Principles of Sustainable AQUACULTURE

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SEM V

K HARISH BABU
PS GOVT COLLEGE PENUKONDA

Four – year B.Sc. (Hons)
Domain Subject: **ZOOLOGY**
IV Year B. Sc.(Hons)–Semester –V

Course 6 A: **SUSTAINABLE AQUACULTURE MANAGEMENT**
(Skill Enhancement Course (Elective), - Credits: 05)

I. Learning Outcomes:

Students at the successful completion of this course will be able to

- Evaluate the present status of aquaculture at the Global level and National level
- Classify different types of ponds used in aquaculture
- Demonstrate induced breeding of carps
- Acquire critical knowledge on commercial importance of shrimps
- Identify fin and shell fish diseases

II. **Syllabus**: (*Total Hours: 90 including Teaching, Lab, Field Skills Training, Unit tests etc.)*

Unit: 1

1.1 Present status of Aquaculture – Global and National scenario
1.2 Major cultivable species for aquaculture: freshwater, brackish water and marine.
1.3 Traditional, extensive, modified extensive, semi-intensive and intensive cultures of fish and Shrimp
1.4 Design and construction of fish and shrimp farms

Unit: 2

2.1 Functional classification of ponds – head pond, hatchery, nursery ponds
2.2 Functional classification of ponds -rearing, production, stocking and quarantine ponds
2.3 Need of fertilizer and manure application in culture ponds
2.4 Physio-chemical conditions of soil and water optimum for culture (Temperature, depth, turbidity, light, water, PH, BOD, CO_2 and nutrients)

Unit: 3

3.1. Induced breeding in fishes
3.2. Culture of Indian major carps: Pre-stocking management (Dewatering, drying, ploughing desilting; Predators, weeds and algal blooms and their control, Liming and fertilization)
3.3. Culture of Indian major carps - Stocking Management
3.4. Culture of Indian major carps - Post-Stocking Management

Unit: 4

4.1 Commercial importance of Shrimp & Prawn
4.2 *Macrobrachium rosenbergii -B*iology, Seed production.
4.3 Culture of *L. vannamei* – Hatchery Technology and Culture practices
4.4 Mixed culture of Fish and Prawns

Unit: 5

5.1 Viral diseases of Fin Fish & Shell fish
5.2 Fungal diseases of Fin & Shell fish
5.3 Bacterial diseases of Finfish & Shell fish
5.4 Prophylaxis in Aquaculture

III. References:

1. Pillay TVR & M.A.Dill, 1979. Advances in Aquaculture. Fishing News Books Ltd., London
2. Stickney RR 1979. Principles of Warm Water Aquaculture. John Wiley & Sons Inc.1981
3. Boyd CE 1982. Water Quality Management for Pond Fish Culture. Elsivier Scientific Publishing Company.
4. Bose AN et.al. 1991. Costal Aquaculture Engineering. Oxford & IBH Publishing Company Pvt. Ltd.

Web Links:

1. http://www.fao.org/fishery/docs/CDrom/FAO_Training/FAO_Training/General/x6708e/x6708e06.htm
2. http://aquaticcommons.org/1666/1/Better-Practice3_opt.pdf
3. https://www.notesonzoology.com/india/fishery/fish-diseases-symptoms-and-control-fishery/871

Course 6 A: SUSTAINABLE AQUACULTURE MANAGEMENT
PRACTICAL SYLLABUS

IV. Learning Outcomes:

On successful completion of this practical course, student shall be able to:

- Identify the characaters of Fresh water cultivable species
- Etimate physico chemical characateristics of water used for aquaculture
- Examine the diseases of fin and shell fish
- Suggest measures to prevent diseases in aquaculture

V. Practical (Laboratory) Syllabus: (30hrs) (Max.50Marks)

1. Fresh water Cultivable species any (Fin & Shell Fish Specimens – Observation of morphological characters by observation and drawings)-5

2. Brackish water cultivable species (Fin &Shell fish- Specimens- Observation of Morphological Character by observing drawing) -5

3. Hands on training on the use of kits for determination of water quality in aquaculture (DO, Salinity, pH, Turbidity- Testing kits to be used for the estimation of various parameters/ Standard procedure can be demonstrated for the same)

4. Demonstration of Hypophysation(Procedure of hypophysation to be demonstrated in the practical lab with any edible fish as model)

5. Viral diseases of Fin & Shell Fish (Observation of his to pathological slides / Charts/ Models of viral pathogens in fin/ shell fish – one edible specimen can be used for observation of same in the laboratory)

6. Bacterial diseases of Fin & Shell Fish (Observation of his to pathological slides / Charts/ Models of Bacterial pathogens in fin/ shell fish – One edible specimen can be used for observation of same in the laboratory)

7. Fungal diseases of Fin & Shell Fish (Observation of his to pathological slides / Charts/ Models of Bacterial pathogens in fin/ shell fish – One edible specimen can be used for observation of same in the laboratory)

VI. Lab References

1. Boyd CE 1982. Water Quality Management for Pond Fish Culture. Elsevier Scientific Publishing Company
2. http://www.fao.org/fishery/docs/CDrom/FAO_Training/FAO_Training/General/x6708e/x6708e06.htm
3. http://aquaticcommons.org/1666/1/Better-Practice3_opt.pdf
4. https://www.notesonzoology.com/india/fishery/fish-diseases-symptoms-and-control-fishery/871

VII. **Co-Curricular Activities**

a) **Mandatory**:*(Student training by teacher in field skills: Total 15 hrs., Lab:10 + field 05)*

1. For Teacher: Training of students by the teacher in laboratory/field fornotlessthan15 hours on Breeding- Induced breeding in carps -hatchery technology of *L. Vennami*- Farming techniques- disease diagnostic techniques—concepts –Demonstration @ any aqua laboratory
2. For Student: Students shall (individually) visit a Hatchery/Farm/ Aqua diagnostic center and make careful observations of the process method and implements- protocols and report on the same in 10 pages hand written Fieldwork/Project work Report.
3. Max marksfor Fieldwork/Project work Report: 05.
4. Suggested Format for Fieldwork/Project work : Title page, student details, index page, details of place visited, observations made, findings and acknowledgements.
5. (IE). Unit tests

b) Suggested Co-Curricular Activities

1. Preparation of Model/Charts of Ideal fish Pond, Cultivable species of fin fish shell fish
2. Observation of aquaculture activities in their area (Observation of any activity related to aquaculture in the vicinity of the college/village)
3. Preparation of Model – charts of Fin /Shell fish Diseases with eco-friendly material.
4. Assignments, Group discussion, Seminar, Quiz, Collection of Material, Video preparation etc., Invited lecture

1.1 Present status of Aquaculture – Global and National scenario

Global scenario

There has been a shift in aquaculture from capture fisheries to culture fisheries. Productivity from capture fisheries has remained almost constant since 1980. In 1974, aquaculture provided 7%, 26% in 1994 and 39% in 2004. China supplies more than 60% of the world's aqua products. In 2014, fish production from culture fisheries surpassed that of capture fisheries. Between 1961 and 2013, fish production increased by an average of 3.2% per year. The average consumption of fish per person increased from 9.9 Kg in 1960, 14.4 Kg in 1990 and 19.7 Kg in 2013. During 2014-15, more than 20 Kg of fish are available as food on an average per year. Per capita fish consumption in developed countries was 5.2 Kg in 1961 and 18.8 Kg in 2013. Poor countries consume only 3.5 – 7.6 Kg as food

Global production from capture fisheries in 2014 was 93.4 million tonnes. Of this, 81.5 MT is available from sea waters and 11.9 MT from inland waters. China is the leading producer of marine fish followed by Indonesia, USA and USSR. 73.8 MT productivity was achieved in 2014 through culture fisheries. This includes 49.8 MT non-vegetative fish, 16.1 MT molluscs, 6.9 MT crustaceans and 7.3 MT amphibians and other aquatic animals. In 2014, China produced 45.5 MT, accounting for 60% of global production. Then there are India, Vietnam, Bangladesh and Egypt. Along with fish, 27.3 MT of aquatic plants have been cultivated. At least 50 countries continue to cultivate seaweed and weeds.

About 56.6 million people are primarily employed in the capture fisheries and aquaculture sector. Of these, 84% work in Asia, 10% in Africa, and 4% in Latin America and the Caribbean. 94% of the 18 million people working in fish ponds are in Asia. 19% women are in primary sector of fish farming and fish processing and storage sector with 50% of men. There are approximately 4.6 million fishing boats in the world. Of these, 75% are in Asia, 15% in Africa, 6% in Latin America, the Caribbean, 2% in North America and 2% in Europe. 64% of all boats are of mechanized type. In 2014, 46% of the fish was consumed directly, i.e. in the live state, through stocking in ice. 12% of fish was consumed in dried form, salted and smoked form, 13% in preserved form and 30% in cold frozen form.

National scenario

After independence in India, the fish industry was recognized as an equal sector along with the agriculture sector. Fish production has increased 11 times in a period of 60 years. It increased from 0.75 million tonnes (MT) in 1950-51 to 9.6 MT in 2012-13. Fish production in Salina increased by an average of 4.5%, ranking China next in the world. 14.5 million people depend on fish for their livelihood. During the year 2012-13, the foreign exchange earned was 3.51 billion US dollars. India has 10% of the world's fish diversity. Presently our country ranks second in the world in fish production with an annual production of 9.06 million metric tons.

Fish production through inland fisheries and aquaculture increased from 46% to 85% in 1980. Freshwater aquaculture has recorded a 10-fold increase from 0.37 MT in 1980 to 4.03 MT in 2010. Salina's average increase is 6%. 95% of the country's production is through freshwater fish farming. Important among these are carp fish, cat fish, freshwater prawns and tilapia farms. In addition to this, Brackish Aquaculture also cultivates shrimps, species Penaeus monodon and exotic Litopenaeus vannamei. 70-75% of the total fresh water fish farming is done by major carp fish like Labeo, Catla and Mrigala. Fish production through ponds has increased from 600 kg per hectare per annum in 1974 to 2900 kg per hectare at present. Revolutionizing freshwater aquaculture through technologies such as induced breeding, polyculture, monoculture, etc. has become a highly economic sector. The fish industry is growing in part due to government lending, fish farmer cooperatives, ICAR research and development activities.

Freshwater shrimp farming has increased over the last two decades due to consumer demand. Macrobrachium rosenburgii is a fast growing species. It is grown along with carp fish in monoculture and polyculture methods. Aquaculture has been initiated in the country. At present, sea weed cultivation and Oyster cultivation are being done to some extent. Seabass and cobia fisheries are in the experimental stage. Only 1% of cold-water fishes such as Mahseer and Schizothoracid are cultivated. Brackish Aquaculture Fish/shrimp farming has been going on in Bheri Ponds (WB), Pokkali Farms (Kerala) in traditional manner for many years. India has 3.9 million hectares of estuaries. Of these, 1.2 million hectares are suitable for shrimp farming. 15% of which is used for aquaculture. Along with Penaeus, milkfish, pearl fish and mullet are also reared in brackish waters. According to ICAR, 2013 the productivity of brackish watersheds is recorded as 0.5-3 tonnes per hectare per year.429 Fish Farmers Development Associations (FFDA) and 39 Brackish Aquatic Fishermen Development Associations (BFDA) in India are working as promoters in aquaculture expansion. Ornamental fish farming and seaweed cultivation are also practiced in India.

1.2 Major cultivable species for aquaculture: freshwater, brackish water and marine

Categorization of Fish by their habitat:

- **Freshwater Fish:** Fish that spend most or all of their life in freshwaters, such as rivers and lakes, having a salinity of less than 0.5 ppt. Around 40% of all known species of fish are found in freshwater.

- **Brackishwater Fish:** Fish that can tolerate a wide range of salinity (0.5 – 30.0 ppt) and live in backwaters, estuaries and coastal waters. Example: Mullet, Milkfish, Seabass, Pearlspot, Mudskipper, etc.

• **Marine Fish:** Fish that spend most or all of their life in seawater, such as Seas and Oceans, having salinity above 30 ppt. There are about 240 species contributing to the marine fisheries. Example: Sardines, Mackerel, Ribbonfish, Anchovies, Grouper, Cobia, Tuna, etc.

Major cultivable species for aquaculture: freshwater

Indian Major Carps

1. Catla catla

Catla is a fish with large and broad head, a large protruding lower jaw and upturned mouth. It has large, greyish scales on dorsal side and whitish on belly. Catla is a surface feeder. Adults feed on zooplankton but young ones on both zooplankton and phytoplankton. Catla attains sexual maturity at an average age of two years and an average weight of 2 kg. Egg laying capacity of per kg of catla is 1-1.5 lakh. Breeding season is June- July. Commonly called as catla in most part of the country. Some state it is called as Bhakur

2. Rohu (Labeo rohita)

Body is moderately elongated, mouth inferior and mouth thick Scales cycloids. Body brownish on back and silvery on the belly sides. Three day old hatchlings, measuring about 6 mm. Rohu are column feeder. They feed on algae and zooplankton. Juveniles feed more than adult one. Sexual maturity attains 1-1.5 kg. Egg laying capacity of per kg rohu is 1.5 to 2 lakh. Breeding season is June – July. Commonly called as rohu in all parts

3. Mrigal (Cirrhinus mrigala)

Body is elongated, depressed with rounded snout. mouth inferior and mouth thick, Upper lips not continuous with lower lip. Large cycloids scales presents. Body dark grey on back and silvery on the belly sides. One pair of short barbles present on the mouth. Three day old hatchlings, measuring about 6 mm. They are bottom feeder. They feeds on decomposed vegetation‘s. Sexual maturity attains 1-2 kg. Egg laying capacity of per kg mrigal is 2 to 2.5 lakh. Breeding season is June – July. Commonly called as mrigal or nain or naini

Exotic fishes

Silver Carp (Hypophthalmichthys molitrix)

The silver carp is a deep-bodied fish that is laterally compressed. They are a very silvery in color when young. In older they get older they fade from a greenish color on the back to silver on the belly. They have very tiny scales on their body but the head and the opercles are scale less. They have a large mouth without any teeth in the jaw, but they have pharyngeal teeth. Its eyes are situated far forward on the midline of the body and are slightly turned down. Sliver carp are filter feeders that eat phytoplankton, zooplankton, bacteria, detritus and they graze aquatic vegetation. Sexual maturity attains at 3 yrs. Egg laying capacity is 1.5- 2 lakh per kg

Big Head fish (hypophthalmichthys nobilis)

The bighead carp is a large, narrow fish with eyes that project downward. Coloration of the body is dark gray, fading to white toward the underside, and with dark blotches on the sides. Its head has no scales, a large mouth with no teeth, and a protruding lower jaw. Its eyes are located far forward and low on its head. It is very similar to the silver carp, and can be distinguished by the dark coloration on its sides. The bighead carp can be identified by a smooth keel between the anal and pelvic fins that does not extend anterior of the base of the pelvic fins. The bighead carp has a very fast growth rate. It feeds on zooplankton

Grass Carp(Ctenopharyngodon idella)

•Light yellow body, grey-green back, grey abdomen.
• Dark green dorsal and pectoral fins, other fins light grey.
• Body of adult fish elongate and sub-cylindrical (length 3.5-4.8 times body height)
• Abdomen round with no ridge.
• Head is compressed and slightly pointed and mouth terminal.
• Eyes small. Snout blunt and the mouth is terminal, lower jaw shorter than upper jaw.
• Lateral line is straight with 37-42 large scales.
• Egg laying capacity of grass carp is 1-1.50 lakh per kg
• Sexual maturity at 3-4 yrs.
• Feeds on aquatic plants

Common Carp (Cyprinous carpio)

•The body of common carp is flat.
• Head is comparatively smaller than their body.
• The body of carpio fish is covered with slight reddish scales.
• The backside is slightly brown colored.
• Belly is golden colored.
• The scales large sized.
• A common carp lengths about 100-120 cm.
• Adult fish weights highest 40 kg.
• They survive for long time.
• Common carp fishes are omnivorous.
• They live in the lower water level.
•Eat water plants, various types of insects, benthic worms, crawfish, crustaceans, zooplankton etc.
•Breeding is two times a year
• Once at summer or rainy season and another time in winter season.
• They lay eggs about 1-1.5 lakh eggs per kg

Major cultivable species for aquaculture: brackish water

1. Mullets

Thirteen species of Mullets are found in India of which eight species contribute to the commercial catches. Mugilcephalus and M. parsia are the two cultivable species. They are euryhaline species that tolerate salinity from 0-35 ppt. They are omnivorous in feeding habit. They feed at the lowest trophic levels on plant detritus and algae. Mullets are known for the high protein and vitamins contained in the muscle tissue. The Roe (ripe ovaries) from mature females are a delicacy, high-valued and sought after in many countries.

2. Milkfish

The Milkfish, Chanoschanos, is the sole living representative of the family Chanidae and is widely distributed in the whole of tropical and subtropical regions of the Indian and the Pacific Oceans. The distribution coincides with coral reef areas where the water is warm, clear and shallow. It is one of the most important species cultured in South-East Asia.

3. Bass

Asian Seabass, Lates calcarifer, commonly called the Giant Sea Perch is an economically important food fish in the tropical and subtropical regions of Asia and the Pacific. Because of its relatively high market value, it has become an attractive commodity of both large and small-scale aquaculture enterprises. The major constraint to rapid expansion of Seabass culture has been the inconsistent supply of fry collected from the wild. The Crescent Bass or Tiger Bass, Terapon jarbua, is common species in the Indo-Pacific; it occasionally makes its way into the aquarium trade.

4. Catfish

NunaTengara or the Long Whiskers Catfish, Mystusgulio, is a common and popular fish because of its nutritional value and taste. Primarily a brackish water fish that enters and lives in freshwater. In freshwater, adults occur mainly in larger water bodies (rivers and streams) with mud or clay substratum, and rarely found in smaller streams. It forms schools of 10 to 25 individuals. Mystusvittatus, the Striped Dwarf Catfish is found in brackishwater systems with marginal vegetation in lakes and swamps with a mud substratum.

Major cultivable species for aquaculture: Marine

1. Sardines

Sardines are one of the two most important commercial pelagic schooling fishes in India (the other being Mackerel). Fourteen species of Sardines are found in the Indian waters. Out of the 14 species, the Oil Sardine Sardinella longiceps alone contributes to the largest single species fishery in the country, comprising about 15% of the total marine fish catches. Nine species of Lesser Sardines occurring in Indian waters, in the order of abundance, are Sardinella gibbosa, S. fimbriata, S. sirm, S. albella, S. dayi, S. sindensis, S. clupeoides, S.melanura and S. jonesi. Four regions of Lesser Sardine concentrations are noticed along the Indian coasts, viz., Goa, Karnataka, Kerala, Tamil Nadu, Pondicherry, Andhra Pradesh and Orissa.

2. Anchovies

Anchovies are small fish having greenish-blue reflections due to a silver-coloured longitudinal stripe that runs from the head to base of caudal (tail) fin. They are found in scattered areas throughout the world's oceans, but are concentrated in temperate waters, and are rare or absent in very cold or very warm seas. Anchovies contributes around 6% to the total pelagic fish landings of India. 28 species of Anchovies are recorded in the Indian waters. Anchovies mostly feed on zooplankton. Andhra Pradesh and Tamil Nadu along east coast and Kerala along west coast are the three coastal states of India which support 95% of the average annual catch of anchovies in the country. There are two fishing seasons: January to May and September to November, the latter period being the peak season for anchovy catches. Major contribution to the fishery is by the genera: Stolephorus, Engraulis, Thryssa, Setipinna and Coilia.

3. Mackerels

Mackerel is a common name applied to a number of different species of schooling epipelagic fish of the family Scombridae. They are found in both temperate and tropical seas, mostly living along the coast or offshore in the oceanic environment. Mackerels typically have: rows of longitudinal bands or spots along upper half of body, dorsal and anal finlets, keels on caudal peduncle and a deeply forked caudal fin. Mackerels found in Indian waters are the Indian Mackerel (Rastrelliger kanagurta) and the Indian Chub Mackerel (Scomber indicus).

4. Tunas

Tunas (family Scombridae) are among the largest, most specialized and commercially important of all fishes. They are found in temperate and tropical oceans around the world and account for a major proportion of the world fishery production. Tunas are unique among fishes because they possess body temperature several degrees higher than the ambient waters and have high metabolic rate that enables them to exhibit extraordinary growth rate. They have streamlined bodies and vary widely in size, colour and fin length.

Shrimps and Prawns

Shrimps and Prawns belong to the Order Decapoda (having 10 pairs of legs: 5 pairs of walking legs and 5 pairs of swimming legs). Generally the smaller forms are termed Shrimp while the larger ones are known as Prawns. In seafood trade, the marine forms are referred to as Shrimp (Family Penaeidae) while the freshwater forms are referred to as Prawns (Family Palaemonidae). However, quite often, these two terms are used interchangeably.

a. Freshwater Prawns:

The Giant Freshwater Prawn, **Macrobrachium rosenbergii**, popularly known as SCAMPI, is the most important species. It is native to the Indo-West Pacific region, from India through Southeast Asia to Northern Australia. It has been introduced to several countries across the globe for aquaculture purpose. Males and females have different growth rates; the males exhibit heterogenous individual growth. Among males there are three different morphotypes (Small Males, Orange Claws and Blue Claws) which display social hierarchy. All three types of males are sexually active, and females that have undergone premating moult will pair with any type male to reproduce. A Blue Claw male protects the female until their shells have hardened but the other two show no such behaviour.

The second largest freshwater palaemonid prawn, **Macrobrachium malcolmsonii**, also called the Indian River Prawn/Monsoon River Prawn/Godavari Prawn, has great potential for aquaculture development in the inland waters of the country. Freshwater prawn farming in India developed during 1999, after marine shrimp culture encountered disease problems

Freshwater Prawns	
Name	**Picture**
Giant Freshwater Prawn (SCAMPI) *Macrobrachium rosenbergii*	
Indian River Prawn *Macrobrachium malcolmsonii*	

b. Marine Shrimp:

Some of the commercially important marine shrimps are **Tiger Prawn (Penaeus monodon),Indian White Prawn (Penaeus indicus),Pink Shrimp (Metapenaeus dobsoni), Brown Shrimp (Metapenaeus monoceros),** etc. For Aquaculture purpose, the exotic **Pacific White Shrimp (Litopenaeus vannamei)** has been introduced into India and is being farmed extensively on a commercial-scale in low-saline or brackish water ponds in Gujarat, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Odisha, West Bengal etc. With the availability of Specific Pathogen Free (SPF) quality brooders and seed and adoption of improved culture techniques, mortality of juvenile and young shrimp due to disease reduced and thereby yields of shrimp increased significantly in the country.

Marine Prawns/ Shrimps	
Name	**Picture**
Tiger Prawn/ Black Tiger Shrimp *Penaeus monodon*	
Indian White Prawn/Shrimp *Penaeus indicus*	
Pacific White Shrimp *Litopenaeus vannamei*	

1.3 Traditional, extensive, modified extensive, semi-intensive and intensive cultures of fish and shrimp.

Fish culture practices can be classified into different kinds or levels on the basis of the intensity of aquaculture in terms of capital as well as operational costs.

Extensive Level

In extensive level of aquaculture, low stocking densities (e.g. 5000 carp fry/ha or 5000 to 10,000 shrimps post larvae (PL/ha/crop) are used and no supplemental feed is given. Fertilization (addition of fertilizer) may be done to stimulate the growth and production of natural food in the water. Carp culture does not require water replacement during culture period, while shrimp culture does which is done through tidal flushings i.e. new water is let in during high tide and used water is drained out during low tide. The ponds used for extensive aquaculture are usually large (more than two hectare). The production is generally low, less than 0.5 ton/ha/year in the case of shrimps and 1 to 3 ton/ha/year in the case of carps.

Modified extensive level

The modified extensive aquaculture system lies in between extensive and semi intensive culture systems. In this system the size of ponds varies between 1.0 to 2.0 ha. The stocking densities are more than extensive and less than semi-intensive (i.e. 30,000 to 40,000 shrimp PL/ha or 5,000 to 7,500 carp fingerlings/ha). In this system ponds are fertilized with organic and inorganic fertilizers and phase manuring is done once a month. Supplementary feed is given at low to moderate amounts. In the case of carp culture, water replacement is done once in two to three months @ 10 to 20%, while in shrimp culture water is replaced once in two weeks @ 10 to 20% from the second month onwards. The production averages about 1.0 ton/ha in case of shrimp and 4 to 5 tons/ha in carp culture.

Semi-intensive Level

Semi-intensive aquaculture uses medium sized ponds of 0.5 ha each with comparatively higher stocking densities than extensive aquaculture (i.e. 50,000 to 1,00,000 shrimp PL/ha or 10,000 carp fingerlings/ha). Supplementary feeding is done in moderate amounts. In the case of carp culture, water replacement is done once or twice a month @ 10%, while in shrimp culture, it is done once or twice every week @ 10 to 20%. The production averages around 1.5 ton/ha in shrimp culture and 5 to 7 ton/ha in the case of carps.

Intensive Level

In intensive level of aquaculture the pond size for the case of operational convenience is generally small about 0.2 ha approximately. In intensive level of aquaculture, very high density of culture organisms i.e. 300,000 to 500,000 shrimp PL/ha or 20,000 to 25,000 carp fingerlings/ha are stocked. The system is totally dependent on the use of formulated feeds. Feeding of the stock is done at regular intervals. In intensive shrimp culture, the computed daily feed ration is given in equal amounts from as low as three to as high as six times a day. Water replacement under intensive culture is affected on a daily basis approximately @25 to 30%. Production under intensive level of aquaculture is much higher, for example, 8 to 10 ton/ha/crop in shrimp culture and about 12 to 15 ton/ha in carp culture.

Super Intensive Level

Super-intensive aquaculture needs almost running water. Daily all the water is exchanged. This system is mostly practiced in cement tanks, fibre glass tanks, and race ways etc. which are fitted with high efficiency biological filters for continuous recirculation of water. The size of the tank ranges between 50-100 m'. In this the stocking is high and supplementary feed is also given high to get the highest yields. The yield is higher than the concentrated method.

Fish Pond Design and construction

Designing and constructing a fish pond requires careful planning and adherence to specific principles to ensure the success and sustainability of the pond. Here are the key steps and considerations for fish pond design and construction:

i. Site Selection:

Choose a suitable location with adequate sunlight, good drainage, and accessibility for maintenance.

Avoid areas prone to flooding, erosion, or excessive runoff.

Consider the availability of a reliable water source for filling and maintaining the pond.

ii. Pond Design:

Determine the size and shape of the pond based on your goals and available space. Rectangular or oval shapes are common, but the design can vary.

Plan for a suitable pond depth, which depends on the fish species you intend to raise. Shallow ponds are typically around 2-3 feet deep, while deep ponds can reach 6-12 feet or more.

Design a water inlet and outlet system to maintain proper water quality and circulation.

Incorporate features like **aeration systems**, sedimentation ponds, and fish shelters if needed.

Consider landscaping and planting aquatic vegetation to improve water quality and provide fish habitat.

iii. Soil Testing:

Conduct a soil test to assess the suitability of the pond site. Soil should be able to hold water without excessive seepage. Evaluate the soil's texture, compaction, and permeability. Soil amendments or liners may be necessary if seepage is an issue.

iv. Construction:

Excavation: Excavate the pond area to the desired shape and depth, ensuring proper slope and compacting the soil.

Embankment and Dike Construction: Construct embankments and dikes to retain water. These structures should be engineered to withstand water pressure and erosion.

Inlet and Outlet Structures: Install inlet and outlet pipes and control structures to manage water flow.

Pond Liner: If needed, line the pond with materials like clay, bentonite, or synthetic liners to prevent seepage.

Aeration and Water Circulation: Install aeration systems like diffusers, fountains, or pumps to maintain oxygen levels and water circulation.

Water Level Control: Implement devices to control the water level and drainage, such as pipes with valves.

Shoreline Protection: Protect the pond's shoreline from erosion by planting grass, installing riprap, or using other erosion control methods.

Filtration and Water Quality Equipment: Depending on the pond's size and purpose, you may need equipment like filters, UV sterilizers, or settling ponds to improve water quality.

Stocking and Management:

Once the pond is constructed and filled, stock it with the desired fish species.

Implement a management plan that includes feeding, monitoring water quality, disease prevention, and regular maintenance.

Maintain a balanced ecosystem with appropriate vegetation, which can contribute to water quality and fish habitat.

Legal and Regulatory Compliance:

Check with local authorities and obtain any necessary permits or approvals for the construction and operation of the fish pond.

Budgeting:

Develop a budget that considers the costs of construction, equipment, stocking, and ongoing operational expenses.

Maintenance:

Regularly maintain and monitor the pond to ensure proper water quality and fish health.

Repair any structural damage or leaks promptly.

Consult with local fisheries experts or agricultural extension services for guidance on fish pond design and construction that suits your specific location, goals, and fish species. Following best practices and local regulations will help you achieve a successful and sustainable fish pond.

Shrimp Pond Design and Construction

Good farm construction begins with good site selection. Complete site analysis is required to assure that a site is suitable for aquaculture. Topography, soil quality and water supply are probably the three most important characteristics of a good site.

I. SITE SELECTION

A preliminary survey of the area is essential before taking up a site for shrimp farming.

- **Topography**: The site may be located adjacent to the sea, creek or estuary or backwaters where tidal water takes its course towards interior of the river mouth or to the lake and flow back into the sea. The elevation of the site in relation to tidal amplitude of the nearby brackish water sources is an important factor for tide-fed ponds.

- **Soil Conditions:** It constitutes sand, silt and clay. Bottom soil comprising 55-65% sand, 15-25% silt and 15-25% clay is ideal with alkaline pH from 7.5 to 9.0. The soil structure in the supratidal zone has loam, sandy clay, sandy loam or sandy clay loam texture. Clay soil is preferred as it is rich in organic matter. At least 20% clay content is required for earthen pond construction. This is important for good water retention.

- **Water:** Water is obviously an important factor for site selection as it is the growing medium for the crop. A plentiful supply of good quality clean water is required for the pond. Complete chemical testing of the water is required since cultured species have some very specific requirements.

- **Other factors on site selection**: The site selected should be free from pollution, easily accessible by road for transportation and should have marketing and storage facilities. The farm labour and skilled labour availability, source of drinking water, electricity etc. are other important factors.

II. LAYOUT AND DESIGN OF FARMS

- **Layout**: The layout of a farm should indicate water distribution and drainage system, water in take and discharge points, design of sluice gate, pond bottom slope, height and width of pond bund, location of power house, approach roads, location of pump house, farm \ buildings ,feed storage sheds, workshops and sheds for security.

- **Pond Design:** The ponds are designed in rectangular shape for better water exchange and aeration for extensive and semi-intensive farming. Square or round ponds with central drainage are preferred for intensive system of farming. Pond size varies from 0.2 ha to 1.0 ha with depth of 1 to 1.5 m in the case of semi-intensive farm. The pond inlet and outlet points are to be fixed taking wind direction. Pond bottom is sloped towards drainage gently 15-20 cm. Construction of a pit at the out let point is desirable.

III. CONSTRUCTION

- The pond should be at a minimum elevation of 0.4 to 0.6 m is essential to ensure proper drainage. The pond should be a minimum of 1.5-2 Meter depth.

- Construction of pond dyke, peripheral dykes etc. are proportionately done with width, height and slope ratios. The dykes of the pond should be 1-1.5 Meter. The slope of the dyke may range from 1:1 for clayey soil and 3:1 for sandy soil. Ponds outside slope of 1:1 and an inside slope of 1:2 should be preferred

- Water intake and distribution with feeder canal, inlet and outlets sluice gates and spillway gates are the major water distribution system and the screens are provided at intake points and outlets. The pond bottom should have a slope of 1:2 towards the outlet with an overall drop of 20-30cm. This will facilitate easy draining and drying of the pond bottom.

- The drainage canal is designed opposite to intake points. The sluices are provided with nylon/velon screens to prevent escape of shrimp. In the case of biosecurity measures like bird cover, crab fencing, and disinfection dip to avoid horizontal contaminants.

IV. OTHER REQUIREMENTS

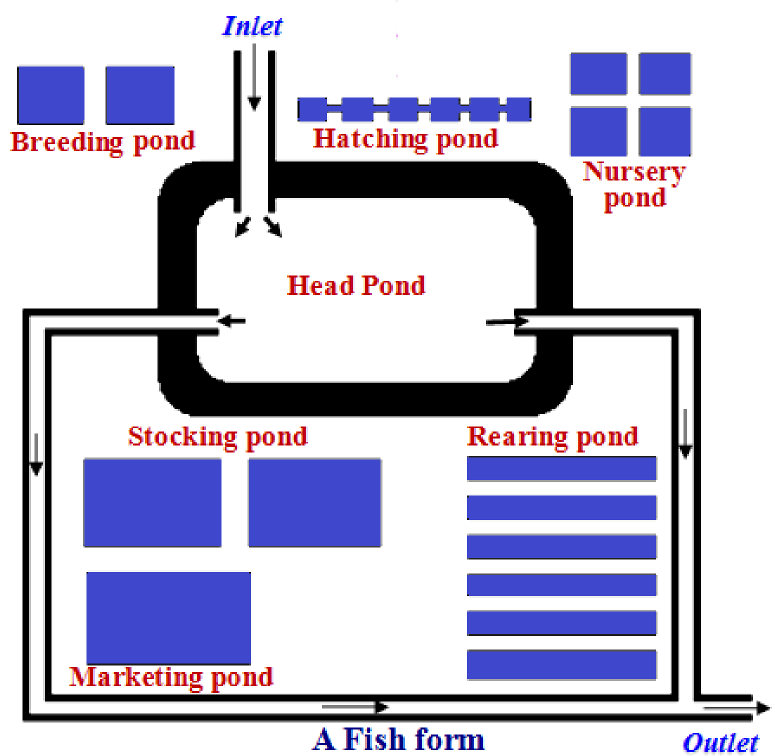
- Other requirements of the farm are the aerators and pumps. Office, laboratory, feed storage shed, electrical board room, generator room, workshop, pump house are the major farm building components.

2.1 & 2.2 Functional Classification of ponds

Any pond can be used to grow fish, but a pond that is dugspecially for fish culture usually has a regular shape, a flatbottom with a slight slope along its length.

When deciding where to locate a new pond, you shouldconsider the **landscape** (find a moderate elevation, gentle 2%or less slope, well drained and not prone to flooding), **landuse**, **soil texture** (15% clay is best for pond constructionand water holding), **water supply** (consider quality, quantityand seasonality), **security** (from theft) and **convenience.**

A fish farm requires different types of ponds for various developmental stages of fish growth. It must be the right size and shape for ponds used for various purposes such as breeding, spawning, hatching, nursery, rearing and stocking.



1. Head Pond:

This pond is usually constructed near a perennial water source. This pond is intended to meet the water needs of the entire form, taking into account the losses due to exchange, infiltration and evaporation.,

2. Segregation Pond:

It is also called brood stock ponds.This pond is for separation fully mature male and female before breeding season. The matured males and females are called brooders, which must be two to three years old and weight about 5 kg.

3. Breeding pond:

Healthy and sexually mature male and female fishes are collected and introduced (2:1) in this pond for breeding. It is also called as spawning or breeding pond, similar types of ponds are constructed in the fish form, or the deeper ponds with circulating water may be utilized by fixing the hapa. In the latter case, the breeders are released into the hapa after injection of hypophysial extract. Spawning occurs within the hapa and the exhausted breeders are removed from it. These ponds are about 0.2 to 0.4 ha in size and are perennial, with a water depth of 2 m in summer.

4. Hatching pondor (Hatchery pond):

These are small tanks, usually 3 X 4 X 2 feet, and are used for hatching the fertilized eggs. These are located near the river catchment area. These ponds are provided with continuous but slow flowing water for aerating the eggs. The tanks are fixed up with hapa called hatching hapa made of coarse cloth or the mosquito curtain cloth. The spawn is collected in the hapa where the hatching takes place. The number of hatching tanks may be up to 6.

5. Nursery Pond:

The smallest and shallowest ponds for fish culture is a nursery pond. These ponds are also called as transplantation ponds. The water is about 1 meter deep. These are about 50 X 50 X 4 feet (0.02-0.05 ha) and may be seasonal so that they may dry up during summer. This helps in eradication of unwanted vegetation, fungi, bacteria and many fish enemies and increasing productivity. The young fry, about 3-5 days old are transferred from spawning ponds to nurseries, where they remain for about 15 days and becomes fry (approximate size 2 - 3 mm). The main objective of constructing nurseries is to create favorable conditions for the availability of food for spawning. The number of nursery ponds may be up to 4.

6. Rearing pond:

A rearing pond is larger than a nursery pond. Its area is 0.08-0.2 ha. The water is about 1.5 to 2.0 m deep. These ponds may be seasonal or perennial of 90 X 30 X 4 feet in size.They are used for rearing fry to fingerling stage (approx. Size: 8 12 cm) for about 2-3 months. These ponds are made long and narrow and slightly sloped to facilitate netting. These ponds are located close to the spawning and nursery ponds and their number may vary depending upon one, two or three year rotation of the carp culture. Their number may be up to 12.

7. Stocking pond:

Stocking pond used for rearing fingerlings to marketable or adult sizes. The stocking pond is much larger, often 300 X 88 X 6 feet or 0.2-2.0 ha. It should be 2.0 to 3.5 m (6 feet) in depth. This pond might be perennial or seasonal and are so constructed that it may facilitate netting.

8. Marketing Pond:

A marketing pond, which is small but quite deep, is used tokeep fish caught from a stocking pond for sale at short noticewhen the demand and price are high. These ponds can be 0.05-0.10 ha in size with a water level of 3-4 m in summer.

9. Quarantine Pond:

Fish brought in from outside are first placed in a small (0.02 ha) but perennial (1.5 m deep) quarantine pondfor a time toverify that they are not infected. You can also use this pondto treat diseased fish from other ponds.

10. Bio pond or treatment pond

Nowadays apart from the above-mentioned fish pond in a fish farm a special type of pond- Bio pond is also seen in some farms. It acts as a large settling tank, where the water used for fish ponds of a farm is purified biologically. On need basis, it may be used as stocking pond also. The area covered by this type of pond is 7-10% of the total productive area of a fish farm.

Need for fertilizer and manure application in culture ponds

i. Fertilizer requirement in rearing ponds

Fertilizing a fish pond enhances fish yield by boosting the pond's natural productivity. Fertilizers supply essential nutrients that are often unavailable in the pond, which, in turn, stimulate plant growth - the primary producers in the aquatic ecosystem. An increase in primary productivity activates the food chain, leading to a rise in secondary productivity. A shorter food chain results in a higher rate of energy transfer and increased productivity. By using fertilizers or compost, plants proliferate, providing food for fish.

When fertilizers are added to nursery ponds, they dissolve and release chemicals into the water, causing the following effects:

- Some chemicals are quickly absorbed by the pond's normal flora, promoting growth and reproduction.
- Other chemicals attach to organic and mineral particles in the pond water, bottom mud, or upper soil layers. These particles slowly release chemicals back into the water over time, affecting pond productivity over the long term.
- Fertilizers encourage the growth of bacteria that decompose organic matter, gradually releasing more nutrients into the soil and water.

These processes are largely influenced by water quality, temperature, pH, alkalinity, and dissolved oxygen levels. To ensure rapid fish growth and sustainable pond ecosystems, natural food availability must be increased. The initial step in fertilization is adding lime to the pond, which raises the pH of the soil and water. Lime acts as a buffer and stimulates nutrient release through microbial decomposition.

Fertilizers are categorized into two types: organic (natural) and chemical (artificial).

ii. Organic fertilizers

Animal excreta are key organic fertilizers. Microorganisms break down these excreta into nutrients that promote plant growth. Natural fertilizers enhance pond productivity in three ways:

a. They stimulate rapid bacterial growth, which in turn breaks down organic matter into inorganic nutrients through mineralization, benefiting plant growth.

b. Organic fertilizers like cattle manure provide nutrients and shelter for bacteria and other microorganisms.

c. Fish can digest undigested food present in green manures and animal excreta, serving as live food for fish.

Commonly used Organic fertilizers: Common organic fertilizers used in fish ponds include domestic animal excreta (e.g., cow, pig, sheep, horse, chicken, and duck), human excreta (night soil), silkworm waste, green manure (plants/grass), compost (green manure + animal excreta), and biogas slurry.

Method of Using Organic Fertilizers: Initially, 20-25% of the total organic manure should be applied to the rearing ponds. The remaining fertilizer should be applied in equal parts every two months after stocking the fish seed. In integrated fish farming, cow dung is typically used at 5000-10000 kg/ha/year. Without additional feed, manure can be increased to 10000-20000 kg/ha/year, depending on pond productivity.

*** Cattle Dung/Excreta:** First, heap cattle manure and green manure in the pond's corners, then place them in small piles in deep water. This allows the manure to decompose quickly and disperse into the water.

*** Human Faecal Urine (Night Soil):** Mix human faecal urine with water in a 1:2 ratio and spray it along the pond banks once a day.

*** Compost:** After the fermentation process, water should flow over the compost. Collect this water and spray it intermittently in the fish pond. These nutrients are immediately absorbed by the plants. Compost uses less oxygen, making it a very convenient approach.

iii. Use of fertilizers - Consequences

Fertilizer applications should commence in the spring when the water temperature reaches 60°F. Prior to application, water purity must be checked, including measuring the light penetration into the water. Fertilizing should start when light can penetrate deeper than 18 inches and should continue throughout the summer.

However, excessive use of organic fertilizers can lead to oxygen deficiency in the pond, a serious issue. The decomposition of organic matter consumes a significant amount of oxygen, potentially resulting in disease and fish mortality. If oxygen levels drop, fertilizer application should be halted until oxygen levels increase. Additionally, some water should be transferred into the pond to help restore balance. Fertilizer use should also be suspended if vegetation becomes so dense that it covers the entire water surface. During periods of intense sun and heat, or when water levels are low, fertilizer application should be reduced or approached with caution.

2.4 Physio-chemical conditions of soil and water optimum for culture (Temperature, depth, turbidity, light, water, PH, BOD, CO_2 and nutrients)

Water is very important for aquatic life. But the water holding soil is just as important. Physical and chemical factors in water such as temperature, turbidity, color, odor, pH, dissolved O_2, CO_2 etc. are useful for the survival of aquatic organisms. Water and soil nutrients play a role in plant production or primary productivity. Soil not only holds water, but also stores and releases nutrients. Water also receives nutrients from the soil, gases from the atmosphere, and energy. These are essential for the functioning of aquatic organisms. The chemical equilibrium between water and soil is enhanced, preventing organisms from being affected by extreme differences in the environment and influencing functions such as productivity, decomposition and utilization. The physicochemical properties of the pond water almost mirror the properties of the underlying soil.

i. Temperature

In fish, shrimp metabolism, optimum temperature is essential for behavior and growth rate. 24-30^{0}C is required for fish growth and 28-30^{0}C for Peneus monodon.

ii. Water Depth

Depth determines the temperature, circulation pattern of water and the extent of photosynthetic activity. In shallow ponds, sunlight penetrates up to the pond bottom and facilitates an increase in the productivity. A depth of 1-2 metres is considered optimal for biological productivity of a pond. If the depth is very less, water gets overheated and thus has an adverse effect on the survival of the fish.

iii. Turbidity:

Turbidity blocks the penetration of light into the water and inhibits photosynthesis. Turbidity is caused by clay, floating flakes or organic matter in the water. Turbidity should be 30-40 cm for fish culture and 30-45 cm for shrimp

iv. Light

Availability of light energy to a fish pond greatly influences its productivity and photosynthesis. In shallow ponds, light penetrates to the bottom and is responsible for lush growth of aquatic weeds. In high turbid waters, the light will not penetrate to the bottom. Due to this, the vegetation at the bottom will decay and produce harmful gasses, which affect the fish and prawn life.

v. Water Color:

If the water color is light green or green in color then it is suitable for fish and shrimp farming. If it is dark brown in color, it is fatal for fish and shrimp farming.

vi. pH:

The concentration of H^+ ions in water is a measure of acidity or alkalinity. Generally suitable pH for fish and shrimp culture is 7.5-8.5 (7-9). If these values increase or decrease, the organisms will be stressed and may die.

vii. BOD, COD:

Oxygen deficiency occurs if BOD and COD are high. It indicates contamination. BOD and COD should be less than 10 ppm, 50 ppm in fish farming and 10 ppm, 70 ppm in shrimp farming respectively.

viii. CO_2 :

Respiration releases CO_2. It exists in the form of carbonates and bicarbonates in water. If it is too high, the pH will drop and the survival of the fish will be endangered. CO_2 in fish farming should be less than 5 ppm.

ix. Organic Carbon:

Organic carbon is an energy source for microorganisms such as bacteria. This causes the bacteria to release nutrients into the pond through biochemical reactions. If the organic carbon content is less than 0.5%, the pond is not productive. 0.5-1.5% is medium, 1.5-2.5% is high productivity.

x. C/N Ratio:

It affects the microbial activity in the soil. They release nutrients from decomposing organic matter. If the C/N ratio is < 10, microbial activity is slow, 10-15 is moderate, and > 20 is rapid.

xi. Nutrients:

Soil contains NPK nutrients. Due to this, the growth of plants. K is small in size. Phosphorus is a key nutrient required to increase pond productivity. It should be 60-120 ppm. Above 120 ppm productivity is high. If nitrogen is < 250 ppm, 250-500 ppm, > 500 ppm productivity is low, medium and high respectively.

Induced breeding

Induced breeding is a technique where by ripe fish breeders are stimulated by pituitary hormone or any other synthetic hormone introduction to breed in captive condition. Then the carps being excited lay eggs in the pond water and the process is called induced breeding. This process of breeding is also known as hypophysation.

Major carps are most important species from the point of view of their high food and nutritive values. Hence, they have kept attention of scientists and aqua farmers. They have peculiar habit of breeding in running waters of rivers and streams where they have large space for movement.

i. Collection of Pituitary gland:

From the matured fishes of both sexes either belonging the same species (Homo plastic) or a closely related (Hetero Plastic) the pituitary glands are collected. It is preferred to collect the pituitary gland from freshly killed fishes. But it has been observed that the pituitary glands taken from five to eight days old ice-preserved fishes have also given successful results. The pituitary glands can be taken out from the posterior end of the cranium through the foramen magnum after cleaning the brain tissue.

ii. Storage of Pituitary Gland

After the collection of the pituitary glands are kept in absolute alcohol for dehydration. After 24 hours, the alcohol is changed for further dehydration and de fattening. The glands are then weighed and preserve in fresh alcohol in dark colored phials. It may be stored at room temperature or in a refrigerator.

iii. Preparation of Pituitary Extract

At the time of injection to carps for the induced breeding, the required quantity of pituitary glands are taken out of the phials and the alcohol is allowed to evaporate. The glands are then macerated with a tissue homogenizer either in distilled water or 0.3 percent of saline water. The gland suspension is then centrifuged and the supernatant fluid is drawn into a hypodermic syringe for the injection

iv. Selection of Breeders:

Medium sized fully ripe and healthy fish of around 2 to 4 years of age is preferred for induced breeding. The weight should be 1 to 5 kg. Healthy male and female breeders should be identified and netted out before the breeding season and should be kept in spawning pools.

v. Method of Injection:

During the rainy season or cloudy, the extract of the pituitary gland of the same species which is prepared on the above said scientific process is injected in the muscle of the matured carps. Just before evening, per one female with two males of the approximate same body weight are to be injected the pituitary extract by hypodermic syringe.

vi. Injection dose and Number of times

In case of male carps the pituitary extracts are introduced once and in case of female carps it is introduced twice. At first, at the rate of 2 to 3 mg of pituitary extract per kg of body weight is introduced in the muscle of the caudal peduncle or near the dorsal fin of the female carp. The needle of the syringe is to be introduced between the scales but with an angle of 45° with the body. After six hours of first injection, the second injection is given to the same female at the rate of 5 to 8 mg of pituitary extract per kg of body weight. There is no need of injecting dose to the male breeder if it in a state of milt oozing.

vii. Synthetic Hormones:

HCG (human chorionic gonadotropin hormone), Synahorin, Ovatide, Ovaprim. It is the new inducing hormone for fish and absolute substitute of pituitary extract though it's costly. Ovaprim is far superior to carp pituitary in inducing spawning in several species of car p s. These synthetic drugs are better than the pituitary extract and easier to administrate. Only single dose injection is enough to induced craps.

viii. Spawning:

Then the carps, one female and two male are placed in a breeding hapa for spawning. Inside of the breeding hapa both the female and male carps are exited. After the excitation the female carps lays eggs. The eggs are externally fertilized by the spermatozoa(milt)that are discharged by the males.

ix. Spawning Hapa:

Hapa for larger fishes its size is 8′ x 3′ x 3′, but for the smaller fishes it is 5'x 3'x 3′. It is held on four bamboo poles, one at each corner of the rectangular case. After that all the fishes are removed from the breeding hapa and then the eggs are collected by a net and are transferred to the inner part of the hatching hapa. After 14 to 18 hours, the spawns enter into the outer hapa and the induced breeding process completed. Then the spawns are collected from the outer hapa and transferred to the pond for nursery.

x. Advantages of Induced Breeding

* A pure spawn of a desired species is made available. The spawn obtained from the rivers are not pure. They are mixed with the spawns of other species and sorting of pure seed from the mixed spawn is not possible.
* Desired species of carps can be cultured through the induced breeding.
* Large numbers of eggs are available from a fish through induced breeding.
* In the same season, a carp can be induced to breed more than once.
* Transportation cost becomes very low as the carps can be breed in any desired pond.
* Between the different species of fishes hybridization can be done and it is possible to get hybrid variety of fishes

Carp Fish Management

The perennial nursery ponds should be subjected to specific management practices which encompasses the following steps

PRE-STOCKING MANAGEMENT

The ponds need to be prepared such that the pond environment provides optimum condition for growth of the fish. The pond environment should be free from predators, aquatic weeds, weed fish; it should have optimum water quality parameters and sufficient natural food should be available in semi- intensive culture systems.

The steps involved in pre-stocking and post-stocking management are similar in the nursery, rearing and grow-out ponds. An additional step in the pre-stocking management in nursery ponds is the eradication of aquatic insects which predate on spawn and fry.

i. Draining & drying:

Pond needs to be drained a dried before culture operations begin. Drying facilitates in
- Oxidation of organic matter
- Degassing of toxic gases such as ammonia and hydrogen sulphide
- It kills pathogenic micro organisms
- Kills predatory and weed fish
- Kills unwanted aquatic plants

Ponds should be dried for 7-10 days till the soil cracks the ponds with clayey soil; in sandy soils they should be dried till the soil supports a person and foot prints do not form on the soil.

ii. Ploughing:

The ponds should be ploughed using wooden ploughs or power tillers or tractors. Ploughing helps in
- Mixing up of soil which helps in oxidation of organic matter
- Proper degassing of soil from toxic gases
- Mineralization of nutrients.

iii. Liming:

The productivity of fish ponds depends on soil qualities such as Texture, Water retention, pH, Organic carbon, Available nitrogen, Available phosphorous.

Pond bottom is important for productivity since process of mineralization of organic matter and release of nutrients to the overlying water takes place. Liming helps in improving the quality of the pond soil, thus enhancing productivity. It also corrects soil pH; the desirable pH is 6.5 – 7.00. A range of liming materials are used such as Agricultural lime or calcite ($CaCO_3$), Dolomite [$CaMg(CO_3)$], Calcium hydroxide/slaked line $Ca(OH)_2$, Calcium oxide/ quicklime – CaO

. The dose of a particular variety of lime depends on its effectiveness and soil pH. Generally, 200-500 kg/ha of line is used for application to pond soil. After application, the lime should be mixed with the top soil with light ploughing. Quick lime is preferred for applying to soil and calcite agricultural lime for application to water after stocking of the ponds.

Liming helps in Correcting soil pH, Mineralization of organic matter, Release of soil sound phosphorous to water, Disinfection of the pond bottom

iv. Pond fertilization

Fry and fingerlings of most fish such as carps feed on zooplankton. Sustained zooplankton production in ponds depends on good phytoplankton and bacterial base. This is maintained through adequate availability of nutrients such as Nitrogen, Phosphorous carbon and micronutrients in ponds. Natural availability of these nutrients in ponds will be inadequate. Hence, they need to be added through external sources for sustaining good plankton growth. Nutrients are added to water through organic manures and inorganic fertilizers.

a. Organic manures: Organic manures are rich in carbon and contain nutrients such as N and P in small amounts. They decompose slowly and release the nutrients slowly. They promote the growth of zooplankton through saprophytic food chain. They promote sustained growth of phytoplankton and zooplankton for longer periods of time. Several types of manures such as cow dung, poultry litter, pig dung, horse dung etc., can be used to fertilize fish ponds. Most common manures used in fish ponds are cow dung and poultry manure. Raw cow dung is generally applied at a rate of 5-10 tons/ha 15 days before stocking. It can be also applied in phases; 2/3 of the amount as basal dose and a second dose after a week of stocking. Poultry manure is 2-3 times richer than cow dung in the content of nitrogen and phosphorus. Hence half the dose of cow dung is used, when poultry manure is applied to the ponds.

b. Inorganic fertilizers: These are concentrated forms of nutrients such as N and P. Urea or ammonium sulphate is used as a source of N while single or triple super phosphate is used as a source of P. Inorganic fertilizers promote the production of phytoplankton on which zooplankton production depends. Their action is very fast and when used in excess quantities promote blooms of undesirable Blue Green Algae (BGA). Hence they should be used cautiously in fish ponds.

v. Clearance of weeds

A balanced biomass of submerged vegetation and algal growth is requisite for the ecosystem of a composite culture pond. Excessive infestation is harmful. Clearance of weeds is the primary consideration in case of reclamation of old ponds for fish culture. Water hyacinth, ipomoea, sedges, rushes, lotus, lilies, otelia, vallisneria, pistia, salvinia, other aquatic grass and planktonic and filamentous algae are the major menace to fish culture ponds. Ponds should be kept free of all these aquatic weeds. Methods of weed control includes:

Manual and mechanical method: When infestation is scanty and scattered or water body is small, weeds can be eradicated by hand picking, uprooting and/or by using scythes. Log weeder fitted with spikes and barbed wire can be dragged. Mechanical winches may also be used for cutting dense submerged weed.

Chemical method: Large water bodies with heavy infestation can be cleared by applying chemical weedicides. Dead weeds generally settle down to the bottom and decompose. Chemical device and subsequent decomposition in situ, must not be adopted in high organic loaded water bodies.

vi. Eradication of predatory and weed fishes

Application of bleaching powder: Bleaching powder (Calcium hypochlorite) can be applied at the rate of 25-30 ppm for this purpose. Required quantity is dissolved in water and sprayed over the water surface. After 3-4 hours of spraying, the killed and distresses fishes are removed by repeated netting. Bleaching powder is effective only when it is fresh and kept in air tight container. Toxicity lasts for 7-8 days. Fishes killed by this method are edible. Dose of bleaching powder can be reduced to half if it is applied 24 hrs after application of urea at the rate 100 kg/ha.

Repeated netting: Drag netting in quick succession is an alternate choice. Complete eradication is not possible by this method.

Application of Mohua oil Cake: Oil cake of Mohua (Madhuca latifolia) can be applied as pesticide at the rate of 250 ppm. Toxicity lasts for 15-20 days. Fish killed by the application of mohua oil cake are edible. Mohua oil cake availability in Assam is limited.

Complete dewatering: Ponds are completely dewatered for proper reclamation and recovering. In such cases, piscicides need not be applied for eradication of unwanted fishes. Fishes are caught after dewatering.

Exposure of bottom to sun: After dewatering, pond bottom should be exposed to bright sun for about 15-20 days till it cracks. Evacuation of ditches of 'Fish-bone' design should be done for draining seepage water during the process. The water should be pumped out regularly.

Removal of muck: The pond bottom should be excavated to the optimum depth. Where optimum depth exists excess muck should be removed.

Repairing of side slopes: Embankments and sides should be repaired while removing the muck. Hard soil should be used for repairing the side slopes.

Soil correction: Bottom soil should be turned up for recovering the pond properly. Ploughing helps in releasing many obnoxious gases and in making the soil soft and bottom should be treated with lime as given in following sections.

vii. Insect control:

* Soap oil emulsion is most commonly used for control of harmful insects like notonecta, ranatra, nepa etc. Soap-oil emulsion is a mixture of oil and soap (vegetable oil @ 56 kg ha-1 with soap @ 18 kg ha-1) used to kill primarily the air breathing insects. The mixture is prepared by slight heating after mixing the ingredients and sprayed over the surface of the water to create an oil film covering the entire pond water surface.

• The mixture should be applied before 20-24 hours of stocking of spawn in the pond. For this a comparatively calm weather with no rain or wind is selected so that the oil film is retained for sufficient period of time to kill the air breathing insects through suffocation.

• After killing, the dead insects may be removed through netting.

• Liquid detergent may also be used in place of soap and in lieu of vegetable oil, diesel, kerosene oil or turpentine may be used. Emulsion of kerosene @ 100-200 litre ha-1 or diesel @ 75 litre ha-1 and liquid soap @ 560 ml ha-1 or detergent powder @ 2-3 kg ha-1 water area can be applied as an effective substitute.

STOCKING MANAGEMENT

Stocking management is the management followed at the time of release of fish seed in fish ponds. Fish seeds of adequate size should be released in pre-prepared ponds after acclimatization to the new habitat. Size and number of fry are important factors for high yield.

In **Nursery pond** One million seed per hectare can be used in nursery pond. Only 20-50% of small fish can survive in this method. By improving the pond conditions, ten million fish seeds per hectare can be used for up to 60% fish survival. At the time the carp fry are released into the nursery pond, if the value of plankton in the water is 30-40 ml / m3, the stock can be 1.5-2.5 million per hectare. Two or more small fish should not be reared in nursery pools. After 3 days of hatching, the fry should be released when they are 0.6 – 0.75 mm in size. There are 500 small fish in one ml of water.

In **rearing ponds**, 12-day-old fingerlings of 20-25 mm size are released up to 2 lakh per hectare. Fish of the same species or of different species can be raised. Small fishes are released in appropriate proportions. Catla, Rohu, Mrigala are dropped in the ratio of 3:4:3 or 4:3:3. They are reared in rearing ponds from fry to fingerling stages. 0.25-0.3 million/ha are left to provide 80% living conditions. The plankton level in the rearing pool should be around 30-50 ml/m3 at the time of leaving the fryers.

Stocking ponds: Healthy fingerling stages of 100-150 mm size are released into stocking ponds at the rate of 4000-10,000 per hectare. Juveniles of 75-100 mm size can also be released into the lagoon if it is ensured that there are no predatory fishes, weed fishes and other fauna that harm the reared fish. Keeping in view the competition between the different heads of the pond i.e. surface water, middle water and bottom water in terms of food for the fry. Juveniles of different species should be released in appropriate proportions. Catla, Rohu and Mrigala are dropped in the ratio of 3:4:3 or 4:3:3. In carp fish polyculture, 5000 small fishes are generally released in one hectare pond, yielding 3-5 tons per year. 8000-10000 small fishes should be released for annual yield of 5-8 tonnes and 15000 to 25000 small fishes for 10-15 tonnes yield.

Method of stacking Fingerlings, fry and fingerling stages should be released into rearing ponds very carefully. Care should be taken to ensure that the fish do not die from stress or infection after release. They should be slowly and gradually acclimated to water temperatures and water quality and released slowly. Open the seed transport bags or containers and slowly add pond water to them to acclimate them to the water. The fry should be released slowly in this manner by slowly holding the seed carrier bag tilted into the pool water for 15-20 minutes, preferably in the cool evening hours.

POST STOCKING MANAGEMENT

This phase includes the activities to be undertaken from stocking of fingerlings up to the final harvesting of fish from the pond. The activities are manuring, feeding, growth and health monitoring, water quality monitoring and harvesting.

i. Manuring / Fertilizing

Besides, application of high dose of basal manuring / fertilizing before stocking, regular addition of manure / fertilizer in small quantities is required in order to ensure in tempted supply of natural fish food. Organisms in the pond manuring / fertilizing should be done monthly or fortnight at regular intervals and the quantities should be in split doses.

ii. Supplementary feeding

a. Feeding management in nursery ponds:

Soon after stocking, the fish start grazing natural food available in the pond irrespective of their stage of life cycle. Spawn feeds voraciously on plankton. Therefore, immediate steps must be taken for providing supplementary feed. In the case of nursery pond where spawn are reared for about a fortnight up to fry stage, supplementary feed is broadcast on the pond surface in the form of fine powder daily in the morning hours at prescribed rates as follows –

Feeding schedule for raising spawn to fry stage – (Nursery ponds)

Period	Rate of feeding per day	Approximate quantity per lakh of spawn/day
1st to 5th day	4 times the initial total weight of spawn stocked	500-600g
6th to 13th day	8 times the initial weight of spawn stocked	1120-1200g
14th day	No feeding	-
15th day	Harvesting	-

• For supplementary feeding a mixture of finely powdered groundnut/mustard oil cake and rice bran polish, in equal proportion by weight is supplied to the spawn. In addition to this mixture micronutrients like cobalt chloride may be added for better result.

• Generally at this stage, finely grind feed is supplied through broadcasting over the pond surface commencing from the day of stocking during the morning hours and it should be stopped one day earlier to the harvesting programme.

• In adverse ecological conditions, feeding should be suspended temporarily. In grass carp spawn raising programme, chopped and minced vegetations like Wolffia and Hydrilla may be provided as feed after 10-12 days of stocking.

b. Feeding management in rearing ponds:

Soon after stocking, supplementary feeding is done as cited under –

• Rice bran and mustard oil cake are mixed at the ratio of 1:1 by weight for preparing supplementary feed for fry. The amount of application of supplementary feed varies depending upon the bodyweight and their age.

• During first month of rearing, supplementary feed is provided at the rate of 8-10% of the total body weight of stocked biomass, while during second and third month, feed is supplied at the rate of 6-8% and 4-6% respectively of their body weight.

• Both bag or tray feeding and broadcasting method are found suitable for feeding the fry.

• For herbivorous fishes like grass carp, aquatic vegetations like Wolfia, Lemna, Spirodela, Azolla, Hydrilla, Valisneria, Najas, Potamogeton etc. and grasses like Para as well as selected terrestrial and semi-aquatic vegetation should be provided after proper washing and mincing.

• Feed is generally not given during cloudy days and also when there is algal bloom in the pond.

c. Feeding management in stocking ponds:

• Supplementary feeding comprising of 1:1 mixture of any oil cake (Mustard/ Groundnut/ Til/ Coconut) and rice polish or rice/wheat bran is given at the rate of 3% of the body weight of the stocked fish per day, commencing from the second day of stocking. The quantity can however be adjusted according to the rate of consumption of the fish through daily observation.

• The feed is better utilized if the fish are fed twice daily – morning and evening.

• Both mustard oil cake and rice bran should be mixed together and made into dough. Then the feed is kept in a bamboo tray and placed at a particular depth of the pond. The feeding tray is tied to a pole fixed on the embankment with the help of a rope to avoid displacement of the tray. For 1 ha of a fish pond, 10 to 15 trays are sufficient. Depending upon the depth of the pond, the feeding trays are adjusted to different depths by shortening or lengthening of the rope.

• The health of fish needs to be checked regularly by periodic netting at least once in two months. Healthy fish grow well and feed voraciously. If it is observed that the feed provided is not being consumed, either the fish is suffering from some disease or the water quality is deteriorated. A check on the water quality and hygiene of the pond and the health of the fish is necessary to take remedial measures.

iii. Regular sampling of fish

In a proper fish production management system, periodic sampling at regular internal is very important with a view to

- Checking the health condition of the fish
- Monitoring the growth rate of fish
- Calculating the quantity of supplementary feed to be applied in accordance with the increasing biomass of fish
- Estimating survival and mortality of fish in the pond

Periodic sampling of fish should be done at least once in a month. In each sampling 10-20 fish of every species should be taken for growth measurement. For sampling, complete netting of pond by seine net is better. However, partial netting of pond also serves the purpose of sampling. During each sampling data relating to fish health and growth rate has to be properly recorded. Any undesirable fish, if somehow get into the pond, must be removed if found in the sample netting. In case of some fish exhibit the symptoms of any disease, suitable curative measures should be taken immediately. However, prophylactic treatment measure such as giving the fish dip in potassium permanganate at 250-500ppm / minutes should be strictly followed before releasing the fish back in the pond.

iv. Harvesting of fish

Harvesting of fish means the complete removal of fish from the pond at the end of production. A single stocking and a single harvesting are the common practice in existence.

a. Harvesting of fry: • The fry in about 15 days of time generally grows up to 25-30 mm in size. They are harvested with fine meshed (1.5 mm) dragnet/nursery net in the cool morning hours avoiding heavy shower or too hot days.

• The fry produced in nursery ponds are harvested after attaining the desired length and are transferred to rearing pond to raise them up to fingerling stage, which is considered as the suitable stage for stocking in culture or grow out ponds.

• In a seed raising farm, a nursery pond can be utilized for raising of 5-6 batches of spawn to fry stage considering average culture period of 20-25 days per batch.

b. Harvesting of fingerling: Harvesting of fingerlings should be done during morning hours with repeated netting with dragnet of suitable mesh size. Supplementary feeding should be stopped one day prior to the day of harvesting. The rearing ponds can be utilized to raise 2-3 batches of fingerlings in a season with average culture period of 2-3 months per batch.

c. Harvesting of fish: Normally in stocking ponds fish is allowed to grow for 12 months and during this period Catla attains a weight of 800 gm – 1 kg; Rohu 600 – 800 gm; Mrigal 400 – 600 gm; Silver carp 1.0 – 1.2 kg; Grass carp 1.0 – 1.5 kg and Common carp 800 gm – 1.0 kg.

Algal blooms

Algae are natural in water. When there is adequate amount of nutrients in the pond, algae will form and the water will be green in color.Sometimes algae develop in the vegetative stage and form algal mats on the surface. Reasons for this include

i. high levels of nutrients such as phosphates in the water,
ii. fertilizers used for agricultural/recreational purposes and
iii. nutrients from domestic sewage entering the pond through water runoff,
iv. high carbon and nitrogen
v. residual sodium carbonate in the waterleads to the formation of excess carbon dioxide in the water. This causes algal blooms to grow abundantly using photosynthesis.

The lifespan of Algae is short. As a result they die and organic matter accumulates in the water and begins to decompose. The decay process uses oxygen dissolved in water, resulting in hypoxic conditions.

Without enough dissolved oxygen in the water, animals and plants die in large numbers. In this condition, many algae die and decompose, consuming more oxygen (increasing BOD). Sudden cold weather, cooling of the pond due to lack of rain, or lack of sunlight for a period of time can lead to dangerous conditions such as algae death.

4.1 Commercial importance of Shrimps & Prawns

The cultivation of crustaceans is of great significance to the global aquaculture industry, as the arthropods are rich in protein, and possibly help to meet the food requirements for mankind's ever increasing population. Marine shrimps, crabs, prawns, and lobsters are valuable food sources, and therefore of substantial economic importance to aquatic industries around the world.

Currently, about 75% of the shrimp and prawn cultivated in the world are produced in Asia (particularly, Indonesia, China, and Thailand). These are majorly genus penaeid, and two species, the Giant tiger prawn (Penaeus monodon) and the Pacific white shrimp (Litopenaeus vannamei, formerly Penaeus vannamei) comprise about 80% of all cultivated shrimp.

The prawns are one of the most economically important fishery organism of India. It helps to earn a sizeable amount of foreign exchange. The prawns are the most esteemed food among the marine food organisms. Therefore, they are in great demand both in the local and international markets.

Export of 'prawn pulp' to Burma and Malaya from earlier times and 'frozen and canned' prawns to USA and Japan in recent years has made Indian prawns a major foreign-exchange earner. Apart from being a delicacy, prawns are an excellent source of protein and vitamins (A, D, and B_6, B_{12}, Niacin). They contains all of the essential amino acids required by the body. They contain considerable quantities of glycogen and free amino acids in their muscles imparting their flesh a sweet taste.

Shrimp, although low in fat, is a good source of polyunsaturated fatty acids (PUFA), especially of the Omega-3 type. Studies have shown that foods with high amounts of Omega 3 are associated with reduced risk of heart attacks and lower blood pressure. In fact, the cholesterol contained in prawns is vital for a healthy diet. As they contain very little fat, they have become a favourite protein food for the weight conscious persons. Shrimp also provide calcium, iron, magnesium, potassium, zinc, and selenium, which are essential for physiological functions and a healthy immune system.

Indian prawns of commercial importance

Penaeus indicus, P. monodon, P. japonicus, Metapenaeus dobsoni, M. monoceros M. affinis, M. brevicornis, Parapenaeopsis stylifera, P. sculptilis, Macrobrachium rosenbergii, M. malcomsonii, Palaeomon tenuipes and P. styliferus

Secondary crop: Freshwater prawns inhabit rivers and lakes across the entire country. They migrate to brackish water for breeding. Eg. ***Macrobrachium***, ***Palaeomon***. Marine prawns occur in shallow coastal waters. They form large shoals close to Malabar Coast during the monsoon season. ***Penaeus***, ***Parapenaeopsis*** and ***Meta penaeus*** are the important genera of the Indian coast. The practice of rearing prawns as a 'secondary crop' between November and April in the paddy fields along the coastal areas in India should be a step towards increased production of fresh water prawns.

Fresh prawns are packed in ice and sent to inland markets for consumption. Large specimens are frozen directly between layers of ice. Smaller varieties are boiled, shelled and then packed between ice. Prawns are also cured. This includes sun drying, salting and pickling.

Ornamental: Several types of shrimp are kept in home aquaria. Some are purely ornamental, while others are useful in controlling algae and removing debris.

4.2 Macrobrachium rosenbergii- biology, seed production.

Macrobrachium rosenbergii, commonly known as the giant river prawn, is a freshwater crustacean species with significant importance in aquaculture due to its large size, rapid growth, and economic value. Here's an overview of the biology of Macrobrachium rosenbergii and its seed production:

Biology of Macrobrachium rosenbergii:

Size and Appearance: Macrobrachium rosenbergii is one of the largest freshwater prawn species, with adult individuals capable of reaching lengths of up to 12 inches (30 cm) or more. They have a distinctive appearance with long, slender claws (chelae) that can be either blue or green, depending on their life stage and environment.

Habitat: Giant river prawns are native to tropical and subtropical freshwater environments, including rivers, lakes, and ponds. They often inhabit slow-moving or still waters, but they are adaptable and can tolerate a range of conditions.

Diet: Giant river prawns are omnivorous, feeding on a wide variety of food sources. Their diet includes aquatic plants, algae, detritus, small invertebrates, and aquatic insects.

Reproduction: The mating (copulation) of adults results in the deposition of a gelatinous mass of semen on the underside of the thoracic region of the female's body (between the walking legs). Successful mating can only take place between ripe females, which have just completed their pre-mating moult (usually at night) and are therefore soft-shelled, and hard-shelled males. Within a few hours of copulation, eggs are extruded through the gonopores and guided by the ovipositing setae (stiff hairs), which are at the base of the walking legs, into the brood chamber. During this process the semen attached to the exterior of the female's body fertilizes the eggs. The eggs are held in the brood chamber and kept aerated by vigorous movements of the swimmerets.

The length of time that the eggs are carried by female freshwater prawns varies but is not normally longer than three weeks. Female prawns of *M. rosenbergii* are reported to lay from 80000 to 100000 eggs during one spawning when fully mature. Egg incubation time averaged 20 days at 28°C (range 18-23 days).

Larval Development: After hatching, the Zoea larvae go through several developmental stages, starting as planktonic larvae and eventually settling on the substrate as postlarvae. The larval stages require specific environmental conditions and appropriate food sources.

Seed Production of Macrobrachium rosenbergii:

Seed production of giant river prawns involves controlled breeding, larval rearing, and nursery management to produce juvenile prawns for stocking in grow-out ponds. Here are key steps in seed production:

Broodstock Selection: High-quality broodstock, free from diseases and with desirable traits, are selected. Broodstock can be either males or females, depending on the breeding goals and methods.

Maturation: Broodstock are placed in specialized maturation tanks or ponds with controlled environmental conditions, such as temperature and photoperiod, to induce maturation and spawning.

Spawning: Induced spawning techniques, such as eyestalk ablation or hormonal stimulation, are used to trigger spawning. Males release sperm, which fertilizes the eggs externally as females release them.

Egg Collection: Freshwater prawn eggs of this species are slightly elliptical, with a long axis of 0.6-0.7 mm, and are bright orange in colour until 2-3 days before hatching when they become grey-black. This colour change occurs as the embryos utilize their food reserves. After spawning, fertilized eggs are collected and transferred to larval rearing tanks or trays. Careful attention to water quality parameters, temperature, and salinity is crucial during this phase.

Larval Rearing: As the eggs hatch, rapid movements of the abdominal appendages of the parent disperse the larvae. Freshwater prawn larvae are planktonic and swim actively tail first, ventral side uppermost (i.e. upside down). *M. rosenbergii* larvae require brackish water for survival. The larvae go through 11 distinct stages before metamorphosing into post larvae. Stage I larvae (zoeae) are just under 2 mm long (from the tip of the rostrum to the tip of the telson). Larvae swim upside down by using their thoracic appendages and are positively attracted to light. By stage XI they are about 7.7 mm long. Newly metamorphosed post larvae (PL) are also about 7.7 mm long and are characterized by the fact that they move and swim in the same way as adult prawns. They are generally translucent and have a light orange pink head area.

Nursery Phase: Once larvae develop into postlarvae, they are transferred to nursery tanks or ponds, where they continue to grow and develop. The nursery phase lasts several weeks until juveniles reach a suitable size for stocking into grow-out ponds.

Grow-Out Phase: Juvenile prawns are stocked into grow-out ponds or aquaculture systems, where they are raised to marketable size. Proper management practices, including feeding, water quality control, and disease prevention, are crucial during this phase.

Harvest: When prawns reach the desired size, they are harvested for the market. Harvesting methods vary but often involve draining ponds or using traps.

Successful seed production of Macrobrachium rosenbergii requires expertise in aquaculture, careful monitoring of water quality parameters, and disease management. It is an economically important species in many countries, contributing to both domestic consumption and international seafood markets.

4.3 Culture of *L. vannamei* – hatchery technology and culture practices

The culture of Litopenaeus vannamei, commonly known as the Pacific white shrimp or whiteleg shrimp, is a significant component of global aquaculture due to its rapid growth, high market demand, and adaptability to various farming conditions. Successful shrimp farming involves hatchery technology and culture practices that ensure the production of healthy and high-quality shrimp. Here are key aspects of L. vannamei culture:

i. Hatchery Technology:

1. **Broodstock Selection:** Start with healthy broodstock that are free from diseases and have desirable traits, such as fast growth and disease resistance. Broodstock management includes proper nutrition, disease prevention, and regular health checks.
2. **Maturation:** Create optimal conditions in maturation tanks or ponds for broodstock to mature and reproduce. Control temperature, photoperiod, and salinity to trigger spawning.
3. **Spawning:** Induce spawning through eyestalk ablation or hormonal stimulation. Females release eggs, which are fertilized externally by males. They produce 100000 - 250000 eggs under artificially matured and controlled conditions. Fertilized eggs are collected and transferred to larval rearing tanks.
4. **Larval Rearing:** Larval rearing involves multiple stages, starting with Eggs hatch at 27-29^{0}C in 14-16 hours to form Naplius larva. It is this free swimming larva. Six nauplius stages undergoes moulting for 5 times in 48-53 hours. Naplius stages do not feed. The embryo uses the yolk as food. After the 6th release, Naplius larva changes into zoea. It starts eating.
5. **Mysis and Postlarvae Production:** As Zoea III develop, they transition through mysis stages and eventually become postlarvae (PL). Provide larger live feeds and gradually introduce formulated diets. Ensure proper water quality and temperature during these stages.
6. **Disease Management:** Implement strict biosecurity measures to prevent the introduction of pathogens. Regular health checks and monitoring help identify and address any disease issues promptly.
7. **Density Management:** Avoid overcrowding in larval rearing tanks, as it can lead to stress and cannibalism. Monitor densities closely and adjust as needed.

ii. Culture practices

On growing techniques can be sub-divided into four main categories: extensive, semi-intensive, intensive and super-intensive, which represent low, medium, high and extremely high stocking densities respectively. There are three types of farming practices used in India.

a) Extensive culture:

Extensive P. vannamei farming is a traditional farming process and is conducted in tidal areas where minimal or no water pumping or aeration is provided. Ponds are of irregular shape, usually 5–10 ha (up to 30 ha) and 0.7–1.2 m deep. Originally, wild seeds entering the pond tidally through the gate, or purchased from collectors were used; since the 1980s hatchery reared PL are stocked at 4–10/m². Shrimp feed mainly on natural foods enhanced by fertilization, and once-daily feeding with low protein formulated diets. Despite low stocking densities, small shrimp of 11–12 g are harvested in 4–5 months. The yield in these extensive systems, is 150–500 kg/ha/crop, with 1–2 crops per year.

b) Semi-intensive culture:

Semi-intensive ponds (1–5 ha) are stocked with hatchery-produced seeds at 10–30 PL/m². Regular water exchange is by pumping, pond depth is 1.0–1.2 m and aeration is at best minimal. The shrimp feed on natural foods enhanced by pond fertilization, supplemented by formulated diets 2–3 times daily. Production yields in semi-intensive ponds range from 500–2000 kg/ha/crop, with 2 crops per year. Farms can function as a rotating shrimp/rice farm or be integrated into mangrove areas.

c) Intensive culture:

Intensive farms are commonly located in non-tidal areas where ponds can be completely drained, dried and prepared before each stocking, and are increasingly being located far from the sea in cheaper, low salinity areas. This culture system is common in Asian farms that are trying to increase productivity. Ponds are often earthen, but liners are also used to reduce erosion and enhance water quality. Ponds are generally small (0.1–1.0 ha) and square or round. Water depth is usually >1.5 m. Stocking densities range from 60–300 PL/m². Heavy aeration at 1 HP/400–600 kg of harvested shrimp is necessary for water circulation and oxygenation. Feeding with artificial diets is carried out 4–5 times per day. FCRs are 1.4–1.8:1.

Careful monitoring and management resistant varieties, feed, water exchange/quality, aeration and phytoplankton blooms results in production yields of 7–20000 kg/ha/crop, with 2–3 crops per year can be achieved, up to a maximum of 30–35000 kg/ha/crop.

d) Super-intensive Culture:

Aquaculture systems with low land requirements and high stocking densities. Some farmers in northeast Brazil are implementing super-intensive forming technology. Ponds have square or rectangular surfaces of 2,500 to 4,000 m^2, depths of 1.8 to 3 meters, bottoms covered with high-density polyethylene (HDPE) geo membranes and central drains. The shrimp are fed several times a day by human broadcast or feeders, the rate of mechanical aeration is high (20 to 30 hp/ha), the initial stockings vary from 120-300 shrimp per square meter and yields can exceed 25,000 kg/ha/crop. Shrimp may also survive considerably greater stocking volume.

	Extensive	**Semi- intensive**	**Intensive**	**Super-intensive**
Stocking density	0.2-5/m²	5-20/m²	15-50/m²	50-200/m²
Nutrition	Natural food	Supplement + Natural food	Commercial Feed	Commercial Feed
Aeration	None	Sometime	Continuous	Continuous
Water exchange Rate / day	Tidal	1-20%	5-30%	50-200 %

4.4 Mixed culture of fish and Prawns

Mixed fish farming is nothing but composite fish farming. Basically it is a fish culture in which more than one type of compatible fish is cultured simultaneously. This method enables maximum fish yield/ production from a pond through utilization of available fish feed.

The main advantage of composite fish culture is high production by utilizing feed in the pond effectively. In this system, farmers can supply different species based on the market demand.

Characteristics Species involved in Mixed Culture

- They should have different feeding habits
- They should occupy different ecological niches
- They should attain marketable size at the same time
- They should tolerate each other
- They should be non predatory

Fish involved in Composite fish culture: Depending upon the compatibility and feeding habits of the fishes, the following varieties of fishes of India as well as exotic types have been identified and recommended for the composite fish culture system.

IMCs		
Rohu	Omnivorous	Column feeder
Catla	Zooplankton feeder	Surface feeder
Mrigal	Detritivorous	Bottom Feeder
Exotic carps		
Grass carp	Herbivorous	Surface, Column and marginal areas
Silver carp	Phytoplankton feeder	Surface feeder
Common carp	Detritivorous/ Omnivorous	Bottom feeder

Pond management plays major and critical role in any fish farming before and after the stocking of fish seed. Fish farmers should consider various measures in pre and post stocking of fish seed mentioned below.

i. Pre-stocking: In case of new ponds, pre stocking operations starts with liming and filling of the pond with water. However, the first step for existing pond requiring development deals with clearing the pond of unwanted weeds and fishes either by manual, mechanical or chemical means. **Lime** is used to bring the pH to the desired level. Based on the quality of the pond soil. **Organic manure** to be applied after a gap of 3 days from the date of liming. Cow dung @ 5000 kg/ha or any other organic manure in equivalent manurial value. **Inorganic fertilisation** to be undertaken after 15 days of organic manuring.

ii. Stocking: The pond will be ready for stocking after 15 days of application of fertilisers. Fish fingerlings of 50- 100 gm size (approx) should be used for stocking @ 5000 nos. per hectare. Depending on availability of seed and market condition, stocking can be of 3, 4 or 5 species combination in the following ratio.

Species combination (ratio)

In a 3 species combination, the optimal ratios are – Catla 4 : Rohu 3 : Mrigal 3.

In a 4 species combination, the optimal stocking ratios are – Catla 6 : Rohu 3 : Mrigal 6 : Common carp 5.

In the 5 species combination, the optimal stocking ratios are Catla 6 : Rohu 3 : Mrigal 5 : Common carp 4 : Silver carp 2 .

iii. Post stocking: Fishes need much more food than what is available naturally in the pond. The recommended feeding rate is 5 - 6 % of the body weight upto 500gm size of fish and then reduce to 3.5% of body weight from 500- 1000gm size. The feeding is supplementary in nature. Organic manuring may be done in monthly instalments @ 1000 kg/ha. Inorganic fertilisation may be done at monthly intervals alternating with organic manuring.

iv. Harvesting: Harvesting is generally done at the end of Ist year, when the fishes attain average weight of 800 gm to 1.25 kg. With Proper management a production of 4 to 5 tons/ha can be obtained in a year. Harvesting is done by partial dewatering and repeated netting.

Mixed Culture of M. rosenbergii (Prawn)

Records exist of the polyculture of various *Macrobrachium* species in combination with single or multiple species of fish, including tilapias, common carp, Chinese carps, Indian carps, ,mullets, ornamental fish. Other combinations may be feasible. The inclusion of freshwater prawns in a poly-culture system almost always has synergistic beneficial effects, which include:

- more stable dissolved oxygen levels
- reduction of predators
- coprophagy (the consumption of fish faeces by prawns), which increases the efficiency of feed
- greater total pond productivity (all species) and the potential to increase the total value of the crop by the inclusion of a high-value species.

Integrated culture with M. rosenbergii:

The wastewater from ponds containing prawns being reared in monoculture or polyculture with fish can be used for the irrigation of crops. Prawns can also be reared in paddy fields, without depressing rice production. This has proved especially valuable in Viet Nam, where it has been shown that the income from prawns in integrated rice-prawn culture can be two or three times as great as that from the cultivation of rice. The introduction of freshwater prawns reduces the area devoted to rice paddy (because deeper areas where prawns can shelter when the rice field is dry have to be provided). It also reduces weeding costs (prawns eat weeds) and fertilization costs.

Prawns being a high value commodity and possessing great potential for export offer greater scope for their larger scale adoption both under monoculture and polyculture.

5.1A Viral Diseases of Fin fish

SL No	Name of the disease	Species affected	Symptoms	Causative factors	Treatment
1	**Spring viremia of carps**	Carps	Colour darkens, haemorrhages in skin & gills, loss of balance, abdomen swollen	Rhabdo virus carpio	*For all viral fish diseases:* 1. Avoid infectious fishes separate them from others 2. Mass vaccination by immersing seeds in hyperosmotic antigen solution 3. Raise the temperature of ambient water 4. Bactrins & Vaccines for control of virus affected fishes 5. Immunization of seeds with live antigens
2	**Channel cat fish virus**	Channel cat fish	Loss of balance, fish hanging vertically in water, abdomen swollen, skin/gill haemorrhages	Channel catfish virus	
3	**Infectious pancreatic necrosis**	Young salmons under culture	Colour darkenes, Spiral swimming behaviuor, abdominal swelling, haemorrhage	Reoviridae IPN virus	
4	**Viral haemorrhagic septicemia**	Rain-bow Traouts	Colour blackens, fish become lethergic, haemorrhage at fin bases, gills & internal organ	Viral haemorrhagic septicemia virus	
5	**Infectious haematopoietic necrosis**	Salmons & Rainbow traouts	Color darkens, abdomen swollen fish becomes lethergic haemorrhage at fin bases	Infectious haematopoietic necrosis virus	

5.1B Viral Diseases of Shell fish

1	**Baculo virus disease**	Young tiger Prawn (P. monodan)	Shrimps becomes lethergic, comes to surface or sides, necrosis leading to organ malfunction	Monodon Baculo virus, high stocking density, poor environment	Prevent entry of wild prawns, crabs & fishes, Avoid fresh food of trash fishes, Prawns, crabs & other crustaceans
2	**Yellow head disease**	Adult tiger Prawn (P. monodon)	Discolouration of cephalothorax to yellowish to pinkish color, reddish body & appendages, lethergic body movement leading to mass mortality	Yellow head disease virus or RNA virus, poor water quality & poor bottom	Dry the pond remove bottom soil, disinfct the pond, sediment, disinfected, disinfected & aerated water
3	**White spot disease**	Adult tiger Prawn (P. monodon)	Lethergic prawns develops irregular whitespots starting from carapace extends allover	Whitespot Baculovirus, crabs being the carriers	Stock PCR tested healthy seeds, avoid over stocking, maintain water quality

5.3A Bacterial diseases of Fin fish

SL No	Name of the disease	Species affected	Symptoms	Causative factors	Treatment
1	**Eye disease of Catla**	Catla catla	Reddish eye turns opaque later, eye-ball putrifies leading to death	Aeromonas liquefaciens	Disinfect pond with $KMnO_4$ @ 1 mg/ lit & Chloromycetin @ 10 mg/ lit bath to fishes
2	**Dropsy**	Catla catla, Labeo rohita, Cirrhina mrigala	Water accumulation in body cavity & scale pockets leading to swollen abdomen & loose scale	Aeromonas spp. Neothelohanelius spp	Treat the pond with $KMnO_4$ @ 5 mg/lit & dip the fishes in $KMnO_4$ solution @ 1 mg / ml or Chloromycetin @ 15mg/li
3	**Columnaris disease**	Catla, Rohu, Mrigala, Grass, Silver carp	Greyish patches on head & dorsal body initially leading to ulceration & erosion of gill lamellae & filaments	Flexibacter clumnaris	Treat the pond with $KMnO_4$ @ 3-5 mg/lit & dip the fishes in $KMnO_4$ solution @ 500 mg / lit
4	**Ulcer disease**	Catla, Rohu, Mrigala, Grass, Silver carp, Magur, Singhi	Reddish pimples on body starts initially leading to loss of scales & ulceration	Aeromonas spp. Pseudomonas spp	Treat the pond with $KMnO_4$ @ 5 mg/lit, Sulphadiazine @ 100mg/kg of feed, Terramycin @ 75-80 mg/kg body for 10 days, wt of chloramphenicol @ 20-30 mg/kg body wt by intramuscular injection twice
5	**Fin & Tail rot**	IMC in culture ponds	White line appears along the outer boarder of the fins which slowly spreads towards fin base to destroy the fins, the fins loose their rays & reduced to stimps, loss of balance & death	Rod shaped bacteria	Bath in 1:2000 CuSO4 solution till fish is in distress

5.3B Bacterial diseases of Shell fish

1	**Vibriosis**	Shrimps under culture	Gills blackenes, creates stress for shrimps	Vibrio causing Bacterial shell diseases, Black gill disease	**For all the Vibrio infections** 1. Maitain constant plankton bloom & use balanced feed to avoid organic load 2. Improvement of water quality sterilising filter water to reduce bacterial load 3. Oxytetracyclin or erythromycin for 5 days @ 50-90 mg/li bath 4. Oxytetracyclin or eryhtromycin for 5 days @ 500-1000 mg/ kg feed
2	**1-month mortality syndrome**	Young tiger prawn (P. monodon)	Sudden mortality of young shrimps	vibrio from decomposing organic matters at pond bottom	
3	**Black spot disease**	P monodon, Macrobrachium rosenbergii	Muscles of abdomen, gill & other organs	Vibrio from putrifying water	
4	**Septic hepatopancreatic necrosis**	Adult tiger prawn (P. monodon)	Hepato pancreas blackens & digenerates	Vibrio from putrifying water	

5.2A Fungal Diseases of Fin fish

SL No	Name of the disease	Species affected	Symptoms	Causative factors	Treatment
1	**Saprolegniasis**	Eggs, Fins & Fingelings of IMC's & Exotic carps	Fish become weak, lethergic, restless & nonresponsive, cotton wool like growth white or colored appears in the affected parts	Saprolegnia parasitica	1. Good & hygeinic water quality, optimum stocking density, well balanced 2. Treat pond by feed $KMnO_4$ @ 1 mg/lit or formalin @ 20 mg/lit 3. $KMnO_4$ bath @ 160 mg/lit for 5 days or $K_2Cr_2O_4$ bath @ 100 mg/lit for a week or NaCl bath @ 304% solution or Malachite green bath @ 1-2 mi/Lit for 30 minutes or 1:3000 $CuSO_4$ solution for 3-4 days
2	**Gill-rot**	Eggs, Fry & Fingelings & adults of catla, Mrigal & Silver carp IMC's & exotic carps	Gill turns yellowish-brown leading to degeneration, respiratory failure, gasping of fishes & mortality	Branchiomyces emigrants, B. sanguinis	Proper water quality, hygienic condition. Treat the pond with lime @ 50 kg/ Ha/ Mt or $CuSO_4$ @ 15 Kg/ Ha/Mt or NaCl bath in 3-5% solution or 5% $KMnO_4$ solution
3	**Dyscentry**	IMCs, Exotic carps	Reddening of rectum, profuse yellowish mucus in the gut	Fungus infected feed suppliment containing excess of proteins & lipids	Stop feeding specially the animal food, water exchange

5.2B Fungal Diseases of Shell fish

1	**Larval Mycosis in Shrimps**	Larval stages are highly susceptible	Eggs and larve are weak and appear whitish. Moratlities may reach 100% within two days. Fungal mycelium replaces the larval tissues and ramifies into all parts of the body and protrudes out of the body and develops into sporangia.	Filamentous fungi of genus Lagenidium spp. Sirolpidium spp. and Haliphthoros spp.	General hatchery management practices such as use of UV sterilised and filtered seawater, adequate water exchange etc., must be strictly followed. Rearing water, equipment used in the hatchery and all hatchery facilities must be thoroughly disinfected before restarting the hatchery operations.

Prophylaxis in Aquaculture

The term prophylaxis refers to all the preventive measures taken throughout a hatchery and farming operation to minimize pathogen load and prevent the onset of diseases, such as vaccination, immunostimulation, prebiotics and probiotics, along with routine husbandry practices for batch improvement. Prophylactic measures therefore lead to the maintenance of health and hygiene of the fish species in aquaculture. Prophylactic aquaculture reduces our dependence on antimicrobials, disinfectants, and antiparasitic drugs, which are harmful to the host and the environment.

Aquaculture prophylactic measures:

In aquaculture operations, prophylactic measures include:

1. Better management practices for optimum culture environments.

2. The use of probiotics and prebiotics.

3. Enhancing the general disease resistance by immunostimulants.

4. Immunization of host against specific pathogen using vaccines.

i. Prebiotics:

Prebiotics are non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth or activity of one or a limited number of bacteria in the colony and thus improves host health. Certain non-digestible carbohydrates seems authentic prebiotics. They include resistant insulin and oligofructose, lactosucrose etc. Prebiotics have the binding capacity therefore increasing the absorption of minerals such as magnesium, calcium and iron. Prebiotics have been reported to have numerous beneficial effects in fish such as increased disease resistance and improved nutrient availability.

ii. Probiotics:

The probiotics are live microbial feed supplements that improve health of an organism (man and terrestrial livestock). Verschuere et al. (2000) defined aquatic probiotics as "Live microorganisms that have a beneficial effect on the host by modifying the microbial community, associated with the host. Probiotics inhibit the growth of pathogenic microorganisms, contribute digestive enzymes to increase feed utilization, provide other growth-promoting factors, and stimulate the immune response of the organism. Probiotics that currently used in aquaculture industry include a wide range of taxa from Lactobacillus, Pediococcus, Streptococcus, Bacillus, Flavobacterium, Cytophaga, Pseudomonas, Alteromonas, Aeromonas, Enterococcus, Nitrosomonas, Nitrobacter, Vibrio species, yeast (Saccharomyces) etc.

Aquatic probiotics are mainly of two types:

1. Gut probiotics: Mixed with feed.

2. Water probiotics: This proliferates in water medium.

iii. Vaccines:

A vaccine is any biologically based preparation intended to establish or to improve immunity to a particular disease or group of diseases. Vaccines are normally administers to healthy animals prior to a disease outbreak. Vaccines work by exposing the immune system of an animal to an antigen or a piece of pathogen then allowing time for the immune system to develop a response and "memory" to accelerate this response in later infections by the targeted disease-causing organism.

Vaccines are administered to fish in one of three ways: by mouth, by immersion, or by injection. Each has its advantages and disadvantages. The most effective method will depend upon the pathogen and its natural route of infection, the life stage of the fish, production techniques, and other logistical considerations. A specific route of administration or even multiple applications using different methods may be necessary for adequate protection.

iv. Immunostimulants:

In general, immunostimulants comprise a group of biological and synthetic compounds that enhance the non-specific defense mechanisms in animals, thereby imparting generalized protection. This protection may be particularly important for fish that are raised in or released into environments where the nature of pathogen is unknown and immunization by specific vaccine may be futile.

Immunostimulants can be classified into different categories based on their origin and mode of action, such as bacteria and bacterial products, complex carbohydrates, vaccines, drugs that enhance the immune system, nutritional factors, extracts from animals, cytokines, lectins, plant extracts, etc.

Some of the common immunostimulants used are Muramyl dipeptide, Chitin and chitosan, Levamisole, Gulcan etc.

v. Bioremediation

Bioremediation is use of living organisms to reduce/eliminate toxic pollutants (NH_3) and other nitrogenous wastes. Living organisms includes bacteria, fungi, actinomycetes, cyanobacteria and plants. In Aquaculture suspended organic matter, accumulated nitrogenous compounds, Unionised H_2S, and Phosphorus neutralized or reduced by bioremediators.

vi. Prophylactic Husbandry Measures in aquaculture

In addition to the above measures, some of the important prophylactic steps that are to be routinely adopted for successful farming hatchery operations.

a. Hatchery Level

1. Use of good quality water (UV filter, sand filter)
2. Use of healthy pathogen free brood stock

3. Following strict sanitary and hygienic conditions
4. Adopting strict sanitary and hygienic conditions
5. Regular health monitoring
6. Use of good quality live feeds
7. Use of treated water

b. Farm Level

1. Proper pond preparation (drying, waste removal, liming etc.)
2. Use of good quality water
3. Use of good quality seed (seeds screening, healthy seed selection)
4. Rational feeding and fertilization schedule
5. Adopting rational stocking policy in order to reduce stress
6. Following strict hygienic condition and quarantine programme
7. Regular health monitoring programmes
8. Use of good quality live feeds