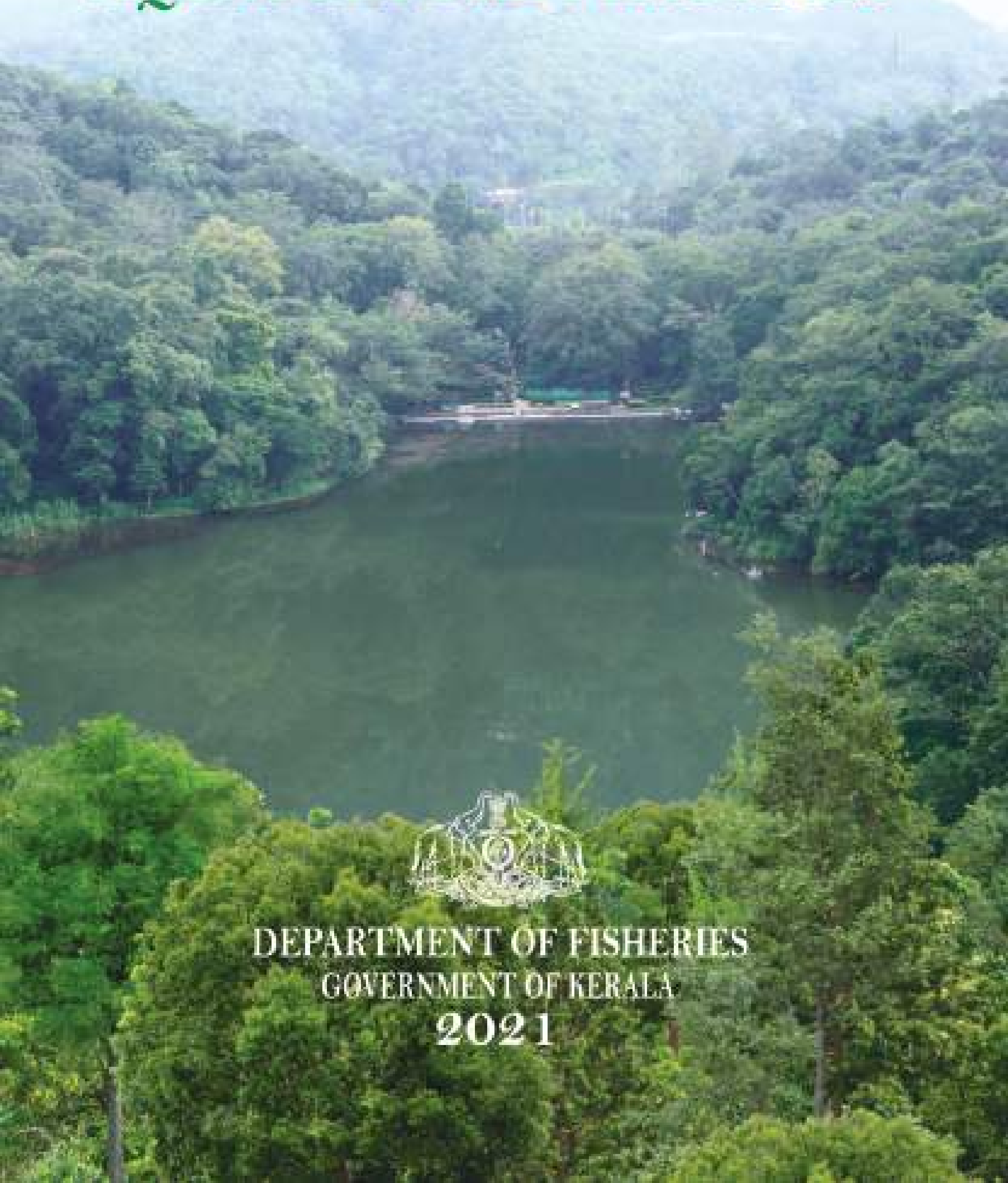
PACKAGE OF AQUACULTURE PRACTICES



DEPARTMENT OF FISHERIES

GOVERNMENT OF KERALA

2021

Package of Aquaculture practices

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Despite every effort, there may still be chances for some errors to have crept in unintentionally which may be communicated to the publisher so that it can be incorporated in the next edition.

Any views or directions expressed in this book are not of the institutes where the authors belong but of the Department of Fisheries, Government of Kerala.

J. MERCYKUTTY AMMA
**Minister for Fisheries,
Harbour Engineering and
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Government of Kerala**

03-02-2021

MESSAGE

It is indeed a great pleasure to learn that Department of Fisheries, Kerala is publishing a book on "Package of Aquaculture Practices". The State of Kerala is blessed with rich marine, brackish and fresh water resources, exporting considerable portion of its seafood to foreign countries to the tune of 1.78 lakh metric tonnes yearly valued at Rs. 5919.06 crores. The inland fishery is also an age old practice in the extensive network of backwaters and rivers of Kerala.

Aquaculture is not only a food production sector, but also a means of livelihood and economic development. The State has been undergoing a paradigm shift in terms of technology, species diversification and intensification, formulating specific action plans for achieving self-sufficiency in food production, which is considered as of utmost importance especially in the wake of covid-19 and its aftermaths. it is implicit that "Package of Aquaculture practices" can contribute very much in achieving this goal.

This book is the result of a collaborative approach and exchange of exhaustive information between scientists, administrators, extension personal and farmers, and this will definitely serve as a guide light for the sustainable development of aquaculture sector. I wish all success for this endeavour.

J. MERCYKUTTY AMMA

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SECRETARY TO GOVERNMENT

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03.02.2021

MESSAGE

The Department of Fisheries has successfully introduced highly intensive technologies like RAS, Biofloc, Cage culture, and Aquaponics, along with the introduction of promising new species like Pearlspot, Nile tilapia, Pompano, Asian sea bass, Cobia, Vannamei shrimp, crab, mussel and oyster etc. which have good consumer demand. The importance of fish in ensuring nutritional food security, as a rich source of essential amino acids, polyunsaturated fatty acids, vitamins and minerals is well known. The State is in the process of enhancing the aquaculture production from 0.25 lakh metric tonnes to 2 lakh metric tonnes by 2025.

Apart from this, serious adulterations are observed in the fish brought from outside the State, which also calls for the production of quality fresh fish locally. Culture fishery is a dynamic sector where technological innovations and interventions are a continuous phenomenon. The interventions in culture fishery focus at increasing both productivity and expansion of culture area and intensification practices hold the major key for enhancing productivity. It is essential to provide a strong base in the seed production and culture practices and also to standardize it, in order to achieve the goal of sustainable production. This book is a comprehensive approach for providing techniques of aquaculture in a uniform and concise way to achieve the objectives of production. I am sure this book will also be a reference for farmers as well as students and other stakeholders of aquaculture and provide extra support for technical staff of the Department of Fisheries. I wish all the best for this publication.

TINKU BISWAL

EDITOR'S NOTE

Fish is considered as the most promising food and its high nutrient profile is very relevant at present, as it helps to develop immunity against the emerging diseases. Even though, considerable quantity of fish is produced in the State of Kerala, about 2 lakh tonnes of fish is brought annually from outside the State to meet the domestic requirement. Enhancing aquaculture production can bridge this gap; for which a shift from extensive to intensive farming practices is needed along with expansion of aquaculture area and diversification of culture species.

The state fisheries department has conducted demonstration farming for the past few years related to high intensive farming practices such as farming of fish in cages, biofloc, aquaponics and recirculatory aquaculture system. The carps and shrimp centered aquaculture have got diversified with the introduction of Nile tilapia, pangasius, pearlspot, seabass, pompano, cobia, vannamei shrimp, mussel, oyster etc. However, introduction of exotic species may add new pathogens into the system and large-scale intensification of aquaculture would lead to disease outbreaks. The prevalence of pseudo-consultants, minting money from fish farmers with their popularity, is another major emerging issue in the State. Ignorance of basic principles behind aquaculture practices often leads to excessive use of feed, chemicals, etc. and adoption of very high stocking density. Hence a standard guideline regarding the aquaculture practices to be followed by the stakeholders becomes relevant, which is obviously lacking in our country.

The lack of a standard procedure for aquaculture practices in the state was noticed during my intervention in the aquaculture sector initially, as the recommendations to the farmers by different extension staff varied with personnel, which leads the farmers in a dilemma. It was also noticed that there is a large disparity between the dosages and other practices which were successful in the field and those written in the publications while reviewing the recommendations of various eminent researchers. It might be due to the difference between the controlled farming conditions for research and the un-controlled conditions prevailing in the field and the differences in agro-climatic conditions prevailing in various parts of the country. Hence, it was decided to demonstrate various new technologies in actual field conditions at various farms under the State Government and collaborating with farmers belonging to various agro-climatic conditions of the State. The positive results received from the field especially in the case of breeding experiments made me interested to record the procedures in the form of a book.

The idea of preparing a Package of Aquaculture Practices was first conceived in 2014. As the past six years was crucial as far as aquaculture sector was concerned, due to the emergence of various intensive aquaculture systems and introduction of new species, and it took almost 6 years to include various innovative practices including biofloc technology in order to have a comprehensive book for aquaculture practices in the state of Kerala.

This "Package of Practices for Aquaculture" is prepared based on the already published results of research and development activities conducted by RGCA, KUFOS and ICAR institutes like CMFRI, NBFGR, CIFA, CIFE, CIBA, CIFRI and DCFR and modified to suit the agro-climatic and socio-economic conditions of Kerala State after conducting field trials, demonstration farming and hatchery operations at various locations in the state.

I acknowledge the Directors of Department of Fisheries, Kerala during last six years for being instrumental in providing institutional and personnel support and encouragement in developing this book.

I also acknowledge the scientists, academicians and officers who have provided photographs and technical details for this document. The contribution of all the resource persons for the book is deeply acknowledged. This book has been prepared to provide an overview of basic guidelines to be followed in aquaculture, presented in a lucid way, so that it is easy to comprehend and implement, not only by the specialist but also by the farmers.

B. Ignatious Mandro
Joint Director of Fisheries
Government of Kerala

FOREWORD

C.A. Latha I.A.S
Director of Fisheries

World aquaculture production of fish, crustaceans and molluscs by inland and marine waters is enhanced from 55.16 million tonnes (2009) to 82.1 million tonnes (2018) with an average annual growth rate of about 4.09%. In India, during the same period it is enhanced from 3.79 million tonnes to 7.07 million tonnes with an average annual growth rate of about 6.43%. Regarding major global aquaculture producers, India has second position behind China (47.6 million tonnes). In terms of value, India contributes USD 13.188 million to USD 250.16 million globally. Out of the total global production of aquatic animals, 21.89% is contributed by carps while in India it is almost 90%. At present considerable diversification in terms of species and systems for aquaculture is being witnessed in the country.

Aquatic ecosystems of Kerala are highly productive and provide significant contributions to food and nutritional security along with economic and social development by way of capture and culture fisheries. The culture fishery is considered as the important food production sector of this century and is placed as one of the high priority areas by many countries around the globe. The investment pumped into this sector for the past years stand as the testimony for the importance it is having in the present world. As fish acts as the largest single source of animal protein, its demand outstrips supply owing to the ever-increasing human population which has already crossed the level of 700 crores.

As far as Kerala is concerned, it is the land of fish consumers with highest per capita consumption. The annual per capita consumption of fish in Kerala is 19.59 kg compared to the national average of 3.24 kg. Capture fishery from sea and inland water bodies serve as the prime source of this delicious live food, for the State but now it is on a declining trend. Over exploitation with increased mechanization makes the capture fisheries production more or less stagnant during recent decades. The traditional practice of hunting and gathering of fish from these natural waters alone cannot meet the requirement of the State especially when there is global demand for our fishery produce. There is no scope for intensification of capture fishery, which would adversely affect the sustainability of the natural fishery resources. The culture fishery is the sole alternative to play an important role in meeting the deficit.

Culture fishery is the husbandry of commercially important aquatic organisms such as fish, crustaceans and molluscs etc under controlled conditions. Even though culture fishery is developed as a commercial business recently; it was practiced in Egypt and China since ancient times by collecting small fish from natural system and growing in ponds. The contribution of aquaculture to national fish production has enhanced from 48.9 % 2011 to 56.12% (2018).

Over the years various practices and methods have been developed

This package of practice is prepared by referring published literature, conducting field experiments and exhaustive deliberations involving experts of scientific communities from central institutes, academicians and officers of the State fisheries department who are well experienced in different aquaculture practices. It covers all the variety of culture practices prevalent in the state with up to date information regarding the procedures to be followed for a particular culture after considering the ground realities in the state.

I acknowledge the Chairman of RGCA, Vice-Chancellor of KUFOS, and Directors of CMFRI, NBFGR, CIFA, CIFE and DCFR, leading institutes in fisheries research and development, for providing technical and personnel support in developing this book. I am sure this will be an important step for the States path towards achieving self-sufficiency in fish production and I wish success for this endeavor.

Vikasbhavan,
3.02.2021

C.A. Latha I.A.S
Director of Fisheries
Government of Kerala

PREFACE

Kerala is endowed with abundant marine and inland water resources like rivers, rivulets, streams, estuaries and backwaters, which are well known for their biodiversity offering immense scope for aquaculture development and expansion. It includes 590 km of coastline, 44 rivers having 85,000 ha area, 49 reservoirs having 34180 ha area, 65213 ha brackish water area, 53 backwaters having 46,129 ha area and 12,873 ha prawn filtration fields. Aquatic biodiversity includes multispecies marine, brackish water and freshwater fin fishes, crustaceans and mollusks including various indigenous species. The Western Ghats of Kerala has the unique specialty of cold water fishery resources in a tropical belt.

Fisheries play an important role in ensuring the nutritional security of the state. Fish is not only a source of cheap protein but also a means of income, which can contribute, to livelihood of the low-income group people. Kerala not only feeds fish to its own people, but exports large portion of the fishery produce to foreign countries. As production from capture fisheries is stagnated, aquaculture can be a reliable alternate for fish production. Aquaculture is the emerging sector, which is considered as the alternative for compensating the deficit in fish production. The state, which has started aquaculture activities as extensive practices, is now gearing up for a quantum jump in aquaculture production. As part of this, high intensive farming practices were introduced for the past few years.

"Package of practices for aquaculture" is carved out of an idea of providing farmers and all stakeholders concise and comprehensive information related to various intensive scientific practices in fish farming currently implemented in the state of Kerala.

The book provides meticulous, yet concise descriptions of aquaculture practices in an exhaustive number of fish and shrimp species. This book contains 30 chapters covering almost all aspects of seed production technologies and hatchery operations necessary for successful management. It also describes farming activities right from pre-stocking management to harvest. The chapters cover essential information such as brood stock management, breeding technique, and nursery rearing. Regarding farming practices, it covers pre-stocking, stocking and post-stocking management to be followed in various systems. The contributors have put in their best effort to include the updated information at field level regarding new farming techniques like culture in biofloc tank, aquaponics and cage. Care has also been taken to consider the field level realities with respect to the existing agro-geographic conditions and other aspects prevalent in the State.

We hope that this book would be of valuable use to extension staff of the fisheries department as well as to students, researchers, academicians and farmers as a practical guide in field. This book includes culture practices for most of the potential species that can be cultured in the State.

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CHAPTER: 1

MAJOR CARPS

The carps are freshwater fishes which contribute about 85% of aquaculture production in India. It has the first position in global freshwater aquaculture production. Commonly cultivated carp varieties are catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) which are of Indian origin and are collectively called as Indian Major Carps (IMC) which depends on different niches of a water body.

Table 1.1 Feeding niche of IMC

Fish	Feeding space	Natural feed
Catla	Surface feeder	Zooplankton
Rohu	Column feeder	Epiphytes and decayed vegetation
Mrigal	Bottom feeder	Benthos and decayed vegetation

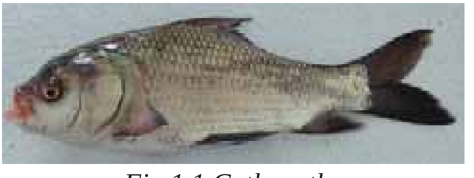

Fig.1.1 Catla catla

Fig.1.2 Labeo rohita

Fig.1.3 Cirrhinus mrigala

In combination with IMC, exotic carps namely common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*) and silver carp (*Hypophthalmichthys molitrix*) are also farmed. The benthic omnivore, common carp is a hardy fish which stirs up pond bottom vigorously and feed on benthic fauna and flora. Common carp can withstand injuries as it has an inherent capacity to regenerate injured tissue. Grass carp feeds on and controls aquatic weeds, and its semi-digested matter enhances plankton and serves as food for bottom feeders. Silver carp is a surface feeder, which feeds mostly on phytoplankton while grass carp feeds on vegetation. Among major carps, only common carp breeds naturally in confined waters.

Fig.1.4 Cyprinus carpio

Fig.1.5 Ctenopharyngodon idella

Fig.1.6 Hypophthalmichthys molitrix

'Jayanti rohu'and 'Amur carp'are the genetically improved varieties by natural selection of rohu and common carp respectively which have better growth rate.

SEED PRODUCTION

Broodstock management

It is the selection and maintenance of mature individuals with desirable hereditary qualities like enhanced gonadal development and fecundity for breeding, thus improving the quality and number of offsprings. Rectangular earthen pond having 0.2-0.5 ha with a water depth of 1.5 m is commonly used to maintain broodstock. Keeping broodfish in raised cement pond is not advisable, as the wider daily fluctuation of temperature may adversely affect the gonad development.

Healthy yearlings without any deformities are selected from different sources to avoid in breeding depression and to promote genetic improvement by out-crossing. Genetic improvement means the production of quality seeds having faster growth rate, better FCR, high disease resistance and better adaptability towards environmental stress. The broodfish is tagged to ensure the breeding between different stocks and to avoid back cross and mating between offspring of the same parent. Tagging of brood helps to identify the source, age and breeding frequency. It is preferable to replace 30-50% of broodfish in every year.

The adult fish is usually transported in a canvas bag with water. The fish brought to the hatchery is disinfected with 40 ppm formalin bath for 2 hours and stocked in ponds at a density of 1500-2000 kg/ha.The provision for running water hastens the maturation process. If there is possibility for aeration or replacement of 20-30% of the water once a month, the stocking density can be further increased. Cowdung at a rate of 250-1000 kg/ha is applied fortnightly to maintain Nitrogen-Phosphorus-Carbon (NPC) ratio as 16:1:106, which ensures sufficient live feed. The broodstock is fed daily at 3% of the bodyweight from February to April and is reduced to 2% of the bodyweight from May onwards. The broodfish is fed twice daily at 6-8 hours interval during daytime with floating pelletted feed (6-8 mm diameter) having 30-35% protein and 10-12% fat, sprouted grain and a formulated diet containing groundnut oil cake and rice bran in 7:3 ratio with nutritional supplements (10 g Vit C, 3 g Vit E, 100 g trace elements and 1.5 kg common salt in 100 kg feed).

The broodstock pond must be free from aquatic weeds or other unwanted fish. The pond is drained once in a year and disinfected by chlorination with bleaching powder (35ppm). The infestation of broodfish with ectoparasites like *Argulus* and *Lernea* may be controlled by manual or biological means. Use of chemicals can have adverse effect on gonadal development.

Multiple breeding of carps is possible with scientific pond management and feeding practices. The broodfish bred once during the previous season is used for multiple breeding upto four times in the next year with an interval of 40-45 days. In the case of repeated spawning, spent fish is disinfected by 5 ppm $KMnO_4$ dip and kept in a separate pond and fed at 5% of the bodyweight for the first week.

Water quality management

To operate a hatchery having the capacity to incubate 20-30 lakh eggs at a time, an over-head-tank of 20 t capacity and an open well or a tube-well (20 t/hr yield) with two water pumps and a generator are required. Presence of a water body in the vicinity is desirable. If surface water is used, suspended particles are allowed to settle, and the water is then passed through a sand filter to remove particles larger than 25µm. The suspended particles may form a coating over eggs or chock the gills of fry. In case of water scarcity, facilities for reuse of water after filtration through screen filter, biofilter, foam fractionators and sand filters are set up. The water should have total alkalinity of 40-100 ppm and iron content of less than 0.4 ppm. The alkalinity of the water can be reduced by adding alum (Every excess 1 ppm alkalinity requires 1 ppm alum), while it can be enhanced by dolomite @ 2-4 g/m^3.

Selection of breeding pair

Generally, IMC and silver carp breed during south-west monsoon, but common carp breeds almost throughout the year with two peaks during June to August and January to March. Grass carp spawns during March to August. As carps are sexually dimorphic, the broodfish are segregated according to sex. Secondary sexual characters usually develop during March and broodstock are segregated and kept @ 1000 kg/ha. The mature male is distinguished by the roughness on the dorsal surface of the pectoral fin. The abdomen of male is comparatively flat, and the vent is not swollen. On applying slight pressure on its belly, milt oozes out. The ripe female of IMC and common carp have soft and bulging abdomen with a swollen pinkish genital opening. The female of Chinese carps is distinguished by visual examination of the ova collected by inserting a catheter through the genital opening. The mature ova measure 1.2-1.3 mm diameter which has pale blue colour in silver carp and yellow to deep golden brown colour in grass carp.

Table 1.2 Optimum age and weight of broodfish

Variety	Optimum age	Minimum weight (kg)
Catla	3-5yrs	2.5
Rohu	2-5 yrs	2.0
Mrigal	2-5 yrs	1.5
Grass carp	3-5 yrs	2.5
Silver carp	2-5 yrs	2.0
Common carp	1-5 yrs	1.5

Spawning

Spawning includes courtship, releasing of gametes and fertilisation. The success of spawning primarily depends on water quality and weather. The optimum water temperature is 26-28°C with drizzling weather. Water containing 5-6 ppm DO promotes spawning and hatching. Male and female are usually selected in a ratio of 2:1 by number or 1:1 by bodyweight. The selected broodfish are handled with minimum stress and kept in breeding hapa or breeding pool for about 6 hours. In a breeding pool, never put different species together.

Breeding hapa is made of fine-meshed net cloth having the size varying from 3.6 m x 1.5 m x 0.9 m to 1.8 m x 0.9 m x 0.9 m depending on the size of the brood. The hapa net is tied to the poles fixed in the water column at both upper and lower corners using laces stitched to it and placed in a fully stretched out condition. Care should be taken to ensure that the bottom of the hapa is not touching the bottom of the water body, and there should be at least 20 cm height above the water surface. For the introduction of broodfish, there is an opening at one end of the hapa, which can be closed by flap or zip.

The breeding pool is circular and made of cement having 6-12 m diameter. The depth at the periphery is 120 cm and the bottom slopes towards the centre. The depth at the centre is 150 cm where there is an outlet pipe having 2-3 inch diameter. The wall of the breeding pool is fitted with duck-mouth inlet pipes fitted at an angle of 45° to create circular water flow. Over-head water showering at the height of one meter is provided with the breeding pool. Water is brought to this pool from an over-head-tank through 2-3 inch diameter pipe. The water depth inside the pool is maintained at 60-100 cm. Small breeding pool made of FRP/polythene-sheet having 4-6 m diameter and 1 m height is also widely used.The breeding pool is cleaned and disinfected with 50 ppm sodium hypo chlorite solution before and after each operation. The broodfish in the pool is kept under the shower before and after hormone injection.

Fig.1.7 Small breeding pool

After proper conditioning, individual broodfish is collected, weighed, placed on a soft cushion and injected in the evening with synthetic hormones like Wova-FH, Ovatide or Ovaprim. Intra-peritoneal injection through the inner side of the pectoral fin base or Intra-muscular injection either on the dorsal part of caudal peduncle or in the dorsal muscle above the lateral line and below the anterior part of the dorsal fin is usually practiced. Intra-peritoneal injection is preferred as it provides minimum stress to the fish. Care should be taken not to prick through the scale while giving the injection. The dosage of synthetic hormone depends on the size and age of broodfish, readiness for spawning, bulkiness of ovary and sensitivity of the broodfish. The optimum dosage of synthetic hormone is given below:

Catla, Rohu	: 0.5 ml/kg
Mrigal, Common carp	: 0.3 ml/kg
Grass carp, Silver carp	: 0.6 ml/kg

The size of the needle depends on the weight of the fish to be injected and it is given below.

1- 2 kg	: Number 24
2-3 kg	: Number 22
>3 kg	: Number 19

Fig.1.8 Induced breeding

After injection, both male and female are kept in hapa or breeding pool at a density of 3-5 kg/m^3 for spawning. After 3 hours of injection, circular water current is provided at 0.2-0.5 m/s. An environment free from stress, human and mechanical interference is required for better success rate. Under the influence of hormone and water current, the broodfish starts courtship. Male starts to chase the female with the splashing of water which creates irregular ripples on the water surface. In the case of IMC, towards the end of courtship, male hits the female's abdomen with its head. The female starts laying eggs, and the male continuously oozes milt to fertilise the eggs. All eggs from the ovary will not be laid at one place or at one time as the pair keeps on moving.

Usually, the response time for courtship is 4-6 hours after injection and lasts for 1-2 hours. Soon after spawning, water flow is stopped, and the spent broodfish is collected back. The average range of fecundity of fish is given below.

Catla	: 0.5-2.0 lakh/kg
Rohu	: 1.0-3.9 lakh/kg
Mrigal	: 0.5-1.9 lakh/kg

In the case of IMCs, the fertilized eggs appear like beads after water hardening and are non-adhesive and semi pelagic. The fertilised egg is transparent, whereas the unfertilised egg appears opaque and whitish. The delay in removing unfertilised eggs causes *Saprolegnia* infection which can be controlled by using malachite green (20ppm) for 20-25 minutes after stopping the water flow. After 8-10 hours of fertilisation, the embryo exhibits twitching movements and the fertilised eggs are volumetrically quantified using a cup or beaker and transferred to the incubation pool. The number of water hardened eggs in one-litre water is about 25,000 for catla, 30,000 for rohu and 20,000 for mrigal. Fertilisation rate is determined by taking egg samples. The usual fertilization rate is 85%.

In silver carp and grass carp, the dry method of stripping is practiced for fertilising the eggs. Before stripping, the fish is anaesthetised by 100ppm ethyl-m-aminobenzoate bath for 3-5 minutes. The female is wrapped in a towel and stripped by gently squeezing the abdomen towards the tail to collect ova in a dry enamel tray or plastic basin and immediately fertilised by milt stripped from male using a feather. The eggs begin to swell on contact with water and attain 4.2 - 4.7 mm diameter. More water should be added so that there will be 3-5 cm of water above the eggs. The water hardening of eggs will be completed within 30 minutes. It is then washed in water 3 - 4 times and put for incubation. Fecundity per kg body weight of grass carp is 0.13 - 0.82 lakh, and that of silver carp is 1.3-1.7 lakh.

In common carp, conditioned male and female in the ratio 1:1are put in hapa or cement cistern during the evening, and it naturally breeds after 6 - 8 hours, if suitable substrates are provided for the attachment of adhesive eggs. Natural substrate like *Hydrilla,* after thorough washing, is provided at the rate of 2 kg for 1 kg fish. However, artificial substrate like synthetic net pieces is preferred as it does not decay in water and can be used again. The substrates attached with eggs are collected in the next morning, washed gently to remove debris and kept for incubation. Salt, urea or skimmed milk powder is used to avoid clumping of eggs. Fecundity of common carp is 1-2 lakh/kg bodyweight.

Incubation

Incubation is the process of maintaining fertilised eggs under suitable conditions for hatching, and it is done in a double-walled hatching hapa or circular hatching pool. The hatching hapa is double-layered nylon net with an outer net having a mesh size of 0.5 mm and inner net having a mesh size of 2-2.5 mm. Both the hapas are fixed in the margin of pond by means of poles. In the inner hapa, eggs upto 50,000/m^3 are kept for incubation. After hatching, the hatchlings alone move out through the mesh of the inner hapa, and it is collected in the outer hapa. The empty eggshells are left in the inner hapa which is removed along with the inner hapa after the hatching is completed.

The circular incubation pool has two chambers. The outer chamber of 3m diameter is constructed with cement, FRP or plastic material and inner chamber of 1.5m diameter is built with net of 320-420µm mesh size, permitting out-flow of water. If the outer chamber of the incubation pool automatically receives eggs from the spawning pool, the opening of the inlet pipe should be 30 cm above the base of incubation pool to prevent injury of eggs. In a circular incubation pool of 3 m diameter, 20-30 lakh eggs are incubated in the outer chamber at once.

Water enters through showers and through 6 - 12 duck mouth valves fitted equidistant in a row on the floor of the outer chamber and a water depth of 80 cm is maintained by overflow facility. The unidirectional continuous water flow in the pool keeps the fertilised eggs evenly distributed and slowly rolling in the water column without settling on the floor or sidewall and helps in removing the metabolic wastes like ammonia and carbon dioxide.

Fig.1.9 Incubation pool

The water flow is maintained at 2.5 l/s for initial 12 hours and reduced to 2 l/s when the embryo inside the egg starts to move. After 6 hours, the water flow is again increased to 3.0-3.5 l/s. A clean bamboo stick of 2 cm width is kept on water surface across the chambers to accumulate and remove the floating foam, debris and insects. The column debris including dead spawn and egg shell can be periodically removed by keeping 5-6 pieces of coir rope of 1m long with smooth bristles tied with bamboo stick. The rate of hatching is usually 95% in the circular pool, while 75% in hapa.The hatching time is as given below,

IMC	: 14-20 hr
Chinese carps	: 24-36 hr
Common carp	: 48-72 hr

The average length of the hatchling is 4.7 mm for catla and 4.2 mm for rohu and mrigal. They are slender, transparent and non-pigmented with club-shaped yolk on the ventral side of the trunk. They have no mouth and fins, but embryonic fin fold can be seen. Soon after hatching, they lie laterally at the bottom and comes up occasionally. They start vertical movements after 12 hours of hatching, and the eyes become pigmented. Pectoral fin is developed by 24 hours after hatching and shows slight darting movement. Mouth, operculum, stomach and intestine appear within 48 hours and the larvae exhibit shooting and darting horizontal movement.

Till the yolk is utilized, larva doesn't feed on exogenous food and remains in the same pool or hapa. The yolk-sac is usually fully absorbed by 72 hours for rohu and mrigal and 96 hours for others but it is reduced to 60 hours in multiple spawning. After yolk absorption, the larva starts to feed on microalgae and zooplankton (ciliates, rotifers, cladocerans and copepods). The hatchlings are measured using measuring cups and collected for nursery rearing. The count of hatchlings ranges from 600-650 no./ml.

Nursery pond design

It involves initial nursery rearing of the 3 - 4 days old hatchlings (5-8 mm) into fry (25 mm) and the subsequent nursery rearing of fry (25 mm) into fingerling (>40 mm). Drainable cement tank with 200 m^2 area and 150 cm depth with a soil layer of 5-15 cm having bottom slope towards the outlet is ideal for nursery rearing. The pond is covered with 50-100 mm mesh size netting to control predatory birds. If the pond is below ground level, the side of the pond is fenced with a net of 26 mm mesh size to prevent the entry of predators.

Fig.1.10 Nursery tank

For providing keel aeration, each 200 m^2 pond is provided with 14 pieces of algal resistant aero-tube rings of one meter lenght with half-inch inner diameter and each aero-tube ring is provided with 1.5 inch PVC pipes loaded with sand inside and sealed at both ends. Two air blowers of (roots type) 5 hp (300 m^3/hr) is required for 10 numbers of 200 m^2 ponds for providing aeration continuously through these aero-tube rings. The blower should be placed close to the pond at a height above the water level to prevent the reverse flow of water.

Fig.1.11 Nursery pond with aero-tube rings

Seasonal earthen pond of 200-1000 m^2 with a water depth of 70-100 cm is also used for seed rearing. The surrounding area of the pond is kept free from the dense growth of vegetation by frequent weed cutting using brush cutters. Seed rearing is also practiced in open water bodies by installing hapa or cage made of close-mesh netting.

Fig.1.12 Nursery rearing in hapa

Nursery pond preparation

Eradication of aquatic weeds, predatory and weed fishes and liming is done as explained in grow-out farming.

Live feed production

The outdoor nursery tank is filled with the filtered water, enriched with inorganic fertilizers (60 g ammonium sulphate, 10 g urea, and 10 g superphosphate in 1000 l water) and aerated well. Cowdung @2000 kg/ha or a mixture of 100 kg fermented (by yeast) groundnut oil cake, 200 kg cowdung and 75 kg single superphosphate per ha is also used.

In the early morning, microalgae (5-25µm) from the indoor lab are inoculated in the tank. They multiply and attain maximum density within 7 days and become ready to form food for zooplankton. Then it is inoculated with zoo-plankton such as freshwater rotifer (*Brachionus rubens*), copepods and cladocerans (*Daphnia* and *Moina*) at the rate of 2 no./ml from stock depending on the mouth size of the larvae to be fed (small: 50 – 100 µm or medium: 100 – 200 µm length). Zooplankton multiply and become suitable feed of the larvae of fish within 7 days. In larval rearing pond, the optimum level of plankton is 2 ml/50 l of water which should contain zooplankton at a level of 2-5 no./ml. Large copepod like *Cyclops* should be avoided. Pure stock culture of desired phytoplankton and zooplankton is specially maintained at the indoor laboratory for the continuous production of live feed organisms. A subsequent dose of cow dung is added at 125-500 kg/ha for every 3 days in accordance with the availability of plankton. Yeast is added as a food source for larvae, but it is mainly fed by zooplankton which is grown for larval culture.

Control of aquatic insect

Aquatic insects like *Notonecta, Ranatra*, and *Cybister* and nymph of *Dragonfly* cause substantial mortality to the hatchlings. Repeated dragging of the pond with fine-meshed net can remove the insects to some extent. Spraying of soap oil emulsion is an effective eradication method. Soap oil emulsion required for one hectare can be prepared by melting 18 kg washing soap in a small quantity of water by mild heating for a shortwhile and then 56 kg vegetable oil is added with constant stirring to form an emulsion. As the emulsion forms a layer at the water surface, it prevents the aerial respiration of insects, but there is no harmful effect on fish seeds or plankton. During calm and non-rainy days, the soap oil emulsion is applied 12-24 hours before stocking.

Stocking in the nursery

The 3-4 days old hatchling is stocked in the early morning or evening. Before releasing into the pond, it is acclimatized as explained in grow-out farming. The stocking density in cement tank provided with continuous aeration facility is 2500 no./m^2 for initial nursery rearing (3-4 days old hatchlings into fry stage) of 15-18 days and thereafter reduced to 1000 no./m^2 for the later nursery rearing (fry stage into fingerling stage) of 25-32 days. The stocking density of seed rearing in an earthen pond is 400 no./m^2 and that of hapa or cage installed in large water bodies is 2000-3000 no./m^3.

Feeding

Even though hatchling primarily grazes on natural feed organisms, supplementary feed having 40-45% protein is broadcasted all over the pond commencing from the first day of stocking. It is fed four times daily during day time with a supplementary feed consisting of finely powdered groundnut oil cake and rice bran fortified with vitamins, minerals and micronutrients. Feed probiotic is also given. The quantity of feed is determined as per the quantity given in Table 1.3 and also based on the regular monitoring during consumption of feed.

Table 1.3 Feed requirement

DPH	Feed size (mm)	Daily requirement/ one lakh spawn
4 -12	0.10 mm	0.5 kg
13-20	0.30 mm	1.0 kg
21-30	0.60 mm	2.0 kg
31-40	0.60 mm	3.0 kg
41-50	0.80 mm	4.0kg
51-60	0.80 mm	5.0 kg

Care and maintenance

Initially the young one has less mobility; hence the water depth is maintained at 40-60 cm at the time of stocking, so that it can find the live feed organism easily. After 4 days, the water depth is slowly increased by 3-5 cm daily. Water quality parameters like pH, hydrogen sulphide, ammonia, nitrite and nitrate are monitored with the help of testing kits. Also, instruments such as 'Secchi disc' for water transparency and DO meter for dissolved oxygen are used. Reduction of DO and build up of ammonia or other toxic substances in the pond are managed by aeration. Continuous sprinkling or exchange of water is preferred, if sufficient quantity of good quality water is available. Water probiotic is used to maintain the water quality during the scarcity of water. In order to condition the bottom soil, application of soil probiotic is also preferred. The hatchery operation may be hindered by power failures, which affect the aeration and water exchange and thereby survival. It may be overcome using diesel-powered power generator.

Harvesting of seed

When the fish seed attains a size of more than 40mm (1g), it is harvested using net having a mesh size of 2mm. The average survival rate of initial nursery phase is 40% and that of later nursery phase is 75%. The harvested seed is starved for one day prior to packing to empty the gut and kept in crowded condition to make it accustomed to the conditions of transport. Usually, conditioning of seed is done in hapa made of mosquito net kept in pond or plastic pool for 12-16 hours at 2000-3000 no./m^3. Frequent splashing of water should be done during conditioning.

Packing & transportation

Fish seed can be transported in an open or closed container. In the open system, the seed is usually transported for long distance in 1-3 t plastic tanks with oxygenation or aeration facility. A cylinder of 340 cm^3 capacity is required to provide oxygen supply to one-tonne tank per hour. 8 - 10 kg of fish seed can be transported in one-tonne tank with water.

The closed system is a common method of seed transportation where polythene bag of 16-18 l capacity is used. After filling one-third of the bag with clean water and transferring the seed, the bag is inflated with oxygen in high pressure from a cylinder to fill the remaining two-third of the bag. The upper 10-15 cm of the bag is twisted, tied airtightly and transported in plastic crates. Packing in a double layered bag is practiced to prevent damage during transportation. Bag of 60-80 µm thickness is used for packing egg, spawn, fry and fingerling and that of advanced fingerling is100-150 µm. During transport, ice packets are used between the bags to maintain the temperature. Hatchlings of about 20,000-40,000 numbers can be packed and transported in a bag for 6-12 hours. For 12 hours transportation in a closed bag, the fish seed of 2 cm size is packed @ 1500 numbers, 4 cm size @ 300 numbers, 6 cm size @ 120 numbers and 8 cm size @ 50 numbers.

COMPOSITE CULTURE IN POND

Composite culture means the farming of different species of fishes, which are fast-growing, compatible and having different feeding niches in a single pond, to obtain the maximum yield. Farming of the IMC with Chinese carp and common carp in a pond is an excellent practice of composite fish culture.

Site selection & pond construction

Availability of water, electricity, transportation and marketing facilities should be considered while selecting a site. Polluted areas should be avoided. Clayey loam soil having good water retention capacity is ideal for pond construction. Rectangular pond having an area of 0.05-2 ha with a water depth of 1-2 m is preferred. There is an elevated edge of minimum 30 cm around the pond to prevent the entry of water run-off during rain. The slope of the bund ranges between 1:1(clayey soil) to 1:3(sandy soil). For proper water exchange, inlet and outlet are installed at diagonally opposite corners of the pond. The long side of the rectangular pond is preferably constructed in parallel to the prevailing wind direction. The pond is covered with 100 mm mesh size net to control predatory birds. The side of the pond is fenced with a stiff net of 26 mm mesh size to prevent the entry of predatory animals such as frog, snake and tortoise and the escape of stock during a flood.

Preparation of pond

The pond is drained completely and dried properly till cracks appear on the pond bottom (usually 15 days). Ploughing is done for tilling the soil to a depth of 30 cm which increases the fertility of the soil. Feeding area, corner and side ditch in the pond is tilled and dried properly to avoid the formation of black soil. The bund is strengthened and the pipe or sluice gate is fitted with close-meshed net to regulate water intake and outflow.

Eradication of aquatic weeds

Aquatic weed reduces the living space and obstructs the free movement of fish and harbours insects which are harmful. It utilizes the available nutrients in the water and causes oxygen depletion during the night. Hence, the aquatic weeds in the pond should be removed manually by handpicking and uprooting. Herbicides like 2,4-dicholorophenoxy acetic acid at 4.5-6.7 kg/ha is used to control floating and emergent weeds and simazine at 6 kg/ha for submerged weeds, but it is not usually advisable.

Eradication of predatory and weed fishes

Predatory fish prey upon the fish seed while weed fish compete for food, shelter and DO. Hence, the predatory and weed fishes present in the nursery pond are removed by dewatering, repeated netting with small-sized mesh (mosquito net), drying and application of fish toxicants. Mahua oil cake (4-6% saponin) at 2500 kg/ha/m kills the fish in 3-10 hours and its toxicity in water lasts for 2-3 days. Ammonium sulphate at 600 kg/ha/m along with quicklime at 1500 kg/ha/m is used to kill all animals, including crustaceans. However, chlorination of pond water at 35ppm using bleaching powder (30% active chlorine) is more effective, but never let-out treated water from the pond into open water body. Chlorination also destroys microbes and parasites in the soil.

Rectification of pH

The pH of soil and water of the pond is checked and rectified by using lime, one week prior to the manuring to accelerate its mineralization. Agricultural lime is usually added to the soil to control the acidity, and its doses with respect to soil pH are given below,

4.0-4.5 pH	: 1000 kg/ha
4.5-5.5 pH	: 750 kg/ha
5.5-6.5 pH	: 500 kg/ha
6.5-7.5 pH	: 250 kg/ha

Fig.1.13 Fish pond after liming

The lime also acts as a disinfectant by killing microbes and parasites and helps to control the bad effects of humic acid or sulphuric acid, if present. Application of dolomite at 200 kg/ha is ideal for stabilizing the soil pH. In highly alkaline soil (>pH 9), gypsum at 1-10 ppm is applied to rectify the soil pH.

Manuring

To ensure optimum production of plankton, manuring the pond with organic fertilizers such as cattle dung at 2,000-2,500 kg/ha or poultry droppings at 500 kg/ha is applied as an initial dose, 10-15 days prior to stocking. If mahua oil cake is used as the fish toxicant, application of fertilizer can be reduced by half. After 10-15 days of manuring, the colour of pond water turns brownish-green due to the development of both phytoplankton and zooplankton which indicates that the pond is ready for stocking.

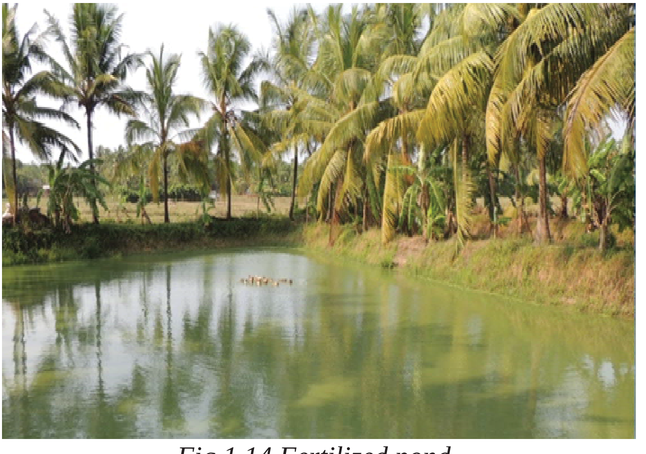

Fig.1.14 Fertilized pond

Water quality parameters

Optimum water quality parameters are given below,

Temperature	: 27-32^{0}C	Alkalinity	: 80-120 ppm
Salinity	: <5 ppt	TNA	: <0.01 ppm
Transparency	: 25-30 cm	NH_4N	: 0.08-0.2 ppm
pH	: 7.5-8.5	NO_3N	: 0.04-0.08 ppm
DO	: >4ppm	P_2O_5	: 0.04-0.1 ppm
Free CO_2	: <5 ppm	Iron	: <0.3 ppm

Stocking

The pond is filled with a minimum water level of 1m prior to seed stocking. At first, the seed is acclimatized to pond water temperature by keeping the seed bag in the same pond for 30 minutes. Then the bag is opened and allowed the slow entry of pond water into it, which helps the seed to get accustom to other water quality parameters. Gradually, the seed swims out voluntarily to pond water.

The stocking density of carps is 0.3-1 no./m^2 depending on system of management. In the case of ponds which cannot be drained to remove the predators, the fish seed of 4 cm is stocked in cage, hapa or pen installed in the same pond for further rearing to attain a size of 10 cm over a period of 30-45 days in order to enhance survival rate. In such cases, stocking density of fry for rearing is 100 no./m^2 for pen and 250 no./m^3 for cage and hapa. Separate earthen pond or tank can also be used for further rearing of seed.

Fig.1.15 Acclimatisation of seed

Fig.1.16 Seed rearing in hapa

In composite culture practice, various species of carps are stocked together. The proportion of catla and silver carp is stocked at 30-40% while the ratio of mrigal and common carp is 25-35%. The ratio of rohu ranges 15-30% based on the water depth. Grass carp is stocked at the rate of 5-10% based on the availability of vegetation. In the case of carp culture with high stocking density of 0.5-1 no./m^2, the ratio of any one species can be enhanced up to 60%. Continuous crops can be taken by keeping another set as stunted fingerlings in cage or pen installed in the same pond. After the harvest of the first crop, the stunted fingerlings can be released into the grow-out pond for second crop. When the stunted fingerlings are used, they show faster growth rate.

Feeding

If the natural feed is available in sufficient quantity by manuring, supplementary feeding can be avoided for the first 3 months of grow-out farming. It can be reduced by 50% for the remaining farming period, which reduces the production cost drastically. In such cases, supplementary feeding with floating pelleted feed having 25-30% protein is ideal for carps, and it is given in the morning at 5% of the bodyweight initially and subsequently reduced to 1% during the last month of culture. Supplementary feeding should be meticulous as excess feeding not only pollutes the pond environment but also escalates the cost of production. The quantity of feed requirement is given in

Table 1.4, but it can be modified based on the growth rate of fish and availability of natural feed organisms.

Table 1.4 Feed requirement

ABW (g)	Protein content (%)	Feed size (mm)	Daily feeding rate (% of ABW)
3-5	34	0.8	5
5-25	32	1.2	4
25-100	28	1.8	3
100-250	24	3.0	3
250-500	24	4.0	2
500-750	24	6.0	2
>750	22	6.0	1

If the natural feed is not available in the pond as in the case of intensive farming, the fish is fed twice daily (morning and evening) at 10% of the body weight initially, and it is gradually reduced to 2% of the bodyweight in the final stage. An appropriate feed storage facility, shall be provided with ventilation to manage humidity. The feed bag is stacked on raised wooden platforms without touching the walls to avoid mould growth. The feed should be used within three months from the date of manufacture.

A wet mixture of groundnut oil cake and rice bran in the ratio of 1:1 is the conventional feed for carps which is given as large balls in trays placed at different areas of the pond. Wheat powder, tapioca powder, *etc*. are also used as feed. Grass carp are fed initially with aquatic plants like *Wolffia*, *Lemna* and *Spirodela* and later with terrestrial grass (*Rye*, *Sudan* and *Napier*).

Care and maintenance

Freshwater is added intermittently to maintain a water depth of 1-2m. Chances for a drop in pH is controlled by adding agricultural lime on the inner sides of bund at 250 kg/ha. Cowdung is applied fortnightly at 250-500 kg/ha along with 20 kg/ha superphosphate and 15 kg/ha urea. Pond stocked with grass carp need not be manured regularly. The N:P ratio of 2:1 to 4:1 and C:N ratio of 10:1 to 20:1 in pond sediments are ideal for ensuring sustainable production of live feed organisms.

If there is an incidence of algal bloom, heavy rain or any other adverse condition, feeding should be reduced or suspended. If the colour of the pond water turns into pale white, red or dark green, water is exchanged immediately. Paddle-wheel-aerator at 2 hp/ha is used, if production of more than 5-6 t/ha is anticipated. Growth assessment is carried out monthly by cast netting.

Routine checking of fish health, at least fortnightly, helps to prevent massive loss of stock. Fish health is checked by observing the response of fish while feeding. Signs of ill health include surfacing, lesion, rash, spot, lump, excessive mucus formation, fin and tail erosion and poor intake of feed. The health of the fish is assured through proper water quality maintenance, nutritionally balanced diet and reduced handling stress.

Harvesting

Harvesting is done during cool morning hours. Partial harvest is done by seine netting or cast netting. Supplementary feeding is stopped 2 days prior to harvest. The final harvest is done during the morning hours by repeated drag netting followed by draining the pond. Within a culture period of 8-10 months, a fish production of 6 t/ha is expected. During this period, carps attain the sizes of 1100 g for catla and grass carp, 1000 g for rohu and silver carp and 900 g for mrigal and common carp. Marketing facilities should be assured before harvesting the fish.

FARMING IN PEN

A pen is erected in shallow protected area of the water body having required water level during the period of operation.

Site selection

The site must be safe from strong wind, current and wave action and free from pollution and anthropological activity. The ideal site should have a depth of not less than 1m during summer and not more than 2 m when the water level reaches the maximum level.

Construction of Pen

It is constructed with good quality bamboo poles and nets of suitable mesh size. The upper end of the pen should be at least 50 cm above the maximum possible water level. Once the site is selected, the boundary is marked with rope where poles are to be erected. Along the boundary, a trench of 30x30cm is made and poles are thrust deep 1 m apart into the trench, so as to remain firmly during the culture period. It is strengthened with horizontal poles. Then the net having 10 mm mesh size is firmly tied to the pole from one end. The bottom end of the net is wrapped and stitched to another pole and placed horizontally into the trench from inside and filled with soil. The free top end of the netting is tied firmly to the top of the pole.

Fig.1.17 Construction of Pen

Stocking

After proper acclimatisation, seeds having 6 cm size are stocked at1-2 no./m^2 depending on water flow.

Feeding

Regular feeding is done twice daily with a formulated floating pelleted feed. The protein content, feed size and daily feeding rate are given in Table-1.5. The daily feed requirement is calculated as the product of the number of fish, survival rate, average body weight and feeding rate.

Table 1.5 Feed requirement

ABW (g)	Protein content (%)	Feed size (mm)	Daily feeding rate (% of ABW)
3-5	34	0.8	10
5-25	32	1.2	8
25-100	28	1.8	6
100-250	24	3.0	5
250-500	24	4.0	4
500-750	24	6.0	3
>750	22	6.0	2

Care and maintenance

Here more care is required as the stocking density is high. Twice in a week, the pen net is cleaned with a soft brush to remove the macrophyte, dirt and any fouling organism and to ensure proper water flow. Any damage to the net is rectified immediately. Small damages can lead to the escape of fish stocked or entry of predator, which may result in huge loss. Once in a month, growth of fish is monitored by taking length and weight of the stock; and the feeding rate and time of harvest is determined accordingly. Water quality parameters are also checked regularly. Carps in pen culture established in open water bodies require full time watch and ward.

Harvesting

A production of 8-16 t/ha can be expected from one crop. Other aspects of harvesting are similar to those of pond farming.

STOCK ENHANCEMENT

Seed stocking

Stock enhancement is practiced in large freshwater enclosures like reservoirs, lakes and public irrigation ponds. Large open waters harbour lot of predators; hence advanced fingerlings of 10 cm size are stocked which give better survival. In general, advanced fingerlings are stocked at 2000 no./ha for small water bodies and reservoirs (upto 500 ha) and 1000 no./ha for medium and large reservoirs.The seed is acclimatized and released into the water body during morning hours. In small water bodies and reservoirs where water level drastically falls during summer, stocking should be done during monsoon so that maximum time is obtained for growth. In the medium and large reservoirs, stocking is possible year-round at regular interval.

Care and maintenance

Once the seed is stocked, regular inspection is done to assess the growth and health of the fish. Care should be taken to prevent juvenile fishing. In large and medium reservoir where natural recruitment is possible, a total fishing ban should be declared during the breeding season, and the natural breeding ground should be identified and protected. The physical, chemical and biological parameters of the system shall be checked periodically and recorded. There is no feeding, manuring or other farming techniques to be followed.

Harvesting

The gear used for selective fishing is a large meshed gill net. The small mesh sized net destroys the juveniles stocked in the system. Harvesting can be done on a daily basis when the fish attains the marketable size of 1 kg.

INTEGRATED FISH FARMING

Under the integrated fish farming system, fish culture is integrated with livestock such as duck, chickens, pig, cattle, goat and rabbit and agricultural crops such as rice, banana, vegetable and coconut thereby producing fish, meat, milk, egg and agricultural crops under one interlinked system for the integrated production, management and full use of resources. Here, the animal manure replaces the commercial feed for fish farming, thereby reducing the production cost.

Duck-fish farming

Duck house is constructed above the pond or dike using bamboo split and cheaply available wood. Floating duck cage is also constructed on empty barrels. During day time, the duck is allowed to scavenge in the pond freely. Suitable duck varieties are ‘*Indian runner*’ and ‘*Kakki kambel*’. Vaccinated ducklings having the age of 15-20 days are selected for rearing at 200-300 no./ha. Carp seeds are stocked at 7500 no./ha having the size of more than 10 cm. Otherwise, small fish may be eaten-up by the duck. Duck feeds on aquatic weed, insect larva, earthworm, insect, snail, frog, tadpole, dragonfly *etc*. thus creating a safe environment for fish. The duck droppings contain organic matter (26.2%), nitrogen (0.9%), phosphorus (0.4%), potassium (0.6%) and calcium, which in turn provide essential nutrients to stimulate the growth of natural feed organisms for fish. As the duck droppings fall directly into the pond, uniform manuring is ensured. Ducks aerate the water while swimming and help in releasing nutrients from the soil, particularly when it agitates the shore areas of the pond. On an average, 4000 kg fish, 18,000 eggs and 500 kg meat can be produced over a period of 10-12 months from 1 ha area.

Fig.1.18 Duck -fish farming

Poultry-fish farming

Poultry shed is constructed above the water level using bamboo pole so that droppings fertilize the fish pond directly. The bird is kept in confinement without access to outside. One bird requires a living space of 0.3-0.4 m^2 inside the shed. In deep litter or battery system, the floor is covered with 10 cm thick layer of chopped straw, dry leaves, or groundnut shell. 'Rhode island red' or 'Leghorn birds' is preferred in the poultry-fish system because of its better growth rate and egg-laying capacity. The left over poultry feed, droppings, litter are used to sustain the biological productivity of the pond. One adult bird usually produces 25-30 kg of compost poultry droppings annually. Poultry droppings contain organic matter (25.5%), nitrogen (1.4%), phosphorus (0.8%) and potassium (0.6%). Poultry droppings @ 50 kg/ha/day is required, for which 500-1000 chicks have to be maintained in the farm.

Fig.1.19 Poultry- fish farming

Cattle-fish farming

Cowshed is constructed in the vicinity of pond so that the slurry is directly discharged into it, which results in increased plankton production. A cattle weighing 400 kg provides about 400 kg of dung and 3500 litres of urine annually. The dung contain 14% organic matter, 0.3% nitrogen, 0.2% phosphorus and 0.1% potassium while the urine contain 2.3% organic matter, 1% nitrogen, 0.1% phosphorus and 1.4% potassium. For 1 ha of pond, 5-6 numbers of cows provide adequate quantity of dung and urine. Non-digested feed present in the dung is consumed directly by fish. The BOD of cattle dung is very low as it is already decomposed by microbes in the ruminant chamber. On an average, 4 t fish and 9,000 l milk are expected over a period of one year from 1 ha area.

Fig.1.20 Cattle-fish farming

Goat-fish farming

The suitable goat varieties are '*Surti*', '*Deccani*', '*Osmanabadi*'and '*Malabari*'. Goat is kept on elevated, pond dyke under a full spread shade tree, to protect them from sunlight. Adequate space, proper ventilation, good drainage facility and plenty of light are provided in the shed. Goats should not be opted for a marshy and swampy farm. The solid excreta of the goat is rich in nitrogen (2-3%) along with organic matter (60-70%), phosphorus (1.5-1.8%) and pottasium (2.3-3%). As it takes more time to decompose, there will not be any problem to keep BOD at the safe level. A healthy goat weighing 20 kg produces 300-400 g excreta on daily basis. In order to sustain the biological productivity of the pond, 50-60 numbers of goats are needed per hectare.

Fig.1.21 Goat-fish farming

Pig-fish farming

It is one of the best integrated farming system in which the meat and fish are produced at a cheaper feed cost. The pig-sty is constructed over the pond in such a way that the wash-out can be directly drained into the pond. But there should be a provision to direct the same out of the pond when plankton production exceeds optimum level. Exotic breeds like *'White-Yorkshire', 'Landrace'* and *'Hampshire'* are suitable for integration with aquaculture. A living space of 3-4 m^2 per animal is required in the pig-sty. The dung contain 15% organic matter, 0.6% nitrogen, 0.5% phosphorus and 0.4% potassium while the urine contain 2.5% organic matter, 0.4% nitrogen, 0.1% phosphorus and 0.7% potassium. An adult pig (70-90 kg) excretes 500-600 kg of dung annually. To fertilize the pond 30-45 no. of pigs per ha are required. Pig can also be fed with aquatic plants. After 6-8 months, pig attains a marketable size of 60-90 kg.

Fig.1.22 Pig- fish farming

Rabbit-fish farming

Rabbit meat is comparatively low in fat content. Breeds like *Grey giant white, New Zealand White* and *Soviet Chinchilla* are suitable varieties. An adult rabbit produces 100 g excreta per day and the excreta contains organic matter (50-60%), nitrogen (2-3%),phosphorus (1-1.5%) and potassium (0.8-1.2%). The rabbit excreta contains 10 times more nitrogen than that of cow dung, releases nutrients gradually, helping to maintain high plankton production over a long period of time. Among the livestock, the rabbit has the highest reproduction rate. The rabbit cage is made of iron mesh net with roof sheet and installed over the dike close to the pond with a clearance of 2 feet from the top of the bundh. A floor space of 0.3 m^2 is required per rabbit for a healthy environment. The young one should not be let-out of the cage. Rabbit attains a slaughter size of 3-4 kg within 6 months.

Fig.1.23 Rabbit-fish farming

Rice-fish farming

In certain areas, paddy cultivation is limited to one crop per year, and the area remains fallow for the rest of the months. Fish farming in rice field provides off-season occupation and additional income. It needs a little modification of rice field such as digging of the peripheral trench, construction of nursery pond and strengthening of dyke. Under this system, the excessive growth of plankton, insect, mollusc and submerged and floating weeds are controlled by fish; otherwise, it adversely affects the rice cultivation. The faecal matter of fish fertilizes the field. Rice-fish farming can be done simultaneously or alternatively. In the simultaneous method, minimum water depth of 60 cm is maintained throughout the year, and the fish is kept in trenches during paddy cultivation. After paddy harvest, entire field is filled with more water upto a height of 1 m for smooth progress of fish culture.

In alternate/rotational culture, fish seed is initially stocked in nursery pond (requires 1% of field area) constructed in the field for the production of stunted seed of 50-100 g. One or two weeks after rice harvest, the field is prepared for fish culture and the stunted seeds are released at 3000 no./ha for grow-out rearing. One-third of total seeds shall be grass carp. The fish attains marketable size of 1 kg within 6 months.

Fig.1.24 Simultaneous rice-fish farming

Fig.1.25 Nursery rearing for rice-fish farming

Horticulture-fish farming

The top, inner and outer dyke of the pond, as well as the adjacent space, is utilized for dwarf variety horticulture crop. The silt removed from the pond bottom rich in nutrients is used for horticulture crops. The residues of horticulture crop are given to fishes, particularly when stocked with grass carp and common carp. The pond water can be used for irrigation purposes.

Fig.1.26 Banana-fish farming

Coconut-fish farming

When coconut is cultivated in rows in wetlands, ditches not less than 70 cm in depth are made between such rows which act as supply or drainage canal. These canals serve as fish culture system owing to its round-the-clock water supply and rich insect population.

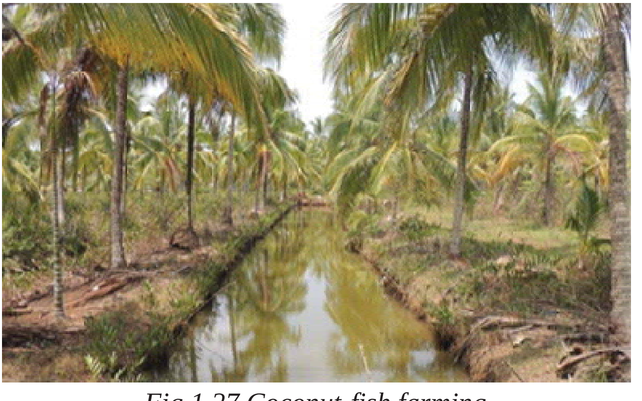

Fig.1.27 Coconut-fish farming

CHAPTER: 2

NILE TILAPIA

Tilapia is a euryhaline fish which can be grown under different culture methods like the pond, cage, biofloc tank, aquaponics and re-circulatory system. It thrives well in shallow freshwater habitats. Owing to its easiness in seed production, hardy nature and adaptability to various habitats, it has got wide popularity in the world aquaculture scenario. It has the second position in global freshwater aquaculture production. It is a prolific breeder which attains sexual maturity in three months. In the natural environment, it overpopulates the habitat, resulting in stunted growth.

Fig.2.1 Oreochromis niloticus

Tilapia is an omnivore which feeds mainly on phytoplankton, periphyton, aquatic plants, small invertebrates, benthic fauna and detritus. It can digest and assimilate plant protein. Even though tilapia mainly feeds by grazing on periphyton mats; it also feeds on entrapped suspended particles by filtration.

Tilapia breeds through-out the year as it has an asynchronous type of ovary with oocytes of different stages of development at a time. It is a nest builder, where the male establishes a territory, digs a spawning nest and guards his territory. The male then courts mature females one after other for spawning. The female spawns in the nest; picks up fertilised eggs immediately and holds it in its buccal cavity for incubation. The female carries the hatchlings there until the yolk sac is absorbed. During this time, the female eats a little or nothing. Both parents show parental care. Even if the fry are released from the buccal cavity, they will swim back when under threat.

'National committee on the introduction of exotic aquatic species' has approved the import of Nile tilapia (*Oreochromis niloticus*) to India during 2006 and its farming was approved during 2011. Nile tilapia farms shall be located in an area which is not prone to floods or in a buffer zone around a declared sanctuary or bio-reserve or other vulnerable areas to avoid escape to the open water bodies. In bio-secure farm, tilapia farming can be done using all-male or sterile improved strains or hybrid seeds, after obtaining registration and license from Department of Fisheries, following the guidelines issued. The *Genetically Improved Farmed Tilapia* (GIFT) and *Chitralada,* are advanced strains developed through the selective breeding of several generations of Nile tilapia by the World fish centre, Malaysia and Asian institute of technology, Thailand recpectively. Strains such as *Big-nin, Nam-sai, Super-red* and *Super-black* are also available.

SEED PRODUCTION

Broodstock management

Healthy and uniform sized pair having a size range of 150-250 g without any deformities are selected as brood. In mature tilapia, sexual dimorphism is evident and is easily distinguished by visual examination of the urinogenital papillae. The adult male has a conspicuous red, blue or black colouration with white or bright dorsal and caudal fin margins, while in female colouration is less. The mature female is distinguished by its soft belly with pink coloured genital pore. The genital papilla in male tilapia has only one opening (urinogenital aperture); while the female has two openings.

The male and female broodfish are separately maintained for 2-3 weeks in hapa (3 x 3 x 1 m) at a rate of 10 no./m^2 and fed three times daily at 2-3% of the body weight with floating pelleted feed having 30% protein. To prevent injuries during mating, upper lip of the male is clipped. Before removing upper lips, male is anaesthetised by using 50 ppm clove oil. After mouth clipping, the wound is disinfected with 10% betadine solution.

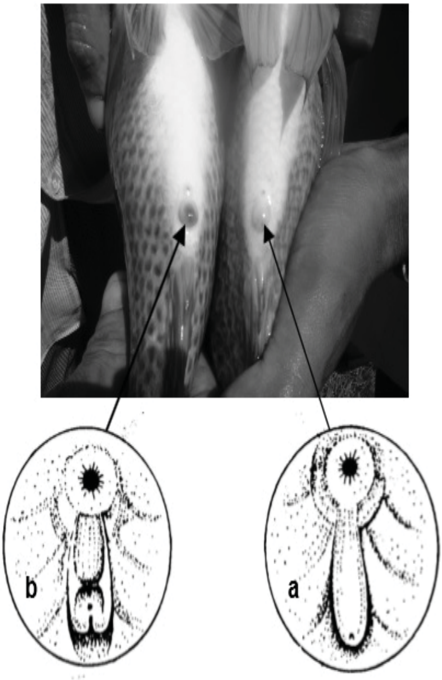

Fig. 2.2 a) Mature male   b) Mature female

(Courtesy: Farming of Tilapia, Hussain, 2004)

Fig. 2.3 Mouth clipping (Courtesy: RGCA)

Spawning

Hormone injection is not used in tilapia to induce spawning. Brooders are stocked at a density of 1-2 no./m^2 in breeding hapa (10 x 3 x 1 m) with a top covering. The ideal ratio of male to female is 1:3 or 1:2 by number. They are fed twice at 1% of the body weight with a feed having 32% protein supplemented with vitamin C, vitamin E and minerals. Even if inside the hapa, the male exhibits digging movements. After a period of courtship, the male chooses the ripest female, and the spawning and fertilisation takes place in the breeding hapa. The male then chooses another ripe female and spawning continues. A female usually spawns 6-12 times in a year with an interval of 10-30 days. If fecundity is reduced, the spent fish is separated by sex and given rest.

Fig. 2.4 Egg collection (Courtesy: RGCA)

After lowering the water level of pond to 60 cm, the breeding hapa and buccal cavity of female is checked individually in every 7-10 days for fertilised eggs and collected carefully into a basin. The wide time gap for egg collection usually results in the production of hatched out fry, which is undesirable for hormone treatment. The ideal time for egg collection is early morning to reduce stress. The collected eggs are separated from unwanted debris, measured volumetrically (2 lakh no./l), cleaned in water and disinfected with 3 ppt brine. Usually, the fecundity is 350-600 no./fish. A small female, produces less number of eggs, which are smaller in size but spawns more frequently. The fertilised egg of tilapia is large yolky, non-adhesive and pale yellow/orange in colour. It is ovoid with 1-2 mm and 1.5-2 mm diameter.

Incubation

The fertilised eggs collected from the breeding hapa are incubated in the indoor round-bottomed jar (10-30 l capacity) which holds eggs at a rate of 1000 no./ l. It is provided with an inlet pipe from the bottom at the centre and an outlet pipe at the top. In the jar, there is a continuous water flow of 2-3 l/hr. It helps to avoid damage to chorion and subsequent loss due to attack by microbes. The hatching takes place within 2-3 days at 30 ^{0}C. Fertilised egg, after passing through several embryonic phases, develops into free-swimming fry by 4-6th day. The out-flowing water from the jar is screened through a net, which enables the collection of hatchlings. The water for incubation is screened for sediments and filtered through a slow sand filter, pressure sand filter, cartridge filter, and UV steriliser/ozoniser. The discharged water is recycled for further use, after storing in a small separate over-head-tank.

Fig. 2.5 Incubation unit

Indoor rearing and sex reversal

Soon after collecting the free-swimming larva from the incubation jar, it is graded by using 3.2 mm mesh material to remove those larvae having more than 14 mm size. The larvae are stocked at 4-10 no./l in indoor FRP tank (2 t capacity) having 60 cm height. As tilapia is a prolific breeder and the male grows twice as fast as female, all-male population is preffered for farming, for which sex reversal of female into phenotypic male is an effective solution. All male population is achieved by the administration of 17α-methyl-testosterone, a synthetic male sex hormone, through feed for 21-28 days to all young ones. A quantity of 60 mg hormone is dissolved in 200 ml ethanol (95-100%) and mixed thoroughly with 1 kg feed until it is moist. After evaporating the alcohol, the moist feed is dried under shade and stored in dark and dry condition, as the hormone breaks down when exposed to sunlight or high temperature.

Fig.2.6 Indoor rearing

The hormone fortified micro-particulate feed of less than 500 µm size having 40-45% protein is continuously fed to the young ones of 1-28 dph. The initial daily feeding rate is 30% of the body weight, which is gradually reduced to 20%. The fry attains an average size of 0.4 g by 28 dph. The success rate of sex reversal is usually more than 95%. The water from the hormone-treated fish tank should not be discharged-out without proper effluent treatment.

Rearing of fry

After preparing the nursery pond as explained for the major carps, the hormone-treated fry is reared in outdoor tank at 1000-2500/m^2 for 30-40 days to attain a size of 1-3 g. It is fed 3-4 times daily with a micro-particulate feed having 40-45% protein of less than 500µm size at 20% of the body weight initially and thereafter 500-800µm size at 10% of the body weight. Daily 10-20% of the water is replaced.

Packing and transportation

The method followed is similar to that explained for major the carps.

FARMING IN CAGE

The water bodies that cannot be drained or seined, which are not suitable for pond aquaculture can be used for cage farming of fish. Cage farming facilitates easy and flexible management practices which include (i) close observation of fish for feeding response, growth and health, (ii) simultaneous keeping of different age groups in various cages for multiple harvest and continuous operation, (iii) possibility of demand harvest, and (iv) low harvesting expenses. The disadvantages of cage farming are that there is complete dependence on artificial diet and more risk of loss due to poor water quality, poaching and damage to cage net by predators or adverse climate.

Selection of site

Potential resources suitable for cage farming of Nile tilapia are freshwater bodies which hold a huge volume of water and non-drainable like reservoirs, lakes, quarries, *etc*. The site should not have any threat from strong wind, current and wave action. Transparency of water body may be 30-40 cm with a pH of 7 to 8. Farming of Nile tilapia in cage is permitted in reservoirs or any other open water bodies, only if tilapia already existed in that habitat.

Cage design

The dimensions and construction materials of cage vary widely with location. Waterbody with a minimum water depth of 4 m is suitable for installing floating GI cages. It consists of rectangular floating platform with 460 x 360 cm outer frame and 400 x 300 cm inner frame made of GI pipe of 1-1.5 inch diameter and 1.5 mm thickness, fabricated and held together with connecting rods and clamps. A handrail of 75 cm height is provided with the inner frame. The outer HDPE cage net of 460 x 360 x 280 cm size is tied with the outer frame, and the inner HDPE cage net of 400 x 300 x 325 cm size is hanged from the top of the handrail. Even though the depth of inner cage net is 325 cm, effective water depth is limited to 250 cm (75 cm freeboard up to the height of handrail). Initially, the mesh size and twine thickness of outer cage net are 18 mm and 1 mm respectively. Later it is enhanced to 36 mm mesh size and 2 mm twine thickness. The inner cage net is of 10 mm mesh size with 0.5 mm twine thickness followed by 18 mm mesh size with 1 mm twine thickness and after that 28 mm mesh size with 1.5 mm twine thickness. Ballasting with GI rod (1.5-2 cm thickness) having the dimension of 380 x 280 cm is done to ensure cuboid shape of the cage.

The cage raft is fabricated on a flat concrete floor or evenly levelled shore to achieve perfect alignment and better joining of pipes. It is better to fabricate the cage raft near to the shore for easy launching. The fabricated cages are towed to the pre-determined location and installed securely using multi-point mooring system with the help of synthetic ropes, sealed hollow floating barrels and anchors. Empty HDPE barrels of 6-8 numbers of 200 l capacity are used as floats, and concrete blocks are mostly used as anchors. A bird protection net of 10 cm mesh size is used as top cover. Different cages are set in open waters in battery alignment.

Fig. 2.7 Floating GI cages

Regarding reservoir, large HDPE floating cage of 100 m^3 (500 x 500 x 400 cm effective inner dimension) is installed in the protected area where the water depth is not less than 7 m so that there will be 3 m gap from the bottom of the cage to the bottom of the waterbody for facilitating sufficient room for water circulation. The components of the cage unit are floating frame, cage net, bird protection net, anchor and a workmen shed. The inner and outer cage net is hung from a floating platform made of HDPE block. The floating platform have a walkway for working personnel. The cage unit may have an outer protective net to prevent the entry of animal predators in the reservoir. The cage is anchored with strong ropes from diagonally opposite sides of the cage structure. Ballast pipe as per cage size is provided in each frame for maintaining the shape intact.

Fig. 2.8 Floating HDPE cages

The arrangement of cage unit is done in such a way that at least one side of a cage has access to open water which is done by arranging two rows of the cage in a line separated by a walkway. On one side of the unit, a workmen shed is built to store the feed, net, twine, rope, medicine, *etc*. and also for the security personnel. Adequate lighting, with solar power system is provided. A small canoe is required to transport personnel and material to the cage site.

Stocking

The seeds procured from a Government approved hatchery are stocked in inner rearing cages of 10 mm mesh size at a stocking density of 125 no./m^3 after acclimatisation and are reared for 6 weeks. As the fish attains a size of 35 g, it is graded by size and stocked in inner grow-out cages with 18 mm mesh size at a stocking density of 60-120 no./m^3 based on water quality parameters. As the fish attains a size of 100 g, it is graded by size again and stocked in inner grow-out cages with 28 mm mesh size. Grading is done by using nets of varying mesh size. Acrylic or metallic graders are also used.

Feeding

In the cage, the fish is fed with a formulated floating pelleted feed. Sampling is done weekly to assess growth rate and the feeding rate is adjusted accordingly. The feed is usually given twice daily during the dry season and four times in the rainy season. The protein content and size of feed and daily feeding rate are determined based on Table- 2.1.

Table 2.1 Feed requirement

ABW (g)	Protein content (%)	Feed size (mm)	Daily feeding rate (% of ABW)
3-5	34	0.8	10
5-25	32	1.2	8
25-100	28	1.8	6
100-250	24	3.0	4
250-400	24	4.0	3
>400	24	6.0	2

Care and maintenance

Constant care is given to the cage installed in open waters as it is often prone to poaching. During adverse weather condition, anchor rope should be checked. Once a week, the cage net is cleaned with soft brush to ensure proper water exchange. The cage net is examined frequently to check for any damages which can lead to intrusion of predators and crop loss.

The health of fish is examined fortnightly by taking it out using hand net. As tilapia is a hardy fish, the occurrence of disease is less. Water quality parameters are also checked regularly. Once in a month, fish growth is monitored to determine the feeding rate, followed by grading and thinning.

Table 2.2- Growth rate

DOC	Size of fish (g)
On stocking	3
45	10
90	100
120	200
140	300
160	400
180	500

Fig. 2.9 Cleaning of cage net

Harvesting

It depends on factors like the preferred market size and seasonal demand. If there is no uniformity in size, the stock that attains marketable size is harvested partially from 5th month onwards, and the remaining fish are allowed to grow further. Harvesting is done by lifting the cage and scooping-out the fish by hand net. Feeding is stopped one day before harvesting to allow the fish to empty its gut. With optimum feeding rate, Nile tilapia grows to attain 500 g within 5-6 months. A production of 25-50 kg/m^3 can be expected from one crop with a survival rate about 85%. It is possible to raise two crops in a year.

Fig. 2.10 Harvesting using a scoop net

AQUAPONICS SYSTEM

The aquaponics system is operated for high fish production from less area. Here, fish farming is integrated with the vegetable crop, by re-circulating the used water from the fish tank and bio-degrading the metabolite like ammonia into nitrate, which is utilised by plants. Simultaneous production of fish and vegetables using the same resources is the visible output of this practice. When compared to extensive pond farming, the requirement of water is merely 4% for unit production in this system.

Design

Circular, rectangular, square or oval-shaped tanks of different size are being used; however, 40 m^3 (5 x 5 x 1.6 m) fish tank with 120 m^2 vegetable beds is the most common. After excavating soil in the required dimension, a protective wall of one feet height is constructed by using hollow bricks at the top edge of the pit. At the bottom of the pit, a layer of cushioning material like hay is provided. After applying insecticide inside the pit, it is lined with polythene sheet of 500 gsm. In low-lying area where high ground water column exists, reinforcement with hollow bricks is given at the bottom and sides of the pit.

The level of DO, TAN and pH in a 40 m^3 fish tank is maintained at the optimum level through continuous water re-circulation with the help of two submersible water pumps (80-120 W) alternately and continuous aeration using two air pumps (90-140 W). An automatic generator (1 KV) or inverter is required as electric power back-up. Bio-fencing is given by covering the roof with UV resistant sheet and sides with orchid netting.

The water from the fish pond is pumped-out into the settlement tank and allowed to pass through a mechanical filter to separate solid waste. Then the water is passed through a bio-filter where the toxic nitrogenous waste like ammonia is converted into nitrite and nitrate by *Nitrosomonas* and *Nitrobacter* respectively. Then the water is allowed to flow intermittently using siphons over the gravel ($^3/_4$ inch size) arranged in the vegetable bed (30 cm height) where the nitrate contained in the water is utilised by the plants, and the water is again supplied back to the fish pond. The vegetable bed also acts as both a mechanical and a bio-filter. Vegetables like cabbage, cauliflower, amaranthus, mint, chilli, coriander, brinjal, eggplant, spinach and tomato are cultivated in the vegetable grow bed.

Fig. 2.11 Aquaponics system

Stocking

The seed of 4-6 cm is stocked after acclimatisation. The maximum allowable stocking density is 150 no./m^3. However, a stocking density of 100 no./m^3 is preferred for better growth rate and survival.

Feeding

Tilapia is fed with a formulated floating pelleted feed for 3-4 times per day. The protein content and size of feed and rate of feeding are determined based on Table- 2.1.

Water quality parameters

Water quality parameters such as DO, temperature, pH and transparency are monitored on daily basis. The level of TAN is checked at weekly intervals or periods of reduced feed consumption. Optimum water quality parameters are given below.

Temperature	: 24-30°C	DO	: >5 ppm
pH	: 6.5-7.5	TAN	: <0.1 ppm
Alkalinity	: 80-120 ppm	NO_2-N	: <0.01 ppm
Hardness	: 60-140 ppm	NO_3-N	: 5-150 ppm
CO_2	: <40 ppm		

Care and maintenance

The possibility of disease in RAS is limited. However, poor water quality management and increased handling stress may lead to diseases. At frequent intervals, the working of mechanical and bio-filter is examined, and then the filters, pumps and siphons are cleaned. Bio-filter is stirred or agitated occasionally to prevent clogging.

Harvesting

The fish grows to a harvestable size of 500 g within 5-6 months. However, partial harvesting is done from a size of 400 g onwards. Production of 40 kg/m^3 is obtained with a survival rate of 90%. Two crops can be raised in a year.

BIOFLOC AQUACULTURE SYSTEM

Biofloc aquaculture system is one of the most promising and affordable intensive aquaculture systems, which is ecologically, nutritionally and economically sustainable. The fundamental principle behind the biofloc system is the process of converting inorganic nitrogen into protein by the addition of an external carbon source. This system reduces the requirement of water and feed and thereby production cost. It also offers scope for high stocking density, improved productivity, bio-security and maximum nutrient utilisation though it requires good technical skill and high electric energy input. In biofloc aquaculture system, different strains of tilapia are found to be performing well in terms of yield and nutrient utilisation. Tilapia tolerates high stocking density and high amount of suspended solids and survives well under a zero water exchange-based system. For biofloc tilapia farming, registration and license should be obtained under Kerala Inland Fisheries and Aquaculture Act, 2010.

It is estimated that 75% of the nitrogen in the feed remains in the water as uneaten feed and through excretion of nitrogenous metabolites generated by fish which adds-up ammonia and nitrite in water which are toxic to fish. In Biofloc system, these nitrogenous compounds are assimilated by the consortia of heterotrophic bacteria under controlled conditions, which further form protein rich microbial diet to fish. The main constituents within the biofloc are the heterogeneous aggregates of extracellular polymeric substances with suspended organic particles to form a matrix that encapsulates the heterotrophic microorganisms of more than 2000 species which predominantly includes diatoms, macro-algae, bacteria and invertebrates. Usually, the density of biofloc will be 10^6-10^9 no./cm^3, and floc size varies from 100-250 μm depending on the extent of aeration. The microbial population is reported to have a protein content of 32-38% and can supplement up to 5-10% of the protein requirement of fish. So the feed protein requirement and the cost of feeding can be considerably reduced.

Biofloc unit design

In this system, a circular tank of 4-6 m diameter with 1.2 m peripheral height with a slope (25:1) towards the centre is ideal. The tank is placed on a levelled hard earthen or cemented platform. The tank is constructed with epoxy coated Galvanized Iron (GI) wire mesh of 4-5 mm thickness with a mesh size of 1-2 inch supported vertically with rectangular epoxy coated GI pipe (0.75 inch thickness and 18 gauge) at a distance of 3 m and horizontally with two circular ribs of steel rod having 8 mm thickness. In places having the possibility of rodent attack, the tank is constructed by using epoxy coated GI sheet of 2800 gsm (g/m^2) thickness supported vertically with rectangular epoxy coated GI pipe (0.75-inch thickness and 16 gauge) at a distance of 50 cm and horizontally with three circular ribs of aluminium beading with 1 inch width and 3 mm thickness. The horizontal ribs are arranged in such a way that one is placed at the inner top edge, the second one at the outer top edge and the third one at the outer middle. Inside the framework, cushioning material like polyfoam mat of 4-6 mm is placed at the bottom and all around the sides to protect the sheet from tearing and temperature fluctuations. Above the polyfoam mat, a polythene sheet (PVC coated HDPE/ nylon) having 1.5 m height with 550 gsm thickness is placed. Out of the 1.5 m height of polythene sheet, remaining 30 cm after covering the total height of the tank, is folded outward through the top surface of the tank and is tied with the outer, middle aluminium beading of the tank by using synthetic rope. The tank has a drainage pipe of 2-3 inch diameter at the bottom centre towards the side for ensuring sludge removal from the tank. A bush system arrangement with perforated pipe is provided inside the tank with the drain pipe. The drain has an outer opening at a height of 30 cm to discharge sludge and another opening to remove overflow water above 1 m height. The tank is provided with shade net roof to control sunlight. Additionally, it can also have a polyvinyl sheet above the shade net roof to prevent rainwater falling into the culture unit.

Fig. 2.12 Homested tank constructed with GI sheet

Each tank of 20 m^3 is provided with two air pumps of 120 l/min capacity each which requires less voltage for maintaining the DO and TAN at optimum level. It is advisable to connect the air pump or blowers in such a way that it takes care of any uncertainity related to damage of one blower for maintaining required aeration. The aeration unit has 8 independent points made with aeroxy tube (algal resistant) in the shape of rings (15 cm diameter) at the bottom. The air pump is connected to these aeroxy tube rings through PVC pipes (2 inch) followed by PVC reducers and garden hose ($^1/_2$ inch diameter). At the periphery 4 more air points (rings) is provided in the water column 30 cm above the bottom, in which non-clogged air stones are used instead of conventional air stones. The air supply through each point is maintained as 5 l/minute using regulators. Care should be taken to place the air pumps above the water level. No external filtration is provided with the system.

Usually, the operation of biofloc units are maintained on zero water exchange mode except for the replenishment of water which is done using a water pump (80-120 W) to compensate the water lost through sludge removal and evaporation. Power failure of more than 1 hr often leads to mass mortality of stock. Hence, there must be an automatic electric generator or inverter of sufficient capacity to ensure uninterrupted supply of electric power. The tanks are arranged in rows for easy operation of aeration, filling and drainage of water.

Due to the increased suspended solids concentration, earthen pond devoid of linning with polythene sheet is not suitable for biofloc culture system. Any polythene lined earthen pond up to 0.1 ha or cement tank with a central drain facility having a volume of 12-30 m^3 with suitable aeration arrangements is ideal. Cemented tank with side drain can also be considered. The pond has 1.2 m height at the periphery with a gradual bottom slope towards the centre so that it becomes 1.5 m height. Besides, there is a sludge collection pit of 60 x 60 x 30 cm at the centre, and it is connected with a drainage pipe. The pond is constructed by excavating the soil and has a protective bund of 60 cm height at the top edge. It is lined with polythene sheet of 550 gsm after applying insecticide and laying cushioning material. Waterlogged area should be avoided.

Two single-phase air pumps or air blower (roots type) of 1 hp capacity fitted with 16 pieces of aeroxy tube of half inch inner diameter (algal resistant) in the shape of rings of 30 cm diameter is required at the bottom for each 2 t fish for providing aeration continuously, to make the biofloc under suspension and also for maintaining the DO and TAN at the optimum level. Bio-fencing is given by covering the sides with orchid netting. To ensure better protection from rainwater and to reduce sunlight PVC sheet may be provided above the shade net.

Fig. 2.13 Biofloc pond

Water source

The tank is filled up to a height of 1 m with good quality water preferably from a well. If water from an open water source is used, it is chlorinated using sodium hypochlorite (35-50 ppm available chlorine) followed by de-chlorination after 24 hours of chlorination by vigorous aeration for 24-48 hours or by treatment with sodium thiosulphate. Check all the water quality parameters of source water in a certified laboratory. The parameters such as pH, alkalinity etc. need to be monitored. The heterotrophic bacterial growth is faster in preferred alkalinity of 80-100 ppm. If alkalinity is less, the required correction can be carried out by adding sodium bicarbonate @ 40 mg/l or dolomite @ 100 mg/l to the water.

Biofloc formation

Biofloc must be made ready before stocking, and for that, a suitable inoculum is developed and inoculated into the culture tank. If carbon source such as molasses, jaggery or rice bran is used for inoculum development, it needs to be fermented with yeast in the ratio of 100:1 with aeration for 24 hours before adding it into inoculum. For a 20 m^3 tank, 200 l inoculum is sufficient which is prepared in a covered barrel (250 l capacity having a wide mouth of not less than 50 cm diameter) under vigorous aeration using 3-4 air points.

After filling 200 l water in the barrel, add 4 kg of soil collected from an existing pond which has no history of any disease and the soil should have sufficient clay and silt portion rather than sand. 10-20 litres of slurry from adjacent biofloc unit can also be used for inoculum preparation. The soil can be partially dried under the shade and used as a seeding source for the bio-flocculating organisms and natural microbes. Complete drying or drying under direct sunlight should not be done as it destroys microbes in the soil. Along with the dried soil, add ammonium sulphate @ 10 mg/l (2 gm for 200 l) and fermented jaggery @ 200 mg/l (40 gm for 200 l) in to the barrel. Aerate the inoculum vigorously for 24-36 hours in the barrel. The inoculum is added to the tank @ 1 l per 100 l of culture water and aerated well. For inoculum preparation, only nitrogen fertilizer should be used and fish feed shall not be used.

The second day after inoculating the tank, it is added with nitrogen fertiliser (ammonium sulphate @ 0.5-3 mg/l). On the next day, fermented jaggery (fermented with yeast for 24 hours) is added as carbon source to maintain the prescribed Carbon: Nitrogen (C/N) ratio at 15:1 to 20:1 during initial days. During subsequent days, nitrogen fertiliser and the carbon source is added at a frequency of 2-3 days interval according to TAN level. When TAN exceeds 2 mg/l, additional carbon source is added with the above C/N ratio. High C/N ratio induces the assimilation of nitrogenous by-product by heterotrophic bacteria and hence ammonia control in culture tank can be achieved.

At first, autotrophs develop which will lead to green colour water followed by a transition phase where foam formation happens. The water will gradually turn into brown colour. The microorganisms develop naturally within 7 days, and thousands of heterotrophic organisms develop within 10-14 days.

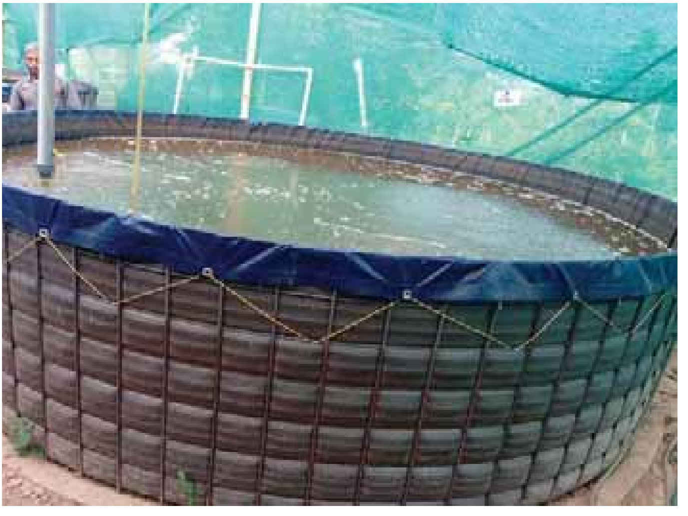

Fig. 2.14 Biofloc formation in tank

Stocking

The biofloc develops and reaches 5-10 ml/l within 10-14 days, and the system becomes ready for stocking. The floc volume is measured with the help of Imhoff cone after settling the water in it for 20-40 minutes, and the floc volume is expressed as ml/l. After PCR screening and proper acclimatisation, tilapia seed of 2-5 g size is stocked @ 50-100/m^3 in tank.

Feeding

Tilapia is fed 3-4 times daily with formulated floating pelleted feed in equal quantities as per Table 2.3. The feed is stored in airtight containers and kept in a moisture free environment to avoid any fungal infection. As the fish consume biofloc, the quantity of feed is reduced by 20-30%. The size and protein content of feed and daily feeding rate are given in Table 2.3, but it should be adjusted according to biofloc density. Biofloc system being efficient in providing in-situ protein to the fish with the FCR of 1.1-1.2

Table 2.3 Feed requirement

ABW (g)	**Protein content (%)**	**Feed size (mm)**	**Daily feeding rate (% of ABW)**
3-5	32	0.8	6
5-25	28	1.2	4
25-100	28	1.8	3
100-250	24	3.0	3
250-400	24	4.0	2
>400	20	6.0	2

If differential growth is observed, feeds of prescribed size for both small fish and large fish should be given together, preferably large fishes to be fed first followed by the small ones. In order to check aflatoxin poisoning, colour and smell of the feed should be monitored for each individual sack opened afresh.

Biofloc maintenance

Continuous and vigorous aeration is mandatory to keep the biofloc in suspension. The quantification of floc volume gives a reference to decide the quantity of sludge drainage. As the fish grows, the floc volume also increases in proportion to feeding. If floc volume exceeds 40 ml/l, the excess floc is discarded out through the drainage pipe with the help of a valve and an equal quantity of water is replenished. In the case of large units of more than 100 m^3, there should be separate provisions for handling and treating the sludge which is discharged from the unit. The sludge can be allowed to settle, and the supernatant water can be pumped back to the culture tanks. The sludge can be further dried and used as a fertilizer for any crop.

Fig. 2.15 Imhoff cone

The quantity of nitrogen generated in water is estimated by multiplying the quantity of feed given daily with a constant of $12x10^{-1}$ and percentage of protein content in the feed. The quantity of carbon source is determined by multiplying 10 with the quantity of nitrogen generated in water and dividing by the percentage of carbon content in the source. (If the fish is fed with 1 kg feed having 28% protein content, the nitrogenous metabolites contain 33.6 g N. As the molasses and jaggery (industrial quality) contain 50% carbon, its requirement is 672 g/kg feed). Moreover, it is advised to add vitamin-mineral mixture and probiotics once in a month during various stages of culture for enhanced production.

Water quality parameters like TAN need to be measured to plan the management protocol. TAN measurement is done once in 3 days during the initial 1 month and can be done once in 6 days later-on. Initial maintenance of C/N ratio is 15:1 to 20:1. It means, to remove 1 mg/l of TAN, the required carbon source is 15-20 mg/l. If the carbon sources are conventional (Jaggery, tapioca, etc.), they need to be added in double the amount should be added : ie, 30-40 mg/l. As the culture progresses, the C/N ratio is maintained at 6:1 to 10:1. Whatever be the carbon source, it should be free from any pathogens. Before addition to the culture pond, carbon sources like molasses, jaggery and rice bran require fermentation by yeast in 100:1 ratio.

Water quality parameters

The water quality parameters such as DO, temperature, pH, TAN, NO_2, NO_3, TSS and alkalinity are monitored on a daily basis initially and subsequently once in every three days or during reduced feed consumption. Collect one litre of water from two opposite points at a depth of 15 cm from the water column in between 10-11 a.m. for estimating water quality parameters. Optimum water quality parameters are given below.

Temperature	: 28-30°C	DO	: >4 ppm
pH	: 7-8.5	TAN	: <1 ppm
Alkalinity	: 100-120 ppm	NO_2-N	: <1 ppm
Hardness	: 60-140 ppm	TSS	: <500 ppm

In order to control alkalinity, either dolomite or sodium bicarbonate should be used. For low pH and high alkalinity dolomite wrapped in small bags can be deposited.

Care and maintenance

The fish is collected using scoop net and examined for health conditions. Morphometric measurements of 5-10 fishes are taken randomly using an electronic balance and stainless steel scale to estimate average body weight and length of fish and the quantity of feed is regulated accordingly. The microorganisms associated with biofloc thrive on metabolic waste, and thus the system becomes bio-secured. Hence, there is no water quality deterioration and entry of pathogen. If PCR screened seed is selected, the possibility of viral disease is limited. Never use a feed of more than 1 kg/m^3/day; in other words, the quantity of nitrogenous metabolites generated from the fish should not exceed 672 g/m^3/day. However, if the biofloc level exceeds the limit of 35 ml/l, feeding and addition of carbon source are reduced or even stopped for a few days till the system stabilises.

After stocking, the TAN level will increase steadily, which should be managed with the regular addition of carbon source in a frequency of 3-

4 days. Addition of excess carbon source leads to more solid accumulation and gill clogging of fish. Failure of proper aeration leads to crashing of the system. Inadequate addition of carbon source leads to the transformation of heterotrophic process to autotrophic, which slows down nitrification and intensive rearing may not be successful in such a system. More than I kg of carbon source should not be added at a time to the culture unit. As a thumb rule carbon source given should be half of the total feed quantity given for the 1st 3 weeks. In biofloc units culturing GIFT, salt addition is not required. If alkalinity is low, supernatant solution of dolomite can be added @ 100 mg/l. As far as possible, the use of commercial inoculum should be avoided.

Harvesting

The fish grows to a harvestable size of 350-500 g within 5-6 months. However, partial harvesting is done from a size of 350 g onwards. Production of 25-40 kg/m^3 is obtained with a survival rate of 80-90%. Being an exotic fish, Nile tilapia should not be marketed in live condition. It is marketed in fresh or iced condition, and there is a good demand for tilapia fillet and hence can explore the value addition in marketing. The advantage of a tank based system is that crop can be grown in different tanks at different time to ensure year-round continuous supply of fish which helps to overcome the fluctuating market demand and price. Two crops can be raised in a year.

FARMING IN POND

Site selection & pond construction

Nile tilapia farming in the earthen pond is more economical as it utilises the available natural feed organisms effectively. Tilapia farming is practised in the rectangular earthen pond having minimum water spread area of 0.05 ha with 1-1.5 m water depth. The slope of the pond dyke is 2:1, as tilapia digs soil which may easily weaken the bund. Bund height is high enough to avoid fish from escaping. The pond is provided with sufficient biosecurity measures including top cover with a net having a mesh size of 50 mm and side fencing with a stiff net of 26 mm.

The discharge water from the pond, if released into open water bodies, is screened with appropriate mesh size and treated, to prevent the escape of fish, eggs or fry into natural water bodies. Other aspects are the same as those of major carps.

Preparation of pond

The pond preparation steps such as de-siltation, bund strengthening, installation of water inlet and outlet, draining, drying, tilling, eradication of aquatic weeds, liming and manuring is followed similar to that of major carps. Use of bleaching powder is ideal for the removal of pathogen, predator and weed fish.

Water quality parameters

Temperature	: 24-36°C	DO	: >4 ppm
Transparency	: 30-40 cm	TAN	: <0.2 ppm
pH	: 7.5-8.5	NO_3N	: 0.04-0.08 ppm
Alkalinity	: 80-120 ppm	P_2O_5	: 0.04-0.1 ppm

Stocking

After the development of plankton, properly acclimatised seeds is stocked in cage, happa or pen installed in the same pond. The stocking density in the grow-out pond is 3-5 no./m^2.

Feeding

Nile tilapia consumes almost all kinds of commercial diet from the fry stage onwards. Formulated floating pelleted feed having 24-34% protein is given as supplementary feed at a rate of 6% of the bodyweight initially and subsequently reduced to 1% during the last month. Feed is given twice daily, in the morning and evening. The details of feed requirement, feed size and protein requirement is given in Table 2.3, but it may be regulated after examining the plankton production, health condition and growth rate of fish at frequent interval.

Care and maintenance

5-10% of the water in pond is replaced with fresh water fortnightly. Paddle-wheel-aerators (4 hp/ha) are installed to maintain water quality.

Intermittent application of agriculture lime, manure and other monitoring procedures are similar to that of major carps.

Harvesting

Feeding is stopped two days prior to harvest. Partial harvesting of large fish is usually done from 5th month onwards with a cast net. During complete harvest, the pond is dragged 3-4 times. A complete harvest is not possible by dragging alone as tilapia can escape from dragnet. Hence, the pond is drained to collect the remaining fish. After harvest, the pond is dried and chlorinated (35 ppm) to avoid the carry over of tilapia fry to the next production cycle. Harvested live fish is kept in clean running water for a day to reduce off-flavour (purging). In semi-intensive culture system, within a culture period of 5-6 months, fish production of 12 t is expected from one crop with a survival rate of 80%. By this period, Nile tilapia attains the size of 500 g.

CHAPTER: 3

MURRELS

The murrels are common air-breathing fishes available naturally in all types of freshwater bodies including marshy fields. They are commonly known as snakehead fish due to the elongated and cylindrical body, flattened head and anteriorly placed eyes on head. Murrels with aquaculture potential available in India are *Channa striatus* and *Channa marulius* which attain 1 kg by 6-8 months and grow in high density even in a tank of 40 m^2. They feed on insects, worms and small fishes. The flesh is whitish, hard with fewer spines and good flavour, which contains more protein and less fat. Murrels are known for their nutritional and medicinal value; especially for asthma and for convalescing patients and are believed to have wound healing property due to high content of arachidonic acid, glycine and polyunsaturated fatty acids in the flesh. Murrels have immense culture potential due to its fast growth rate, hardy nature, high consumer preference, lucrative market value and their ability to withstand adverse conditions.

Fig. 3.1 Channa striatus

Fig. 3.2 Channa marulius

Murrels survive in drought by aestivating for months in moist mud. They can live out of water for a long period, if covered with a wet cloth. They can tolerate salinity up to 12 ppt and annual temperature variation from 15^{0}C to 35^{0}C. Though sensitive to a sudden change in pH, they can survive in both acidic (down to pH 4) and alkaline waters (up to pH 9).

Murrels attain sexual maturity within 1-2 years and breed naturally throughout the year with a peak during monsoon season. They build a trough-like nest using vegetation in shallow marginal waters. The eggs float at the surface and are kept within the circle by the parents who guard them fiercely. They are highly predatory and exhibit cannibalism during early stages. As it hooks easily, it has excellent scope in sport fishing or angling tourism. In fry stage, the murrels are treated as ornamental fish owing to its beauty.

SEED PRODUCTION

Broodstock management

Pond design is same as that explained for pond farming of carp. The pond is prepared by de-siltation, bund strengthening, draining, drying, tilling, eradication of aquatic weeds, liming and manuring as explained for the major carps. Before breeding season, adult fish are procured during November-January period from farm or wild and disinfected by dip in 200 ppm formalin for 40 seconds and stocked in a pond at a density of 1-2 no/m^2. It is fed thrice daily at 5% of the body weight with a mixed diet containing animal and vegetable protein sources in the ratio 4:1. The animal protein sources comprise of forage fish, prawn waste, tadpole, beef liver and silkworm pupae.

Selection of brooder

Male and female fish are identified easily by external visual examination. Male has an oval head and dark body colour, rough pectoral fin, pale vent and prominent reddish genital papillae with a pointed tip, while the female is characterized by rounded head and light body colour with a soft swollen belly, round and reddish vent and broad and blunt anal papilla with reddish dots. When it attains sexual maturity, on applying gentle pressure on the belly, the male oozes milt and the female releases eggs. Physical condition and maturity stage of fishes are checked periodically to select them for spawning.

Spawning

A pair of conditioned male and female are selected and transferred to each breeding pond. The breeding pond can be a circular (4 m diameter) or square (4x4 m) earthen pond with 1.5 m depth or circular cement cistern of 2 m diameter provided with 15 cm thick layer of soil. No need of water circulation in breeding pond as it spawns successfully in stagnant freshwater. The breeding pond is covered with grass or floating aquatic weeds like water hyacinth to one-fifth of the water surface area to stimulate spawning by providing natural environment. The fish usually prefers to lay eggs in a nest made of aquatic vegetation. There should be at least two feet of free board in breeding pond with a net covering, to avoid jumping out of fish during spawning.

Usually, the pair spawns naturally in breeding pond or can also be induced to spawn by intramuscular injection at the base of pectoral fin of female and male fish with synthetic hormone like Wova-FH @ 0.6 ml/kg and 0.4 ml/kg body weight, respectively. Before spawning, they move in pair and chase each other. Spawning begins within 16-18 hours after injection. The spawning process extends for 15-25 minutes, and the eggs laid by the female in the nest are fertilised with the milt oozed by the male. The fertilised eggs are transparent spherical, non-adhesive, golden-yellow and freely float at the centre of the nest as a thin film while the unfertilised eggs are opaque/white. The egg mass is 6-14 cm in diameter. The size of the fertilised eggs range between 1.1-1.4 mm. Fecundity is 5000-15,000/kg bodyweight. The fertilization rate is 80%.

Incubation

Usually, the egg mass is allowed to be in the breeding pond for incubation and it hatches out within 16-20 hours. The parents, especially the male, guard the hatchlings. Hatching rate is 70-95%. In certain cases, the eggs are collected with the help of plankton net and kept in FRP tanks for hatching.

Rearing of hatchling

Three days are required for the complete absorption of yolk sac and formation of mouth. By this time, the hatchling attains a size of 3.5 mm and starts to swim freely and feeds on zooplankton. As the fish exhibits intensive parental care, the hatchling is allowed to stay with the parents and fed with live zooplankton dominated by *Moina* up to 10 dph and later with *Moina* and minced trash fish for a period of 10-20 dph. The young one attains 25 mm size in 20 dph with a survival rate of 50%.

Rearing of fry

The 20 dph fry is transferred to outdoor cement cistern of 2-4 m diameter and 75 cm depth at a stocking density of 25-75 no./m^2. It is fed with aquatic insects, tubifex worm, minced trash fish, prawn, chopped earthworm and powdered artificial feed (42- 44% protein) for a period of 20-30 dph and after that restricted to pelleted feed till 60 dph @ 10% of the bodyweight. Heterogeneity and cannibalism can be reduced by grading and high feeding rate. After two months, the fry attains 5-6 cm with a survival rate of 30%. Water should be completely removed after every batch of operation. Fry of each species have different colours and retain its colour up to 3 months. Fry of giant murrel has dark grey body and a lateral orange-yellow band from eye to the caudal fin while that of striped murrel has a bright red body with a reddish golden band and a dark black band from eye to the caudal fin.

Fig. 3.3 Fry of Giant Murrel

Fig. 3.4 Fry of Striped Murrel

Production of forage fish

Two months before the stocking of murrel, forage fishes like barb (3-5 cm size) and tilapia (5-7 cm size) are stocked at a density of 1000 each in a seperate earthen pond of 400 m^2 and it is manured with cow dung @ 500-1000 kg/ha/week to enhance plankton production for forage fish. The young-ones produced by the forage fishes are used to feed murrel.

Production of zooplankton

Moina is cultured in the same pond used for broodstock development. The pond is manured with a mixture of 300 kg groundnut oil cake, 2000 kg cow dung and 75 kg single super phosphate per ha and inoculum of *Moina* is poured into the pond. It is estimated that 150 kg of *Moina* can be collected in a day for giving to the young-ones in the rearing pond.

Health

The fry and fingerling may be affected with fin rot in the nursery. This can be controlled by giving a bath in 0.3% formalin solution for 10 minutes or till the fry and fingerlings show sign of distress.

Packing and transportation

The seeds are harvested when they attain a size of 60-80 mm. One day prior to that, feeding shall be stopped. Harvesting is done with a fine-meshed (2 mm) dragnet in cool morning hours. If the distance is less, seeds are transported in a perforated container by leaving enough space for its habitual breathing. Small amount of aquatic plants may be provided in the container to avoid fish seed from jumping out during transportation. If the distance is more, it is better to transport them in oxygen packed polythene container.

Fig. 3.5 Fingerling transportation

FARMING IN POND

Selection of pond

Rectangular earthen pond with 0.1 ha area and 1 m depth is ideal. The sides of the pond are fenced with pole and net up to a height of 90 cm to prevent the escape of fish by jumping and crawling through moist land. If the side bund of the earthen pond is weak, it should be lined with materials like polythene sheet. At the bottom of the pond, layer of mud should not be more than 15 cm.

Preparation of pond

The pond is prepared by desiltation, bund strengthening and installation of water inlet and outlet. Draining, drying, tilling, eradication of aquatic weeds and predators, liming, and manuring are done similar to that explained for the major carps.

Water quality parameters

Salinity : 0-5 ppt
pH : 7.5-8.2
Temp : 28-31^{0}C

Stocking

As cannibalism is high in the earlier stages, uniform-sized fingerlings having the size of 8 cm are stocked into the pond after acclimatisation at a density of 2 no./m^2.

Feeding

The weaned seed is fed twice daily at 2-10% of the body weight with a formulated feed (36-45% protein). It is also fed with trash fish, prawn waste, boiled slaughterhouse waste and silkworm pupae. The details of feed requirement, feed size and protein requirement are given in Table 3.1, but it can be modified according to the plankton production, health condition and growth rate of fish at frequent interval. The daily requirement of feed quantity is calculated by multiplying the number of fish seed stocked, survival rate, average body weight and feeding rate.

Table 3.1 Feed requirement

ABW (g)	Protein content (%)	Feed size (mm)	Daily feeding rate (% of ABW)
<5	45	0.8	10
5-20	40	1.2	8
20-100	40	1.8	5
100-500	36	2.5	4
500-1000	36	4.0	3
>1000	32	6.0	2

Care and maintenance

Murrels are generally hardy and tolerate organic pollution in derelict waters to some extent. However, the replacement of 10% of water fortnightly is ideal. Growth assessment is carried out monthly by cast netting. Intermittent application of agricultural lime, manure and other monitoring procedures are similar to that of the major carps. Incidence of the disease is not common, but there is a possibility of infestation by ectoparasites like *Lernea* and *Argulus*.

Harvesting

If the management practices are proper, murrels attain a growth of 1-1.5 kg within a culture period of 8-10 months. Partial harvesting is done by seining after lowering the water to 60 cm. Final harvesting is done during summer season after complete dewatering of the pond and picking them manually as the fish shows burrowing habit in the bottom mud. The fish can be kept in live condition out of water for a long time. Hence, it is transported and marketed in live state to distant markets and fetches high demand and decent price. The fish gets high market value, especially during festival seasons.

FARMING IN CAGE

HDPE floating cage (100 m^3) and GI floating cage(30 m^3) are generally used for murrel farming. Site selection and cage design are similar to that explained for the Nile tilapia. Advanced fingerlings of 8-10 cm size are stocked at a density of 80 no./m^3 and fed with a floating pelletted feed (36-45% protein) twice daily at 10% of the body weight initially and 2% at the final stage. Other aspects of cage farming are same to that explained for the Nile tilapia. The anticipated production is 64-80 kg/m^3/crop.

CHAPTER: 4

PANGASIUS CATFISH

The pangasius catfish, *Pangasianodon hypophthalmus,* is an exotic fresh water fish introduced in India during mid 90's. It is also known as iridescent shark, due to the typically attractive appearance during the juvenile stage, which has demand in the ornamental fish trade. It is a highly migratory benthopelagic riverine fish that makes long-distance migration between upstream spawning habitat and downstream feeding habitat. It is omnivorous; the early stages feed on algae, macro vegetation, zooplankton and insects while the adult also consumes fruits, crustaceans and fish.

Fig. 4.1 Pangasianodon hypophthalmus

It is a facultative air breathing fish, which can tolerate very low DO levels even to the tune of 0.1 ppm for short durations. Owing to its fast growth rate, hardy nature, good disease resistance and adaptability to high stocking density, it is considered as a potential species for intensive aquaculture and is at the third position in the freshwater aquaculture production. Pure white meat of the fish mainly sold as fillets is a major value added commodity throughout the world.

SEED PRODUCTION

Broodstock management

The broodstock pond is prepared as explained for the major carps. The adult fish collected from farms are stocked in earthen ponds of 0.1-

0.4 ha size at a stocking density of 5-10 t/ha. The fish are fed twice daily with a floating pelletted feed having 35% protein at a rate of 1% of the bodyweight or trash fish/ meat at a rate of 5% of the bodyweight. Three months before the breeding season, male and female fish are segregated, kept in separate ponds and provided with feed containing 1% vitamin premix. The male attains sexual maturity in the first year, whereas the female matures in 1-2 years depending on the photoperiodic cycle.

Spawning

Usually, spawning takes place during monsoon season. Sex can be distinguished by visual examination just prior to breeding season. The mature female has big, soft and distended belly with swollen and reddish pink vent, while the male has a reddish genital opening and oozes milt when the abdomen is pressed. The ripe ovum collected using catheter has yellowish colour. The mature fish are induced to spawn by injection using synthetic hormones like Wova-FH with a single dose of 2 ml/kg bodyweight for female and 1 ml/kg for male. The fish spawn as single pair or in groups. After injection, the fish are returned to the breeding pool and both sexes are dry stripped after 5-6 hours. One fish usually spawns twice in a season. The fecundity is 4-6 lakh/kg bodyweight. The fertilised egg is round, transparent, adhesive, and greenish-brown in colour. Tannin, skimmed milk powder or milk solution (7 ml milk in 1-litre water) is applied to remove the stickiness of eggs. The eggs are thoroughly rinsed with clean water, measured in a graduated bucket and kept for incubation with mild aeration.

Incubation

The fertilised eggs are incubated in round-bottomed conical-shaped transparent indoor jar (25-30 litre capacity) which holds about one litre of fertilised eggs (7.5 lakh numbers) and keep the eggs in suspension with the upward flow of water. The rate of water flow is regulated to keep the eggs in suspension. Other aspects are similar to that of incubation jar for the Nile tilapia. The egg usually hatches out within 22-26 hours at 28-30^{0}C and yolk sac absorption takes place within next two days. Hatching rate is often 40-60%. After 72 hours from fertilisation, the free swimming hatchlings are collected from the jar through overflown water with collection net. To avoid cannibalism, the hatchlings are transferred to nursery pond just before full yolk sac absorption. The water used for incubation is screened, filtered and re-cycled as explained for the Nile tilapia.

Nursery rearing

The earthen nursery pond of 0.1-0.4 ha size is ideal for rearing. After preparing the nursery pond as explained for the major carps, water is filled by filtering through a fine-meshed cloth followed by adding 2000 kg/ha cow dung, 300 kg/ha groundnut oil cake and 75 kg/ha superphosphate to augment the production of natural food organisms. The larvae are stocked in nursery pond at a rate of 100-125/m^2 just before yolk sac absorption. Any delay in transferring the hatchling to plankton enriched pond leads to mass mortality.

The free-swimming hatchling commences aggressive feeding and becomes highly cannibalistic from 72 hours of hatching. The larvae are fed 5-6 times daily with a mixed emulsion consisting of boiled egg yolk and fish/clam/shrimp meat till 14th day. It can be replaced with powdered rice flakes and groundnut oil cake powder (1:1) in dry form. Presence of rich population of *Moina* in the nursery pond reduces cannibalism substantially. Up to 8 dph, its daily feed can be partially replaced with earthworm powder. The larvae are weaned on a commercial micro-pelletted feed by 14 dph and continued till 28 dph. If adequate food is not provided, cannibalism will be significant. No water exchange is required but the evaporation loss should be replenished. It attains 8 cm size by 42 dph with a survival rate of 30%.

Packing and transportation

The seeds are harvested using a seine net after reducing the water level. Utmost care is taken when the seeds are harvested as it is highly sensitive to temperature. Conditioning, packing and transportation are carried-out similar to that of the major carps. Transpotation in large open container is preferred over closed polythene bag.

SEMI INTENSSIVE FARMING IN POND

Pond construction

The earthen pond of 0.05-2 ha size with a water depth of 1-2 m is ideal. The pond is covered on top with net having a mesh size of 50 mm and sides are fenced with a stiff net of 26 mm as a bio-security measure to prevent the intrusion of fish to the natural openwater bodies.

Preparation of pond

The desiltation, bund strengthening and installation of sluices are done similar to that of the major carps.The pond is drained completely, and the bottom is sun-dried so that cracks are developed, and it is tilled to expel the toxic gases. Chlorination with bleaching powder (35 ppm) is used for the removal of pathogens, predators and weed fishes. Only a nominal dose of agricultural lime (250 kg/ha) is required since the fish prefer neutral pH. Water is let-in through the water inlet covered with a fine meshed net to prevent the entry of fish and other organisms, and the water level is initially maintained at 50 cm. Cow dung @ 4,000 kg/ha or poultry droppings @ 1000 kg/ha is added to the pond 10-15 days prior to seed stocking for augmenting live feed organisms.

Stocking

After acclimatisation, uniform sized seeds of 8 cm are stocked and fed with pelletted feed at 5% of the bodyweight for a period of 2 months till they attain the size of 15-20 g. It is graded frequently, and shooters are removed to prevent cannibalism. The advanced fingerlings of 15-20 g are stocked at a density of 2-3/m^2 in the grow-out pond. The production of stunted seeds are also practiced by stocking them at a very high density in a separate small earthen pond and feeding at 2% of the bodyweight. It results in the production of stunted fingerlings weighing 100-150 g. When the stunted fingerlings are shifted to a large pond at normal stocking density, it grows at a faster rate.

Feeding

The fish is an omnivore which utilizes the entire column of water and accepts domestic food remains, rice bran, groundnut oil cake and formulated floating pelletted feed having 20-28% protein. For better flesh quality, it is fed with formulated pelleted feed alone. The fish is fed twice in a day during morning and evening. The daily ration during the initial days of the stocking is 6% of the bodyweight and it is gradually reduced to 1% towards the end of culture.

Care and maintenance

Fortnightly, 10-20% of the water in the pond is replaced with fresh water. Two paddle-wheel aerators of 2 hp capacity are installed per hectare of pond area to maintain water quality. Growth assessment is carried-out monthly by cast netting. Intermittent application of agricultural lime, manure and other monitoring procedures are similar to that of the major carps.

Harvesting

It attains a weight of 2 kg within 8-10 months. It is advisable to harvest large fish from 6^{th} month onwards. Otherwise, they may retard the growth of smaller ones. Starving the fish for 2-3 days prior to harvest improves the flesh quality. After harvest, the fish is chilled immediately. A high productivity of 30 to 50 t/ha can be expected in a crop.

INTENSIVE FARMING IN LINED POND

Pond construction

It is usually practised in small homestead pond of 80 m^2 lined with polythene sheet. In soil allowing seepage of water, it is usually constructed by excavating 50 cm soil from a demarcated land of 8.9 m x 8.9 m and forming a bund of 100 cm height, 180 cm base width (including 50 cm for inner slope and 100 cm for outer slope) and 30 cm top width with excavated soil around the pond to get a final depth of 150 cm. After leveling the bottom with fine sand, cushioning materials like empty sacks are placed to avoid the puncturing of the sheet by any pointed objects. Then the pond is lined with PVC coated nylon sheet of 8.4 m x 8.4 m bottom dimension and 2.4 m height with 550 gsm thickness (total weight 88 kg) with a bottom slope of 45:1. The remaining sheet after lining 1.5 m pond depth is spread on top and outer side of the bund. The inner dimension of the pond at the top will be 9.9 m x 9.9 m. Sufficient slope of 1:0.5 is given on the inner side of the bund to prevent the slipping of the polythene lining. The outer side of the bund will be provided with a slope of 1:1. The outer dimension of the pond including bund width at ground level will be 12.5x12.5 m. Based on the local conditions, pond can also be constructed either above or below the ground level. Likewise, dimension of nylon sheet and slope of bund may vary depending on type of soil.

Rectangular shape can also be adopted for making ponds but the carrying capacity of the pond might be adversely affected due to the formation of dead zones with no water circulation and probable ammonia accumulation. Bund can also be constructed by using sacks filled with sand around the pond where there is loose soil or where sufficient land is not available for conventional construction of bund.

Fig. 4.2 Lined pond above ground

Fig. 4.3 Lined pond below ground

Fig. 4.4 Traditionally lined pond

Fig. 4.5 Polythene lined pond

At the centre of the pond, there should be a bottom drain of 5-10 cm diameter to discharge the accumulated sludge. Drain can also be provided at one side of the pond but the efficiency may be less. Sludge can also be removed by siphoning-out from the pond bottom, if it is above the ground level or by pumping-out using a submersible water pump (1/4 to 1/2 hp), if it is below the ground level. There should be an overflow pipe either separately or connected with the drainpipe, to discharge excess water caused due to rain. If the overflow pipe is connected with drainpipe, it facilitates the removal of bottom water during rain and addition of new water as the part of water exchange.

In soil with no seepage of water, lining material is not required for the pond. In this case, use of *venturi* pump and removal of sludge from the pond bottom may become difficult. This can be overcome by placing the drain at the opposite end of the inlet pipe, if sufficient water supply is available for frequent water exchange. It can also be tackled by using commercial/ farm made probiotics or doubling the area of the pond for the same production.The top of pond is covered with net having a mesh size of 60-80 mm to prevent the entry of predatory birds. The sides of the pond should be fenced to avoid the entry of frog, snake, tortoise *etc.*, if the pond is constructed below the ground level. The area prone to frequent floods should never be used for lined pond construction. There should be a provision for the entry of personnel into the pond.

Preparation of pond

The pond is filled with good quality freshwater up to a height of 125 cm. Water is let-in through the water inlet covered with fine meshed net to prevent the entry of unwanted organisms. If the water is taken from an open source, it should be disinfected with bleaching powder (35 g/m^3) followed by de-chlorination by aeration. Agricultural lime is applied to enhance water pH @ 75 g/m^3 for pH 4.5-5.5 and 50 g/m^3 for pH 5.5-6.5. After two days of liming, dolomite or sodiumbicarbonate @ 5-10 g/m^3 can be applied to enhance alkalinity of water. Inorganic fertilizers like urea @ 2-5 g/m^3 and super phosphate @ 2.5 g/m^3 can be applied after stabilizing pH and alkalinity to optimum level. This will be helpful for augmenting the production of live feed organisms in the pond. The pond will be ready for seed stocking within 10-14 days.

Water quality parameters

Temperature	: 26-30^{o} C	pH	: 6.5-7.5
Transparency	: 20-40 cm	DO	: > 3 ppm
Alkalinity	: 80-140 ppm	TAN	: < 1 ppm

Stocking

The pond is stocked with uniform sized seeds of 8 cm size at a stocking density of 5-10/m^3 after acclimatisation. The seed should be preferably transported in drums and should be disinfected by giving dip in 2 ppm $KMnO_4$ followed by 20 ppt salt solution for a period of 30-60 seconds each before stocking. Quarantine of seed is preferred before releasing into pond while nursery rearing of seed in hapa is not recommended. Multiple stocking must be avoided due to the cannibalistic nature of the fish particularly during early stage.

Feeding

The fish is fed with a floating pelleted feed particularly formulated for pangasius twice in a day during morning and evening. FCR will be 1.3 to 1.5, if the culture conditions are satisfactory. The requirement of protein content, feed size and daily feeding rate with respect to fish body weight is given in the Table 4.1, which may be slightly modified at frequent interval according to the situations to the plankton production, health condition and growth rate of fish.

Table 4.1 Feed requirement

ABW (g)	Protein content (%)	Feed size (mm)	Daily feeding rate (% of ABW)
<5	32	0.8	8
5-20	28	1.2	8
20-100	28	1.8	6
100-500	24	2.5	4
500-1000	24	4.0	3
1000-1500	20	6.0	2
>1500	20	8.0	1

Care and maintenance

The sludge accumulated at the centre of the pond bottom due to the movement of the water can be removed by discharging through the bottom drain at the centre, by siphoning or by pumping-out using a $^{1}/_{4}$ hp submersible water pump. A venturi pump of about 370 W (470 l/m) is used to reduce TAN in water by continuous water circulation and aeration and it can be used daily 2 hours during initial days and even up to 12 hours during the final days.

The water in the pond is drained weekly and replenished with fresh water @ 10% for the initial days and @ 25% in the later stage. If there is water scarcity, instead of water exchange, probiotics can be used to improve water quality.

Homemade inoculum prepared by fermenting jaggery (200 g) and rice bran (800 g) with yeast powder (10 g) in a container with 10 litre water for 36-48 hours is applied to pond water of 100 m^3 once in a week to accelerate the growth of natural food organisms and keep the pond environment healthy.

Agricultural lime and sodium bicarbonate can be added to raise the pH and alkalinity respectively, if needed. Use of dolomite will stabilize both pH and alkalinity. Inorganic fertilizers are added at frequent intervals of 1-4 weeks to maintain the growth of plankton and the frequency of application is adjusted in accordance with primary productivity. When the water has plenty of plankton, the application may be delayed, but it is critical not to allow the plankton abundance to fall too low before the next fertilizer application. Growth assessment is carried-out monthly by using scoop net.

Harvesting

Generally, during a culture period of 8-12 months, the fish grows to about 1-1.5 kg. Starving the fish for 2-3 days prior to harvest improves the flesh quality. A high productivity of 10 kg/m^3 can be expected in a crop with a survival rate of 80%. It is better to conduct the partial harvest of large sized fish from eighth month onwards to regulate the pond biomass and to realize better market price.

FARMING IN CAGE

In large and deep water bodies like the reservoir, HDPE floating cage of 100 m^3 (5 m x 5 m x 4 m effective inner dimension) and in smaller water bodies, GI floating cagesof 30 m^3 (4 m x 3 m x 2.5 m effective inner dimension) are generally used for *Pangasius* farming. Site selection and cage design are similar to that of the Nile tilapia.

The advanced fingerlings (15-20 gm size) are stocked at a density of 60-75/m^3 and fed with a formulatted floating pelletted feed (20-28% protein) twice daily at 10% of the bodyweight initially and 2% at the final stage. Other aspects of cage farming are similar to that of the Nile tilapia. The anticipated production is 100-120 kg/m^3/crop.

Fig. 4.6 Cage farming in Floating HDPE cage

CHAPTER: 5

WALKING CATFISH

The walking catfish is an air-breathing fish commonly known as magur, which lives in all types of fresh waterbodies. *Clarias magur, Clarias dussumieri* and *Clarias dayi* are the main species of walking catfish found in India. The pectoral fin of this fish is characterized by a rigid spine-like structure which is adapted for terrestrial movement even over dry land and hence, it is named as "walking catfish". The body is elongated and narrow towards the caudal region. It has a flat and broad head with small eyes, four pairs of sensory barbels, wide mouth with fleshy lips and small teeth patches on both upper and lower jaws. As a defence mechanism, the fish can cause painful stings with its pectoral fin spine. It posess arborescent organ for aerial respiration.

Fig.5.1 Clarias dussumieri

The walking catfish is adapted to live in water with less DO (0.1 ppm) and high CO_2 (70 ppm), which makes it suitable as a candidate fish for intensive farming in derelict waters. It undergoes aestivation for months without feeding in order to overcome water scarcity. It is a voracious feeder preferring small fish and insect. The population of walking catfish is being threatened due to the destruction of its natural habitat coupled with excessive use of pesticides and herbicides. Walking catfish has an excellent nutritional profile due to high protein, low fat and high iron content of flesh. It is beneficial for pregnant and lactating women and convalescing persons.

SEED PRODUCTION

Broodstock management

The fish having minimum 150 g (20 cm) size is procured from farm or wild three months prior to the breeding season, disinfected with 200 ppm formalin dip for 40 seconds and stocked at a density of 2-4 no./m^2 in outdoor circular cement cistern of 2-4 m diameter and 1.2 m depth. The tank is covered with nylon net (2 mm mesh size) leaving a clearance of 60 cm from the water surface to prevent the fish from escaping. The broodfish is fed twice daily at 10% of the body weight with a mixed diet consisting of clam meat, shrimps and trash fish. It can be replaced with a formulated feed having 35% protein containing a mixture of fish meal, groundnut oil cake, soya bean meal and rice bran augmented with vitamin-mineral mixture @ 2-3% of the body weight. As the fish is active in the dark, feed is given between dusk and dawn. The bottom of the tank is provided with 5-10 cm layer of washed sand as substrate and pieces of PVC pipes (5-10 cm diameter) as hide-outs. Water hyacinth can be maintained in the pond up to 20-25% of the surface area to simulate the natural condition. The plant also acts as shelter as well as a source of periphyton. Fortnightly the tank is cleaned and 30-50% of water is replaced.

Selection of brooder

By the first year,the fish weighing 200-400 g, attains sexual maturity and spawns in open or confined waters during June to August. Sexual dimorphism is exhibited from sub-adult stages. The mature female has swollen abdomen, reddish vent, round and button-shaped genital papilla and releases eggs on applying slight pressure on the highly distended abdomen. In mature male, the genital papilla is elongated and pointed. The ripe male does not discharge milt even by applying pressure on the abdomen. Maturity stage of female is ascertained by collecting the ovaries using a catheter and examining it under a microscope. If the egg size is 1.2-1.4 mm, the female is selected for spawning. Prior to breeding season, mature fish are collected from pond and kept sex wise in seperate indoor tanks.

Spawning

Broodstock collected from farm responds better to induced breeding compared to wild caught ones. *Clarias magur* is induced to spawn by intramuscular injection with synthetic hormones like Wova-FH @ 1 ml/kg body weight as a single dose and kept in an FRP tank of 1 t capacity. The broodfish exhibits pre-spawning activities for 6-8 hours and thereafter spawning activity starts and is continued for another 6 hours at short intervals. The fertilised eggs are golden-yellow in colour, while unfertilised eggs are milky white. The eggs are demersal and slightly adhesive. Hence, egg collectors are used for collecting them. Fecundity ranges between 30-60 no./g body weight. The average rate of fertilisation is 75%.

In the case of *C. dussumieri,* hormone is injected @ 0.6-0.8 ml/kg for female and @ 0.3-0.4 ml/kg for male. The fish is kept unfed at least for one day prior to hormone injection to avoid faecal contamination during stripping. Before stripping the female, testis is collected from the male fish. After anaesthetising the male fish with 300-400 ppm 2-phenoxy ethanol, a cut is made at the vent of the male with sharp scissors. The testis is removed with forceps and the cut portion is sutured with surgical twine, and the fish is given a bath in a disinfectant solution. The collected testis is ground in a mortar after adding 0.9% saline solution. The macerated tissue becomes inactive in this medium and it can be refrigerated. When freshwater is added, the sperm become re-activated.

After 14-17 hours, the injected female fish is cleaned with a towel and stripped into a clean and dry stainless steel, enamel or plastic tray/ basin. The fish is kept outside the water in an inclined position with the head up and the ventral portion over the tray. Slight pressure is applied gently with the thumb and index finger on the swollen belly, slowly descending towards the lower end of the body down to the vent. The fully gravid female normally releases a stream of ripe eggs, which flow out as a jet under this pressure and are collected in the tray. This process is repeated until all the ripe eggs are released. Care is taken to avoid contamination of eggs with blood and excreta from fish. Fully mature eggs are dark brown or brownish-green in colour. The stripped female fish is given a bath in disinfectant solution and released back to the tank.

Fig.5.2 Stripping of female fish

The stripped eggs in the tray are sprinkled with sperms within one minute, and it is mixed thoroughly for 2-3 minutes by shaking the tray or using a quill feather or a fine fur brush. Then it is washed in fresh water for two minutes. The fertilised eggs are adhesive, demersal, spherical in shape and golden-yellow in colour. It is disinfected and carefully transferred for incubation. Fecundity is 50-80 no./g body weight. The ideal sex ratio is one male for 2-3 females.

Incubation

If egg collectors are used, it is washed thoroughly in freshwater with attached fertilised eggs and disinfected by dipping in malachite green (20-60 ppm) for 10-30 seconds. If fertilised by stripping, the eggs are washed in freshwater and disinfected. The fertilised eggs are incubated in a simple flow-through system which comprises of a rectangular FRP tank with 200 x 60 x 30 cm size on a stand of 90 cm height with separate inlet and outlet at opposite ends with a continuous feeble water flow arrangement in such a way that the rate of drained water is equal to that of incoming water. The inlets are so designed to sprinkle the incoming water. The incoming water should be cleaned and filtered, having more than 5 ppm DO. Each tank holds four plastic or FRP hatching trays having the dimensions of 50 x 30 x 10 cm and its bottom and sides are fitted with a synthetic net of 1 mm mesh size. The water level inside the tank is maintained in such a way that there is water up to a height of 4 cm inside the tray. Ideal water flow rate for incubation is 0.5-1 l/min.

Fig.5.3 FRP tank and incubation tray

Continuous freshwater flow maintained in the tank keeps the egg devoid of contamination. Each tray can hold 6000-18000 eggs (1000-3000 no./l), which mainly depend on water quality. (Water having 5-9 ppm DO is ideal). The eggs are uniformly distributed in the tray to avoid crowding, fungal infection and clogging.

In the case of *C. dussumieri,* hatching takes place within 17-20 hours while for C. *magur,* it is 24-27 hours at 27-30ºC. The newly hatched larva measures about 4 mm in length. They usually remain at the bottom of the tray, resting on the side and move very slowly due to the heavy yolk sac. The yolk sac free larva moves in the water and starts feeding by 4 dph. No feed is provided during the first three days as yolk sac serves as food.

Rearing of hatchling

Just before completing yolk sac absorption (usually 3-4 dph), the larvae are transferred from incubation unit to indoor nursery rearing unit. In nursery-rearing unit, the larvae are stocked at a density of 4-6 no./l in FRP tank (1t capacity with 40 cm height) having 15-20 cm depth of water. The hatchling subsists on endogenous nutrition for 3-4 dph. On complete absorption of yolk, hatchlings are fed 4-6 times daily with a heterogeneous mixture of zooplankton including *Rotifer,Ciliates* and *Moina* at 0.2 ml/l for the period up to 12 dph. The live feed is thoroughly sieved to avoid entry of *Cyclops, Daphnia* and other big zooplankton. *Artemia* nauplii at a density of 300 no./l or powdered yolk of boiled eggs are also given daily from 7 dph onwards. At the time of feeding, the sprinkling of water and aeration is stopped for 30 minutes.

The larvae absorb DO from the water up to 10-12 dph. Hence, mild aeration is provided continuously without disturbing the water always to maintain DO level above 5 ppm. Water quality is also maintained by providing 50% water exchange twice daily by continuous flow-through system. The waste from the tank bottom is removed by siphoning twice daily. The larvae show high cannibalistic behaviour during 2-5 dph and hence survival during this stage is very much crucial. During the early larval stage, size grading is done frequently and the shooters are removed for better survival.

By the 10-12 dph, the larvae start the vertical movement and come to the water surface for taking oxygen directly from the air, which is the critical period in larval rearing. Subsequently, aeration is stopped, and the height of the water column in the tank is reduced to 10 cm for the next two days.

The metamorphic larva (12 mm size) is adapted for aerial respiration and it is kept in 15 cm water depth with the flow-through system up to 22-24 dph at a density of 1000 no./m^2. Continuous aeration is not required from this stage onwards. The larva is fed *ad-libitum* with cut pieces of *Tubifex* worm, clam meat and egg custard. Subsequently the quantity of *Artemia* nauplii is reduced. It is gradually weaned on micro-encapsulated shrimp larval feed or a powdered mixed diet consisting of fishmeal, groundnut oil cake and rice bran from 14 dph onwards. About 30 minutes after feeding, the left-over feed is removed. Daily siphoning is done to remove wastes accumulated at the bottom of the tank. Water quality parameters are checked once in every 3 days and are kept at optimum levels. Sampling is done once in 6 days for the estimation of growth and length-weight relation. Daily monitoring is done to correlate the number of larval deaths with those survived for estimating the rate of cannibalism. Larvae are assessed daily for its body colouration, clustering, swimming pattern and aggressive behaviour. Maintenance of water quality, nutritionally balanced feed, thinning of larvae and pathogen and predator-free environment, are essential to prevent heavy mortality in the early stages. It attains a size of 20-25 mm by 24 dph with a survival rate of about 20-40%.

Rearing of fry

The fry can be reared in an earthen pond (200-400 m^2) or outdoor cement tank of 40-80 m^2 size having 1.2 m depth. The cement tank is provided with soil at 15 cm thickness. The nursery pond preparation and manuring for live feed production is similar to that prescribed for the major carps. The water level is maintained at 30 cm initially and gradually enhanced to 60 cm. The pond/tank should have a freeboard of 60 cm to prevent the fingerlings from jumping out.

The tank is inoculated with plankton to ensure natural food organisms. The fry is stocked at a density of 100-200 no./m^2 and fed daily during dark hours with a formulated feed (40-45% protein) or shrimp larval feed at 10% of the body weight, which can be replaced by egg custard with minced clam meat, prawn meat, tubifex or low valued fish or crumbled formulated catfish feed. In the earthen pond, 20-25% of the water surface is covered with floating aquatic plants such as *Pistia* and *Eichhornia* in order to provide shelter and to absorb noxious gases that accumulate in the water. The fish seed grows to 1g size by 40-50 dph with 50-75% survival rate.

Water quality requirement

Temperature	: 27-30°C	Alkalinity	: 90-160 ppm
DO	: >3 ppm	Nitrite	: < 0.25 ppm
Ammonia	: <0.05 ppm	Carbon Dioxide	: < 15 ppm
pH	: 7.0-8.5	Hardness	: 80-150 ppm

Packing and transportation

The method of packing and transportation is similar to that explained for the murrels.

FARMING IN POND

Selection of pond

Earthen pond of 0.05-0.2 ha size with a water level of 75-100 cm is desirable. The bottom and sides of the pond have to be made free from holes or crevices. Since the fish is an air-breather, it normally comes up to the water surface for taking atmospheric oxygen. This kind of habit attracts birds for predation. Therefore, the pond should be covered with net. Optimum pH is 6.5-8.5, but this fish can survive at low pH up to 5.

Pond preparation

As a preliminary activity, mahua oil cake is applied @ 2.5 t/ha/m to eradicate predatory as well as weed fishes. No manuring is done, but it is dried between crops and treated with lime. Inner bund of the pond should be firm. The pond should have not less than 75 cm free board and be fenced with stiff net (12 mm mesh size) along the margins of the pond to a height of 60 cm to prevent the 'walk-out' of fish.

Stocking

The stocking is done 15 days after the application of mahua oil cake. The seed is stocked @ 5-7 no./m^2. As the fish exhibit cannibalism in the early stage, uniform-sized seeds (1 g) are selected for stocking, however big sized seed (5 g) shows good survival and growth rate. A dip in 200 ppm formalin for 40 seconds before stocking helps to avoid infection.

Feeding

The fish is fed twice daily with a formulated pelletted feed having 30-45% protein at a rate of 5% of the body weight initially and gradually reduced to 2% in the later stage. This feed can be replaced with a mixture of rice bran, groundnut oil cake and chopped fish in the ratio of 1:1:1.

Care and monitoring

Presence of aquatic vegetation like *Eichornia, Lemna,etc* in the pond helps to control algal bloom and provide shade and shelter to the fish. It also promotes the growth of insects, which forms the basic food for the fish. But these plants should not occupy more than one-fourth of the pond as it may create hindrance to air breathing activity. There may be occasional accumulation of metabolites, rise in ammonia or algal bloom in the pond. Water exchange is done on acute deterioration of water quality. Periodic sampling is done to monitor the fish health and growth and to schedule the management procedures accordingly.

Harvesting

The fish attains a marketable size of 200-250 g within 10 months. Other aspects of harvesting are same as that of the murrels.

CHAPTER: 6

STINGING CATFISH

The stinging catfish, *Heteropneustes fossilis* is commonly called as *Singhi,* is a freshwater air-breathing fish, which survives even in oxygen-depleted waters due to the presence of tubular air sacs as outgrowth of the gill chambers extending as far as the middle of the tail region for aerial respiration. It tolerates low water quality and high concentration of carbon dioxide. The pectoral spine is very sharp and can make a painful wound, if the fish is handled without proper care.

Fig.6.1 Heteropneustes fossilis

It is an omnivore, which thrives in all kinds of shallow freshwater habitats. It breeds in confined waters during monsoon. It can tolerate overcrowding and is reared at extremely high stocking density. It also tolerates slightly saline water.The fish is mainly caught from weed-infested ponds and paddy fields. During summer months when the seasonal ponds get dried, stinging catfish bury into the soil. The fish fetches high price due to fewer spines in the flesh, less fat, high digestibility and high iron and calcium content. It is believed that the fish is suitable for sick and convalescence persons.

SEED PRODUCTION

Broodstock management

The fish weighing not less than 100 g is procured from farm or wild prior to 3 months of the breeding season and disinfected. The broodfish is stocked at a density of 3-5 no./m^2 in outdoor circular cement cistern of 2-4 m diameter and 1.2 m depth and covered with nylon net (2 mm mesh size) leaving a clearance of 60 cm from the water surface. The broodfish is fed twice daily at 2-3% of the body weight with a formulated feed having 30-35% protein containing a mixture of fish meal, groundnut oil cake, soya bean meal and rice bran augmented with the vitamin-mineral mixture. Other aspects of broodstock management are similar to that explained for the walking catfish.

Selection of brooder

The fish at the age of one year (150 g) attains sexual maturity and spawns during June-August. The female is larger than the male and has a soft swollen abdomen with a reddish vent that releases eggs on applying slight pressure on the abdomen. In a male, the genital papilla is conical and pointed, protruding and highly vascularized during the breeding season, but doesn't discharge milt on applying pressure on the abdomen.

Spawning

The mature and healthy female and male in the ratio of 1:1 by body weight are induced for spawning by intramuscular injection of synthetic hormone like Wova-FH as a single dose of 0.6-0.9 ml/kg body weight. The injection is given during evening near the base of dorsal fin above the lateral line at an angle of 30^0 to the body and to a depth of 2-3 cm using an insulin syringe. Care should be taken such that needle does not touch the vertebral column. The hormone is injected slowly allowing it to disperse properly into the body; otherwise, when the needle is withdrawn, the solution may be ejected out.

Fig.6.2 Hormone injection

After injection, the broodfish is released into an FRP tank of 1 t capacity, where water depth is maintained at 30-45 cm with mild aeration. Adequate quantity of *Hydrilla is* provided to simulate the natural breeding habitat. The top of the tank is covered with nylon net. A temperature of 25-28^{o}C is most conducive for spawning.

The fish exhibit pre-spawning activities for a period of 6-8 hours and display prolonged and intermittent courtship and spawning behaviour for the next 6 hours. Perforated rubber mat of 5 cm thickness with holes of 3 cm diameter is placed to cover the entire tank bottom facilitating free fall of the egg into the tank bottom, thereby preventing egg damage. Soon after the completion of spawning, the spent parent, aquatic plant and rubber mat are removed from the breeding tank. If the fish doesn't spawn naturally, semi-wet stripping is done for female. In the case of male fish, the testis is collected and macerated, as explained in the case of walking catfish, to fertilise the eggs.

The fertilised eggs are spherical, moderately adhesive, demersal and greenish-blue in colour and tend to settle at the bottom with heavy yolk and have 1.1-1.6 mm diameter. It is disinfected in 5 ppm malachite green for 10 minutes and carefully transferred for incubation. The fecundity is 50-350 no./g bodyweight. The unfertilised egg is whitish in colour and float at the water surface.

Incubation

Fine mesh nylon net is spread horizontally in the incubation tub 10 cm below the water surface, and fertilised eggs are spread evenly in a single layer over the nylon net. The incubation tub is kept under running water for maintaining quality. Hatching takes place within 16-20 hours at 27-30^{o}C.

The newly hatched larvae move to the bottom of the container through the meshes, leaving the eggshell over the nylon net. It is transparent and faintly brown in colour and measures about 2.5-3 mm in length with a large yolk sac, which gets absorbed in 72-96 hours. The unfertilised and dead eggs and eggshells should be removed immediately by lifting the mesh to avoid fouling of water.

Rearing of hatchling

The larvae are about 2.7 mm having a large yolk sac. After 48 hours, the healthy ones will swim towards the corner of the tank and remain in a group. The yolk sac is completely absorbed within 3-4 dph and the larvae are transferred from the incubation unit to an indoor nursery rearing unit. In the nursery-rearing unit, the larvae are stocked in FRP tank (1t capacity with 40 cm height) with 15-20 cm water depth at a density of 4-6 no./l. The hatchlings are fed 4-6 times daily with minute rotifers, ciliates, *Artemia* nauplii and boiled egg yolk till 12 dph. From 13 dph onwards, the larvae are fed with chopped molluscan meat in addition to zooplankton. The feed size varies from 10-20 µm upto 8 dph and which can be increased to 40-50 µm thereafter.

The larvae absorb DO from the water up to 10-12 dph. Hence, mild aeration and water quality management is done similar to that explained for the walking catfish. The larvae start the vertical movement by 10-12 dph and come to the water surface for taking atmospheric oxygen. Subsequently, aeration is stopped and the height of the water column in the tank is reduced to 10 cm in the next two days. After 19-20 days, larva transforms into fry.

Rearing of fry

The fry can be reared in an earthen pond (200-400 m^2) or outdoor cement tank of 40-80 m^2 size provided with 2-3 cm thick layer of soil on the bottom. A water depth of 30 cm is maintained initially in the pond/tank and gradually enhanced to 60 cm. The pond/tank is kept in the shade allowing partial exposure to sunlight. The nursery pond preparation and manuring for live feed production is similar to that prescribed for the major carps. The pond/tank should have a freeboard of 60 cm. Plankton collected from ponds is inoculated into these tanks at periodic intervals. The fry is stocked at a density of 150-500 no./m^2 and fed *ad libitum* daily during dark hours with finely ground trash fish, prawn meat, chopped clam meat, *tubifex* and rice bran, which can be replaced with egg custard and minced meat, or crumbled formulated catfish feed. The fish seed grows to 4-5 cm size by 30-40 dph.

Harvesting

The method is similar to that explained for the murrels.

FARMING IN POND

The stinging catfish can be effectively cultured in low lying areas such as unutilized swamp, marshy land, wetland and other derelict water bodies.

Selection of pond

The pond having 0.05-0.2 ha size and 75-100 cm depth is ideal. Pond having mud upto 15 cm thickness at the bottom is better; but this may lead to difficulty in the harvest. Culture in a shallow pond helps to reduce the energy consumption for the vertical movements of fish for respiration. Optimum pH is 6.5-8.5.

Pond preparation

It is similar to that of the major carps. The inner side of the bund should be firm and fenced with bamboo, cane or wire screen to a height of 60 cm to prevent the escape of fish.

Stocking

Seed with a size of 5 cm can be selected for stocking. Uniform sized seeds are selected for stocking to reduce cannibalism during early stages. Stocking density of 6 no./m^2 is usually practised. A dip in 200 ppm formalin for 40 seconds before stocking helps to avoid infection.

Feeding

The fish is fed *ad libitum* with a formulated pelletted feed with a protein content ranging from 28-35%. It can also be fed witha mixture of rice bran, groundnut oil cake and animal protein in the ratio of 1:1:1.

Care and monitoring

It is done similar to that explained for the walking catfish.

Harvesting

The fish attains a marketable size of 160-170 g in 10 months. Other aspects of harvesting are same as that of the murrels.

CHAPTER: 7

BUTTER CATFISH

The butter catfish is a non-air breathing freshwater catfish. It is nocturnal, predatory and carnivorous that inhabits the wetland and open water channels connected to lower reaches of rivers. The adult fish thrives on insects and their larvae and other small fishes, while the early fingerling (40 mm) feeds on cladocerans, copepods, rotifers, protozoa and insect larvae and advanced fingerling (>70 mm) feeds on small insects, nematode worms, annelids, small minnows, shrimps and detritus. It grows to a size of 30-40 cm.

Fig.7.1 Butter catfish*, Ompok malabaricus*

The butter catfish attains sexual maturity in the first year. Male become ready to breed by late April, while the female during late May. Its breeding season extends from early June to August with a peak in July. During the breeding season the fish move in shoal and migrate from water-logged area towards the mouth region of the shallow confined water adjoining the river where breeding occurs. The consumer demand for the fish is high due to its unique flavour, soft flesh, shiny appearance, less spine, easy digestibility and high nutritional value. Over the last few decades, its wild population has been declining rapidly due to various anthropological activities.

SEED PRODUCTION

Broodstock management

The fish weighing not less than 40 g size is procured from farm or wild during January to February, disinfected with 200 ppm formalin dip for 40 seconds and stocked at a density of 10 no./m^2 in outdoor circular cement cistern of 2-4 m diameter with 1.2 m depth or at a density of 5 no./m^2 in earthen ponds having about 0.02-0.1 ha area with 0.75-1.5 m water depth. The broodfish is fed twice daily at 5% of the body weight with a mixed diet consisting of clam meat, shrimps, chopped earthworm, trash fish and boiled fish waste. It can be weaned gradually to take a formulated pelletted feed having 35% protein. The pond is provided with floating aquatic weeds like water hyacinth up to 20-25% of surface area, which offers shelter and hiding places and harbours many insects as feed for fish. Ceramic pipe of 5-10 cm diameter is also provided as hideouts.

Selection of brooder

The male and female show sexual dimorphism and are easily identified by the secondary sexual characters developed during the breeding season. In the case of a mature male, the genital papilla is elongated and pointed or somewhat conical in shape. The pectoral fin is thick and serrated with a relatively large spine, and the body is slender, smaller in body size, less pigmented and more translucent. In the case of a mature female, the spine is very feeble. The abdomen is soft, round and bulged and the genital papilla is somewhat fleshy, round, bulged and large in size with reddish vent. The mature female has distinct granular ovaries with orange-yellow colour. When the female becomes ripe, on applying slight pressure on the belly, orange-yellow bulged transparent ova come out through the genital aperture.

Fig.7.2 Flat abdomen of male

Fig.7.3 Swollen abdomen of female

Spawning

The mature female and male are selected and induced to spawn by intramuscular injection of synthetic hormones like Wova-FH at 1.5 ml/kg body weight for female and 0.5 ml/kg body weight for male as a single dose. After a gap of 8-10 hours of hormone injection, natural spawning happens under favourable conditions. Otherwise, the abdomen of the male is cut-open and testis is removed, chopped and macerated to prepare sperm suspension followed by stripping the female fish as explained for the walking catfish. The collected eggs are mixed thoroughly with the sperm suspension using a feather by adding a little amount of freshwater to activate the sperm. The fertilised eggs are then washed with freshwater, cleaned and transferred for incubation. Fecundity is 200-300 no./g body weight.

Incubation

It is almost similar to that explained for the walking catfish. Hatching takes place within 22-24 hours after fertilisation at a temperature of 27-30^{0}C and alkalinity of 100-150 ppm. The hatchlings are cylindrical in shape, transparent, devoid of mouth, and have pectoral fins and body pigments. The yolk sac is pale greenish in colour and is absorbed in 3 days.

Rearing of hatchling

Just before the opening of the mouth, usually 2 dph, the larvae are transferred from incubation unit to an indoor nursery rearing unit. The nursery-rearing unit may be cement cistern or FRP tank having 1 t capacity and 40 cm height. At the bottom of the cistern/tank, 5 cm thick layer of soil is provided. Initially, the water depth in the tank is maintained at 10 cm, and it is gradually raised up to 20 cm within a period of one week in accordance with different stages of larval development to minimize stress.

The soft water with less alkalinity and rich organic carbon base is ideal. Hence, water from a disease-free natural pond is used, instead of ground water, which would usually be hard with high alkalinity. The disinfection of water is done by filtration/ UV sterilization in place of chlorination. The ideal water temperature and DO for larval rearing is 28-32^{0}C and >5 ppm respectively.

The 2 dph larvae are stocked in the nursery-rearing tank, initially at a density of 15 no./l. As it shows extreme cannibalism from the 2 dph onwards, wherein the healthy larvae eat upon the weaker ones, subsequent size grading is done once in 3-5 days, and the density is further reduced to 5 no./l by thinning and stocking into different tanks. A little amount of live feed is provided from 2 dph onwards. The larvae are fed *ad-libitum* with live zooplankton up to 7 dph. Later, mixed zooplankton (@ 8-10 cc/ l) along with *tubifex* and egg custard is given twice daily @ 25% of the body weight up to 15th day.

Daily 50% water is exchanged twice to maintain water quality or provided with the continuous re-circulation system. The unwanted material accumulated at the tank bottom is removed by siphoning twice daily. Water quality parameters are checked once every 3 days.

Rearing of fry

Adequate hiding place is provided for better survival, as the larvae prefer darker places. After 15 dph, the fry is fed 2-3 times daily @ 5% of the body weight with a formulated diet comprising of egg custard, fish meat/meal and silkworm pupae powder. It can also be replaced with chopped or minced fish. The fish seed attains 5-6 cm size within a rearing period of 40-45 days with 80% survival.

FARMING IN POND

Selection of pond

Earthen pond of 0.05-0.2 ha size with a water level of 75-100 cm is desirable. The bottom and sides of the pond have to be made free from holes or crevices.

Pond preparation

Pond preparation practices including removal of predatory and unwanted fish, liming, manuring *etc* are to be followed as explained for the farming of the major carps. The pond is provided with floating aquatic plants like *Eichornia* up to 25% of the water spread area to simulate their natural habitat.

Stocking

Seeds having an average size of 6 cm (1 g) are stocked at a rate of 6-8 no./m^2. Seeds of grass carp may also be stocked @ 500 no./ha.

Feeding

The fish is fed daily twice (early morning and evening) with a formulated pelletted feed having 30-35% protein @ 10% of the body weight initially and gradually reduced to 3% in the final stage.

Harvesting

The fish attains the marketable size of 50-60 g in 8-10 months culture period. Usually, multiple harvesting is practiced by drag netting, followed by complete harvesting by hand picking after dewatering the pond.

CHAPTER: 8

YELLOW CATFISH

The yellow catfish or sun catfish, *Horabagrus brachysoma* primarily inhabits fresh waters and sometimes available in backwaters. It is greenish-yellow in colour on the dorsal side with brilliant gold flanks and a large black spot on the shoulder surrounded by a light-yellow ring. The dorsal and anal fins are yellowish orange in colour and stained dark at margins. The attractive golden colour and peaceful nature makes the fish suitable for ornamental industry.

Fig. 8.1. Horabagrus brachysoma

The yellow catfish is benthic in habit, which has affinity towards mud and sand substrate and is nocturnal in nature. It takes natural shelter inside submerged aquatic plants in the shallow areas of water body. It is an opportunistic benthophagic omnivore, which widens its dietary spectrum in response to the available food.

The yellow catfish has a prolonged breeding season which peaks during June to July, however, an individual spawns only once in a season. It grows to a maximum size of 50 cm and approximately 1 kg weight and the longevity has been estimated as 5-6 years. It is a popular food fish endemic to the Western Ghats and as per IUCN categorization, the fish is classified under "Vulnerable" category. The high fecundity of this species is yet another attribute that makes it an ideal candidate for commercial utilization. The ICAR-NBFGR jointly with Regional

Agricultural Research Station, Kumarakom developed breeding and cryopreservation protocol of this species for conservation purpose under NATP-NBFGR Project. Continuous ranching of this fish was carried out under this project and yielded 12% more catch of this species from Vembanad Lake. Subsequently, it was found that fishery of this fish improved in almost all the freshwater areas of Kuttanad region. It is also one of the important fisheries in Kole wetlands in Thrissur, especially during monsoon (Fig 8.2).

Fig 8.2. Catch of yellow catfish from Kole wetland

SEED PRODUCTION

Broodstock management

The broodfish of 80-100 g size are stocked in earthen ponds at a stocking density of 1-2/m^2. It is weaned on a pelletted feed (30-32% protein) fed at 2-5% of the body weight. The fish can also be fed with wet feeds comprising of fish offal, rice bran and groundnut oilcake

Selection of brooder

The yellow catfish is heterosexual. Sexual dimorphism is apparent among ripe fish only during the breeding season. The male has streamlined body, generally brighter, smaller in size and exude copious milky milt on slight pressure. Amongst catfishes, this is one of the very few species that freely exude milky milt. The male attains sexual maturity in the first year and female in the second year.

The male at 17-18 cm and female matures at 18-19 cm and exhibits synchronous ovarian development. During spawning season, the female possesses swollen abdomen with wide and bright red genital opening whereas the male has rudimentary genital papilla having reddish pointed tip. As the fish has the habit of hiding in dark corners, PVC pipes of 30-40 cm length and 15-20 cm diameter are put as hide-outs in the pond. It does not breed spontaneously in pond.

Fig 8.3. Sex identification

Spawning

Male and female fish are selected in the ratio 1:1 by body weight or 2:1 by number and induced to spawn by intramuscular injection of synthetic hormones like Wova-FH at 1-1.5 ml/kg body weight as a single dose. The latency period is 8-14 hours. After 12-13 hours of injection, there is a free flow of eggs on applying gentle pressure on the abdomen. Stripping of the female is done by pressing the belly gently. Similarly, milt is also collected from the male by stripping and that from one male is sufficient to fertilise all the eggs of a female of similar size. Being hardy, the stripped fish regain health fast after stripping and the male has been found to regain milting condition during the same season.The eggs and milt are mixed thoroughly with a feather to ensure good fertilisation rate. The average rate of fertilisation is 60-80% in artificial breeding and the fertilised egg has 1.4 mm diameter.The highest GSI for both sexes are normally observed immediately after the onset of monsoon. The fecundity ranges from 40,000-1,24,000.

Incubation

The fertilised eggs are kept in tubs for hatching, with running water. These are heavily yolked, translucent, golden-yellow in colour and spherical in shape. Hatching is observed in 22-29 hours at 24-26^{0}C. The hatchling has a size of 4-5 mm (1-2 mg). The hatching rate is 40-60% and even 95% was achieved at experimental set up at RARS, Kumarakom. The hatchling subsists on yolk for 3 days and later they feed on plankton and artificial diet like egg custard.

Rearing of hatchling & fry

The hatchling is reared in large open nursery hapa (5 m x 4 m x 1 m) fixed in nursery pond. Feeding is done using egg yolk at spawn stage. Powdered compounded feed concentrate is utilized as feed supplements in addition to the live plankton. The characteristic yellow ocellus appeared in one-week old larvae. The 30-45 dph fry are transferred to earthen pond and fed with groundnut oil cake and rice bran mixture feed. The prepared pond is used for stocking of hatchlings @ 50-100/m^2. The seed attains 6-7 cm in 3 months of rearing.

FARMING IN POND

The farming of yellow catfish has not been given much importance till date; however, it is more suitable for smaller homestead pond. Similar sized individuals of native barbs and cichlids could be raised with the yellow catfish. Some of the locally available candidate species like *Labeo dussumieri, Systo mussarana and Etroplus suratensis* can be cultured together with it. In Kerala, two farming practices are in vogue; extensive systems to produce large adults of over 200 g for the local food market and intensive systems for value addition of fry and fingerlings for the demanding global ornamental trade. Based on its euryphagous feeding habits, yellow catfish is also suitable for integrated farming system. Another attractive proposition would be to use the yellow catfish in predator-prey culture systems using tilapia or other weed fish as forage species.

CHAPTER: 9

CLIMBING PERCH

The climbing perch, *Anabas testudineus* is a small sized fish that inhabits both freshwater and brackish water habitats. It is a slender fish with large scales and spines on the gill cover. The fish is hardy in nature and thrives even in oxygen-depleted waters with the help of accessory respiratory organ (labyrinthine organ) situated on the upper part of gill chamber. The fish is called climbing perch due to its ability to wander or crawl across land.

Fig.9.1 Anabas testudineus

It is an omnivore, feeding mainly on insects and small fish, but the larvae and juvenile thrive mainly on plankton. The fish is generally shy, but become aggressive during spawning period. In nature, the fish is known to mature at 70-100 mm size and breeds prolifically with the onset of monsoon in natural habitats such as paddy fields and seasonal ponds having 10-25 cm water depth. It grows to a maximum length of 25 cm, but commonly not seen more than 16 cm. There is a fast growing strain named *'Koi Anabas'* which attains 400 g in 4-5 months compared to local strain, which reaches only 100 g size in 9 months.

The fish is much popular for good flavor and prolonged freshness even after catch. It is a preferable diet for sick and convalescent people. The flesh of the fish contains 17% protein and 13% lipid on wet weight basis. The fish also contains high iron and copper content, which are essentially required for haemoglobin synthesis.

SEED PRODUCTION

The breeding season of climbing perch usually starts from March and continues till late August with a peak in May-June. Under captivity, it attains sexual maturity in the first year at a size of 8.0-9.2 cm (14-18.2 g). Although the fish spawn naturally once in a year, multiple spawning is possible by hormonal administration.

Broodstock management

Fish weighing a minimum of 40 g is procured, disinfected and stocked at a density of 5-7 no./m^2 in outdoor cement cistern having 2-4 m diameter and 1.2 m height. All other aspects of broodstock management are similar to that explained for the walking catfish.

Selection of brooder

Broodstock kept in outdoor cement cistern is regularly checked for its gonadal development. Sexual dimorphism is not distinct till breeding season, except that male often tends to be smaller and slender than the female. The male and female develop secondary sexual characters during the breeding season. The ripe female develop prominent outgrowth at the vent in the form of genital papilla. Even on slight pressure on the abdomen, the eggs are released. The mature male is dark and has longer anal fin than the female and the ripe male oozes out white milt upon gentle pressure on its abdomen. During breeding season, fully mature fish are collected and males and females are kept separately in FRP tanks. Maturity stage of female can be examined by catheterisation. The female is suitable for breeding when the diameter of egg is 0.6-0.8 mm. The healthy and mature fish is induced to breed in March. After prophylactic treatment with potassium permanganate, the same fish is maintained separately with utmost care for next breeding. Within 50-60 days, it will be ready to breed again.

Spawning

The conditioned fish are selected in 2:1 male to female ratio and induced to spawn by the administration of synthetic hormones like Wova- FH @ 1 ml/kg body weight as a single dose. The hormone is injected intramuscularly in single dose during evening. Proper care must be taken to avoid injury by the sharp spines of the fish during handling. The injected fish are released to an FRP tank for spawning. After administration of hormone, it takes 7-14 hours to spawn. Lowering of water level in the tank to 20 cm, in conjunction with frequent water exchange induces the fish to spawn.

The climbing perch spawns at night and each brooder spawns several times by changing its partner. Both courtship and spawning occur in the water column. Spawning is preceded by the courtship period that continues for 3-7 hours, after the hormone injection. Usually, male follow a female trying to snuggle up to its side, half way to the female. If the female do not respond or try to escape, the male exhibit an aggressive behaviour, including bumps and bites.

The female which is ready to spawn turns around by 180° around the male head, and get in a position of “head to tail,” and then the pair forms a ring “nose to the tail” and performs one to two circular motions after which they move apart. Another variant is when both partners perform several convulsive ‘S’ shaped bends with the body and release the gametes. After this, the partners move apart, but almost immediately resume spawning. Sometimes the spawning stops for several minutes, after which it is resumed. In case of disturbance, the fish easily descend to the water column but rise rapidly in quiet water. The fertilised eggs are floating, translucent and non-adhesive with 0.9-1.0 mm diameter while the unfertilised eggs are opaque. The fecundity of female is 100-200 no./g body weight. The climbing perch shows no sign of parental care, but feed upon their own eggs and young ones.

Incubation

The fertilised eggs are cleaned, disinfected and kept for incubation similar to that explained for the walking catfish. Hatching takes place by 10 hours at 26-30ºC. While resting free embryo is seen scattered near the water surface with their yolk sac upward. During active movement in the water column, wrigglers turn over into natural position. This phenomenon is observed up to the yolk resumption stage. The hatchling measures 1.6-1.8 mm in length and rests at the bottom of the tub in an upside down position.

Rearing of hatchling

Just before completing yolk sac absorption (usually 2-3 dph), the larva is transferred from incubation unit to indoor nursery rearing unit. The other aspects may be carried out similar to that explained for the walking catfish.

Rearing of fry

It is similar to that explained for the walking catfish.

FARMING IN POND

Monoculture system is usually practiced for the farming of the climbing perch.

Selection of pond

Stone pitched pond is ideal as the fish exhibits climbing behaviour. The pond having a size of 0.05-0.2 ha is ideal. To prevent the escape of fish, 75° slope for embankment or fencing the sides of the pond with poles and net upto a height of 60 cm is provided.

Pond preparation

In order to avoid predation by birds, the pond is covered with net. Pond preparation practices including removal of predatory and unwanted fish, liming, manuring *etc* are to be followed as explained for the farming of the major carps. The pond is provided with floating aquatic plants like *Eichhornia* up to least 20% of water-spread area to simulate their natural habitat.

Water quality parameters

The water quality parameters required for the farming of climbing perch are given below:

Temperature	: 20-30^{0}C	pH	: 6-8.5
Salinity	: <10 ppt	TAN	:< 0.5 ppm

Stocking

The fish seed having an average size of 5-7 g is stocked at a rate of 10 no./m^2. The stocking density can be increased to 30 no./m^2, provided that weekly water exchange of 25% is ensured. In cage culture, stocking density of 200 no./m^3 is preferred. This fish is suitable for farming in RAS with high stocking density of 400-500 no./m^3.

Feeding

It is fed with a floating pelletted feed having 30-35% protein or chopped fish. The fish being primarily an insectivore, fixing a hanging light just above the tank/pond/cage is a really good way to attract insects, which provide an additional source of food.

Harvesting

The fish attains a marketable size of 100 g in 8-10 months. Complete harvesting can be done by dewatering the pond and the fish can be collected by hand picking.

CHAPTER: 10

MAHSEER

The Deccan mahseer, *Tor khudree* is common in the upstream regions of rivers originating from the Western Ghats, and is included in the list of endangered species as per IUCN status. Ranching of hatchery produced seed can be adopted as an ex-situ conservation practice. The mahseer inhabits fast flowing streams and rivers of the hilly areas with richly oxygenated waters and rocky bed. It is the most preferred fish in hilly area, attaining large size, having excellent taste and ornamental beauty. It is a powerful fish which exhibit good fighting skill to wriggle-off the angling hook. Hence, it is considered as an ideal sport fish that provide incomparable recreation to anglers and offers excellent prospects for the growth of eco-tourism.

Fig.10.1 Tor khudree

Mahseer is endowed with good power of locomotion. The fish is omnivorous in the larval stage, carnivorous in the juvenile stage, and herbivorous in the adult stage. It has mouth suitable for rasping encrusted organisms and removing algal slime on rocks and boulders. It has narrow gill opening and reduced gill; hence it needs water with DO above 7 ppm. Sexually mature fish ascend to a height ranging from 800-1800 m above MSL, travelling a long distance and prefer clean water for breeding. During floods, the stream swells due to monsoon rains and the newly inundated area serves as nursery ground and forms a secured site for the young-ones which mostly prefer the marginal upland area having stones constantly flushed by the flow of water rather than the swift currents of lower regions of river. The factors that influence its spawning include water temperature, velocity, pH, turbidity and rain. Breeding season of mahseer is July to September. It breeds several times in a year and usually lays eggs in sheltered rock pool.

The major reasons for depletion of mahseer stock are degradation of aquatic ecological conditions, indiscriminate fishing of broodstock and anthropogenic interventions in breeding habitats. Destructive fishing methods like use of dynamite, poison, electricity and construction of barrier in natural migratory routes prevents the breeding migration.

SEED PRODUCTION

Broodstock management

The male and female fish attain maturity in 2nd year and 3rd year respectively. The brood fish is maintained in earthen pond or cage and fed with a formulated feed having 40% protein prepared with groundnut oil cake, rice bran and fish meal in the ratio of 3:3:4, which results in faster and healthy gonadal development. The gravid fish is also collected from the wild during its spawning migration by using gill net. The gravid fish generally releases ripe eggs with a slight struggle on entangling with the net. So, wild caught ripe fish is stripped immediately, to avoid loss of eggs.

Selection of brooder

The male and female fish is segregated in the early hours of the day. During spawning season the ripeness of the female fish is ascertained by the softness of abdomen, pink colouration of the vent and the free release of eggs on applying a slight pressure on the belly. In male fish, its readiness is confirmed by the oozing out of milt on exerting gentle pressure near the vent.

Spawning

The brooder is induced for spawning by intramuscular injection of synthetic hormone like Wova-FH as a single dose at 0.8 ml/kg of the body weight for female and at 0.4 ml/kg of the body weight for male. (The brooders collected from natural spawning ground are kept in spawning tank with showering but without hormone administration). If the pair does not spawn within 6-12 hours, stripping is done. The female is stripped as explained for walking catfish. Colour of the egg is pale yellow to bright orange. The stripped eggs are adhesive in nature till they become 'water hardened'. After the eggs are stripped, the milt extruded from the male fish in the similar way is poured over the eggs. One teaspoon of milt is sufficient to fertilise the eggs produced from 2-3 females. The fecundity is 3500-8900 no./kg bodyweight.

Fig.10.2 Stripping of female *Fig.10.3 Stripping of male*

(Courtesy: DCFR)

Fig.10.4 Fertilisation (Courtesy: DCFR)

Fertilisation takes place instantly while mixing the eggs and milt with a quill feather. The eggs are allowed to remain inside the basin to ensure complete fertilisation. The basin is kept undisturbed for 30-40 minutes with protection against direct sunlight for 'water hardening'. After that, excessive milt and extraneous materials are removed through repeated washing. The fertilised egg is demersal and attains a size of 3.5-4.0 mm on water hardening. The comparatively larger size of the ova is an adaptation to tide over the scarcity of larval food during monsoon, when the fish spawn.

The rate of fertilisation is ascertained by acetic acid method. A sample of water-hardened egg is kept in 5% glacial acetic acid solution for 24 hours. The viable egg is transparent while the unfertilised one becomes translucent. Proper stripping of the ripe brooder ensures more than 90% fertilisation. After water hardening process, the eggs are quantified by volumetric method. Normally, the egg density is 35-60 no./ml. The fertilised eggs are transferred for incubation and protected from direct sunlight.

Incubation

The fertilised eggs are disinfected and placed for incubation in rectangular FRP hatching trays of 75 cm x 50 cm x 10 cm and its bottom and sides are fitted with wire mesh of 1 mm mesh size. Two such hatching trays are placed in an FRP tank of 200 cm x 60 cm x 30 cm size on a stand of 90 cm height with separate inlet and outlet at opposite ends in such a way that the rate of drained water is equal to that of incoming water. The inlets are so designed to sprinkle the incoming water. The incoming water should be cleaned and filtered, having more than 5 ppm DO. The water level inside the tank is maintained in such a way that there is water up to a height of 4 cm inside the tray. Continuous freshwater flow is maintained in the tank and the ideal water flow rate for incubation is 0.5-1 l/min. Each tray can hold 15000-30000 eggs, which mainly depend on water quality. The eggs are uniformly distributed in the tray to avoid crowding, fungal infection and clogging. The eggs hatch out in 76-96 hours at 19-24^{0}C with a hatching rate of 80-85%. Yolk absorption is completed in 10-12 dph.

Fig.10.5 FRP tank with incubation tray

Large wooden hatching tray is also used for incubating the eggs, where it is placed in cement tank as shown in Fig. 10.6.

Fig.10.6 Cement tank with incubation tray

Rearing of hatchling

Rectangular FRP tank with 200 x 60 x 60 cm size or circular cement cistern with 2 m diameter and 0.6 m height having separate inlet and outlet facility is used for rearing the hatchlings. The swim-up fry is fed with sieved zooplankton like *Moina*, *Daphnia etc* or boiled and macerated egg. Micro-encapsulated feed can also be used. Feeding is done 3-5 times daily. It attains a size of 12 mm in 15 dph and is transferred to cement tank with 4 m x 2 m x 0.75 m size. The stocking density is 1000 no./m^2. Continuous water flow at 3 l/min is maintained in the tank. It attains a size of 25-40 mm in 30 dph.

Rearing of fry

The fry is further reared in earthen pond with a stocking density of 500 no./m^2. The continuous water flow is enhanced to 4-6 l/min. The young one is fed with a formulated feed consisting of groundnut oil cake, fish meal, ragi flour and chicken egg yolk in equal proportion.

Packing & transportation

As the hatching period is more than 76 hours, the fertilised eggs after water hardening is placed as 2-3 layers in between moist cotton kept in a plastic box and transported. After proper conditioning, seeds are transported in oxygen filled bag. Use of 0.05-0.3% salt during transportation decreases its metabolic activity and sensitivity to stress.

CHAPTER: 11

MISS KERALA

The "Miss Kerala" (*Sahyadria denisonii*), is a barb endemic to the Western Ghats of India and is found in the fast flowing hill streams with rocky pool and thick vegetation. It is listed as an endangered species by IUCN. Ranching of hatchery-produced seed can be adopted as an ex-situ conservation practice. It has a torpedo shaped body with silver scales having horizontal red line starting from the snout through the eye to about half way down the body and a black line that runs the entire length of the fish from snout to caudal peduncle below the red line. It has a forked tail with black or yellow spots. The mouth is sub-terminal with one pair of barbel. It grows to a maximum length of 15 cm and has a life span of 5-8 years.

Fig.11.1 Sahyadria denisonii

The Miss Kerala is omnivorous in nature, which feeds on worms, insects, crustaceans, plant materials and other organic debris. It also accepts pellet and other processed food. Feeding with diet rich in carotenoids can intensify red pigmentation in its body. It thrives well in subtropical climatic condition. It is more active from dusk to dawn than daylight hours. In nature, breeding occurs from October to March with maximum fecundity from November to January. The fish does not breed naturally in confined condition, but can be induced to breed throughout the year.

SEED PRODUCTION

Broodstock management

Male and female fish having 8 months growth and 15-25 g size are selected and segregated by mild stripping and reared in separate cement tanks or earthen ponds at a stocking density of 10-15 no./m^2 with provision for moderate water circulation and high DO in water. The brood fish is fed thrice daily at a rate of 2-3% of the body weight with high quality protein feed with low lipid content, which is ideal to attain sexual maturity. The diet includes a mixture of live feed (mosquito larva, earthworm and *Artemia nauplii*), animal protein (shrimp meat), steamed egg yolk and shrimp larval feed. Other artificial feeds include pelletted feed, *Artemia* flake, frozen *Artemia,* tubifex worm etc. Daily siphoning of waste, weekly water exchange @ 30-40% and regular monitoring of water quality parameters are highly essential. The optimum levels of a few water quality parameters are:

pH	: 6.5-7.8;
DO	: >5 ppm;
Temperature	: 18- 26°C
Hardness	: 100- 400 ppm

Selection of brooder

Under captive condition, the male attains sexual maturity at 75 mm size and 8 months of age while the female attains it at 85 mm and 12 months of age and it is distinguished by the development of a distinctive greenish-blue mark on the top of the head. Fully mature male and female fish are selected from broodstock tank by physical examination and mild stripping. The mature female is identified by soft, round and swelling abdomen and it releases ova on applying gentle pressure. The mature male oozes white milt on applying gentle pressure on abdomen. The maturity of the female is assessed by collecting 10 numbers of eggs through gentle stripping, treating with egg clearing solution and viewing under a compound microscope. Fish having eggs with central nucleus is immature while those having egg with peripheral nucleus is mature. Mature fish are kept in separate tanks for hormone injection.

Spawning

As the fish is delicate and sensitive, it is anaesthetised with 300-400 ppm 2-phenoxy ethanol solution before induced breeding. The sedated fish lies down at the bottom of the tank upside down with reduced muscular movement, but the opercular movement continues. Single dose of synthetic hormone like Wova-FH @ 1.5-2 ml/kg of the body weight is injected intramuscularly by using a graduated insulin syringe at a point of fair amount of muscle. The dorsal muscle just below the dorsal fin is the most suitable position. After anaesthetic recovery, injected male and female fish are kept in separate tanks with ample aeration.

After a gap of 14-16 hours of hormone injection, male and female fish are again anaesthetised. Then the female fish is stripped, by applying gentle pressure over the abdomen and the eggs are collected in a watch glass. Without further delay, male is stripped and the milt is directly poured over the eggs. The eggs and milt are mixed thoroughly using a fine fur brush. After 45-90 seconds, the fertilised eggs are washed with fresh saline water to clear off excess milt and other exogenous matter. The fertilisation rate will be high when the mixing of gametes takes place within 30 seconds. Then the fertilised eggs are transferred to a glass trough for incubation. The fecundity is 200-3000/fish.

Fig.11.2 Stripping of male

Fig.11.3 Fertilisation

It is very important to handle the brooder with utmost care, as it could be used again for breeding after 30-45 days. The same brooder is found to release more eggs in the subsequent trials with high fertilisation rate.

Incubation

The fertilised eggs are small, bead like and transparent with 0.5-0.8 mm diameter. The unfertilised eggs are opaque. The fertilised eggs, which remain at the bottom are incubated in a glass trough with well aerated water. The incubation period is 24-30 hours at 24-26°C. Hatching rate is 75-80%.

Fig.11.4 Fertilised egg

Rearing of hatchling

The newly hatched young one is transparent, gel like which measures 2-3 mm in size, which subsists on its yolk for two days. After 2 dph, mouth appears and the larva starts swimming slowly and starts feeding. Details of feed given to the larva is given in the table below:

DPH	Feed
3-4	Infusoria, freshwater rotifer and *Spirulina*
5-6	Bread worm
7-9	Newly hatched *Artemia* nauplii
10-27	Artificial feed < 100µm
>28	Artificial feed + live feed + egg custard

CHAPTER: 12

MALABAR LABEO

The Malabar labeo, *Labeo dussumieri* is a fresh water fish endemic to southern India and Sri Lanka, found in west flowing rivers of the Western Ghats up to north Canara. It inhabits the flood plain areas, reservoirs and backwaters. Its maximum size reported is 50 cm length and 2 kg weight. In Kerala, the species is one of the esteemed food fish and commands a higher price as compared to the major carps.

The Malabar labeo is herbivorus and illiophagic. It is benthic in nature, which feeds by browsing at the bottom and main food items include detritus, decaying organic matter, diatom, green algae and submerged aquatic vegetation. In summer season, the fish is found to thrive in the deeper waters in the upstream reaches of river systems. It migrates massively for breeding during monsoon- a phenomenon vernacularly known as '*Thooliyilakkam*' in Kerala.

Fig.12.1 Labeo dussumieri

Body of the fish is elongated and compressed with snout slightly projecting beyond mouth, without any lateral lobe. The mouth of the fish is sub-inferior with fleshy and fringed lips; with two-minute pairs of rostral and maxillary barbels. The width of the head equals its length behind the angle of the mouth. Numerous pores are present on the snout, which extends posteriorly as far as the orbits and below the nostrils. The dorsal fin with concave upper edge commences midway between the end of the snout and ends at the base of the anal fin. Caudal fin of the fish is deeply forked. The colour of the body is greyish; scales small and having a reddish centre, edged with a darker side.

The breeding protocol for Malabar labeo has been developed by ICAR-NBFGR with Regional Agricultural Research Station, Kumarakom. Due to the concentrated effort to revive this species, the fish received an IUCN status upgradation from "endangered category" to "least concern" category, as assessed in the Conservation Assessment and Management Plan (CAMP) workshop (1998).

SEED PRODUCTION

Broodstock management

The broodstock can be collected from the flooded rivulets using trap made up of bamboo during the onset of monsoon, their breeding season. The broodstock is raised in earthen pond having a minimum water depth of 1.5 m at a stocking density of 2000 kg/ha. Periodic manuring is done with cow dung @ 250-1000 kg/ha fortnightly to facilitate plankton production. The fish is fed daily at 2% of the body weight with a formulated diet having 30-35% protein comprising of rice bran and groundnut oil cake or a commercial feed. Periodic water exchange in pond at definite intervals stimulates gonadal development.

Selection of brooder

Sexual dimorphism is very similar to Indian major carps and is exhibited only during the breeding season. The female can be identified by distended and swollen abdomen, and eggs will ooze out with slight pressure. The vent appears reddish and vascular. Male have a streamlined body, extruding milt on slight pressure. The pectoral fins of the male become rough during breeding season and are smooth in case of the female.

The ovary is bilobed and slightly asymmetrical. The mature ovary is dark green in colour and is highly vascularised. The testis is pale white and bilobed. Presence of a distinct and a single mode of mature ova and only one clutch of mature oocytes in the ripe ovary indicate short total synchronous spawning habit of fish. The mature eggs are greenish and spherical with a diameter of 1.0-1.3 mm. The fish is found to attain maturity by the end of the first year at a size of 25cm for female and 23.5 cm for male. The fecundity is 15,000- 25,000/kg body weight.

Spawning

Malabar labeo spawns once in a year, and peak breeding coincides with monsoon. Induced breeding can be attained using synthetic hormones like Wova FH @ 0.3 ml/kg for female and @ 0.2 ml/kg for male, in a single dose. Spawning can be facilitated in circular breeding pool by providing circular and concentric water flow. Sympathetic breeding is possible by stocking together several sets of brooders and hormonal administration of 50-60% of the broodstock under Chinese hatchery system. Spawning takes place in 9-10 hours after exhibiting vigorous courtship behavior. Fertilisation rate ranges from 64-100%. The fertilised eggs are spherical, translucent, demersal and non-adhesive.

Fig.12.2 Hormone injection

Incubation

The fertilised eggs are transferred to circular incubation pool of the Chinese hatchery system and hatching takes place within 10-12 hours, with concentric flow of water @ 6-8 l/s as compared to 20-22 hours in the hapa system. Hatching rate ranges from 80-100%. Hatching of eggs is also performed in floating egg trays with flow-through system in which the incubation period is 17-18 hours. Hatchlings are transparent and free swimming with yolk sacs; yolk gets absorbed within 1-2 days.

Rearing of hatchling

The hatchlings are transferred to nursery hapa installed in earthen nursery pond or cement tank. The preparation of nursery pond and other management aspects are similar to that explained for the major carps.

Rearing of fry

After a week, the hatchlings are released to previously prepared earthen pond. Fry are raised mainly on plankton and supplementary feeding is done using rice bran, groundnut oil cake or powdered commercial pellets @ 3-5% of the body weight. The preparation of nursery pond and other management aspects are same as that explained for the major carps. The fry attains 7-8 cm in three months and are easily collected by fingerling net.

POND FARMING

The farming practices of Malabar labeo are similar to that of Indian major carps and it is a good species to replace mrigal in composite culture of carps. In earthen pond, the fish grows 650-1200 g in a year with supplementary feeding. Under cage culture systems, the fish attains 600-700g in 8 months.

CHAPTER: 13

PULCHELLUS CARP

The pulchellus carp has been described with various names like *Puntius pulchellus*, *Puntius dobsoni* and *Hypselobarbus pulchellus* due to the wide colour variations seen not only in juvenile but also in maturing male and female of the species. This endemic fish seen in the peninsular rivers is presently included in the list of critically endangered species. It is a bentho-pelagic fish which inhabits the deeper part of large streams and rivers along the base of Western Ghats. Under riverine condition, this fish is reported to attain maximum size of 78 cm in length and 8 kg in weight. However, recent surveys revealed that as of now, only 0.5-1.8 kg size groups are available, though less in number. The fish is considered to be the only endemic fish consuming aquatic weeds and submerged grasses and could be used in controlling aquatic vegetation in reservoirs, tanks and irrigation canals. Though herbivorous, it is known to change its feeding habits depending up on the availability of food.

Fig.13.1 Puntius pulchellus.

In natural waters, the breeding of *P. pulchellus*is reported to commence soon after the monsoon months from September which continues until April with a peak in September and January. However, under pond culture conditions, it attains first maturity during June/July and breeding continues till October of the same year. Induced breeding of this fish has been successfully done by ICAR-CIFA.

SEED PRODUCTION

Broodstock management

The male and female weighing not less than 800 g are stocked in earthen pond having a minimum water depth of 2 m at a stocking density of 2000/ha, three months prior to breeding season with provision for regular health checks and management of water quality. The pulchellus prefers clear waters with ideal water quality parameters. It is advisable to provide aeration to the pond, as slight lowering of DO, especially during morning hours, often results in heavy mortality of the stocked fish. The ponds are manured initially with cow dung @ 2-4 t/ha, 7-10 days prior to stocking. The fish is fed with a formulated diet having 35% protein. As the fish has a shoaling tendency and swims in groups, it is easy to observe the fish and record any abnormal behaviour or swimming pattern.

Selection of brooders

The fish cultured in pond attain first sexual maturity at 1.5-2 years of age and for breeding, it should attain a weight of at least 1 kg. It has a prolonged spawning period and the fish is observed to spawn four times in a year (batch spawner) during a particular breeding season. Hence, the number of ova released at each spawning is limited.

The fish is observed regularly for sexual maturity by periodic samplings. It is easy to select brooders for induced breeding programme as sexual dimorphism is exhibited very distinctly by mature male and female. Male during breeding season is distinguished by dark colour, especially at the abdominal region and pinkish-red prominent tubercles on the snout between the eyes, in contrast to the white and swollen belly, plain and smooth snout and swollen pinkish vent of female which however, had a deep pink lateral band. Male gonadal maturity can also be judged by the production of milt, which gets expressed on application of slight pressure on the lateral sides of the abdomen near the vent. The appearance of tubercles in male is seasonal and disappears after 3-4 months of its onset. Many a times, an immature male is mistaken for a female because of the absence of the tubercles as it appears only during the breeding season. The success of the induced breeding mostly depends on selecting a breeder at its prime stage of maturity.

Fig.13.2 Pink snout with tubercles

Fig.13.3 Plain snout of female

Fig.13.4 Dark colour at the abdomen

Fig.13.5 Swollen belly

Spawning

It is successfully bred with synthetic hormones like Ovatide/ Wova FH administered by injection twice to female and male on subsequent days. The first injection of the hormone preparation is given to both sexes at a dosage of 0.5 ml/kg body weight. All injections are given intramuscularly between the base of the dorsal fin and lateral line by lifting the fish scale to insert the needle and after injection and withdrawal of the needle, the area is gently massaged to aid distribution of the hormone into the musculature and to prevent any backflow. The injected brooders are released to the breeding pool of a Chinese hatchery and are allowed to remain there with circulating water and overhead shower running throughout. After 16-18 hours, when the belly of the female became soft and swollen, the second dose of hormone is injected to both male and female at the same dose given earlier. After 18-20 hours of the second hormone administration, the fish is anaesthetised by submersing it in 25 ppm solution of clove oil (5 ml of clove oil: ethanol mixture (1:4) is dispersed in 40 l of water) till their opercular movement becomes slow and the fish becomes non-responsive to touch. Then the fish is dry stripped. At first, the female fish is taken, wiped gently with dry and clean cloth and held in an inclined position with the head up and the ventral portion over the basin and gently applied slight pressure with the thumb and index finger on the swollen belly, slowly descending towards the lower end of the body down to the vent. The fully mature female normally releases stream of ripe eggs which flow out as a jet under this pressure. The faecal matter and blood, if any, coming out of the fish should be avoided as much as possible. The eggs flowing freely upon the application of gentle pressure at the lateral side of the abdomen indicates that the eggs are fully mature. Immediately after stripping the eggs, the procedure is repeated with the male and the milt is directly stripped on the eggs. The eggs and milt are mixed by slow orbital rotation of the basin for a period of 10 minutes facilitating fertilisation of the eggs. Alternatively, the gametes are mixed with the help of a feather. The eggs are then washed with freshwater, till the washings become clear of the milt.

Fig.13.6 Stripping of female & male

Fig.13.7 Mixing of gametes

The fertilised eggs appear bright orange in colour. The released eggs measured 2 mm in diameter which upon fertilisation increase to 2.75-3 mm in diameter. This fish is a batch spawner and a fully mature female on first spawning releases about 10000-12000 eggs per kg body weight.

The fish on second spawning during the same season releases relatively less number of eggs, 5000-8000 per kg body weight.

Fig.13.8 Fertilized eggs

Incubation

The fertilised eggs are transferred to a hatching unit specially designed for heavy-yolk laden eggs, consisting of a series of rectangular FRP tanks with plastic trays inside with continuous flow of water on a re-circulatory mode with necessary biofilters to ensure good water quality. The DO, pH, hardness, temperature and alkalinity of water are of utmost importance for egg development and its hatching. The recommended values are

pH : 7.0-8.5;
alkalinity : 80-150 ppm;
hardness : 50-150 ppm;
DO : >5 ppm
Temperature : 26-28^{o}C.

Each tank houses a plastic tray with synthetic net bottom (1 mm mesh) immersed in water. The fertilised eggs are spread uniformly on the trays and water level of 5 cm or above should be maintained over the eggs and it should be ensured that there is an uninterrupted flow of water over these eggs to prevent clustering of eggs, which is very crucial for the development and hatching of eggs. The eggs attain a size of about 3 mm in 48 hours. At this stage the eggs become translucent and the twitching larvae can be clearly seen inside when examined under an inverted microscope.

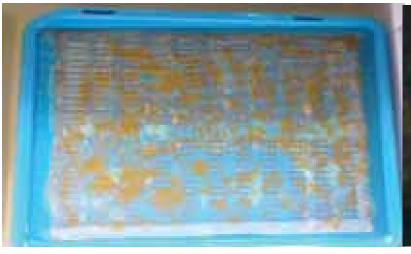

Fig.13.9 Hatching trays

Fig.13.10 Hatchling

Fig.13.11 Re-circulatory egg hatching system

Larval development

The development of embryo is slow with the elongation of the yolk mass which takes about 24 hours. Sporadic twitching movement of the embryo is observed only 4 hours before the larvae is hatched from the egg shell and by this time the egg had swollen to a size of 3 mm and appears quite transparent under a microscope. As the embryo advances in its development, the movements become more vigorous. The hatching takes place within 48-72 hours post-fertilisation at 22-24°C. The newly hatched larvae are transparent with no chromatophores, pale orange in colour with a heavily laden yolk sac. Though the embryo at this stage had clearly differentiated head and tail regions, they are not yet free from the ovoid yolk mass. These larvae move sporadically with a propelling movement. After 24 hours of hatching, the eyes are observed which appear to be faintly dark with a central pigmented area surrounded by a colourless rim. Anterior part of the yolk sac appear globular with a narrow smooth ending. The anal pore appears as a depression where the yolk sac ends and the larva attains a total length of 5 mm and weight of 4 mg at this stage. The yolk appears pale orange in colour. The head and tail are colourless (transparent) and the mouth is clearly visible and the eyes are heavily pigmented. Anal depression too is well marked. The yolk appears oblong in shape and ends abruptly. Complete yolk absorption in the larvae takes place by 6 dph at 24-26°C.

Rearing of hatchlings

For better survival, the larvae after yolk absorption on 6 dph is kept in glass aquaria @ 2000/m^3 at 26^{o}C with constant aeration. They are fed with filtered zooplankton for a period of 5 days followed by a combination of filtered zooplankton and finely ground pelleted feed containing 35% protein as additional supplementary feed for another 10 days. The spawn immediately after shifting to the aquaria aggregates at the dark corners with little movement, but after a couple of days starts moving around and can be observed in all areas within the aquaria. The dead larvae, if any, along with other uneaten feed and faecal matter at the tank bottom should be removed daily before feeding. On every third day, one third of water from the tank is removed and replenished with fresh water. Ideal conditions of water quality as mentioned earlier should be maintained during this larval rearing phase also as slight deterioration in the water quality parameters usually result in mass mortality of the larvae. The fry thus obtained 15 days after hatching is transferred to nursery tank/pond for further rearing.


Fig.13.12 Initial aggregation


Fig.13.13 Free swimming stage

Rearing of fry

Cement tank with soil bottom is initially fertilized with a mixture of 750 kg groundnut oil cake, 200 kg cow dung and 50 kg single super phosphate per hectare. A day prior to stocking the fry, soap-oil emulsion is applied to tank water for killing the aquatic insects and their larvae. The fry from aquaria is transferred to these tanks at a stocking density of $45/m^2$ for further rearing into fingerling stage. The fry is fed with a mixture of rice bran and powdered groundnut oil cake (1:1) for the first month @ 10% of the body weight followed by fishmeal based 2 mm pelleted feed having 35% protein @ 8% of the body weight for the second month and @ 6% of the body weight during the third month. While the mixture of rice bran and groundnut oil cake is broadcasted in powdered form on the water surface, the pelleted feed is given in plastic trays, once daily, preferably in the morning hours. Feeding *ad libitum* in plastic trays resulted in faster growth in tank. As this fish prefers clean waters, subsequent fertilization of rearing tank is generally not recommended as the tank become green due to unconsumed feed and faecal matter of fish. The fry of 1.2 cm stocked at $45/m^2$ attains a length of more than 5 cm at the end of 3 months reared in soil based cement tank.

CHAPTER: 14

CAUVERY CARP

The Cauvery carp, *Puntius carnaticus*, is an endemic and threatened fish of the Western Ghats. Its maximum weight recorded is 12 kg with a length of 60 cm. It is threatened by a wide range of factors including decline in habitat quality due to destructive fishing practices, altered river flow due to construction of dams, competition with exotic fish varities and man-made pollution of its habitat.

Fig.14.1 Puntius carnaticus

It prefers large pools in rivers and streams, where the adults have a tendency to hide under bedrock, boulders and within caves. It feed on the fruits and seeds that fall from the canopy above. It naturally spawns in flooded rivers during July to August. The adults migrate upstream for spawning and breed in the flood waters. The fry is found in these waters during September to December. The young are seen in groups along the banks of rivers and reservoirs, but the adult ones are rarely seen along the banks.

The Cauvery carp does not normally breed under captive conditions, but its induced breeding has been done successfully by ICAR-CIFA. The fish can be induced bred at farm conditions from July to November. However, induced breeding has been achieved throughout the year with better management practices.

SEED PRODUCTION

Brood stock management

The male and female weighing not less than 300 and 500 g respectively, are stocked in earthen pond @ 2000/ha three months prior to breeding season. The pond is manured initially with cow dung @ 2-4 t/ha, 7-10 days prior to stocking. A minimum water depth of 90 cm is maintained throughout in the pond. The fish is fed with a diet having 35% protein. The fish is examined regularly for maturity through periodic sampling. Male maintained in pond attains first sexual maturity within 8-9 months, whereas female by 15-24 months. The male after becoming sexually mature, produces milt throughout the year.

Fig.14.2 Testes of mature male

Fig.14.3 Ovary of mature female

Selection of brooders

The success of induced breeding mostly depends on selecting a broodfish at its prime stage of maturity. Sexually mature male and female are identified based on secondary sexual characters like round and swollen belly and pinkish vent of female and white coloured tubercles on upper snout of male. On application of slight pressure on the lateral sides of the abdomen near the vent, the mature male discharges milt which is thick, viscous and milky white in colour.

Spawning

Like other peninsular carps, it does not naturally breed under confined condition. Under captivity, mature male and female are administered with injection of synthetic hormones like

Ovatide/WovaFH @ 0.5 ml/kg body weight. The injected brooders are released to the breeding pool of a Chinese hatchery and are allowed to remain there for 18-20 hours with circulating water and overhead shower running throughout and after that ferilisation is carried-out by dry stripping method. The fertilised eggs appear bright yellow in colour. The released eggs measured 1.0 mm in diameter which upon fertilisation and water hardening increases to 1.9 mm diameter. The fecundity of this fish is 45,000/kg bodyweight during its first maturity.

Fig.14.4 Stripping of female *Fig.14.5 Stripping of male*

Incubation

It is done as explained for the pulchellus carp

Fig.14.6 Re-circulatory egg hatching system.

Embryonic and larval development

The process of organogenesis in fertilised eggs begins at 12-14 hours post-fertilisation and continues until hatching of the eggs, which commences at 48 hours. Differentiation of head and body occurs at 14-16 hours, followed by the development of pear shaped embryo at 18-20 hours. Hatchling emerges from yellow coloured egg between 48-56 hours post-fertilisation at 20-22^{0}C. The newly hatched free embryo with limited movement is negatively phototactic and congregate at the corners. The yolk of the larva gets completely absorbed by 5 dph.

Fig.14.7 Eggs mixed with milt

Fig.14.8 Fertilized eggs

Rearing of hatchlings

It is done as explained for the pulchellus carp

Rearing of fry

The fry of about 1.35 cm from aquaria is stocked for next 3 monthsin manured cement tank with soil base at a stocking density of 60 no./m^2 for further rearing to fingerling stage of 5 cm. The other aspects of rearing of fry is similar to that explained for the pulchellus carp.

CHAPTER: 15

PEARLSPOT

The pearlspot is a high valued food fish endemic to peninsular India and Sri Lanka. It has an elevated laterally compressed body and a small cleft mouth. In the natural habitat, the fish is light green in colour with eight vertical bands. Scales are slightly ctenoid. Most of the scales above the lateral line have a pearly white spot and some irregular black spots are seen on the abdominal scales. The species was declared as the 'State fish of Kerala' in the year 2010. It is considered as one of the potential candidate species for aquaculture, because of its high market demand, hardy nature, non-predatory habits and ability to breed naturally in confined waters.

Fig. 15.1 Etroplus suratensis

Pearlspot is a euryhaline fish, thriving well in brackish waters and has the ability to live both in fresh and saline waters. It is an omnivorous detritus feeder which feeds mainly on plankton, small worms, prawns and algae. Periphyton dominated with spirogyra is its favourite food. Pearlspot usually attains sexual maturity during first year. Sexes are separate, but can accurately be identified only during the breeding season. It has an asynchronous type of ovary which indicates its continuous spawning habit. It breeds throughout the year with two peaks during the monsoons.

SEED PRODUCTION

Breeding behaviour of pearlspot involves pairing, courtship, chasing, nest making and parental care. Induced breeding through hormonal manipulation has not been successful, because of its complexity. The breeding protocol has been developed by RARS Kumarakam and the commercial production was first achieved at state Government hatchery at Azhikode.

Broodstock management

Usually earthen pond is used for developing broodstock; which is prepared by strengthening of bunds, eradicating aquatic plants and unwanted organisms and liming as explained for the major carps. The pond is manured with cow dung at 1250 kg/ha for plankton production and a water transparency of 40-50 cm is maintained which plays a major role in pair formation. The pond is stocked with adult fish at a density of 2500 no./ha and fed with a formulated feed consisting of 45% rice bran, 40% groundnut oil cake, 15% fish meal fortified with vitamin E and mineral mix. Daily feeding is done at 3-5% of the body weight either in pellet or in dough form in feeding trays as two rations (morning and evening). The trays are taken out and cleaned every day. Excess feeding should be avoided to prevent water pollution.

The male and female fish with specific attributes get closer to form a spawning pair. The most prominent indication of a pre-mating pair formation is the clear intensification and darkening of bands in male. The male broodfish is also characterized by a bluish-green irridescence and sparkling pearly white spots. The rayed/pointed portions of the dorsal and anal fins turn a little red. The female is generally small with black spots on the ventral side between pelvic and anal fin. The genital papilla of female is oval and swollen with a blunt tip whereas in male, it is thin. The pairing of broodfish happens within 30 days. A success rate of 60% can be expected in forming breeding pairs.

Spawning

Either the same earthen broodstock pond or separate tank (cement tank of 4 x 2 x 1 m or FRP tank of 1 t capacity) is used for spawning. If tank is used, one third area of the tank bottom is filled with sand after demarcation with a single line of bricks. Then, egg attaching substrates like tiles, bamboo pieces, PVC pipes and cement bricks are placed in the sandy area of the tank/pond. In the tank/pond, the brood fish weighing 150-200 g in the sex ratio of 1:1 are stocked for spawning at a density of one pair per 1-2 m^2. The fish is fed at 2-3% of the body weight. In tank, excess feed and organic waste are siphoned-out daily and a partial water exchange of 20-30% is done twice in a week.

The breeding pair swims along the sides in search of substrates for the attachment of eggs. When they find an appropriate substratum, both male and female partners engage actively in nest preparation. They clean-off the substrates by browsing the algal growth by rhythmic jaw movements. Selection of the nesting site and cleaning of spawning surface are often completed within a week and the paired fish are found to form an isolated territory.

The male fish begins to excite the female by hitting on the vent and nibbling on the abdomen and the pair swims around the chosen substratum. During ovulation, the female lays flat on the spawning site and gently moves from end to end and begins to attach eggs carefully with the help of its ovipositor. The female fish attaches its sticky eggs by pressing closely on the nest surface, one by one in a single layer, supported by its pelvic fins. After releasing eggs, the male fish which follows close behind the female, sprays milt over the eggs in a quick movement and fertilise them instantly. The process of egg laying and fertilisation is continued several times and usually completed in 1-2 hours. The fertilised eggs are yellowish in colour and oblong in shape with 2 mm diameter. They are placed closely in a chain, not touching each other. When the embryo develops, the yolk sac become pigmented and turns brownish. Fecundity is 500-1500 no./fish.

Incubation

The female remains always close to the eggs while the male guards the territory to prevent the entry of intruders. Simultaneously, both of them together make pits of 5-10 cm diameter and 2-4 cm depth near the substratum. The eggs hatch out in 72-80 hours. The hatchling has only limited power of locomotion and are immediately picked up by the female with its mouth and placed in the pits. Both the parents guard the pits together. The hatchlings remain in pits for 5-7 days and on development of fins, they start moving-out of the nest under the watchful eyes of the parents. The young-ones of one pair move in a group and do not mix-up with other. The pairs will be breeding at regular intervals and many groups of young-ones can be seen at a time. Under natural condition, the parental care lasts till the young ones attain about 2-3 cm size.

Nursery rearing

When young-ones show active movement in tank (usually after 10-20 days of hatching), they are collected using 300 µm harvest net, while in earthen pond the young-ones are allowed to be with parents till it attains 2 cm size. The collected young-ones are stocked at a density of 1000 no./m^2 in cement rearing tank (8 t) or FRP tank (1 t). The young-ones are initially fed twice daily with small zooplankton or freshly hatched *Artemia* nauplii at 20-30 no./larva. Spirulina at 1g/tank is added to enhance the production of *Brachionus*, *Moina* and *Daphnia*. Shrimp larval feed with 100 µm size is also used for feeding. After 15 days of hatching, the fry accepts feed of 200 µm size and is subsequently weaned on 500 µm feed in 25 dph.

It grows to a size of 2 cm in 30 dph. The fry with 2 cm size is thinned to a density of 500 no./m^2 and fed with micro particulate diet of 500-800 µm having 40% protein. The seed attains 4-6 cm size in 60 days and is collected using net trap, scoop net or dip net without disturbing the pond bottom.

Packing & transportation

Pearlspot is euryhaline, and can be easily acclimatised to the salinity of the waterbody to be stocked. Acclimatisation time of 30 minutes is required for adjusting salinity difference of each 5 ppt. The other aspects of packing and transportation are similar to that of the major carps.

Fig. 15.2 Conditioning of seed

FARMING IN CAGE

Site selection

Cage farming can be done in open brackish waters such as estuary, backwaters and lakes. The site should have moderate tidal water flow (0.25 m/s) and protected from strong wind and rough weather. The site should be free from navigation channel, dredging, rotting of coconut husk, fouling of aquatic weeds, pollution from industries, domestic waste *etc*. Bottom should be sandy or sandy clayey. The site should have a minimum water depth of 2 m for fixed cages and 4 m for floating cages during low tide. Transparency of water body shall be more than 30 cm with an optimum pH level in between 7.5 and 8.5.

Cage design

In deep brackishwater area having minimum 4 m depth, floating cages can be established having 460 x 360 cm outer frame and 400 x 300 cm inner frame with salt resistant GI pipes of 1-1.5 inch diameter and 1.5 mm thickness and held together with connecting rods and clamps. A hand rail of 75 cm height is provided with the inner frame and one more connecting rod at the middle parallel to lengthwise sides. One outer frame can hold two outer HDPE cages having 360 x 230 x 280 cm size and two inner HDPE cage netting of 300 x 200 x 325 cm size are hanged from the top of the handrail and the connecting rod in between at the middle of lengthwise side. Eventhough the depth of inner cage netting is 3.25 m, effective water depth is limited to 2.5 m. The other details on cage fabrication and mooring system are same as that explained for the Nile tilapia. Ballasting with GI rod of 280 x 180 cm having 1.5-2 cm thickness is done to ensure cuboid shape of the cage.

In shallow brackish water area having less than 4 m depth and locations close to shore, fixed square PVC cage having a size of 2 x 2 x 1.5 m size is made by PVC pipes of 1.5-2 inch diameter held together by PVC joints. The PVC frame at the top is hollow and that at the bottom is kept open. The sides and bottom of the cage is wrapped around with inner HDPE netting. Top of the cage is also wrapped with the same netting material with special provision to facilitate opening and closing of the cage. The inner cage net is then covered with an outer HDPE net. The cage unit is fixed conveniently in the pre-determined location with good quality bamboo poles having 3-4 inch diameter by using synthetic ropes. In between the cages, additional ramp is provided to facilitate easy access for handling, feeding, grading, cleaning and monitoring. In areas having the attack of animals like otter and rat, an extra protection is given for the entire cage unit by using bamboo poles and net. Care should be taken to ensure that the cage has a minimum clearance of 50 cm from the bottom of water body.

Fig. 15.3 Floating GI cages

Fig. 15.4 Fixed PVC Cages

Stocking

Pearlspot seeds of 4-6 cm size can be stocked at a density of 80-200 no./m^3 after proper acclimatisation. Initially, fish seed is stocked in inner rearing cage having 10 mm mesh size with 0.5 mm twine thickness. As the fish attains the size of 10 cm, it is transferred to grow-out cage having 18 mm mesh size with 1 mm twine thickness. The outer cage of

18 mm mesh size with 1 mm twine thickness is used initially and followed by 36 mm mesh size with 2 mm twine thickness.

Feeding

Quality feed in required quantity is very important for sustainable cage farming. Water stable floating pelletted feeds having 38-42% protein and 6-8% fat is given at 2-10% of the body weight. The quantity, size and protein content of feed are determined based on Table- 15.1. Initially, feeding is done four times daily and is reduced to twice daily (morning and evening) after 2 months. Floating PVC feeding ring made of closed net having 15 cm height can be used to prevent the loss of feed due to strong tidal current.

Table 15.1. Feed requirement

ABW (g)	Protein content (%)	Feed size (mm)	Daily feeding rate (% of ABW)
3-5	42	0.8	10
5-25	42	1.2	8
25-50	40	1.8	6
50-100	40	2.5	5
100-200	38	2.5	4
200-400	38	4.0	3
>400	38	6.0	2

Fig. 15.5 Floating feeding ring

Care and maintenance

Eventhough pearlspot grazes on periphyton attached to the cage net, it shall be cleaned once in a week using brush (made of natural fibres) to ensure proper water flow and to remove any fouling organism. Regular sampling of fish at fortnightly interval shall be done for evaluating the growth and health. Thinning can be done once in a month as per the size grade, if necessary.

Table 15.2- Growth rate

DOC	Size of fish (g)
On stocking	3
30	7
60	13
120	30
180	80
240	155
300	250

Harvesting

The fish grows to a harvestable size of 250 g within 8-10 months with an expected survival rate of 80%. Based on market demand, fish can be marketed in live condition to ensure premium price. Feeding should be stopped one day prior to harvest. Pearlspot has market demand starting from 200 g size onwards; hence partial harvesting is preferred from this size onwards using scoop net. The anticipated production from a well maintained cage is 24-40 kg/m^3.

FARMING IN POND

Serious efforts are required for the productive utilization of the available brackish water ponds for both monoculture and polyculture of pearlspot with milkfish and/or mullets.

Site selection & pond construction

Rectangular pond having minimum 0.2 ha area and 1-2 m depth is ideal for the farming of pearlspot. It also thrives in small irrigation tank and backyard pond. Pearlspot farming in earthen pond is more sustainable as it breeds naturally and also utilises the naturally available feed. The pond is covered with bird net of 100 mm size for controlling predatory birds. The side of the pond is fenced with stiff net of 26 mm to prevent the entry of predatory animals. Other aspects of site selection and pond construction are same as that of the major carps.

Pond preparation

The pond preparation steps such as de-siltation, bund strengthening, installation of water inlet/ outlet, draining, drying, tilling, eradication of aquatic weeds and predators and liming are similar to that of the major carps. After filling 25-30 cm water column in the pond, poultry dropping at 500 kg/ha or cow dung at 2000 kg/ha is applied to boost natural feed production in the culture pond. As the plankton production is enhanced within 7 days, the water level is slowly raised to 100 cm. Bamboo poles and coconut leaves are placed along the sides of the pond with 2 m interval for facilitating the growth of periphyton. It will also act as egg attaching substrates during breeding.

Water quality requirements

Temperature	: 25- 32°C
Salinity	: 0-30 ppt
pH	: 7.0- 8.5
Transparency	: 25-40 cm
DO	: >4.5 ppm
Alkalinity	: 200-300 ppm

Stocking

After the development of plankton and raising the water level to 1 m, properly acclimatised seeds having a size of 4-5 cm are stocked in cage, happa or pen installed in the same pond to ensure maximum survival. As the growth rate is relatively poor in pond, seeds are stocked @ 30,000/ha for monoculture. If it is polyculture, stocking density is reduced @ 15,000/ha along with milkfish or mullet at 5000/ha.

Feeding

The fish is fed in the morning and evening with a formulated floating pelletted feed or conventional feed having groundnut oil cake, rice bran and fish meal with vitamin-mineral mix as ingredients. The feed contains 24-34% protein and 5% fat.

Table 15.3. Feed requirement

ABW (g)	Protein content (%)	Feed size (mm)	Daily feeding rate (% of ABW)
3-5	34	0.8	6
5-25	32	1.2	4
25-50	28	1.8	3
50-100	28	2.5	3
100-200	24	2.5	2
200-400	24	4.0	2

Care and maintenance

Water is added intermittently to maintain a water depth of 1-2 m. Moreover, 20-30% of water is replaced fortnightly. Chances for drop in pH can be avoided by the application of agricultural lime on the inner bund @ 250 kg/ha. Subsequent doses of cow dung are added at 250-500 kg/ha for every 7 days in accordance with the availability of plankton. Paddle-wheel-aerators at 2 hp/ha are installed for a production of more than 6 t/ha. Growth is monitored by periodic sampling using cast net.

Harvesting

The fish attains marketable size of 250 g over a period of 10-12 months with a survival rate of 80%. A production of 6 t/ha can be expected.

CHAPTER: 16

MILKFISH

The milkfish, *Chanos chanos* is one of the ideal candidate species for farming in coastal areas. It has a symmetrical and streamlined body with large forked caudal fin. It has no teeth and predominantly feeds on algae and invertebrates. It tolerates a wide range of temperature (15-40^{o}C) and salinity (0-145 ppt).

Fig.16.1 Chanos chanos

Adult fish spawn in the open sea with a water depth of about 50 m. The female fish (6-7 years old) spawns annually or biannually, releasing about 3-7 lakh eggs/kg body weight at a time. The planktonic eggs are 1.10-1.25 mm in diameter and hatch-out within 24 hours. The pelagic larvae and eggs drift along with the ocean current and get carried to the inshore waters. The young-ones get into coastal waters along with the tidal inflow. Mangrove ecosystem with plenty of micro and macro live feed organisms and high organic matter, provides an excellent feeding ground to them till the sub-adult stage. On attaining a size of 200-300 g, the fish migrate back to the sea. The adult fish feed mainly on the mats of detritus consisting of plankton, microalgae and associated organisms. Aquaculture of the species depends on wild-collected seeds in India, however, ICAR-CIBA has developed commercial seed production technology in the recent years. The seed collection season extends from March to June with a subsidiary season from October to December.

SEED PRODUCTION

Broodstock management

The sub-adult fish collected from wild or farm is anaesthetised, length and weight of body measured and reared in floating sea cage or in the earthen saline pond for developing as broodstock. The pond is fertilized for the production of natural feed, "*lab-lab*" which is a complex benthic organic mat consisting of blue-green algae, diatoms, bacteria, nematode worms *etc*. The broodstock is also fed twice daily with a floating pelletted feed (36% protein and 6% lipid) @ 1-2% of the body weight. It matures on reaching a size of 3-5 kg within 5 years. The gravid male and female brood fish are selected by visual examination of the urino-genital region. Male has two openings externally, whereas the female has three. After proper quarantine, the brooders are shifted with mild sedation in a transportation tank (oxygen maintained at saturation level) and released into spawning tank (100 m^3).

Water quality management

Water is taken directly from the sea or a well at the shore. After removing the debris through a screen net, the collected seawater is allowed to settle in a sedimentation tank to remove suspended particles followed by chlorination (35 ppm) in a tank. After de-chlorination by aeration, the seawater is passed through a slow sand filter and pressure sand filter to remove particles larger than 25 µm. Cartridge filter (1 µm level) is also required for water filtration. Finally, it is disinfected by UV sterilizer or ozonizer. EDTA (5-10 ppm) is also added in the reservoir tank or directly to the rearing tank to remove heavy metals and reduce contamination.

Spawning

The male and female fish attain sexual maturity within 4 and 5 years of age, respectively. The domesticated milkfish spawns naturally in the pond or circular spawning tank in correlation with the lunar cycle. It is induced to spawn by the injection of HCG at 350-500 IU/kg body weight for the female. A combination of LHRH-a and 17α- methyl testosterone is also used for inducement after careful assessment of oocyte diameter. The male to female sex ratio maintained is 2:1. Induced female, along with conditioned males, are released in a floating cage. The cage is covered with a closed mesh net for collecting the eggs. Fertilisation is external, and the fertilised eggs are spherical, translucent, buoyant and measure 1.23 mm in diameter. After spawning, the brooders are released back into the broodstock pond. The rate of fertilization is determined by collecting samples of eggs using a scoop net of 300-500 μm mesh size and measuring in a graduated bucket. Fecundity is 3-7 lakh/kg body weight. Optimum temperature and salinity for spawning are 29-32^0 C and 26 ppt.

Incubation

The fertilised eggs for incubation are kept in bucket with mild aeration. These are disinfected with a dip in 100 ppm betadine for one minute. The fertilised eggs are incubated in cylindro-conical FRP incubation tank (500 l) at a density of 500-1000 no./l with mild aeration. The eggs hatch out in 20-35 hours at a temperature of 26-32ºC and salinity of 29-34 ppt. The newly hatched larva has an average total length of 3.4 mm with a large yolk sac. The mouth of the hatchling opens on 3-4 dph and show phototaxis and rheotaxis during day time.

Live feed production

The treated seawater is filtered into the outdoor tank through 1 μm filter bag, aerated and then fertilised with 100 g ammonium sulphate, 10 g urea, and 10 g superphosphate per 1000 litres of water. In the early morning, it is inoculated with rotifers at a density of 50 no./ml and also with freshly harvested algae (*Chlorella)* 400 ml at 1.6x10^6 cells per ml from the indoor culture room. During the first 2 days, the culture volume is doubled to dilute the rotifer density to half. Within 3 days, rotifer increased to 200 no./ml. During the following days, half the tank volume is harvested and refilled again to decrease the density to half. On the fifth day, the tank is harvested completely, and the process is repeated. Pure stock culture of required phytoplankton and zooplankton have to be maintained in an indoor laboratory to ensure uninterrupted production and supply.

Rearing of larva

The larvae of 3 dph are transferred to outdoor cement tank (200 m^3 capacity) containing filtered seawater having 27-28 ppt salinity at a density of 2-3 no./l. Good quality live algae such as *Chlorella virginica, Isochrysis galbana* and *Tetraselmis chui* are directly added to larval rearing tank to maintain the required phytoplankton cell density of 35000 no./ml (green water system) with mild aeration. It helps in maintaining water quality, controlling bacteria, enriching zooplankton and easy feeding of larvae. Start feeding the larvae from 2-3 dph for 2-3 times daily with enriched *Brachionus plicatilis* at a density of 5-10 no./ml until 15 dph. *Artemia* nauplii are used as feed along with *Brachionus plicatilis* from 14 dph. Weaning on formulated microencapsulated feed starts from 15 dph onwards. The larvae reach 14-16 mm by 21 days after hatching. On reaching 20 mm, it is transferred to an earthen pond for further rearing.

Rearing of fry

The earthen pond up to 0.2 ha with a water depth of 1 m is ideal for nursery-rearing.The nursery pond is prepared by de-siltation, bund strengthening, installation of sluices, draining, drying, tilling, eradication of aquatic weeds and liming as explained for the major carps. Chlorination using bleaching powder (35 ppm) is ideal for the removal of pathogen, predator and weed fishes. After filling the pond up to 25-30 cm height, raw cow dung slurry @ 1000-2000 kg/ha and poultry droppings @ 250-500 kg/ha are applied in the culture pond to boost the growth of diatom and zooplankton respectively. After 3-7 days, "*lab-lab*", the favourite food of the growing milkfish fry, develops at the bottom of the pond. Then the water level in the nursery pond is slowly raised at an increment of 2-3 cm per day so that the organic complex of the benthic mat does not get detached from the pond bottom and thereby doesn't float at the surface. The stocking of fry is done when the pond is rich in "*lab lab*". Coir mat is usually placed below the water surface about 30 cm above the pond bottom to accelerate the production of "*lab lab*". Poles are erected along the embankments and covered with a net to deter predatory birds.

The fry having 2 cm size are stocked at a density of 100-300 no./m^2 during cool hours of early morning or late evening. The fry feeds actively on the "*lab lab*" and other phytoplankton and grows rapidly even up to a rate of 1 mm per day. Supplementary feeding with rice bran is given depending upon plankton production. By the end of 30-45 days, it attains a size of 5-8 cm (1.5- 5 g).

Packing and transportation

It is usually harvested using dragnet after reducing the level of water during low tide followed by pumping out of water. During conditioning, the seed is acclimatised to the salinity of grow-out pond. The procedure of packing and transportation is similar to that of the major carps.

FARMING IN POND

Site selection & pond construction

Rectangular pond having a minimum of 0.2 ha area and 1 m depth is ideally required for the farming of milkfish. Sluice gates are installed to regulate the inflow and outflow of water. The pond is covered with bird net of 100 mm mesh size to control predatory birds. The side of the pond is fenced with a stiff net of 26 mm to prevent the entry of predatory animals. Other aspects of site selection and pond construction are the same as that of the major carps.

Pond Preparation

Before stocking, inorganic fertilizers such as urea (15 kg/ha) are also applied along with organic manures in order to ensure the availability of "*lab lab*". The fish also feeds on filamentous green algae, copepods, mysids, *etc*. The other aspects of pond preparation are similar to that explained for nursery rearing.

Water quality requirements

Salinity	: 10-30 ppt	pH	: 7.5-8.5
Temperature	: 26-30^{o}C	DO	: >4.5 ppm
Transparency	: 25-40 cm		

Stocking

After the development of "*lab lab*", the water depth is raised to 1 m and seeds having a size of 4-6 cm is stocked in happa or pen installed in the same pond for further nursery rearing to ensure maximum survival. Small nursery pond located inside the grow-out farm can also be used for rearing, which occupies about 2% of the total area. Before releasing the seed, temperature and salinity in the bag carrying the seed is gradually equalized with those in the pond by acclimatisation. In grow-out pond, fingerlings are stocked at a density of 7,500 no./ha for monoculture. In polyculture, stocking density is reduced to 5,000 no./ha along with pearlspot at 15,000 no./ha.

Feeding

Generally, milkfish thrives on natural food available in the pond. Supplementary feeding is also given with a formulated floating pelletted feed, rice bran and wheat bran. The protein requirement of the species is 20-32% in the grow-out stage. The feed is given twice daily (morning and evening).

Table 16.1. Feed requirement

ABW (g)	Protein content (%)	Feed size (mm)	Daily feeding rate (% of ABW)
5	32%	0.8	5%
50	28%	1.2	5%
100	28%	1.8	4%
300	24%	3.0	3%
500	24%	4.0	3%
700	20%	6.0	2%
900	20%	6.0	1%

Care and maintenance

Even though, milkfish is generally free from diseases, it is essential to manage the pond with due care and attention. Periodic liming at 250 kg/ha is done for correcting the pH, if necessary. Whenever the density of *lab lab* in the pond decreases, subsequent doses of cow dung are added at 500-1000 kg/ha in pond to enhance its production. Water is added intermittently to maintain a water depth of 1-2 m. Moreover, 20-30% of water is replaced fortnightly. If an anticipated fish production of 6 t/ha is targeted, paddle-wheel-aerators at 2 hp/ha are installed. It is essential for keeping the DO level above 4 ppm to ensure proper growth and survival. Growth is monitored by periodic sampling.

Table 16.2. Growth rate

DOC	**ABW (g)**
0	5
30	35
60	90
90	140
120	260
180	550
240	800

Harvesting

The fish attains a marketable size of 1 kg within a period of 8-10 months with a survival rate of 80%. Seine net, gillnet or drag net is usually used for harvesting the farmed milkfish. If the length of seine net is equal to the length of the pond, repeated netting would result in complete harvesting. When more than one size group is present, 'cull harvesting' is adopted using gill nets of appropriate mesh size to capture the fish of desired market size. Gill net is stretched in a zig zag line across the pond. Care should be taken to ensure that the fish is not injured and the scales remain intact. Considering the aggressive nature of fish during harvesting, the personnel involved must wear all safety accessories like helmet etc. Fish is often dipped in ice water to prevent the loss of scales during handling. Harvested fish is marketed daily and usually consumed in fresh condition and never kept in ice for more than a day. Frozen fish is not preferred in the market. The expected production is 6 t/ha.

CHAPTER: 17

GREY MULLET

The grey mullet, *Mugil cephalus* is one of the important brackish water cultivable species. The fish is notable with greyish green colour on the dorsal surface and silver-white on the ventral side, an elongated body, broad and flattened head with a small, inferior mouth. Eyes are often covered by adipose tissue.

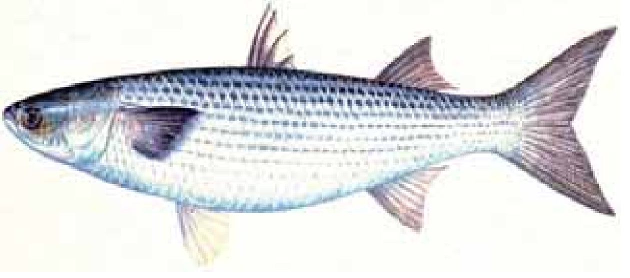

Fig.17.1 Mugil cephalus

Grey mullet is euryhaline and eurythermal. It is cultured in seawater and brackish water. They feed at low trophic levels, consuming microorganisms, decaying organic matter, algae, insect larvae and small molluscs from the bottom. Due to its benthic feeding behaviour, the species is considered as an efficient bio-remediator in aquaculture, and forms part of polyculture systems to manage the quality of sediments.

Natural breeding of grey mullet occurs in the sea, and the fry drifts back towards estuaries. These are areas from where wild seeds of grey mullet are collected. The seed of grey mullet collected from the wild may often be mixed with other unwanted species.

SEED PRODUCTION

Broodstock management

Similar to broodstock management of the milkfish, the grey mullet broodstock are also maintained adhering to the principles of high-quality feed, water quality and health management and it is almost similar.

Water quality management

It is also practiced in a similar way to that explained for the milkfish.

Spawning

The male and female fish attains sexual maturity within 2-3 years and 3-4 years of age, respectively. Based on the gamete quality, male and female fish are selected and released into breeding tank of 50 m^3 having 1.5 m depth. Female is induced to spawn using a total dosage of LHRHa, 400 µg/kg as priming and resolving injection in two split doses. Two running males are released with the female after second injection and spawning occurs by 12 hours. Fertilisation is external, and the fertilised eggs are buoyant (pelagic), spherical and transparent with 0.8-0.9 mm diameter size. Eggs are collected as explained for the milkfish. Fecundity is 5-10 lakh/kg body weight.

Incubation

The fertilised eggs are measured and incubated as explained for the milkfish. The eggs hatch out by about 30 hours at 32^{o}C. The newly hatched larva has 2.0-2.5 mm size with a large yolk sac, and it remains suspended in water in an inclined position with the ventral side directed upwards and avoids light.

Rearing of larvae

The larvae of 2 dph are transferred to indoor FRP tank (2-30 t capacity) containing filtered seawater at a density of 10-25 no./l. No feed is given for the first two to three days and rotifer is used as live feed from 3-5 dph onwards. Artemia nauplii are given as feed from 20 dph to 35 dph. Fry attains a length of 2 cm within one month of rearing.

Live feed production

It is practiced in a similar way to that explained for the milkfish.

Rearing of fry

Earthen nursery pond of 0.2 ha area with 1 m depth is ideal for the rearing of fry. The nursery pond is prepared by de-siltation, bund strengthening, installation of sluices, draining, drying, tilling, eradication of aquatic weeds and liming as explained for the major carps. Use of bleaching powder is ideal for the removal of pathogen, predator and weed fish. Before filling water to the pond, cow dung is added to the pond at 2500 kg/ha. Subsequently, poultry droppings at 500 kg/ha or chemical fertilizers (Urea at 100 kg/ha, Superphosphate at 200 kg/ha) is added as per the requirement to ensure sufficient plankton in the pond. After acclimatisation, fry of 2 cm size is stocked in the nursery pond at a density of 100-300 no./m^2. Ideal transparency of the pond water is 20-30 cm. Rice bran or wheat bran is used as a supplementary source of feed depending upon plankton production. In the nursery pond, the fry is grown to fingerling stage (5-8 cm) in two months.

Non-availability of hatchery-produced seed is the main bottleneck for the expansion of grey mullet farming. Presently, wild seeds of the mullet concentrating in shallow estuarine regions during the breeding season are collected for aquaculture; however, their survival is low due to handling associated stress and injuries.

Packing and transportation

The fingerlings are caught by netting or by draining the nursery pond. Packing and transportation are being carried out similar to that of major carps.

POND FARMING

Site selection & pond construction:

All the aspects of site selection and pond construction are same as that of the milkfish.

Pond Preparation

Before stocking, the pond is prepared by de-siltation, bund strengthening, installation of sluices, draining, drying, ploughing, eradication of aquatic weeds, liming and manuring as similar to that explained for the major carps. Then the pond is fertilized with poultry droppings at 500 kg/ha or cow dung at 2000 kg/ha. Water is added to a level of 25-30 cm and maintained for 7-10 days to develop natural feed. Then the water level is increased to above 1 m before stocking of fingerlings. The productivity is maintained at the required level by adding subsequent doses of poultry droppings and chemical fertilizer.

Water quality requirements

Salinity	: 5-30 ppt	pH	: 7.5-8.5
Temperature	: 26-30^{o}C	DO	: >4ppm
Transparency	: 30-40cm		

Stocking

Stocking in the grow-out pond is done after the development of natural food and increasing the water depth to 1 m. As mullets can be cultured in salinities ranging from freshwater to seawater, the seed should be properly acclimatised. The fingerlings of 4-6 cm are preferably stocked in hapa or pen installed in the same pond till it reaches 10 cm size and thereafter released at a stocking density of 10,000 no./ha for monoculture. Being a peaceful herbivore, grey-mullet is also stocked (5000/ha) along with pearlspot (15,000/ha) in the polyculture system.

Feeding

Generally, grey-mullet thrives on organic material available at the pond bottom. Rice bran or wheat bran is given as supplementary feed daily at 1-5% of the body weight. Its protein requirement is 20-32%. All the aspects of feeding are the same as that of the milkfish.

Care and maintenance

Periodic liming at 250 kg/ha is done according to the pH of water. Whenever the density of plankton in the pond decreases, subsequent doses of cow dung are added at 500-1000 kg/ha in the pond to enhance production. Monthly sampling is done to assess the growth and health. All the aspects of care and maintenance are similar to that of milkfish.

Harvesting

Within a period of 8-12 months, the fish attains a size of 750-1000 g. The harvesting aspects are almost same as that given for the milkfish.

CHAPTER: 18

COBIA

The cobia, *Rachycentron canadum* is a marine fish that lives upto a water depth of 1200 m. It is a candidate species for aquaculture because of its fast growth rate, excellent meat quality and high demand in the domestic and international market. The white meat of the fish is served as raw fish, *Sashimi*. Male and female fish attain sexual maturity at 1-2 years and 2-3 years of age, respectively. It exhibits annual oceanodromous migration. It is carnivorous and mainly feeds on fish. Its colour is dark-brown dorsally, pale-brown laterally and white ventrally with a black lateral band, as wide as its eyes, expands from snout to the base of the caudal fin, bordered above and below by pale bands. The body is elongated and sub-cylindrical, but the head is broad and depressed. Scales are small, embedded in thick skin. Absence of air bladder is one of the peculiar characters.

Fig. 18.1 Rachycentron canadum

SEED PRODUCTION

Broodstock management

The sub-adult fish is collected from wild or farm for developing into broodstock. Wild fish is collected by hook and line, anaesthetised with 25 ppm clove oil (*Eugenol)* solution and is transported by boat in covered FRP tank with aeration facility. The biomass of the fish should not exceed 50 kg/m³ in the tank during transportation. The fish is released into cage after measuring its body weight and length. Thereafter, the gravid brood fish are selected, anaesthetised with clove oil (10-20 ppm) and transferred to quarantine tank after giving freshwater dip for 3-5 minutes. In order to remove ectoparasites and other microbes, the fish is kept under quarantine for a period of 3 weeks.

Fig. 18.2 Quarantine (Courtesy: RGCA)

After quarantine, the fish having not less than 5 kg weight is transferred to the maturation tank (25-100 t capacity) having re-circulation facility. The brood fish is fed twice daily at 1-2% of the body weight with formulated fish sausage supplemented with vitamins and minerals for ensuring balanced nutrition.

Fig.18.3 Fish sausage (Courtesy: RGCA)

Water quality management

It is practiced as explained for the milkfish.

Spawning

The fish is anaesthetised and gametes collected periodically using a 40-60 cm long, transparent and flexible cannula (1 mm inner diameter and 2 mm outer diameter) guided into the urino-genital orifice of male and oviduct of female to determine gonadal development. Then suction is applied at the other end as the cannula is withdrawn and the cannulated sample is placed in a petri-dish and observed under a microscope for determining the size and stage of development of ovum of female and the density of milt of male.

Fig.18.4 Cannulating brood fish

The female fish with ova of minimum 600 µm diameter and male with thick milt is selected in 1:1 ratio for induced breeding. The females are injected with LHRH-a at 20 µg/kg, and males are injected with 10 µg/kg. After hormone injection, spawning occurs within 36-40 hours at 26-27°C. Fertilisation occurs externally, and the fertilised eggs are transparent, globular and cream coloured having 1.35-1.40 mm diameter size with a single oil globule. The fertilised eggs are floating while the unfertilised eggs generally sink to the bottom. Fecundity is 2-4 lakh/kg bodyweight.

Fig.18.5 Hormone administration

Incubation

After 12 hours of spawning, the eggs are collected using a large scoop net (1x1x1 m) of 300-400 μm mesh size and kept in graduated buckets with mild aeration. The fertilised eggs are measured, disinfected with betadine (100 ppm) dip for one minute, and the rate of fertilisation is determined by taking a sample. They are incubated in cylindro-conical FRP tank (500 l) at a density of 300-500 no./l with mild aeration or directly stocked into indoor nursery rearing FRP tank (10-30 t) at a density of 10-20 no./l. The eggs hatch-out within 21-24 hours at 27-30ºC. The average hatching rate is 80%. The newly hatched larva has an average total length of 3.5 mm with yolk sac. The mouth of the hatchling appears on 3rd dph with an opening of about 200 μm size.

Live feed production

The method is same as that explained for the milkfish.

Rearing of larvae

If the incubation is done in cylindro-conical FRP tank, the 3 dph larvae at a density of 5 no./l are transferred to indoor FRP tank (10-30 t capacity) containing filtered seawater, kept as such after removing the waste. Pure live microalgal culture of *Nannochloropsis oculata* is directly added to larval rearing tank to maintain the required phytoplankton concentration of 50,000 cells/ml (green water technique) with mild aeration. It helps in maintaining water quality, controlling bacteria, enriching zooplankton and easy feeding of larvae. Larval feeding can be initiated on 3rd day for 2-3 times with enriched *Brachionus plicatilis* at a density of 10-15 no./ml until 12 dph. *Artemia* nauplii are used for feeding from 6 dph upto 10 dph. Usually 2-3 lakh nauplii hatchout from 1 g of high-quality cysts. Enriched artemia is fed from 8 dph to 28 dph. Weaning on artificial diet starts from 15 dph.

Fig.18.6 Artemia hatching tank

Fig.18.7Artemia enrichment tank

Table 18.1 Feed requirement

DPH	Feed size (µm)	% of body weight
15-19	300-400	18%
20-24	500-700	15%
25-30	800	13%

Metamorphosis of larvae takes place within 10-15 dph. By this time, the colour of the larva changes from dark reddish-brown to black. During metamorphosis, there is a change from cutaneous respiration to gill respiration, which can lead to mortality due to respiratory distress. During this time, addition of pure oxygen shall be provided along with aeration. Cannibalism is a serious problem in larval rearing due to its size variation, which can be controlled by proper size grading and by increasing feeding frequency. Bottom siphoning should not be done upto 25-30 dph, but the water quality and tank bottom condition should be maintained by adding probiotics. The young-one attains the size of 0.4 g within 25-30 dph.

Fig 18.8 Rearing of larvae (Courtesy: RGCA)

Rearing of fry

After 30 dph, the larvae are size graded frequently, and the different size groups are reared separately in separate FRP/cement tank (30 t capacity) containing filtered seawater. The seeds of 1-1.5 cm are stocked at 1000 no./t. The fry is fed initially with a formulated micro-encapsulated feed of 800 µm size and progressively changed into an extruded larval feed of 1.2 mm in 35 dph and 2.2 mm in 40 dph. Water quality parameters like salinity, temperature, pH, DO, ammonia *etc.* are closely monitored. Daily water exchange at 100- 200% is done. Feeding frequency is 4-5 times depending upon the water quality and feed intake. The seed is harvested at 2-5 g size by 45 dph.

Packing and transportation

The seed is usually transported for long distance in 1-3 t tanks with oxygenation or/and aeration facility. DO level is maintained above 8 ppm using oxygen cylinders for which one tonne tank requires 340 cm^3 cylinder capacity for each hour. The seed is transported in an open tank with maximum biomass of 10 kg/m^3 with water. It is starved for 48 hours before transportation. Mild sedation is given with 2 ppm *Euginol*. To control ammonia, de-ammonifier like 5 ppm *Ammonil* is used.

FARMING IN CAGE

Site selection

Being a marine fish, it can be cultured in marine waters and also in brackish waters having minimum 15 ppt salinity. A calm area having 10-30 m water depth, 30-50 cm/s water current velocity and low wave with sandy or rocky bottom is suitable for sea cage farming. Transparency should be more than 5 m. The site should also be free from any type of turbidity. Other aspects are similar to those explained for the pearlspot.

Water quality requirement

Temperature	:	23- 30°C	Ammonia	:	<0.02 ppm
Salinity	:	15-35ppt	TAN	:	< 0.1 ppm
DO	:	>5 ppm	Nitrite	:	< 0.05 ppm

Cage design

In off-shore waters, a circular cage having 6-12 m diameter and 6 m depth is used. Cage raft with HDPE material is highly durable, resistant to direct sunlight and chemicals. HDPE cage is fabricated with 25 cm diameter pipe (10 kg/cm^2, 24 mm thickness) and the handrails with 11 cm diameter pipe (10 kg/cm^2, 10.6 mm thickness). The pipes are joined by butt fusion, a joining technique by melting the pipe (fitting) ends and holding them together. The HDPE cage raft is fabricated on a flat concrete floor or evenly levelled seashore to achieve perfect alignment and better joining of pipes. It is better to fabricate the HDPE cage raft near to the seashore for easy launching. The fabricated cages are towed to the identified location and moored using multi-point mooring system with Samson type anchors weighing 500 kg and Dyneema anchor ropes (25 mm thickness). The length of the anchor rope should not be less than 3 times than the water depth. Grid type anchoring system is preferred for the easy management with provision for allowing the individual cage to move freely.

Fig 18.9 Circular HDPE cage (Courtesy: RGCA)

According to the size of fish, polyester knotless inner netting with mesh size 10-36 mm are attached to the inner ring, and outer netting with mesh size 18-50 mm is attached to the outer ring of cage frame. There should be floating buoys and navigational light buoys for demarcating the cage structure.

In the protected bay and brackish water area, circular GI cage frame having 6 m diameter and 4 m depth is used. The inner ring of the frame is attached with HDPE cage net having 10-36 mm mesh size and the outer ring of the frame with a cage net having 18-50 mm mesh size according to the size of fish. The fabricated cages are towed to the identified location and moored by using multi-point mooring system with Grapnel type anchors weighing 80 kg and UV resistant PP ropes. The other aspects are the same as that prescribed for the pearlspot.

Fig. 18.10 Circular GI Cage (Courtesy: CMFRI)

Stocking

After acclimatisation, the seeds of 10 g size are stocked at a density of 30 no./m^3 in rearing cage (10 mm mesh size). Subsequently, the cage net is replaced with large mesh size, and the stocking density is reduced to 5 no./m^3 as given in Table 18.2.

Table 18.2 Stocking density & mesh size

ABW (g)	Stocking density (no./m^3)	Cage mesh size (mm)	
		Inner net	Outer net
10	30	10	18
50	15	18	36
1000	8	28	36
3000	5	36	50

Feeding

The cobia is weaned on a floating or slow sinking pelleted feed, shrimp waste and chopped fish and fed twice (40% in the morning and 60% in the evening). Based on the body weight, the fish is fed with pelleted feed having 40-45% protein, and 10-12% fat and its details are given in Table 18.3.

Table 18.3 Feed requirement

ABW (g)	Feed size (mm)	Daily feeding rate (% of ABW)	Daily feeding frequency
10	1.2	10.0	4 times
15	1.8	8.0	4 times
30	1.8	6.0	3 times
80	2.5	5.0	3 times
150	4	4.0	3 times
250	6	3.5	2 times
500	8	3	2 times
1000	10	2	2 times
2000	10	1.5	2 times
3000	14	1.2	2 times

Chopped fish/prawn waste can replace feed pellets, and it is fed @ 15% of the body weight at 150 g size and is subsequently reduced to 4.5% upto 3 kg size, to facilitate faster growth rate and reduction in feed cost.

Fig 18.11 Feeding of cobia (Courtesy: RGCA)

Care and maintenance

In the case of cage farming, there is a high risk of poaching and attack by animals. Hence, a watch house with 24 x 7 watchman security and a CCTV camera has to be provided. A warehouse and a boat are provided for the storage and transportation of feed, net, *etc*. Any damage to the cage net, noticed through frequent inspections, is immediately repaired; otherwise, it may cause heavy crop loss. Once in a week, cleaning of cage net with a soft brush is carried out to ensure proper water exchange. To avoid bio-fouling, net exchange is done fortnightly during the initial period and gradually reduced to once in two months at the later stage. There should be one set of spare cage net for a replacement. For net exchange, the upper edge of the two sides of the clogged net is tied with the fresh net. A weight is tied at the middle part of the net for sinking into water and to render easy movement of fish to the otherside of the fresh cage net. The clogged net is slowly lifted up from the other side and lifted into a boat and brought to the shore for immediate cleaning using high pressure jet pumps of 200 psi pressure followed by sun drying.

When fish is reared in high salinity, parasitic infection of copepods may occur. Periodic dip in freshwater for 5 minutes to remove ectoparasites, keeps the fish healthier. The fish is regularly monitored for any clinical signs for the early detection of disease. Generally, good quality water, good husbandry practices and adequate nutrition keeps away diseases. Once in a month, the length and weight of the fish are measured followed by grading and thinning. As the fish grow, it is transferred into cages with larger mesh netting. Quantity of feed also is determined accordingly. Water quality parameters are checked regularly. During periods of bad weather, anchors and fastening ropes should be checked. The fish is taken-out fortnightly using hand net and health is examined. The growth pattern is given in Table 18.4.

Table 18.4 Growth pattern

DOC	ABW in g
0	10
30	150
90	300
150	600
210	1200
270	2500

Harvesting

In the case of cage farming, harvesting mainly depends on climate. Hence, culture activities should start by September and end before the onset of monsoon. The fish usually attains 2.5 kg within 9 months. It has both domestic and export market. When growth is non uniform and a few among the stock attains marketable size, selective harvesting of larger fish from 7th month onwards is ideal which facilitates the smaller one to grow at a faster rate. Fish is starved for one day prior to harvest to keep its gut empty. The fish is harvested by scooping out using a hand net and is placed into a chilled container, chill killed, bled and packed in ice prior to transportation. Feeding with chopped fish during the end of the culture period gives better growth of fish. A production of 16 kg/m^3 can be expected from one crop. Survival rate in cage farming is 85%.

CHAPTER: 19

ASIAN SEABASS

The Asian seabass, *Lates calcarifer* has an excellent demand in both domestic and international markets. It is euryhaline; hence it can be cultured in freshwater, brackish water and seawater. Juveniles inhabit backwaters and estuaries, while adults are marine. Usually, seabass shows protandrous hermaphroditism. The fish in size range of 2-4 kg matures as male and transforms to female when it attains the size of more than 4 kg. It is carnivorous, feeds mainly on small fish, shrimps, *etc*. It has an elongated and compressed body with a large, slightly oblique mouth. Upper jaw extended behind the eye, the lower edge of pre-operculum serrated with a strong spine. The eyes are bright pink and glow at night.

Fig. 19.1 Lates calcarifer

SEED PRODUCTION

Broodstock management

The collection of sub-adult and quarantine protocol is the same as that explained for the cobia. After quarantine, the fish weighing above 3 kg is transferred and stocked in a tank (100 t capacity) having 2 m depth with aeration and re-circulation facility. The fish is stocked at a density of 2 kg/m^3 and fed with trash fish at 5% of the body weight initially and two months before spawning it is reduced to 1%.

Water quality management

It is practiced in a similar way to that explained for the milkfish.

Spawning

Seabass spawns round the year. As it is a protracted spawner, eggs are released in batches. Hence, the same female fish is induced to breed at an interval of 15 days. Morphological identification of sex is difficult; therefore catheterisation is done to determine the sex. Female fish having eggs with a size of more than 400 µm is selected for induced breeding. Both male and female fish are injected with LHRH-a at 25-35 mg/kg bodyweight for induced spawning and released to FRP tank (20 t capacity). The eggs are released by the female after 34-36 hours of injection. Simultaneously, the male oozes the milt, and fertilisation takes place externally in water. The fertilised eggs are floating and transparent with a size of 0.8 mm diameter. The unfertilised eggs are opaque and sink to the bottom. The fish spawns in 3 consecutive nights. The fecundity is 1.5-3 lakh/kg of the body weight. Optimum temperature and salinity of spawning are 27-32^{0}C and 30-32 ppt.

Incubation

The fertilised eggs are collected in the morning by scoop net with 300-400 µm mesh size and incubated in cylindro-conical FRP tank of 500 l at a density of 500-1200 no./l with mild aeration. The eggs hatch out within 17-18 hours, and the newly hatched larva has a size of 1.5 mm.

Live feed production

The method is similar to that explained for the milkfish.

Rearing of hatchling

The hatchlings at the density of 30 no./l are initially transferred to indoor FRP tank of 5 t capacity containing filtered seawater for the first 10 days and then transferred at the density of 5 no./l to indoor FRP tank of 10-30 t capacity. The newly hatched larva does not feed until 48 hours after hatching. After 36 hours of hatching, rotifers, *Brachionus plicatilis* and *Brachionus rotundiformis* are added in the rearing tank at a density of 15-20 no./ml per day until 12 dph. The microalgae such as marine *Chlorella, Nannochloropsis, Isochrysis, etc*. are maintained for feeding rotifers at a density of 1-2 lakh cell/ml. From 8 dph onwards, the larva is also fed with *Artemia* nauplii at a density of 1 no./ml/day. On 15^{th} dph, the density of *Artemia* nauplii is increased to a rate of 5-10 no./ml/day. *Artemia* biomass at a rate of 1 no./ml/day is provided from 23^{rd} dph and then weaned on artificial diet. The young one attains a size of 1-1.5 cm in 30 dph.

Rearing of fry

Fry having 1.5 cm size is reared to the size of 7 cm in indoor/ outdoor tank, hapa or cage. The tank (1-10 t capacity) having minimum 1 m water depth with continuous aeration and daily 100% water exchange is used for nursery rearing. The fry is fed with a formulated diet 3-4 times daily at 20% of the body weight. Initially, the feed size is 0.5 mm, which is gradually increased to 1.2 mm for nursery rearing. Grading is done at an interval of 7-10 days to avoid cannibalism. During grading, the stocking density is regulated according to the size of fish as given in Table 19.1. Nursery rearing period is 40 days and the expected survival is 60%.

Table.19.1. Stocking density for rearing fry

Rearing system	**Stocking Density(no./m^3)**	
	30 dph seed	70 dph seed
Tank with aeration	2200	1500
Nylon hapa	500	250
Cage	900	630

Packing and transportation

The method is similar to that of the cobia.

CAGE FARMING

As seabass exhibits a high rate of cannibalism in the early stages, cage farming is better than pond culture.

Site selection

Being highly euryhaline fish, it can be cultured round the year in freshwater, brackishwater and seawater. Other aspects are similar to those of the pearlspot.

Water quality requirements:

Temperature	: 27-30^{o}C
pH	: 7.3-8.5
Transparency	: 30-50cm
Salinity	: 0-35ppt
DO	: > 4ppm

Cage design

Regarding sea cage farming, the design should be the same as that specified for cobia, and in case of brackish water for cage culture it can be done as specified for pearlspot. The mesh size required for cage net is provided in Table 19.2.

Fig. 19.2 Cage culture (Courtesy: RGCA)

Stocking

After acclimatisation, the hatchery-produced seeds having a uniform size of 7 cm (5 g) are stocked at a density of 20 no./m^3. Subsequently the cage net is replaced with higher mesh size as given in Table 19.2

Table.19.2. Mesh size of cage net

TL (cm)	Cage mesh size (mm)	
	Inner net	Outer net
7	10	18
15	18	36
20	28	36
25	36	50

Feeding

The growth rate of sea bass and the details of feeding ration of dry feed are given in Table 19.3. Other aspects are same as those for cobia.

Table. 19.3. Feeding requirement

DOC	ABW (g)	Daily feeding rate (% of ABW)	Pellet size (mm)
0	5	8.0	1.2
30	20	7.0	1.5
60	53	4.0	1.8
90	110	3.5	2.5
120	200	3.0	2.5
150	330	2.5	4.0
180	480	2.0	4.0
210	530	2.0	6.0
240	720	1.5	8.0
270	800	1.5	10.0

Care and maintenance

The growth rate of sea bass is given in Table 19.3. As the fish shows differential growth rate and cannibalism, it is periodically graded by size, thinned-out and reared in separate cages. Grading is done using nets or grader. Initially, the fish is graded once in 7 days and later on, once in 30 days. Other aspects are similar to that explained for cobia.

Fig. 19.3 Size grader (Courtesy: RGCA)

Harvesting

The fish attains 1 kg within a culture period of 10-12 months. It has both domestic and export market. A production of 16 kg/m^3 can be expected from one crop. Survival rate in cage farming is about 80-85%. Other aspects of harvesting are same as that of cobia.

GROW OUT CULTURE IN POND

It is advisable to rear the seed in nylon hapa or indoor/outdoor tanks.

Site selection & pond construction

Freshwater, brackish water as well as seawater ponds having not less than 0.2 ha area with 1-2 m depth is ideal for the farming of seabass. Sluice gates should be provided to regulate the inflow and outflow of water. Predatory birds are controlled by covering the pond with bird net of 100 mm size. The side of the pond is fenced with stiff net of 26 mm to prevent the entry of predatory animals or escape of the fish. Area prone to flooding should be avoided. Other aspects of site selection and pond construction are the same as that of the major carps.

Pond preparation

Before stocking, all the pond preparation procedures should be followed.

Nursery rearing and stocking

Before releasing into grow-out pond, the hatchery-produced seeds of uniform size are stocked at a stocking density of 500 no./m^2 in cage or hapa of 2 x 2 x 1.5 m dimension having 10 mm mesh size mounted on PVC floating structure installed in the pond until it attains 50 g size and thereafter it is released into the pond. This helps to reduce cannibalism. Ideal stocking density for grow-out farm is 1 no/m^2.

Feeding

Feeding in pond culture is same as that explained for the cage farming.

Care and monitoring

Periodic liming at 250 kg/ha is done to manage the pH. Water is added intermittently to maintain a water depth of 1-2 m. Plankton bloom is essential for early stages of culture (until 100 g). If the pond water appears clear, a mixture of cow dung at 100-150 kg/ha and inorganic fertilizers at 10-15 kg/ha can be applied at regular intervals to develop natural food organisms. Sufficient water level is maintained in the pond to reduce the growth of benthic algae. The water depth in the shallow part of the pond should be at least 100 cm. Water quality can be maintained by exchanging 10% of the water once in a week for the first 3 months. After 3 months, this is increased to 20% per week and to 30% per week after 6 months. Paddle wheel aerators are placed in the pond to maintain the DO level above 5 ppm, which is vital for proper growth and survival. Growth is monitored by periodic sampling.

Harvesting

Harvesting of seabass is carried out using the drag net. To maintain the freshness and quality of harvested fish, washing in clean water and chill killing can be adopted.

CHAPTER: 20

POMPANO

The silver pompano, *Trachinotus blochii* and Indian pompano, *Trachinotus mookalee* are the candidate species for aquaculture due to its good meat quality and high market demand. They are less cannibalistic and resistant to a wide range of diseases and easily mature under captive condition. Juvenile inhabits sandy coastal waters and estuaries in small schools, while adults are usually solitary. It is a voracious carnivore which feeds on even hard-shelled invertebrates including molluscs. Large adults are mostly golden orange, especially on the ventral side. The dorsal snout is very steep but rounded.

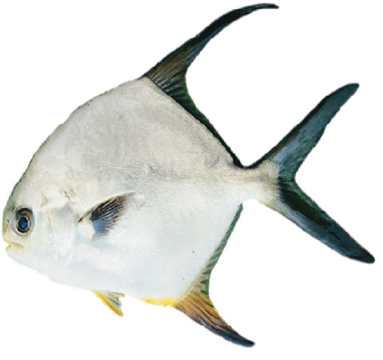

Fig. 20.1 Trachinotus blochii

Fig. 20.2 Trachinotus mookalee

SEED PRODUCTION

Broodstock management

The collection of sub-adult and quarantine protocol is the same as that explained for cobia. After quarantine, the fish weighing not less than 1.5 kg is stocked in a tank (10 t capacity) having re-circulation facility. The fish is fed with squid, cuttlefish, crab, shrimp and chopped oil sardine along with pelleted feed and fish sausage.

Water quality management

It is practiced in a similar way to that explained for the milkfish.

Spawning

After anaesthetising the fish, cannular biopsy is done periodically to assess ovarian maturation. The female having ova with a minimum size of 500 µm diameter is selected for breeding. Female to male ratio is maintained at 1:2. They are induced to breed by the injection with HCG at 350-500 IU/kg body weight for both the sexes. Spawning occurs in circular tank within 36 hours after hormone injection. Fertilisation is external and the fertilised egg has one prominent oil globule and is buoyant, transparent and yellowish with a size of 0.9-1 mm diameter. It is collected from the water surface for incubation. The unfertilised eggs which settle at the bottom are removed by siphoning. Fecundity is 0.6-1.8 lakh/kg body weight, and the fertilisation rate is 75-90%. The domesticated pompano spawns naturally in accordance with lunar cycle.

Incubation

The fertilised eggs are collected and incubated in a similar way as explained for the cobia. The eggs hatch-out between 18-22 hours. The hatchling is observed under a microscope for pigmentation and appearance of internal organs and deformation or abnormalities, if any. The mouth of the hatchling appears in 3 dph with an opening of 230 µm.

Live feed production

The method practiced is the same as that explained for the milkfish.

Fig. 20.3 Rotifer culture (Courtesy: CMFRI)

Indoor rearing

The stocking rate, size of indoor rearing tank and maintenance of phytoplankton is same as that explained for cobia. Larval feeding can be started from 3 dph with enriched *Brachionus plicatilis* at a density of 8-10 no./ml for 2-3 times daily until 14 dph. Mixed feeding with rotifer and enriched *Artemia* nauplii is carried-out during 11-14 dph. The *Artemia* nauplii are provided at a density of 2-5 no./ml upto 19 dph.

Fig. 20.4 Indoor rearing (Courtesy: CMFRI)

Weaning on artificial larval feed starts from 15 dph onwards and mixed feeding with *Artemia* is continued till 19 dph. From 20 dph onwards, the feeding is entirely on artificial diets. The metamorphosis of the pompano larva starts on 18 dph and metamorphoses into juveniles within 25 dph. Though cannibalism is not much prevailed, grading should be done during 20-25 dph for separating shooters. No water exchange is normally required till 7 dph and later on it is done at 10% from 8 dph which is gradually increased to 100% from 25 dph.

Rearing of fry

After 25 dph, the larvae are graded by size and the different size groups are reared in separate tanks. The fingerling attains 5-7 cm size within 55 dph. The tank capacity, stocking density, feeding and water quality management are similar to that explained for cobia.

Packing and transportation

The method followed is similar to that of cobia.

FARMING IN CAGE

Site selection

Eventhough it is a marine fish, it can be cultured in brackish waters with a salinity of not less than 10 ppt. The site should also be free from turbidity. Other aspects of site selection are similar to that of cobia.

Water quality requirements

Temperature	: 27- 30°C
pH	: 7.5- 8.2
Salinity	: 10-35ppt
DO	: >5 ppm
TAN	: < 0.5 ppm
Turbidity	:<10 NTU

Construction of cage

In the case of sea cage farming, the design should be same as that specified for cobia and for brackish water cage farming, it should be done as specified for pearlspot.

Stocking

After acclimatisation, the hatchery-produced seeds of 5-7 cm (2-3 g) size are stocked at a density of 40 no./m^3. The mesh size required for the cage net is given in Table 20.1.

Table 20.1. Mesh size of cage net

TL (cm)	Mesh size (mm)	
	Inner cage net	Outer cage net
4	10	18
10	18	28
15	28	36
20	36	50

Feeding

Pompano is a fast moving fish and it requires nutritious feed to meet the energy requirement. The growth rate and the details of feeding ration are given in Table 20.2. Other aspects are the same as that of cobia.

Table 20.2. Feed requirement

ABW (g)	Feed size (mm)	Protein (%)	Lipid (%)	Daily feeding rate (% of ABW)	Frequency
2	0.8	50	10	15	4
10	1.2	45	10	10	4
50	1.8	45	10	8	3
100	2.5	45	10	7	3
250	4.0	40	10	5	3
500	6.0	40	10	3	3

Care and maintenance

Procedures for these are similar to that explained for cobia. The growth rate of pompano is given in Table 20.3 below.

Table 20.3. Growth rate

DOC	ABW (g)
0	2
30	20
60	40
90	80
120	120
150	200
180	280
210	370
270	600

Fig. 20.5 Sampling

Harvesting

Selective harvesting of large fish is done from 6th month onwards. In the domestic market, pompano fetches good market demand from 300 g size onwards. The fish usually attains 600 g within 9 months. A production of 16 kg/m^3 can be expected from one crop. Survival rate in cage farming is 80-85%. Other aspects of harvesting are similar to that of cobia.

CHAPTER: 21

GROUPER

Groupers are important fish, particularly for live seafood markets in several Asian countries and highly prized for the quality of their flesh. Orange spotted grouper, *Epinephelus coioides* inhabits a depth of at least 30 m, over mud and rubble in shallow reefs and lagoons; while the juvenile are found in the shallow waters of estuaries over sand, mud and gravel and among mangroves. It is eurythermal and euryhaline. It feeds mainly on fish followed by crustaceans and molluscs. It is a diandric protogynous species, where male is either derived from a juvenile phase or the transition from post spawning female. The female matures at 320 mm size at an age of 2 years, whereas the primary male matures at 242 mm size at an age of 1 year. The sexual transition occurs at a size of 550-750 mm at the age of 5-6 years. The major spawning period is March to June. It probably spawns during restricted periods and form aggregations for spawning after the full and new moon.

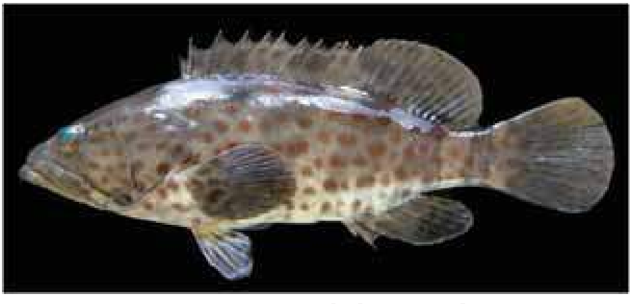

Fig. 21.1 Epinephelus coioides

SEED PRODUCTION

Broodstock management

For developing broodstock, the adult fish weighing not less than 2 kg are sourced from wild using hook and line or from a farm. The collected adult fish are given mild sedation using 50 ppm 2 phenoxyethanol solution and transported in covered tank containing aerated water. After arrival in the hatchery, the gas filled in the air bladder (barotrauma) is removed by inserting a needle in to gas bladder through anus.

Fig. 21.2 Collected fish from wild showing barotrauma

Once the fish is swimming normally with controlled buoyancy by maintaining its position in the water column, it is shifted to quarantine area for 2 weeks, where it is provided with a bath in 200 ppm formalin solution for 30 minutes followed by 5 minutes dip in freshwater, once in every 3 days. After quarantine, the fish are transferred to maturation cum spawning tank (125 t capacity) having re-circulatory water system. The fish is fed to satiation once daily in the morning with fresh or frozen squid. Micro nutrients namely, vitamin A, vitamin B-complexes, vitamin C, vitamin E and vitamin–mineral mix are supplemented once a week along with the feed.

Fig. 21.3 Maturation cum spawning tank

After one month, the fish are cannulated using fish cannula or baby feeding tube CH-6 having an inner diameter of 1 mm and outer diameter of 2 mm for collecting gametes. After anaesthetising the fish using 200 ppm 2-phenoxy ethanol for 2-3 min, the cannula is guided into the urino-genital orifice of male and the oviduct of female for a distance of 6-7 cm into the body and suction is applied to the other end of the cannula as it is withdrawn. After withdrawal, the sample within the cannula is expelled onto a microscope slide for immediate examination or into a vial containing 1% neutral buffered formalin for later measurement of egg diameter.

Fig. 21.4 Cannulation of orange spotted grouper

Water quality management

Re-circulatory water system connected with maturation cum spawning tank will provide optimum water quality for the fish. The water quality management practices are similar to that explained for the milkfish.

Sex Reversal

Generally the wild collected fish is female; however, both sexes are required for the spawning purpose. Hence, 50% of fish are implanted with pellet containing 17 α methyl testosterone and letrazole @ 5 mg/kg and 0.2 mg/kg of the body weight respectively. The pellet is prepared using gum acacia, cholesterol and 17 α methyl testosterone in the ratio of 1:2:1. The pellet is implanted on dorsal side of the broodfish below to the dorsal fin in musculature. The female is converted to male within 2 months after pellet implantation.

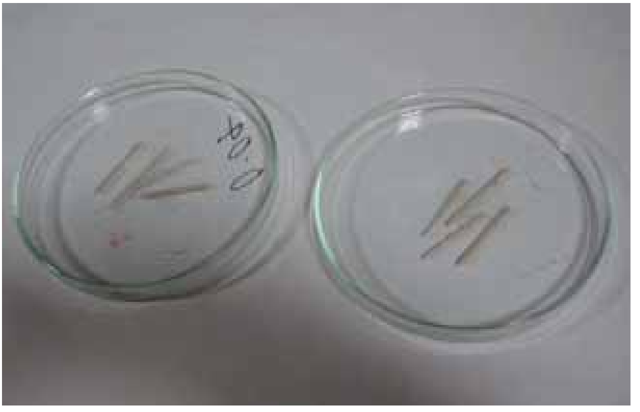

Fig. 21.5 Hormonal pellet for sex reversal

Spawning

Natural spawning starts from 4th month onwards after stocking, and they spawn 4-10 times in a month. The spawning continues round the year. Generally fish spawn during evening hours before sunset. The spawning pair shows courtship behavior with a typical vertical burst of swimming just before release of gametes. Fertilisation occurs externally and fertilised eggs are transparent and floating in nature having 850-900 µm diameter with a single oil globule. On an average, 2-3 lakh fertilised eggs are collected from each spawning.

Incubation

After 14 hours of spawning, the eggs are collected using hapa net (1x1x1 m) of 500 µm mesh size fixed in the egg collecting chamber. The collected floating eggs are disinfected with 20 ppm active iodine solution for 10 minutes and stocked in aquarium (100 l capacity). Fertilisation rate is estimated by taking sample from aquarium. The fertilised eggs are either incubated in the aquarium at a density of 400 no./l with mild aeration or directly stocked into indoor nursery-rearing FRP tank (2 t) at a density of 10 no./l. The eggs hatch-out within 18-20 hours at 28-30ºC. Average hatching rate is more than 85%. The newly hatched larva has an average total length of 1.6 mm with yolk sac. Mouth of the hatchling appears after 48-56 hours with an opening of about 120 µm.

Live feed production

The production method is same as that explained for other marine finfish. Live feeds used for orange spotted grouper larval rearing comprises of microalgae (*Nannochloropsis* sp. and *Isochrysis* sp.), copepod nauplii and adult (*Parvocalanus crassirostris*), small rotifers (*Brachionus rotundiformis*), large rotifers (*Brachionous plicatilis*) and brine shrimp (*Artemia*) nauplii.

Rearing of larvae

The sea water used in larval-rearing tank is passed through sand filters to remove particulate matter and is then sterilized by ozone treatment to eliminate pathogens. Generally fertilised eggs are stocked in larval rearing tank just before hatching.

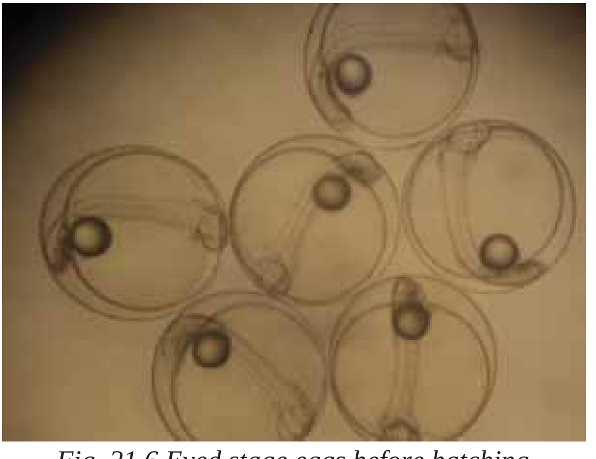

Fig. 21.6 Eyed stage eggs before hatching

After hatching, bottom of the tank is siphoned to remove any un-hatched eggs as well as eggs shells. Tank is covered with black cloth till the first feeding. Oil is added to form a thin film on the water surface (around 0.2 ml/m^2) during 1st to 4th dph for preventing surface aggregation mortality in early-stage grouper larvae. The yolk sac (endogenous source) provides nutrient for 2-3 days in grouper larvae. Then, the exogenous feeding starts when the mouth opens after the 3rd day. Its initial mouth gape is very less and therefore, it has to be provided with appropriate size of feed i.e. copepod nauplii and screened rotifers. *Nannochloropsis* sp is introduced into the larval-rearing tank on 2 dph at an algal cell density of 1×10^5 no./ml. Rotifers filtered with 80 µm mesh and copepod nauplii filtered with 100 µm mesh are introduced into the larval rearing tank on 2 dph, after the larval mouth opening has been formed. The rotifer and copepod nauplii density in the larval-rearing tank is maintained at 5-7 and 2-3 no./ml during 2 to 5 dph. After 5 dph, small rotifers (filtered with 150 µm mesh) are introduced at density of 10-15 no./ml, which is gradually increased to 20 no./ml from 11 to 18 dph. Freshly hatched-out *Artemia* nauplii are used as feed at density of 0.5 no./ml from 17 dph and their size increasing with advancement in rearing period. Adult copepods are given as feed during 16 to 20 dph in larval-rearing. Weaning of grouper larvae with artificial diet starts from 20 dph. Artificial diet with a particle size of 200-300 µm is used initially. The formulated feed is sprinkled onto the surface of the water in small amounts frequently throughout the day. The size of particulate feed is increased to 400-800 µm from 30 to 40 dph.

Fig. 21.7 Larval-rearing unit

The larval rearing tank is maintained without water exchange until 7 dph, and then from 10 dph, 5-10% of daily water exchange is required to maintain the water quality. Bottom siphoning of the tank should be started on 7 dph. From 12 dph, faeces, dead larvae and uneaten food which accumulate on the tank bottom should be siphoned out at least once daily for maintaining the water quality. Daily water exchange is increased to 20%, when both rotifers and *Artemia* are given together as feed (15 to 20 dph) and it is gradually increased to 50% from 25th dph, and 100% from 35 dph onwards.

Metamorphosis of larvae takes place within 30-40 dph. Cannibalism is a serious problem during metamorphosis due to its size variations which can be controlled by proper size grading and by increasing feeding frequency.

Fig. 21.8 Metamorphosed larvae

Rearing of fry

After 40 dph, the larvae are shifted from larval rearing tank to fry rearing tank. Fry rearing is carried out in light coloured tank. The seeds of 1.5-2 cm are stocked at 1000 no./m^3. During the fry rearing, the larvae are size graded once weekly, to avoid cannibalism. The fry is fed initially with a formulated micro-encapsulated feed of 800-1000 µm size and progressively changed onto an extruded larval feed of 1.2 mm by 50 dph. Water is exchanged 100% daily. Feeding frequency varies from 5-7 times in a day. The seed is harvested at 5-6 cm size by 60 dph.

Second phase of nursery-rearing is required for growing 5-6 cm to 10-15 cm for stocking in cage as well as in pond. During this period, the fingerlings are reared either in pond based hapa (4 mm mesh size), flow through cement tank or in re-circulatory system. The fry is fed with a floating pelleted feed with 45% protein and 10% fat of 1.2 mm and 1.8 mm sizes @ 10% of the body weight thrice in a day.

Fig. 21.9 Orange spotted grouper fingerlings

Packing and transportation

The seed is usually transported for long distances in oxygenated plastic packet @ 10 no./l and for short duration in open tank system with oxygenation or/and aeration. DO level is maintained above 8 ppm using oxygen cylinders. Fish is starved for 48 hours before transportation.

FARMING IN CAGE

Site selection

The farming of grouper is preferably carried out in cage. A calm area with more than 10 m water depth, 30-50 cm/s water current velocity with sandy or muddy bottom is suitable for sea cage farming.

Water quality requirement

The optimum water quality requirement is given below.

Salinity	:	15-35ppt	TAN	:	< 0.1 ppm
Temperature	:	23- 30°C	DO	:	> 5 ppm
Nitrite	:	< 0.05 ppm			

Cage design

Cage made up of HDPE or GI material are used for culture of grouper. The size of the cage (diameter and depth of net) depends upon operation feasibility. Circular cage of 6 m diameter and 4 m net depth are easily managed with the involvement of 5-6 people. HDPE cage is better for off shore cage farming while GI cage is used in protected areas or in backwaters.

Different mooring systems are used for cage culture such as grid type anchoring system, single point mooring, *etc*, based on the suitability of the site selected. Generally, cement blocks connected with 14 mm alloy steel long linked chains are used for single point mooring of the cages, which allow free movement of the cage in 360^{o} depending upon the current direction.

Fig. 21.10 Circular HDPE cage

The cage bag is a flexible mesh material, which can be prepared by different synthetic materials, including HDPE, polyester (PES) and polypropylene (PP) or polyamide (PA). Among all, the Polyester material offers economic and technical advantages such as breaking strength, resistance to fouling and resistance to abrasion. The square shaped mesh size is always preferred and to get the proper shape, the net panel is attached to head rope with a hanging ratio (E) of 0.71 to produce square meshes, which helps against fouling and provides maximum surface area. Two net bags are used in a cage, i.e., inner and outer net bags in inner ring and outer ring of the cage respectively. The mesh size of both the net bags depends on the size of the fish stocked for culture. Initially, inner mesh size of 6-8 mm are used then increased to 12 mm after 3-4 months and finally, 18 mm mesh size is used after 6 months. A ballast of 60 kg weight is attached to the bottom ring of inner cage net to maintain the shape of the net bag.

Stocking and feeding

After acclimatisation, the seeds of 30 g size are stocked at a density of 35 no./m^3 in rearing cage. After 4-5 months of culture period, the stocking density is reduced to 20 no./m^3. The fish are initially fed with pelleted feed having 40-45% protein and 10-12% fat, @ 8-10% of the body weight as two rations in morning and evening. As the fish grows to a size of 100 g, it is fed with low value fish @ 10% of the body weight twice in a day.

Care and maintenance

Cage with net and mooring system should be checked periodically during the culture period. Generally algae grow on the cage frame, which makes the frame slippery, hence it is scrapped once in a month to keep cage frame clean, so the worker can easily work by standing on the cage. The chain and floats attached to the mooring system is inspected not later than once in a month for any damage such as shackle loosening and chain damage. If any damage is noticed, it should be repaired immediately. The mooring system is compulsorily checked after every bad weather conditions such as cyclones, storms, depressions, *etc*. As the cage net is always inside the water, settlement of fouling organisms such as barnacle, algae, *etc* would happen; hence it is frequently checked for assessing the extent of fouling and if 50 % of the net meshes are clogged, the net must be replced. The inner net of the cage should be changed every month for first three months, followed by once in two months. The net must be checked frequently for any damage.

A warehouse and a boat with 24x7 round the clock security including watchmen and CCTV camera are provided for the storage and transportation of feed, net, *etc*. For net exchange, ballast is released from the inner net and hang freely in the outer cage net with help of PP rope. Inner nets are lifted half, followed by inserting the cleaned net from one side of the cage frame to the other side and tied on the hand rail. Then, the older net knots are released from the hand rail and the net is dragged from one side to the boat, while doing so, the fish will move from the older net to the cleaned net from the other side of the net. Then the nets are dried in sunlight and cleaned and repaired.

Fig. 21.11 Harvested orange spotted grouper

The fish stock is regularly observed without unduly disturbing them and this provides a general understanding of how they behave under normal environmental conditions. If something wrong is observed, then fish are sampled and examined. Fish sampling is done at least every month, so that their growth is monitored regularly. This information is required for calculating the feed requirement for the stock. It will give a fair idea about the stock performance and the feed requirement for the future. Records of the farming practices such as daily mortality, feed consumption, and growth rate should be maintained. It is crucial in understanding the epidemiology of diseases and allows to identify the critical management point in the production cycle. The growth pattern is given in Table 21.1.

Table 21.1 Growth rate

DOC	ABW in g
0	30
30	52
90	110
150	268
210	455
270	735
330	1070
390	1420

Harvesting

Harvesting of fish is done continually or in batches depending on how the production cycle is managed. Before harvesting, the fish are starved for a day to have empty gut, which helps in increasing the shelf life of the produce. Fish are harvested in-situ or the cages are towed to convenient places where the netting operation is carried out without any obstacles. The process of harvesting is simple, where the net is lifted up and the fish are concentrated to a small volume and scooped out and are then placed into a chilled container, chill killed and packed in ice, prior to transportation. A production of 16 kg/m^3 is expected from one crop with survival rate of 80-90%.

CHAPTER: 22

TIGER SHRIMP

The tiger shrimp, *Penaeus monodon* is one of the fastest growing species among cultured shrimps. The species is euryhaline and can even tolerate near freshwater conditions. In India, shrimp culture has been followed as a traditional activity since ages. However, it made a phenomenal growth during 1990's due to the adoption of scientific practices. Farming of tiger shrimp is generally practiced in the tidal flats and other areas adjacent to the coastal waters. The steady demand in the global market and high economic return has attracted farmers to adopt tiger shrimp culture.

Fig.22.1 Penaeus monodon

SEED PRODUCTION

The hatcheries in India follow the 'Galveston system' (Clear water system) with physically separated facilities for quarantine, broodstock maturation, spawning, hatching, larval rearing, post-larval rearing, indoor & outdoor algal culture and artemia hatching. The collection, holding, transportation, maturation and spawning of the broodstock is done as carefully as possible to minimize stress, injury, infection and mortality. Maintenance of proper water quality, aeration and feeding are the important factors in hatchery management. The water taken to the hatchery and that discharged-out should be of stipulated quality and free of pathogens.

Procurement of broodstock

The availability of good quality broodstock is the primary requirement for the successful seed production. Healthy and disease free female weighing 150-200 g and male weighing100-120 g are collected from the wild (sea), kept individually and transported to the hatchery in oxygenated spawner bags filled with filtered, clean sea water already sterilized using UV light or ozone. Care is taken to minimize handling. Place a rubber tube on the rostrum of the animal to avoid puncturing of the bag. The polyethylene bag, used for transportation of broodstock should not be re-used.

On reaching the hatchery, the brooder is slowly acclimatised and disinfected in 100 ppm formalin solution for 30 seconds. The disinfected female is tagged to identify individually and kept in the quarantine area which is separated from other units of the hatchery. The equipment and accessories (tank, bucket, air stone, net etc.) are disinfected carefully with 100 ppm chlorine before and after every use.

Fig.22.2 Quarantine tank

A gross examination of each brooder is done to ensure that it has a clean body and gills, bright colouration, intact appendages and undamaged eyes. Shrimp with black melanised lesions, large areas of white muscle, or bright red in colour is discarded. A small piece from a pleopod is cut-off and sent for PCR test for ensuring the health status of the animal.

Water quality management

The procedure is similar as explained for the milkfish.

Maturation

The male and female broodstock are held separately in dark-coloured and smooth-sided tank of 10 t capacity with 1.2 m height at a density of 2-4 no./m^2. They are fed 3-4 times daily @ 6% of the body weight with fresh polychaete worm, squid, mussel, clam and enriched adult artemia. Alternatively, it can also be fed @ 2% of the body weight with high quality formulated broodstock feed (50% protein and 10% lipid). The water level inside the tank is maintained at 70 cm with mild aeration and 100% water exchange in alternate days with filtered water having a salinity of 28-35 ppt. Maintenance of constant temperature (28-29^{o}C) and pH (7.5-8.5) is critical for the successful maturation of the brooder.

Fig.22.3 Broodstock tank

Eyestalk ablation

The female is given sufficient time to recover from transportation stress before eyestalk ablation. In pre-moult or post-moult stages, duration of one week is given to enable the animal to withstand the ablation stress. During inter-moult period, one of the eyes of the female is cut-off with hot pincers or tied with string or cut-off with scissors or a sharp knife. The area around the ablated eye is disinfected with povidone iodine followed by bath in a tank containing 10 ppm oxytetracyclin for an hour and the animal is returned back to the maturation tank. After 3 days of ablation, the water level in the tank is reduced to 50 cm. An ablated female usually takes 3-7 days for spawning.

Courtship and mating behaviour

Mature hard-shelled males are released to the tank where the eye stalk ablated females are kept (male to female ratio is 1:2). Tiger shrimp has a closed thelycum, hence insemination is possible only immediately after each moulting of the female. Male swims parallel to and positions itself below the female and bends its body in such a way that both are in close contact ventrally. Courtship and mating continue for 1-3 hours. Finally the male turns perpendicular to female and mating usually occurs during night. The lateral plates of thelycum lead to a seminal receptacle where the spermatophores are deposited by the male using the petasma soon after the female has moulted. After mating, the spermatophore can be easily seen externally as vertical, milky white streaks on both sides of the thelycum.

Spawning

The gravid female has dark green, granular ovary having a diamond shaped swelling. Using underwater torch females with spermatophore visible on the thelycum are sourced from the maturation tank in the evening and are transferred to separate FRP spawning tank of 500 l capacity having 300-400 l clean sea water with very mild aeration. Each brooder is individually kept in tank to reduce the risk of horizontal transmission of diseases. The tank is designed to facilitate easy and complete harvesting of egg with minimum damage or loss.

Spawning usually occurs in the late night or early morning. The spent female is immediately shifted back to the maturation tank and any metabolic waste in the spawning tank is siphoned-out. The eggs are collected with a harvest bucket of 100 µm mesh size or siphoned out, washed with filtered and sterilized sea water, disinfected with iodopovidone (50-100 ppm) for 10-60 seconds, rinsed with clean sea water and finally transferred into hatching tank. Fecundity is 3-5 lakh depending on the size of the female. Fertilisation rate is determined by examining some samples of eggs and it is usually found to be more than 90%. In order to ensure good quality seed, each female is allowed to spawn to a maximum of three times only. Records of spawning are maintained to enable traceability. After collecting eggs, the tank is disinfected with 100 ppm formalin for 30 seconds or 50-100 ppm povidone iodine for 1-3 minutes. Treflan at a dose of 0.05-0.1 ppm is added to combat fungal infection.

Incubation

Incubation is carried out in an FRP hatching tank of 0.3-1 t capacity, which allows good water circulation, mild aeration and easy harvesting. The eggs are incubated at a density of 4000 no./l in suspension by providing mild aeration with manual mixing of the water until hatching. After spawning, the fertilised egg hatches out into nauplius (first larval stage) within 12-15 hours at 28-32^{0}C and 29-34 ppt salinity and the aeration is increased thereafter. The nauplius subsists on its yolk material. In order to harvest the nauplii, the aeration is stopped and the healthy nauplii which are phototactic (attracted and aggregated towards light) are collected by siphoning or scooping. The un-hatched egg and weaker nauplii that remain in the tank are then discarded and the tank is cleaned and disinfected. The harvested nauplii at stage 4 from incubation tank are treated by immersion in 100 ppm formalin for 30 seconds followed by a thorough wash in filtered and sterilized water. The quantity of healthy nauplii is counted to estimate the hatching rate and transferred to the larval rearing tank.

Rearing of larvae

The larval stages are very critical and very sensitive phases of life cycle of the shrimp. Shrimp larva passes through nauplius (6 stages), protozoea (3 stages) and mysis (3 stages) to become post-larva(PL). Metamorphosis from one stage to another takes place followed by a moulting. Flat bottomed circular or rectangular FRP tank of 10 t capacity with continuous aeration facility is usually used for larval rearing. Rectangular tank is space saving and more convenient while circular tank is easy to clean and will ensure better water circulation. The tank is disinfected with 200 ppm sodium hypochlorite solution for 10 hours, washed with freshwater, dried under shade for 24 hours and half-filled with disinfected and filtered sea water.

The nauplii at stage 4 are stocked after acclimatisation at a density of 100 no./l with aeration. The nauplius completes six moults within 36 hours and metamorphoses into protozoea. The larva starts feeding on unicellular algae immediately after nauplius stage. Hence, from the nauplius at stage 6 onwards, the tank is inoculated with unicellular live diatom such as *Chaetoceros*, *Skeletonema* and *Thalassiosira* cells @ 50,000 no./ml of tank water to avoid starvation of metamorphosed protozoea. Feeding with unicellular diatom is continued throughout the zoea and mysis stage and it is subsequently reduced to 10,000 no./ml of tank water on reaching the PL stage. The algae also help in maintaining the water quality by utilizing carbon dioxide and ammonia produced in the tank. Alternatively, *Spirulina* and encapsulated feed is also given at 3 hours interval. As the protozoea is positively light sensitive, the tank is covered to ensure darkness. The protozoea undergoes 3 sub-stages within 3-6 days.

Healthy protozoea with adequate feeding (indicated by the presence of faecal thread) metamorphoses into mysis which undergoes 3 sub stages and metamorphoses into Post Larva (PL) within 3-5 days. Algal feed is continued as the larvae retains filter feeding habit but partially replaced with artificial diets. Quantity of artificial diet is determined based on the observations of the larval feeding habits and water quality. Overfeeding should be avoided as it may degrade the water quality.

No water exchange is done for the first six days. The water level in the tank is gradually raised until the larva reaches Mysis-1 stage and thereafter water exchange is done daily at 30% until the larvae metamorphose to PL. The nauplius, protozoea and mysis stages of tiger shrimp are completed within 8-10 days at 30°C. In general, the survival rate during the larval rearing is 40-50%.

Rearing of Post-Larvae (PL)

Once the larva metamorphoses to the PL, it is shifted to the outdoor PL rearing tank (Parabolic cement tank of 20 t capacity) or retained in the indoor larval rearing tank (FRP tank of 10 t capacity). The stocking density of PL is 75-100 no./l. Overstocking leads to stress and results in cannibalism. As PL ceases filter feeding and switch over to pick up feeding, it feeds on zooplankton well and so fed with live *Artemia* nauplii. Decapsulation of *Artemia* is done to avoid contamination and cyst feeding by the larva. It also ensures hatching efficiency of *Artemia*. One million PL requires 6 kg of *Artemia* cyst and the details of daily ration are given in Table 22.1.

Table 22.1 *Artemia* nauplii requirement

PL stage	*Artemia* nauplii per ml	Daily frequency
3-6	2 no.	Thrice
7-12	3 no.	Thrice
13-20	3 no.	Once

From PL7 onwards, *Artemia* nauplii is gradually replaced with micro-encapsulated feed and egg custard (<500 µm size) as the shrimp larva becomes able to consume food materials available at the bottom. When formulated diet is used to supplement the live feed, it is important to feed a small amount of high quality and appropriately sized diet frequently. From PL-13 onwards, as the frequency of feeding with *Artemia* nauplii is reduced to once daily, artificial feed is given for remaining two times daily @ 50 g/million PL. The quantity of artificial feed may be split into various lots with an interval of 3-4 hours to ensure good water quality. Failure to provide sufficient feed can lead to stress, poor growth, impaired moulting, mortality, cannibalism, deformity and increased levels of epibiont fouling. While procuring and storing feed, it should be ensured that the feed is free from pathogens especially fungi.

Fig.22.4 Larval rearing

Water exchange is done 50% daily until harvest. Unconsumed feed, faecal matter and other waste materials are daily siphoned out after turning off the aeration. The bottom debris is carefully siphoned-out into a fine mesh net (250 µm) to prevent PL from escaping from the tank. The survival rate from larva to PL is 65-75%.

Monitoring

Health assessment of larva, water quality parameters and density and quality of algae are regularly monitored in the morning so that decisions on water exchange, feeding and other management activities could be planned and executed in the day time itself.

Besides, visual inspection of the larva and water in each tank is done 3-4 times daily by taking samples in beaker to monitor the larval stage, health, activity, behaviour and abundance of feed and faeces. The equipment and materials used to harvest the nauplii are washed daily with 30 ppm sodium hypochlorite solution to prevent contamination to subsequent batches. The details of water quality parameters and feeding are recorded and maintained properly. A sample of larvae is sent to the laboratory for detailed microscopic examination of the larval stage, digestion and presence of any disease or physical deformity. A deformity rate of less than 5% is generally considered acceptable. Besides, sample is sent twice for PCR screening during the cycle. Health of the nauplii is also checked by phototaxis.

Fig.22.5 Monitoring of PL

Algal culture

Algal culture facility consists of indoor and outdoor sections. In the indoor section, pure strain of algae is isolated and cultured in axenic culture media in vessels having sizes ranging from 10 ml test tube to 20 l carbouys. Micro algal culture requires extreme hygiene in the indoor phase to prevent contamination, which includes the use of laboratory grade chemicals, thorough disinfection, filtration of water up to <0.5 µm and proper aeration facility. Air conditioning is also necessary to maintain temperature at 22-24^{o}C. The algae thus produced in the indoor section are brought to the outdoor algal tank for mass culture.

After filling the outdoor tank with filtered sea water and fertilised with the nutrient media, it is inoculated with the algae brought from the indoor section. Continuous aeration is provided in the tank to keep the algae in suspension and allowed to multiply for 2 days. Then it is pumped into the larval-rearing tank or the concentrate is harvested through a fine mesh filter net and added to the larval rearing tank to get the cell density of 50,000 cells/ml.

Fig.22.6 Algal culture

Artemia hatching

In clean cylindro-conical tank, decapsulated artemia cyst is incubated @ 2g/l with continuous vigorous aeration to prevent the cyst from settling. Sufficient light (1000 lux) is also provided to enhance hatching. The nauplii are harvested after 18-24 hours of incubation. Prior to the harvest of artemia, the aeration is turned off. The phototactic nauplii are attracted towards the illuminated translucent bottom of the tank and collected in 100 µm mesh net. The collected nauplii are washed thoroughly in clean running water before feeding.

Fig.22.7 Artemia nauplii

Harvest and transportation

The seed is harvested and transported at PL15 stage onwards, *i*.e. 23-28 days after hatching. The harvest should be with minimum stress to ensure better survival. Seeds are acclimatised to the salinity of the grow-out pond by adding freshwater to the rearing tank. Such salinity adjustments are done only after PL10 stage. Salinity adjustment up to 4 ppt can be done in a day. After draining the water from the tank, PL is harvested using a scoop net and packed in polythene bag with one third water of the desired salinity as explained for the major carps. The stocking density of PL15 during transportation is 500-2500 no./l depending on time and distance. Live *Artemia* nauplii are added @ 15-20 no./PL for every 4 hours of transportation. A few granules of washed activated carbon as an adsorbant may also be added to each bag to control ammonia level during long transportation. It is advisable to transport the seed at night when the temperature is low, for reducing stress during transportation.

POND FARMING (zero water exchange)

Site selection and pond construction

Since shrimps are benthic organisms, type of soil is the most critical factor in site selection. The soil should have good water holding capacity and could be shaped into a ball which does not crumble even after considerable handling. Clayey loam soil is preferred while acid sulphate soil is not advisable. Samples of soil is taken from a depth of 1 m and tested for various parameters. The ideal soil quality parameters include 6.5-8 pH, 1.5-2.5% organic carbon and >4 μΩ electrical conductivity. Pond having the size of 0.5-2 ha water spread area with length to width ratio of 2:1 and a depth of 1-1.5 m is ideal. The site with an elevation of 0.2 to 0.5 m above the high tide level allows easy pond preparation and harvesting.

The components of a shrimp farm are water control structures such as dyke, feeder canal, sluice gate and supporting facilities such as water pump, aerator, generator, warehouse, farm house, farm road, effluent treatment system *etc*. The excavated earth is utilized to construct the peripheral dyke with about 60 cm height above the maximum flood level and 3 m top width and the internal bund with 30 cm freeboard and 1 m top width. There may be separate inlet and outlet facilities diagonally with sluice gates of 150 cm wide for every one ha water spread area. The water intake point to the reservoir pond is fenced with bamboo poles and net.

Fig.22.8 Water outlet

Fig.22.9 Fencing for bio-security

Entry of unwanted organism including fish and the escape of stock from the pond is prevented by using wire mesh filter net in the outer side and nylon screen net in the inner side of sluice gate. The mesh size of the nylon screens should be as follows.

<15 DOC	- 600 µm
15-45 DOC	- 1200 µm
>45 DOC	- 1800 µm

As a part of ensuring bio-security measures and to prevent the entry of birds and animals, the top of the pond is covered by net of 100 mm mesh size and the side is fenced with stiff net of 26 mm mesh size or shade net up to a height of minimum 1.8 m.

Drying and liming

In the case of existing pond, dykes are strengthened by plugging holes and crevices to prevent the leakage of water. Sluice gate is repaired and the farm machineries are serviced and fixed in the desired positions. Draining the pond and exposing to sunlight increase the productivity and help in eliminating unwanted organism. Ploughing the pond bottom to a depth of 15-20 cm helps the release of poisonous gases. The sludge accumulated at the centre of the pond during the previous farming period should be removed.

Fig.22.10 Sludge removal

In the case of pond having acid sulphate soil, complete drying of pond bottom is not recommended. Zeolite or aluminium silicate at 250 kg/ha is applied to prevent the contact of water with the acid sulphate soil by forming a sediment layer in between. Initial dose of agricultural lime is added to enhance soil pH as below:

4.0-4.5 pH	: 1500 kg/ha
4.5-5.5 pH	: 1000 kg/ha
5.5-6.5 pH	: 700 kg/ha
6.5-7.5 pH	: 500 kg/ha

Liming is also required during rain fall at the rate of 250 kg/ha of lime applied over the slope of the dyke, so that it slowly dissolves in water.

Disinfection of pond

Two weeks prior to stocking, water is allowed to enter the pond and is disinfected by chlorination (35-50 ppm) using calcium hypochlorite (30% active chlorine) to destroy all undesirable organisms including microbes and parasites in the soil. The water has to be dechlorinated by exposing to sun or by aeration. The pond water with chlorine is never let-out directly into open water body.

Manuring

Prior to 10-12 days of stocking, the water is fertilized with inorganic fertilizers containing nitrogen and phosphorous @ 40-50 kg/ha to stimulate the growth of diatoms. In low saline water, urea and super phosphate are used in the ratio 2:1 while in high saline water, use of equal quantity of urea and super phosphate is ideal. Application of silicates @ 30 kg/ha also stimulates growth of diatoms.

Water quality requirements

Temperature	: 28-32ºC	DO	: >5 ppm
pH	: 7-8.5	TAN	: <0.1ppm
Transparency	: 25-45 cm	NO_2-N	: <0.1ppm
Salinity	: 10-35 ppt	NO_3-N	: <10 ppm
Alkalinity	: >200 ppm	H_2S	: <0.1ppm
Hardness	: 100-150 ppm	Iron	: <1 ppm

Stocking

The hatchery produced PCR screened uniform sized healthy seeds (PL-15) are stocked either during morning or evening hours at a density of 6 no./m^2 after acclimatisation. Acclimatisation to salinity is done at the hatchery itself.

Fig.22.11 Acclimatisation of seed

Feeding

The tiger shrimp is fed with a sinking pelletted feed containing 35-40% protein and 3-5% lipid and having water stability for 3-4 hours. Feeding should be avoided near the drain and aerator. In ponds with sandy bottom, broadcasting is preferred while in those with loamy bottom, tray feeding is better. Check trays are used to monitor the feed consumption and the feeding ration is adjusted accordingly.

Fig.22.12 Check tray observation

Recommended feeding rate is followed during the first month of culture; later feeding ration is adjusted with the help of check tray analysis. The details of feeding rate are given in Table 22.2.

Table 22.2 Feed requirement

DOC	ABW (g)	Daily feeding rate (% of ABW)	Feeding frequency
1	0.02	50.0	2
15	0.95	10.0	2
30	2.90	8.0	3
45	7.00	6.4	3
60	11.00	4.9	4
75	16.50	3.7	4
90	24.30	3.0	5
105	32.00	2.3	5
120	35.00	2.3	5

The quantity of feed given is recorded daily. Wet/moist feed should be avoided as far as possible since it could be potential source of pathogen. To assess the growth rate and biomass of stock, sampling with cast net is done biweekly. Analysis of the gut content of the shrimp gives an indication of the feeding conditions. Feed is stored in dry, well ventilated protected places.

Care and monitoring

Replenishment of water is done to compensate evaporation loss. The water drawn to fill the pond should be devoid of toxic gases and other pollutants. Never take water directly from natural open source as it has the risk of containing potential pathogens and their intermediate hosts. Use of filter net having mesh size of 60 µm in inlet pipes and sluice gates controls the pathogen and young stages of carrier organisms. The water is disinfected in a reservoir pond by chlorination (35-50 ppm) with calcium hypochlorite prior to filling the culture pond as pathogens like WSSV can survive as free-living form up to seven days.

Left over feed, metabolic waste or sudden death of plankton may lead to the rise of ammonia. As there is no water exchange during the entire culture period, probiotics are applied to maintain water quality at desirable level, initially 3 days before stocking and subsequent doses in every 10 days interval based on the condition of the pond. The water quality is also maintained using aerators @ 1 hp for every 500 kg of biomass. The aerators are placed in such a manner that all of them create circular water movement of water in the same direction and produce only minimum dead space. It accumulates the waste at the centre portion of the pond. The aerators are used only for 6 hours in the first four weeks, which is then increased to 9 hours by 10^{th} week and further to 12 hours until harvest with proper day to day monitoring.

Homemade inoculum made by fermented jaggery (10 kg) and rice bran (40 kg) with yeast powder (500 g) in a barrel with 500 l water for 2 days is applied to pond water once in a week @ 500 l/ha to keep the pond environment healthy. Commercial probiotics are also applied to feed, water and soil whenever required. Mineral mixture, zeolite, ammonia reducer, *etc.* are also used as per the requirement.

Weekly assessment of shrimp for its growth and well-being is essential. Weekly growth rate will be about 2 g. Sudden changes in the water quality parameters adversely affect shrimp growth and health. The schedule for the observation of water quality parameters is given below:

Temperature	: 6 am, 2 pm
pH	: 6 am, 2 pm
DO	: 5 am, 5 pm

(Ammonia, Nitrite and H_2S are monitored twice in a week).

Transmission of disease between ponds may occur through farm implements and farm workers. Providing independent implements for each pond and its routine disinfection before use should be made mandatory. Movement of workers between ponds should be minimized.

Harvesting and marketing

Tiger shrimp attains 30-40 g size within 105-120 days at the given stocking density. The crop can be easily harvested using conical bag net fixed at sluice gate and letting out the water during low tide. The remaining shrimp is harvested by cast netting and hand picking after draining the pond. In ponds where draining is not possible, the water is pumped out. Final harvesting generally carried out in the night hours and completed within 6 hours after draining the pond to ensure low temperature levels during catching and handling. The stock should be 'chill killed' immediately after harvest to prevent discolouration and stored in ice for marketing. Total production of 1.4-1.9 t/ha can be expected per crop with a survival rate of about 80%.

Organic farming

Organic farming is a holistic method of shrimp culture based on organic inputs alone without the use of any antibiotics or chemicals from hatchery operation onwards. It helps in value addition of the product with high market demand and premium price. Though organic agricultural products are already being marketed, organic farming of shrimp is still in a nascent stage in India which has immense potential in the future, considering our ecological conditions and environment.

CHAPTER: 23

INDIAN WHITE SHRIMP

The Indian white shrimp, *Penaeus indicus* a native of India and South East Asia, is one of the suitable species for brackish water aquaculture. In natural conditions, the adult is seen up to 90 m depth over muddy or sandy sea bottom while the post-larva and juvenile inhabit shallow estuarine waters. It fetches good price in local markets even at small sizes. The exoskeleton is relatively thin, which provides more edible meat per unit total weight of the shrimp.

Fig.23.1 Penaeus indicus

SEED PRODUCTION

Seed production of Indian white shrimp is similar to that of the tiger shrimp with slight variations in the rearing techniques and feeding patterns. The major advantage is that the gravid female in the required size is locally available in all seasons.

Procurement of broodstock

The gravid female in the size range of 30-50 g is selected and kept for spawning in an FRP tank with clear seawater and mild aeration.

Water quality management

It is same as that explained for the milkfish.

Maturation

The process is similar to that explained for the tiger shrimp.

Mating

It is similar to that explained for the tiger shrimp.

Spawning

Spawning takes place in the night. The female may feed on spawned eggs; hence a mesh tray is installed on the bottom of the spawning tank or the eggs are taken-out during early morning using scoop net. The eggs are kept for hatching and metabolic wastes from the tank are siphoned out. Fecundity is usually 0.5-1 lakh per individual, which varies according to the size of the female. Other aspects are similar to that explained for the tiger shrimp.

Incubation

It is almost similar to that explained for the tiger shrimp. The eggs are incubated at a density of 4000 no./l in hatching tank of 0.3-1 t capacity at a temperature of 28-32^{o} C and salinity of 28-35 ppt. The hatching takes place in 12-15 hours. The hatching rate is usually more than 70%. The egg hatches out into nauplius, a non-feeding stage and takes almost 36-40 hours for moulting and becomes protozoea.

Rearing of larvae

There are 3 protozoeal stages, which may take almost 4 days (PZ1-36 hr, PZ2-24 hr and PZ3-36 hr) to metamorphose into the next stage called mysis. The mysis has 3 stages which take another 4 days (M1- 36 hr, M2-24 hr, M3-36 hr). The larvae (protozoea and mysis stages) are stocked at a density of 100-150/l and are fed with live diatoms like *Chaetoceros* and *Skeletonema* @ 80,000 cells/ml of water in the tank. The other aspects are similar to that explained for the tiger shrimp. The mysis moults into the post-larva.

Rearing of Post-Larvae (PL)

The stocking density of PL in tank is 100 /l. The PL1 to PL 7 is fed with live *Artemia* nauplii and PL8 to PL15 with an artificial larval diet. It can also be fed with squilla meat, taking care of the water quality by removing the waste periodically. Well performing PL diets are also available in plenty in the market. The other aspects of PL rearing are similar to that of the tiger shrimp. The easy availability of spawners makes Indian white shrimp a desirable species among hatchery operators even now. At the same time the demand for the seed is far less compared to tiger shrimp and so the seed price is too low.

Monitoring

It is same as that explained for the tiger shrimp.

Harvest and transportation

The seed is harvested and transported at PL12 to PL15 stage which takes 22-25 days from hatching. Other aspects are same as that explained for the tiger shrimp.

POND FARMING

Site selection & pond construction

The aspects of site selection and pond construction are similar to that explained for the tiger shrimp.

Preparation of pond

Pond preparation steps like draining, drying, liming, eradication of unwanted organisms and manuring are followed more or less in a similar way as prescribed for the tiger shrimp.

Water quality requirements

The suitable range of water quality parameters considered to be optimum are given below:

Temperature	: 26-32ºC	TAN	: <0.1ppm
pH	: 7.5-8.5	NO_2-N	: <0.1 ppm
Transparency	: 25-45 cm	NO_3-N	: <10 ppm
Salinity	: 25-35 ppt	H_2S	: <0.1 ppm
DO	: >4 ppm	Iron	: <1 ppm
Alkalinity	: ~200 ppm	Hardness	: 50-150 ppm

Stocking

The PCR screened seed (PL-12) is stocked after acclimatisation at a density of $10/m^2$. Since Indian white shrimp prefers high salinity regimes (20-25 ppt) than tiger shrimp, its culture is normally scheduled during the summer months in Kerala. Stocking is scheduled during mid-January, so that the culture period can be extended up to the end of April. In the coastal area where tidal effect is used for farming, the rules and regulations of Coastal Aquaculture Authority, Chennai need to be strictly adhered to.

Feeding

The Indian white shrimp is fed four times daily with a sinking pelletted feed having 30-35% protein. Other aspects of feeding are similar to that of the tiger shrimp.

Care and monitoring

Water quality parameters should be checked and managed as in the case of the tiger shrimp.

Harvesting

The Indian white shrimp attain 20-25 g size within 90-110 days. Harvesting is done as explained for the tiger shrimp. Production of 1.6-2 t/ha can be realized with a survival rate of 80%. Even though duration of farming of the Indian white shrimp is less than 4 months, only one crop is generally taken in a year to ensure high salinity and environmental sustainability. For the rest of the year, the same pond can be used for paddy cultivation.

Fig.23.2 Conical bag net

Fig. 23.3 Hand picking

CHAPTER: 24

VANNAMEI SHRIMP

The vannamei shrimp, *Penaeus vannamei* commonly known as white legged shrimp/ Pacific white shrimp/ Mexican white shrimp is the native of Pacific coast of Mexico and Central and South America. It is greyish-white in colour. The maximum weight of female in the wild is 120 g and that of male is 80 g. It is an omnivorous scavenger and less aggressive and less carnivorous than the tiger shrimp. It prefers clayey loam soil which can also remain in the water column during culture.

Fig.24.1 Penaeus vannamei

In India, its large-scale introduction was permitted in 2009 with specific guidelines for the import of broodstock, seed production and culture in a highly bio-secured environment. In order to eliminate the presence of virus in the seed, Specific Pathogen Free (SPF) brood stock has been developed by keeping a number of generations in highly bio-secured facility with continuous surveillance. Offspring of SPF shrimp is not considered as SPF unless it is produced and maintained at an SPF facility.

SEED PRODUCTION

Procurement of broodstock

Specific pathogen free or specific pathogen resistant broodstock of 30-40 g size is procured, quarantined and kept in hatchery under strict bio-security measures.

Water quality management

The method is similar to that explained for the milkfish. Water is allowed to drain-off from the facility only after proper effluent treatment.

Maturation

The male and female broodstock are held separately in grey-coloured and smooth-sided maturation tank of 20-30 t capacity having clean filtered seawater up to a level of 50-70 cm with continuous mild aeration and re-circulation or with a daily water exchange of 250-300%. It is fed with fresh or frozen feed (krill, worms, squid, oyster, polychaete *etc.*) at 20-30% of the body weight or a dry feed having 45% protein @ 4-6% of the bodyweight. The maturation tank is maintained under dark condition. Other aspects of maturation practices and process of eyestalk ablation are similar to that of tiger shrimp.

Mating

For mating, gravid female is released into a mating tank of 20 t capacity with male in the ratio of 1:1 and density of 6-8 no./m^2 for 4-5 hours. Water temperature is maintained at 27-28°C with a salinity of 30-35 ppt and pH of 8.0-8.2.

Spawning

It is similar to that explained for the tiger shrimp. Fecundity is 1-1.4 lakh eggs for a female of 30-35 g body weight. The female is removed from the maturation unit after 15 spawnings or 3 months.

Incubation

It is similar to that explained for the tiger shrimp. The eggs are incubated at a density of 4000 no./l in hatching tank of 0.3-1 t at a temperature of 29-32°C and salinity of 32-35 ppt. The incubation period is 36 hours and the hatching rate is 70-80%. The eggs hatch out to nauplii and become protozoea within next 36 hours.

Rearing of larvae

Nauplii at stage 4 are harvested, disinfected and stocked in a tank of 10-40 t capacity at a density of 150 no./l. It is fed with unicellular algae such as *Chaetoceros* and *Thalassiosira* @ 80,000 cells/ml throughout the protozoea and mysis stages. Other aspects are same as that explained for the tiger shrimp.

Rearing of Post-Larvae (PL)

The stocking density of PL in tank is 100-150 no./l. Other aspects are same as that explained for the tiger shrimp.

Monitoring

It is similar to that explained for the tiger shrimp.

Harvest and transportation

The seed is harvested and transported at PL12 stage *i.e.*, after about 21 days from hatching. Other aspects are same as that explained for tiger shrimp.

FARMING IN POND

Site selection & pond construction

The first and foremost requirement for starting a Vannamei shrimp farm in CRZ area is to obtain permission from Coastal Aquaculture Authority (CAA), Chennai by applying in prescribed form through the State Fisheries Department. A number of mandatory conditions have to be satisfied for getting the license from CAA.

The aspects of site selection and pond construction are almost same as that followed for the tiger shrimp. The major variation is regarding the depth of water column. As vannamei shrimp lives in column waters, increasing the depth of the pond helps in increasing stocking density. Hence, a water column of 1.5-2 m is preferred. Size of the pond varies from 0.1-1 ha. If the pond bottom or dyke is not compact, it should be lined with polythene sheet to avoid erosion of soil by strong aeration and constant water current. Zero-water exchange system of farming is mandatory and any discharged effluents should be treated in ETS.

Fig. 24.2 Lined pond

Preparation of pond

Pond preparation steps like draining, drying, liming and eradication of unwanted organisms and manuring are followed in a similar way as prescribed for the tiger shrimp farming.

Water quality requirements

The optimum range of water quality parameters are given below:

Temperature	: 30-34ºC	TAN	: <0.1ppm
pH	: 7.5-8.5	NO_2-N	: <0.1 ppm
Transparency	: 25-40 cm	NO_3-N	: <10 ppm
Salinity	: 5-40 ppt	H_2S	: <0.1 ppm
DO	:>4.5 ppm	Iron	: <1 ppm
Alkalinity	: ~200 ppm	Hardness	: 50-150 ppm

Stocking

The hatchery produced PCR screened uniform sized SPF seed (PL-12) from a certified hatchery is stocked in the pond after acclimatisation. The maximum permitted stocking density by CAA is 60 no./m^2.

Feeding

Vannamei is fed 4-5 times daily at 16% of the body weight initially and gradually reduced to 2% (15g) with a sinking pelleted feed having 25-40% protein, 6-8% lipid, 2% unsaturated fatty acids and 0.25-0.4% cholesterol. Other aspects of feeding are similar to that of the tiger shrimp.

Care and monitoring

The quality of pond water is monitored and maintained as in the case of the tiger shrimp. Aerators @ 1 hp per 500 kg of biomass are positioned in such a way that the sludge is accumulated at the centre of the pond bottom. It is removed during culture using bottom central drainage or sludge pump, which is essential for high density culture. In order to aid the process, sludge settled at other places should be disturbed regularly. This is achieved through dragging of chains at the bottom at regular intervals from all the sides of the pond. Weekly growth rate will be 1.5 g. Other aspects are same as that of the tiger shrimp.

Harvest

The vannamei shrimp attain 20-25 g size within 90-120 days depending on the stocking density. As it lives in water column, majority of the stock is harvested by cast netting and drag netting which reduces overcrowding and stress. Production of 6-10 t/ha can be obtained with a survival rate of 80%. The FCR will be normally 1:1.25.

FARMING IN BIO-FLOC POND

Biofloc unit design

Biofloc farming is a sustainable type of intensive aquaculture using highly aerated and biosecure system. The technology works with manipulation of carbon-nitrogen ratio which promotes heterotrophic bacterial growth. The farming is usually practiced in an area outside the CRZ. It is done in tanks of 80-1000 m^3 size lined with PVC coated nylone sheet having 550-750 gsm thickness.

Polythene lined small earthen pond of 100-1000 m^3 can also be used which can be established by excavating 50 cm soil and forming a bund of 100 cm with the excavated soil around the pond. The bottom of the pond is lined using polythene sheet after it is levelled with good quality sand and cushioning material in order to avoid the puncturing of the sheet due to any sharp or pointed objects. It has a slope (50:1) towards centre drain to facilitate accumulation of any solid material at the bottom and its efficient removal through a drainage pipe of 3-6 inch diameter at the centre. Sufficient slope along the inner side of the bund is ensured in order to prevent the slipping of the polythene lining. A bush system arrangement is provided inside the pond with drain pipe. At the outer part of the pond, the drain has an opening at a height of 70 cm to discharge sludge and another opening at a height of 125 cm to remove overflow water.

Two single phase air pumps or air blower of 3 hp capacity fitted with 96 pieces of algal resistant aeroxy tube rings of 50 cm with half inch inner diameter are required for each 1000 kg biomass for providing aeration continuously to make the biofloc under suspension and also for maintaining the DO and TAN at optimum levels. The air pump should be placed close to the pond at a height above the maximum water level to prevent reverse flow of water and each aeroxy tube ring is provided with 1.5 inch PVC pipes loaded with sand inside and sealed at both ends. Usually no water exchange is done for the culture but replenish the evaporation loss by using a water pump of $^1/_4$ hp. Power failure of more than 1 hour leads to mass mortality of stock. Hence, there must be a backup to ensure uninterrupted supply of electric power. Top of the pond is covered with shade net to control sunlight and entry of birds.

Water treatment

At first, the tank is filled with good quality water up to a height of 125 cm. If it is freshwater, add raw salts @ 5 ppt. After that, it is chlorinated (35-50 ppm) using sodium hypochlorite followed by de-chlorination by exposing to sunlight or through vigorous aeration after 24 hours.

Biofloc formation

Biofloc must be made ready before stocking and for that inoculum is developed and inoculated into the culture tank. Flocculation of heterotrophic bacteria occurs, which are consumed by the shrimp, reducing dependence on high protein feeds. The process of developing biofloc is same as that explained for Nile tilapia. In bigger ponds, the inoculum can be prepared within pond at low water volume by adding calculated amount of pond soil, fertilizer and fermented carbon source and aerate till phytoplankton growth occurs and then transforms to heterotrophic system.

Stocking

The biofloc develops and reaches 5-10 ml/l within 10-14 days and the system becomes ready for stocking. After PCR screening and proper acclimatisation, vannamei seeds (PL 12-14) are stocked @ 200-400/m^3.

Feeding

It is fed 2-5 times daily with a low protein sinking pelletted feed (20-32% protein) at 12 % of the body weight initially and 1.5% at the final stage. The usual FCR is almost 1:1, hence this mode of culture is more cost efficient.

Care and maintanance

The biofloc density is measured and maintained in between 10-15 ml/l as explained for Nile tilapia. If it is less than 10 ml/l, carbon source is added. Other water quality parameters are also maintained as explained for the Nile tilapia. The sludge accumulated at the centre of the pond bottom is discharged through a bottom drain at the centre or by pumping-out using a $^{1}/_{4}$ hp motor. Probiotics are also used to improve the water quality. There should be separate provisions for handling and treating the sludge which is discharged from the unit.

Harvesting

The shrimp grows to a harvestable size of 20 g within 120 days. Production of 4-8 kg/m^3 is obtained with a survival rate of 80%. Being an exotic species, Vannamei shrimp should not be marketed in live condition and the harvested ones should be kept in insulated crates with sufficient quantity of ice. Ideally, 2-3 crops can be taken per year so that the sustainability and profitability can be ensured. Moreover, the product harvested is of premium/organic quality as far as the marketability is concerned.

CHAPTER: 25

GIANT FRESHWATER PRAWN

The giant freshwater prawn, *Macrobrachium rosenbergii*, native to India and South East Asia commonly known as '*Scampi*' is the biggest among freshwater prawns. It is a candidate species for aquaculture owing to its very fast growth rate, market demand, hardness, euryhaline nature and its compatability with Indian major carps. It is sluggish by nature and remains half buried during the day time in the sediment or hidden in shelter which is well protected from direct sunlight. Usually, it seeks shallow regions rich in aquatic vegetation and organic detritus. It breeds throughout the year even in captivity with peaks during monsoon season. It needs freshwater and brackish water habitats to complete the lifecycle. The larva feeds on zooplankton, while the juvenile and adult are benthic omnivores. Scampi grows to a size of 30-32 cm (350-450 g) and half of the body is occupied by its cephalothorax.

Fig.25.1 Macrobrachium rosenbergii

Mature male prawn is noticeably larger (heterogenous individual growth-HIG) than the female and the second chelipedes are significantly larger and thicker. The head of the male is also proportionately larger, and the abdomen is narrower. The genital pores of the male are placed between the fifth walking legs at the basal region. There are three distinct male morphotypes namely small male (SM), orange claw male (OC) and blue claw male (BC). The second pair of peraeopods of BC male is blue in colour and extremely long, those of OC male is golden coloured and those of SM male is small, slim and almost translucent. Interestingly, a number of intermediate male forms have also been recognized, including weak orange claw (WOC), strong orange claw (SOC) and transforming orange claw (TOC) males.

The female genital pore is situated at the base of the third walking legs. The pleura (overhanging sides of the abdominal segment) is longer in female than in male and the abdomen itself is broader. These pleura of the first, second and third tail segments of female form a brood chamber in which the eggs are carried during the incubation period *ie*. between laying and hatching. A ripe or 'ovigerous' female can easily be identified because the ovary can be seen as large orange-coloured masses occupying a large portion of the dorsal and lateral parts of the cephalothorax. Female prawns are sometimes referred to as virgin females (V or VF), berried (egg carrying) females (BE or BF) and open brood chamber (spent) females (OP). In India, the technique of mass rearing of larvae on commercial basis was first developed at Azhikode hatchery of State Fisheries department, Kerala.

SEED PRODUCTION

Broodstock development

The sub-adult/ adult is collected from wild or grow-out pond (weighing not less than 60 g) and transported carefully in an aerated plastic container or polythene bag (after capping the rostrum, telson and chelipedes). On arriving at hatchery, it is disinfected with 0.3 ppm

$CuSO_4$ for 30 minutes and stocked in an earthen pond of 0.2-1 ha water spread area with a water depth of 1 m. The stocking density of 0.5-1 no./m^2 with a male to female sex ratio of 1:4 is usually adopted. Procuring adults from different locations would help to maintain the genetic quality of the broodstock and offspring. Proper quarantine protocols and health check-up for the presence of virus, bacteria and parasites need to be followed to avoid the disease occurrence. The prawns can be fed thrice daily @ 3-5% of the body weight with a commercial pelleted feed containing 35-40% protein.

Mating

The mating of adults result in the deposition of a gelatinous mass of spermatozoa (spermatophore) on the underside of the thoracic region and between the walking legs of the female's body. Successful mating can only take place between hard-shelled males and soft-shelled ripe females, which have just completed their pre-mating moult usually at night. All of the various types of males are capable of fertilising females but their behaviour can be different. Under natural conditions, mating occurs throughout the year with regional climate linked variations. Also, there are sometimes peaks of activity related to environmental conditions like monsoon showers, saline ingress and temperature. In temperate areas the breeding takes place generally in the summer.

Within a few hours of mating, eggs are extruded through the gonopores and guided by the ovipositing setae (stiff hairs), which are present at the base of the walking legs, into the brood chamber. During this process, the eggs are fertilised by the spermatozoa attached to the exterior of the female's body. The eggs are held in the brood chamber (stuck to the ovigerous setae) and kept aerated by vigorous movements of the pleopods/swimmerets. The length of time that the eggs are carried by female for incubation is normally three weeks with slight temperature dependent deviations. The temperature of 28-30^{o}C can be considered as ideal for the satisfactory incubation.

The fecundity depends on the size of the female and ranges from 80,000 to 100,000 eggs during one spawning when fully mature. However, first brood (i.e. those which are produced within their first year of life) often lay 5,000-20,000 numbers of eggs only. The thumb rule is that 1 g of a healthy female can yield about 500-1000 larvae.

Seed production

The berried female bearing dark grey coloured eggs are sourced from the brood stock pond or natural waters and is held in PVC pipes or cylinders capped on both sides with netting to prevent puncturing of the bag. The rostrum and telson are capped with protective rubber tubes. Temperature is controlled using ice bags in the container during transportation. Starving of prawn for a few hours before packing reduces accumulation of metabolites during transport. Immediately after arrival at the hatchery, the berried prawn is given a bath in 100 ppm formalin for 10 minutes followed by rinsing in freshwater to eliminate the epifauna, if any. The berried female is kept individually in separate FRP tanks of 500 l capacity with 300 l filtered water at 6 ppt salinity and fed with oyster or clam meat. Mild aeration is provided continuously. Left over feed and metabolic wastes are removed from the tank and half of the water is replaced during every morning hours.

Fig.25.2 Maturity stages

Initially, the colour of the egg is yellow, then it changes to bright orange to pale grey, and further it darkens to slate grey by the time of hatching. Once, the egg colour turns dark grey, hatching will be started within 48-72 hours at 26-31^{0}C. The larvae are collected in the early morning using a scoop net. Soon after hatching, female is carefully shifted back to stock tank.

Rearing of larvae

The larva passes through 11 zoeal stages before metamorphosis into post-larva (PL) which is carried-out normally in an FRP tank of 500 l capacity but varies as per convenience and capacity of the hatchery. The hatched larvae are stocked @ 100-300 no./l. Water quality parameters required for the larval rearing are given below.

Temperature	: 29 ± 2ºC	Turbidity	: Nil
pH	: 7-8.5	TAN	: <0.1ppm
Salinity	: 12±2ppt	NO_2-N	: <0.01ppm
DO	: >5 ppm	Iron	: <0.02 ppm
Alkalinity	: 80-100 ppm	Hardness	: <120 ppm
Photoperiod	: 12/12 hr L /D	TDS	: <200 ppm

Filtered seawater and freshwater are mixed to prepare 12 ppt saline water and it is chlorinated (35 ppt) with sodium hypochlorite solution, which is then aerated for 24 hours for de-chlorination. Excess chlorine is removed by treating with sodium thiosulphate, if necessary. The larvae are fed with live *Artemia* nauplii, egg custard and a formulated feed. Feeding is done with extreme care to avoid over/under feeding and the details of daily ration are given in Table 25.1. Daily, 60-80% of the water is replaced. On every morning, left over feed, metabolic wastes, detritus, shell and dead larvae are removed by turning-off the aeration and siphoning-out the settled particles from the tank bottom. The metamorphosis is non-synchronous and undergoes 11 larval stages within 16-28 days according to the temperature and water quality. Up to stage-V, the healthy larva swims at the water surface, while the un-healthy larva accumulate at the tank bottom.

Table 25.1 Artemia nauplii requirement

DOC	No. of artemia nauplii requirement/ larva	Daily feeding frequency
3-4	10	Three
5-6	15	Five
7-8	20	Five
9-11	30	Six
12-14	40	Six
15-24	50	Seven
25-30	40	Seven
31-35	30	Seven

Rearing of Post-Larvae (PL)

The metamorphosed PL (7-9 mm) is more benthic and resembles the juvenile which rest or crawl on the tank surface. It is kept in cement tank (20 t capacity) with a stocking density of 40-60 no./l with continuous aeration and gradually acclimatised to freshwater. Submerged artificial shelters (tiles, PVC pipes *etc.*) are provided to prevent cannibalism. It is fed with a pelleted feed in fine crumble form 3-4 times daily @ 10-20% of the body weight. Pelleted feed can be replaced with egg custard and minced fish/mollusc/shrimp flesh for 1-2 times daily. A water exchange of 60-80% should be done daily. It attains 16-21 mm size by next 15 days with a survival rate of 70-80%. Since the PL are cannibalistic in nature, proper feeding plays a key role.

Harvest and transportation

PL is harvested from the tank by scooping-out. The left-over PL get concentrated near the illuminated area of the rearing tank covered with dark sheets. Before packing, the salinity of the rearing tank is reduced to desired levels. The PL is spooned-out to polythene bag @ 1000-2000 numbers depending on size of PL and duration of transportation. Other aspects are similar to that of the tiger shrimp.

POND FARMING

Site selection and pond construction

Rectangular ponds of 0.2-0.4 ha area with a water depth of 100-150 cm is ideal for freshwater prawn culture. The pond should have a smooth bottom and gradual slope from water intake to outlet. Sandy-clay or sandy-loam soil is suitable for farming. The banks of the pond must be high enough to protect from floods. The intake water should be free from contaminants. Other aspects are almost similar to that explained for the major carps.

Preparation of pond

The pond after complete draining is dried under sunlight for about 2 weeks until the soil cracks which destroys pathogen and increase the soil fertility. The pond bottom should be tilled for the oxidation of organic matter and to enable the escape of foul gases. The rest of the pond preparation activities are carried out as explained for the farming of major carps.

Water quality requirements

The optimum range of water quality parameters are given below:

Temperature	: 26-31ºC	TAN	:<0.1ppm
pH	: 7-8.5	NO_2-N	:<0.01ppm
Transparency	: 30-40 cm	NO_3-N	:<10 ppm
Salinity	: 0-7 ppt	Calcium	: 50-100 ppm
DO	: >4ppm	Iron	:<1 ppm
Alkalinity	: 80-120 ppm	Hardness	: 40-100 ppm

Stocking

The seeds (PL-15) are stocked at the density of 2-3 no./m^2. Healthy seeds swim with straight body, display a complete array of appendages, respond rapidly to external stimuli and actively swim against current when the water in the container is rotated. When the current subsides, it will tend to cling to the sides rather than being swept into the centre of the container. In order to ensure maximum survival rate, initially the seed can be reared in a small nursery pond at a density of 20-25/m^2 till reaching a size of 3-5 g. About 5-10% of the total grow-out area could be used as nursery pond.

Feeding

The prawn is fed twice daily with a sinking formulated feed containing 25-30% protein and 8-10% fat @ 8% of the body weight initially and further decreased to 2% towards the end of the culture period. It can also be fed with clam meat, if available at a low price.

Care and monitoring

The water taken from natural open source is filtered through a filter net having mesh size of 60 µm to avoid the risk of pathogens and carrier organisms. Fortnight assessment of growth and well-being of animal and water quality are essential. Sudden changes in the physio-chemical parameters of pond water adversely affect the health. Left over feed, metabolic wastes or sudden crash of plankton may lead to the rise of ammonia and result in mass mortality of the animal. The species exhibit high rate of cannibalism and hence cut branches of trees, nylon screen, pipes, *etc* are placed as hide-outs.

Harvesting

Culling of large individuals on regular basis is a common practice in freshwater prawn farming. The entire crop is harvested at the end of the culture period after the prawn has grown to the marketable size of 50-100 g. The culture period is normally 6-8 months.

INTEGRATED FARMING WITH PADDY

Fresh water prawn is one of the suitable species for rotational culture with paddy where not more than one crop of paddy is possible. After filling the field with 30-60 cm water, 1000 kg cow dung, 500 kg poultry droppings and 100 kg superphosphate per hectare is added. The water level is slowly raised to 100 cm by the next 14 days. The prawn seed is initially reared in nursery pond for 30 days and released, two weeks after rice harvest, at a stocking density of 1 no./m^2 for grow-out rearing. In this system, a production of 300-500 kg/ha is achieved within 6 months.

ALL MALE CULTURE OF SCAMPI

All male culture has several advantages over the conventional culture like good FCR, survival, individual size and overall economic output from farming. Juveniles reared in nursery pond for 45-60 days are harvested using a seine net or cast net and males are manually segregated by skilled labour. Manual segregation is carried out by visual examination of the last peraeopods where the gap between the bases of the two walking legs is less in the case of male. The segregated male juveniles are stocked at the density of 1-2 no./m^2 in grow out pond. If the pond bottom is firm enough, after 75-120 days (depending on the size of the prawn), seining is carried out for “cull harvesting” to remove all the fully grown blue clawed males (80-100 g) and any female (30-40 g) that might be accidentally present. About 20% of the large prawn is thereby removed at this stage, while the smaller prawn is returned to the pond, allowing them to grow further. After 30 days, the second seine netting is carried out; which is the major cull harvest in which 60% of the full sized males are caught. Final harvest is carried out after another 30 days completing the culture period of 6-8 months.

Fig.25.3. Male and Female

CHAPTER: 26

MANGROVE CRAB

The mangrove crab, *Scylla serrata,* which has huge demand in both domestic and international markets, is commonly found in mudflats and mangrove areas of India and South East Asia. It has flat and broad body covered with a fan shaped carapace. Adult crab migrates to the sea for spawning and the larval stages are completed in seawater. The instar migrates back to the brackish water for further growth and development. Eventhough hatchery seed production technique is available with RGCA, crab farming still depends on wild seed collection.

SEED PRODUCTION

Broodstock management

Broodstock collected from wild or farm is brought with its walking legs in tied condition, disinfected with 100 ppm formalin for 30 seconds, acclimatised to hatchery condition and quarantined. It is stocked at a density of 1 no./m^2 in an FRP tank (2 t capacity with 1.2 m height) containing washed coarse sea sand of 10 cm thickness spread at the bottom which is cleaned fortnightly. Filtered sea water is maintained in the tank to a level of 80 cm and aerated. It is fed with fresh wet feed @ 5-10% of the body weight. PVC pipes and tiles are kept in the tank as hideouts.

Fig.26.1 Mangrove crab under tied condition

Sexes are separate and it can be distinguished based on the shape of abdominal flap, which is slender and triangular in male while it is broad and almost semicircular in female.

Fig.26.2 Female crab

Fig.26.3 Male crab

Spawning

The mangrove crab spawns throughout the year. The mature female weighing a minimum of 500 g size is selected for spawning. Eyestalk ablation is carried out to induce gonadal development, if required. The colour of fertilised egg which is brilliant orange initially, gradually changes to greyish orange and finally to grey. The egg mass seen at the abdominal flap of the female crab is shifted to incubation tank (300-500 l) with moderate aeration. Egg hatches out into zoea larva within 10-12 days and it is collected.

Rearing of Larvae

The zoea larvae are stocked @ 100 no./l in tank with clean filtered sea water having 28-34 ppt and 28-30^{0}C. The zoea has 5 stages of development and is fed with *Nannochloropsis* and *Brachionus* for initial two stages and *Artimia* nauplii for the later 3 stages. The zoea metamorphoses into megalopa, which again metamorphoses into tiny crab called crab instar. The megalopa is fed with fish or mussel meat or *Artemia* biomass. Larval development is completed within 25-30 days.

Rearing of crab instar

The crab instar of 0.3 to 0.4 cm carapace width (CW) is reared into crablet of 2.5 cm CW @ 25-30 no./m^2 for 30-40 days in HDPE or nylon nursery hapa with a mesh size of 1.5 mm supported with bamboo poles having 5x4 m size installed in pond with not less than 1 m water depth and 20-35 ppt salinity. Hapa can be installed prior to filling of water in the pond. Inorganic/organic fertilizer is applied to enhance the natural food production. Catwalk is constructed for feeding and monitoring the crab instar. Crab instar is initially fed twice daily with mascerated fish/mussel or clam meat @ 50% of the body weight and subsequently reduced to 30% after one week and to 20% thereafter two weeks (40% in the morning and 60% in the evening).

Fig.26.4 Rearing of crab instar in hapa(Courtesy: RGCA)

Cannibalism is a serious threat in obtaining good survival rate. Hideouts are provided to minimize cannibalism during the nursery rearing period. PVC pipes or tiles are generally used as hideouts. Grading and thinning are done periodically for maintaining uniform size. Survival rate from crab instar stage to crablet is usually 60%.

Harvest and transportation

While harvesting the crablets, care must be taken, not to expose them to direct sunlight. The crab-lets can be transported in ventilated bamboo basket, plastic tray, straw bag or thermocol box stacked with wet sand, mangrove leaves, shade net or seaweed to minimize attacking each other and to keep the temperature low in the container during transport.

GROW OUT FARMING

Pond culture

The grow-out pond having a size of 0.2-1 ha and water depth of about 100 cm with proper inlet and outlet for water management is ideal. Net with polythene sheet enclosure should be set up along the inner side of the earthen pond dike as shown in the figure 26.5 to prevent the escape of crab. Pond preparation can be done as similar to that for the shrimp.

Fig.26.5 Pond fenced with net

Pen culture

Farming of the crab in pen is done in an earthen pond or open mangrove area and mudflat, which facilitates easy growth monitoring and stocking of different sized crabs in different pens simultaneously. It is usually reared in pen having dimension of 20 x 10 x 1.7 m. In order to install pen, trench of 50 cm deep and 20 cm width is excavated and concrete filled PVC pipe or bamboo poles of suitable height are thrust deep into the trenches one metre apart so as to fix them firmly. It can be strengthened more with horizontal or diagonal poles. Then it is wrapped with HDPE net of 10 mm mesh size and firmly tied. The bottom of the net is wrapped and stitched onto pole or sinker and placed into the trench from inside. Then the trench is filled with soil. The free top end of the net is tied firmly to the top of the poles. The inner side of the upper end of the net is tied atleast 50 cm above the water level with polythene sheet.

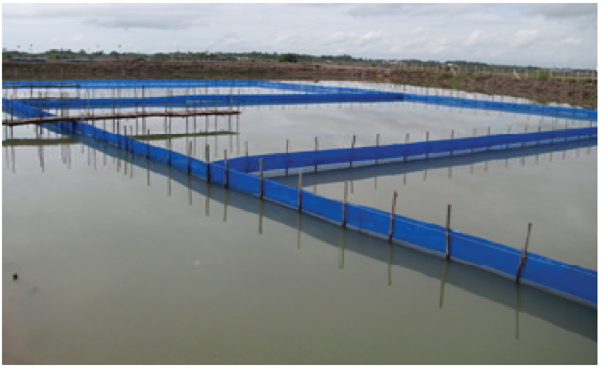

Fig.26.6 Pen culture (Courtesy: RGCA)

Box culture

In recent times, farming of mud crab individually in LDPE perforated box having the size of 30 x 20 x 15 cm with lid is widely practiced.

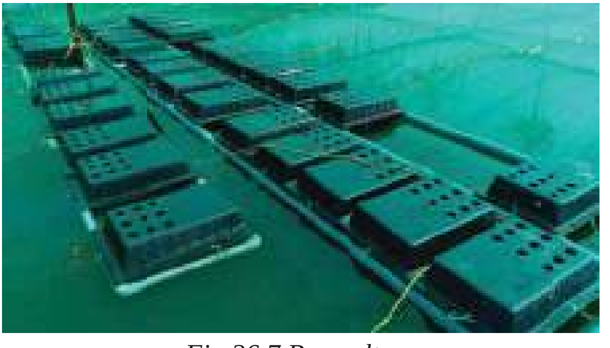

Fig.26.7 Box culture

Water quality requirements

pH	: 7.5-8.5
Salinity	: 15-30 ppt
Temperature	: 28-32°C
DO	: > 4ppm

Stocking

Uniform sized crablet of 2.5 cm CW is stocked @ 1 no./m^2 after proper acclimatisation.

Fig.26.8 Acclimatization of crablet

Feeding

The crab is fed with chopped fish twice daily (40% in the morning and 60% in the evening) @ 10% of the body weight initially till it attains a carapace width of 6 cm and later it is reduced to 8% for the carapace width in between 6-15 cm and thereafter reduced to 6%.

Care and Monitoring

Highly fluctuating survival rate due to cannibalism is the major problem in farming, which can be controlled by placing proper hide-outs such as mangrove twigs, sand heaps, tiles, earthen/cement/PVC pipes, hollow blocks *etc.* in the culture system. Monitoring of water quality parameters such as temperature, salinity, DO and pH is done fortnightly. Water exchange is carried out to maintain water quality as per requirement.

Harvesting

During the culture period, cull harvesting with lift net or scoop net is done at required times to remove the shooters and to allow smaller crab to grow faster. After the culture period of 8-9 months, the pond is drained for complete harvesting by lift net or scoop net and hand picking. The expected size at harvest is more than 500 g with 40% survival. A production of 2 t/ha can be achieved annually.

CHAPTER: 27

MUSSELS

The mussels are bivalve molluscs found attached to the hard surfaces in the littoral and sublittoral zones. They attach themselves to the substrate by secreting long threads called byssus. Though they are considered sedentary, they may move from one area to another, if exposed to unfavourable environmental conditions. Mussels are regarded as one of the best candidates for aquaculture since they are filter feeders obtaining nourishment from the lowest level in the food chain; they feed on phytoplankton, detritus and associated microscopic flora and fauna. The two important species of mussels in India are the Green mussel, *Perna viridis* and the Brown mussel *Perna indica*.

Fig.27.1Perna indica

Fig.27.2 Perna viridis

Table 27.1 Comparison between brown and green mussel

Brown mussel	Green mussel
Dark brown colour	Green colour
Brown mantle margin	Yellowish green mantle margin
Ventral shell margin almost straight	Highly concave
A distinct dorsal angle or lump	Acute middle dorsal margin
The anterior end of the shell is pointed and straight	Pointed and beak down turned
One large tooth on the left valve and a corresponding depression on the right valve	Two small hinge teeth on the left valve and one on the right valve

The green mussel has a wider distribution along the west and east coasts of India, including the Andaman Islands. In contrast, the brown mussel is restricted to the southwest coast of India. Now fishery for the green mussel exists in the region from Kollam to Kasargod and for brown mussel from Kollam to southwards along the Kerala Coast. Mussel provides animal protein of high nutritional value. Fast growth rate, adaptability to varying environmental conditions such as short periods of exposure to extreme temperatures, salinities, desiccation, relatively high levels of turbidity and simple culture technique makes it a candidate species for aquaculture in coastal waters.

SEED PRODUCTION

A primary requisite in any farming operation is an abundant, reliable and inexpensive supply of seed. At present, most bivalve culture operations in the world are moving to hatchery produced seed rather than collecting seeds from natural sites. The natural seed is collected by keeping substrate or spat collection ropes in breeding areas to collect metamorphosing larvae, or the juveniles and transferred to growing areas for culture (grow-out) to marketable size. In other operations, juveniles are gathered from areas of natural abundance and are transported to growing fields that may be distant from the source of the seed. The alternative for the collection of the natural spat of bivalves is to produce seed in the hatchery. The uncertainty in the availability of natural spat in good quality and quantity has led to the stagnation of mussel farming in the last decade. And this has prompted ICAR-CMFRI to develop the hatchery technology for bivalves. The hatchery must be located close to the sea where pollution-free seawater of desired salinity is available throughout the year. Preferably an area where adult and mature mussel of the required size is available.

Procurement of broodstock

In mussels, the sexes are separate, and they attain sexual maturity within a year. The mature broodstock having a minimum size of 6-7 cm size is collected from the wild, quarantined and maintained primarily in the broodstock holding tank of 1 t capacity at a density of 3-4 g/l of its live weight. Before feeding in the morning, the water in the tank is replaced daily to avoid build-up of bacteria and metabolic waste and provided with *Isochrysis sp*. and *Chaetoceros sp.* cells @ 5-6 million/ml. Around 60-80 l of algal culture per tank is used to feed daily. If sufficiently mature brood-mussels are available, they can be directly used for spawning or kept under low-temperature re-circulation system for a long time.

Maturation

Maturation of broodstock is done in an FRP tank of 1 t capacity which has special provision for photoperiod adjustment and hot and cold water facilities. For gonadal maturation, adult male and female mussels are placed in the tank at a density of 3-4 g/l of the total live weight biomass by adjusting the photoperiod (12 hr light and 12 hr dark) and maintaining the water temperature between 20-26^{o}C. It is fed with *Isochrysis galbana* and *Chaetoceros sp* @ 7 million cells/ml. Algal culture of 80-100 l per tank is used for daily feeding.

Spawning

The mussel can be easily stimulated to spawn in a hatchery, if they are fully mature with turgid gonad. In mussel, sexes are separate, and the reproductive condition of broodstock is determined by visual examination of the gonad which includes the assessment of the physical extent, fullness and colour of gonad and the degree to which it is filled with gametes. The testis is creamy white in colour while that of the ovary is orange or reddish. During spawning, mussel loses up to one-third of its body weight. Spawning of the mature brooders can be carried out in spawning tank of 200-500 l capacity or trays at a density of 3-10 numbers. A rise in 4-8^{0}C above the ambient temperature induces spawning of green mussel. Millions of eggs are freely released by the female into the water, which are fertilised simultaneously by the sperms of males, and the eggs settle down. The fecundity of adult mussel is 5-20 million, and the hatching rate from egg to larva is 95 %.

In the case of strip spawning, sperm suspension is added to egg suspension. The gamete suspension is then gently mixed, and a sample is examined to ensure a sufficient number of sperms. The fertilisation occurs almost instantly in tanks, upto 10-15 minutes after the females spawn. The first polar body can be observed under a microscope 15-20 minutes after fertilisation.

Fig 27.3 Spawning of P.viridis

Incubation

After spawning, the adults are removed from the spawning tank, and the fertilised eggs are collected and rinsed by pouring through a 20 µm sieve held in a basin of filtered seawater to remove the excess sperm, unfertilised egg and metabolic waste. It is then incubated at a density up to 10-15 no./ml in a glass tank (200 l) or FRP tank (500-1000 l) provided with gentle aeration. The fertilised egg starts cell division in 20 minutes, divides repeatedly and hatches-out into morula larva. After hatching, the embryos are passed through a 100-150 µm mesh screen suspended in the tank to remove larger debris. Optimum salinity and temperature are 25-35 ppt and 24-27^{0}C.

The morula exhibits phototropism, swims and congregates at the surface. 5 hours after fertilisation, it gets transformed to blastula by the re-orientation of the cells. The cells then convolute in and form dermal layers and gastrula stage is formed within 6-7 hours after fertilisation. Gastrula stage transforms into trochophore within 7-8 hours by developing a long single flagellum and tuft of cilia at the apical side and the rear side and swim with the flagellum. The ectodermal cells of trochophore secrete embryonic shell material and assume a 'D' shaped veliger or straight hinge stage by 18-20 hours at 27ºC in which the flagellum and tufts of cilia disappear, and a new locomotory organ called velum develops. The early embryonic development of the larva is completed by veliger stage which measures 50-55 µm dorso-ventrally.

Fig 27.4 Fertilised egg

Rearing of larvae

The D-veliger larvae are transferred into an FRP larval-rearing tank (2-10 t capacity) for rearing till the settlement or transferred at eyespot stage to a downwelling system. Washing, grading, counting and measuring the larva is done in every alternate days. The veliger metamorphosed into umbo stage (130-260 µm) within 7-15 days in which shell valves are equal, and mantle folds develop. The umbo stage reaches the eyespot stage (260-367 µm) within 14-17th day when the blackspot is seen at the base of foot bud with the development of ctenidial edges. The larvae are fed with mixed algal diet consisting of *Isochrysis galbana, Nanochloropsis oculata* and *Pavlova sp.* The daily requirement of algal cell up to eyespot stage is given in the Tabe 27.2.

Tabe 27.2. Feeding schedule

Stage	Day	No. of Cells/ larva/ day
D- veliger	1-7	5,000
Umbo	7-15	10,000
Eyespot larva	14-17	15,000

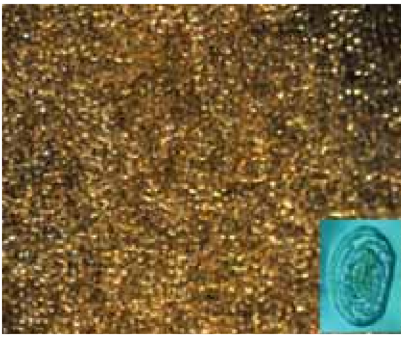

Fig 27.5 D-veliger stage

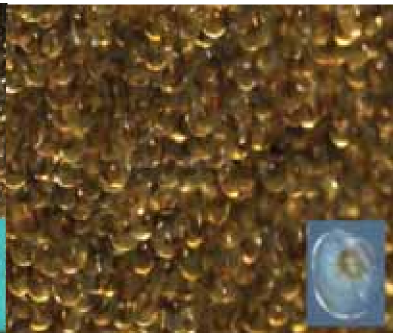

Fig 27.6 Umbo stage

Fig 27.7 Eye-spot stage

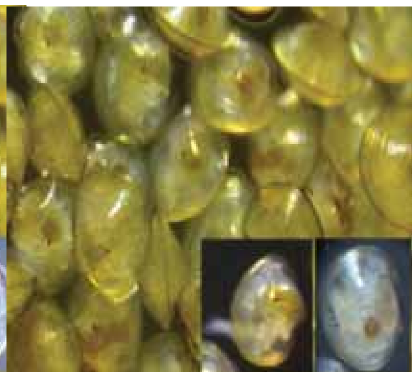

Fig 27.8 Pediveliger stage

Settling of larvae and rearing of juveniles

Development of foot is observed on 17-19 days indicating the transformation of eyespot larva into pediveliger stage with the appearance of gill filaments and it is transferred into upweller microhatchery unit. Once the foot becomes functional, the ciliated velum disappears, and the larva starts settling to the bottom, and byssal gland becomes active and secretes byssus threads for their attachment. The pediveliger stage is a transitional stage from swimming to crawling, and the larva has both velum (velar cilia) for swimming and foot for crawling. Plantigrade stage (390-470 µm) is reached within 20-21 days by the secretion of the adult shell with fast shell growth all along the margin, except umbo region. Labial palps, additional gill filaments and byssus threads also develop further at this stage. The transformation of plantigrade into spat (490-550 µm) starts within 21-28 days by the extension of anterior and posterior ears wherein left valve is slightly concave than the right. On the 42nd day, the spats are harvested from the rearing tank.

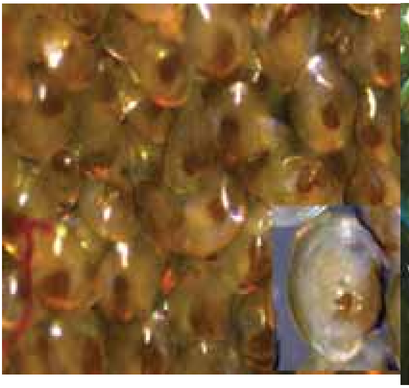

Fig 27.9 Plantigrade stage

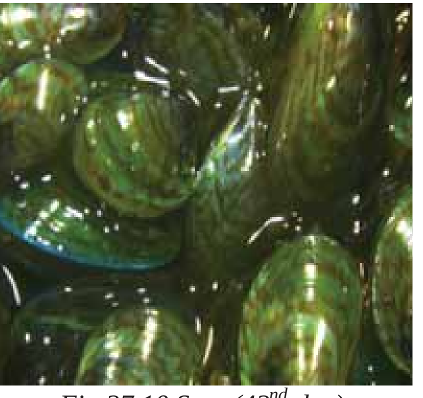

Fig 27.10 Spat (42nd day)

The settled spat are stocked in the tank for culture until they reach 2 mm shell length. Larval-rearing can be done from the eyespot stage, and further rearing in nursery phase can be done in up-wellers, down-wellers or tray systems of varying configuration.

After settlement, the larvae are fed with mixed algal diet consisting of *Chaetoceros spp.* and *Isochrysis spp.* at algae cell density of 25,000 no./ml along with *Nanochloropsis marina* at a cell density of 50,000 no./ml. The daily requirement of algal cell to feed the bivalves from the pediveliger stage to spat is given in the Tabe 27.3.

Table 27.3 Feeding schedule

Stage	Day	No. of cells/ larvae/ day
Pediveliger	17-19	20,000
Plantigrade	20-21	25,000
Spat settlement	22-24	30,000
Spat	30-60	50,000
Spat	60-90	>1,00,000

Fig 27.11 Upweller micro-nursery

Fig 27.12 Seed produced in tank 27.13 Seed produced in micro-nursery

Algal culture

The success of a bivalve hatchery depends on the production of algae. Large quantities of high-quality algae must be available when needed. Since algae are used in all phases of production, the facility should be located centrally and conveniently. Space required for algal culture depends partly on levels of production, methods of culture and whether algae will be raised entirely inside the hatchery with artificial illumination, or if it will be raised outside under natural light, or a combination of the two. A well-ventilated greenhouse is required if algae are grown in natural light, and this structure needs to be placed so as to obtain the maximum amount of sunlight. Shading may be needed to protect younger, less dense cultures from strong sunlight.

Primarily algal culture unit consists of stock culture unit, carboy culture unit and indoor mass culture unit, or outdoor mass culture unit. The stock culture unit is a small air-conditioned insulated room where the isolated algae from the source water are cultured in various containers placed in shelves with fluorescent lights and aeration. Test tubes with algal slants and small flasks with the stock culture that are monospecific and axenic are kept in this room often in a refrigerated, illuminated incubator.

In carboy culture units, the algae are grown in carboy bottle of 20 l using the algae grown from stock culture unit as inoculums which can be made as a part of the stock culture facility or as a separate unit outside the stock culture area. Here also illumination with fluorescent lamps, aeration and carbon dioxide supply are required to maintain the healthy development of algae. Stock and carboy culture of algae are the two major units which have to be maintained with utmost care. For maintaining the healthy growth of the algae, the water used for preparing the culture medium must be sterile and free from any contamination. Sterilization of the water is achieved by ozone treatment of the water before preparing the medium. Indoor mass culture of algae is done in FRP tank of 1 t capacity which is housed in a building provided with intermittent opaque and transparent portions for subdued light penetration for the development of desirable species of the algae with a continuous aeration supply. Outdoor mass culture of algae is done in tanks of 2-5 t capacity. Indoor/outdoor raceways can also be used.



Fig 27.14 Stock culture *Fig 27.15 Carboy culture* *Fig 27.16 Mass culture*

Water Intake and Treatment system

Water is pumped directly from the sea through in-situ filters which is first filtered using slow sand filters that filter out most particulate material greater than 20 µm. A slow sand filter consists of a tank inside of which lies a bed of sand supported by gravel. Water is allowed to flow through this layer of sand with particles of varying sizes and depth. The layer is not dense but contains a number of channels and holes created between the particles that constitute filter medium. When water passes through the filter medium, particles larger than a specific size will be trapped in the medium and get filtered.

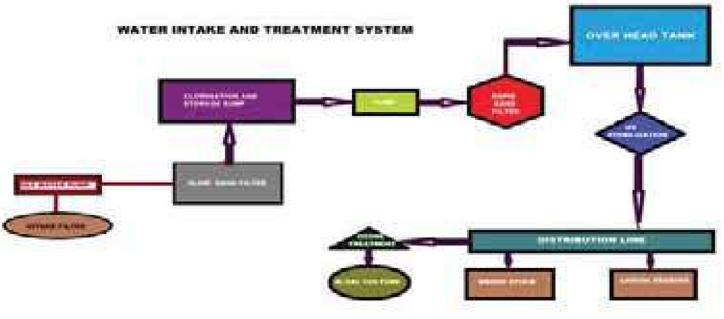

Fig 27.17 Water Intake, Treatment and Distribution System

Water filtered through the slow sand filter is collected in a water storage sump and treated with chlorine to remove the microbes and after dechlorination, again filtered through rapid sand filter to remove minute particles and stored in an over-head-tank so that the effect of gravity maintains a sufficient water flow through various units of the hatchery. Before utilizing the water for various hatchery purposes, final sterilization is achieved by UV irradiation. Sea water intended for stock culture of algae is further sterilized by ozone treatment to achieve 100% disinfection, which is highly essential for maintaining the pure culture.

Harvest and transportation

Mussel seed can be harvested from micro meshed cages or nursey silos by hand and transported safely in wet gunny bags upto 12 hours.

Fig 27.18 Micron-mesh cage

Fig 27.19 Spat in mesh cage

FARMING IN BACKWATERS

Site selection

Coastal waters free from navigation are suitable for mussel farming. Fluctuation in salinity during monsoon season is one of the main constraint in estuarine mussel farming. Usually, the culture period is from November to May in Kerala.

Water quality parameters

Water current	: 17-35 cm/s
Temperature	: 25-33^{o}C
Salinity	: 22-33 ppt

Farming structure

Rack culture is ideal for estuarine conditions where the water depth is between 1.5-3 m. The ideal size of fixed rack culture is 25 m^2 (5x5 m) which is fabricated by placing bamboo/casuarina poles and tying with nylon ropes. Nine poles having length more than the water depth during maximum high tide is driven into the bottom and spaced at a distance of 2.5 m apart, and it is connected to each other in both directions by horizontally placed six poles of more than 5 m length. The horizontal poles should be above the water level at high tide, and the seeded ropes are suspended from it. In shallow areas of below 1.5 m depth, both ends of the seeded ropes are horizontally tied on to poles.

In on-bottom culture, mussel seeds are relayed on the bottom of a water body leaving them to grow until the harvest, and this is generally practised in open waters or pens which can also be practised in shrimp or fish pond at a low stocking density. In this case, the mussel seeds will form clumps within a week and grow.

Fig 27.20 Rack for Mussel farming

Fig 27.21 On-bottom culture

Fig 27.22 Pen for on-bottom culture

Raft culture is ideal, if the water depth is more than 3 m, where the ropes are suspended from a floating raft of 25 m^2 (5x5 m) at the surface of the water. The raft is made of bamboo poles placed parallel and across and tied with synthetic rope, and it is held afloat by tying with four airtight barrels of 200 l capacity at the corners and moored with concrete block. Protected bay and harbour are ideal for this.

Seeding of green mussel

Farming of mussel is mostly dependent on wild-collected spat which is collected manually during low tide from the natural bed available in the intertidal and sub-tidal waters. At first, the collected spat is thoroughly cleaned to remove epifauna and other organisms. The length of the seeded rope ranges between 1-2 m depending on the water depth. At first, a mosquito net of 20-25 cm width and required size is cut and spread on a smooth and flat surface in a shady place. At the middle of these pre-arranged netting, a rope of 18-22 mm diameter is placed length-wise. The spat of 15-25 mm @ 600-1000 g/m is spread uniformly in the netting and over the rope and thereafter wrapped inside the netting by keeping the rope at the centre and stitched tightly to get the spat cover around the rope. For avoiding slippage of mussels, knots are made or 10-15 cm length bamboo peg is inserted horizontally in between the twists of the seeded rope at regular interval of 25 cm.

Fig 27.23 Seeding the rope

After seeding, the seeded rope is suspended immediately from the farming structures. Generally, 60-120 no. of seeded strings with a length of 1-2 m are suspended 0.5-1 m apart. Within 2-3 days, the cloth starts to disintegrate, and the seed gets attached to the culture rope using byssus thread.

Care & Monitoring

The growth of the mussel depends on tidal flow and primary production. When the mussel is continuously submerged in water having good phytoplankton productivity and adequate particulate organic matter comprising of detritus, it grows rapidly. The seeded rope should be regularly examined and cleaned gently with a brush made of natural fibre to remove mud, silt and any fouling organisms. The major predators of mussel are crab, lobster and starfish.

Harvesting

Typically, harvesting of the mussel is done during April to June along the west coast of India and farmers are forced to sell their crop before the onset of monsoon to avoid mass mortality due to freshwater influx depending on the distance from bar mouth. Under culture conditions, green mussel and brown mussel attain a size of 80-88 mm (36-40 g) and 60-65 mm (25-40 g) respectively and yield production @ 5-10 kg/m of rope over 6-7 months. The farmed mussels give a better meat yield compared to those from the natural bed. As a filter feeder, it harbours microorganisms and contaminants present in the surrounding waters. Hence, a cleaning process called depuration is necessary to render the animal free of bacterial load and contaminants. When blooms of dinoflagellates occur, the harvest of mussel should be suspended as consumption of mussel from the affected area may cause gastro-intestinal disorders to the consumer.

MUSSEL FARMING IN THE SEA

Mussels can be farmed in the sea using rafts or long lines; protected areas like bays are preferred compared to open waters. The long line culture is ideal for marine conditions at a depth of 5-20 m. Seeding and other management procedures are the same except that it has to be appropriately moored using heavy anchors or gabion boxes loaded with rocks. The long line is made of a 50-150 m long and 16-22 mm diameter synthetic rope which is held afloat with barrels or large floats and moored with anchors. The seeded ropes are suspended from the mainline. Sea farming of mussel is vulnerable to poaching, unpredictable climatic conditions and predation.

Fig 27.24 Raft culture

Fig 27.25 Long-line culture

Fig 27.26 Carrying of seeded rope

Fig 27.27 Tying of the seeded rope

CHAPTER: 28

EDIBLE OYSTERS

Edible oysters are the most widely cultivated bivalves in the world. They are sedentary animals, which grow by permanently attaching the left valve (lower valve) to the hard substratum and the right valve (upper valve) act as a lid. Oysters occur naturally in the intertidal areas, backwaters, muddy bays, lagoons and creeks with salinities of about 10-25 ppt, though it can tolerate higher salinity. It forms dense aggregations, often called as beds.

In India there are four important species of edible oysters, namely Indian backwater oyster (*Crossostrea madrasensis),* West coast oyster *(C. gryphoides),* Chinese oyster *(C. rivularis)* and Indian rock oyster *(Saccostrea cucullata)* Among these, Indian backwater oyster is the most dominant one, which has irregularly shaped shell valves. The left valve is deep while the right one is slightly concave. Adductor muscle is kidney-shaped and the shell has a dark purple coloured adductor scar. The inner surface of the shell is glassy and white.

Fig. 28.1 Crossostrea madrasensis

Oysters are filter feeders, and they feed on phytoplankton, detritus and associated microscopic flora and fauna in the natural condition, whereas in captivity oysters are provided with a mixed culture of microalgae in different cell concentrations. The spawning season of oyster in the wild varies with region and in Kerala, it is during November-February. Edible oyster fishery forms the second important component of bivalve fishery after clams. The flesh of oyster is highly nutritious containing 8-10% protein and 2% fat, in addition to minerals like calcium, phosphorus, zinc and iodine. Though the technology of seed production and farming has been developed by ICAR-CMFRI, oyster culture is not yet developed commercially in India due to the lack of awareness regarding the nutritional quality, non-availability of seed and lack of entrepreneurship. However, it is one of the most preferred seafood items in Europe, USA and many south-east Asian countries. It has immense scope for export, if produced in substantial quantities.

HATCHERY TECHNIQUES

Throughout the world, source of seed is changing from natural spat collection to hatchery-produced triploid oyster spat eventhough hatchery-produced seed is expensive than wild-collected ones. The natural spat fall is unpredictable and low in quality. If the oyster seed is produced in hatchery, the availability of desirable stage (eyespot stage/spat) in the required quantity and quality throughout the year can be guaranteed.

Broodstock collection and conditioning

Adult oysters collected from the wild are brought into the hatchery, and their shells are thoroughly scrubbed and rinsed to remove epifaunal organisms and sediments. After that these brooders are rinsed with freshwater followed by 10 ppm chlorinated seawater and placed in broodstock conditioning tank, which should always be kept separately to prevent the transfer of pathogens and parasites to the culture system and also to avoid disturbance. In an FRP broodstock conditioning tank of 120-150 l capacity, 5 kg of live weight can be stocked. Effluent water discharged from conditioning tanks should be treated with 100 ppm free chlorine or ozone for a minimum period of 24 hours before releasing, if wild oysters are brought from far away places.

Oysters usually attain sexual maturity by the age of one year. In oysters, sexes are separate; occasional hermaphroditism is also seen. Males are smaller than females; 75% are presumed to be males among zero-year class (upto 78 mm length), while 72% to be females among one-year class and above (80-120 mm length). Oysters of length ranging from 60-120 mm are selected for breeding of which 30% within 60-75 mm to ensure the presence of males.

The broodstock is fed with a mixed algal culture diet of *Isocrysis galbana* and *Chaetoceros calcitrans and Pavlova sp*. Feeding schedule for most warm water bivalves are the same as explained for mussels. Mature females will have creamy white gonad whereas males will have white gonad with oozing milt. Maturity is checked by taking smear from the gonad and examining under a microscope. Mature eggs are pear-shaped and 48-62 µm in size.

Spawning

In India, induced spawning is mostly achieved by thermal stimulation, for which 20-25 numbers of oysters are selected and kept in seawater with aeration in air-conditioned room at 23˚C for 12 hours followed by transferring them to an FRP tank of 1 t capacity at 30-32 ^{0}C. The water temperature is usually raised with the help of immersion water heater. Mild aeration is also provided in the tank. Sudden rise in the water temperature induces the oysters to spawn. Chemical stimulation is another method where ammonium hydroxide, sodium hydroxide/tris-buffer is added to the broodstock kept in a tank, but here viability of eggs will be less. In another method, freshly stripped sperm is added to the broodstock tank, which in turn induces the female to release eggs. Among these, thermal stimulation offers less stress to the animal. A fully ripe animal may spawn just due to handling stress while cleaning and may not require any induction.

Generally, male oyster responds within 1-2 hours and releases sperm as a continuous stream of milky fluid whereas after 15-60 minutes, female releases eggs into the surrounding water with periodic shell closures. The fertilisation takes place externally in water and the eggs settle down to the tank bottom. The seawater should have salinity in the range of 32-35 ppt and pH in the range of 8-8.4. After spawning, the broodstock from the spawning tank is transferred to prevent accidental filter-feeding of eggs by themselves. Excess sperm in spawning tank can cause abnormal fertilisation of the eggs. Hence, the surface water with sperm is replaced with fresh seawater. If an adult doesn't respond within the period, it should be returned to the conditioning tank for further one week.

Fig. 28.2 Oyster spawning (release of milky fluid)

Initially, eggs of oyster are pear-shaped which measures 48-62 µm in diameter and become spherical in shape after water hardening. Eggs that do not round-off after 15-20 minutes should be discarded. When the fertilised eggs settle at the bottom, aeration is suspended. It is then siphoned and filtered through 90 µm mesh to remove the metabolic waste of adults from the egg. Then eggs are filtered-out with 20µm mesh and washed with fresh seawater. Cleaned eggs are transferred to a container of 10 l capacity. Eggs are gently mixed, 1 ml of sample is pipetted and placed on Sedgwick-Rafter cell for counting the number of fertilised eggs. Usually, the fecundity of oyster is 20 million, and the survival rate from egg to larva is 50%.

Incubation

FRP tank of 1 t is cleaned, disinfected by chlorination, filled with filtered seawater and stocked with fertilised eggs at a density of 500-1000 no./ml, and the tank is aerated gently. The first polar body is formed after 20-40 minutes of fertilisation. Fertilised egg undergoes cleavage within 45 minutes and reaches morula stage after 6^{th} division. Gastrula stage is reached between 5-6 hours after fertilization.

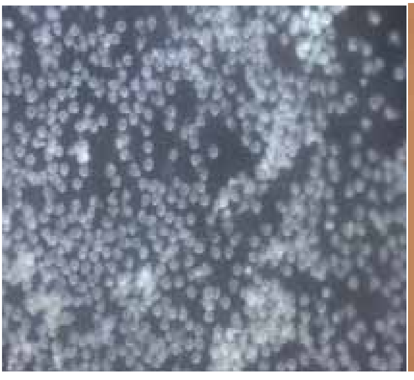

Fig. 28.3 Pear shaped eggs

Fig. 28.4 Two cell stage

Rearing of larvae

D shell or straight hinge larval stage is reached after 20 hours. Larvae are transparent, swim vigorously and measure about 66 µm. Water is drained slowly from the incubation tank through 40 µm size sieve which is kept partially immersed in seawater trough to avoid dry filtration. The larvae retained in the sieve are transferred to a beaker of a known volume of treated seawater (e.g., 10 L). One ml samples are taken and the larvae are counted in a Sedgwick-Rafter cell. The formula for calculating the total number of larvae is given below.

$$\text{Number of larvae} = \frac{\text{Average no. of larvae in a sub-sample x total volume (ml)}}{\text{Volume of subsample (ml)}}$$

The counted larvae are stocked at the density of 5-10 no./ml in the cleaned and disinfected larval-rearing tank of 1- 2 t capacity, filled with treated seawater. Mild aeration is also provided. Larvae are fed with culture of *Isochrysis galbana.* Every alternate day, process of filtering and cleaning of the tank is repeated till the settlement of larvae; sometimes larvae are transferred to a cleaned and dried new tank.

On the third day, the larva appears slightly oval (100 µm size) and reach the early umbo stage. Second sieving is also done using 40 µm mesh. On the seventh day, umbo will have concentric rings on the shell. Between 12-15 days, the larva will reach late umbo stage and measure 150 µm size. Eye spot develops between 13-17 days larval-rearing and larva measures 280 µm in size. From D shape larva to eyespot larva 40 µm mesh is used for filtration. From eye spot onwards 150 µm mesh is used for filtration. Larva reaches pediveliger stage between 14th-18th days, and a functional foot develops which can be seen. Larva measures 330-350 µm in size. Once the pediveliger larva loses its velum, it will start settling down, develop adult features and metamorphose into a spat.

The larvae are fed with mixed algal diet consisting of *Chaetoceros calcitrans*, *Isochrysis galbana*, *Pavlova spp*., and *Nannochloropsis spp*. The feeding schedule of oyster larvae at different stages is similar to that given for mussel culture. The daily requirement of algal cell upto eyespot larva stage is given in the Tabe 28.1.

Tabe 28.1. Feeding schedule

Stage	Day	No. of cells/larva
D- veliger	1-2	5,000
Umbo	3-14	10,000
Eyespot larvae	14-17	15,000

Fig. 28.5 D-Veliger stage

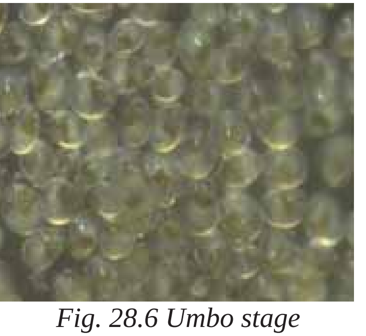

Fig. 28.6 Umbo stage

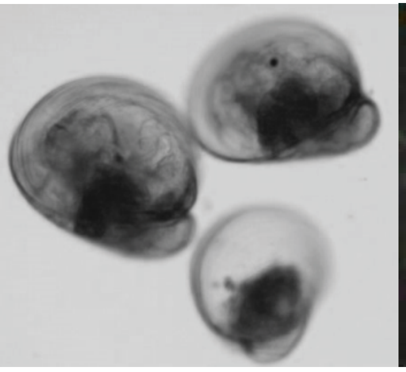

Fig. 28.7 Eye spot stage

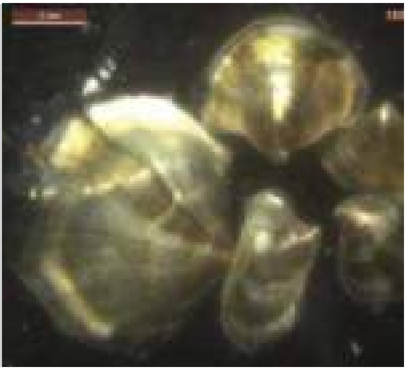

Fig. 28.8 Oyster spat

Settling of larvae and rearing of spat

Once eye spot develops, the larva is ready to attach to a surface and undergo metamorphosis into spat. The eyed pediveliger larva of more than 290 μm starts to settle and moves shorter distances. The process of settlement is prolonged for additional 2-6 days, and at this stage, finding a hard substratum is essential for survival. The settling of larvae can be done using different materials. The settling of larvae on 'cultch' (dead oyster shell) is the most common method. The shell is dried at least for a month to reduce the risk of pathogens, cleaned and aged in seawater for a few days for the formation of a biofilm on cultch, which enhances the settling of larvae. The daily requirement of algal cell to feed the bivalves from the pediveliger stage to spat is given in the Table 28.2.

Table 28.2 Feeding schedule

Stage	Day	No. of cells/larva
Pediveliger	17-19	20,000
Plantigrade	20-21	25,000
Spat settlement	24-29	30,000
Spat	30-60	50,000
Spat	60-90	>1,00,000

Oyster ren making

Oyster cultch is made either as oyster shell string or shell bag. In a 1.5 m length synthetic rope of 4 mm diameter, 8-10 shells are attached in regular intervals. These strings are suspended by hanging rens from plastic pipes or wooden sticks or prepared oyster shells are spread as a layer in 1 t FRP tank and then eye spot larvae are added to the tank. Cultch less spat can be produced in micro-nursery using upwelling downwelling systems as described for mussel culture.

Fig. 28.9 Settling of oyster larvae

Fig. 28.10 Oyster spat on the shell

Fig. 28.11 Oyster rens kept in the tank for settlement

Settling on a whole shell or other large cultch is done by placing the cultch in large mesh bags. These bags are transferred to the tank with treated seawater. Eyed larvae are introduced @ 100 no./shell which will settle within 2-3 days and attach permanently to the hard substratum and transform into the spat. Usually, 5-10 spats may get attached on a single oyster shell. Mild aeration should be given, and mixed algae is given as feed. Tank containing shell bags is cleaned to remove algae. Since this method occupies more space and labour, after 1 or 2 weeks, these shell bags are transferred to farming sites. Once spat attains 10 mm to 12 mm size, shell bags are opened and individual oysters are spread on the bottom for further growth. The eyespot stage larvae can be transported in moist cloth and used for remote settling near the farm. The larvae are released to the tank containing cultch near the farming area and fed by pumping natural water into the tank before transferring them to the grow-out area.

Algal culture

Sufficient quantity of algae is vital for any bivalve rearing, and the algal culture methods are same as that described for the mussel.

Water intake and treatment system

Water used for spawning and larval rearing tanks is filtered mechanically with the help of fine mesh bags, sand filters and cartridge filter and disinfected with UV radiation or by ozone. The other aspects of the water treatment system are same as that described for mussel culture.

FARMING METHODS

Site selection

The availability of vast expanse of brackish water area offers considerable scope for edible oyster farming in Kerala. The estuaries with clear water, rich plankton and free from strong wave and domestic, industrial or sewage pollution are ideal for oyster farming. Moderate water current brings the required plankton for feed and carries away the silt.

Water quality parameters

The optimum water quality parameters are given below:

Temperature	: 23-34^{o}C
Salinity	: 10-34 ppt
Water current	: 1-5 m/s
DO	: 3-5 ppm
pH	: 6.5-8.5
Wave turbulence	:< 0.5-1 m
Transparency	: 0.5-1.5 m

Rack and ren method

The rack and ren method is ideal for estuarine conditions where the water depth is in between 1.2-3 m. The ideal size of a fixed rack can be 7x7 m fabricated using bamboo or casuarina pole and tied together with nylon ropes. Sixteen poles having length more than the water depth (at maximum high tide) is driven into the bottom and spaced at a distance of 2.3 m apart and it is connected to each other in both directions by horizontally placed 8 poles of 7 m length which are above the water level during high tide, and the 'rens' (oyster shell strings) are suspended from these racks.

Fig. 28.12 Tying of the ren to the rack

On bottom culture

The on-bottom culture of oysters is ideal where the water depth is below 1.2 m where the oyster seeds attached to the collectors are directly planted on the bottom and allowed to grow. The tray unit having the size 60 x 45 x 30 cm with 3 horizontal shelves of 10 cm height, suspended in the water column using float and anchor is also used for oyster farming.

Seeding

The oyster spat is attached to the 'cultch' at hatchery itself @ 5 no./cultch which is then transported to the culture site. In rack and ren method, such 8-10 spat attached cultches are connected through a string of 1-1.5 m long to form a 'ren' and 80-100 such 'ren' are suspended from a rack of 7 x 7 m size. Here the survival rate is about 55-60%.

In the tray method, the nursery-reared single spat (cultch-free) measuring about 25 mm are kept in a tray unit of size 60 x 45 x 30 cm at an oyster-line density of 200-250 no./unit.

Care & Monitoring

The ren is periodically checked for replacement of broken structure and fastening of loosened ren, if it touches the bottom. If the ren falls on the ground, survival will be low. In the case of farming in the tray, once the oyster reaches 50 mm length, it is segregated, and slow-growing ones is culled and fast-growing ones are placed back on the tray. The barnacle that settles on the wooden structure, tray and oyster may add more weight to the ren or tray and competes for food. Crab and starfish, polychaete and gastropod are the primary predators of edible oysters. Hence, timely cleaning and due care should be given. The average growth rate of the oyster is 7 mm/month, and at the end of 12 months, the oysters attain an average length of 85 mm. Compared to the ren method, tray method gives more production, but the production cost is higher. Other aspects are same as explained for the mussel farming.

Harvesting

The ideal period for harvest in Vembanad Lake and Ashtamudi Lake is in May or September when the gonad is ripe before spawning. It attains a size of 50 g (shell-on) over 6-7 months and yields a production of 10 kg/m rope. The yield of the meat usually ranges between 7-20%. The farming of edible oyster with triploidy (all season oysters) or tetraploidy can give better meat yield, but they are not available in India.

Fig. 28.13 Oyster harvest

As oysters are filter-feeders, after harvesting, depuration is necessary to clean the animal from bacterial load, faeces, sand particles, silt and other contaminants in its gut. Initially, oysters are placed for 12 hours in a tank under a flow of filtered seawater. After draining the tank, oysters are then cleaned by a strong jet of water. The tank is again filled with filtered seawater, and the oysters are placed for another 12 hours. Then again, the tank is drained and flushed with a jet of filtered seawater. The oysters are held for about 1 hour in 3 ppm chlorinated seawater and then washed once again in filtered seawater before marketing. Oysters can be kept alive for upto three days under moist and cold conditions.

The oyster is subjected to processes such as, immersion in hot water, freezing, vacuum and steaming for 5-8 minute to make the oyster open their valves and facilitate the removal of the meat which is called the shucking process. A stainless-steel knife is usually used to shuck the live oyster. The edible oyster is even eaten fresh from the half shell in Malabar region.

CHAPTER: 29

CLAMS

Among the bivalve resources of India, clams are undoubtedly the most widely distributed and abundant. The clams of the estuarine and backwater regions provide livelihood to those who exploit them for meat and shell. Being a rich and cheap protein source when compared to other aquatic food varieties, clam is regularly harvested and meat is sold in local as well as export markets for consumption. The clam shell also holds commercial importance being the raw material for the manufacture of cement, calcium carbide and sand lime bricks. They are also used for lime burning for construction, in paddy field and fish farms for neutralizing acid soil and as slaked lime.

Fig.29.1 Black clam

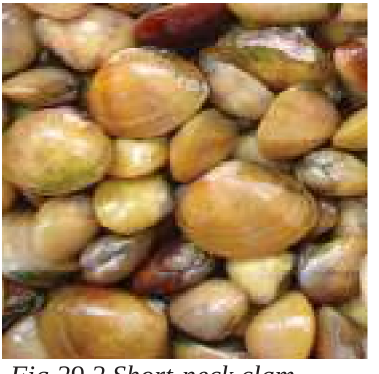

Fig.29.2 Short-neck clam

The black clam, *Villorita cyprinoides* and short-neck clam, *Paphia malabarica* are the commercially important clam species found especially in Vembanad Lake and Ashtamudi Lake respectively. The black clam is the most important clam species landed in India which contributes about two-thirds of the total clam landings of Kerala. It spawns twice a year, from May to August, and from January to late March.The short-neck clam is a fast-growing species with a peak spawning season of December to February and has a maximum lifespan of around 3 years.

SEED PRODUCTION

The hatchery technology for the large-scale production of their seed has been developed by ICAR-CMFRI.

Broodstock management

The black clam and short-neck clam attain sexual maturity in its first year at a shell length of 15-20 mm and 30 mm respectively and mature ones are procured from wild for hatchery seed production. Adult clams are conditioned at a density of 30 no./m^2 in a tank of 50-70 l capacity having unfiltered seawater at 22-24^{0}C and fed intensively with mixed microalgae reared in outdoor tank. After about 3 weeks of conditioning, the clams attain full gonadal development and are subjected to thermal stimulation by slowly raising the water temperature to 32^{0}C. If spawning does not occur, they are transferred back to 22-24^{0}C seawater and the process is repeated every two hours. Spawning can also be induced by placing the clams in the buffer solution of 9.0 pH for 1-2 hours and later transferring them to normal seawater. The optimum salinity for spawning is 10-12 ppt for black clam and 25-30 ppt for short-neck clam.

Rearing of larvae

The fertilised eggs settle at the bottom and are reared in FRP tank (70-100 l capacity). After a series of cell divisions, they develop into veliger larvae. The unicellular microalgae, *Isochrysis galbana* is given as food to the larvae from day 2 onwards. In the clam hatchery, biological filtration of the sea water which allows the nanoplankter and smaller algae, measuring upto 10 µm is found to be beneficial since supplementary feed is available to the larvae and spat. After passing through the umbo and pediveliger stages, the larvae settle on the tank bottom as spat in 7-10 days depending on the clam species. The larvae are reared at a density of 5 no./ml of seawater. Spat settlement at 20-30% of the initial stock of veliger larvae is considered as satisfactory. The freshly set spat measures about 300 µm and reach 2-5 mm length in the next 4-6 days. The spat are fed with mixed microalgae.

Transportation

The spat of clam is transported in wet condition under shade.

CLAM FARMING

Clam can be cultured on the bottom of protected coastal waters such as backwaters, bays, creeks and estuaries scientifically by adopting proper site selection, relaying, stocking and monitoring.

Site selection

The occurance of natural clam population in the vicinity generally indicates the suitability of the site for its farming. Water quality parameters like salinity, temperature, pH, DO, chlorophyll-a, TSS *etc*. and sediment characteristics like percentage of sand, silt, clay *etc*. of the sites are analysed. Clam farms are located in areas having 70-80% sandy substratum. The shallow waters with moderate water flow and little wave action is preferred. Strong water currents may dislodge the clam from the burrow. Areas prone to frequent changes of the contour and vulnerable to pollution are avoided. Tidal exposure at low tide for 1-2 hours is desirable as it helps in the management of the farm, particularly to remove the predators, but the prolonged exposure of the clam farm during the tidal cycle results in poor growth due to reduced feeding and in summer there may be mortality due to dessication. Also, the usual fishing grounds should be avoided.

Water quality parameters

The salinity tolerance limits and type of substratum preferred varies with the clam species. Black clam prefers low saline waters and occurs in salinity range of 3-16 ppt while that of short-neck clam is 20-34 ppt.

Water current	: 1-5 m/s
Temperature	: 23-34^{o}C
DO	: 3-5 ppm

Farming structure

Clam farming with on-bottom pen system is the best for both species in which usually 2 ha area is demarcated with bamboo poles or floats with net as markers. At first the ground is levelled and cleared from predators. Eventhough the movement of the clam is limited and fencing is not necessary, synthetic fibre net pen can be erected to hold the clams within the farming area.

Seeding

In the commercial culture of clams, seed requirement is mostly met by collection from the natural bed, because the heavily accumulated wild baby clam during breeding season may naturally get destroyed during a period of time due to overcrowding and stunted growth on one hand and the production cost of hatchery produced seed is expensive on the other hand. The spat fall season of black clam is mainly during June and November and that of short-neck clam is January to February.

The baby clam of 10-12 mm size (1 g) is collected during early morning with a hand operated scoop net or a dredge (*Kolli*) having 2-5 mm mesh size, kept in country craft under wet condition, tugged to the site and relayed immediately or by the late afternoon of the same day. Optimum stocking density for both species is 500-600 g/m^2. Seeds are planted in the farm by evenly dispersing them as far as possible.

Care & Monitoring

After seeding, 10 mm synthetic netting is laid on the bottom and is held in stretched position by stakes; this net cover offers protection against predation and strong water current. As clams are filter feeders which thrives on natural food available in the water, no artificial feeding is required.

Harvesting

It reaches a size of 28-30 mm (10-12 g) within a culture period of 7-8 months and is harvested either by handpicking or by a hand-operated dredge. The anticipated production is 3.5-5 kg/m^2 with an expected survival rate of 70%.

CHAPTER: 30

SEAWEEDS

Seaweeds are a large and diverse group of marine macrophytic algae, a primitive type of plants lacking true root, stem and leaf. It can be found in intertidal and subtidal coastal region to considerable depths of ocean, floating freely or attached to substrate.These are simple in their structural compositions because they take up nutrients into their blades or fronds directly from the seawater. India possesses 434 species of red seaweeds, 194 species of brown seaweeds and 216 species of green seaweeds.They are classified into these three groups according to their unique photosynthetic pigments, which give them their characteristic colors and unique properties. *Kappaphycus alvarezii* is a fast-growing species which has wide acceptance for seaweed farming in India.

Fig. 30.1 Kappaphycus alvarezii

Seaweeds are raw material for extraction of phycocolloids (agar, alginate and carrageenan), which have applications in the food, beverages, pharmaceutical, chemical, cosmetic and textile industries. In Kerala coast,the agar yielding seaweeds such as *Gelidium*, *Gelidiella*, *Gracilaria* and *Plerocladia*; the agaroid yielding seaweeds *Hypnea* and *Acanthophora*; the algin yielding seaweed *Sargassum* and edible seaweeds *Ulva, Caulerpa, Enteromorpha* and *Porphyra* occur in appreciable quantities.

Seaweeds are considered as medicinal food of the 21stcentury. They are high in trace elements, vitamins, and unique bioactive compounds, making them highly nutritious for people, animals and plantsand have yielded molecules for anti-HIV drugs. They also provide a strong base for growth promoters for several plants and are expected to be the major source of bio fertilizers to start organic agricultural revolution.

SEED MATERIAL

Since they are grown by vegetative propagation method, fragments from grown plant are used as seeding material. The seedling to be collected should be brittle, shiny and must have young branches with sharp pointed tips and there should not be any grazing or whitened thallus (which can be the indication of diseases). It is collected by leaving the basal portion for regeneration. Small wiry plant like *Gelidiella acerosa* which is attached firmly to substratum, is collected using a scalpel. The lengthy plants like *Sargassum* and *Turbineria* can be collected easily by hands alone. *Caulerpa racemosa*, *Ulva lactuca* and *Enteromorpha compressa* which grow on the intertidal and shallow water areas can be collected by hand picking. *Acanthophora spicifera* and *Hypnea valentiae* is also collected by hand picking. *Gracilaria edulis* grows attached to small stones, pebbles and as epiphytes on seagrass and available upto 1-2 m depth. It is slender and easy to remove from the substratum. The seed materialis collected in polythene bag or plastic bucket containing seawater. The water is changed frequently on the way for long distance transportation.After the material is brought to the shore, itis transferred to plastic bin or FRP tank containing clean seawater. In the case of seaweed farming unit, if the conditions are favourable in the field for further cultivation, the remnants of first harvest are allowed to grow further or a part of the harvested materialis used as seed material for subsequent crop.

OPEN WATER FARMING

Site selection

The farming area must be well sheltered from very strong wave, current and wind. The bays, creeks, lagoons and coral reefs are suitable areas for the farming of seaweeds. The site should have a rapid water turnover, but not heavy enough to damage the farm. The ground should be stable enough to permit easy installation of stake or bamboo. The soil of the site should be clayey and not of humus sand or mud.

Water quality parameters

Salinity	: >25ppt
pH	: 8.2-8.7
Temp	: 25-30^{0}C
Water current	: 30-60 cm/s

Single Rope Floating Raft (SRFR) method

A long polypropylene rope of 10 mm diameter is attached to 2 wooden stakes with 2 synthetic fiber anchor cables of 1-2 m and kept afloat with synthetic floats. The length of the cable is twice the depth of the water column (2-4 m). Each raft is kept afloat by means of 25-30 floats. The cultivation rope (1 m long x 6 mm diameter polypropylene) is hung with the floating rope. A stone is attached to the lower end of the cultivation rope to keep it in a vertical position. Generally, 10 fragments of *Gracilaria edulis* are inserted on each rope. The rope is untwisted slowly and the fragments of seed materials is inserted inside the gap and the rope has to be released to tighten the seed material. The distance between two rafts is kept at 2 m.

Tube net method

In this type of culture method seaweeds are cultured using a net tube, which is attached to a bamboo raft. The net tube is made up of 3 m length and 1 m perimeter made of 25 mm mesh size. 30 numbers of such tubes are tied at an interval of 50 cm to a bamboo raft of 15x3 m size. 50 litre water cans are used as floating material to keep the units buoyant. 25 kg of seeding material can be planted in one such unit.

Monoline method

Four poles of bamboo with 3 m length are fixed andthe four sides are tied using a 6 mm rope and the polypropylene seeding rope are attached to this. One segment (36 m length and 6 m breadth) constitutes 10 monoline units. Seedlings are planted at a distance of 15 cm. 40 seedlings can be planted in one monoline. The total seed requirement is 60-80 kg. HDPE fishing nets can be used for making fencing for avoiding grazing fishes and drifting away of the seaweed seeded nets. Used PET bottles can be tied on each rope for increasing the buoyancy.

Care and maintenance

The growth of seaweed is observed twice in a week by taking random measurement of their length and biomass. The hydrological and environmental parameters such as water current, transparency, turbidity, light intensity, temperature, pH, DO, salinity, phosphate, silicate, nitrite, nitrate, sedimentation, fouling organisms (epiphytes and epifauna) and predators are monitored regularly. Netting is placed around the units to avoid grazing by herbivorous organisms. Remove undesirable algae, barnacles or attached sediments by periodic cleaning. Check and tighten loose ropes. Check for any signs of diseases.

Harvesting

In the presence of sunlight, on the surface water, they can grow 5 times more of their original weight within a culture period of 45 days. It is recorded that a growth of 30 fold increase in yield in 63 days during post monsoon period was obtained for *Kappaphycus alverizii* by adopting suspended nylon hook method at Thikkodi near Calicut, Kerala.

Harvesting can be done by handpicking or using scissor/knife. The harvested seaweeds should be thoroughly washed in clean seawater to remove the sand and other foreign materials Seaweeds can be sold wet or dry. Theclean seaweed sundried for 2-3 days and with moisture content of 35-39% fetches more price. The harvested seaweed must be kept in a cool dry and wellventilated place.

POND FARMING

In the pond culture, the seed material has to be cut into small pieces and broadcasted uniformly on the bottom of the pond. Seed material introduced on long line ropes and nets can also be cultured in the pond water at subsurface level.In pond culture, water depth has to be monitored and maintained at 30-40 cm. The depth has to be increased to 60-80 cm during summer months to prevent a significant rise in water temperature. Frequent exchange of water (50-75%) is necessary to maintain the optimum temperature of water in the ponds. Fertilization with either organic or inorganic fertilizer can be done to enhance growth. For pond culture, the site should be located near seawater sources and the bottom of the pond should be at or near zero tidal level.

INTEGRATED MULTI TROPHIC AQUACULTURE (IMTA)

Aquaculture management can be done effectively by integrating seaweeds into aquaculture systems. It is done either by stocking seaweeds along with shrimps, fishes or mussels in optimum stocking density or by recycling the water through a pond supplemented with seaweeds. Integration of *Kappaphycus alverazii,* the carrageenan yielding red seaweed with green mussels (*Perna viridis*) at Padane, Kasaragod District, Kerala produced a maximum of 20.1 fold increase in yield in 80 days and a minimum of 13.2 fold increase in yield in 40 days. *Gracilaria verrucosa* is an ideal seaweed for integration with shrimp in brackish water pond which reduces stress on shrimp by utilizing excess nitrogenous wastes from the system andalso results in luxuriant growth of *G. verrucosa*.

Annexure-I
VERNACULAR NAME

Name of the fish	Vernacular names in Malayalam
1. Major carps	*Carp*
2. Nile tilapia	*Tilapia, Siloppi*
3. Murrels	*Varal, Cheran*
4. Pangassius catfish	*Bassa, Malaysian vala, Assam valla*
5. Walking catfish	*Nadanmushi*
6. Stinging catfish	*Kaari, Kadu*
7. Butter catfish	*Thonnanvala, Chottuvala, Dharman*
8. Yellow catfish	*Manjakoori*
9. Anabas	*Karoopu, Karippidi, Andikalli, Kallemutti*
10. Mahseer	*Kuyilmeen, Manjakadanna, Manjachoora*
11. Miss Kerala	*Chorakaniyan, Chorakanni, Chenkanniyan*
12. Malabar labeo	*Pullan, Thooli*
13. Pulchellus carp	*Eattapachila*
14. Cauvery carp	*Palkadanna, Pachilavetti*
15. Pearlspot	*Karimeen*
16. Milkfish	*Poomeen*
17. Grey mullet	*Thirutha*
18. Cobia	*Motha*
19. Asian seabass	*Kalanchi, Narimeen, Koduva, Kotti*
20. Pompano	*Vellavoli, Valavodu*
21. Grouper	*Kalava*
22. Tiger shrimp	*Karachemeen, Pulikonchu*
23. Indian white shrimp	*Naranchemeen*
24. Vannamei shrimp	*Vannameichemmeen*
25. Freshwater prawn	*Aattukonchu, Ashtamikonchu*
26. Mud crab	*Kayalnjandu*
27. Mussels	*Kallumekay, Chippy*
28. Edible oysters	*Kadalmuringa*
29. Clams	*Kakka*
30. Seaweed	*Kadal payal*

Annexure-II

ABBREVIATIONS AND UNITS

ABW	:	Average Body Weight
C	:	Celsius
cm	:	centimeter
DO	:	Dissolved Oxygen
DOC	:	Days of culture
dph	:	days post hatching
FCR	:	Food Conversion Ratio
FRP	:	Fibre Reinforced Plastic
g	:	gram
GSI	:	Gonado somatic index
ha	:	hectare
hp	:	horse power
hr	:	hour(s)
IU	:	International Unit
kg	:	kilogram
l	:	litre
m	:	meter
min	:	minute
ml	:	millilitre
mm	:	millimeter
no.	:	number (s)
PCR	:	Polymerase Chain Reaction
ppm	:	parts per million
ppt	:	parts per thousand
psi	:	pound per square inch
PL	:	Post larvae
PVC	:	Poly Vinyl Chloride
s	:	second
t	:	tonne

TAN	:	Total Ammonia Nitrogen
TL	:	Total Length
µm	:	micrometer

Annexure-III

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