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HANDBOOK ON OPEN SEA CAGE CULTURE

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MUSSEL FARMING

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Introduction

The mussels are bivalve molluscs typically inhabiting the littoral to shallow sub-littoral zones of the coastal areas. The soft tissue of bivalves is enclosed in a shell consisting of two valves joined at one edge by a flexible ligament called the hinge. Mussels are found attached to the hard surfaces in the littoral and sub-littoral zones by secreting long fine silky threads called byssus threads. Being sedentary, they can tolerate short periods of exposure to extreme temperatures, salinities, desiccation and relatively high levels of turbidity. The two species of mussels with good potential for culture in India are the green mussel, *Perna viridis* and the brown mussel *Perna indica.*

Advantages of mussel farming

Less labour intensive practice

Mussel farming is a relatively less intensive form of aquaculture that depends upon natural stocks for seeding and relies on primary productivity for feeding.

Utilization of water column

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.

Eco-friendly farming practice

Mussels are filter feeders, feeding exclusively on plankton and suspended organic particles that are available in the surrounding environment. Suspended materials available in the waters are trapped onto the mucous coating of the gills and are ingested. Mussel farming therefore involves the utilization of natural productivity in the farm area, resulting in zero effluent discharge and minimal water quality issues.

Food conversion efficiency

Mussels are efficient in converting plankton and organic matter to high quality animal protein.

Short Duration crop

The mussels are farmed for duration of 5-6 months in the tropical waters during the high-saline phase following the monsoon.

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

Mussel culture sites should not be in the vicinity of strong currents as strong currents usually generate high turbidity and high siltation rates. However, 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. The most important consideration with regard to water depth is avoiding long exposure periods during the extreme low-tides.

Salinity

Mussels grow well above 20psu, but the ideal salinity for rearing is 27-35psu. Open coastal areas are usually fully saline with minor seasonal variations. In estuarine areas, decrease in salinity is usually the major and frequent problem, mainly caused by the influx of freshwater from rivers or land runoff during the rainy season. Therefore sites with a high inflow of fresh water are not suitable for the farming of mussels. The culture season for mussels is December to May, when the estuaries are in the marine phase.

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. In addition, low primary productivity is often the case in sites of high turbidity due to the reduced penetration of sunlight in the water column. As a result poor growth results due to reduced feeding time and limited food availability. It is found that water containing a high suspended load of more than 400 mg/1 have harmful effect on the grow-out of mussels.

Primary productivity and food organisms:

The of food available at a site cannot be easily evaluated by inspection of a few water samples, as there are wide variations in the quality and quantity of micro algae, seasonally as well as annually. Clear seawater with rich plankton production (17-40mg chlorophyll/l,) is considered ideal for mussel culture. The presence of suitable micro algal species is usually not a limiting factor; however, problems do arise when the availability of food is limited.

Source of Seed

Mussel culture requires a proximity to spat or seed source, which may affect site selection criteria. However, if it has to be transported from elsewhere, it should be transported to the farm site within a reasonable time and cost. Transportation itself is not only costly, but usually negatively affects the quality of bivalve seed due to stressful conditions. The mussel (*P.viridis*) seed can remain without water for about 24 h and hence offers easy transportability.

Pollution

The sedentary bivalve fauna are exposed to very high probability of contamination and could act as vectors due to their peculiar feeding habits and bioaccumulation potential. Bivalves are known to accumulate trace metals and pollutants. Waters with heavy industrial contamination such as trace metals and organic compounds are therefore unsuitable for mussel farming. Further, shellfish from contaminated areas are known to accumulate bacteria and viruses that are pathogenic to human beings. 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) (Table 1&2). These classification systems assign the shellfish harvesting areas as approved, restricted and prohibited based on the faecal coliforms and/or *Escherichia coli* levels. Regulatory agencies may close a fishery when contamination is detected.

Table 1. Limits set by National Shellfish Sanitation Programme for bivalve shellfish harvest (US FDA)

US FDA Classification	Geometric mean[4]	90th Percentile treatment required	Bivalve	Criteria
Approved	MPN <14/100ml	MPN <43/100 ml	None	Acceptable no significant pollution sources
Restricted	MPN <88/100 ml	MPN <260/100 ml	Depuration or relaying	Evidence of marginal pollution
Prohibited	No harvest allowed			Evidence of gross pollution

Table 2. Limits set by EC Directive (91/492/EEC).

EC Directive (91/492/EEC)	Geometric mean	Criteria
Category A	<230 *E. coli*/100 g flesh or <300 FC /100 g flesh.	Direct human consumption permitted.
Category B	<4,600 *E. coli*/100 g flesh or <6,000 FC /100 g flesh (in 90% of samples).	Purification in an approved plant for 48 hours prior to sale for human consumption.
Category C	<60,000 FC/100 g flesh.	Relaying for a period of at least two months in clean seawater prior to human consumption.

Harmful algal blooms

Another criterion of deciding the suitability of potential culture site is eliminating the threat of 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. Unfortunately, it is often difficult to predict if any area is prone to be affected by these toxic blooms, however, during the site selection process, an enquiry of the past history of the HAB in the area is necessary. Bivalves affected with red tides are not usually killed, but tend to accumulate toxic substances in their flesh. Depuration studies have shown that those bivalves can be depurated, however the longer depuration time required would make it very uneconomical.

Farming area

Open Sea farming

This 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.

This method is generally practiced for thinning overcrowded mussel bed by re-laying spats at lower densities in locations with ideal substratum, that are free from silt and predators. The growing sites are usually prepared to stabilize the bottom before seeding.

Bouchot culture

This method involves farming mussels in intertidal mud flats on poles combining spat collection with ongrowing. Initially poles are set in the intertidal seabed in rows to allow mussel spat to settle and grow. Mussel spats settlement occurs directly on these wooden poles or onto the horizontal coconut fibre ropes strung onto the poles before settlement. When the spat grows slightly bigger they are transferred to tubular nets and transferred to "*bouchot*" placed in shallow waters in the same region. The mussels attain marketable size on the poles.

Suspended farming methods

For suspended farming method, the water depth can be a limiting factor as a minimum water column is essential all throughout the culture period

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.

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 l 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).

Long-line method: Considered ideal to resist storms and wave effect, in unprotected open sea conditions and are particularly adopted in areas having high tidal amplitude. Synthetic rope of 16-20mm diameter is used for the long-line (main line). The main horizontal line is supported with floats/ buoys at every 5m. The seeded ropes are suspended from the main line 1.5-2m apart. The 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

Mussels are characterized by a high fecundity and a free-living larval phase. Though 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 October to December along the Karnataka coast progressing from the south to the north. Mussel spats are collected by physically scrapping them from the intertidal or sub tidal 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 and 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 June. Mussel ropes are collected manually and brought to the shore for harvest. The ropes are 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. At present farm gate price of green mussel is Rs. 4-5 per Kg in Karnataka. Meat from depurated mussel can be shucked in fresh condition or after boiling or steaming. Further processing of the mussel meat can be done after blanching in 5% salt solution for 5 minutes.

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 need 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.

Expenditure:

Table3.Tentative cost of Mussel Farming – Rack Culture Rack size 30m x 20m (600 sq. m) (1200 ropes of 1 m)

A. Initial Expenditure

	I. Farming	Amount
1	Bamboo poles of 4 m length 160 nos @ Rs. 110/-	17,600
2	Bamboo poles of 5 m length 110 nos @ Rs. 125/-	13,750
3	Seeding rope 18 mm (1500 m), 300 kg @ Rs. 125/-	37,500
4	Rope tying the seeded rope; 4 mm, 20 kg	2,650
5	Semi automated seeder	5,000
	II. Post Harvest	
6.	De-clumper	8,500
7	Plastic crates for depuration, (30 nos @Rs.400/-)	12,000

8	Aluminium vessels for heat shucking	10,000
9	FRP tank, 2 ton for chlorination	12,000
10	FRP tank, 1 ton for depuration 2 nos	12,000
11	1HP pump, hose & accessories	10,000
	Total	**141,000**
	B. Recurring Cost	
1	Cotton netting (250mtr @ Rs.15/mtr)	3,750
2	Twine	150
3	Cost of seed (1800 kg @ Rs.6/kg)	10,800
4	Charge for seeding (30 man days @Rs.200/head)	6,000
5	Hire charge of canoe	2,500
6	Charge for harvesting, de clumping and cleaning	10,000
7	Labour for depuration	3,000
8	Plastic wares	4,000
9	Marketing	5,000
10	Miscellaneous	3,800
	Total	49,000
	Expenditure Total (A + B) 1,90,000	**190,000**

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. ■

Suggested reading:

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