Developments in Mollusc Farming in Southeast Asia

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Abstract

Southeast Asia has a relatively long tradition in mollusc culture. The mollusc species of commercial significance in this region are the blood cockles (*Anadara granosa),* the green mussels (*Perna viridis),* the oysters (*Crassostrea* spp.) and the horse mussels (*Modiolus* sp.) Mollusc production has been observed to fluctuate dramatically in recent years due mainly to the inconsistent seed supply from the wild, which varies geographically and annually. These variations are often associated with pollution and also the uncontrolled harvesting of adults irrespective of their sizes, which reduces chances of spawning among adults. Production of the above-mentioned species in Southeast Asia in 1997 amounted to 73 820, 62 073, 36 779 and 5 300 mt., respectively. The culture of these bivalves is still dependent on traditional methods of obtaining seeds from the wild and transplanting them to culture sites for grow-out. Culture techniques for these bivalves are basically the same all over Southeast Asia, except for minor variations in the use of structures and materials to suit the local conditions. Whilst efforts are geared towards developing new technologies to promote mollusc culture in the region, it is important to facilitate and stimulate environmentally acceptable developments and sustainable management practices. Although hatchery propagation techniques have been developed for these cultured and other non-cultured species, the technologies have yet to be taken up commercially. Some of the common problems confronted by the region, which varies greatly by species and location, are inconsistent seed supply, lack of suitable areas for expanding culture activities, poor post harvest handling techniques, demand levels being below production capacity, environmental pollution, vagaries of nature, low price and lack of access to export markets.

Introduction

Amongst the four main groups of aquaculture products of the world, molluscs form the major component, followed by finfish, crustaceans and seaweeds. Molluscs are estimated to contribute about two thirds of the total global aquaculture production, while Asia accounts for two thirds of the world's molluscs produced. In Southeast Asia, countries which are actively involved in marine mollusc farming (based on their annual production) are Thailand, Malaysia and the Philippines (FAO, 1999) and the significant commercial species landed are the blood cockles (*Anadara granosa*), green mussels (*Perna viridis*), the oysters (*Crassostrea* spp. and *Saccostrea* sp.) and the horse/brown mussels (*Modiolus* sp.). However, several species, although widely harvested from the coastal waters, like the carpet clam (*Paphia undulata*), razor clam (*Solen* spp.), abalone (*Haliotis* spp.), hard clams (*Meretrix* spp., *Callista* sp), the giant clams (*Tridacna* spp.), pen shells (*Pinna* spp.) are not cultured.

Mollusc landings in Southeast Asia fluctuate yearly, and in recent years, annual production has in fact decreased in the region. The production of molluscs in Thailand, Malaysia, Philippines and Singapore for 1995-1997 is shown in Table 1 (FAO, 1999). Production data from other countries (Indonesia, Vietnam, Laos, Cambodia) are not available probably because of the lack personnel to gather the statistical information. In 1995, mollusc landings from countries with production data amounted to 222,980 mt compared to 188,393 mt and 178,022 mt in 1996 and 1997, respectively. This apparent decrease has been associated with several factors, namely the inconsistent and lack of seed supply, heavy exploitation of culture sites, resulting in lack of suitable areas for further expansion, poor post-harvest handling techniques, demand levels being below production capacity for certain species like the mussels, environmental pollution, vagaries of nature (monsoons and other calamities), low price for certain mollusks, and lack of access to export markets.

Table 1: **Annual mollusc landings (mt) by species for countries in Southeast Asia from 1995 to 1997 (FAO, 1999)**

Country/Species	**1995**	**1996**	**1997**
Thailand			
Perna viridis	51,182	35,489	45,800
Crassostrea sp.	23,037	23,420	22,800
Anadara granosa	14,403	15,836	15,420
Modiolus sp.	4,211	5,483	5,350
Total	92,833	80,228	89,370
Malaysia			
Anadara granosa	100,276	71,795	58,400
Perna viridis	778	1,164	1,779
Crassostrea spp. and *Saccostrea* sp.	26	42	126
Total	101,080	73,001	60,305
Philippines			
Crassostrea iredalei	11,874	11,776	13,853
Perna viridis	14,688	21,027	11,658
Total	26,562	32,803	25,511
Singapore			
Perna viridis	2,505	2,361	2,836
Total	2,505	2,361	2,836

Most countries in Southeast Asia share rich endowments of similar mollusc species and possess suitable environmental conditions for their culture. However, the status of development and the economic importance of the shellfish industry may differ in the respective countries. Although the farming technology of most molluscs in the region depends on conventional methods of collecting spat from the wild to be transplanted to the grow-out sites, the culture practices have been gradually and systematically improved over time by coastal fisherfolks with the aim of increasing production through sustainable management practices. This paper attempts to discuss some of the methods employed by coastal communities in Southeast Asia in the farming (spat collection and grow-out methods) of the various mollusc species.

Blood Cockles (*Anadara granosa*)

Major producers of cockles are Malaysia and Thailand and the most common species cultured is *Anadara granosa,* although *A. nodifera* and *Arca* sp. have also been reported to be cultured in Thailand (Sahavacharin, 1991) and in the Philippines (Davy and Graham, 1982), respectively. Extensive culture of *A. granosa* has also been reported in Vietnam but published information is limited. The culture methods in these countries are similar (Tookwinas, 1987) and to date, the system of cockle culture has been most developed (Davy and Graham, 1982). Both the spat and adult cockles inhabit the coastal mud flats, which are often classified as sandy-loam, and their distribution is intertidal or marginally sub-tidal (Broom, 1985) where water depth does not exceed 3 m, beyond which the pole dredge cannot be used to harvest cockles (Kamal, 1996). They require high salinity regimes and thus are found at highest densities in mudflats away from the estuaries.

Spatfall collection

In Malaysia, cockle spats are usually available throughout the year but two main peaks could be distinguished. The first peak is from January to March while the second is from May/June to September (Kamal, 1986). Consistency of spatfalls in an area is greatly dependent on the spawning success of both naturally occurring and cultured cockles, including water current, which disperses cockle larvae during their planktonic phase. As a result, Spatfall areas and the quantity of spat are not predictable and is expected to shift from place to place and varies yearly. Availability of spat in an area during a particular season does not confirm Spatfall in the subsequent years. Cockle spats are also found in coastal mudflats and usually these areas are protected by classifying them as Spatfall areas (in Malaysia), so that no culture work is carried out here. Utilising a Spatfall area for culture work can damage spats during culling activities in the culture plot for grow-out.

Spats are usually collected with a hand core (hand-made wire scoops with very fine mesh size of 2x2 mm) during low tide by sieving the mud flats and rinsing them in seawater prior to emptying the spat into plastic sacks, which weigh about 60 kg (when full) or in tins (18 l when filled). No mechanized collection is allowed. In Malaysia, spat collection is allowed from 6 am to 6 pm as specified in the Fisheries Act (1985) and only if a license is obtained from the Department of Fisheries after notification of Spatfall by the relevant authorities. The preferred spat size ranges from 6 to 10 mm in length and the best quality spat are those caught in the first few weeks of collection. In Malaysia, the legal size considered as spat for collection are those with an average size greater than 6.4 mm, which should be landed at sites specified by the Fisheries Authorities to facilitate monitoring. The size specified is in view of reducing mortality of spat while being collected and also during transportation to culture sites. The spat can be transported under semi-dry conditions (mixed with mud) over 48 h with very low mortality rate (about *5%).* The quality of spat depends on the content of impurities comprised of detritus and other clams.

Suitability of grow-out area

Areas considered suitable for cockle culture are tidal flats of soft flocculent mud, protected from strong wave action, and situated outside the mouth of estuaries. Some features in choosing a site for cockle culture are:

- Well sheltered from strong wind and current to prevent the spat from being buried under the mud;
- Mudflats with sandy-loam soil texture (mud content 40-50%);
- Salinity range of 28-30 ppt;
- Stable culture bottom with gradual or no slope; and
- Areas without pests or pollution.

Culture areas are usually further away, and in most cases, very far off from natural grounds. In Malaysia, most of the cockle culture operations are well organised by the Fisheries Development Authority (FDA) or through the Fishermen's Cooperatives, but some are operated by private organisations. The culturists would have to apply for a temporary occupation license (TOL), which is charged on a yearly basis by the land office to operate the culture beds. Currently some 4,500 hectares of mudflats are in use for the culture of cockles in Malaysia.

Preparation of culture plots

Most of the culture plots are bounded by natural landmarks, but where these are lacking, the boundaries are marked by other means such as mangrove poles and 'watch huts'. Prior to sowing of spat, the culture plots would be cleared of empty shells and predators if the area is small. But in some cases, the culturists reckon that clearing of extensive culture plots, which may easily exceed 100 ha, is extremely tedious and expensive. They also feel that, given time, the empty shells would sink into the mud. Thus, as soon as a batch of cockle is harvested from the plot, new spat are sown immediately into the area.

Due to lack of culture sites in the intertidal areas in Malaysia, efforts have been geared to utilise deeper areas (exceeding 3 m and about 500 m from the shoreline) for cockle culture. Due to the depth of water, harvesting of cockles have to be carried out by using a boat-towed dredge, similar to that used for collecting carpet clams (*Paphia undulata*). Preliminary results showing that survival rate was higher (90%) compared to the usual rate obtained (70-80%; Kamal, 1996) have been encouraging. The usual problems of barnacle encrustation and predators were minimal.

Stocking density

Stocking density of spat per acre depends on the size of spat. For spats of about 5000 pieces per kg, 150 to 200 tins of spat per acre appear to be the best stocking density. Expected yield per acre from 200 tins of 5000 pieces per kg spat is about 1,200-1,400 gunny sacks (each sack is about 80 kg of adult cockles). Some of the cockle densities recommended by the culturists from the various culture sites are as follows:

Number of spat (per kg)	Size of spat (mm)	Culture density (spat per m^2)
6,700 - 8,000	5 - 6	3,000 - 4,000
3,300 - 5,000	7 - 8	1,600 - 2,000
1,600 - 2,500	9 - 10	1,600 - 2,000
1,000 - 1,200	11 - 12	650 - 900
250 - 400	> 13	320 - 640

The most sought after spat are those of about 8,000 pieces per kg, but the most commonly available spats range from 5,000 to 6,000 pieces per kg. Some culturists buy spat in bulk and stock them in an area where they are culled from time to time using a bigger core (various mesh sizes for varying spat size) with a handle into grow-out areas. The stocking rate can thus range from 220 to 320 tins per ha. Spats brought to the culture area are sown during high tide, to enable the boats to go round distributing the spat on the seabed. Spats are poured off the sacks from the rear of the boat so that the propeller can help to distribute the spat in the water column. Or, spats are spread with a plate or scoop as the boat is moving. Spats are sown at a high density in a corner of the culture plot before being culled or spread into the grow-out area over the culture period.

Management

As usually practiced, the first thinning or culling is done after two months then every 3 weeks or so. In cases of deeper water of more than 3-4 m, no thinning is required because of the difficulty in collecting and distributing the cockles. The culture period is usually more than a year.

Harvesting

The culture period for cockles usually exceeds a year but this depends on the initial size of the spat used. Cockles are harvested from a boat during high tide by means of a core (coarser mesh size) with a handle. The average cockle size allowed to be harvested is no less than 31.8 mm for conservation purposes (Malaysian Fisheries Act, 1985). About 10-15 gunny sacks (weighing 80 kg per sack) of adult cockles can be harvested by 2 persons working 5-6 hrs a day. Harvesting of marketable cockles depends on demand, which is usually practiced on a contract basis. Some are sold in dried or canned form (Mohd. Noor, 1988).

Mussels

Green mussels (*Perna viridis*)

This bivalve, noted as an inexpensive protein source, is common in the Southeast Asia and is an important commercial species cultured in Thailand and the Philippines. Small-scale cultures are carried out in Singapore, Malaysia, Vietnam, and Cambodia. In most of these countries, mussel production was developed by artisanal fishermen who harvested them from the wild from bamboo fishing stakes during low tide. Green mussels are found clustered in the intertidal and sub-littoral zones. Owing to their ability to secrete byssal threads, they are found attached onto hard substratum. As in the case of cockle culture, mussel culture operation also involves four stages namely, spat collection, grow-out, management, and harvest.

Spatfall and Collection

Forecasting of Spatfall is very important to ensure the timely collection of spat on the cultch materials. Like cockle spats, mussel spatfalls occur almost throughout the year with peaks around February-May and October-November in Singapore and Malaysia (Cheong and Beng, 1984). However, their seasons and densities vary yearly and geographically.

Depending on the type of grow-out operations, countries have adopted various methods to collect mussel spat. Spats are collected from the culture sites or obtained from distant areas for transplantation. In Thailand, the pole method is popular wherein collected spats are left to grow to harvestable size in bamboo poles driven into the mud bottom (Sahavacharin, 1991). In the Philippines, bamboo poles, abaca ropes, coco wood and *cabo negro* (black natural fibre) are used as cultch for spat collection (Samonte *et al.,* 1992). In Malaysia, old fishing nets (trammel nets) are twisted to form a rope of 2 m length to collect mussel spat from the water column (Mohd. Noor and Choo, 1985) and the spats are allowed to grow to an average size of 20-30 mm before they are transplanted for the next phase of culture. During transplantation to the culture site, they are further wrapped with medical gauzes to prevent the spat from dropping off the cultch.

Suitability of grow-out area

The presence of mussel stocks in area is an important criterion in establishing spat collection/ culture site as this would ensure a reliable source of spat. Most of the spat collection farm sites are situated in sheltered estuarine areas. Some of the considerations for a good culture site are:

- presence of good mussel stock around the proposed culture site;
- well-sheltered from very strong winds and current;
- salinity range of 27-32 ppt;
- chlorophyll a content ranging from 15 to 40 mg per 1 seawater; and
- depth of water and substrate bottom depending on culture system.

Culture methods

Collected spats are transplanted to the culture sites using boats or lorries in the case of distant sites. The culture period usually takes about 7-8 mos depending on the size of the spat. Several methods are employed for the grow-out of mussel spat. In Thailand, the major culture areas are located near estuaries of large rivers where spat are collected on bamboo poles driven into the mud bottom and are grown to harvest size in the same area (Sahavacharin, 1991). A number of culture systems are employed in the Philippines (Samonte *et al*., 1992) namely:

- *On bottom culture:* This method is used in relatively shallow waters where spat collected on bamboo poles are relayed on the semi-muddy bottom of the farm which is located in estuarine areas.
- *Stake culture:* Since spats are collected using bamboo poles, the manner of staking appears to vary with the strength of water current and the depth, which differ in the various provinces. The sizes of stakes used and the distance they are placed apart also tend to differ. The advantage of this system is that it is cost-efficient and allows easy harvest.
- *Raft culture:* Rafts measuring 9x12 m composed of 40-50 posts are allowed to float within the confines of the bamboo posts in the first 2-3 mos. When the mussels become too heavy, the rafts are tied to the posts at a fixed position in the water column. The material for raft making varies from country to country depending on the culturists' capacity.
- *Rope-web method* (Rosell, 1982b): This method employs webbed synthetic ropes and bamboo poles. Two 6 m long synthetic ropes positioned 2 m apart are tied to bamboo poles positioned 5 m apart in the mud bottom. Another 40 m polypropylene rope is webbed between the two 5 m parallel baseline ropes in zigzag fashion at 40 cm intervals. Pegs are inserted at contact points with baseline ropes to prevent the sliding of zigzag lines when the top is heavy with mussels.

In addition to these methods, the rack culture is also used for mussel culture in Malaysia. The dimensions of racks are similar to those of the rafts (6.7x6.7 m), but they are stationary and are supported by 'nibong' (local palm highly resistant to seawater and marine borers) poles driven into the bottom. Racks can be relatively cheaper if made of mangrove poles.

Management

The very common management practices in mussel farming are:

- Thinning ensures better growth rates so that competition for space and food is reduced;
- Cleaning of bio-foulers such as barnacles, tube-worms, sponges and sometimes other mollusks require regular cleaning to ensure the appearance of the harvested mussel.
- Control of predators such as crabs, starfish, and puffer fishes are required since they prey on small mussels (20-30 mm long), which are most vulnerable.
- Maintenance of breeding stocks in the farm is a common practice. Mussel stocks are not harvested completely in order to enhance the population stock in the area.

Harvesting and Product Form

Mussels are harvested when they attain an average length of 7-8 cm. Handling of the harvest (declustering) is done either at the culture site or at the landing sites depending on the culture operation. In the Philippines, mussels are selectively harvested by cutting off their byssal threads with a sharp blade or stripped off the bamboo poles with spade or any hard object (Rosell, 1982b). But the former is noted to be a better method because it prevents damage to the byssal gland and prolongs the life of the harvested mussels. Usually the bigger ones are taken first, leaving the under-sized stock behind for the next cropping. Freshly harvested mussels can retain their freshness for about 1-2 days if they are kept moist in gunny sacks (Cheong and Beng, 1984). They are sold in various forms such as shell-on (fresh), boiled/steamed but shell-on, shucked but fresh and shucked but preserved (smoked, sun dried, pickled, canned, bottling, freeze dried etc.).

Horse/brown mussels (*Modiolus metcalfei*)

Horse mussel is another bivalve commonly distributed and cultured throughout the coastlines of Thailand and in some parts of the Philippines. The requirements of this species are different from the cockles and the mussels. Its culture requires a hard substrate with a mixture of silt, sand and mud and they are usually found to inhabit the intertidal shallow waters having depths of usually less than 3 m. Probably due to its low market demand (Sahavacharin, 1991), the culture of this species is not widely developed in Thailand except in Chonburi Province (Yan, 1990). The culture method is simple. Farmers collect spats when they average 5-10 mm in size and transfer them to suitable mud flats that usually ranges from 9 to 10 rais (6.25 rais = 1 ha). The culture period extends from 8 to 12 months and the mussels are harvested by dredging when they attain an average size of 20-30 mm. The production per rai ranges between 12 and 35 mt.

Oyster

Several species of oysters have been reported to be cultured in the region namely, *Crassostrea belcheri, C. lugubris, C. iredalei, C. malabonensis, Saccostrea* spp. and *Ostrea folium.* However, oysters of the genus *Crassostrea* and *Saccostrea* are most commonly and widely cultivated and these will be considered for the purpose of discussion here. Oysters in general require a hard substrate for attachment such as wood, plastic drums, roots of mangrove trees, stones or rocks. Both the spat and the adult inhabit estuarine areas and the culture systems employed depend on the type of substratum in the area.

Spatfall collection

Oyster culture in the region is still dependent on the spat supply from the wild. These spats are either raised in the vicinity of collection or can be transplanted to other suitable areas for culture. Spatfall is seasonal as in the case of cockles and mussels and varies with locality. In the Philippines, spatfalls peak within the months of May to September (Rosell, 1982a) while in Malaysia it coincides with rainfall when salinities drop, i.e. April to June and October to December (Wong *et al*., 1991; Ahmad *et al.,* 1992; Hasbullah, 1992).

Knowing the appropriate time to suspend collectors/clutches can be easily determined by using gonad maturity studies, plankton hauls, test panels, and observation of spat on substrates. The choice of cultches depends on the type of culture system employed. Some of the kinds of collectors used are:

- *Stake method* is very common. Often, bamboo poles or wooden stakes are driven into the mud and spats collected are grown until size at harvest is attained.

- *Hanging method* is considered effective and practical. The common cultches used are oyster/ coconut shells threaded by synthetic ropes or wires, netlon pieces dipped in a cement-sand mixture and these cultches are hung from long lines, rafts or racks.
- *Broadcast method* employs empty oyster or other mollusc shells, which are scattered on the bottom of an area where Spatfall is likely to occur, usually on a hard substratum.
- *Used tyres* are either used as a single piece or tied together to form a reef and placed in locations where Spatfall usually occur.
- *Rock method* is also very common in Thailand where rocks are used as substrate for spat collection. Rocks are piled in groups of 50-80 cm apart. Some farmers in Chonburi and Chantaburi Provinces, Thailand use concrete poles instead of rocks.

Suitability of grow-out area

Paramount criteria for site selection are the setting intensity and the duration of Spatfall for a profitable operation. However, if the spat is transplanted from elsewhere, then some considerations for the culture are:

- salinity range of 25-30 ppt. depending on the species;
- protection from strong winds if raft culture/long lines are to be employed;
- culture systems do not interfere with fishing activities or navigation;
- moderate depth, to reduce anchoring of culture systems;
- proximity to the farmer's village to reduce maintenance and operation costs and to simplify watch-and-ward.

Culture Systems

Most culture methods employed are semi-traditional and are more or less similar to the systems used for mussel culture. Some of the most common culture systems used are:

- *Rack method* is usually used in shallow areas, e.g. lagoons in Malaysia. They are stationary and their heights are adjusted according to water depth in the area during high and low tides.
- *Concrete pole tubes* have a dimension of about 15 cm diameter and 40 cm height (Sahavacharin, 1991). Oyster spat are cemented onto these concrete tubes and they are fitted onto bamboo stakes driven into the mud bottom of the culture area. The pole or tubes are placed in rows and the oyster spats are left there until they attain harvest size. This technique is widely practiced in Surat Thani Province, Thailand.
- *Raft method* employs structures made of good quality wood/bamboo/mangrove poles and acts to support and hang materials like trays (tyres, plastic trays/baskets, netlon holders) to hold the oysters for grow-out.
- *Longlines* that stretch about 50 m have been found economical in Malaysia. The simple structure consists of parallel polyethylene ropes lashed to 40 l plastic drums which serve as floats. The longline is anchored at either end, with allowance for the depth difference between low and high tides. Longlines are well suited for slightly exposed areas, allowing for better water circulation around the oysters to promote fast growth (Nair *et al.*, 1993).

Management

An advantage of oyster culture as an income generating activity for the culturists and fisherfolks is its relatively low operating cost. However, labour is required to maintain stocks in optimum condition and to maximize production. The basic maintenance operations are similar to mussel culture:

- *Controlling siltation and bio-fouling organisms* such as sponges, ascidians, barnacles and blister worms is important. Heavy siltation can foul culture trays, which can be overcome by using a water jet, vigorous shaking of the cultch or trays or removing fouling organisms manually.

- *Culling* oyster spats (if single spat are used) monthly reduces density and separates fast-growers from others to enhance growth rates. In other cultches, spats are left to grow until the large ones are harvested.
- *Controlling predators* such as crabs can be made by covering culture trays or baskets.

Harvesting

Harvesting methods depend on the culture system. Those hanging method employs declustering oysters from their cultch. Oysters cultured on hard substratum are knocked off and often their meat is shucked, especially if shell shape is not presentable. In the broadcast method, oysters are either handpicked (for small areas) or dredged (for larger areas) and selective harvesting is practiced whereby smaller oysters are thrown back to sea for the next cropping. Oysters separated during the spat stage to be cultured as single spat in baskets or in trays will be sold shell-on. Oyster meat is either sold fresh for stews, omelets or processed like frozen, salted, sauce and canned.

Pearl oysters (*Pinctada spp.*) and Mabe oyster (*Pteria penguin*)

Most countries in Southeast Asia (Indonesia, Malaysia, Philippines, Thailand, and Myanmar) have private farms for pearl oysters. Pearls are objects of high value while pearl shells are used for decorative objects (Gervis & Sims, 1992). Some of the pearl oyster species cultured are *Pinctada maxima, P. margaritifera,* and *P. fucata* for the production of spherical pearls while *Pteria penguin* is cultured for the half-pearl industry. Hatchery propagation of pearl oysters has been developed for *P. maxima* (Philippines, Indonesia, Malaysia, Myanmar, and Thailand) and *P. margaritifera* (mainly Philippines), but production is still limited due to heavy fouling in the grow-out areas.

Pearl culture operations typically involve three phases: collection, on-growing and pearl culture. Farming methods typically employed for pearl oysters are the raft and longline methods. Basket nets of various shapes and sizes are used for intermediate culture; choice oysters are hung in unit net panels with pockets or in galvanised wire baskets in waters 6-10 m deep.

Adult *P. maxima,* which is used for nuclei insertion, is about 25 cm, while *Pteria penguin* can range from 15 to 20 cm in length (Sahavacharin, 1991). Round pearls are harvested in 1-2 years, while half pearls in about a year. The major constraints facing the expansion of this industry are lack of trained personnel for nuclei insertion, limited seed supply, and the availability of nuclei.

Window-pane oyster (*Placuna placenta*)

Although this species is distributed throughout the region, it is a major export commodity in the Philippines. The industry is based on the shells and not for the meat. The thin translucent shells are used in the handicraft industry for window glazing, shellcraft, and other decorative items.

A sedentary benthic bivalve, it remains unattached in the bottom of bays, coves and estuaries with sandy-muddy or bluish muddy substratum in the interdtidal area at depths of 10 m (Rosell, 1991). A suitable salinity range of 18-35 ppt is required for this species; however, they can also be encountered in salinities of 2-40 ppt.

At present, no commercial culture has been reported, but successful trials have been conducted in the Philippines by some farmers who collect them from wherever and whenever they may be found and then transplanted to the culture site.

Other Molluscs

Abalone (*Haliotis spp.*)

There are about 100 species of abalones but only some are of commercial importance. The larger ones are common in temperate areas, the smaller ones in tropical waters. The common and most suitable species for culture in the tropics is *H. asinina* because of its comparatively large size (large fleshy foot), although other small abalones such as *H. varia*, *H. ovina*, and *H. diversicolor* have also been considered for culture. These species have been harvested from the wild to be sold live or in processed forms. The increasing demand and the lucrative prices offered for these gastropods have aroused the interest of research institutions in the region to develop hatchery propagation techniques and culture methods.

Although extensive research in the hatchery propagation of abalone and culture methods in tanks and ponds and net cages have been developed in Thailand, Philippines, and Vietnam, no commercial farm is in operation so far. This could be due to farmers' reluctance to gather wild or grow cultured seaweeds (another valuable fishery commodity) just to be fed to abalones. Moreover, abalones have slow growth rates (Anon; 1997).

Giant clam (*Tridacna spp.*)

Giant clams are the only known phototrophic animals which command high price for their adductor muscles. Populations of the tridacniids in Southeast Asia are in a state of decline due to reef degradation and overharvesting to meet commercial and subsistence needs (Deliani *et al.*, 1998; Tan & Zulfigar, 1998). Thus, mariculture of this bivalve has become a serious consideration to enhance the population in the wild (Govan, 1995), which requires large-scale production of these clams in the hatchery. Many countries in the region are actively indulged in seed production of tridacniids.

Most of the species like *T. maxima, T. squamosa* and *T. crocea* (mainly for aquarium) have been successfully induced bred and raised in land-based nursery or in ocean-based nurseries and grow-out systems. Several culture facilities are available in countries like Indonesia, the Philippines, Malaysia, and Thailand, which employ all or some of the above nursery and grow-out systems (Govan, 1995).

Constraints Facing the Mollusc Industry

Most problems faced by the industry in the region are similar and inter-related. Some of the more common but serious constraints are:

- **Inconsistent and inadequate seed supply.** Mollusc culture operations are dependent on the seed supply from the wild, which is highly seasonal. The wild seed supply being irregular and most often inadequate to fulfill the needs of the culturists, the industry has been unable to maintain or increase its production levels.
- **Poor post-harvest handling techniques.** Reports of diseases (hepatitis) have been one of the major factors that have affected the consumption and the marketing of shellfishes. Most shellfish produced are handled at landing complexes, which make use of nearby river water, that could be contaminated, to rinse the harvest. The shellfish are then packed into gunny sacks (common packing method) and the waiting period to be loaded onto lorries can sometimes be a few hours before finally arriving at the marketing outlets. This condition leads to a further deterioration of the quality of the shellfish. In some cases, the concentration of enteric or feacal bacteria far exceeds the World Health Organization's (WHO) standards or the Food Acts Regulation of certain countries in importing food products.
- **Harmful algal blooms.** Threats of red tide (often in the Philippines, Sabah, Malaysia, and

Indonesia) caused by dinoflagellates (*Pyrodinium bahamense var compressa*) often render shellfish cultured in the affected area unsafe for consumption.

- **Lack of regulatory measures in harvesting shellfish.** Most countries in this region do not have regulatory measures pertaining to the harvest of shellfish, especially for those with slow growth (abalones and *Tridacna*). This often results in the indiscriminate harvest and collection of shellfish irrespective of their sizes, obviously contributing to the depletion of wild stock that takes a long period to replenish.
- **Low market price/market demand for certain species.** Certain molluscs like mussels fetch very low prices locally or even abroad so that the price offered is not even able to offset operational costs. This deflects the farmers' interest to indulge in other more profitable culture operations like shrimp or fish farming.
- **Inadequate processing and packing systems.** The 'half shell' for oysters and 'live' market for other species have been identified as a most potential or lucrative outlet. Very few processed forms exist to extend their shelf life in the market. The most commonly processed shellfish are in the form of canned product, dried, smoked, pickled or salted and are not innovative enough to win new markets.

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