outlet with a harvest basin. Tanks are generally provided with substrates. Aeration equipment like paddle wheels and air blowers are provided, especially in larger pond systems (fig. 25.14). Stocking densities ranging from 200 to 250 fry/m^2 are common. High-protein formulated diets are fed daily and frequent exchange of water is ensured. The yield from a 1000 ton tank is reported to be about 1.5–3 tons per crop, and in special ponds up to 28 tons/ha per year. However, very intensive culture using high stocking densities and heavy feeding can sometimes result in serious environmental and health problems, leading to large-scale mortalities, as has happened in Taiwan.

Pen culture of shrimps is practised in Japan and has also been carried out on an experimental scale elsewhere, such as in lagoons in southern India. Suitable intertidal areas are enclosed by net fencing. Japanese pens are made of vertical walls of concrete, constructed to a height of about 1 m for holding water during low tide, with a wooden frame with nylon netting set on top of the concrete wall to prevent the escape of shrimps and to facilitate water exchange during high tide (Kungvankij,

A large-scale commercial shrimp farm in Hawaii.

A large-scale shrimp farm in Taiwan.



Paddle-wheels used for aeration in intensive pond culture of shrimps in Taiwan.

In spite of the general belief that polyculture yields higher production, most shrimp culturists seem to prefer monoculture of the fastest growing species available, and they resort to polyculture with other shrimp species mainly because of the shortage of seed stock of the preferred species, as for example *P. monodon* in Asia. Even polyculture with milkfish as practised in some Philippine farms is usually due to the scarcity of shrimp fry or because of market demands. It is claimed that polyculture of *P. vannamei* and *P. stylirostris* is beneficial and, if stocked in the ratio of 2:1 respectively, the harvest can be more than doubled. But it is known that *P. stylirostris* will not grow well if stocked at high densities, and the stocking rate should not be more than two per m^2, whereas *P. vannamei* can be stocked at the rate of four to five per m^2. However, behavioural disparities and the differences in salinity and substrate preferences, as well as temperature and feed requirements, can more effectively be made use of by rotating species to ensure continuous use of rearing facilities and an overall increase in yields and income, but sustainable system development also needs paramount consideration (see Chapters 2 and 15). From an economic point of view, monoculture has been shown to be more profitable, mainly because of the higher market price of shrimps. According to Shang (1983) the average gross revenue per unit area of monoculture farms growing tiger shrimps is about double that of polyculture farms growing the same shrimps together with milkfish and crabs.

Food and feeding

In Chapter 7 the paucity of information on the nutritional requirements of shrimps has been emphasized. Much of the existing information relates to a couple of species and most of it is proprietary and not readily available. It is, however, known that there are considerable differences in dietary requirements between species, particularly with regard to protein levels. Some of the marine shrimps seem to require relatively high protein levels. For example, the protein requirement of *P. japonicus* is between 48 and 60 per cent. The protein requirement of *P. monodon* is about 35–39 per cent, of *P. setiferus* 20–32 per cent, of *P. aztecus* 23–40 per cent, of *P. vannamei* 30 per cent, of *P. stylirostris* 35 per cent and of *P. indicus* 43 per cent. Shrimp feeds require sterols and also fatty acids of the linoleic and linolenic series, as *de novo* syntheses of these do not take place in crustaceans (see Chapter 7). Dietary lipids are provided mainly by fish oils with high levels of polyunsaturated fatty acids. Very little is known about the requirements of vitamins and minerals, although standard premixes are added in all diet formulations.

In the present state of knowledge on shrimp nutrition, fresh food continues to be important in larval and fry rearing as well as adult grow-out. Commercial feeds are becoming available in many areas, but their acceptance in commercial farming is rather slow. When used, many farmers supplement them with natural food and feedstuffs. Water-stable pellets of different shapes and sizes (worm-like or crumbles) are prepared using finely ground ingredients and different kinds of binders, by cooking-extrusion or dry or wet pelletizing.

As is evident from the description of shrimp hatchery operations, the production of adequate quantities of the required type of live food for larval and post-larval stages is a major problem, and because of this several efforts have been made to develop microparticulate or microencapsulated larval diets. However, these have not so far resulted in products which have wide commercial application. Crustacean wet tissue suspension is reported to be used as larval feed successfully in small-scale hatchery operations in India (Hameed Ali *et al.*, 1982). *Mysis* and *Acetes*, blended into a fine particulate suspension and graded by fine-meshed sieves, have been used as the only feed during the entire larval phase, and an average larval survival of 44 per cent has been reported. This type of larval feeding resembles the use of fish flesh suspension in the