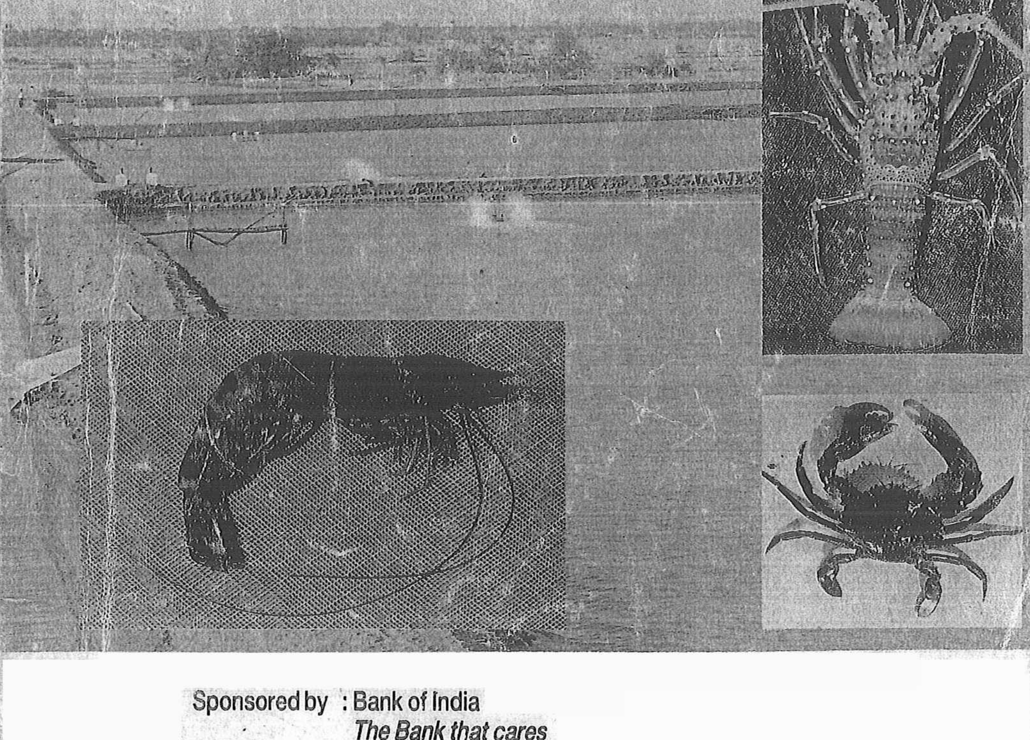
Handbook on Aquafarming

SHRIMPS LOBSTERS MUD CRABS



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Part I

SHRIMPS

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SHRIMPS

1.1 Introduction

Among edible crustaceans (shelled organisms) shrimp is considered as a highly valuable commodity. The great economic use of this resource for domestic and export purposes has led to over exploitation of most of the major shrimp stocks of the world. According to World Fishery Statistics, the global shrimp production, showing a rather slow annual growth rate of 4.5 to 10% during 1981-87 period, has been stagnating at about 2.5 million tonnes per year during 1988-90 period. The Indian ocean accounts for an average of about 3.6 lakh tonnes (17%) annually, of which nearly 65% comes from the Eastern region. While the fishery of this region showed an upward trend during the past few years mainly due to increased landings in Indonesia, Bangladesh and East coast of India, the fishery of Western Indian Ocean remained more or less steady at about 2.3 lakh tonnes. From the present level of shrimp production against the effort input it is universally believed that further increase in production of this resource from the conventional shrimp grounds is not possible to any appreciable extent. This being the case, development of deep-sea shrimping and aquaculture of shrimp has been given considerable stress as alternate means of augmenting production through out the world.

In shrimp farming, considerable progress has been achieved in many of the south eastern countries in recent years, which are leading in shrimp production through aquaculture. At present, over 50 countries undertake shrimp farming on commercial scale and produced an estimated quantity of 6.3 lakh tonnes of shrimp in 1990, 7.3 lakh in 1991 and 7.2 lakh in 1992. Farm raised shrimp accounted for 2.1% of the total prawn landings of the world in 1981 which by 1989 rose to 26% and in 1991-92 period to 28%. China, Indonesia, Thailand, Ecuador are the leading countries in shrimp production through aquaculture. China produced the maximum quantity till 1991 when an estimated amount of 1.45 lakh tonnes was realised. Thailand, which occupied the third rank in 1991 with 1.10 lakh tonne of cultured shrimp, came up as the leading country in 1992 with an estimated shrimp production of 1.5 lakh tonnes relegating China to the second place.

In India, with the development of an organised export industry for the seafoods coupled with the technological advancement for directed fishing for shrimps, exploitation of shrimps in the traditional as well as extended fishing grounds has increased considerably over the past two-three decades. This has considerably increased the shrimp production and consequently the export earnings from shrimp products which continue to be the mainstay of the marine products exported from the country. A perusal of the statistics of shrimp production in India for the past ten years (1981-90) would reveal an average annual production of 1.95 lakh tonnes. The annual shrimp landing ranged from 1.45 lakh tonnes in 1981 to 2.44 lakh tonnes in 1990, showing a gradual increasing trend over the years although the landings declined marginally in some of the years. About 85% of the catch was obtained from the west coast and the rest only from the East coast. According to the recent report on revalidation of the potential marine fishery resources of Indian EEZ, it is estimated that the potential shrimp resource in the EEZ is only about 2.4 lakh tonnes. It is evident that shrimp fishing in Indian coast has considerably exceeded the potential stock available on the shelf waters. The exploratory surveys conducted in the deeper waters along Indian coast during the past few years have revealed the existence of limited resources of deep-sea prawns beyond the presently exploited fishing zone, especially between 200 and 400 meters depth along the south west coast. The potential stock of this untapped resource is estimated to be about 5000 tonnes, which offers scope for commercial exploitation.

The dwindling catch returns of shrimps in the conventional shrimp grounds of Indian coast has caused serious concern to the fishing industry. In order to step up shrimp production, various organizations in the country have initiated efforts to develop appropriate technologies for shrimp farming during the past two decades, and as a result of this, the prawn farming has taken roots in the country now. Encouraged by several promotional programmes offered by Government Agencies and Financiers and the techno-economic viability of commercial shrimp farming demonstrated by the research and development organizations in the country, several entrepreneurs have stepped into this field and are prospering in this relatively new area of shrimp production.

Shrimp farming the country can be seen to have undergone tremendous change from the age-old traditional shrimp filtration practices to the highly advanced scientific farming with considerably high production rates. At present India ranks 5th among the countries producing shrimp, through aquaculture in the world, with an estimated annual production of about 45,000 tonnes (1992). According to a recent survey, about 70000 hectare of brackish water area is brought under shrimp cultivation out of the total cultivable area of nearly 1.2 million hectares available in the country. The state wise details of total brackish water area available and the area at present used for aquaculture are shown in Table 1 together with the production figures of cultured shrimp.

It is thus evident that we have to go a long way in reaching, the level of many of the advanced countries with regard to shrimp production through farming, with the vast cultivable areas available for shrimp farming.

1.2 Resources

The shrimp fishery of India is spread over the entire coastline, and extending up to a depth of about 80 m. Fishing beyond 50 m depth is carried out mainly by large trawlers about 20 m OAL. Several types of gears (fixed bag nets, seines, bottom-set gill nets etc.) operated in the traditional sector by motorised and non - motorised country crafts and bottom trawls operated by small land medium sized mechanised boats are engaged in this fishing. Shrimp fishing extends almost throughout the year on most of the regions of the Indian coast except for a short period of off season during the monsoon period. In Kerala, however, peak shrimp fishing takes place during the south west monsoon period especially by trawlers at the major centres like Cochin and Sakthikulangara.

Table I. Statewise details of total brackishwater areas, area under culture and production

State	Estimated Brackish water area (ha)	Area under Culture (as on March 1992)	Estimated Production (April 91- March 92)	Percentage of Production
West Bengal	4,05,000	33,918	13,800	34.50
Orissa	31,600	7,417	3,800	9.50
Andhra Pradesh	1,50,000	8,100	9,700	24.25
Tamil Nadu	56,000	480	700	1.75
Kerala	65,000	13,145	9,500	23.75
Pondicherry	800	Neg.	Neg.	-
Karnataka	8,000	2,542	1,100	2.75
Goa	18,500	525	300	0.75
Maharashtra	80,000	1,869	930	2.32
Gujarat	3,76,000	231	170	0.43
Total	11,90,900	68,232	40,000	100.00

Out of the average shrimp production of 1.95 lakh tonnes about 40% is accounted by the traditional sector and the rest 60% by trawlers.

In the total shrimp landings about 65% is recorded in Kerala and Maharashtra alone. Among the other maritime states, Gujarat, Andhra Pradesh and Tamil Nadu together contribute about 27.7%, Karnataka, Orissa and West Bengal 6.5% and Goa, Pondicherry and Andamans 2.6%

Two categories of shrimp, namely penaeid and non-penaeid, support the fishery. From the export point of view the penaeid shrimp are more important than the non-penaeid shrimp on account of their larger sizes and high unit value. The important species contributing to the fishery are *Solenocera crassicornis, Penaeus indicus, P. merguiensis, P. monodon, P. semisulcatus, P. canaliculatus, Metapenaeus dobsoni, M. affinis, M. monoceros, M. brevicornis, M.kutchensis, Parapenaeopsis stylifera, P. hardwickii, P, sculptilis, Acetes indicus, Nematopalaemon tenuipes, Exopalaemon styliferus* and *Exhippolysmata ensirostris.* The penaeids account for an average of about 65% and non-penaeids 35% in the total fishery. The trawl fishery is mainly supported by penaeid shrimp (92%). The important species constituting the trawl catches are *S.crassicornis, M.kutchensis, P.stylifera* and *P. hardwickii* on the Gujarat coast, *M.affinis, M.monoceros, P. stylifera, P.hardwickii* and *P. sculptilis* on the Maharashtra coast. *M. monoceros, M. affinis P. merguiensis* and *M. dobsoni* on the Goa and North Karnataka coast, *P.stylifera, M.dobsoni, P. indicus, M.monoceros* and *M.affinis* on the southeast coast, *P.indicus, P.semisulcatus* and *M.dobsoni* on the south west coast, *M.monoceros, M.dobsoni, P.stylifera, M.brevicornis, P.indicus, P.monodon* and *M. affinis* on the Andhra coast and *M.monoceros, P.indicus, P.monodon, P.merguiensis* and *P. hardwickii* on the northeast coast. The fishery of indigenous gears is also multispecies in character, constituted by both the penaeid as well as nonpenaeid prawns. The fixed bag nets (dol nets) operating in the inshore waters of Gujarat and Maharashtra register the bulk of nonpenaeid landings in the country (70-75%) of which about three fourth is constituted by Acetes spp. Among the penaeids encountered in the indigenous gears, the most dominant are *M.kutchensis, M.dobsoni, P.stylifera and P. indicus* on the southwest coast and *P.indicus,M.dobsoni, M.monoceros, M.brevicornis and P. monodon* on the east coast. Among nonpenaeids, besides Acetes spp. N.tenuipes and E. ensirostris contribute substantially to the landings of dol nets on the Bombay Saurashtra coasts and *E.styliferus* on the coast of West Bengal.

Besides the conventional prawn fishery, commercially exploitable stocks of deep sea prawns are also known to exist in certain regions like the Kerala coast at depths between 200 and 400 m., Regular exploitation of these resources with the help of large trawlers will go a long way in increasing our shrimp production.

Prawn fisheries of considerable magnitude also exist in the inland waters such as rivers, creeks, bays, mangrove swamps, lagoons, estuaries and back waters. The adult population of the giant freshwater prawn Macrobrachium rosenbergii and the river prawn *M.malcolmsonii* are fished extensively from the rivers and estuaries. The Hoogly-Matlah estuarine system, Chilka lake, Godavery estuary, Kakinada back waters, Pulicat lake, Ashtamudi lake, Cochin backwaters and the Rann of Kutch support lucrative fisheries for juvenile penaeid prawns. It is estimated that about 20-25 thousand tonnes of juvenile prawns are exploited every year from the brackishwater systems in the country.

Though the Indian shrimp fishery is supported by several species belonging to the penaeid and non-penaeid categories, only a few of them belonging to Genus Penaeus (Family Penaeidae) are important for aquaculture purpose on account of their large size and other favourable qualities which make them ideal candidates for farming. the important species which can be considered for aquaculture in India are *P. indicus, P. monodon, P. merguiensis, P. semisulcatus, P. japonicus, P. canaliculatus and P. latisulacatus.* These species have the following morphological features in common which are characteristic of the genus:

Body entirely smooth; rostrum well developed, toothed dorsally and ventrally; carapace without longitudinal and transverse sutures; telson with deep median groove, without fixed (immovable) lateral spines, exopods present on first 4 pereopods (walking legs).

In order to identify the different species, a knowledge of certain morphological characters is essential. These characters are shown in fig. 1 and 2.

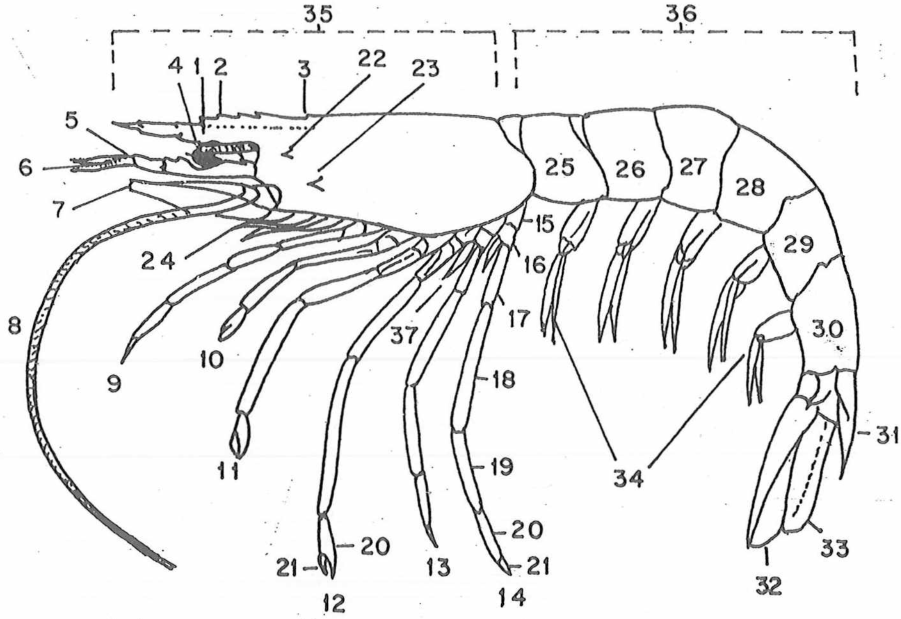


Fig 1. Diagramatic drawing of a prawn to illustrate its taxonomic characters. 1. Rostrum, 2. Rostral spines, 3. Epigastric spine, 4. Eye 5. Antennule, 6. Antennular fragella, 7. Antennal scale, 8. Antennal flagellum, 9. Third maxilliped, 10-14. 1st to 5th pereopods, 15. Coxa, 16. Basis, 17. Ischium, 18. Merus, 19. Carpus, 20. Propodus, 21. Dactylus, 22. Post-orbital spine, 23. Hepatic spine, 24. Pterygostomian spine, 25-30. 1st-6th abdominal somites, 31. Telson, 32. Exopod of the uropod, 33. Endopod of the uropod, 34. Pleopods, 35. Carapace, 36. Abdomen, 37. Exopodite.

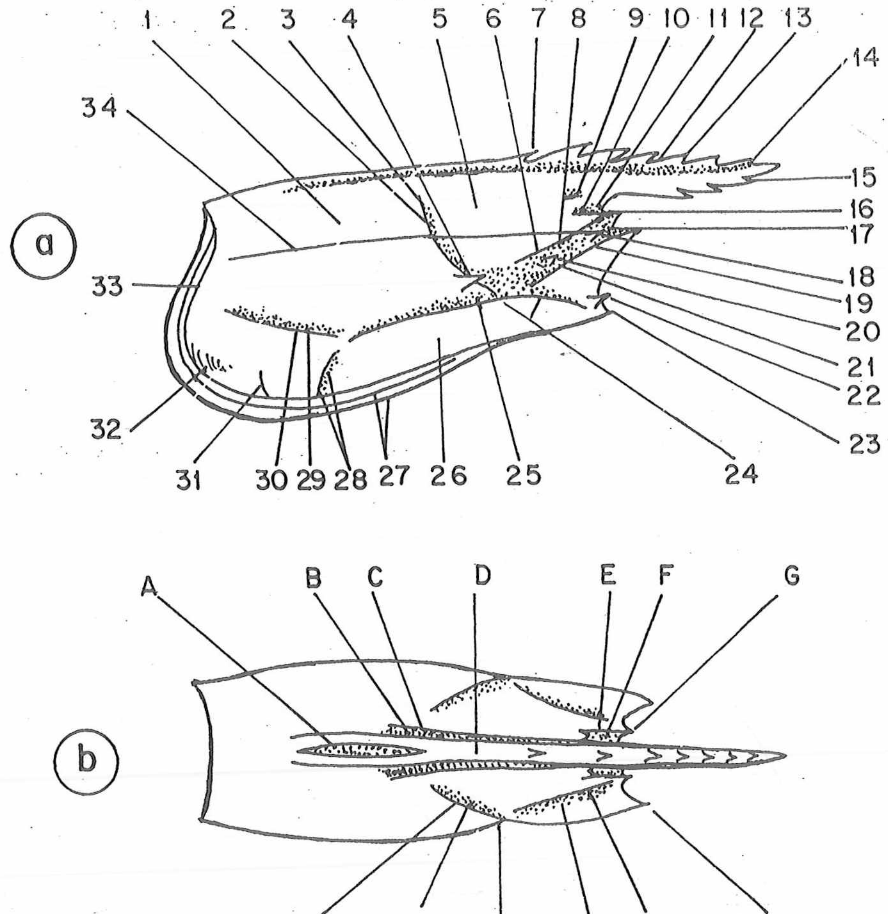


Fig.2. (a) Diagramatic representation of carapace to show features of taxonomic importance. 1. Cardiac region, 2. Cervical carina, 3. Cervical sulcus, 4. Hepatic spine, 5. Gastric region, 6. Gastro-orbital carina, 7. Epigastric spine, 8. Orbito antennal sulcus, 9. Postocular sulcus, 10. Gastrofrontal sulcus, 11. Gastrofrontal carina, 12. Adrostral carina, 13. Adrostral sulcus, 14. Rostral tooth, 15. Ventral rostral tooth, 16. Orbital or supra-orbital spine, 17. Antennal spine, 18. Postorbital spine, 19. Antennal carina, 20. Post antennal spine, 21. Orbito-antennal sulcus, 22. Branchiostegal spine, 23. Pterygostomian spine, 24. Hepatic carina, 25. Hepatic sulcus, 26. Pterygostomian region, 27. Marginal region, 28. Inferior carina and sulcus, 29. Branchiocardiac, 30. Branchiocardiac sulcus, 31. Transverse suture, 32. Stridulating organ, 33. Pterygostomian sulcus, 34. Longitudinal suture.

Fig. 2.(b) A. Postrostral or median sulcus, B. Adrostral sulcus, C. Adrostral carina, D. Postrostral carina, E. Gastrofrontal carina, F. Gastrofrontal sulcus, H. Antennal spine, I. Gastro orbital carina, J. Orbito-antennal sulcus, K. Hepatic spine, L. Cervical sulcus, M. Cervical carina

Key to cultivable species of genus *Penaeus*

1.	Rostrum with 1-3 ventral teeth	2
	Rostrum with more than 3 ventral teeth, hepatic carina absent	6
2.	Rostrum with 2 or 3 ventral teeth; adrostral carina not reaching beyond the middle of carapace	3
	Rostrum with 1 ventral tooth; adrostral carina reaching almost to posterior border of carapace	4
3.	Hepatic carina horizontally straight; 5th pereopod without expodite; white and brown vertical bands on the body	*P. monodon*
	Hepatic carina oblique antero-vertrally; 5th pereopod with small expodite; white and greenish brown vertical bands on the body	*P. semisulcatus*
4.	Telson with movable lateral spinules	5
	Telson without movable lateral spinules; body with yellow and brown cross bands	*P. canaliculatus*
5.	Body with yellow and brown cross bands	*P. japonicus*
	Body without coloured cross bands	*P. latisulcatus*
6.	Gastro-orbital carina occupying the posterior $^2/_3$ distance between hepatic spine and orbital angle; rostral crest only foobly elevated	*P. indicus*
	Gastro-orbital carina occupying the middle $^1/_3$ distance between hepatic spine and orbital angle; rostral crest elevated to form a triangular shape	*P. merguiensis*

1.3 Biology of important cultivable species

All the penaeid prawns are basically marine. They are distributed throughout the Indian coasts at all depths on the continental shelf and beyond. These species breed in the sea when they are about 6 to 8 months old in different depth zones depending on species. Most of the species are continuous breeders with definite peak periods of breeding which vary from coast to coast. The eggs after spawning undergo a brief period of embryonic development and hatch out as a small nauplii. This larval stage passes through other stages such as protozoa and mysis and completes the larval metamorphosis in the sea. The mysis further transforms into the various post larval stages and then to juveniles in the sea or in the adjoining estuaries and backwaters which are used as nursery ground by some of the estuary dependent species. Around attainment of maturity the prawn returns to the sea for breeding (Fig 3). The growth is rapid in the initial period of life and the animal becomes mature only in the marine condition. Almost all the species live for about 2 years.

Penaeus indicus (Fig. 4)

Popularly known as the 'Indian white prawn', this species has a distribution extending from Goa downwards to Cape Comorin on the west coast and throughout the east coast. Supports a fishery of considerable magnitude in the inshore waters of Kerala, Tamil Nadu and Andhra Pradesh. It is estimated that about 10000t of this species is caught annually from the sea along the Indian coast. It grows to a maximum size of 230mm in total length; Juveniles upto about 130mm are caught in abundance in estuaries and backwaters of both coasts of India. This is an important estuary dependent species highly suited for brackishwater culture.

This prawn attains sexual maturity when it is about 130mm size and breeds many times in its life time. Spawning takes place in comparatively deeper waters (30 to 50 metres) with peak spawning activities during October-December and May-June in the south west coast, February-May and October-November in the south east coast and February-March, May-June and November-December in north east coast. Fecundity ranges between 68000 to 731000.

Penaeus monodon (Fig. 5)

Commonly known as Jumbo tiger prawn, this is the largest known marine prawn in the world which attains a maximum size of 365 mm (440 g in weight). Though found throughout the Indian coasts, it occures in maximum abundance along the north east coast of India. Being an estuary dependent species, juveniles and subadults are abundantly available in estuaries, backwaters and mangrove areas. This species can tolerate comparatively very low salinity conditions than other species of the same genus. The estimated landing of this species amounts to about 900 t per year of which nearly 600 t is caught from the coasts of Andhra Pradesh and Orissa. Juveniles are caught on commercial scale in Chilka lake, Pulicat lake and Hoogly Matla estuarine system,. It is the most highly preferred species for aquaculture purpose due to its large size and adaptability to highly varying salinity conditions.

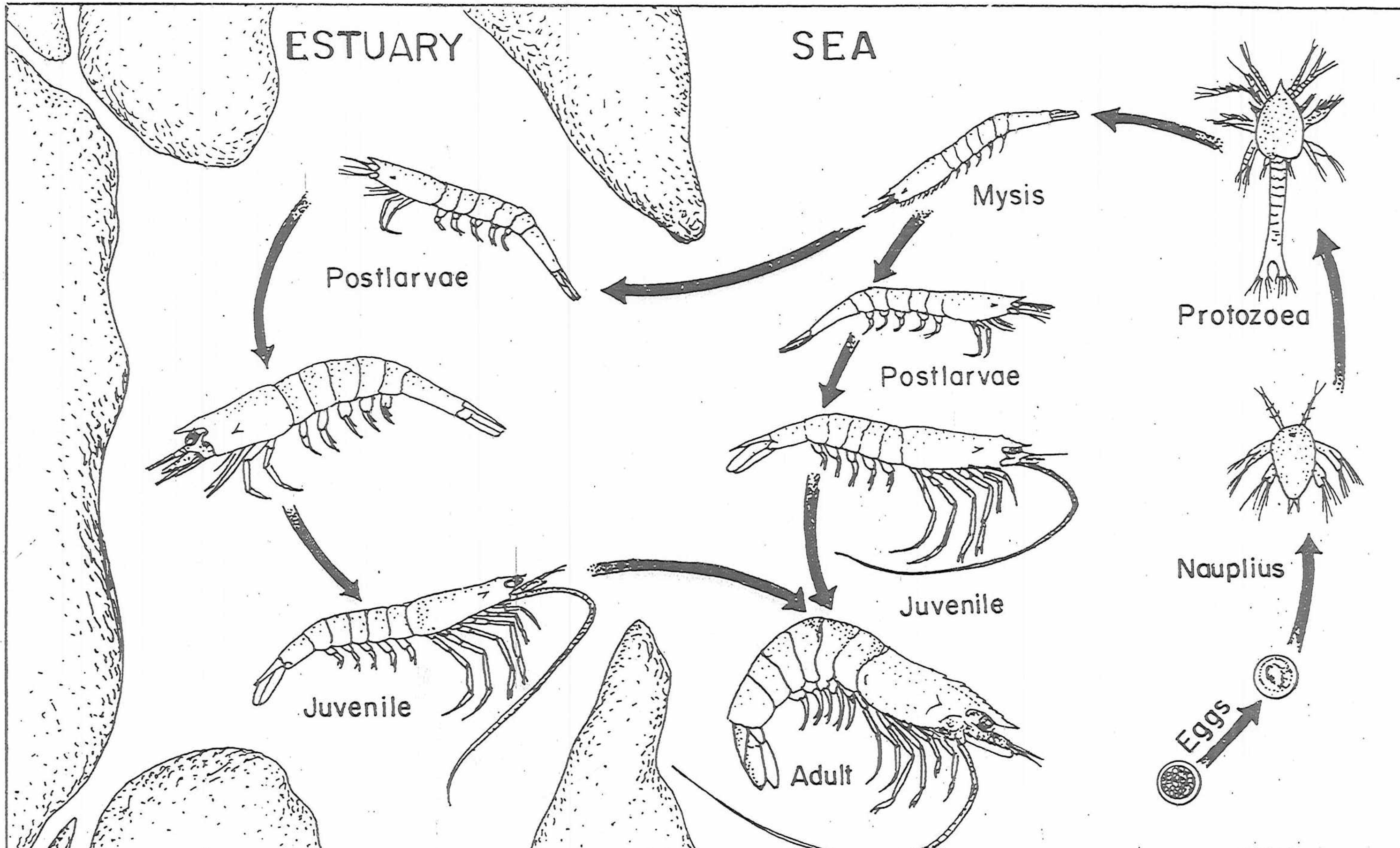
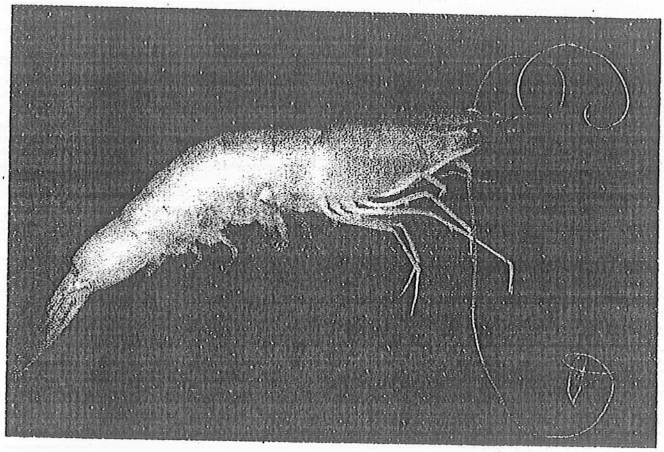
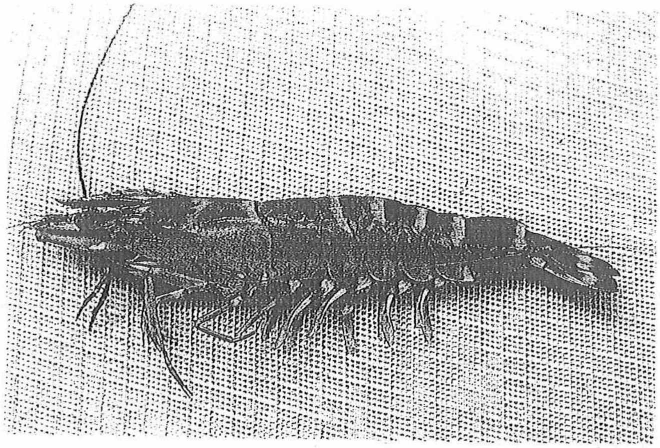


Fig.3. Life cycle of penaeid prawns.

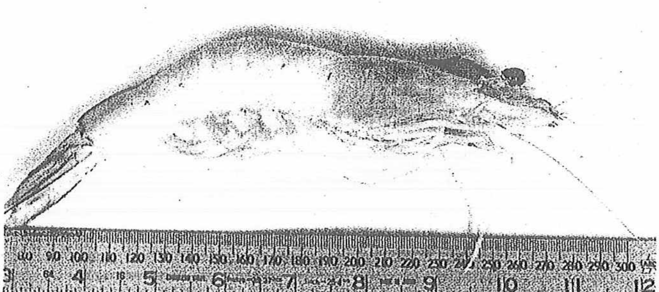
Penaeus indicus



Penaeus monodon



Penaeus merguiensis



The prawn attains maturity when it is about 200 mm in size. Spawning takes place at depths between 30 and 60 meters with peak spawning activities during October - January and march - April in the north east coast. Each prawn produces about 2 to 19 lakh eggs in each spawning at a size range of 200-260 mm.

Penaeus semisulcatus

Known as "Green tiger prawn", this species grows to a maximum size of 280 mm. It is found in maximum abundance in the Gulf of manner and Palk Bay area of south east coast. Minor fishery also exist in Gujarat, Kerala and Andhra Pradesh. Annually about 8000 t of this species are caught of which, over 7000 t are landed in the Tamil Nadu coast alone. Being predominantly a marine prawn, juveniles are not generally abundant in estuarine area. In the sea the juvenile prawns prefer shallow coastal waters having luxuriant growth of sea grass. It is most active during night time.

This prawn matures when the it is about 130 mm. Breeds almost throughout the year in the Palk Bay and Gulf of manner region. Peak spawning is observed during December-March in Tamil Nadu coast. Fecundity ranges between 52000 and 660,000 eggs.

P. merguinensis (Fig. 6)

Popularly known as "Banana prawn", this species enjoys a restricted and discontinuous distribution along the Indian coasts, of south Maharashtra, Goa, North Karnataka on the West coast and Andhra Pradesh and Orissa on the east coast. It grows to a maximum size of 240 mm in size. At accounts about 1300 t in the total marine shrimp catch of the country with maximum landing in Andhra Pradesh, Maharashtra and Goa. It is also an estuary dependent species, the juveniles growing faster in the brackishwater environment.

The prawn attains maturity at about 140 mm in total length. It breeds most actively during October - January on the north east coast and produces about to 4.5 lakh eggs in each spawning.

Penaeus Japonicus

This is the well known Japanese species the 'Kuruma shrimp'. It is found occasionally in fairly large quantities in the Maharashtra and Tamil Nadu coast. In Maharashtra about 500 t of this species is caught annually by trawlers. It grows to a maximum size of about 270 mm length and is known to inhabit mostly the marine environment where it prefers sandy bottom within 50 m depth. This species is most active during night. Juveniles are caught in small quantities occasionally in the estuaries of Tamil Nadu and Karnataka.

The size at first maturity is around 150 mm when it is about 10 months old. Peak spawning is observed during July-September in Bombay waters.

Penaeus canaliculatus

Commonly known as 'Witch prawn' this species is one of the large growing one attaining a maximum size of 225 mm in length. It inhabits the coastal waters up to about 60 m and contributes to a minor fishery in Kerala coast where an estimated quantity of nearly 400 t is landed annually by trawlers. It is one of the highly priced shrimp for export under IQF packing. This is also one of the nocturnal species mainly caught by night trawling. This is very rarely encountered in the estuarine environment and is considered to be a candidate species for sea farming.

Peak breeding takes place during October December in Kerala coast at a depth of 40 to 60 meters.

Penaeus latisulcatus

Commonly known as 'King prawn' this species grows to a maximum size of 200 mm and supports a minor fishery in the Tuticorin region of Tamil Nadu coast. It is estimated that about 200 t of this species are landed annually along the Tamil Nadu coast. This is also a purely marine species, rarely encountered in estuarine areas during early part of their life. Most active during night.

Females attain maturity when they are about 125 mm in total length and produce about 100000 to 650000 eggs in each spawning.

Brood stock

In regions where non-native species are farmed or seed requirement is improportionate to local spawner availability, maintaining brood stock in captivity is inevitable. This ensures supply of seed through out the year. Spawners are usually obtained from wild.

Method of collection: While spawners are obtained from trawl catches, the towing time of trawl may be limited to 30 minutes to avoid congestion stress which leads to ovary resorption and low spawning rate. Tangle nets and traps yield spawners in good condition. Bottom- set trammel nets when lifted frequently, bring spawners in good conditions. Animals caught in the forenoon and brought to hatcheries before dusk give better results.

Transportation: Spawner can be transported from the collection site by keeping them individually perforated plastic or PVC cylinders capped on both sides with pieces of netting. During transit, the containers are oxygenated by oxygen or compressed air. Good quality water is an essential requirement for spawner transportation. For short distances tanks or bins are well suited for this purpose.

During long distance transportation, tips of rostrum and telson may be banded or capped with protective rubber tubes and transported in plastic bags filled with water and oxygen (1:1). This is to avoid physical damage to spawners and bag.

Temperature can be controlled by keeping small ice bags alongside the plastic containers and keeping inside the bins / tanks. Metabolite accumulation in the medium can be delayed by starving the animals for few hours before packing for transport. Spawner transportation, particularly by air, by adopting chilled saw dust method is not advisable to any of the currently cultured species in India. *P. monodon* cannot tolerate a temperature below 12°C and *P.semisulcatus* cannot withstand exposure for long.

Quarantine : Immediately on arrival in the hatchery, the spawners may be given a dilute formalin treatment dip (200-400 ppm for 1-2 hours and then rinse). This prevents introduction of epifauna into the hatchery.

Farm reared spawners: It is grown in a pond near the hatchery at low density between 0.5-1/m^2. The pond should be so designed that easy harvest without stress, high water quality maintenance and the depth of 1-1.5 m for the water be ensured. In the subtropical regions during pronounced winter, shrimp from the previous harvest may be allowed to grow in the pond under glass house coverings to maintain a higher temperature which would accelerate maturation process.

Maturation in captivity: Responses to maturation methods among penaeid prawns are different and among individuals of same species itself it is erratic. It has therefore become essential to induce mother prawn to mature under controlled condition by unilateral eye-stalk ablation or environmental manipulation. Adult females of appropriate size (in weight) obtained from culture ponds or from the nature are used for this purpose. Gravid females caught from wild, after initial spawning are also induced by eyestalk ablation to spawn 5 to 6 times when they are kept along with adult males at 1:1 ratio.

Indoor facilities are more preferable for maturation purpose than outdoor as temperature, light intensity, and photo period could be easily controlled in indoor tanks. In sheltered calm sites large pens can be erected and males and eye ablated females at equal ratio are stocked at the rate of 0.5-1.5 N/m2. The animals should be fed with mussels and clams.

Most indoor systems use circular tanks made of fibreglass, plastic, or cement and stocked with shrimp at the rate of 5 to 10/m^2, with a water depth ranging 0.5 - 1m. Ideal temperature is 28-29°C and salinity 30-35%. Flow through unpolluted water system is ideal and to restrict high water demand, recirculation system can be resorted to. This system helps to retain higher temperature in region beyond tropics. Better results are obtained when sand substrata is provided in the maturation tanks. In all cases, special attention is to be given to feeding rate and feeding schedule, and minimising disturbances. Always pH of the water has to be maintained between 8.1 and 8.3

Artificial insemination is advisable in the case of females not impregnated. In the prawns with open thelycum, only sperm mass is applied to the thelycum before each spawn, while in those with closed thelycum, as in the case of *P.monodon*, the whole spermatophore is squeezed out of male mechanically and transferred to the female's thelycum immediately after moulting.

1.4 Prawn seed resources

One of the essential inputs required for successful prawn culture is the availability and the timely supply of prawn seed for stocking in the ponds. In nature, larvae, postlarvae and juveniles of different species of prawns occur throughout the year in the inshore waters and in the estuaries and backwaters. However, their abundance varies from place to place, from season to season and from year to year depending on the spawning season of adult prawns, spawning intensity, survival of eggs and larvae and the ecological variations. Reliable data on quantitative and qualitative estimation of seed resources and their availability in space and time in different regions of the country are lacking except for a few centres. Such information particularly on the species selected for culture, is of vital importance for initiating large scale intensive culture. The prawn seed collected from wild is often a mixture of desirable and undesirable species. Hence the seed collected from natural sources like estuaries and backwaters should be sorted out before stocking in nurseries or farm ponds.

1.5 Shrimp Farming

1.5.1 Farming methods

Shrimp farming refers to the culture of baby prawns in an enclosed water body adopting selective stocking and scientific pond management. Ponds with varying shapes and sizes are used for farming in different parts of the world. Currently practiced shrimp farming can be broadly classified as traditional, extensive, semi-intensive and intensive, based on the stocking rate and farm management.

Traditional shrimp farming in India is practiced in West Bengal, Kerala, Karnataka, Goa and Maharashtra. In this system, the incoming tides are allowed to enter the pond through a sluice gate. The young ones of shrimps along with fishes etc. brought by the tide are auto-stocked in these farms and allowed to grow for 30-35 days, and harvested periodically. Here, there is no control over the species specificity, quantity and predators which results in unpredictable low production (200-700 kg/ha/season).

Extensive farming is an improved traditional system and is considered as a simple culture method. Either traditional ponds are converted or new ponds of 1-5 ha are constructed. Water management is by tidal fluctuations or by pumping or both. Contrary to the traditional system, here selective stocking of desired species, either collected from the wild of from hatchery are stocked at a rate of 50,000 to 1 lakh/ha depending on the species. Supplementary feeding is done as per requirement. Production varies from 1-1.5 ton/ha/crop.

In semi-intensive system, ponds of 0.2 to 2.0 ha are used. Water depth is maintained between 0.8-1.5 m. Water exchange is done to a level of 20-50% /day. Generally a nursery phase is also included. Stocking rate is high, from 1 to 3 lakh/ha depending on the species. Very good aeration and suitable supplementary feed are provided. Production varies from 4-5 ton/ha/crop in 4-5 months.

In intensive system, ponds of 0.1 to 0.5 hectare (generally cement ponds of 0.03 to 0.1 ha) are used. Stocking rate is more than 3-10 lakh/ha. Very good water quality has to be maintained by upto 300% exchange daily. Vigorous aeration is provided by air blower/paddle wheels /agitators. High energy feed is used and the production is over 10 tons/ha/crop

"Super intensive" shrimp farming is in the trial stage globally. It calls for greater control environment, high energy feed, and round the clock monitoring. The period of diseases hang over this system as remedies are yet to come. So far intensive and super - intensive shrimp farming have achieved only marginal success in the long run.

1.5.2 Farming in India

In India shrimp farming is being carried out mostly in a traditional way. In recent years scientific shrimp farming is picking up fast in most of the maritime states. Generally the extensive and semi-intensive system are being followed. Important phases of farming are 1) site selection 2) pond construction 3) preparation of pond 4) stocking 5) pond management 6) diseases and 7) harvesting

Site selection

Of late shrimp farming is fast emerging as an industry, which is species and stocking density specific, site selection parameters are uncompromisable as sites are not be so easily manipulated. Similarly the genetic characters of culturable candidate species with reference to environment preference and tolerance range for best growth are marked and is different from one another, particularly in salinity and temperature. The above parameters, though range wide for a species, a sudden increase or decrease registers a shock to the animal which adversely tell on its growth. Therefore it is better to select a suitable site rather make it suitable.

Some of the most critical aspects that cannot be over looked while selecting of a site are climate, water, land elevation, soil quality, pollution, seed resources and proximity to market. The factors that influence the climate of a particular locality are temperature, rainfall, wind, evaporation and humidity and sunshine, which have to be thoroughly studied before selecting the site.

The site should be closer to any one main source of water supply such as sea, estuaries, creeks or back waters. It must be made sure that good quality water in abundance is within the cost effective reach round the year. Water quality being the most important one for farming, few essential physico-chemical parameters and their ideal ranges for best farming are given below:

Parameter	Range
Temperature (°C)	26-33
Salinity (ppt)	15-35
Transparency (cm)	25-60

Dissolved oxygen (ppm)	3-12
pH	7.5 to 8.7
Total ammonia (ppm)	less than 1.0
Free Ammonia (ppm)	less than 0.25
Nitrie (ppm)	less than 0.25
Hydrogen sulphide (ppm)	less than 0.25
Heavy metals	
Mercury	less than 0.0025
Copper (ppm)	less than 0.1
Iron (ppm)	less than 0.01
Zinc (ppm)	less than 0.25
Cadmium (ppm)	less than 0.15
Pesticides	
Malathion (ppb)	less than 0.0004
Parathion (ppb)	less than 0.001
Arzodin (ppb)	less than 0.01
Paraquet (ppb)	less than 0.01
Endosulfan (ppb)	less than 0.01
Butachlor (ppb)	less than 10.00

N.B. ppt = Parts per thousand; ppm = parts per million; ppb = parts per billion

Factors affecting water supply and drainage in the pond operation are site elevation and tidal amplitude. Low-lying areas will have drainage problems making pond preparation very difficult and high elevation may cause seepage and require extensive use of pumps. Sites with average elevation which can be watered and drained with ordinary high tides and low tides respectively would be the most ideal site. Sites for extensive ponds should be slightly above Maximum Low Water Level (MLWL), while for semi-intensive ponds sites should be between slightly above MLWL to slightly above MHWL but should not exceed 2 metres above MHWL.

As regards topography, flat, plain lands are preferred. Clayey loam type of soil which has low permeability is good for construction of pond. Soil which can be shaped into a ball without crumbling even after considerable handling will make good sites with minimum or no seepage. Loamy to sandy bottom is preferred for extensive farming. Whereas sandy clay loam to sandy loam is preferred for semi-intensive farm. Sandy and peaty soil, soil of acidic nature or soil which becomes acidic due to exposure to air should be avoided since it requires expensive treatment. Vegetations are a good indicator of soil property, elevation and salinity range. Dense vegetation and large trees may involve high cost for clearing. Climatic conditions such as rain fall, temperature, prevalent winds, rate of evaporation, seasons wave strength, currents, storms, possible floods are to be noted. Support facilities such as proximity of the site to roads, railways, airports, availability of seeds, electricity, power, drinking water, skilled labour, market will be of great benefits for farming activities.

After selection of site, a number of detailed investigation are to be carried out at the site. The different types of investigation and micro survey to be carried out include, geodetic survey, to fix the boundaries and levelling of the site for preparation of contour map. Detailed investigation regarding the tide is to be carried out at the water source. The micro level survey also includes details on hydrometeorological data, engineering properties of soil to delineate grain size distribution, co-efficient permeability, cohesion and shear strength, compaction and settlement properties etc. Biological assessment is also carried out to know the fauna and flora of the environment

Pond construction

The components of a shrimp farm consists of water control structures such as dikes, canals and sluice gates and support facilities such as pumps, aerators, generators, warehouses, farm houses, roads, bridges, workshops etc. Considering the size and type of the culture system, the farm is to be designed to include these components. The layout of the ponds has to be designed properly with the held of a qualified Aquaculture Engineer to decide the relative position of nursery and grow-out ponds, main, and secondary drainage canals, main and secondary sluice gates pump houses etc. for effective water management and control of predators and harvesting. Individual nursery and grow out ponds could be of a size of 500 sq.m and 10,000 sq.m and depth of 80 and 100 cm respectively. For semi intensive farming smaller size ponds with more depth (150-220 cm) are preferred. For effective water exchange, it is preferable to have square or rectangular shaped ponds with width to length ratio of 1:2. Water intake system is to be located where abundant good quality water is available throughout the year. If the elevation of the site is more, extensive excavation will be required to maintain one metre water depth in gow-out ponds. In such sites, peripheral trenches can be cut to have sufficient depth & water column in ponds. The dimensions of the main dike may vary from place to place depending upon the maximum flood level of the area, wave, tidal thrust, quality of soil and the purpose it has to serve. The peripheral dike should be atleast 60cms above the maximum flood level of the area and slope depends upon the seepage gradient of the soil used. Feeder canal dikes should have atleast 50cm free board above the average spring high tide water level, with a top width of 100cm. Internal bunds between ponds can have a top width of 100cm and height of 130cm including 30cm free board. A berm of 100cm width and 15cm free board shall be helpful to prevent erosions of dikes from wave actions. Depending upon the elevation of the site and tidal amplitude excavation may be required to maintain one mete water depth.

Earth required for peripheral dike should be dug out from the site itself to minimise the cost. As a general rule, earth excavated to maintain one metre water depth should be equivalent to the earth required for formation of embankment.

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

Preparation of pond

To generate natural productivity of a pond and to provide congenial conditions for normal growth of shrimps, ponds have to be eradicated and properly fertilized before stocking. For eradication ponds must be completely drained and sundried for 2-3 weeks. Drying and tilling the bottom soil helps to remove obnoxious gases, oxygenate the bottom soil and increase its fertility. If ponds cannot be drained completely, eradication of predators is effected by using any one of the following-lime, Ammonia, Mahua oil cake, derris root, tea seed cake. After draining the water in the pond to a maximum possible level, spread quick lime (CaO) uniformly (100-600kg/ha). Application of ammonia at a rate of 10ppm is more economical, effective and ensures quick results. Mahua oil cake contains 4-6% saponin and applied at the rate of 200ppm. Derris root is crushed and then soaked in water over night and applied at the rate of 25kg/ha.

After thorough eradication, the pond is fertilized to enhance the production of lab-lab. Productivity of the pond and nutrients analysis of the soil must be undertaken before attempting for fertilization. Ponds having a productivity of 2000mg/c/m^3/day need no fertilization. Mahua oil cake and ammonia, if used for eradication of predators also act as fertilizers, promoting good growth of lab-lab.

For fertilization, inorganic fertilizers such as quick lime (400-500kg/ha), nitrogenous fertilizers like urea, ammonium sulphate and organic fertilizers, such as cowdung and poultry dropping are used. Any one of these can be selected as per the requirement, after studying existing natural fertility of the pond. Urea can be applied at the rate of 50-100kg/ha. Urea and superphosphate mixed in a ratio of 4:1 can also be applied at a rate of 100kg/ha. The rate of application for ammonium sulphate is 50kg/ha.

When cowdung or chicken droppings is used, the rate of application per hectare is 1000-4000 and 500-1000kg respectively. If an excess phytoplankton bloom is noticed in the water, manuring should not be done. When both organic and inorganic fertilizers are used, apply them alternately. After application of fertilizers, pond water will turn dark green in due course and a layer of lab-lab will grow in the bottom. At this stage the water level in the pond is increased and the pond is kept ready for stocking

Stocking

Seed acquisition:

Seed is a major input in shrimp farming. Tropical and subtropical Asian countries rely mainly on wild seed. Seeds are collected either through trapping in ponds or collecting from areas where seeds are abundant in nature.

Post larvae of shrimps which are carried into brackish water areas in the rising tides are allowed to enter the adjoining ponds through sluice gates. As the force of the incoming tide slows down, sluice gates are closed and the seeds are trapped. By repeating this method, the pond is continuously stocked with seeds making use of the high tidal flow.

A major draw back of stocking this way is that many undesirable organisms also enter the ponds. To avoid this seeds are collected from areas where they are naturally abundant; seeds of candidate shrimp are sorted out and stocked.

Many methods are currently used for collection of shrimp seed from the wild. The behaviour of the shrimp seeds differ from species to species. They are available in shallow lagoons, estuaries, protected coasts and surf areas. Depending on the species and area mode of collection varies as described below:

i. A close meshed nylon net of 2m x1m size, used in surf zone or near shore areas of backwater. Two persons drag the net keeping the upper margin of the net well above water surface and lower margin just over the bottom but not touching for 5-10 minutes. The net is lifted and seed transferred to containers for sorting.

ii. Scissor nets; A close meshed net with or without codend is tied along two poles as shown in the figure. These nets are pushed by hand or boat along the shallow beach, lagoons, bays, near shore surf areas or estuaries.

iii. Small bunches of twigs are suspended as lures close to or placed on the bottom of shallow lagoons, estuaries, and protected coasts. During low tide, bunches of twigs are very slowly lifted and the shrimp seeds clinging on the them are collected using a scoop net.

iv. Seed traps. This fixed gear consists of a wing and a collection chamber. The codend of the collection chamber is kept afloat by bamboo raft and the wing is fixed with bamboo poles against the incoming water

Shrimp seed collected from wild are sorted out species wise before counting.

Seed transportation

Seeds either from wild or hatcheries have to be counted, packed and transported to farm without any stress.

Counting

Seeds collected from wild or obtained from hatcheries are maintained in happas kept in running water for counting before transportation. Seeds (PL20) are collected in small scoopnets (3x6x8 cms) for counting. About 1000-1500 seeds are scooped and the volume of larvae noted. They are released into a plastic (9-10L) tray having 4-5 l water after counting. This is taken as a standard and further counting is done by eye estimation. Once counted, the seeds are kept in holding nets.

It is desirable that post larvae be given temperature shock in new water a few days prior to transportation. This induces moulting (during which the shrimp is most vulnerable to handling and cannibalism) before transport instead of during or immediately after transport minimising mortality.

Short duration transport

One ton fiberglass tank (divided vertically in to 3 compartments) loaded on a truck and provided with oxygen bubbling can transport 1.5 to 2.5 lakh PL 10-15 for a period of $1^1/_2$ to $2^1/_2$ hrs. Before transportation the tank is covered with wooden sheet which is firmly screwed to the tank to avoid splashing and loss of larvae. Tanks have exit tubes at the bottom, to transfer PL to the pond. After acclimatisation, PL is directly transferred to the pond through a hose attached to the exit tube.

Plastic bins of about 60 l capacity can also be used for transportation of seeds (PL 10-15). A plastic bag of same size and shape is kept inside each plastic bin. It is filled with water and 20-25 thousand seeds (PL 10-15) are transferred into each of the bag and the mouth is tied after providing continuous oxygen bubling and transported with in 2 hours.

Long duration transport

Pl 10-15 are transported under oxygen packing in plastic bags of suitable size. $^1/_3$ the bag is filled with water in which seeds are released and $^2/_3$ filled with oxygen and packed. These bags are kept inside cardboard boxes, and transported (200-250 Pl 15-20 per litre for 24-36 hrs)

Selective stocking

Selection of species for farming is of great importance. It is better to select a native species which has a ready market and can grow fast in the prevailing ecological conditions. In India *Penaeus indicus* and *P. monodon* have proved to be the most suitable species. Other species which can be tried are *P. merguiensis* in the north west and northeast coasts, *P. semisulcatus* and *P. latisulcatus* in suitable areas along the Tamil Nadu Coasts, *P. japonicus* along the Maharashtra, Goa, Tamil Nadu and Andhra coasts and *P. canaliculatus* on the Tamil Nadu and Kerala coasts.

When seeds are transported from distant places, it is essential to acclimatise them before stocking. Temperature and salinity acclimatisations are to be done very slowly. Bags containing seeds are floated in the ponds for a considerable time to equalize the temperature. Once temperature is equalised, the seeds have to be acclimatised to the pond water conditions. For this, the transportation bags are opened and kept on the bund under shade. Then pond water is slowly added in small quantities into the bag. Thus seeds are properly acclimatised within 3-4 hours and are released evenly at different points in the pond. It is always better to rear seeds of smaller size in nursery ponds or happas maintained inside the ponds for 7-15 days, before stocking. In a happa of 3x2x1 m size, 30,000 PL 20 can be stocked, and grown for 7 days. They must be properly fed during this period.

Stocking density in the pond mainly depends on the species, quality of water, natural fertility of the pond and water management practices. In an extensive or semi intensive system depending on the species stocked the stocking density range from 50,000 to few lakhs/ha.

Pond management

Water management and monitoring the growth of prawn in the shrimp farms are of utmost importance.

1 to 1.5 m water in the ponds is desirable and should be oxygen rich free of pests poisonous metabolic waste and products of anaerobic decomposition; and have nutrients to maintain optimum phytoplankton growth. Surface sea water brought by high tide or pumping from sea may have pollutants, predators and pests. Hence the incoming water is to be efficiently screened using fine meshed seives. Depending upon the productivity, growth, turbidity and stocking density, the exchange of pond water is maintained. Proper exchange of pond water by tide or by pumping has to be carried out to maintain optimum salinity, dissolved oxygen and pH levels in the pond throughout the culture period.

Water quality measurements may be done at the exist point where depth is more. Dissolved oxygen measurement should be done twice a day, one in afternoon and another at dawn to find the maximum and minimum D.O. levels respectively. Samples from bottom water should be obtained for D.O. estimation.

Dissolved oxygen level may be between 3 to 12 ppm. But desired level is little above 5 ppm. Demand for oxygen is more for moulting-prawn and they moult during night only. During that time in any pond system oxygen level will be low. During day time phytoplankton consumes carbondioxide and releases oxygen. This process reverses during night and overcast days. The upper layer of pond water interacts with atmospheric oxygen and enriches itself. On windy days the surface water thus enriched mix with bottom water. In calm weather stratification sets in pond water and this does not permit mixing.

In the high density culture system naturally replenished oxygen is inadequate to support the shrimp biomass. This is particularly true in the dark hours when phytoplankton turns to oxygen consumption. Hence artificial oxygenation is essential. Oxygenation is done by aerators and aspirators. Number of aerators vary according to the water spread, stocking density weather, temperature and many other factors. Normally 8 to 10 one H.P. paddle wheel aerators are kept along the edge of a one hectare pond all around to effect a centrifugal water movement in the pond water. This movement disperses the oxygen throughout the pond and congregating the bottom debris at the centre where the drain is always located. This is more effective in ponds less than 2 ha (Square or rectangular). The ability to destratify and ensuring oxygenated water to reach the pond bottom is as important as water exchange in high density culture. Mixing also helps to have uniform temperature in pond. This reduces cannibalism, aggression and decreases heterogeneity of prawn size.

In a feed-intensive system the left over food and excrement accumulate and decomposes particularly when oxygen is depleted in water. This leads to the formation of Hydrogen sulphide which gives rotten egg smell to the bottom. It immediately affects species of prawns which have burying habits. In this situation Ferrous oxide can be applied to convert H_2S into a harmless precipitate of Ferrous sulphide. Scattering red soil, rich in iron content serves the same purpose. Feeding rate should be reduced on such conditions.

In the high density culture system when the excretion of nitrogenous wastes are faster than the rate of removal by phytoplankton, toxic ammonia and nitrite accumulate. It is more so when dissolved oxygen level is low. Indication is prawns swim in surface. Zeolite powder (25 kg / 0.1ha) could be applied to absorb Hydrogen Sulphide and Ammonia. Alternatively nitrifying bacteria (15kg / ha) could be applied to speed up nitrification. Application of photosynthetic bacteria (Rhodopseudomonas sp) is supposed to facilitate break down of Hydrogen Sulphide. Carbon dioxide acts as an acid in water. During photosynthesis it declines and pH increases. A higher pH level of 9 or 10 may impair growth of prawn and similarly lower critical level is 5. Optimum is between 7.5 and 8.7. pH will be minimum by dawn.

Optimum level phytoplankton growth in pond water is essential as it produces oxygen during day times and intakes nitrigenous wastes also. Communities of green algae and phytoflagellates are more stable and it gives light green colour to pond water and s preferred over diatoms and zooplankton which gives brown colour and is less stable. To maintain and encourage the production of natural food organism, repeated application of fertilizers may be necessary. Frequency and dosage of the fertilizers are to be judged periodically.

After stocking, regular monitoring of the stock in the ponds is necessary to decide on supplementary feeding and maintenance of water quality. Uniform sized cast net is operated at 8-10 points of the pond and the prawns netted without causing any damage are measured, weighed and number of prawns/haul noted.

During the first month the baby prawns, grow fast feeding on the rich natural food organisms developed in the ponds due to fertilizer application. Afterwards this has to be supplemented by providing feed at the rate of 5-10% of the standing crop per day, in 2 or more doses, placed in feeding pans at different places. Behaviour of prawns may be noted every day and if the prawns are moving on the water surface during day time, replenish the water immediately. Shrimps observed to be inactive, swimming sluggishly or dwelling at shallow parts of the pond during day time may be due to infection or other problem.

Diseases

One of the major factors that limit the successful shrimp culture operation and reduce profitability has been identified to be the diseases affecting the species selected for culture. As India is poised for large scale development of aquaculture of prawns with stress on high density semi-intensive or intensive culture systems, it is natural to expect increasing hazard of diseases in these systems.

Atleast 28 disease conditions of penaeid prawns are identified from the wild. Of these about one third are non infectious- related mainly to nutritional or environmental deficiencies. The diseases of shrimps are broadly classified into:

1) Viral diseases
2) Bacterial diseases
3) Fungal diseases
4) Protozoan diseases
5) Metazoan parasites
6) Nutritional deficiency diseases
7) Diseases caused by environmental stress

8) Toxic diseases and
9) Miscellaneous diseases

Viral diseases

Bacculovirus infections are the most commonly occurring viral infection in prawn. Important among them are BP, MBV and BMNV viruses. The infection sites are frequently the hemocytes and hepatopancreatic cells. Many viruses are found in association with other viruses indicating the possibility of synergism for viral expression.

Although several viral diseases have been identified in penaeid prawns, there have been very little progress in their control.

Bacterial diseases

The bacteria affect all the life stages of penaeid prawns. Their infection causes localised pits or melanised erosions of cuticle on the general body surface, gills or appendages or abscesses in the gut, muscles and gills or they produce generalised septicaemia. While some bacteria like *vibrio* are primary pathogens most bacteria are secondary opportunistic pathogens that cause disease in severely stressed prawns or as secondary invaders in prawns with weakened defence mechanism due to wounds or other diseases.

Several methods of treatment for bacterial diseases have been reported. Drying, cleaning, disinfection of spawning, hatching, larval rearing and nursery tanks considerably reduce bacterial infection. Supply of adequate amounts of good quality water, filtration and sterilisation of water and alleviation of stress factors have also been suggested for reducing or preventing bacterial diseases.

Use of certain antibiotics such as furacin, furanace, chloramphenicol and oxytetracycline, either by direct addition to the water in the tank or by incorporating in the feed, has been found as successful therapy. Bacterial diseases caused by vibrio spp, in P. japonicus can be cured by feeding the prawns with compounded feed mixed with sulphozozole, nifurstyric acid and chloramphenicol. Discolouration of gills caused by certain bacteria can be effectively treated by immersing the prawns in 2 to 3 ppm furazolidin, Filamentous gill disease caused by Leucothric infestation could be treated effectively using a sea water soluble copper compound, commercially known as cutrine plus. Potassium permanganate is also effective in treating filamentous bacterial infestation.

Fungal diseases

Malachite green oxylate at 0.006 ppm or trifluralin at 0.01 ppm is effective in treating lagenidium infection in penaeid prawns. This disease can also be controlled by furanace. Antibiotic such gallymycin and fungicide trifluralin are used to control infection in larval rearing tanks. *lagenedium* and *Heliphthoros philippinensis* isolated from *P. monodon* have been found to respond well to treatment with antimycotic chemicals. Although several fungicides have been reported to be promising in the treatment of Fusarium infection, practical methods of chemotherapy for this infection is still lacking.

Protozoan diseases

Several chemicals are available for the control of ciliates and other protozoan infestations. Formalin at the rate of 25 ppm is effective in controlling ciliates infestations. Glutaraldehyde 2 ppm, chloramine T, qunine sulphate or qunine bisulphate at 5 ppm and quinacrine hydrochloride at 0.6 ppm concentration are also effective in treating ciliates and other protozoan epicommensals in culture tanks. *P. indicus and P. monodon* in high density culture system have been observed to be infested by peritrichous ciliate Zoothamnium colonising the gills of prawns. Death occurs when the effective respiratory surface of the gills is reduced by the presence of numerous colonies of Zoothamnium spp. and coinciding with periods of low concentration of dissolved oxygen in water. Repeatedly flushing the ponds with fresh unpolluted tidal water or by pumping good quality filtered seawater can effectively check this infestation.

Microsporidiosis in penaeid prawns or 'cotton' or 'milkshrimp' disease is caused by a number of microsporidaian pathogens parasitising the shrimp, especially Thelohania semisulcata. Microsporidian infestation can be controlled or treated by disinfecting the culture system, with a commercial bleach (purex-Fleecywhite^{R} Bleach with 5-25 percent sodium hypochlorite) or a disinfectant containing iodine (wescodyne^{R} with 9.1 per cent polyethoxy polypropoxy polyethoxy ethanol iodine complex and 8.74 per cent nonylphenoxypoly (ethyleneoxy) ethanol iodine complex.

Metazoan parasitic diseases

Several species of helminth parasites belonging to digentic trematodes, cestodes and nematodes been reported from penaeid prawns. The extent of damage or loss to shrimp aquaculture due to the helminth infestation is comparatively low.

The bopyrid isopods have been reported to parasitise the branchial chamber of penaeid prawns. The two commonly occuring species are *Epipenaeon ingens and E. elegans.* There seems to be no gross effects of infestation on the normal bodygrowth of the host; except that the secondary sexual characters and the reproductive organs fail to develop leading to the disease known as parasitic castration.

Nutritional deficiency diseases

Besides the diseases caused by biological agents, several abiotic agents affect the penaeid prawns. With the increasing stress on semi-intensive and intensive culture systems in recent years, compounded diet to enhance the growth and survival of farmed prawn are being frequently used either to supplement the natural food available in the culture system or as a complete diet in controlled culture operations. One such deficiency disease reported commonly is the' black death disease' caused by ascorbic acid (vitamin C) deficiency. Severe vitamin C deficiency causes characteristic blackened haemocytic necrotic lesions in the epithlial and subepithelial connective tissue of the stomach, gills and other organs. Once the disease become apparent, affected prawns stop feeding and die within 24 to 26 hours. This disease can be controlled by providing feed containing 2000 to 3000 mg vitamin C per kilogram of feed or by feeding a supplement of fresh algae to the affected prawns.

Disease caused by environmental stress

Stress conditions such as supersaturation of atmospheric gases, low dissolved oxygen levels, sudden changes in salinity or temperature . overcrowding and rough handling lead to unhealthy state in prawns, at times causing large scale mortalities. Gas bubble disease occurs when prawns are subjected to water supersaturated with atmospheric gases. Several other diseases such as muscle necrosis, cramped tail condition, broken back syndrome, soft prawn syndrome, tail necrosis etc are supposedly caused by a combination of adverse changes in culture medium. Erythrocine at the rat of 250mg, per tonne of water daily is reported to be effective in controlling necrosis in prawn. The prawns recover when the stress factor is reduced or eliminated. Frequent flushing of the culture system with good quality water is by far the best remedy for environmental stress induced diseases.

Toxic diseases

Toxic diseases manifest mainly from sources such as toxic algae, pollution of water by pesticides, industrial chemicals, chlorinated hydro-carbons, petroleum products, certain heavy metals and sewage. Blooms of certain diatoms, dinoflagellates and filamentous blue green algae are reported to be toxic to cultured prawns at different stages of its life. Ammonia, nitrite and nitrate in excess are also toxic to prawns in culture system.

Some of the chemotherapeutic chemicals used in the treatment of diseases are also toxic to prawns at certain concentrations.

Miscellaneous diseases

There are several diseases and abnormalities of prawns which are of unknown etiology and which do not fall under any of the categories detailed above. Among such diseases or abnormalities can be mentioned the tumour like growth 'fibroma' in the cephalothoracic region of *P. indicus,* identified as 'benign neoplasm' formed from the fibrous connective tissue. These abnormalities are normally non-infectious and does not cause any serious threat to aquaculture.

In conclusion it can be said that appreciable advances have been made on the control of diseases affecting the shrimps in aquaculture systems. In recent years, greater emphasis has also been given to prophy-lactic measures and prevention of diseases through better water quality management and minimising the environmental and handling stresses.

Harvesting

On finding the shrimp has grown to marketable size, the farmer has to find the freezing capabilities and market requirements and decide on the harvesting strategy. When perceptible differential growth among the stock is found selective harvest should be resorted to since after thinning the undergrown will show spurt in growth and reach marketable size fast. On a castnet check-catch; if moulting is observed in good percentage it is better the harvesting is delayed. Moulting activity is more during full moon. Hence harvesting can be in any day, 4 days after full and new moon. Most of the penaeids bury during day and active during night. Their swimming behaviour can be encouraged by increasing water movements. As per the market demand farmer may resort either to single complete harvest or multiple partial harvest.

Harvesting is done by draining, seining, cast netting trapping or electrofishing. The most popular draining method is by keeping the screens in position in the sluices and making the shrimps gather in the harvest pit near the sluice. Then the screens are removed and shrimps are swept into the tapering collection bag, a staked enclosure, which can be open topped. While the draining is on during dark, few lighted torches can be kept near the sluice gate for attracting the shrimps.

Behaviour of different shrimps differ. *P. monodon* is more reluctant than other penaeids to swim out of a pond during night

Trapping is done taking advantage of the movement of prawn in pond and hence done during night. A leader made of netting or bamboo slats is arranged at right angles to be bund and this guides the shrimp into a net or bamboo catching chambers which have to be frequently emptied. The slat spacing or mesh size of the leader and catching chamber can be so arranged to effect selective or total harvest.

Drag nets the floats and sinkers are also found to be effective by repeated operation. But complete harvest is not possible.

Electro fishing in vogue in many shrimp fishing countries is yet to enter India. It makes use of an electric current to stimulate shrimp to jump and get collected into a moving net. Pond water level should be brought down to 70 cm before fishing. The shocker is powdered by an 8V60 AH battery in a water proof box on top of a float and is connected to a bare copper cable along the foot rope of the seine. The seine is stretched horizontally by a 4.5 m long and 5 cm diameter bamboo stock which floats on the surface and is tied into the waist of an operator with three pieces of long rope. This operator wades in the water along the length of the pond pushing the battery float forward and meanwhile dragging the seine several metres behind him. A single seine is used for 0.1 water area. It enables the shrimps to be collected in excellent condition.

In any of the operations, draining and refilling the ponds frequently for harvesting may trigger moulting.

Economics of shrimp farming

Like any other commercial venture, shrimp farming, too requires investment both of non-recurring and recurring nature. Non-recurring capital investment in shrimp farming covers construction of main and subsidiary bunds/dikes, sluice gates, excavation of the pond area for retaining the required level of water, construction of watchmen shed cum store house, cost of equipments such as pumps, aerators, nets, traps, screens, shutters to the water gate etc. These components may vary depending upon the size of the farm and its nature of operations. The operational cost of recurring nature for shrimp farming includes cost on pond preparations, seed, fertilizers, chemicals feed, fuel, maintenance and repairs of bunds, replacement of short lived farm equipments, wages for workers, annual land leasing rent, repayment of the loan taken for development and interest on the loan. A farm developed for shrimp farming, can be utilised in the existing condition for a minimum of two crops in year. Depending upon the water quality, the ponds can be stocked either with white or tiger shrimp for both the crops or it can be used for alternative crops. The economics worked out for an extensive and semi-intensive shrimp farm of an average size of 5 ha area are given in the accompanying statements. The capital investment required will be location specific and vary from region to region and the estimate provided is based on our overall experience at the national level.

From the statement it may be seen that to take up an extensive type of shrimp farming in a 5 ha water spread area a sum of Rs. 11.95 lakhs (Rs. 5.95 lakhs towards capital cost and Rs. 6.00 lakhs towards operational cost for two crops) in a year is required. A net profit of Rs. 2.96 lakhs is possible at the end of the 1st year operation, after meeting all the expenses towards operational cost for a year, repayment of loan component and interest etc. The per hectare net profit comes to Rs. 60,000/- per annum at the end of 1st year and Rs. 93000/- at the end of the 7th year.

Similarly for taking up semi-intensive shrimp farming in 5 ha water spread area, the capital investment and recurring expenditure required for two crops in a year, are estimated at Rs. 27.50 lakhs and Rs. 37.54 lakhs respectively and the net profit before depreciation at the end of the 1st year of operation will be Rs. 1.4 lakhs which is likely to increase to Rs. 9.43 lakhs at the end of the 7th year. The per ha income will be Rs. 28,000 per annum at the end of 1st year and Rs. 1,89,000 at the end of the seventh year. After the 7th year the gross profit will equal net profit.

The above estimates are based on the national level experience and on certain assumptions. However, the profit margin will go up according to the efficiency in farm management.

Economics of extensive farming (Tiger Shrimp)

1. Assumptions

a) Farm size (water spread area)	:	5ha
b) Culture period	:	4 to $4^1/_2$ months
c) Stocking rate	:	50,000 nos/ha

d) Survival rate : 70%
e) Average shrimp weight at harvest : 1000 kg/ha/crop
g) Feed conversion ratio : 2.5 : 1 (with feed costing Rs. 12 per kg)
h) Pond size : 1 ha (5 no.)

II. **Development cost estimate (5 ha water area)**

(Rs. in lakhs)

a) Earth Work (15000 m^3)	:	3.00
b) Stone pitching on one of the four sides	:	0.30
c) Main outlet (1 no.) for drainage, canal	:	0.20
d) Individual pond inlets (5 nos.)	:	0.10
e) Sluice gate for each pond (outlets 5 nos.)	:	0.40
f) Pump (10HP x 4 nos. including one 10 HP standby diesel pump)	:	0.85
g) Pump house cum shed	:	0.40
h) Store cum office	:	0.60
i) Miscellaneous	:	0.10
Total	:	5.95

Development cost per ha = 1.19 lakhs

III. **Operational cost for one crop (5 ha water area)**

(Rs. in lakhs)

a) Seed (2.5 lakhs @ Rs. 200/1000 nos)	:	0.50
b) Feed (12500 kg @ Rs. 12/- per kg)	:	1.50
c) Fertilizers and manures for pond preparation	:	0.15
d) Staff salary (one farm supervisor @Rs. 1500/- per month One Watchman @Rs. 600/- per month and two labourers @Rs. 60/- per month)	:	0.20
e) Fuel & electricity	:	0.40
f) Harvest	:	0.05
g) Miscellanenous expenses	:	0.20
Total	:	3.00
Operational cost per year for two crops	:	Rs. 6.00 lakhs
Production cost per kg = $\frac{\text{Rs. 3,00,000}}{\text{5000 kg}}$	:	Rs. 60.00

IV. Gross income from sales

		(Rs. inlakhs)
a) From one crop for 5 ha (5000 kgs x Rs. 120/-)	:	6.00
b) Per year	:	12.00
c) From one crop per ha	:	1.20
d) Per year per ha	:	2.40

V. Economics and repayment

A) Total investment	:	Cost of development + operational cost of 1st crop = Rs. 5.95 lakhs + Rs. 3.00 lakhs = Rs. 8.95 lakhs
B) Gross profit before interest and payment	:	Gross income per year - (operational cost for next year + depreciation @ 10% of cost of development) Rs. 12.00 lakhs - (6.00 + 0.60) Rs. 5.40 lakhs

Economics of semi intensive farming (Tiger Shrimp)

1. Assumptions

a) Farm size (water area)	:	5 ha
b) Pond size	:	0.5 ha (10 nos.)
c) Culture period	:	4 to $4^1/_2$ months
d) Stocking rate	:	3 lakhs nos./ha
e) Survival rates	:	70%
f) Average shrimp size at harvest	:	25 gm
g) Average yield	:	5000 kg / ha / crop
h) Feed converstion ratio	:	1.5 : 1 (with formulated pelletised feed costing Rs. 30/- per kg)

II. Development cost (5 ha water area)

		(Rs. in lakhs)
a) Earth work for construction of ponds drainage & feeder canals etc. (2000 m^3)	:	4.00
b) Lining of feeder canal	:	0.70
c) Water inlet structures for ponds (20 nos.)	:	0.50
d) Water outlet structures for ponds(10 nos.)	:	1.0

e) Mian outlet slucies (2 nos.)	:	0.30
f) Pump house, generator shed cum work shop and diffuser tank etc.	:	1.50
g) Office, laboratory, dormitory and store	:	3.00
h) Watchman shed (2 nos.)	:	0.20
i) Drinking water storage and supply network including installation of borewell	:	0.75
J) Pumps (3 nos. mixed flow pump, each 25 HP)	:	2.55
k) Aerators (30 nos. 1 HP each)	:	6.00
l) Electrical installations and electrification	:	2.00
m) Generators (2 nos. x 30 KVA)	:	3.50
n) Lab and farm equipments	:	1.00
o) Miscellaneous expenditure	:	0.50
Total	:	27.50

Development cost per ha = Rs. 5.5 lakhs

III. **Operational cost for one crop (5 ha water area)**

		(Rs. in lakhs)
a) Seed @ Rs. 200/ 1000 nos. for 15 lakhs	:	3.00
b) Feed @ Rs. 30/kg for 37,500 kgs)	:	11.25
c) Chemicals and manures for pond preparation (@ Rs. 15000/- per ha)	:	0.75
d) Fuel and electricty	:	1.50
e) Annual maintenance repairs	:	0.70
f) Harvesting	:	0.50
g) Labour (for pond preparation stocking etc)	:	0.20
h) Staff salary (one FarmManager @ Rs. 2500/- per month one mechanic @ Rs. 1200/- per month two farm hands @ Rs. 600/- per month two watchman @ Rs. 600/- per month)	:	0.37
i) Office expenses and other miscellaneous expenses	:	0.50

Total	:	18.77
Operational cost per year for two crops	:	37.54
Production cost per kg Rs. 18,77,000 / 25,000	:	37.54

IV. **Gross income fromsales**

(Rs. in lakhs)

a) From one crop (25000 kg x Rs. 110)	:	27.50
b) Per year	:	55.00
c) Per ha per crop	:	5.50
d) Per ha per year	:	11.00

V. **Economics and repayment**

A. Total investment : Cost of development + operational cost for 1st crop

= Rs. 27.55 lakhs +

Rs. 18.77 lakhs

= Rs. 46.32 lakhs

B. Gross profit before interest and repayment : Gross yearly incoem - (operational cost of next year + depreciation @ 10% of the development cost)

= Rs. 55 lakh - (Rs. 37.54 lakhs + Rs. 2.76 lakhs)

= Rs. 14.70 lakhs