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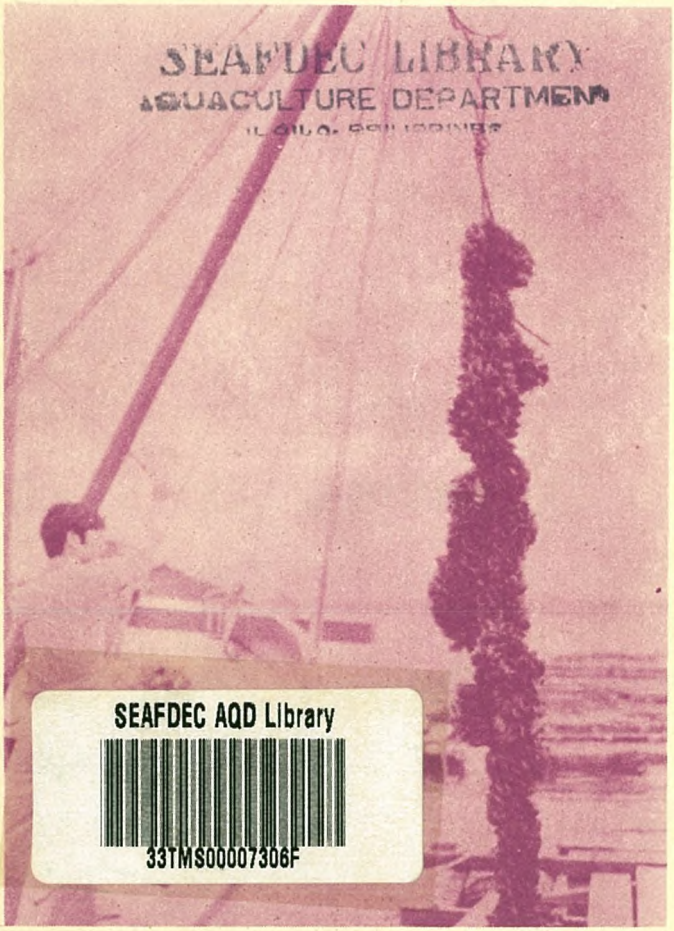
# MUSSEL FARMING






by
Leslie Cheong and Lee Hoe Beng

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# MUSSEL FARMING

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Aquaculture Unit
Primary Production Department
Republic of Singapore

The Secretariat
Southeast Asian Fisheries Development Center
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This manual is based on a technical paper: Manual on Mussel Farming in Singapore by Leslie Cheong and Lee Hoe Beng, presented at the Workshop on Bivalve Culture in Asia and the Pacific which was organized by the International Development Research Centre (IDRC) of Canada in Singapore, 16-19 February 1982. It has been adapted by the authors to meet extension requirements.

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## INTRODUCTION

The green mussel, *Perna viridis* Linnaeus, locally known as *Kupang* in Malay and *dan cai* in Chinese, occurs in abundance along the coasts of the eastern and western parts of the Straits of Johore. It is found in the intertidal and subtidal zones where it occurs in clusters attached to stakes (nibong poles) of palisade fish traps (kelongs), rocks and jetties. Annual production in the Republic of Singapore is estimated at 500 tons, of which half is derived from the wild by artisanal fishermen, who harvest the mussels from nibongs at low tide, and half from culture on rafts.

Mussels are filter feeders of planktonic matter, which they convert effectively into animal protein. The meat contains over 60% protein in 100g dry weight, and its nutritive value compares favourably with other food items like beef, mutton, pork, chicken and eggs. It also contains minerals such as calcium,

phosphorus, iron, iodine, and copper as well as small amounts of thiamine, riboflavin and niacin.

Owing to their ability to secrete byssal threads called "beards", by which they attach themselves to substrates, mussels are very suitable for aquaculture as they can be easily collected and transplanted. Three methods are used by different countries in the culture of mussels, i.e., bottom culture, pole culture and rope suspension culture. Bottom culture is widely practised in the Netherlands. Mussels are cultured on the sea bottom and harvested mechanically by boats. Extensive areas of shallow sea are required for this method of culture. In the pole method, practised mainly in France, Thailand and the Philippines, poles made of oak, bamboo or other materials available locally are used. However, extensive mud flats are required for driving in the poles.

The rope suspension method can be of two types, the floating or the fixed suspension type. In the latter, ropes are hung from poles driven into the sea-bed. This method, also called the rack or table method, is practised in the Mediterranean off the coasts of France and Italy, in areas where tidal fluctuations are not normally experienced so that the greater portion of the culture rope remains constantly submerged. In the floating type, ropes are hung either from a raft or a long-line held afloat by buoys. Spain has established itself as the leading country in the use of the raft method, while South Korea and New Zealand both have extensive areas of long-line mussel culture. In both types, mussels remain constantly submerged and can feed continuously throughout all tidal periods.

Rafts are better suited for sheltered waters, while the use of long-lines is appropriate in unsheltered areas where currents are too fast for mooring rafts.

Spain has demonstrated that mussel yields per unit area are highest in the raft method. Hence, in late 1975, the Primary Production Department of the Ministry of National Development, Singapore, embarked on investigations to determine the feasibility of this farming method under local conditions, the aim being to maximize the utilization of the Republic's limited water resources and to develop a source of inexpensive animal protein for the people. Moreover, the lack of extensive mud flats is an unfavourable factor in implementing bottom and pole culture in Singapore, and the presence of mussel stocks in the sheltered waters of the Strait of Johore does not necessitate the establishment of long-lines.

This manual describes various aspects of mussel farming, using the raft method of culture, in Singapore. It is based on experiences gained by the Primary Production Department during its research studies and investigations made between 1975 and 1981. The findings from a Mussel Culture Project conducted jointly between the Primary Production Department and the International Development Research Centre (IDRC) of Canada are also incorporated.

## CULTURE OPERATIONS

### 1. Site Selection

The presence of a good mussel stock in an area is a useful indicator of the suitability of the site for farming since it would ensure a reliable source of mussel spats. Such stocks are located mostly in sheltered estuarine areas. In Singapore, spat grounds are found in the estuaries of Sungei (River) Serangoon, Ponggol and Seletar in the east Johore Strait and Sungei (River) Kranji and Sarimbun in the west Johore Strait (Fig. 1). Studies show that spatfalls at Sarimbun are more frequent, occurring about once every two months. An adequate spatfall for commercial farming is one that contains at least 5,000 spats/$m^2$ rope surface. Spats can, therefore, be collected in spat grounds and transferred to areas which are suitable for grow-out or production but which have poor spatfalls owing to inadequate mussel stocks.

Spat grounds are typified by waters having a high phytoplankton concentration averaging 30.6 mg (range 23-40) Chlorophyll-*a*/litre sea water, net primary productivity of about 100 mg C/$m^3$/h and currents of 0.17 (flood tide) to 0.25 (ebb tide) m/sec. Such grounds also support grow-out, although mussels grown here tend to drop off easily owing to weak attachment of the byssal threads to the rope as a result of the slow moving waters.

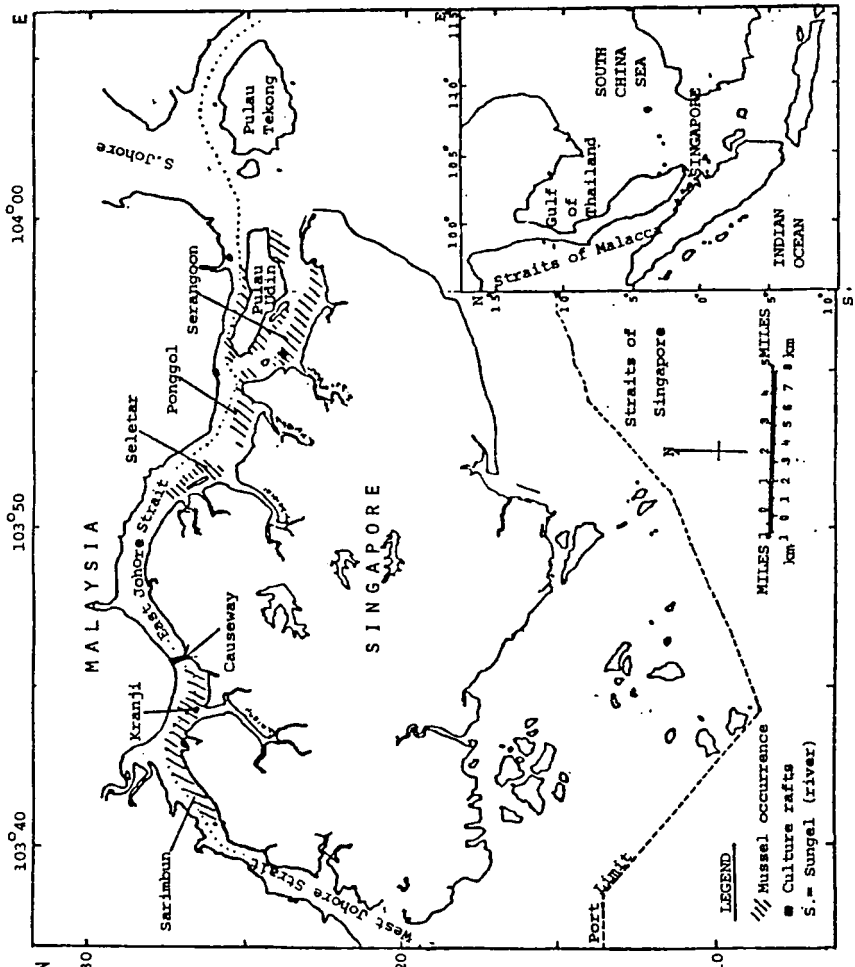


Fig. 1. Distribution of mussels in Singapore

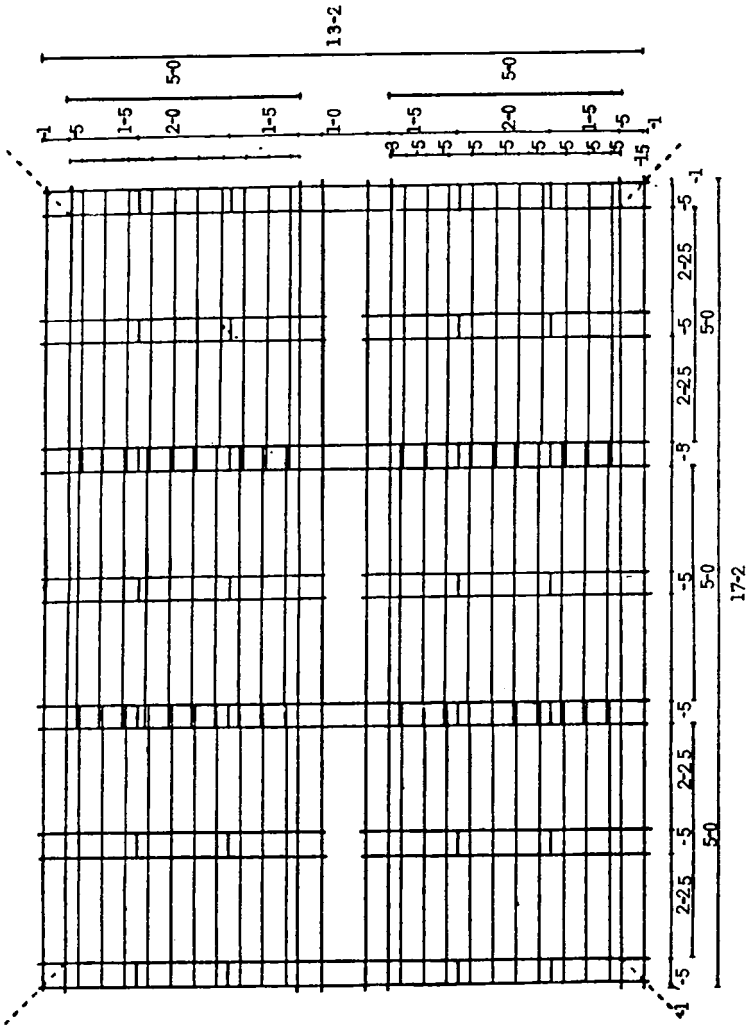


Fig. 2. Plan of a 150m$^2$ Mussel Culture Raft (Specifications in metres)

Denotations : —— main frame; —— cross-beam; --- anchor line

Sites which are suitable for grow-out have fast-moving waters of about 0.25 - 0.35 m/sec. Phytoplankton concentration is lower, averaging 24.5 mg (range 17-33) Chlorophyll-*a*/litre sea water, and net primary productivity, as a result, is poorer, averaging about 73 mg $C/m^3/h$. The areas include waters off Loyang and northern parts of Pulau (Island) Ubin.

## 2. Raft Specifications

The raft is basically a wooden pontoon with cross-beams for suspending the culture ropes. Specifications for the effective productive area, i.e., the space where ropes are suspended, may be 5 m x 5 m (25 $m^2$); 15 m x 5 m (75 $m^2$); or 15 m x 10 m (150 $m^2$). The actual dimensions of the raft would be slightly larger since an outer margin for the placement of floats would have to be included. The plan of a 150 $m^2$ raft is illustrated in Fig. 2.

Wooden beams of the mixed medium or heavy hardwood variety can be used for the main frame. The cross-section measures 10 cm (4") by 7.5 cm (3"). The length should exceed 6.5 m so that the beam adequately covers the margins as well. The cross-beams are of the mixed light hardwood variety measuring 7.5 cm (3") by 5 cm (2") in cross-section and 6.5 m in length.

The main frame is bolted into position by galvanized bolts of 20 cm (8") in length and 1.3 cm (½") in diameter, while nails are used to fix the cross-beams to the main frame. All metal parts should be painted over

with anti-rust paint to minimize corrosion from sea water spray.

Wooden planks of the *Kapur (Dryobalanops aromatica)* variety are placed on top of the completed raft to serve as walkways. A lamp should be placed on the raft as a warning to navigation at night. If the raft is left unattended, automatic light-sensitive signal lamps, as used at road works, can easily be installed.

## 3. Floatation System

Used metal or plastic drums, or styrofoam (polystyrene) can be used to float the raft. Generally drums of a 200-litre (44 gallons) capacity are more convenient to handle since they can be slipped in between two parallel beams of the main frame of the raft and can easily be dislodged manually when they need replacing. For a 150 $m^2$ raft, approximately 30 drums would be adequate to keep it afloat. However, when stocked with ropes laden with mussels, more drums are needed. A total of 60 to 65 drums are required to float a 150 $m^2$ raft stocked with 600 ropes laden with market-sized mussels of 6 to 8 cm in shell-length. A farmer would, therefore, have to add more drums to the raft as the culture progresses.

Metal drums which have previously contained oil need to be washed externally with detergent. The caps should be tightened before painting the drum first with red lead (primer) and finally with an anti-corrosive paint. Usually, drums can remain about six months in the sea before corrosion sets in.

Plastic drums can last much longer and some remain functional even after five or more years. The wall of such drums, which have generally been used for holding acids, is sufficiently thick and ribbed. When the drums are forced under the wooden beams of the raft, the ribs prevent excessive pressure on the drum wall. Caps can be sealed with fiberglass. The drum should be coated with anti-fouling paint to protect it against borers, namely *Teredo* sp.

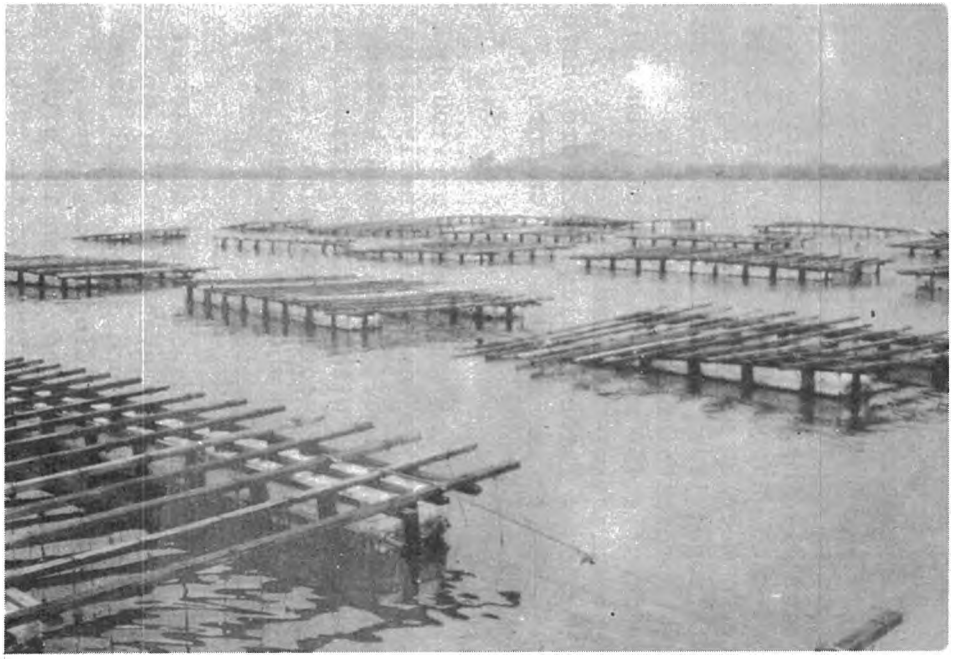

Fig. 3. Overall view of a commercial farm at Sarimbun, showing linear arrangement of rafts and use of styrofoam floats

## 4. Anchoring

Rafts can be arranged singly or, as has been found more practical, in a row parallel to the flow of flood and ebb tides. The latter arrangement not only minimizes the problem of rope entanglement often encountered with individually anchored rafts but also maximizes the utilization of water space (Fig. 3). Concrete blocks are used as anchors. For single rafts, anchors can be made by filling empty metal drums with concrete. For a series of rafts, larger anchor blocks weighing as much as two tons each are generally required.

The raft can be tied directly or indirectly to the anchors. In either case, anchor ropes are of polyethylene material, usually 40 mm in diameter. In the latter arrangement, the anchor rope shackled at one end to the ring of the anchor is connected to a floating drum which, in turn, is connected by another rope or wire cable (2.5 cm diameter) to the raft. In commercial practice, short portions of galvanized pipes are sometimes driven into the sea-bed for staking the anchor ropes, thus replacing the anchor blocks.

The total weight of the anchors should be twice that of the combined weight of the raft and the mussels. The weight of the raft can be calculated from the density of the wood used; the weight of the mussels in water being 1/5 (20%) of their weight in air. More anchors should be provided at the side of the raft which faces the stronger current. In the Straits of Johore, the ebb tide is stronger than the flood tide

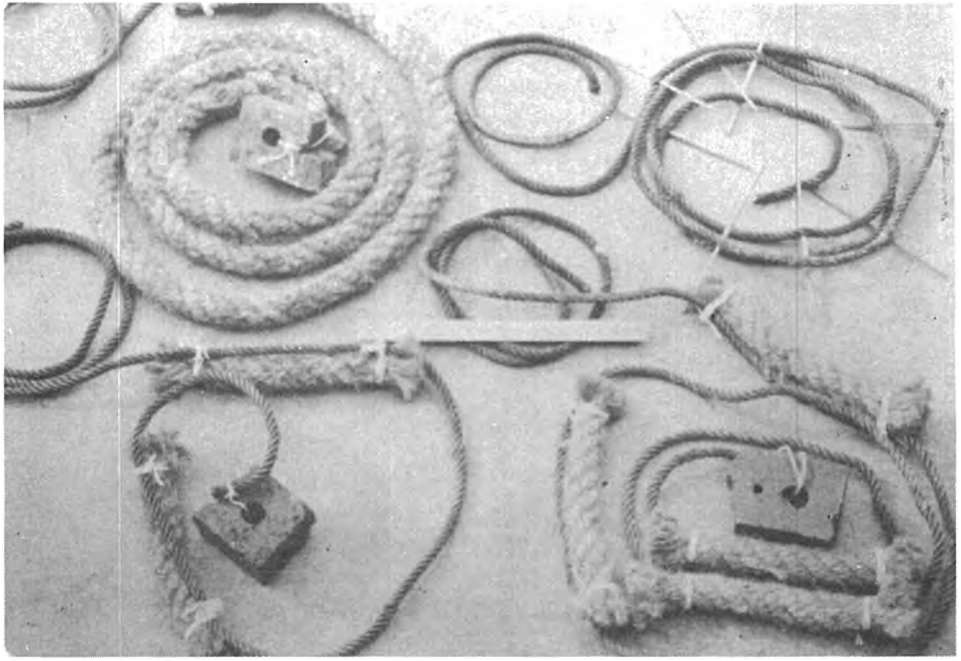

Fig. 4. Ropes used for mussel culture (Clockwise from top left: 4 m coconut coir rope, 4 m polyethylene rope, 4 m polycoco rope, 2 m polycoco rope)

and, hence, more anchors are needed at the ebb-tide end of the raft. The length of the anchor rope should be four to six times that of the water depth at Low Water Spring Tide (LWST) to allow for raft movement caused by tidal fluctuations and current.

5. Spat collectors

Various materials, such as fishing nets, coconut husks, used tires and coconut coir ropes, are suitable as spat collectors. Of these, coconut coir ropes which are not oiled are most suitable and practical. The fibrous and rough surface of the coconut fibers provides a good substrate for spat settlement. Coir, however, has a short life span of about 4 to 6 months in sea water as it tends to be bored through by *Teredo* sp. It is, therefore, suitable for short immersions, specifically for spat collection, but should not be used for grow-out, as portions of the rope when laden with mussels may snap under the weight.

A culture rope combining both collection of spat and grow-out has been devised. This rope, termed polycoco, consists of a main polyethylene rope 14 mm in diameter with pieces of coconut coir rope 30 cm long and 40 mm in diameter tied at the middle of each meter of the culture portion of the main rope (Fig. 4). Depending on the depth of the water at the farm site, the culture portion may vary from 2 to 4 m and should not exceed 5 m, which is the extent of the eutrophic zone in local coastal waters. A short portion of the main rope, normally 1.5 m in length, is provided for tying the rope to the raft.

The combined surface area of the culture portion of the polycoco rope is 0.164 $m^2$ for a 2 m rope and 0.328 $m^2$ for a 4 m rope. Hence, with a spatfall of 5,000/$m^2$ rope surface, there would be approximately 820 and 1640 spats on a 2 m and 4 m polycoco rope respectively. Assuming negligible mortality during the grow-out phase, then, on the basis of a body weight of 30 g each after 6 to 7 months of culture, yields of 25 kg and 49 kg of mussels from 2 m and 4 m polycoco ropes respectively can be expected at the time of harvesting.

## 6. Spatfall

Accurate forecasting of spatfall is very important because it ensures the timely collection of spats on the culture ropes after the latter have been immersed. This, in turn, results in a predictable production cycle. If immersion is not properly timed, heavy encrustation may settle on the ropes, requiring them to be hauled onto the raft for sun-drying and scraping off of fouling organisms. Hence, additional work is incurred and production plans have to be rescheduled.

A simple method of forecasting spatfall would be to immerse a few spat-collecting ropes from the raft every day for a fortnight after heavy rain. The appearance of spats (Fig. 5), which may be as small as 0.5 mm (visible only with a hand-lens of 10 x magnification) on the collectors at >5000/$m^2$ would signal the start of the spat season, which normally lasts approximately two to three weeks. Farmers sometimes use the colour of the mussel mantle (the inside tissue lining the inner shell) to ascertain the

Fig. 5. Spats on coconut coir rope

onset of spawning. When most of the mussels have reddish coloured mantles, it indicates that they are ready for spawning and that spat settlement will occur in one to two weeks' time. A plankton net can also be used to sample the water for D-shaped mussel larvae. However, this particular method requires a microscope and is time-consuming for a farmer to undertake. Moreover, he would need to be trained to identify the larvae.

Spatfalls occur throughout the year with peaks around February-May and October-November in the east Johore Strait, and in June-August and November-December in the west Johore Strait. However, these seasons may vary from year to year, the density of spatfall being generally related to the prevailing weather. It has been observed that spatfall can be expected after prolonged dry weather which is broken by a spell of heavy rain. However, such a change in weather must coincide with the gonadal "ripeness" of the mussel before it can affect spawning. Spatfalls are more frequent in the west, especially off Sarimbun, and may recur as often as once every two months. The season normally lasts 2 to 3 weeks with densities ranging from 5000 to >10000/$m^2$.

With larger parent populations established through increased farming activity, heavier and more regular spatfalls can be expected. This is the case at Sarimbun in the west Johore Strait, where good spatfalls were observed only when farming activities became established there in the last few years. With overharvesting, the parent mussel population would be depleted and poor spatfall might result.

At the onset of spatfall, usually identified by the forecasting technique described above, culture ropes, i.e., either polycoco or coconut coir ropes, should be immersed within the same week. The ropes may be initially suspended at $8/m^2$, i.e., 1200 per 150 $m^2$ raft, and thinned out to $4/m^2$ for grow-out two months later when the spats attain about 1 cm in length. Each rope should be weighted with half a brick. If the site shows better spat settlement at the upper two metres of the water depth, then the 4 m long rope may be folded or rolled up to half its length, and suspended as indicated above. When sufficient spats have settled throughout the entire rope length, the rope may be unrolled and suspended to its full length.

Shades made from the fronds of palm *(Nipa frutescens)* may be placed on top of the raft during spat collection. It has been found that the brighter upper two-metre water zone has a higher spat settlement and this results in uneven spat settlement on the rope. This often occurs with coconut coir ropes. With shading, settlement is more uniform on a 4 m rope. By using polycoco ropes, shading is not necessary because the coconut coir rope pieces, which are placed at regular intervals along the whole rope, distribute spat settlement evenly throughout the rope.

7. Production rope

If coconut coir ropes are used as spat collectors, and overcrowding occurs, spats will have to be thinned out to production or grow-out ropes, otherwise whole clusters of mussels may

slip off owing to the weight of the mussel clumps amassed on the rope. Production ropes are made of polyethylene and measure 4 m in length and 14 mm in diameter. To prevent the mussels slipping off during grow-out, bamboo pegs or chopsticks should be inserted at regular intervals - usually ½ m apart - along the rope. At times, the mussel clumps may be so heavy that they break the pegs. Therefore, care should be taken when harvesting. The length of the whole rope comprises an additional 1.5 m for tying purposes.

8. Thinning

Thinning is a process whereby spats from one rope are transferred to another in order to reduce the density of the mussels, thereby allowing for better growing conditions. The operation is carried out usually 1 to 2 months after settlement, when the spats are still small, i.e., 1 to 2 cm in length. The falling-off rate of older mussels after thinning is higher, and over 50% of the transferred mussels may be lost.

The operation involves plucking the spats off the nursery or spat collector and then placing them on and binding them to the production rope with a cotton net of a mesh size which is smaller than the spats. A twine is used for binding. Approximately 3,000 spats are placed on the production rope. A spat rope is normally able to produce sufficient spats for 3 to 5 production ropes. After about 10 to 14 days, the cotton net disintegrates and leaves behind the spats which have by then attached themselves to the polyethylene rope (Fig. 6). The process of thinning is, however, laborious and time-consuming

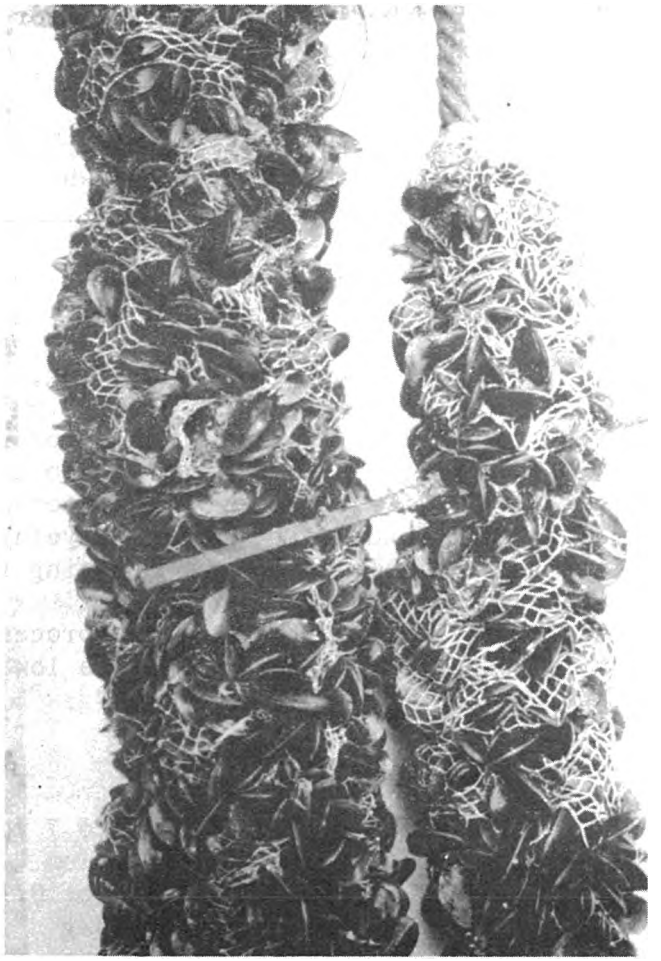

Fig. 6. Disintegration of cotton net on polyethylene production rope

since it takes a trained operator 10 to 15 minutes to complete one production rope. Hence, for a 150 $m^2$ raft which can hold 600 ropes, the operation would take a farmer approximately three weeks to complete if he worked full-time, spending eight hours per day on the job. Thinning is thus a constraint to large-scale operations where several rafts are involved.

With the use of the polycoco rope, thinning is eliminated. The mussels which had initially settled on the coconut coir rope pieces (Fig. 7) will, as a result of overcrowding, migrate up or down the main polyethylene rope and thereby thin themselves out in the process (Fig. 8). There is, therefore, no need to use two types of rope, i.e., the spat collector or nursery rope of coconut coir and the polyethylene production rope. The use of cotton netting for binding the spats is also dispensed with. Therefore, by eliminating the thinning process, a net saving is effected, resulting in a lower cost of production.

9. Grow-out

The mussels take about 6 to 7 months to attain the marketable size of 6 to 8 cm shell-length, after growing from spats of 0.1 mm. The final weight at harvest averages 25 g (range: 20-30 g). The monthly growth rate averages 1.06 cm shell-length.

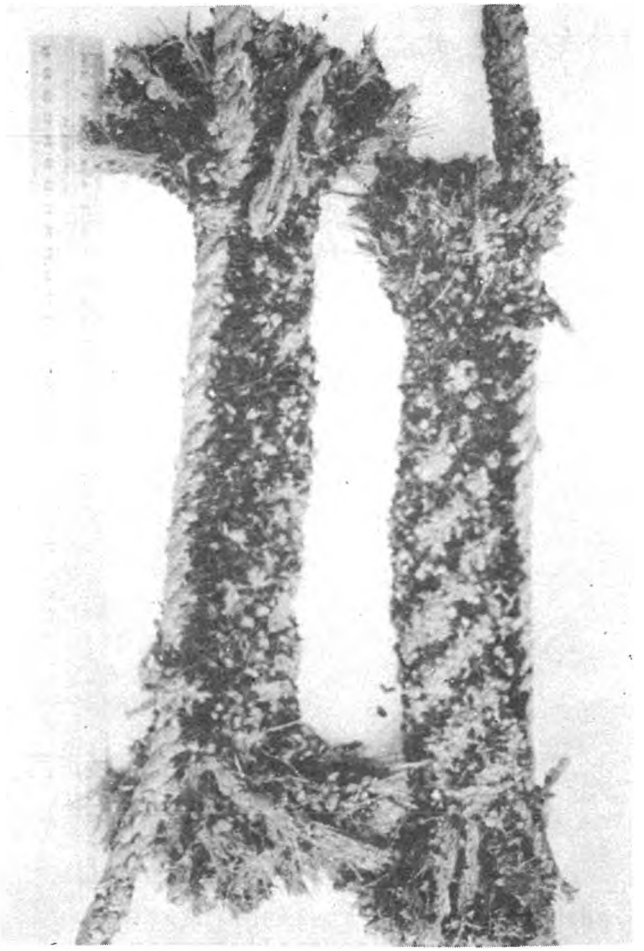

Fig. 7. Mussel spats on polycoco rope, with settlement restricted mainly to coconut Coir Rope

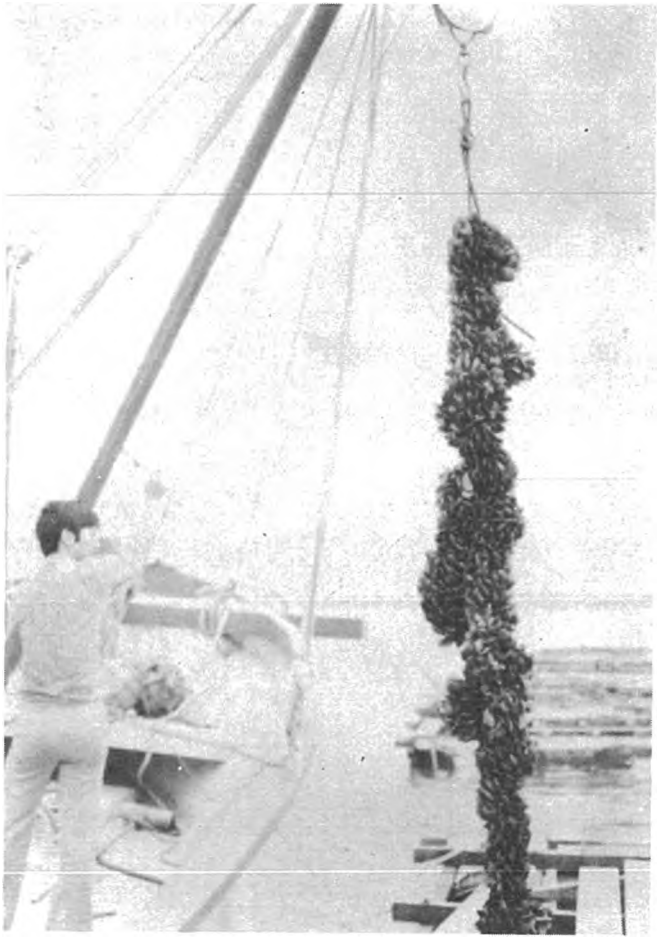

Fig. 8. Harvesting of a 4 m polycoco rope on which natural thinning has occurred.

The Condition Index[1/], which is the measure of the volume of the meat, is 80 at harvest. The growth rate is more rapid in fast moving waters.

Rope density during grow-out is maintained at $4/m^2$. A 4 m polycoco rope will yield 56 kg shell-on market-sized mussels (range: 42-70). With proper immersion at spatfall, it is possible to obtain two harvests in a year with the same set of ropes. If spatfalls are more frequent, another set of ropes for spat collection could be suspended alongside those with on-growing mussels. However, the floating capacity of the raft would have to be considered and more drums would have to be added during culture.

Nursery grounds can also be used as grow-out areas, in which case there would be no need to transfer ropes. However, where the grow-out areas are located away from nursery grounds, the ropes should be transferred about 1 to 2 months after spat settlement when the spats

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1/. Calculated by the formula: Weight of dry meat (weight after 24 h drying in oven at $100^{o}C$) ÷ Volume of meat occupying mantle cavity (obtained by subtracting the Volume of fresh shell-on mussel from the Volume of the shell; the volume being obtained by water displacement) x 1000.

are still small. During grow-out, the ropes should be hawled up occasionally to check the mussels and to help remove the silt which may have accumulated in the mussel clusters.

Disease in mussels is not commonly encountered, because culture takes place off the bottom. Crabs are, however, found on the ropes, eating dead or dying mussels. The mussel clusters also harbour fishes such as gobies and grouper fingerlings.

10. Maintenance

With proper maintenence, the raft can remain operational for as long as five years. Regular checking of the condition of the wooden beams, especially the main frame, is necessary. Cracked beams should be replaced immediately. Nuts and bolts must also be replaced, if necessary.

Metal drums are usually replaced once every six months, depending on their initial condition. Routine maintenance consists in scraping off mussels, barnacles and seaweeds. The added weight of such fouling organisms reduces the buoyancy of the drums.

If plastic drums are used, they need to be rotated once every three months so that the fouling organisms can be scraped off. After six months, the drums should be taken out for scraping and washing before being re-coated with a layer of anti-fouling paint. Uncoated drums are subject to boring by *Teredo* sp. (Fig. 9). The drums may be used for five years or more.

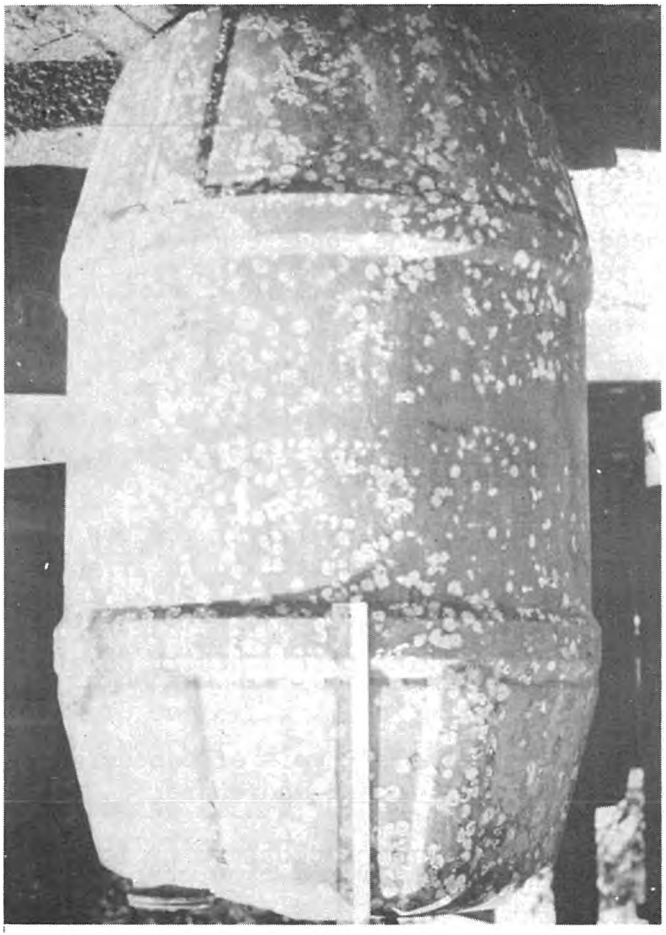

Fig. 9. Signs of boring on uncoated plastic drum

It is essential to inspect the condition of the anchor ropes once every 3 to 6 months. This would ensure that the rafts are still properly positioned. Maintenance also includes scraping off fouling organisms on the ropes, checking the condition of the shackles, e.g., whether there are signs of their becoming loose, and periodic greasing if wire-cables are used. If polyethylene ropes are used for alignment of the rafts, occasional adjustments are needed because the ropes can become distended under tension.

## POST-HARVEST OPERATIONS

### 1. Sanitation

Mussels being filter feeders tend to accumulate filtered matter in their guts. In the process bacteria and other micro-organisms present in the surrounding waters may accumulate and reach levels which pose a health hazard to the consumer.

Acceptable levels of bacteria for raw shellfish meat in Singapore are:

Aerobic plate count - equal to or less than 500,000 MPN/g

*Escherichia coli* count - equal to or less than 20 MPN/g

*Vibrio parahaemolyticus* count - equal to or less than 100 MPN/g

*Salmonella, Shigella* and *Vibrio cholera* - nil in 25 g

The Primary Production Department continuously monitors the heavy metal and bacteria levels in the water and mussels from farm areas. Results so far show that the levels are, on the average, within acceptable limits.

2. Depuration

One method of ensuring marketable shell-on mussels is to depurate them after harvest. The process of depuration consists in the bivalves cleansing themselves through filter feeding. During the operation the bivalves are placed in sterilized sea water which, by passing through their gut, purges the gut within the allotted time.

There are three methods of depuration generally employed, i.e., chlorination, ozonation, and ultra-violet (UV) radiation. The last of these methods has been tested by the Department and found to be the most suitable in the Singapore context where high density depuration within limited confines is required. By using the UV sterilizer, and recirculating the sterilized water within the depuration system, it is possible to reduce bacteria loading in the mussels from >2400 *Escherichia coli* Most Probable Number (MPN)/g meat to an acceptable level of <20 (MPN)/g within 48 hours. *Escherichia coli* is the bacteria which usually indicates bacterial pollution in the environment.

The mussels which are to be depurated are first broken off manually in small clumps from the culture rope. They are then placed in shallow trays which are stacked over a tank containing sea water (Fig. 10). Recirculation is done by means of a pump which drives the water through the UV sterilizer and delivers the sterilized water over the multi-tiered tray arrangement. The enclosed water tube-type UV sterilizer is more effective than the weir-type, and is therefore recommended. After a 24-hour depuration, the water is drained off and the mussels hosed down. Fresh sterilized sea water is then added for a further 24-hour depuration before the mussels can be removed for the market. This method of depuration can be applied in both small and large-scale operations and is therefore suitable for restaurants as well as processing plants.

3. Handling

The main constraint in mussel farming is the handling of large quantities of fresh mussels at a time. At present, this operation is done manually by the farmer. Usually three to five family members are involved, and about 100 to 300 kg of fresh shell-on mussels are shucked in a 4 to 6 hour operation. The mussels, in clusters, are first steamed in a metal drum, then shucked and sold in the form of cooked meat. Excess quantities of meat are sauteed on a hot plate and later sun-dried on zinc sheets or straw mats laid over tables in the open. Sun-drying is usually done for two days during fine weather, after which the meat is placed in biscuit tins and sold. During sun-drying, the meat should be protected from flies.

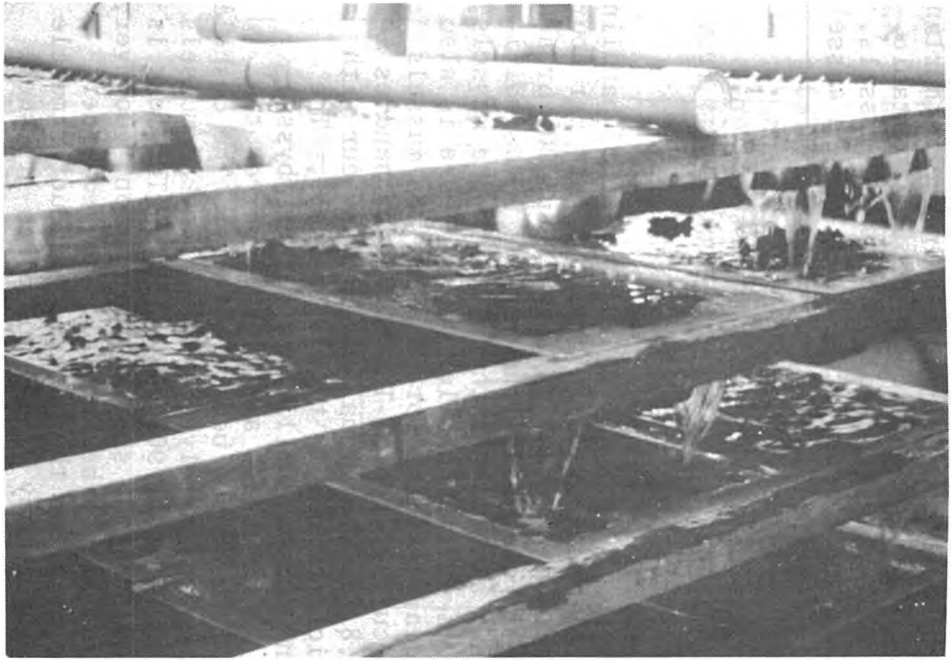

Fig. 10. Arrangement of mussels in trays for depuration, showing tier arrangement and overflow system

Large-scale mussel farming requires mechanization of the post-harvest handling operation, as is done in the Netherlands. Based on designs developed by farmers in the Netherlands, the Department has developed machines suitable for the post-harvest handling of local mussels. The machines are used for breaking up the mussel clusters into individuals, a process called declustering; pinching the byssal threads ("beards") from the individual mussels, or debearding; and dislodging the cooked meat from the shell, or deshelling.

A declusterer is capable of handling one ton of mussel clumps (gross weight) per hour with approximately 90% efficiency and 10% breakage. It not only declusters the mussels into individuals, but also washes the silt off the mussels, and grades out the smaller ones. There is also a subsidiary machine for scraping the mussels off the culture rope. The debearder handles about 0.8 ton individual mussels an hour with 60% efficiency and 15 to 20% breakage. The remaining mussels still retain their byssal threads. The beards are pinched off as the mussels fall over a bed of rollers. The desheller handles approximately 0.6 ton of cooked mussels an hour with about 90% efficiency. The meat is dislodged from the shell by vibration. However, the mussel has to be specially cooked under pressure to cause the posterior adductor muscle attaching the body of the mussel to its shell to retract, thereby effecting dislodgement when shaken. Illustrations are given in Figs. 11, 12 and 13;

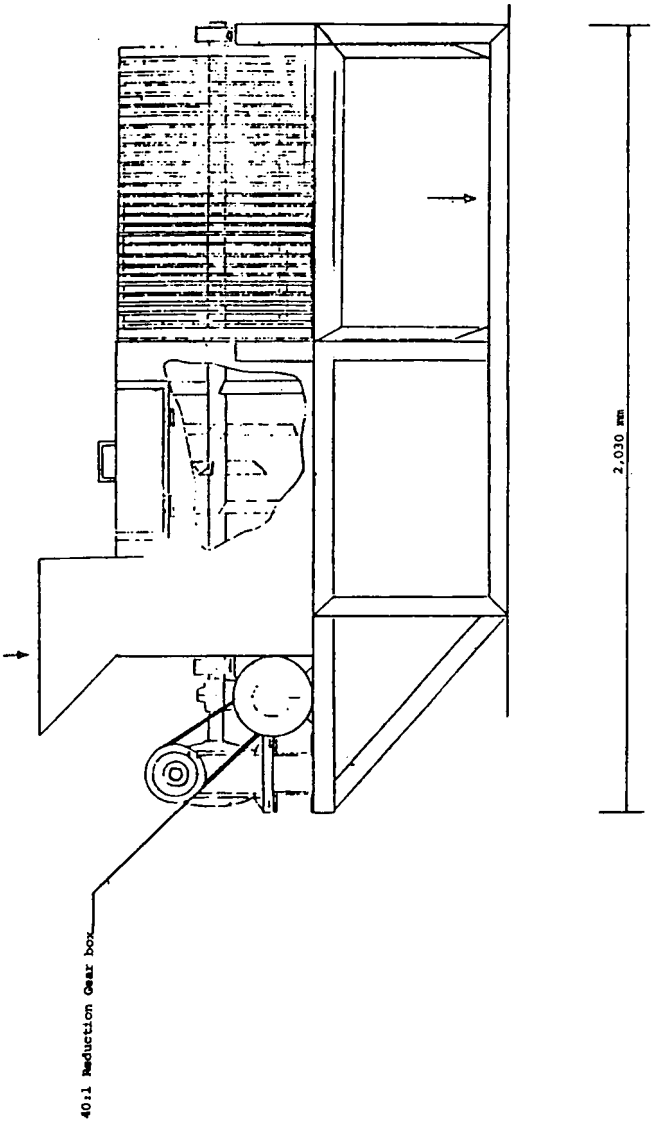


Fig.11. Sideview of declusterer

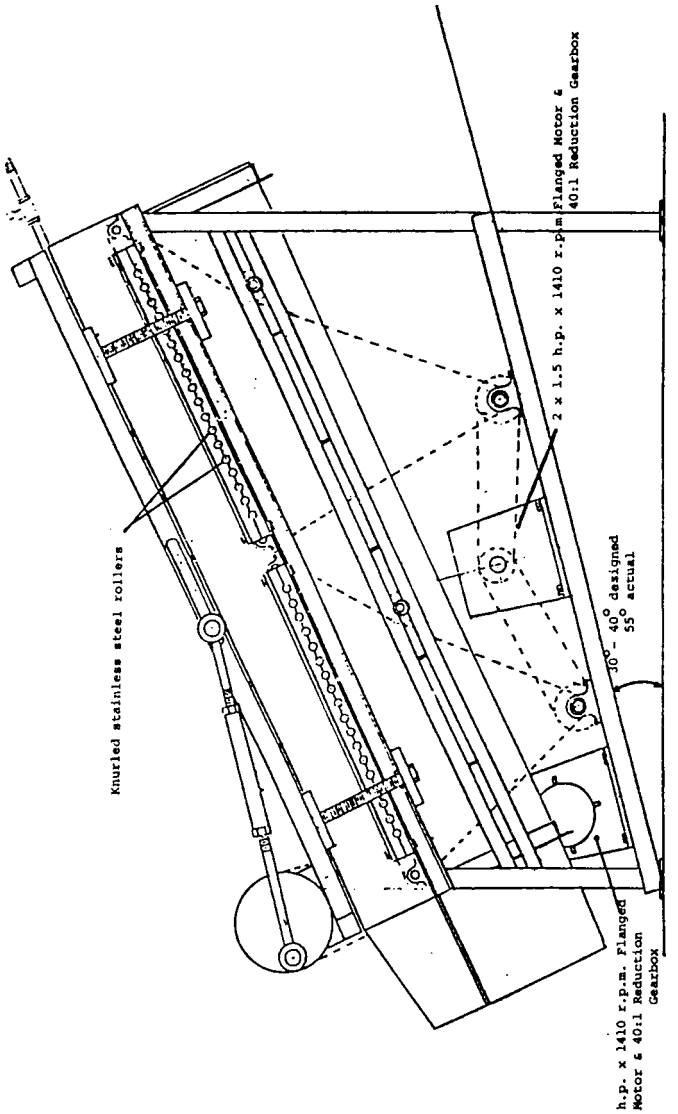


Fig.12. Sideview of debearder

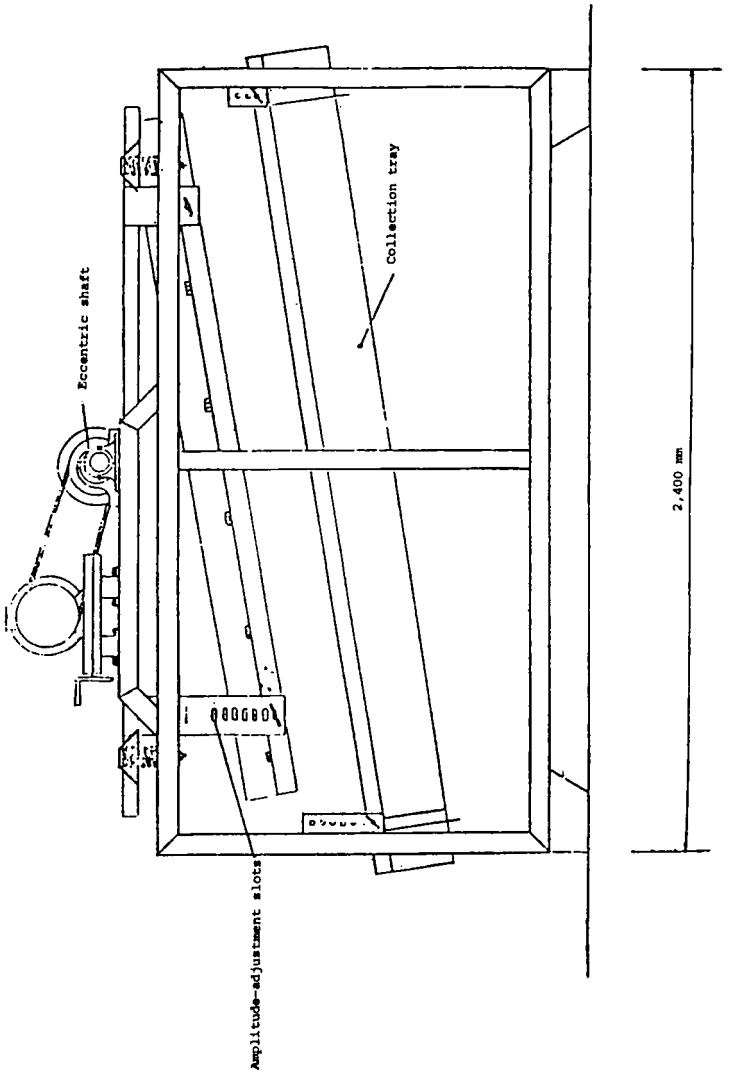


Fig. 13. Sideview of desheller

4. Shelf-life

Freshly harvested mussels generally retain their freshness about one to two days if they are kept in moist gunny sacks in normal room conditions (Fig. 14). Studies show that shelf-life can be extended to as much as four days if the mussels are placed in clusters in shallow trays receiving a steady flow of sterilized water (see Depuration, section 2 above). Hence, mussels can be depurated while they are being stored or transported from the farm to the market.

Shell-on mussels can also be stored in the freezer at -30°C for as long as six months to a year. They can subsequently be cooked, with no deterioration in meat quality, by plunging them directly into boiling water. This prevents tearing of the meat, which would otherwise occur if the frozen mussels were first allowed to thaw.

Processed mussels have a long shelf-life. Cooked meat, for example, can remain fresh in the refrigerator for one to two weeks and in the freezer for as long as two to three months. If blast frozen, it can be stored for as long as one to two years with no deterioration in meat quality. Glazing of individually quick frozen (IQF) mussels helps to retain the shape of the mussels and enables easy handling during defrosting (Fig. 15).

Fig. 14. Packing of fresh mussels in moist gunny sacks, laced up to retain moisture.

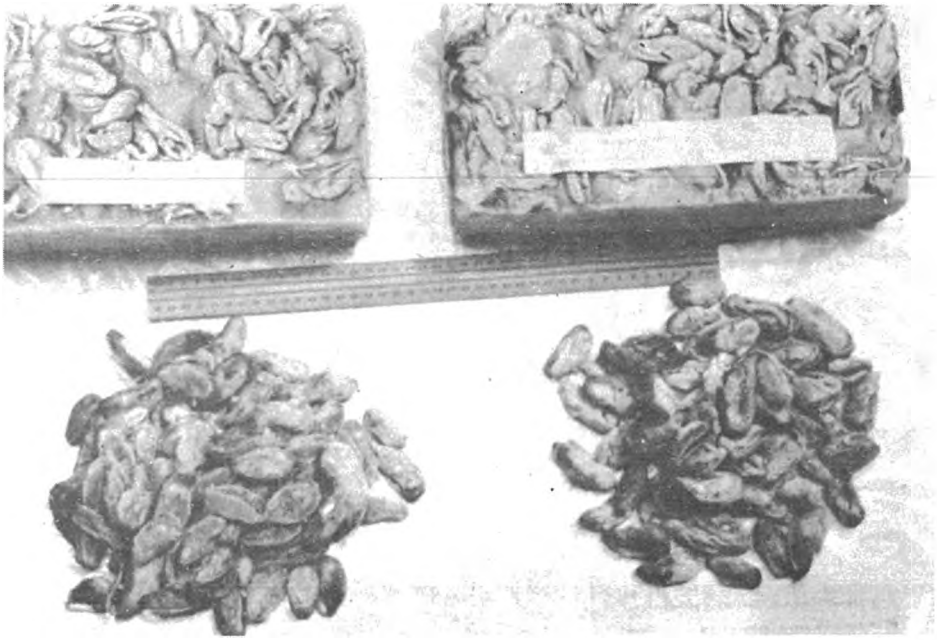

Fig. 15. Block and individually glazed frozen mussels (Clockwise from top left: block frozen mussels, cooked and frozen on same day; block frozen mussels, stored as frozen shell-on, then cooked and refrozen a year later; individually glazed frozen mussels, stored as frozen shell-on, then cooked, glazed and refrozen a year later; individually glazed frozen mussels cooked, glazed and refrozen on same day)

The shelf-life of dried mussel meat is dependent on the moisture content of the meat. After sun-drying, the moisture content is about 10% of the dried meat weight. Such meat can be stored for about four months, provided that it is kept in air-tight containers.

The shelf-life of cooked meat can be further extended by smoking, pickling, or preserving it in brine or sauces. At present, there are no local canneries canning mussels and all of the canned or bottled products are imported from Europe and South Korea.

5. Market Demand

Mussels are consumed by various ethnic groups in Singapore. However, they are generally more popular with the Malays, who eat them in a dish called *sambal* containing chilli paste. The Chinese prefer to buy the dried meat for boiling in soup. In restaurants serving Western cuisine, mussels are prepared in the shell, i.e., steamed; in half-shell, i.e., escargot; or as cooked meat, and chowder.

The market demand is limited. In 1976, there was a higher demand for dried mussel meat, estimated at 145 tons annually. However, with increasing awareness of mussels, the public now prefers to buy the cooked meat. This is sold either to supermarkets packed in styrofoam trays or direct to food vendors (hawkers).

Some Western and local recipes for preparing mussels are given in the Appendix.

# READING LIST

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Appendix

# RECIPES FOR PREPARING MUSSELS

## Shell-on

### a) Paella[1/]

A rice speciality from Spain, this dish combines various seafood with meat in rice casserole. Recipe serves 6-8 persons.

1 lobster, shell split, claws cracked and grey sac removed

75 cc (3 fl. oz or 3/8 cup) olive oil

1.4 kg (3 lb) chicken, cut into 12 serving pieces

6 lean bacon slices, chopped

2 large tomatoes, blanched, peeled, seeded and chopped

2 garlic cloves, finely chopped

225 g (8 oz) mange-tout, washed

450 g (1 lb or 2 2/3 cups) long-grained rice, washed, soaked in cold water for 30 minutes and drained

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1/ Adapted from I. Moore (Ed.) 1976. Supercooking! Marshall Cavendish, London & New York, 384 pp.

2 teaspoons paprika

1.2 l (2 pints or 5 cups) water

2 teaspoons salt

1/4 teaspoon ground saffron

12 small mussels, steamed

6 snails

225 g (8 oz) baby squid, cleaned

6 lemon wedges

Remove the lobster meat from the shell and claws and cut into 2.5 cm (1 inch) pieces.

In a large flameproof casserole, heat the olive oil over moderate heat. When it is hot, add the chicken pieces and the bacon and fry, turning occasionally, for 5 to 8 minutes or until the chicken pieces are slightly browned. Add the tomatoes and garlic and fry for a further 5 minutes, stirring frequently.

Using a slotted spoon, remove the mixture from the casserole. Set aside.

Add the rice and paprika to the casserole and, shaking it frequently, cook for 3 minutes or until the rice is well coated with the oil. Add the water, salt and saffron, stir and bring to the boil. Reduce the heat to low, add the chicken and vegetable mixture and cook for 10 minutes, stirring occasionally. Add the mussels, snails, squid and lobster and cook for a further five or ten minutes

or until the chicken is thoroughly cooked and all the liquid has been absorbed by the rice.

Remove the casserole from the heat. Serve, garnished with the lemon wedges.

b) Sambal Shell-on

A local dish served hot; eaten with the fingers. Recipe sufficient for 4 persons.

250 g ($8\frac{3}{4}$ oz) uncooked mussels (cleaned)

1 stalk Chinese celery

1 tomato (cut in wedges)

2 eggs (use egg white only)

chopped garlic (little)

10 g (2/5 oz) chilli paste

30 g (2/5 oz) blachan (prawn paste)

cooking oil

salt, pepper and seasoning

100 c.c. (½ cup) chicken stock

cornflour )
water ) mixture for thickening

Fry chopped garlic in hot kauli (wok) with oil until light brown. Add minced prawn, blachan and chilli paste. Pour in cleaned mussels. Over high heat stir for a few seconds, then add chicken stock and cover the kauli for about five minutes until cooked.

Remove the cover, add seasoning, tomato and Chinese celery. Thicken with the cornflour mixture. Finally, add in the egg white when ready to serve.

c) On the Grill[1/]

Good for barbecues; recipe serves four persons.

2 kg uncooked mussels (cleaned)
melted butter or margarine
lemon wedges

Arrange a grill 10 to 12.5 cm (4-5 inches) above intensely hot coals of a wood or charcoal fire. Place mussels in shells on grill (on flat pan if necessary) and cook until most of them gape open. Discard those that do not open. Serve at once with melted butter for dipping and lemon to squeeze over the meat.

Half Shell

a) Mussels à l'Escargot

(adapted from Hurlburt, 1977)

Mussels are used as an appetizer, which can be prepared days in advance, frozen and

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[1/] Adapted from S. Hurlburt, 1977. The Mussel Cookbook. Harvard University Press, U.S.A. 160 pp.

popped into the oven at the last minute. Recipe serves four persons.

24 fresh mussels in shells of at least 7 cm (2¾ inches) long, steamed in pot under cover for 5-7 minutes at high heat.

125 g (¼ lb or ½ cup) softened butter or margarine

1 tablespoon finely chopped parsley (optional)

1 tablespoon lemon juice

1 shallot, minced (optional)

3 large garlic cloves, pureed or finely chopped

1 slice uncooked bacon, minced (optional)

Salt, pepper and grated Parmesan cheese to taste

Remove mussels and discard half the shells. Blend butter and the remaining ingredients thoroughly. Put a dab in each remaining shell and cover with more butter. Sprinkle some grated cheese on top.

Put shells side by side in a shallow packing pan. Bake in preheated oven at 200°C (400°F) for 15-20 minutes, until hot and bubbly. Serve sizzling hot on plates with cocktail forks or small picks.

b) Baked Stuffed Mussels[1/]

A tasty dish suitable for cocktail parties. Serves four to five persons.

250 g (1 cup) cooked mussels, chopped

62.5 g (¼ cup) butter or margarine

3 tbsp minced onion

3 tbsp chopped parsley

3 tbsp chopped celery

1 tbsp minced green pepper

About 3 tbsp mussel broth

1 cup bread crumbs

a few drops of chilli sauce

Salt

Butter with grated Parmesan cheese

Lemon wedges dusted with paprika

Melt butter in frying pan. Add onion, celery and green pepper; saute until tender. Remove from heat. Add mussels, parsley, breadcrumbs, chilli sauce and just enough broth to bind the mixture. Season to taste.

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[1/] Adapted from "25 Ways with Mussels" LIVING. April 1978: 97-99

Fill all the shells with the mixture and arrange on baking sheets. Dot with butter. Bake in a preheated oven at 230°C (450°F) for about 15 minutes or until the cheese melts. Garnish with lemon wedges.

Cooked meat

a) Singapore Pupus

(adapted from Hurlburt, 1977)

An appetizer as a cocktail snack. Serves eight persons.

500 g (2 cups) cooked, chopped and drained mussel meats

2 green onions, finely chopped

125 g (½ cup) finely chopped and drained water chestnuts

2 tbsp chopped pimiento

1 teaspoon soy sauce

¼ teaspoon ground ginger

1 tbsp sherry

1 egg, well beaten

250 g (1 cup) fine dry bread crumbs

Salad oil for deep-frying

In bowl, combine all ingredients, except crumbs, and oil. Mix well, then form into balls about 2.5 cm (1 inch) in diameter; roll each in bread crumbs. Heat oil to 190°c (375°F) and fry a few at a time until golden brown. Serve piping hot with small picks inserted. Makes approximately 24 appetizers.

b) Sambal Mussel

A popular local dish eaten with rice. Serves four persons.

150 g (5¼ oz) cooked mussel meat

30 g tomato paste

1 teaspoon lemon juice

50 cc. (¼ cup) coconut milk (concentrated)

20 g minced dry prawn meat

3 teaspoon chilli powder

25 g ginger )
25 g shallot ) Pound to a paste (Rempah)
10 g garlic )

Salt

Pepper

Seasoning

Cooking oil

Fry the paste in a hot pan with oil until light brown. Add chilli powder, minced prawn meat, tomato paste and lemon juice. Finally, add the mussel meat and fry for thirty seconds. Do not over-cook the mussels. Add the coconut milk and serve.

C) Sautéed Mussel

100 g (3½ oz) cooked mussel meat

50 g ($1\frac{3}{4}$ oz) ginger (sliced)

2 stalks spring onion (cut 2.5 cm or 1 inch long)

8 black mushrooms (sliced)

chopped garlic

| | | |
|---|---|---|
| sesame oil | ) | |
| Chinese wine | ) | |
| Oyster sauce | ) | |
| Salt and pepper | ) | Mixture for thickening |
| Cornflour | ) | |
| Water | ) | |
| Cooking oil | ) | |

Fry chopped garlic in hot pan with oil for about ten seconds until it turns light brown. Add the ginger and black mushrooms and saute them for a short while. Finally, add in the mussel meat and spring onions, and season to taste. Stir quickly over high heat and serve hot.

## List of SAFIS Extension Manuals

SEC/SM/1 Khumua liang pla namcheut (Freshwater Fish Farming: How to Begin)-- in Thai

SEC/SM/2 Oyster Culture

SEC/SM/3 Mussel Culture

SEC/SM/4 Ang pagpuna ug pagtapak sa pukot (Net Mending and Patching)-- in Cebuano-Bisaya

SEC/SM/5 Mussel Farming

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# SAFIS

0 What is SAFIS?

SAFIS is the Southeast Asian Fisheries Information Service. It is a project of the SEAFDEC Secretariat set up to provide extension materials for small-scale fishermen and fish farmers in the region.

0 What are its objectives?

The immediate objectives are to collect and compile fisheries extension manuals, brochures, pamphlets and related aids for small-scale fisheries development, and to translate selected literature into local languages for distribution to fisheries extension workers in Southeast Asia.

0 What services will SAFIS provide?

SAFIS will attempt to provide information and publications such as:

- lists of available texts in fisheries extension services,
- translation of suitable manuals,
- manuals of appropriate technologies,
- photocopies of appropriate fisheries extension literature,
- a current awareness service of regional fisheries.

0 How much will these services cost?

A nominal cost of US $0.15 per page will be charged for photocopying, handling, and surface mail. Airmail costs will be extra. The publication cost per manual will vary according to the book.

SAFIS is the Southeast Asian Fisheries Information Service. It is a project of the SEAFDEC Secretariat set up to provide extension materials for small - scale fishermen and fish farmers in the region. For additional information, contact the Project Leader of SAFIS

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