6. BIVALVE FARMING

Geetha Sasikumar, Mangalore Research Centre of CMFRI

1. MUSSEL FARMING

Introduction

The mussels are bivalve molluscs typically found inhabiting the littoral to shallow sub-littoral zones of the coastal areas by secreting long fine silky threads called byssus threads. They can tolerate short periods of exposure to extreme temperatures, salinities, desiccation and relatively high levels of turbidity. Mussel farming that began in the thirteenth century is practiced in many countries world over. In India, commercially mussel farming is relatively recent and is practiced in the estuarine stretches of the Northern Kerala (Malabar area) and in few locations in southern Karnataka.

Advantages of mussel farming

- Mussel farming is a relatively less intensive form of aquaculture that depends upon natural stocks for seeding and relies on primary productivity for feeding.
- Mussel mariculture is carried out in coastal and estuarine waters by suspended farming method in order to utilize the water column. Suspension of the culture substrate enables complete utilization of the water column and facilitates increased production per unit area.
- Mussels are filter feeders, feeding exclusively on plankton and suspended organic particles that are available in the surrounding environment, resulting in zero effluent discharge and minimal water quality issues.
- Mussels are efficient in converting plankton and organic matter to high quality animal protein.
- Short duration of 5-6 months is sufficient for farming mussels in the tropical waters during the high-saline phase.

Candidate Species

The two species of mussels with good potential for culture in India are the green mussel, *Perna viridis* and the brown mussel *Perna indica.*

Site-selection

The success of mussel mariculture depends largely on the selection of an ideal culture site. Selection of an appropriate culture site shall be based on careful consideration of a number of factors that are critical to the species selected. The range of tolerance of the selected species to various environmental parameters will be the primary consideration in the site selection. Further, the site will have to be suitable to the culture method or system intended to be practiced. The important parameters to be considered while selecting the site for mussel farming are detailed below:

- Water current: Moderate currents (0.17-0.25m/s at flood tide and 0.25-0.35m/s at ebb tide) are needed to provide adequate food supply as well as to carry away the excessive build-up of pseudofaeces and silt in the culture area.
- Water Depth: The depth of water column of a location determines the type of culture method to be adopted. It can range from 1-15 m at average mean low tide.
- Salinity: Mussels grow well above 20psu, but the ideal salinity for rearing is 27-35psu.
- Turbidity: The presence of suspended particles above a certain level disrupts the filtering activity of the bivalve, as the mussels remain closed to avoid tissue damage and also due to gill clogging.
- Primary productivity and food organisms: Seawater with rich plankton is considered ideal for mussel culture.
- Source of Seed: Proximity of farming site to adequate spat or seed source is an important criteria for site selection.
- Pollution: Sedentary bivalve fauna are exposed to very high probability of contamination. Regulations have been established in many parts of the world that provide a system of classification of bivalve shellfish growing/ harvesting areas, broadly based on water test results (National Shellfish Sanitation Program, (NSSP) of USA and Canada; Australian Shellfish Quality Assurance Program, ASQAP of Australia) or tissue test results (Council Directive 91/492/EEC of Europe). These classification systems assign the shellfish harvesting areas as approved, restricted and prohibited based on the faecal coliforms and/or Escherichia coli levels.
- Harmful algal blooms: Some coastal waters are known for the appearance of sudden blooms of certain phytoplankton capable of producing highly potent toxins that are harmful to marine fauna and any other animal that feed on them.

Type of farming

- Open Sea farming is practiced in areas with a depth of 5-20m. The selected area of culture should be free from strong wave action, less turbulent and with high productivity. Long line and raft culture techniques are ideal for open sea farming. Disadvantages of this type of farming are poaching, unpredicted climatic changes and predation.
- Estuarine farming: Compared to the open sea, the estuarine ecosystems are less turbulent and shallow (<4m). Stake and rack culture (horizontal and vertical) are ideal for estuarine conditions. Fluctuation in salinity during monsoon season and pollution

through domestic and industrial waste are the main constraints in estuarine mussel farming. On-bottom culture by relaying of mussel seed in pen enclosures is also practiced.

Farming technique

- On-bottom method: In areas where water depth is less than 1.5 m, mussels can be farmed by sowing directly on the bottom substratum/ or seabed.
- Bouchot culture: This method involves farming mussels in intertidal mud flats on poles combining spat collection with ongrowing.
- Suspended farming methods: For suspended farming method, the water depth can be a limiting factor as a minimum water column is essential throughout the culture period
-

1. Rack method: Suitable for estuaries and shallow seas. Bamboo or Casuarina poles are driven into the sea/ estuarine bed at a spacing of 1-2 m and are connected horizontally. Seeded ropes are suspended from the horizontal frames or in shallow areas, they are placed horizontally between the vertical poles. This method is practiced in India and Philippines in shallow waters where the depth is <1m. Due to the effective utilization of the productive upper water column this type of culture gives better yield.

2. Raft method: This farming method is suitable in deeper open-sea conditions which is not turbulent. It consists of a square or rectangular bamboo or casuarina pole lattice structure from which ropes are hung. The raft is buoyed up by styrofoam / ferroconcrete buoys or metallic/ HDPE barrels of 200 liter capacity (metal oil barrel painted with anticorrosive paint). Ideal size of the raft is 5 x 5 m. The rafts are to be positioned at suitable location in the sea using anchors (grapnel, granite, concrete).

3. Long-line method: Considered ideal in unprotected open sea conditions and are particularly adopted in areas having high tidal amplitude. Synthetic rope of 16-20mm is used for the main-line, supported with floats at every 5m. Seeded ropes are suspended from the main line 1.5-2m apart. Long-

lines with floats are anchored in position using concrete blocks and nylon ropes or metal chain at both the ends.

Seed source and seeding

The key issue in mussel farming is the inconsistent or irregular spat settlement in natural beds affecting the seed supply, hatchery sources are not generally depended up on for the mussel spat. Mussel farming mainly depends on the natural spat. The spat-fall in mussel beds commences from September to December along the west coast progressing from the south to the north. Mussel spats are collected by physically scrapping them from the intertidal or subtidal natural beds. Submerged beds are ideal for sourcing mussel seeds. About 500 to 750 g of 15-25 mm seeds are required for seeding 1m of the culture rope. Nylon rope of 12-14mm or 15-20mm coir rope can be used for farming. Seeding is done by placing the culture rope within the pre-stitched tubes of bio-degradable wrapping material and filled with mussel seeds. Generally cotton mosquito nets are used for wrapping the seeds, which degenerates in 2-3 days. By this time the seeds will secrete byssus thread and will get attached to the rope.

Growth

The seed, which get attached to ropes, show faster growth in the suspended water column. If the seed is not uniformly attached, crowded portion always show slipping. To avoid slipping, periodical examination of seeded rope and thinning of the same is essential. The culture ropes also should be at least 1 m above the sea floor during extreme low water spring tides in order to prevent predators from

reaching the bivalves, to avoid exposure of the molluscs to high water turbidity near the seabed and to avoid losing the bivalves at the end of the rens. The top seeded portion of the culture rope should be prevented from exposure for longer period during low tide. Seeded mussel on the upper portion of the rope shows faster growth due to the abundance of phytoplankton. For better growth the seeded ropes should be spaced at a distance of 25 cm. The mussel grow relatively fast in the suspended farming systems. They attain 80-90 mm in 5-6 months with growth rate of 8-11mm/month.

Post-harvest handling & marketing

Mussels are harvested once they attain the marketable size and condition index is high, i.e., before the spawning and onset of monsoon. Normally harvest season is from April to May. Mussel ropes are removed manually and washed thoroughly using water jet to remove grit and slit. The mussels removed from the ropes are maintained in re-circulating seawater for 24h and are washed again in fresh seawater. This method of depuration is effective in reducing the bacterial load of the mussel meat by 90%. Depurated mussels are then sold mainly in the local market as live shell-on mussel. Meat from depurated mussel can be shucked in fresh condition or after boiling or steaming.

Depuration

Depuration of the harvested mussels is necessary to increase the quality of the mussel meat and to avoid the risk of consuming contaminated mussel meat. Mussels during their process of feeding may accumulate undesirable materials including harmful microorganisms. Before the product reaches the market, it needs to be ensured that the mussels are safe for human consumption. This process of

purification is called depuration. The mussels are kept in cleaning tanks under a flow of filtered seawater for the period of 24h. In the depuration tanks about 10-20% of the seawater is continuously replaced. At the end of 12 hours the water in the tank is completely drained and mussels are cleaned by running water to remove the accumulated faeces. The tanks are again filled with filtered seawater and the flow is maintained for another 12 hours. Then the tanks are drained and flushed with a jet of filtered sea water. Further, the mussels are held for about one hour in seawater chlorinated at 3 ppm, and then washed in filtered seawater.

Conclusion

Commercial mussel farming gained rapid strides since 1996 in India. In the recent years it showed spectacular improvements with the farmed mussel production of the country reaching a total of 18,432 t (2009). Though efforts to popularize the technology were undertaken in the States of Kerala, Karnataka, Goa, Maharashtra and Tamil Nadu a quantum leap in the mussel production was observed only in the state of Kerala. The availability of large extent of natural mussels beds along the coast for sourcing the seeds; high price realized for the produce in domestic market; minimal operational expenditure and short term eco-friendly farming techniques are expected to encourage more farmers to come forward to adopt the practice in coastal areas.

2. EDIBLE OYSTER FARMING

Introduction

Oysters are highly esteemed sea food and considered a delicacy in USA, Europe, Japan etc. As early as the first century BC the Romans were the first to develop simple methods of collecting oyster seeds and growing them for food. In India there is a growing demand for oyster meat in some parts of the country. Until recently, oyster farming has been considered as a traditional practice followed only in the temperate countries. The awareness about the vast potentialities for development of oyster farming in tropics is recent. Serious efforts are now being directed in its development under tropical conditions. Vast stretches of backwaters, estuaries and bays spread over several lakh ha are present along Indian coast harbouring natural population of the oyster suggesting suitability of the habitat for oyster culture. Being filter feeders, the oyster converts primary production in the water into nutritious sea food.

Species

The commercially important edible oysters available along the Indian coast are *Crassostrea madrasensis* (Indian backwater oyster), *C. gryphoides* (West coast oyster), *C. rivularis* (Chinese river oyster) and *Saccostrea cucullata* (Rock oyster) of which *C. madrasensis* farmed along the Kerala coast.

Food and Feeding

The edible oyster is a sedentary animal belonging to the Class Bivalvia. Oysters have a soft body, which is protected by two hard shells. Shape of the oyster is extremely variable depending on the environment in which it is grown. The food consists of organic detritus and phytoplankters such as diatoms and nanoplankters. The food particles are entrapped in the mucus of the gills and are passed in the water currents towards the mouth by the rapidly beating gill cilia (fine hairs).

Reproduction

In the genus *Crassostrea* sexes are separate but occasionally hermaphrodites occur. The ovary and testis consist of a series of branching tubules, also called follicles, on either side of the body. During spawning, ripe eggs and sperms are discharged into the exterior where fertilization takes place. During the non-breeding season the gonad is replaced by connective tissue called Leydig tissue which mostly consists of glycogen. In this stage the sex of the oyster cannot be determined. The sex of the oyster may change during the breeding season.

Information on spawning period is essential for seed collection

Species/ Region	**Spawning period**
C. madrasensis	
Kakkinada Bay	January-June
Madras Harbour	Year round spawning
Adayar estuary	October-December and March-April
Tuticorin	July- September and February-April
Mulki estuary	April-June, November
Ashtamudi	November to December
C. gryphoides	
Kelwa backwaters (Bombay)	July and September
Bhatia creek (Ratnagiri)	September and November
S. cucullata	
Ratnagiri	October-January

Condition Index

The condition index of the oysters denotes the quality of the meat and it is useful to determine the best period for harvest. High condition indicates greater proportion of meat in the whole weight of the oyster; those in prime condition are tasty.

Edible Oyster Farming in India

Oyster farming technology developed by Central Marine Fisheries Research Institute is a simple and easily adaptable technique. Kerala is the first state to commercialize this technology and many coastal

villagers have benefited from this. These farming activities have increased national production of farmed oyster from nil to 4,700 tonnes in 2013.

Culture Technology Edible oyster culture is a very simple technology, which can be easily practiced. There are a few critical factors (such as seed collection and harvesting period) which are governed by the biology of the species which affect the profit of the farming operations.

- **Seed Collection**: Oyster seeds are collected from estuaries by placing suitable collectors called cultch in the water column at appropriate period. During spawning seasons the spat collectors are suspended from racks. Cultch is the term used for spat/ seed collector. For suspended method of oyster culture cutch made of oyster shells have been found to be ideal. Empty oyster shells are cleaned manually to remove the foulers and then washed to remove silt. A small hole is made on the shell and these are strung on 3mm dia nylon rope with a spacing of 15 to 20 cm between each shell (5 shells per meter rope). Such strings are called ren. The spaced rens can be used as such for grow out system. For seed collection purposes the shells are strung continuously without spacers (10 to 15 shells per meter) and after the attachment of seed they shells can be removed and restrung at the rate of 5 shells per meter which is the ideal density for grow out. If the oysters are to be grown by the tray method then empty shells or lime coated tiles can be placed in the trays for seed collection. Lime coated tiles gave encouraging results and on a single tile, as many as 120 larvae are known to settle.
- One of the main factors that determine the success of the farming operation is the period when the clutches are placed for seed collection. If they are laid in advance of spatfall, they may be covered with silt or settlement of foulers, making them unsuitable for the oyster larvae to settle. The larval period in *C. madrasensis* is 15-20 days. The ideal time for laying the spat collectors in the water is about 7 -10 days after peak spawning (as determined by gonad examination and abundance of early larval stages in the plankton). Strong currents interfere with larval settlement and may result in poor spat collection.

Selection of farm site

For site selection several factors are to be considered

Parameter	**Range**
• Salinity (ppt)	10 to 38
• Depth (m)	1.5-4.0
• Temperature ^{0}C	23-34
• Dissolved oxygen (mg/l)	3-5 mg/l
• pH	6.5-8.5
• Water current (m/s)	1-5
• Clarity (m)	0.5-1.5

- Availability of seed — within 100 m
- Local market — average to good

Sheltered areas offering protection from strong wave action are preferred. From intertidal region to areas extending upto about 5 m depth can be considered for adopting suitable culture method. Similarly the culture technique is adopted depending upon the type of substratum. On-bottom culture method is substrate-specific while off-bottom method has little to do with the nature of substratum. Large-scale moralities have been reported in salinities below 10 and above 40 ppt when the natural oyster populations of *C. madrasensis* were exposed for prolonged periods. The natural populations occur at a temperature range of 21 to 31^{0}C.

Farming methods

They are broadly grouped as bottom (on bottom) culture and off-bottom culture. Raft, rack, long-line and stake are used in the various off-bottom culture practices. The off-bottom culture methods are advantageous over the bottom culture in the following respects.

- Relatively rapid growth and good meat yield.
- Facilities three-dimensional utilization of the culture area.
- The biological functions of the oyster such as filtration feeding etc. are carried out independent of the tidal flow.
- Silting and predatory problems are negligible.

On bottom culture

The oysters are grown either in the intertidal or subtidal area directly on hard substratum. For intertidal culture a minimum of 16 hours submergence is suggested to ensure adequate food supply. Oyster seed attached to the collectors are planted on the bottom and allowed to grow for the market. The disadvantages of this method are increased exposure to benthic predation, siltation and low production. In U.S.A. the production is estimated at 5 t/ha/year and in France 7.5 t/ha/year. This method is yet to be experimented in India.

Rack and Ren Method

This method is also called ren method. Racks are constructed at 1 to 2.5m, depth. There are several variations in the types of racks. The single beam rack consists of a beam placed and secured to the top of posts driven into the bottom. A series of single beams are placed in a row. The crossbeam rack is constructed by placing cross bar on top of single posts and two long beams are secured on the end of cross beams. In the farm, the shell strings are suspended from racks.

Rack and Tray Method

The nursery-reared single spat (cultch-free) measuring about 25 mm are transferred to trays of size 40 x 40 x 10 cm at a density of 150 to 200 oysters/ tray. The tray is knitted with 2 mm synthetic twine of appropriate mesh and is suspended from rack. Once the oysters reach 50 mm length they are segregated and transferred to rectangular tray of size 90 x 60 x 15 cm these trays are placed on the racks. Each tray holds 150 to 200 oysters. 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 85mm in Tuticorin. The production is estimated at 120 t/ha/year. Compared to the string method, this method gives production but the production cost is high.

Stake culture

A stake is driven into the substratum and on the top end one nail and on the sides two nails are fixed. The nail holds in position a shell with spat attached. The stakes are placed 60 cm apart. In this method, the nursery rearing of spat is carried on the same stake. For about two months the spat on the top end of the stake are covered by a piece of velon screen. Once the oysters attain 25-30 mm the velon screen is removed and in another 10 months they reach the marketable size. The growth rate of the oysters in this method is the same as that of the oysters raised by the string method. The production is estimated at 20 t/ha/year.

Harvest of oysters

The oysters are harvested when the condition is high. At Tuticorin good meat yield is obtained during March-April and August-September and along Kerala harvest is ideal during May in Vembanad and Chettuva estuary and during August-October in Ashtamudi Lake. In Karnatka condition is high during September-November and March. Generally high condition index is obtained when the gonad is ripe prior to spawning. Harvesting is done manually.

Post-harvest Processes

Depuration

Oysters, like other filter-feeding bivalves, accumulate pathogenic organisms in their body. The bacteria of concern are *Vibrio, Salmonella* and *Escherichia* (Coliform type). Members of the Salmonella group cause typhoid fever, while coliforms and vibrios cause gastroenteritis. By depuration the bacterial load is brought down to permissible levels, also faeces, sand particles and silt are removed from the alimentary canal of oysters.

The oysters are placed for 24 h in cleaning tanks under a flow of filtered seawater. About 10-20% of the seawater is continuously replaced. At the end of 12 h the water in the tank is drained and oysters are cleaned by a strong jet of water to remove the accumulated faeces. The tanks are again filled with filtered seawater and the flow is maintained for another 12 hours. Then the tanks are drained and flushed with a jet of filtered sea water. The oysters are held for about one hour in 3 ppm chlorinated seawater, and then washed once again in filtered seawater before marketing.

Transport and storage

Oysters kept under moist and cool conditions survive for several days. However it is desirable that they reach the consumer within three days of harvest. Studies indicate that oysters packed in wet gunny bags are safely transported for 2530 h without mortality and in good condition.

Shucking

The removal of the meat from the oyster is called shucking. A stainless steel knife is used for the purpose. To render shucking easy, oysters are subjected to a wide range of treatments such as exposure to week hydrochloric acid, heat cold, vacuum, microwaves and lasers. Freezing the oysters or immersing them in hot water are the two methods commonly followed. However in India steaming the oysters for 5 to 8 minutes has been found to be ideal to make the oysters open the valves.