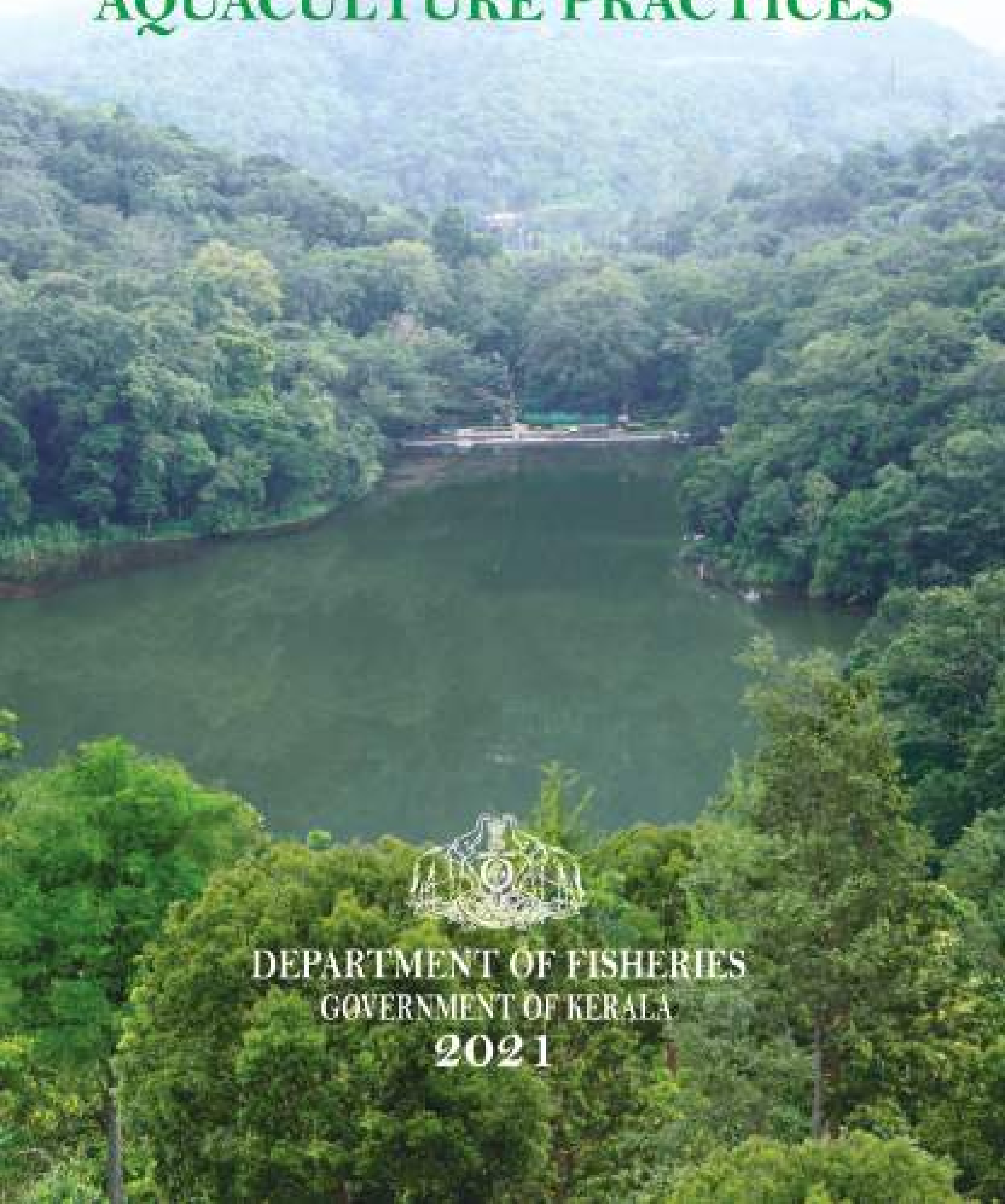
PACKAGE OF AQUACULTURE PRACTICES



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,
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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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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: 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

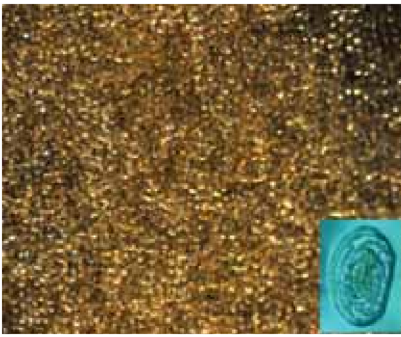

Fig 27.5 D-veliger stage

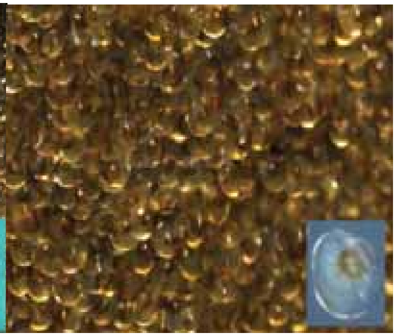

Fig 27.6 Umbo stage

Fig 27.7 Eye-spot stage

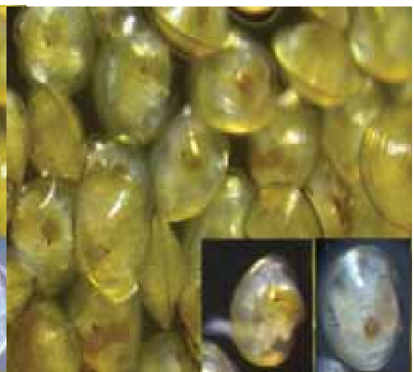

Fig 27.8 Pediveliger stage

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 42^{nd} day, the spats are harvested from the rearing tank.

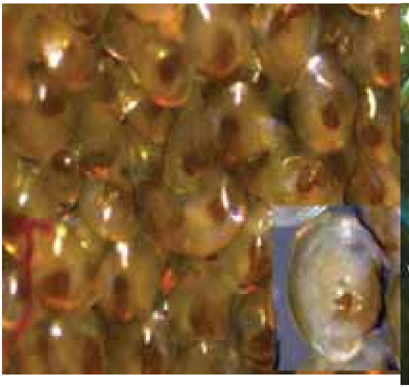

Fig 27.9 Plantigrade stage

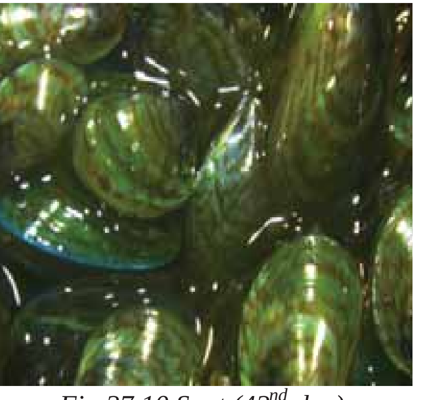

Fig 27.10 Spat (42^{nd} day)

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.

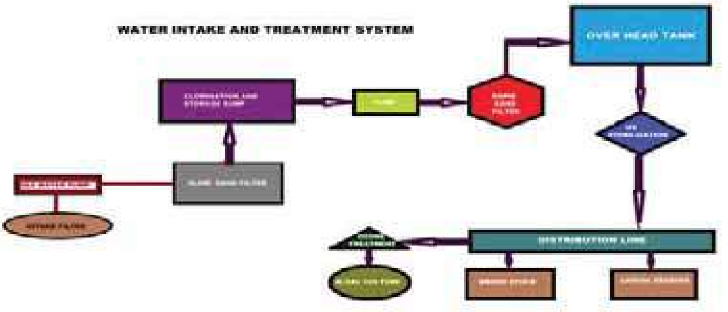

Fig 27.17 Water Intake, Treatment and Distribution System

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