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Applied Zoology

Culture of Freshwater Prawn

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Introduction:

Freshwater prawn culture has now occupied a significant position in inland aquacultural practices. Although India has vast freshwater resources for aquaculture, these are generally being exploited for carp and other finfish culture that's too in a limited scale. Composite fish farming activities using different native as well as exotic finishes have now become a common practice in many parts of the country. Similar sincere and faithful efforts are also being made for prawn farming singly or in combination with finfishes. Culture of freshwater prawns along with major carps has been an important step towards achieving this goal.

The practice of culturing prawn in ponds is flourishing because growing prawn in ponds is proving a more useful practice than to catch them from lakes, rives, canals or streams or estuaries.

Prawns grow very fast in freshwater ponds reaching the marketable size (150-180 mm) in about six months time. In fertilised ponds they grow even faster. Ponds for aquaculture can be built wherever the soil, shape of the land and water supply are appropriate. A pond for prawn and/or finfish culture can be prepared from a rice/paddy or an unused grain field.

Out of 2.6 million hectares of Indian estuaries and backwaters, only 1.4 million hectares are suitable for prawn farming. Of these 1.4 million hectares, only a small fraction is being utilized for culture of prawn. The impounded freshwater bodies in the various states of India offer immense potential for freshwater prawn culture. Hence, there is a possibility to increase the prawn production from the Indian brackish waters. Lot of scope for prawn culture also exists in neighbouring countries like Bangladesh, Srilanka and Pakistan.

The Prawn:

Common cultivable species:

Among the different species of prawns, *Macrobrachium rosenbergii* (DeMan) , the giant freshwater prawn popularly known as the scampi is the most preferred variety being liked by both the consumers as well as the producers (fish farmers) equally. This species can be cultured in freshwaters as well as in brackish waters. It can be cultivated for export through monoculture in existing as well as in new ponds or with compatible freshwater finfishes in existing ponds. Fortunately India has both freshwater as well as brackish water prawn culture potentialities. However, the management practices under freshwater and brackish water prawn culture differ substantially, hence described separately.

The giant freshwater prawn, *M. rosenbergii* is one of the important commercial species of freshwater prawns. It is widely distributed in the Indo-Pacific area and constitutes an important component among the commercial prawn catches from estuaries. It is present in freshwater rivers, canals, reservoirs and tanks in India. It is the largest freshwater prawn of the region reaching the size of 150 to 250 mm (maximum size 320 mm). Because of its high growth, omnivorous feeding habits, and high demand in market, the giant freshwater prawn has attracted the attention of fish farmers and entrepreneurs to undertake their large-scale production.

Species of the freshwater prawn genus *Macrobrachium* are distributed throughout the tropical and subtropical zones of the world. They are found in most inland freshwater areas e.g. lakes, rivers, swamps, irrigation ditches, canals and ponds, as well as in estuarine areas. Most species require brackish water in the initial stages of their life cycle although some complete their cycle in inland saline and freshwater lakes. . *M. rosenbergii* is found in extremely turbid conditions. From their natural locality many *Macrobrachium* species have been transplanted

to other parts of the world. *M. rosenbergii* still remains the most preferred species most used for commercial farming. It has been introduced into almost every continent for farming purposes. *M. rosenbergii* is now farmed in many countries; the major producers (>200 mt) are Bangladesh, Brazil, China, Ecuador, India, Malaysia, Taiwan Province of China, and Thailand. More than thirty other countries have also reported the production of this species in the year 2000. Vietnam is also a major producer. *M. rosenbergii* in Bangladesh, India, and several countries in Southeast Asia are mostly caught from the nature hence also come under capture fisheries.

Apart from the *Macrobrachium* species, the penaeid prawns are perhaps the most popular amongst both, the producers as well as the consumers. The commonest among them is *Penaeus monodon*, popularly known as ‘tiger prawn’ (growing up to 33.7 cm in length). It is a highly priced species in the international market. The juveniles feed on diatoms and algae and other planktonic organisms. The genus *Penaeus* has several other species (e.g. *P. indicus*, *P. japonicus*, *P. duorarum*, and *P. semisulcatus*).

The members belonging to penaeid prawns are mostly brackish water species that can also be cultured in various types of ecological conditions like derelict waters, saltpans and shallow canals in the coconut groves. The tiger prawn spawns throughout the year with their post larvae (PL) available round the year in estuaries.

Considering the great scope for export, *Macrobrachium rosenbergii*, enjoys immense potential for culture in tropical and subtropical climates of the Indian subcontinent. It is hardy and can adapt to various types of fresh and brackish-water conditions. It can feed on pelleted feed. Their preferred habitat especially during spawning is the natural environment, lower reaches of rivers, tidal inlets, where water is directly or indirectly connected with sea

Classification:

The prawns belong to the suborder Natantia of order Decapoda under Class Crustacea. The members of this suborder have laterally compressed body and rostrum with larger and lamellar antennal scales. They have five pairs of pleopods modified for swimming. Common and most important cultivable prawn species belong to two families: Palaemonidae (includes mostly freshwaters species) and Panaeidae (includes mostly marine and brackish water species). The members of these two families are commonly available in and around estuaries:

Systematic position of two most popular prawns of the Indian subcontinent

Kingdom	Animalia	Kingdom	Animalia
Phylum	Arthropoda	Phylum	Arthropoda
Class	Crustacea	Class	Crustacea
Order	Decapoda	Order	Decapoda
Sub-order	Natantia	Sub-order	Natantia
Family	Palaemonidae	Family	Panaeidae
Genus	<i>Macrobrachium</i>	Genus	<i>Penaeus</i>
Species	<i>rosenbergii</i>	Species	<i>monodon</i>

Until recently, *M. rosenbergii* was also known as *Palaemon carcinus*, or *P. dacqueti*, or *P. rosenbergii*. However since 1959 its present scientific name, *Macrobrachium rosenbergii* (DeMan 1879) has been universally accepted.

Body shape and appearance:

The bilaterally symmetrical body is elongated, more or less spindle-shaped with the size varying from species to species. While the young stages are translucent and whitish, the adults are differently tinted in different species.

Body division:

The body of a fully developed prawn is made of 19 appendage-bearing segments, divisible into two different regions: an anterior cephalothorax and a posterior abdomen (Fig. 1):

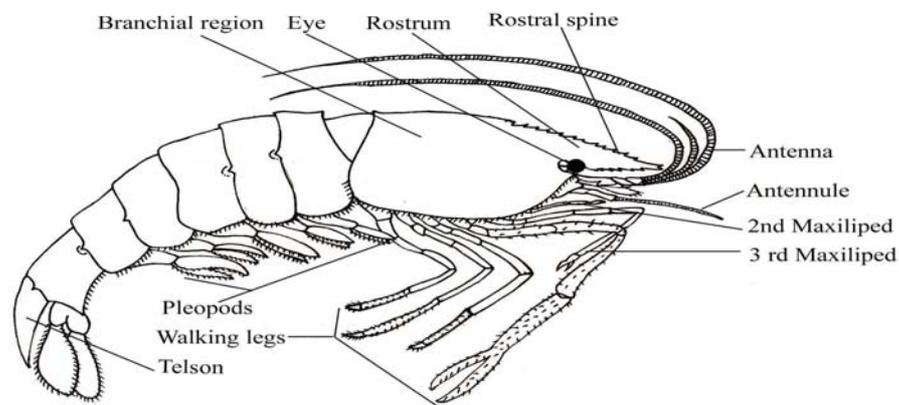


Fig. 1: The Prawn

Cephalothorax:

The un-jointed large rigid, cylindrical cephalothorax is formed by the fusion of the head (comprising five appendages-bearing segments), and the thorax (comprising eight segments).

Abdomen:

Unlike the cephalothorax, the jointed abdomen is composed of six distinct observable segments and a terminal conical piece the telson or tail plate. Each abdominal segment bears a pair of jointed appendages, called pleopods or swimmerets.

Exoskeleton:

A hard, chitinous exoskeleton covers the entire body including the appendages. The exoskeleton is comprised of several plates called sclerites. The sclerites from the dorsal and ventral side of the cephalothorax fuse to form a single large dorsal shield. The posterior region of the dorsal shield is known as carapace. The sclerite of each abdominal segment is separate, ring like and articulates with the neighbouring sclerites by a thin arthrodial membrane. The dorsal broad plate of each of the abdominal sclerite is called as tergum while its ventral narrow plate as sternum and lateral flap-like plate as pleura.

Appendages:

One pair of the jointed appendages is placed on each segment. The prawn has 19 pairs of appendages: thirteen in the cephalothorax and six in the abdomen (Fig. 1). Out of these thirteen, five anterior pairs are cephalic appendages (namely, antennules, antennae, mandibles, maxillulae and maxillae) and the rest eight posterior pairs are thoracic appendages (namely anterior three pairs of maxillipedes, and five pairs of walking legs). Also, there are six pairs of abdominal appendages, one pair in each of its segment. While the first five pairs are swimming pleopods used as paddles, the sixth pair is the uropod, which along with the telson constitutes the tailfin. The prawn crawls at the bottom by means of its walking legs. It swims by beating its swimmerets or the abdominal appendages. The mandibles, maxillulae, maxillae maxillipedes either help or take active part in feeding. All the appendages are based on biramous plan.

Fresh Water Prawn Culture

Construction of the pond:

In aquaculture, a pond is a shallow water body used for the controlled culture of aquatic species. It is constructed in such a way that it can be easily and completely drained. Before construction, selection of the site for the construction of the ponds is of prime importance. The number and type of the proposed ponds to be built must also be decided before hand. The size and surface of the ponds can vary considerably. The medium and small sized ponds are easier to manage, hence proportionately most productive too. A pond size of 0.5 to 1.5 acre is quite handy and easy to manipulate. It is easy to harvest if the pond is rectangular (0.6-hectare pond is 30 m wide and 200 m long). The length of the pond should be decided on the basis of site and topography as well as farm lay out. A pond with a width between 30 to 50 metres is always easy to operate. The depth of the pond should range between 0.75 to 1.20 m with an average depth of 0.9 m. Deeper ponds are difficult to manage. The ratio between the dyke and pond slope should be maintained at 2:10. The dyke must always rest on solid and watertight ground. The bottom of the pond must be smooth without having projecting rocks or tree stumps on it. The pond bottom must slope gradually and smoothly from the water intake end towards the drain end (a 20% slope (1:500) is suggested for ponds of 0.4 ha or more in area and 5 % (1:200) for smaller ponds towards the outlet, where drain harvesting is practised. This prevents retention of pockets of water in which prawns often get trapped and die ultimately during total drainage of the pond. Narrow ponds should be oriented in such a way that the prevailing wind (which enhances the dissolved oxygen content of the water) blows down the long axis towards the drain end, to minimize erosion of the bank. Each pond should have a proper drainage system and care should be taken to prevent mixing incoming water with the outlet one. Large ponds are normally wider than 30m and regularly drained for harvesting. Freshwater prawns can also be stocked into concrete and earthen reservoirs, ponds, irrigation ditches, cages, pens and natural waters. In general, a freshwater prawn farm has many similarities with that of a freshwater finfish farm.

During the cool weather, water temperature at the bottom of deep ponds may drop enough to reduce feed consumption by the prawns. On the other hand, the water temperature in shallower ponds may rise too high for the prawns. Also the water becomes quite clear, exposing the prawns to greater predation. Further, shallow ponds tend to support the growth of rooted aquatic plants hence are not recommended.

Following points be considered while constructing a freshwater pond for prawn culture:

Topography:

Topography is the word that describes the shape of the land – whether it is flat, hilly upland or lowlands. The topography of the land often decides the kind of pond that can be built. Marking the area of the proposed pond is the first step of pond construction. If the pond is built on a flat piece of land, the pond basin should be made sloppy towards the outlet for easy drainage. The main wall of the pond should always be erected at the slope end. Apart from the topography, of the area, soil condition, water quality also play important role in prawn culture. Several other considerations including approach road, market, consumers' food habits/status and availability of labour and ice etc.

Site:

Like the finfish culture, the selection of the site also plays a very important role in prawn culture as the entire management practices of the farm depends on the availability of the facilities at the site. It should be kept in mind that the income from the pond must be more than that of the land itself:

The selected site should be thoroughly surveyed to decide the best layout of ponds for water intake, access roads, and effluent discharge. Rectangular ponds are most suitable to use seining for harvesting, which is commonly applied in freshwater prawn farming.

For successful rearing of *M. rosenbergii* larvae, (a) optimal temperature range, (b) suitable feed and (c) maintenance of water quality in rearing tanks are required. A temperature of 28°C is considered congenial for larval development; however, the larvae can grow in the temperature range of 26.5 to 31.5°C.

Soil:

The next important step of pond construction is the soil of the pond. The best soil for the prawn-ponds should contain a lot of clay silt mixture with smooth and slippery texture with water holding properties. Sand loam comprising 60% sand and 40% silt are often recommended. If the soil is rocky or has shifting sand etc., only small ponds can be built. The soil is greatly responsible for the fertility of the water because of its nutrient contents. Fertility is the measure of the nutrients in the pond, and it simply refers to how much food is available in the pond for the prawn/fish to consume. The soil should contain the necessary nutrients like iron, calcium and magnesium. Sometimes it may also contain certain harmful substances like acids. If the soil is good for agriculture, it ought to be good for aquaculture. The laying down of ponds is often economically best on sandy or marshy grounds, which are not economical for other types of exploitation. The pond must give a better return than what the land would have given. It has often been found that poor agricultural land can be turned into very good fish ponds. In general better is the soil, better will be the production in such culture ponds. If the pond is built on poor quality agricultural land, and the pond is cared well, the pond bottom soil becomes more fertile than what it was before, in due course of time.

Under integrated farming, many farmers often grow prawn and other finfishes in paddy fields, with the dual benefits of the earning from the paddy as well as the prawn/finfish.

Improvement of soil:

Acid soils are not good for prawn productivity. Hence these soils should be treated (often with lime) to improve the alkalinity of pond water. If the pH of the pond water is 6.5 or less

than 6.5 at sunrise, the soil should be treated with the lime before the pond completely gets dried out. This enables the lime to dissolve and penetrate into the soil. Routine liming increases total alkalinity. Agricultural limestone is the best compound to use for increasing alkalinity. However, the quantity of lime required depends on the type of soil and its pH. Ponds having a high water pH can be improved by 'ageing'. This is done by filling the ponds with water 2-4 weeks before stocking and allowing natural biological processes to buffer the pH. However, this may also increase the chances of growing predators and weeds.

Fertilization:

In order to maintain an abundant food supply to the young prawns and preventing growth of aquatic weeds, fertilization of the pond should be encouraged in prawn culture. The main objective of fertilization of ponds should be to direct all primary, secondary and tertiary levels of productivity towards maximum productivity of fishes/prawns. The natural productivity of the pond can always be enhanced by application of fertilizers (inorganic and organic). Hence to begin with, the pond should be conditioned with inorganic as well as organic fertilizers until a mixed bloom of zooplankton and phytoplankton develops. Fertilization of ponds already having relatively thicker density of microorganisms may increase further their number rather rapidly.

A layer of lime should be placed at the bottom of the pond whether the pond is old or new. Subsequently, the pond should be fertilized with cow dung, which is considered as one of the best organic manures. The organic manures for the fish ponds are classified on the basis of the following criteria:

- a. Organic fertilizer with little or no carbohydrates (e.g. liquid manures from the stables byres (cow-sheds), guano (excreta of birds), slaughter house refuse etc.
- b. Organic fertilizer with carbohydrate contents only (e.g. Mustard oil cake, green manuring components).
- c. Fertilizer with carbohydrates and nitrogenous matters (e.g. Poultry wastes-matters, sewage, sludge, farmyard wastes etc.).

The type of organic manures required depends upon the variety of fish proposed to be cultivated. Organic fertilizers added @ 24 kg/acre/week produce abundant zooplankton populations. Cottonseed meal is one such good source of organic material that is easily available. The cottonseed meal has higher fibre contents than other organic substances like soybean meal, fishmeal and manures. Mahua oil cake although acts as a poison for killing fish in the initial stages of application, it also serves as a good fertilizer and induces plankton production. Inorganic fertilizers having nitrogen and phosphorus may be added until a phytoplankton bloom develops in the water. In a properly fertilized pond, the visibility of the water column should be less than 18 inches.

The water supply:

Availability of good quality of water for filling the water body is perhaps the most important factor for selecting the site for pond construction. It should be ensured that water should be available throughout the tenure of prawn culture.

Water in the pond can be obtained from several sources:

- Rainfall: some ponds called sky ponds depend only on rainfall to fill.
- Runoff: Some ponds are gravel and sand pits that fill when water from the surrounding land areas flows into them.
- Natural waters: A large number of ponds are getting their water supply from natural springs, wells, lakes, rivers etc.

Quality of water:

The ponds should get good quality water having no foul smell or bad taste. It should be clear showing no turbidity. If the water is muddy, it should be allowed to settle before the water is used in the pond. If the water is bright green, it contains a lot of food. If the water is dark, brownish, it may contain acid in it and lime should be added to neutralize the water. Knowledge of the source of the water and the **distance it travelled prior to reach the pond is absolutely necessary.**

Farms must be designed with a proper water distribution system that allows simultaneous filling of all the ponds. A total hardness between 50-100 mg/L (CaCO_3) is ideal for freshwater prawn rearing. Hardness of very soft waters can be increased by adding calcium sulphate (gypsum). 2 mg/L of gypsum increases the total hardness by 1 mg/L. However no treatment is generally required for hard waters.

Care has to be taken that incoming water should not get contaminated with out going or drained waters of the same or neighbouring ponds. Hence the water inlet should always be placed opposite to the drainage point (Fig. 2). Each pond must have its own independent water supply from a central distribution channel and should not receive the outflow from another pond. Water from one pond should not be transferred to another one because phytoplankton and zooplankton blooms develop rapidly when water from a reservoir or adjacent pond is introduced into the prawn pond.

Preferably, water should be distributed through pipes or open channels and should fall into the pond by gravity (to improve dissolved oxygen content). This can be achieved by placing the inlet supply pipes or channels above the water level in the ponds so that the incoming water falls onto the surface of the water.

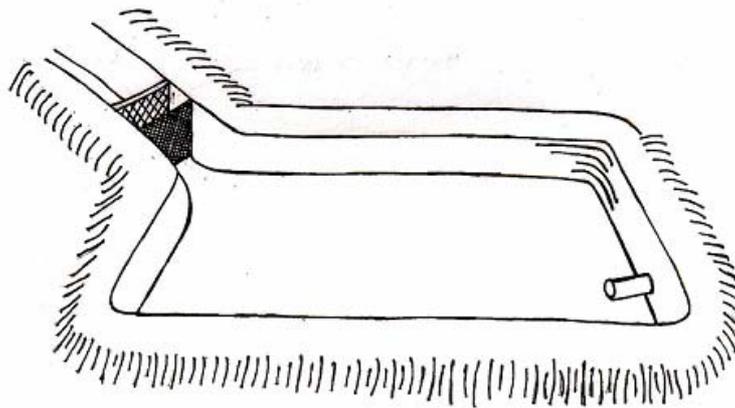


Fig. 2. A typical freshwater pond showing the water inlet and outlet systems

Filling of the ponds:

Fifteen days after liming, the pond is filled slowly with good quality water. It is better to allow the water to drop into the pond from the inlet situated at a height so that the water gets oxygenated. If the water is allowed to enter very fast, the bottom may get stirred up and may become muddy. Therefore the water should be allowed to settle down for a few days. Prior to introduction of the juveniles/PL into the pond, the quality of water should be tested. The water entering freshwater prawn ponds is not generally treated with lime or other chemicals. Valves, weirs, stop-logs or plugs must control the flow of water into each pond. Incoming water should be allowed to pass through a small screen that can restrict the entry of fish eggs, small fish and insects and other predators. Filter fabrics with 300-100 micron mesh can filter out all unwanted predators.

Ponds should be stocked with the PL within seven days after filling with water, as the population of insects will be least during this time. Water from tube wells and pumping systems may also be used. Well water is usually hypoxic hence requires aeration that can be done by cascading or by allowing to fall into the pond water level from a height.

To maintain good water quality, most prawn farms regularly exchange water that also keeps dissolved oxygen at high levels. Building ripples into gravity inflow channels can also enhance the dissolved oxygen level of incoming waters. Aeration equipment may be needed at the time of oxygen depletion, which is a very common phenomenon of tropical ponds. Artificial aeration is needed to maintain the water quality for increased productivity, especially after partial harvesting. Aeration is also needed to maintain dissolved oxygen levels during the daytime especially at the pond bottom where it becomes low (most prawns dwell at the bottom of the ponds).

Drainage:

Each pond should have a water inlet and outlet independent from those of other neighbouring ponds (Fig. 3). The water should be replenished every week or fortnight depending upon the requirement. The pond should have very effective drainage systems so that it may be possible to empty and subsequently dry the pond. The emptying can be achieved by means of a series

of drains or ditches, which may terminate at a monk. These structures help in drainage and are situated at the deepest end of the pond. A monk apart from helping in total draining of the pond also facilitates to control the water level during seine harvesting, flushing and water circulation. The monk is very much like a sluice, but unlike the sluice, it is not built into the pond wall. However, sometimes, the back of the monk touches the wall. Ponds should drain out by gravity, preferably through the 'monk' or sluice gate (Fig. 3). The out going water must also be screened to prevent the escape of the fish. Where drainage by gravity is not possible, pumping can be employed.

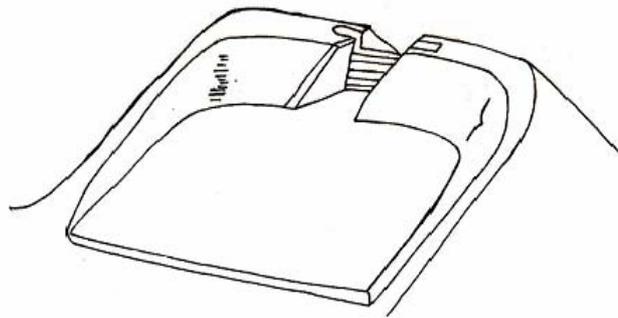


Fig. 3. A typical freshwater pond showing the outlet controlled by either a sluice gate or monk.

Temperature:

The prawns have wide range of temperature tolerance (15 to 35°C). However 28°C is perhaps the most desired temperature for the development of larvae, even though they can thrive well in the temperature range of 26.5 to 31.5°C.

Sudden changes in temperature as well as pH can cause mortalities when prawns are stocked. Before their release into the pond, the bags containing the PL should be allowed to float in the pond water to bring the temperature of the bag gradually to the level of the pond water. Any adjustments to the pH of the transport water should be made in the hatchery itself prior to their transport.

Culture of Prawn:

Preparation of the pond:

After the final harvest of the last batch of prawns, the pond should be drained to get rid of all the predators. Pond sediments if any should also be removed. The pond should be dried completely for 2-3 weeks after every harvesting or at least once a year. The pond bottom may be ploughed to increase the oxygen content of the soil, especially if it has a heavy texture (clays and clay loams). 1000 kg/ha of agricultural limestone (CaCO_3) or 1,500 kg/ha of hydrated (slaked) lime should be spread on the dried pond basin especially if there has been a severe infection during the previous crop. After adding limestone the pond should be sun-dried for 15 days. Necessary repairs to the pond banks and the major structures including inlets and outlets should also be made.

Brood stock:

The sexes in prawn are separate. Fertilization is external; the male deposits the sperms near the genital openings of the female and the eggs get fertilized as soon as they leave the female's body. Subsequently, the fertilized eggs get fastened to the pleopods by a sticky secretion of tegumental gland. In this way the female carries hundreds of the eggs attached to hairs on her pleopods until the eggs hatch. Such females are said to be 'in berry' or 'berried' females, and carry up to 4000 eggs for about 4 months. The females bend down her abdomen first to protect the eggs and later the youngs cling to the swimmerets of the mother for a short period.

3.4.11.1 Brood stock females:

The word broodstock usually means the female prawns especially in tropical fresh water farms where adult prawns are available round the year. These adult ('berried' also called ovigerous) females are kept in hatcheries for laying their eggs. Berried females should be carefully selected. They should be healthy and active, well pigmented, with no missing appendages or other damages, and loaded with large number of ripened eggs. With the ripening of the eggs, the colour of the prawns changes from bright orange through brown to finally greyish-brown just a few days (2 –3 days) before hatching. The number of females required depends on the volume or capacity of the hatchery tank(s) to be stocked with larvae, and also on the number of eggs being carried by each female. After spawning these spent females are discarded or sold in the fish market. The berried females in the tropics can be obtained round the year from prawn farms. They can also be collected from rivers, canals and lakes in areas where they are indigenous (native). In the wild, berried females are most abundant around the beginning of the rainy season. Collecting ovigerous females from the wild often results in considerable egg loss during transport. In tropical conditions, about 50 berried females are needed for each larval cycle of a hatchery using a total larval pond volume of 50 m³ (e.g. ten 5 m³ ponds) producing a total of 50, 0000 PL per cycle (assuming a larval survival rate of 50% to metamorphosis). This is on the assumption that eggs produced by each berried female can hatch into 20,000 viable stages-I larvae. When freshwater prawns are introduced into an area where they are normally not found in the wild, great care must be taken to follow national and international guidelines for introduction, including quarantine.

Management of the broodstock:

Practices of outdoor management of broodstock in the tropics are more or less identical to those of rearing facilities. Immediately after receiving the broodstock at the hatchery, they should be disinfected with 0.2 to 0.5 ppm of copper sulphate or 15 to 20 ppm of formalin for 30 minutes with proper aeration. Subsequently, they should be transferred to ponds having an optimum water temperature ranging between 27-31°C. The physicochemical properties of the pond water for broodstock maintenance are more or less identical to that for hatcheries. A nutritionally complete diet is essential to promote superior egg production and quality. Commercially pelleted feeds can be used but need supplementation. Broodstock should be fed at a daily rate of 1-3% of total biomass. 50% of the pelleted feed should be replaced with the equivalent amount of liver or squid or mussel flesh, at least twice a week.

Collection of seed/juvenile:

Freshwater prawns are obtained from rivers, or (less frequently) from nurseries, for stocking into open waters. The breeding takes place in low saline waters, which is also needed for larval and PL development after incubation. Breeding of *M. rosenbergii* takes place in estuaries.

The collection of seed from the natural resources has many practical advantages that include: (i) the cost for seed procurement is cheap without the use of any advanced technology, (ii) the method of collection is very simple, (iii) because of their mass movement, pure prawn seed can easily be collected. Juveniles are collected in large numbers during rainy and post rainy (up to November) seasons.

Prawn juveniles are either collected by scoop net or with the help of traps. A trap made of bunch of various bushes tied with monofilament or coir ropes are fixed at a water depth 5-6 feet during high tide and 3-4 feet during low tide in the river for 3 to 10 days. The bush trap where the juveniles have taken shelter is lifted up and shaken to collect them on a stretched piece of cloth of 5' x 3' size. They are then transported in open plastic tubs of 5 x 4 feet or 6 x 3 feet to a market or to the fish farmer's tanks.

Though the prawn seed is generally collected from the natural resources, they are only available to a limited extent. Therefore, for large-scale culture and for ensuring regular availability, seed should be produced at prawn hatcheries. Many of the prawn species require certain degree of salinity and longer gestation period for the development of their larvae.

The growth rate and survival of each population of prawns depends on several factors like density, predation, feed and temperature. These factors are site- and operation specific. Survival rates during the grow-out period should be maintained above 50%.

Management of stocks for rearing:

Individual prawns within a population grow at different rates, some growing very fast than the rest, while some do not grow at all. The disparity in growth rate is more pronounced among males than females and in mature population of freshwater prawns.

The size of the prawn to be harvested for selling decides the stocking rate that depends upon several factors. Some of these factors include: demand of the local, national, or international markets, period of the growing season, and on the management practices being employed. Older ponds are more productive than newer ones. The lower stocking rates result in production of prawns of larger average sizes. Higher stocking rates result in greater total productivity (metric ton/ha/crop) but of smaller average sizes. If stocking of juveniles are made, there are some advantages in grading them before stocking.

During culture operation, the ponds need proper maintenance including the safeguarding of the water inlet and outlet fittings along with their filters (screens, socks). Plantation of vegetation along the pond bank minimizes erosion of the pond bank. The pond depth should be maintained at an average of 0.9 m. The presence of aquatic plants below the water line however provides food and a habitat for the prawns. The plants *Elodea* sp. and *Hydrilla* make a good substrate for prawns. However excessive growth of vegetation prevents light penetration.

The ponds should be stocked with the juveniles within 7 days after the pond is filled, when the predaceous insects are at low densities. In case the size of the PL obtained from the hatcheries are very small, they should first be reared in nurseries for 4 to 5 weeks till they attain a length of 40 to 50 mm with weight of 1 to 3 g. Depending upon the type of management practices, 4000 to 5000 PL per hectare are released into the ponds. The culture practice may be monoculture or polyculture with major carp. In polyculture system, the depth of the pond should be increased to 4 or 5 feet. While the number of PL of prawn in polyculture should be from 2500 to 20000, the number of carp fingerlings should range from 2500 to 5000. While In monoculture practice, the culture period for rearing varies between 6 to 8 months, the period under polyculture practice ranges from 8 to 12 months. Depending

upon the type of management practice, the survival rate varies from 50% to 70%. Other important management practices include regular feeding, aeration and water renewal etc.

Genetic improvement:

Until recently, no much progress had been made in the genetic improvement of *Macrobrachium*. Freshwater prawns that hatch early from eggs appear to have an advantage in grow-out because they are the first ones to establish themselves as dominant blue claw males. Genetic advantages, if any, of these 'early hatchers' over the 'late hatchers' is yet to be substantiated. Selection of large sized females carrying more eggs may not be a good practice. It is better to select fast-growing, berried females from ponds three months after they were stocked, than choosing large females six months after stocking, for a positive genetic effect on weight at harvest. Collecting the faster growing females and rearing them in specialized broodstock ponds help the farmer to use selection to improve grow-out performance and also give them the ability to hold the animals until their clutch size becomes larger.

Ablation of one of the eyestalks of female broodstock often increases the number of mature females in a captive broodstock and diminishes the time between each spawn. Young females (about 4 months old after stocking at PL size) spawn about 20 days after eyestalk ablation. They spawn again after about 30 days.

Genetic degradation due to inbreeding has been noticed in several countries including the Martinique (Caribbean islands), Taiwan Province of China, and Thailand. This problem has occurred because of the 'recycling' of the prawn (brood stock for hatcheries being obtained from rearing ponds and the process being repeated for several generations). In countries where this species has been imported for transplantation, the problem is still continuing. Using more wild broodstock and genetic improvement may solve the problem.

Sex ratio of the stock:

Often the proportion of females under rearing conditions is kept greater than males, because, to maximize the total weight production of prawns per hectare, rearing of all-female populations at very high densities has been found substantially effective. For maximizing the income from the ponds, proper management of mixed-sex or all-male populations is best, since the larger-sized prawns normally have the greatest unit market value.

Semi-intensive monoculture:

Freshwater prawn monoculture can be extensive, semi-intensive or intensive but the definition of these terms is rather vague. In extensive culture, rearing of prawn is done in ponds (but also in other impoundments such as reservoirs, irrigation ponds and rice fields) that produce less than 500 kg/ha/yr of prawn. In this type, the prawns are frequently stocked from wild sources, with PL or juveniles at 1-4/m². Neither the water quality is controlled nor the growth and mortality of the prawns is generally monitored. Similarly, supplemental feeding is also not provided. Fertilisation of the ponds with organic manures is a rare phenomenon. In semi-intensive systems fertilisation of the pond is done with a supply of balanced diet. Water quality, prawn health and growth rate are monitored with regular controlling of predators and competitors. Semi-intensive prawn culture is most common in tropical areas involving stocking of PL or juveniles of freshwater prawns (usually from hatcheries) at 4-20/m² in ponds, with a productivity of more than 500 kg/ha/yr. However, productivities ranging between 1000-3000 kg/ha/yr have frequently been reported.

In intensive culture freshwater prawn farming is practiced in small earthen or concrete ponds (up to 0.2 ha) provided with high water exchange and continuous aeration, stocked at more than 20/m² and achieving an output of more than 5000 kg/ha/yr. The costs of construction and maintenance of these types of ponds are high and require high degrees of management practice including the use of a nutritionally complete feed, the eradication of predators and competitors, and controlled water quality.

Control of weed fishes and infecting organisms:

The treatment with teaseed cake (containing 10-13% of saponin) @ 50-70 g/m³ (500-700 kg/ha in 1 m deep ponds) is adequate to remove unwanted fish. 20 g/m³ (200 kg/ha in 1 m deep ponds) of rotenone powder (equivalent to 1 g/m³ of pure rotenone) is also effective.

Polyculture

A considerable, but unquantified proportion of global freshwater prawn production comes from polyculture and integrated culture. Polyculture of various *Macrobrachium* species in combination with one or more species of fish, including tilapias, common carp, Chinese carps, Indian carps, golden shiners, mullets, ornamental fish, and red swamp crayfish are being carried out. Other combinations may also be in practice. The inclusion of freshwater prawns in a polyculture system almost always has synergistic beneficial effects, which include:

1. More stable dissolved oxygen levels;
2. Reduction of predators;
3. Coprophagy (the consumption of fish faeces by prawns), which increases the efficiency of feed;
4. Greater total pond productivity (all species); and
5. The potential to increase the total value of the crop by the inclusion of a high-value species.

The management of a polyculture practice is very complex especially during harvesting of the produce. Large sized finfishes can be cull-harvested from the polyculture ponds that interfere with the culture of prawns. Prawn-fish polyculture systems are thus normally batch-harvested. Often it is difficult to synchronize fish production of the marketable size with that of prawn to achieve the maximum production.

The inclusion of prawns to fish polyculture ponds does not normally decrease the quantity of fish production. On the other hand, the addition of fish to a prawn monoculture system markedly increases total pond productivity due to increased production of the finfishes. However, this may reduce the total prawn production below the monoculture level. Polyculture may pose some practical problems. For example, tilapias in prawn ponds may have serious competition for food. Also once introduced it is very difficult to eradicate tilapias from the freshwater prawn ponds. It has been found that the growth and production of giant freshwater prawn is improved and additional production of snakeskin gourami in some polyculture combinations can be obtained with same feed input as in the monoculture of giant freshwater prawn. However, monoculture versus polyculture decision is site-specific and depends on economic factors, namely balancing the relative market values of the various species with the cost of a more complex management system.

Integrated culture

The water from culture ponds (in monoculture or polyculture with finfish) can be used for the irrigation of agricultural crops. Prawns are often reared in paddy fields, without any decrease of the paddy production. Investment cost for farmers to integrate fresh water prawn culture with rice is low. In Vietnam, the income from prawns in integrated rice-prawn culture was two or three times more than that from the cultivation of rice alone. The introduction of freshwater prawns reduces the cost of fertilisation and weeding (prawns eat weeds). The pH in the paddy field and in the trench varied from 6 to 9.8, which is suitable for prawn to thrive in. The temperature in such a culture system (26° to 32°C) is also suitable for the prawns. However the paddy fields should be prepared properly with fencing the dikes, screening the inlet and outlet pipes and digging a trench around the paddy culture area. Proper levelling of the field is also very important for effective harvesting of prawns. The rice plants provide additional shelter and increase feeding surface area for the prawns which are important for their growth and survival rate.

In certain districts of Bangladesh like Khulna, marine shrimp culture is also practised in paddy fields which are subjected to regular tidal inundation from the nearby canal. Culture season continues from January or February to June or July when the canal water is brackish. During the rest of the year, the canal water is fresh hence the fields are utilized for growing paddy crop. The juveniles/post larvae (PL) of *Macrobrachium rosenbergii* are naturally stocked in the ditches and low-lying areas within the paddy fields and show quick growth. In Chittagong, another district of Bangladesh, shrimp culture extends over a more prolonged period and is discontinued during the heavy monsoon when water salinity becomes unsuitable for holding marine shrimp. Studies conducted at Farming System Research Institute in Bangkok and the Sakolnakorn Fisheries Station in Sakolnakorn in the North-east Thailand have found that about half of the PL raised in rice fields in concurrent cultivation with rice reached the marketable size within 3 months of rearing which increased considerably gross income of the farmers.. Rice fields having no prawn stocked generally produce comparatively less paddy than those fields stocked with prawn. The higher paddy production in the integrated culture fields may be attributed to the presence of prawns which till the soil resulting in the release of the nutrients.

The stocking density between 0.6 and 1.25/m² has the best potentialities. High rice plant densities adversely affect the survival rate of the prawn. The grow out period in the rice field is 120 days for increasing prawn production in comparison to 75 days in most of the ponds.

Feeding:

A small quantum of freshwater prawn production (perhaps 200-300 kg/ha/year) can be achieved by allowing the prawn to feed on natural food only. However, for successful semi-intensive prawn farming supplementary feeding is must. Some of the farmers rely on fertilisation than on supplementary feeding. An initial algal bloom through the addition of an inorganic fertilizer can be stimulated. Supplementary feed from the beginning of the rearing period also improves the performance and is cost-effective. Whether the feeds are pelleted mixtures or individual ingredients (such as distillery by-products), they actually act as both feeds and fertilizers. At the beginning their primary use may be as an organic fertilizer that enhances the availability of natural feeds in the rearing ponds. Subsequently, as the prawns grow, they directly consume the feed. The application of feeds/fertilizers from the beginning of the rearing period not only increases the availability of natural food but also decreases the transparency of the water, therefore reducing the growth of weeds.

The PL can be fed with different types of feeds, e.g. egg custard and Artemia, fish flesh and Artemia nauplii, tubifex worms and nauplii etc.

The types of feed used in freshwater prawn farming vary extensively and include individual animal or vegetable raw materials and feed mixtures prepared at the pond site are generally referred to as 'farm-made feeds'. In addition, ready-made commercial feeds designed for freshwater prawns are also available in the market. Being omnivorous, their nutritional requirements are not very demanding hence can be fed on a variety of feed ranging from wet feeds made from rice bran, oil cake, flesh of fish and other animals (e.g. squids, mussels shrimps) and Artemia, tubifex worm, nauplii, egg custard to scientifically formulated pellet feeds. Prior to stocking, the ponds must have high density of zooplanktons which provide the most favourable food for small sized prawn. No prawn should be stocked if the pond water is clear. A complete diet must be provided for proper growth of the prawn. It takes both natural as well as formulated feed. Feeds and feeding progressively change from a fertilization schedule to feeding a slow sink pellets. Common agricultural by-products such as cottonseed meals and distillers grains may be used to feed the prawns during the initial two months of rearing. However during the last one to two months' of growth, pelleted feed preferably water stable must be provided. Water-stable feeds provide the prawns with a balanced diet. Well-bound compounded feeds also result in less water pollution and make the analyses of the daily feed requirements easier. Feeds can be made water-stable by including a wide range of naturally occurring and modified gums and binders, by adding pre-gelatinized starch, and by certain specific processing techniques used by different feed manufacturers. The feed should be scattered evenly on the pond basin. Feeding should be done @ 4% of body weight/per day. To analyze growth and the effectiveness of the feeding schedule, periodic sampling to measure the increase in weight must be carried out. A digestible protein level of above 35% is required for maximum growth and protein efficiency.

The feeding for polyculture systems is normally directed at the finfish and not at the prawns because the finfish explore the supplemental feed faster than prawns. The prawns consume feed which drops to the bottom of the pond along with the faeces of the finfishes and draw nutrients derived from the detritus. Tropical polyculture practices often use simple mixtures of rice bran with plant oilcakes like mustard and groundnut.

Management problems arising from prawn culture and their solution

Sudden heavy or low mortalities in small numbers over a period of time may indicate reassessment of the culture applications. Prawns covered with algae or absence of recent moulting may indicate their unhealthy conditions and/or poor culture conditions. The reasons may be poor farm management leading to derelict water quality and/or attack of disease. Other external factors like pollution from pesticides and herbicides may be some of the other factors. The most likely source of external water pollution is from pesticides and herbicides.

Frequent exchange of a small proportion of the water is the usual way of maintaining water quality. Cannibalism is common in prawns. A scum of phytoplanktons often covers the surface of the pond causing low DO problems after sunset. Low DO should be suspected if prawns begin to crawl out of the ponds or congregate at the edges of the pond in daylight. This can be controlled by reduction in feeding and also by exchanging water. If this problem persists flushing the pond is recommended. Dense phytoplankton bloom often causes high pH. Due to very high pH levels prawn mortalities may take place.

Predation:

The most important way to prevent appearance of predatory animals is to stock prawns immediately after filling the ponds so that predators and competitors do not get established.

The PL of *M. rosenbergii* themselves, can also control the dragonfly population, if stocked before the hatching of the insects, The presence of good population frogs and toads in the pond is indicative of absence of predatory fish to a great extent. Predation is caused mainly by other aquatic species (belonging to the same or different groups) like insects, amphibians, birds, snakes and mammals. Mosquito fish (*Gambusia affinis*) and related species are often stocked in freshwater prawn ponds to control insects. Two of the greatest reasons for damage during freshwater prawn culture occur due to predation and operational faults caused by the human beings. Perimeter fencing, lighting, employment of dogs and reliable watchman may help to minimize predation by human beings. Loss of prawns through operational faults and poor management is also very common. Examples of operational deficiencies include too low water levels causing excessive increase in water temperatures, or hypoxic waters. Both these errors decrease the population of the prawn. If the outlet structures are not properly maintained, the prawns very often escape from them. Using rotenone or teaseed cake between cycles can effectively control unwanted fish. Passing the intake water through suitable screens or gravel filters can prevent the entry of fish and some insects. In nutshell, efficient management of prawn competitors and predators includes stocking prawns immediately after the pond is filled, seining periodically, and totally draining and treating the ponds at least once per year.

Diseases:

Diseases in freshwater prawn ponds are relatively low, in comparison to other forms of aquaculture. This may perhaps be due to relatively low stocking densities of the prawn practised so far. With the increased stocking rates, problems may also increase. Diseases occur in freshwater prawn ponds when the quality of the water deteriorates. Disease problems may also originate during the transfer of animals from one site to another, including the introduction of animals into a location where they are not indigenous. Hence Proper precautions to prevent the attack or spread of diseases and other problems should be taken. There are a number of other problems during rearing of freshwater prawns such as nutritional deficiencies, fouling or parasites.

There are certain diseases, which are non-specific or are of unknown origin. Their treatment is also not normally practicable. All life stages of freshwater prawns face a disease known as muscle necrosis when the affected prawns show a whitish colour in the striated muscles of their tails and appendages. The necrotic areas may increase in size and become reddish, a colour identical to cooked specimens due to the decomposition of the muscular tissues. Secondary infectants (e.g. bacteria and the fungus *Fusarium*) also get associated with the affected areas. Prawns suffering from chronic muscle necrosis do not generally survive and heavy mortality rates varying from insignificant to 100% may occur. This disease may occur due to poor management practices, particularly when stocking rates and handling stress are high resulting in poor environmental conditions (e.g. low dissolved oxygen, temperature fluctuations, and salinity fluctuations). Good management practices minimize the occurrence of these problems.

Parasitic infections are quite rare in cultured *M. rosenbergii*. However, the freshwater prawns act as hosts for the isopod *Probopyrus*. These parasites attach themselves to the interior of the gill chamber, causing swelling. This is a common problem in captive broodstock, as it interferes with egg production. Wild freshwater prawns of various species also act as intermediate hosts for trematodes. Prawns are also host for the Asian lung fluke whose role in mammalian subjects has not yet been established.

The general body surface of the prawn can serve as a substrate for single or colonial protozoa, filamentous bacteria and algae. The problem is particularly noticeable in large

animals, especially blue-claw males, which moult less often. Moulting temporarily frees prawns from these fouling microorganisms. Although these organisms do not invade the tissues they make it difficult for the prawns to move and feed, particularly in the larval and post larval phases. Extreme infestation on the gills impairs their physiology leading to their mortalities in juvenile or adult stages. Heavy infestation over the exterior surface can also reduce their market value. Infestation by filamentous algae has been observed to occur in rearing ponds with high water transparency (above 40 cm). This problem can be overcome by lowering water transparency through feed management.

The effects of fouling organisms can be controlled by good management practices, especially by proper treatment of the incoming waters, proper cleaning of the tank basins, and the treatment of artemia cysts. Avoidance of over-feeding and increased water exchange may also help to minimize the incidence of fouling. Chemical treatments against fouling organisms are not generally recommended.

Brackish Water Prawn Culture:

Introduction:

Many of the management practices described above are also applicable to brackish water prawn culture practices.

Apart from *M. rosenbergii*, *Penaeus monodon* is another important culturable prawn species which is hardy, fast growing that can tolerate wide ranges of temperature and salinity changes. It subsists on both vegetable as well as on animal matters.

In spite of the increasing importance of prawn aquaculture, differences in the productivity of prawn farms are poorly understood. Water temperature, mortality and pond age significantly affect growth rates of *P. monodon*. Amongst these, temperature affects the growth rate of the prawn at different stages of its life-history. The optimum growth has been observed at 27–33 °C. Growth is slow at lower temperatures and at 18°C it is only 14% of the optimum rate. Traditional pond management, together with gradual improvements in husbandry techniques, particularly feed management, are responsible for such types of changes. It has been observed at Honduran shrimp farms that most seasonal variations in yield are caused by temperature. A regular exchange between tidal water and pond water is done to maintain optimum temperature required for the prawn growth. Apart from temperature, salinity is also known to influence the growth rate of *P. monodon*, although the exact nature of the relationship is not understood. A range of 15–25‰ is ideal for this species. However, different species of *Penaeus* can tolerate different concentrations of salinity (4 ppt. {tolerated by *P. indicus*} to 25 ppt {tolerated by *P. styliifera*}).

Similarly, the impact of other water quality parameters (e.g. dissolved oxygen, pH) on pond productivity has not yet been properly defined. Stocking density also affects the growth rates of prawns, both in culture as well as in natural systems. Depression in growth rate of *P. vannamei* has been noticed in coastal lagoons when its density was above 2.5 m⁻². However, the degree of density-dependence also depends on certain other parameters of the culture management, like water quality, water exchange rates and feeding rates etc.

Major collapses in prawn/shrimp aquaculture have been noticed in Taiwan, the Philippines and China, with severe disease problems in Thailand and the US. These calamities have been caused by bacterial and viral diseases aggravated by high stocking density at farms and increasing intensity of production. Gradually deteriorating pond basin conditions partially contribute to reduced productivity with each successive crop.

Brackish water pond management:

Diverse types of bottoms are needed for different species of prawns. Generally, shallow, muddy, tender basins with plenty of organic detritus and different types of food items are required for prawn culture. Certain species (e.g. *P. duorarum*, *P. japonicus*, and *P. indicus*) prefer sandy basin conditions. The water should be free from pollutants and regularly purified by exchanging the water with fresh, well oxygenated seawater to prevent mortality and stunted growth. Presence of sufficient quantity of calcium in the pond soil helps for quick growth and regular moulting of the prawn. To prevent silting of prawn pond, routine annual dredging operation is suggested. Silt level should be maintained below 20 cm so that growth of food organisms is not affected.

To prevent dyke erosion, plantation of marginal weeds (e.g. long stalked grasses) should be encouraged. These weed also help in productions of diatoms and accumulation of planktons. Often these weed provide hiding place for the moulting prawns.

The pH and dissolved oxygen concentration of the brackish water pond for *P. monodon* should range between 8.2 to 8.4 and 8 to 9 respectively. Abrupt changes in salinity (e.g. due to heavy rain) should always be avoided by letting out the pond water and refilling with tidal waters. To compensate the loss of nutrients and preventing the rapid fluctuation in salinity, pH and dissolved oxygen concentration, the pond should be frequently flushed with fresh high tide waters.

In an ideal brackish water pond, the natural food available is sufficient for the growing prawns for the first two months. Subsequently, any shortfall in the availability of natural feed is supplemented by artificial feeding (@ 2% of the weight). Slaughter house wastes, molluscan and trash finfish meat has been considered to be ideal for supplementary feeding.

It is one of the good management practices to monitor certain other water quality parameters such as pH, temperature and dissolved oxygen routinely, so that production rates can be linked with the environment of each pond and its management practices.

After one year of rearing, the prawns in brackish water ponds easily attain 25 to 27 cm in length and 140 to 160 gm in weight. However, there is always a danger of total loss of stock due to several adverse conditions, often beyond the control of the farmers. Hence to avoid these inherent disadvantages of long-term prawn culture, short-term crop after three months stocking may be suggested. However, bigger the size of the catch, higher is the price.

The methods of harvesting are more or less identical to those already described above. Complete harvesting is possible only after complete drainage of the pond. Also it is easy to collect the catch after dewatering the pond. Partial catching (applied mostly to smaller ponds) is however possible by netting or trapping. Netting is effective in post winter months. Trapping operations using a stretched net fitted at the area of sluice opening and lifted periodically are quite effective for collecting the produce. It is a matter of great concern that due to high price of prawn and ready export market, there is a tremendous pressure for catching large quantities of prawn from the coastal waters. As a result the total catches of prawns has come down in the past years and in some areas small and undersized prawn are caught in large numbers.

Harvesting:

The produce:

Farmed prawns are better than the wild-caught. Good quality harvested prawns have a greenish or bluish tint with bright blue or orange chelipeds (claws). Harvesting of prawn can be identical to seining (approx. ½” mesh size: the mesh size should however be decided

before harvesting) provided the pond is free from obstruction. Once the prawn are collected after harvesting, the larger specimens are sorted out with a bar grader and also by hand picking. Smaller specimens should be returned to the water for continuation of rearing. Removal of large blue claw prawns allows other prawns to grow to a larger size. A substrate in the holding tanks should be provided to keep the harvested prawns alive as the prawns can seek refuge from their hostile companion. Prawn jump considerable distance; hence a cover should be placed over the holding tank. Prawns cannot survive out of water for more than a few minutes.

Methods of harvesting:

Harvesting can be made either by culling (sometimes called cull-harvesting) or draining (drain-harvesting). The time to harvest depends on the growth rate, size of specimen being caught and the pond management technique applied. Cull harvesting is used to harvest market-sized prawns from the pond at regular intervals and removes the faster growing specimens. The rest of the prawns are harvested when the ponds are drained at the end of the culture period. In tropical ponds, cull harvesting usually starts 5-7 months after PL have been stocked, or sooner if juveniles have been stocked. The market-sized specimens are removed for selling. The smaller ones and soft-shelled individuals are retained in the pond for further growth. After about 8-11 months, ponds are drained and the entire catch is sold. After drain harvesting, the pond can again be prepared, refilled and restocked immediately, or be kept empty until sufficient water is available again for rearing.

Cull harvesting is not very efficient in removing harvest-sized prawns. It does not maximize the total quantity of marketable prawns, which could be achieved, partly because some marketable animals remain in the pond longer than necessary and partly because the smaller prawns do not get the maximum chance to grow faster than they would have, if dominant prawns continued to be present. Theoretically, the best way would be to harvest is, to empty the pond totally and remove all the dominant animals, and restock the others in the same and/or different ponds. However, cull harvesting, followed by total drain harvesting before re-stocking with a new batch, is perhaps the best management practice for small freshwater prawn farms. All harvesting operations should be practised in the early morning hours when atmosphere is cooler and low water levels do not harm the pond inhabitants due to direct exposure to the sun. The method and efficiency of drain harvesting depends on the design of the pond. Like any other method, speed of harvesting operation is important. The pond water level can be lowered during the night before commencing harvesting.

Post-harvesting care of the catch:

For selling of live prawn, clean and well-aerated water is essential for keeping them in peak condition (Martinique). The value of the harvested products depends on their quality. Quick chilling with ice and transfer of the catch to cooler place prevent physical damage and helps in getting good price. Prawns should not be allowed to die from asphyxia by leaving them out of water. Mud collected with the harvested prawns may cause microbial contamination. Live prawns should not be transferred straight onto ice because this may result in a slow decline in body temperature. It causes stress, and accelerates the deterioration process, which occurs after death. For live sale, prawn should immediately be washed in clean water and killed in a mixture of water and ice at 0°C. Subsequently, the catch should be washed in chlorinated water (5 ppm active chlorine). After their death, the prawns should be removed from the cold water and immediately placed in isothermal boxes, with alternate layers of ice and prawns, placing ice (made with chlorinated water) in the first and last layers. They can then be refrigerated at 0°C for short-term on-farm storage for sale as fresh prawns or for transport to market or processing facilities (-10°C is not necessary and is much more

expensive in terms of equipment and running costs). Prawns should not be refrigerated at 0°C for more than 3 to 5 days. It is advised not to use large blocks of ice for storage or transport on ice because they will damage the prawns: use flaked or crushed ice.

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