Bivalve Mariculture in India

(PEARL OYSTER, EDIBLE MUSSEL AND OYSTER)

A SUCCESS STORY IN COASTAL ECOSYSTEM DEVELOPMENT

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FOREWORD

The Asia-Pacific Association of Agricultural Research Institutions (APAARI), since its establishment in 1991, has been stressing on strengthening agricultural research and development in the Asia-Pacific region through mutual sharing/adoption of technologies developed by the NARS'. In this context, APAARI has so far published 15 success stories on diverse topics/themes of regional and national interest. These publications highlight significant breakthroughs, achieved in this region by NARS, and deal with crops and commodities, farming systems and management/exploitation of bio-resources. These success stories have focused on inter-institutional collaboration in sharing of available expertise and R&D findings to boost agricultural production.

Realizing the richness and potential of littoral bio-wealth of this region, and that several national programmes are engaged in exploitation of marine biodiversity, it was felt that some successful initiatives be reviewed and information synthesized for the benefit of the NARS. This success story on "Bivalve Mariculture in India" dealing with the pearl-producing pearl oyster and the protein rich mussel and edible oyster, which are important to the coastal villagers, is thus of great relevance. The Central Marine Fisheries Research Institute (CMFRI) located at Cochin in the South-West Coast of India, is one of the pioneer institutes which has over the last three decades contributed enormously towards management and use of marine wealth. It has been instrumental in developing a full-fledged pearl culture technology and techniques for mussel and edible oyster culture, and transforming this know-how to farmers. The efforts put forth by Dr V.N. Pillai

(Director, CMFRI) and his associates Drs K.K. Appukuttan, V. Kripa, T.S. Velayudhan, K.S. Mohamed, A.C.C. Victor, P.S. Kuriakose, P. Laxmilatha and P. Muthiah, in bringing out this well synthesized and illustrated information, are thankfully acknowledged. The case studies of cooperative participatory efforts as demonstrated through initiatives undertaken in the States of Kerala, Karnataka, Tamil Nadu and Andhra Pradesh, and technologies developed and practiced, will be found useful by other NARS engaged in similar research endeavours.

Overall, it is felt that this well illustrated account will add to our knowledge on this aspect of study, and dissemination of information and particularly technology transfer, will promote such R&D programmes within NARS so as to bring economic benefits to the rural communities in particular.

New Delhi
12th July, 2000

(R.S. PARODA)
Executive Secretary
APAARI

INTRODUCTION

India has a coastline of 8129 km of which the mainland coast accounts for 6000 km and the islands of Andaman and Nicobar, and Lakshadweep, the rest. Coastal aquaculture and mariculture occupy an area of about 120,000 ha providing employment to more than 200,000 people. However, as the present region under production forms only 10% of the identified potential area in the coastal belt, there is great scope for increased thrust for the development of mariculture.

The bivalve resources of India, comprising the pearl-producing pearl oyster and the protein rich mussel and edible oyster, have become an important source of income to the coastal villagers. The Indian marine pearls have now entered into the world gem trade after a gap of nearly three decades. The revival of this industry, which had flourished in the ancient times, has become possible only through the development of a full-fledged pearl culture technology by the Central Marine Fisheries Research Institute (CMFRI), Cochin.

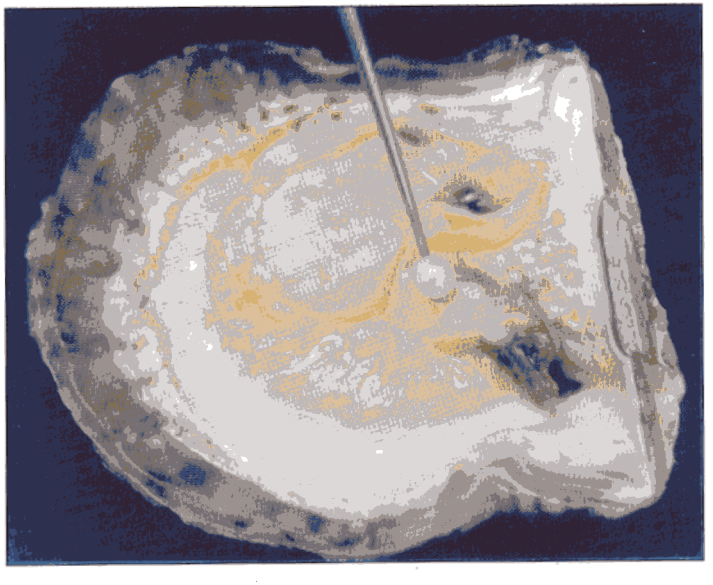
The CMFRI has also developed techniques for mussel and edible oyster culture similar to those followed in other countries. These have been upgraded and refined to suit the Indian ecosystems, which are characterized by frequent changes in environmental conditions predominantly due to the monsoon. Efforts were made to popularize these technologies in the maritime states of India by setting up demonstration farms with farmer's involvement. The social impact of these programmes is the development of a group farming activity supported by financial aid from village level rural development programmes.

The national annual mussel production, which stood at less than 10,000 tonnes till the beginning of this decade, has more than doubled due to development of mussel farms in the coastal areas. The edible oyster production from the natural beds was supplemented by farmed oysters produced through adoption of farming practices by fishers. Internal market development for bivalve meat through consumer awareness programme supported the growth of this new industry.

The technological developments made in the field of bivalve mariculture in India, its impact on rural income generation through the adoption of mussel and edible oyster mariculture technologies and development of entrepreneurship by the adoption of pearl culture technology are incorporated in this success story.

PEARL CULTURE

Pearl is one of the oldest of the known gems, produced by the living animal called the pearl oyster. India is well known for the production of natural pearls from time immemorial. There are recorded historical evidences that the country had exported this valuable merchandise to Greece and Rome more than 2000 years ago. India has a wealth of pearl producing oysters: the *Pinctada fucata* distributed in the Gulf of Mannar, Palk Bay and Gulf of Kutch and the blacklip pearl oyster, *P. margaritifera* in the Andaman and Nicobar Islands.



The Indian pearl oyster, Pinctada fucata, with a 5mm cultured pearl in situ

Pearl Culture Programme

Technology Development by CMFRI

The Indian pearl fisheries were compared at one time with the Persian Gulf fisheries for the production of the finest oriental pearls. Unfortunately this activity dwindled gradually and virtually came to a halt in Southeast coast around 1960's. The collections from Gulf of Kutch also ebbed out in 1966. In nature, pearl is formed in an oyster when some extraneous matter such as sand grain, piece of shell etc. enters the tissue of the oyster which causes irritation to it. As a defence mechanism, the oyster's pearl secreting cells of the mantle migrate into the tissue, multiply by cell division and surround the foreign particle and form the 'pearl sac'. This secretes the nacre, which gets deposited over the particle producing a natural pearl. It was in this context that a Pearl Culture Programme was started by CMFRI in 1972.

The technology for pearl production, based principally on the Japanese methodology of pearl production, was tried and developed successfully in the Indian pearl oysters. The technology

Cultured pearls produced using CMFRI technology in different farms along the East Coast of India

essentially involves the introduction of an artificial bead along with a secretory mantle tissue into a recipient oyster. The tropical marine environment of India is found conducive to foster the formation of perfectly spherical pearls within a period of 6-8 months. The brief details of the technology for production of high quality marine pearls and protocol are given in Table 1 and Fig. 1.

A well directed research on pearl culture was organized by the CMFRI in collaboration with the Government of Tamil Nadu as an *ad-hoc* scheme on pearl culture under the ICAR, from 1973 to 1978. During this period multiple production of cultured pearls was achieved and surgical equipments for nucleus implantation were also developed indigenously. This led to the establishment of a pearl farm at Krusadai Island by the Govt. of Tamil Nadu. Concurrently, pearl oyster spats were observed on mussel ropes hung in Vizhinjam Bay. This enabled the institute to build a pearl oyster stock through farming and subsequently start trial production of cultured pearls. Following this, the Govt. of Kerala executed a pilot project on pearl culture in Vizhinjam.

Though the technology of pearl oyster farming and pearl production were available indigenously, the natural beds of pearl oysters were 'barren' and there were apprehensions that the technology could not be put to use due to the dearth of pearl oysters. In this context, the CMFRI launched another research project for the production of pearl oysters under hatchery conditions. This project made a breakthrough in 1981 by large-scale seed production. This gave the answer to the critical predicament of paucity of resource for carrying out cultured pearl production. Thus, the CMFRI became the nucleus of pearl culture research and development in India.

Training and Human Resource Development

With indigenous developments in pearl culture technology, the CMFRI over the years has adopted an open policy of training. Possibly, this is the only centre that offers such training in pearl culture not only for Indian nationals but also to foreign technicians

Table 1: **Steps to be followed in undertaking a pearl culture venture**

Pearl culture site selection and implantation		
SELECTION OF SUITABLE SITES	Areas with • Salinity above 30 parts per thousand • Good phytoplankton production • Mild/moderate current • Low siltation • Depth 2 to 3 m and above	
SELECTION OF OYSTERS FOR OPERATION	Age of oyster	Above 1.5 to 2.0 years
	Weight	> 25 g (40 mm)
	Stage of maturity	Spent resting stage
	Overall health	Good, free from polychaetes/sponge trematode infections
CONDITIONING	Arranging oysters in a container with their hinge pointing downwards Narcotization of selected oysters by sprinkling menthol in the seawater Insertion of a small wooden peg between the two valves to facilitate nucleus implantation	
PREPARATION OF GRAFT TISSUE	Select healthy non narcotized oyster Cut mantle into thin strips of 5 cm length and 0.5 cm width Remove mucous and muscle from the mantle Cut the mantle strip into 20 to 25 pieces of 2–3 mm squares Keep cells live by adding Azumin/Eosin solution in sterilized SW and use within 15 minutes	
IMPLANTATION	Mounting oyster in the stand with the valves facing upwards Making incision at the right place and placing the graft mantle piece	Single implantation - in the gonad near the intestinal loop Double implantation - additionally, close to hepatopancreas Multiple implantation - more than double implantation
	Placing the sterilised nucleus on the graft mantle piece	
CONVALESCENCE	Placing the implanted oysters in fresh seawater with mild circulation for two to three days Maintaining water quality by water exchange Removing dead oysters and shifting the healthy implanted oysters into the natural environment	

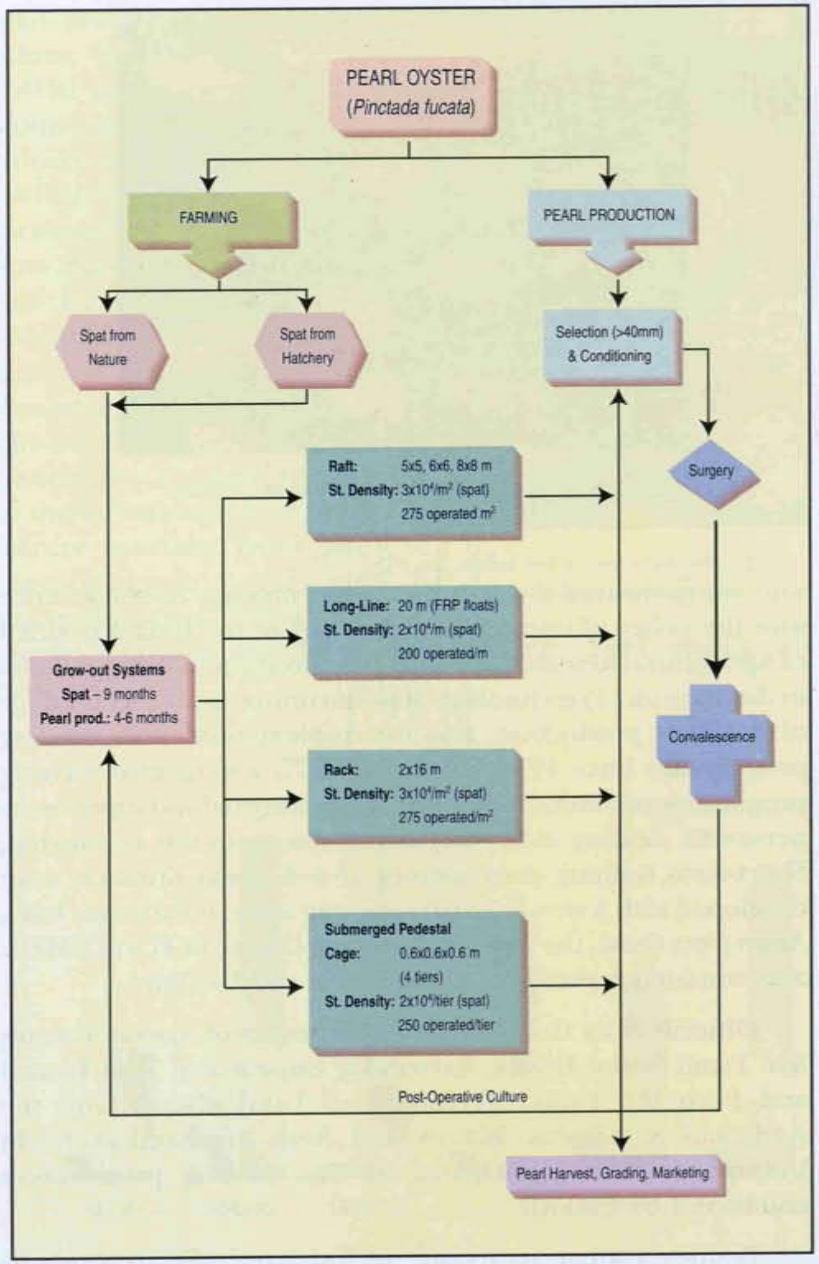


Fig. 1: Protocol for pearl oyster farming and pearl production in India

Hatchery produced and farm reared pearl oysters

who are sponsored through their governments. In consonance with the policy of transfer of technology of the Indian Council of Agricultural Research, the Institute developed training courses in the areas of: (1) technology of pearl culture, and (2 technology of hatchery production, and has implemented such training programmes since 1976. During 1976-77, a long-term training programme of 6 months duration for managerial and supervisory personnel dealing with pearl oyster resources was conducted. Short-term training programmes of 4–6 weeks duration were developed with a view to impart training at the technicians level. Apart from these, the Trainers' Training Centre (TTC) of CMFRI also conducts training programmes in pearl culture.

Officials from the fisheries departments of maritime states like Tamil Nadu, Kerala, Karnataka, Gujarat and West Bengal and from the Union Territories of Lakshadweep, and the Andaman & Nicobar Islands and from the Konkan Krishi Vidyapeeth have participated in the training programmes conducted by CMFRI.

Besides Indian nationals, technicians/officials/students sponsored from other countries like Philippines and Belgium

have been trained in Pearl culture by CMFRI. In 1991, CMFRI was the venue for the training programme on Pearl culture under the FAO/ UNDP/NACA project on Sea Farming in which 26 trainees from nine South, Southeast and East-Asian countries (Bangladesh, China, Indonesia, Korea, Malaysia, Myanmar, Philippines, Thailand and Vietnam) participated. They were trained on the various aspects of pearl culture starting from site selection to pearl surgery and pearl production. The training courses conducted and the number of trainees 1994 onwards are given in Fig. 2.

A skilled technician implanting graft and nucleus into an oyster

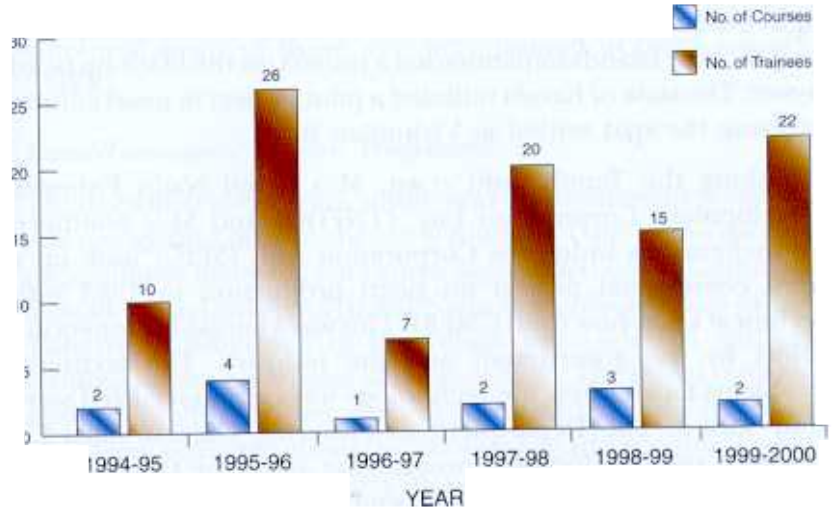


Fig. 2: Pearl culture training courses conducted by CMFRI

FAO-NACA training programme for Southeast Asian countries conducted by CMFRI during 1991

Technology Adoption

The impact of training programme was positive and some maritime states initiated their own projects on pearl culture. The Union Territory of Lakshadweep started a project at Bangaram Island using the local pearl oyster resource. The Central Agricultural Research Institute of the ICAR at Port Blair, Andaman and Nicobar Islands implemented a project on the black-lip pearl oyster. The state of Kerala initiated a pilot project in pearl culture utilizing the spat settled at Vizhinjam Bay.

Along the Tamil Nadu coast, M/s Tamil Nadu Fisheries Development Corporation Ltd. (TNFDC) and M/s Southern Petrochemicals Industries Corporation Ltd. (SPIC) took up a joint commercial project on pearl production in 1983 with technical know-how from CMFRI. This was a laudable pioneering effort by the government and the industry. The technical problems faced when the technology was commercialized were duly solved. The Department of Fisheries, Gujarat started a research and development programme along the Gujarat coast with the natural pearl oyster resource. Later, to enhance the depleted stock, pearl oyster spat were also supplied from the shell

PEARL CULTURE TECHNOLOGY DEMONSTRATION

In 1997, ICAR provided US $ 71,430 to CMFRI to demonstrate the profitability of pearl culture ventures to the industry. This activity is successfully going on at the Mandapam regional centre of CMFRI and income worth US $ 26,000 has already been realized. Besides, pearl oyster spat are regularly supplied to the industry on cost basis from this project.

As a spin-off to this activity, several young women in the locality are being trained in pearl surgery in this pearl farm and these women find ready employment in the fledging pearl industry developing along the southeast coast of India.

fish hatchery of CMFRI at Tuticorin. However, commercial ventures by industrial houses were restricted to the areas around the natural pearl oyster beds in India.

Women were found to be more efficient in nucleus implantation and activities related to pearl culture. Several private entrepreneurs employed many of those who were trained in pearl surgery at CMFRI.

Rural/Community Welfare Programme

The need to develop pearl culture as a rural upliftment programme was recognized only in the early nineties. One of the successful programmes involving fishermen was carried out at Valinokkam, a small coastal village of Tamil Nadu in southeast coast of India. Twenty-five fishermen of the village were selected and given training in various aspects of pearl culture. The initial reluctance noticed among the fishermen was overcome by proper motivation. They were educated about the importance and economic returns of pearl culture. Active participation of the fishermen and their family members was observed from the fabrication of grow-out structure to pearl harvest. Part of the pearls produced was given

to the fishermen as an incentive. The scope for large scale pearl production through village level community participatory programmes with proper technical and financial support from developmental organizations was clearly indicated by the 'Valinokkam Bay Programme'.

An evaluation of the economics of pearl culture was worked out based on the pearl culture programme at Valinokkam Bay in 1993 (Table 2). The rate of return was found to be 56.7%.

Table 2: **Pearl production/culture programme at Valinokkam Bay**

Valinokkam pearl culture – A group farming success						
Number of oysters implanted			9414			
Total expenditure incurred			US $ 1571			
Total pearls harvested			1849			
Pearls distributed to fishermen			250			
Revenue earned from sale of pearls			US $ 2178			
Expenditure incurred (as percentage of total)						
Raft	Cages	Pearl oyster (for implantation)	Pearl oyster (for graft tissue)	Shell bead nuclei	Labour	Miscellaneous
24	18	24	2	17	6	9

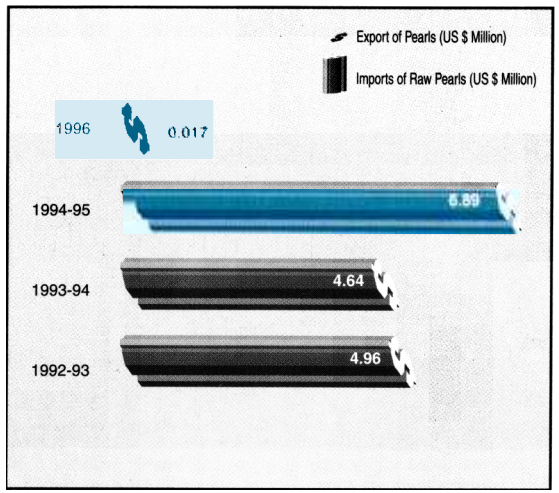
Possibility of pearl production along the West Coast in the Arabian Sea during the post-and pre-monsoon period (December to May) has been experimentally proved. But the strong upwelling currents and the turbid sea cause disturbance to the farm structure and the oysters during June to September. However, the nacre formation is faster than that along the East Coast. The quality and lustre of the pearls are comparable to those produced in the natural pearl beds in the Bay of Bengal. Commercial ventures in the Arabian Sea are yet to be developed.

View of offshore demonstration farm with both rack and raft method in the Gulf of Mannar, East Coast of India

Industrialization of Pearl Culture

Production of good quality pearls by the industrial houses has proved beyond doubt the soundness of the technology. Pearl culture is a composite industry like textiles, with different components viz. mother oyster culture, pearl production, processing and marketing. Each component is a specialized field requiring separate technology, skill and equipment. The Indian pearl industry has developed in the recent years, with several companies engaged in pearl production (ITAP Ltd, Tuticorin; Orkay Company, Mandapam; Master Pearls Ltd, Chirala; Pearl Beach Hatcheries, Visakhapatnam). What started as an experiment in 1972, has supported the growth and development of an industry. Table 3 shows the chronological events in the development of pearl culture as an industry in India. While India has been a net importer of raw pearls during the early nineties, from 1996 onwards, it has also been able to export cultured pearls albeit in small quantities (Fig. 3).

As mentioned earlier, it was the Government of Tamil Nadu and the SPIC, which started commercial production of pearls for the first time in the country. Later, after a gap of nearly a decade,



3: Indian xport pori

Table Chronological events in the development of pearl culture industry in India

Significant achievements in Pearl Culture in India	
1972	Initiated a project on pearl culture at Tuticorin Research Centre of CMFRI along the southeast coast
1973	Production of first cultured marine pearl in India
1981	First batch of pearl spat produced in Hatchery
1985-87	Initiation of pearl culture programmes in different maritime states
1985-90	Sea ranching of pearl oyster larvae and spat to revive the natural stock
1991	India hosted the FAO/NACA* training programme on pearl culture at CMFRI – imparting training on pearl culture to trainees from other South, Southeast and East Asian countries
1993	Village level pearl production through direct involvement of small-scale fishers. Pearls worth US $ 2178 were produced
1994	Pearls produced along west coast through farming operations in the Arabian Sea
1996-99	Signing of Memorandum of Understanding with private entrepreneurs
1997	Development of an indigenous pearl nucleus upto 18 mm size by a private entrepreneur

Network of Aquaculture Centr n Asi

An Australian black pearl produced using an Indian nucleus developed by Mr A.K. Sonkar, an innovative entrepreneur from Allahabad, India

other firms also started pearl culture programmes. Some of the pearl farms are located in the Krusadai Island while others are in the Palk Bay, Gulf of Mannar and in Andhra Pradesh (Fig. 4).

Fig. 4: Location of pearl culture demonstration farms set up by CMFRI and established commercial/community farms set up along the East Coast

In the forthcoming years thrust will be given to develop pearl culture as a community programme involving fisherwomen. On the research front, techniques to produce pearls in onshore tanks with artificial feeding and by laboratory tissue culture are being attempted.

MUSSEL FARMING

Marine mussels form one of the most dominant cultivable species all over the world. They give the highest conversion of primary producers (phytoplankton) to human food, and culture of mussels in the column waters can increase the seafood production several fold. In India, two species of marine mussels (green mussel *Perna viridis,* and the brown mussel, *P. indica*) are distributed in the rocky coastal areas where they support a traditional sustenance fishery, but, scope for increasing natural production from the existing beds is rather limited.

During post-monsoon period there is heavy settlement of mussel spat along the west and east coasts in the intertidal

Rich carpet green settlement of mussel seed near Cochin

and subtidal rocky areas. During this season many millions of mussel seed are attached to the hard substratum, but only a small percentage of these grow to become adults, mainly due to sand deposition and receding tides. The mussel culture technology developed by CMFRI during the early seventies envisages using these perishing spat for seeding ropes.

Mussel Farming

Technology Development

Giving priority to the development of a technique for farming mussels, the CMFRI started a project at Vizhinjam in Kerala in 1971. In 1976, at Calicut, attempts were made to develop open sea farming of the green mussel. The programme was extended to the east coast at Madras during the same year. All these efforts led to the development of technology for mussel culture in the open sea and in protected bays. The mussel seed collected from the natural beds are wrapped around a thick nylon rope by using a biodegradable cloth, which degenerates within a fortnight. The seeds gets attached to the rope by this time and continue to grow there utilizing the natural food. These 'mussel ropes' are suspended from grow out structures like raft or long line deployed at a productive and unpolluted site (see-methods of farming). The complete protocol developed for farming marine mussels in India is shown in Fig. 5. Harvestable sizes are usually attained within 4-6 months depending on the area of grow-out.

Maritime states along the West Coast of India have extensive estuaries, which open to the Arabian Sea. These estuaries are subjected to wide variations in hydrographic condition due to the southwest monsoon during June to September and a less intense northeast monsoon from October to November. The mean of annual rainy days in Kerala has been estimated as 130 days and of this, 66% is during June to September, 19% during October to December and 15% during January to March. Based on the hydrographic condition, in most estuaries, two phases *viz.*, a marine phase during December to May, and a brackish

METHODS OF FARMING

Rack Method

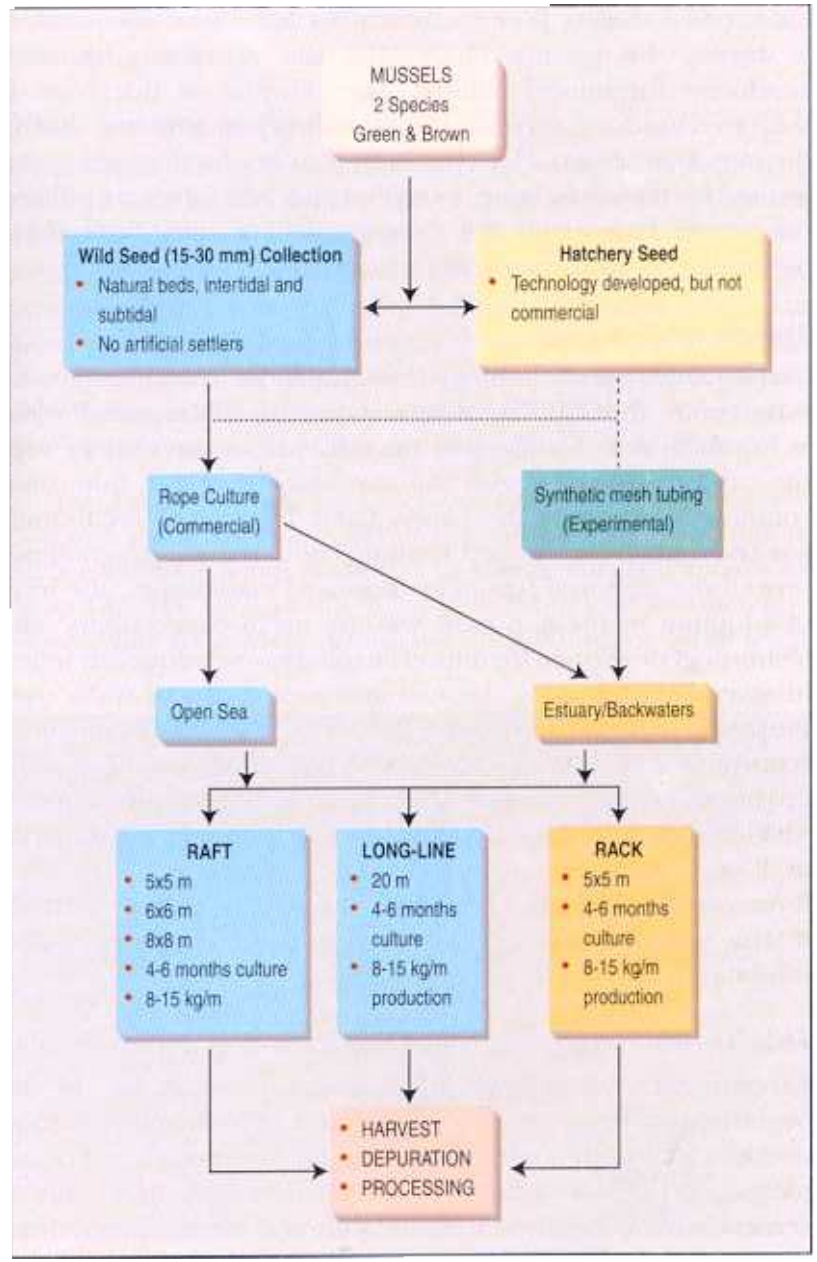
This method is especially suited for estuaries and shallow seas. Bamboo or Casurina poles are driven into the bottom spaced 1-2 m apart. These stakes are connected horizontally with poles. The horizontal poles should be above the level of water at high tide. Seeded rope can be suspended into the water for farming from these poles. Three seeded ropes can be suspended from one square metre area of the rack.

2. ***Long-Line Method***

This method is considered ideal for unprotected open sea conditions. Synthetic rope of 16-20 mm diameter is used for the long-line (main line). The main line is supported with 220 litre barrels tied to it, spaced at 5 m. The long-line and barrels are anchored in position at either ends using concrete blocks and nylon ropes. Seeded ropes are suspended from the long-line.

Raft Culture

Ideal for open sea conditions which are not rough. Square or rectangular rafts are made with sturdy bamboo or Casurina poles. Buoyancy for the raft is given by tying 5 barrels of 200 litre capacity (metal oil barrel painted with anticorrosive paint or synthetic barrel). Ideal size of the raft is 5x5 m. The rafts are to be positioned at suitable site in the sea using anchors (grapnel, granite, concrete). Three seeded ropes can be suspended from one square metre area of the raft.



water phase during June to November have been observed. It is during the marine phase that the ecosystem becomes conducive for mussel culture. The offshore of this coast is subjected to strong currents and upwelling phenomenon during the monsoon season. However, in the fair season these areas can be used for mussel farming. Long line units and rafts were utilized for mussel farming in the deeper offshore sites. Both these methods proved to be highly successful.

Transfer of Technology

Consequent to the technology development, as a part of extension programme, the CMFRI took up an Operational Research Project at Kovalam, near Madras on integration of mussel culture with the capture fisheries, with the involvement of the fishermen community. Similarly, the Lab to Land Transfer of Technology was taken up at Calicut and Karwar. Though these programmes proved the technical feasibility of mussel mariculture, the level of adoption by the end users was not up to expectations. The technology developed for mussel farming was subsequently tested in several places along the east and west coasts of India over the past 20 years, and has been improved for large-scale production. It proved the technical and economic viability of growing mussels on ropes, besides proving the advantages of a tropical environment, which reduced the duration of culture to five months as compared to 2 years in temperate waters. The constraints which were foremost in stalling the development of mussel culture industry in the seventies and eighties were, lack of awareness, social inhibitions and finance.

Field Demonstrations with Direct Involvement of Fishers

Perceiving the drawbacks in extension programmes, in the beginning of nineties, an action research programme was initiated for location testing as well as for disseminating farming technology. It was decided to set up demonstration units at several sites along the coastline with the direct involvement of fishermen. This led to the growth and development of mussel farming as a rural development programme especially

in the southwestern parts of India, in the states of Kerala and Karnataka (Fig. 6).

Mussel Farming in Kerala

Kerala state along the southwest coast of India is known for its traditional mussel fishery and the state consumes more than what it produces. The feasibility of utilizing the extensive coastal areas for mussel farming was proved by the demonstration programme implemented with the active participation of local fishermen in these areas. Simultaneously, fishermen were taught the significance of depuration. Mussel being filter feeders accumulate bacteria, heavy metal etc within their tissue which has to be removed by placing them in clean seawater.

In one of the open sea demonstration programmes done in the Arabian Sea near Cochin (Andakaranazhi), five longline units each 20 m long, anchored by 150 kg concrete blocks and floated by 100 litre plastic floats were fabricated and launched by involving fishermen. About 100 mussel lines of 4-6 m length

Fig. 6: Location of CMFRI's demonstration farms and the subsequent commercial farms which developed around such demonstrations

were hung at an interval of 0.75-1 m. Average production per metre length of the rope was 10-12 kg at harvest. From this farm, about 1.0 tonne of mussel was harvested. This programme aroused the interest of local fishermen to initiate similar mussel farming.

Women farmers in North Kerala cleaning mussel seed for subsequent seeding onto ropes

At another site near Cochin (Narakkal), mussel culture was done by the raft method. A bamboo raft of 25 m^2 was launched at a depth of 4 to 5 m with the help of the fishermen. Mussel seeding was done by the local women after collecting seed from

A farmer tying his mussel rope onto a raft in the Arabian Sea near Cochin (Kerala)

Women farmers near Cochin seeding clean mussel seed onto ropes

the intertidal zone. About 58 seeded mussel ropes of 3m length were seeded and suspended from the raft. Mussel seed was also stocked in nylon net bags of 1.5 to 2 m in 5 to 6 pouches separated by knots tied at equal intervals to reduce labour and time. In each tube, mussel seed were stocked @200 g/pouch and 28 net tubes were prepared.

A seeded mussel rope ready for suspending on a grow-out structure near Cochin

After a grow-out period of 4 months, the mussels were harvested. The profit from the sale of mussel meat was given to the fishermen who had actively participated in the farming programme. To create awareness among the local people about the profitability of mussel culture, a small function was held in which the President of the village governing body (Panchayat) handed over the profit to the fishermen. The fishermen also spoke about their experience. Motivated by the profit earned, these fishermen fabricated their own rafts and initiated mussel farming in the subsequent seasons. The village governing bodies also recognized and identified mussel culture as a viable programme for employment generation among the rural fishers and financial support was extended to them. This marked the beginning of commercial mussel culture in the Arabian Sea by the small-scale fishers.

In another demonstration farm in central Kerala, integrated culture of mussel and oyster was done. In addition to rack, small long lines were also launched. From the demonstration unit about 1.7 tonnes of shell-on mussel and oysters were harvested.

Convinced by the feasibility of mussel culture, the local fishers of this area set up their own mussel farms with technical guidance from CMFRI and financial assistance from local governing bodies. From the ensuing season onwards, different fisher groups took up mussel farming as a seasonal avocation and farmed mussel production in the region was trebled. These farmers found that harvesting mussels in a phased manner from the time they reach marketable size gave higher profits (Fig. 7).

Community Welfare Programme

Compared to the open sea, the estuarine ecosystems are less turbulent and shallow (<4m). Accordingly, racks were constructed in different estuaries to suspend the seeded ropes. The first site was in Padanna (Kasargod region), which is famous for its offshore mussel fishery. About 100 seeded ropes were suspended during January 1996, which reached harvestable size within 5

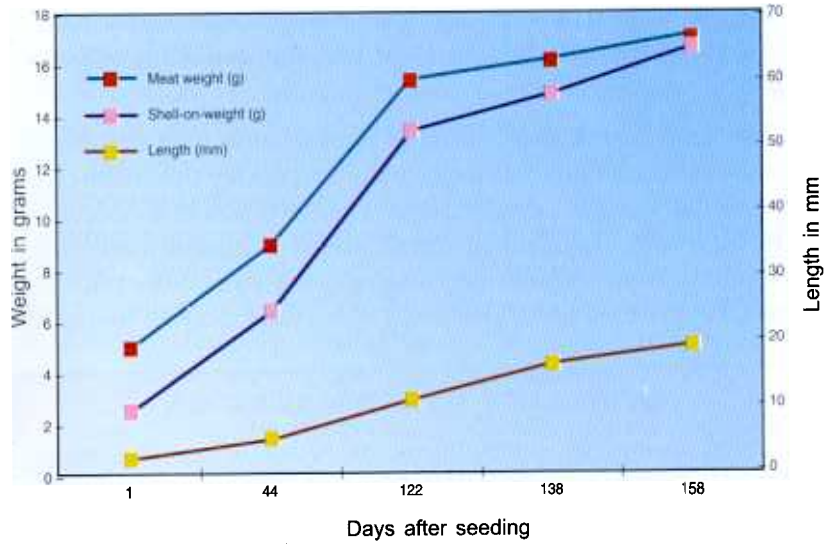


Fig. 7: Average growth in weight and length of mussels cultured in an estuarine system (Chettuva Estuary in Central Kerala)

Two month-old mussels suspended from an estuarine rack in North Kerala

months with a total weight of 12-15 kg/m length. A farmer who was impressed by the farming methods set up his own farm for mussel in a 200 m^2 area and seeded 175 ropes during the same period. The meat yield was 30% of shell-on weight. This was the first instance of large-scale mussel farming in the estuaries of India. This demonstration impressed the local mussel picking

families as well as the village level co-operative sector banks and what followed was a virtual revolution in mussel production from the region.

The scientists of the CMFRI in consultation with the district administration created a master plan to transfer the technology to potential women beneficiaries. The DWCRA (Development of Women and Children in Rural Areas) was identified as the most suitable scheme intended for groups of women beneficiaries below the poverty line. The local governing bodies identified

TECHNOLOGY ADOPTION BY WOMEN

In 1996, groups of women from the North Kerala (Kasargod district), started their own mussel farms with the financial support extended by the Development of Women and Children in Rural Areas (DWCRA) and Training of Rural Youth in Self Employment (TRYSEM). The entire farming operation viz., starting from seed collection to marketing was done by the women themselves. They were able to pay back the loan within the stipulated period. In succeeding years the farming activities were intensified by the involvement of more groups. Now, mussel farming is a part time vocation of the coastal women of North Kerala. The local banks and district administration have taken a lead in providing financial assistance to these fishers. Mussel farms are usually set up by November-December and the crop is harvested before June (to avoid large-scale destruction due to monsoon). Though, it is only seasonal, women have recognized that it is something which they can do with minimum effort and financial commitment.

Women farmers checking the health of their farmed mussels in a farm under the DWCRA scheme

the beneficiaries with the help of village extension officers and district administration. The selection criteria took into consideration (i) primary school as the minimum education level; (ii) age of the beneficiaries between 28-62 years, and (iii) fisheries/agriculture as the major occupation. After the selection of beneficiaries, a series of awareness camps on mussel farming were conducted by the institute in each panchayat (village). Beneficiaries were given training in their own farms from seeding to harvesting. One-day workshops were organized in different villages involving bank officials, officers of the district administration and village extension workers.

Loans from the government developmental agencies like DWCRA (Development of Women and Children in Rural Areas), IRDP (Integrated Rural Development Programme), TRYSEM (Training of Rural Youth in Self Employment) and Farmers Co-operative Banks to newly formed village mussel farming groups (average 13 members in each group) resulted in starting of several mussel farms in this region (Table 4). All technical help to the farmers was provided by the CMFRI.

Table 4: **Loan and subsidy provided to women mussel farmers in Kasargod district of Kerala under the DWCRA scheme**

	Women Mussel Farming Groups						
Particulars	**1**	**2**	**3**	**4**	**5**	**6**	**Average**
No. of beneficiaries in each group	13	15	13	12	15	11	13
Amount of Loan (US $) for 5 years	2786	2143	2143	2738	3143	2334	2548
Amount of Subsidy (%)	33.3	50	50	50	50	50	47.2
Revenue Earned in one year (US $)	1950	1500	1650	1917	2200	1634	1809

Impact of Mussel Farming

The experiences of CMFRI, in transfer of technology programmes have clearly shown that fishermen can accept a scientifically proven technology only if they actually observe the benefits from it. Participation by the villagers was found to make the demonstration and adoption processes a sure success. Though the culture technique is the same, to give wider publicity, different small mussel farms were set up in the estuarine systems of this state. The overall social impact was the emergence of mussel farming as a group/community activity.

The establishment of mussel farms in Kerala State led to a dramatic increase in farmed mussel production (more than 500 tonnes in 1998). As a direct result of this, new marketing channels were opened up and now there is wider acceptance by the public about mussels as quality seafood. The overall impact of this research and development efforts carried out in a phased manner is given in Table 5.

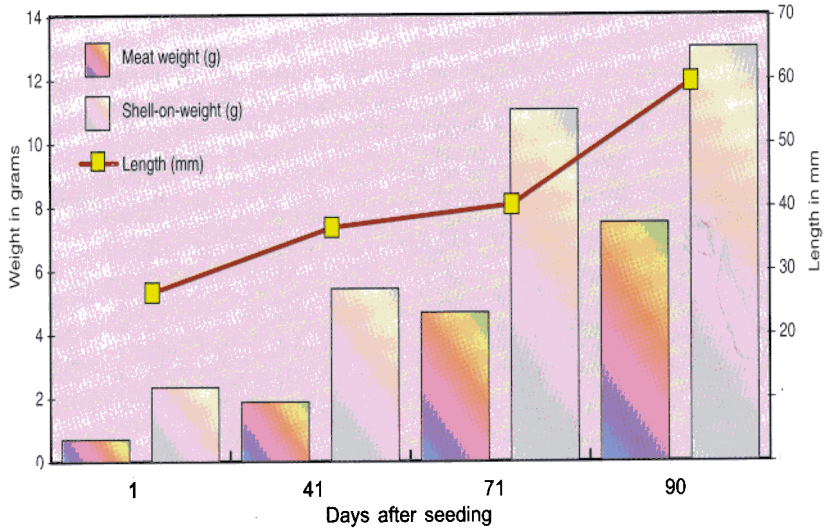


Fig. 8: Average growth in weight and length of mussels cultured in the Arabian Sea (off Narakkal in Central Kerala)

Table 5: **Impact of demonstration of mussel farming in Kerala**

	Scientific outcome	*Social impact*
Open sea mussel farming		
Phase I: 1995-96	• High production rates	• Participation of fishers only in the institutional activities
Phase II: 1997	• High production rates and growth rate (Fig.8) 15 kg per metre. • Possibility of two crops, Nov–Feb; Mar-May.	• Motivation for farmers to set up own farms • Approval of financial aid to mussel farmers • Emergence of open sea farming as a group farming activity
Estuarine mussel farming		
Phase I: 1996	• High survival (>95 %) and growth of mussels in estuaries • Low fouling	• Privatization of mussel farming • Group farming activities by women under IRDP/DWCRA TRYSEM
Phase II: 1997	• Integrated bivalve farming of mussel and oyster • Harvesting mussel in a phased manner	• Motivation for farmers to set up own farms • Approval of financial aid to mussel farmers • Employment opportunities for women during seeding and harvesting • High consumer demand for farmed mussel

Women farmers displaying their harvested mussels from a farm in North Kerala

Harvested green mussels ready to be processed and marketed

Mussel Farming in Karnataka

Karnataka is characterized by a coastline consisting mainly of sandy beaches with some rocky patches and islands. Demonstrations of mussel farming were successful and this led to technology adoption in certain coastal areas (Table 6).

Along the coast, long-line culture of mussels was demonstrated in 1996 in two areas where mussel beds and seasonal small-scale fishery occur. Long-lines each measuring 20 m of 24 mm thick nylon rope were moored in the sea at 8 m depth using

The long-line unit being launched in the sea off Karwar (Karnataka)

Table 6: **Impact of demonstration of mussel farming in Karnataka**

Type of ecosystem	*Scientific outcome*	*Social impact*
Open-sea	• High production rates	• Utilization of easily available material for fabrication of long-line • Motivation for farmers to set up own farms
Estuarine	• High survival (>95%) and growth of mussels in estuaries • Fast seeding and less labour for mussel culture using net bag	• Motivation for farmers to set up own farms • Approval of financial aid by BFFDA to mussel farmers • NABARD approves bankable schemes for mussel farming

rock anchors and 100 l FRP (fibre reinforced plastic) drums. Motivated by the CMFRI's demonstration, a small scale gillnet fisherman in Byndoor launched his own mussel line during December 1996. With CMFRI's help, he set his long-line at a depth of 6 m. Each seeded rope measured 4 m. Floatation was ensured through small net buoys and FRP drums. He looked after his line by examining them during his fishing trips in

Seeded mussel ropes ready to be taken to the offshore long-line

the sea. In total he harvested close to 400 kg of mussels from his single line and it fetched him US $130. The profit margin was comparatively high because many of the materials he used were those already available with him.

Consequent to the success of long-line demonstration, estuarine rack culture of mussels was demonstrated by the CMFRI in Mulky estuary about 30 km north of Mangalore. Racks were constructed using bamboo poles during the first week of November 1996, when the salinity in the estuary rose to above 25 parts per thousand. Novel tubular net bags made of old stretchable purse seine nets were designed to prevent mussel seed slippage. This demonstration paved the way for developmental funding from the Brackish water Fish Farmers Development Agency (BFFDA) to fishers. Those who availed this support were able to harvest the crop profitably and repay the loan. Besides, the National Bank for Agriculture and Rural Development (NABARD) approved mussel farming as a bankable scheme having IRR (internal rate of return) above 50% and benefit-cost ratio of 1:1.34.

Mussels have traditionally been the food of the working class, but in recent years there has been a growing interest in mussels among higher income consumers as well. As mussels are a relatively low priced product, international trade in the live form is limited by the transport costs associated with shipping live/fresh animals where the meats constitute a minor portion of the live weight. Export of mussel products from India is relatively recent and the quantities are not substantial (see section on post-harvest and marketing).

Farmed green mussel ready for harvest from long-line in Karnataka State

EDIBLE OYSTER FARMING

Oysters occur in shallow waters and form subsistence fisheries in several coastal regions along the Indian coast. Of the six species of oysters, the Indian backwater oyster, *Crassostrea madrasensis* is the dominant species having a wide distribution. The annual catch which was estimated at less than 4000 tonnes was substantially increased in the recent years due to farming practises in the estuarine systems. Characters like high tolerance to environmental variation and rapid growth have made oysters a candidate species for commercial farming in some parts of India. Being a filter feeder, it gives high production per unit area and eliminates the cause for additional expenditure on supplementary feed.

Technology Development and Transfer

Since the early seventies, CMFRI has taken up R&D programmes on all aspects of oyster culture and as a result, a complete package of the technology is now available in the country (Fig. 9). In 1978, a Lab to Land project on edible oyster was implemented along the East Coast (Tuticorin) with farmers participation. The beneficiaries were selected after a benchmark survey giving priority to fishers affected by the mechanization of inshore fishing fleets. Proper orientation training programmes were conducted wherein various aspects of the technology were demonstrated. This led to the establishment of 33 farms using the rack and tray method. However, this did not lead to sustained oyster farming in the region. The problems identified were several, among which the main constraint was the high cost of production with reference to the market price.

OYSTER FARMING PROCESS

- Oyster seed is collected either from the natural beds or produced in hatcheries, on suitable cultch materials.
- For spat collection from wild, suitable spat collectors are set at the appropriate season. For Indian conditions, the rack & ren method is advocated for which the oyster shell ren is used as spat collector. The rens are made by stringing 5-6 cleaned oyster shells on to a 3 mm nylon rope at spaced intervals of 15-20 cm. The collectors are suspended from racks at the time of settlement of spat.
- The rack and ren method is most ideal for shallow estuaries, bays and backwaters. A series of vertical poles are driven into the bottom in rows to which horizontal bars are connected on top of the poles. Oyster strings (rens with spat) are suspended from the racks. The spat collection and further rearing can be carried out in the same farm site.

  The oysters reach harvestable size (80 mm) in 7-8 months. Harvesting is done manually. The meat yield is 10% of the total weight. 80-100 tonnes/ha (10-12 kg/string) is obtained by this method of culture.

Ren spended in an estuary to capture edible oyster seed during the spatfall season

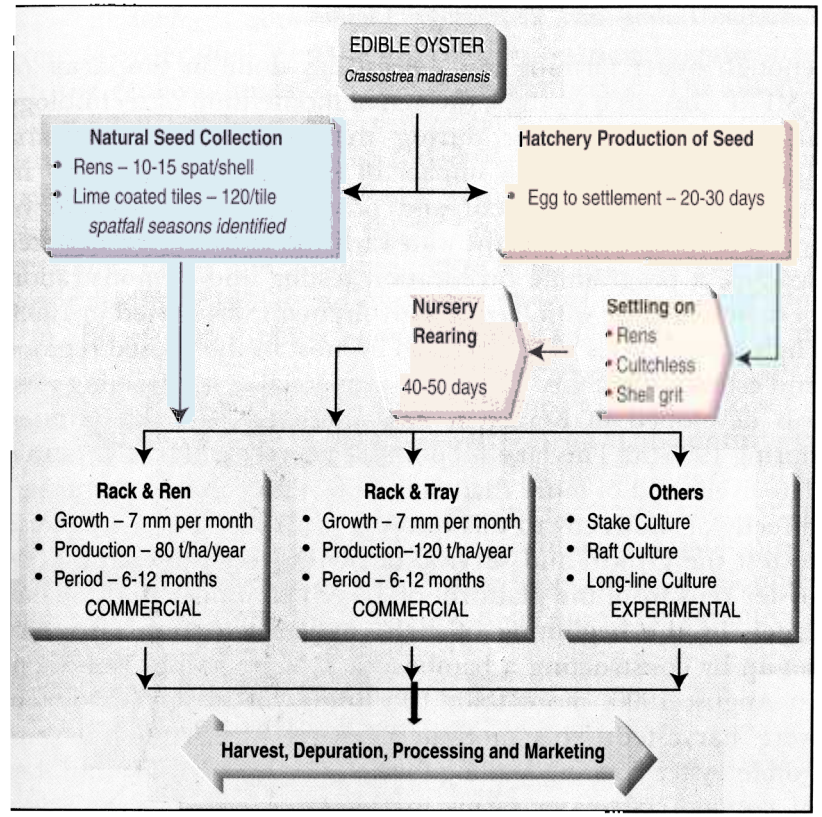


Fig. 9. Edible oyster farming protocols followed in India

Further, in 1978, fishers could not overcome the psychological barrier of considering mariculture of oysters as an additional avocation.

Following this, the scientists of the institute developed a new cost effective method of farming called the rack and ren method (Fig. 9). This method reduced the cost of production of oysters very significantly. Consequently, in 1991, the institute collaborated with NABARD to implement a scheme (as a bankable project) on farming oysters using the rack and ren method.

Location Testing and Technology Adoption

Though oyster farming was successfully done in the farms of CMFRI's research centres, the actual momentum of technology adoption was felt only during the past five to six years. Table 7 summarises the impact of such successful efforts in research and development and promotion/dissemination of technology. Considering the wide variation in the different water systems, a programme on location testing and demonstration of oyster farming with farmer's involvement was started in 1993. High growth rates were obtained in most of the coastal regions and estuarine systems. The first commercial oyster farming area was developed in Kerala in Ashtamudi Lake (Dalavapuram) during 1995-96. This lake supports a wide range of bivalve fauna. The livelihood of more than 3000 villagers of this area is linked directly or indirectly to this resource. In 1993, a trial was done to test the growth and survival of oysters by suspending a few oyster rens from the platform of a Chinese dipnet in the Lake. Later, by the beginning of 1994, a demonstration farm was set-up by constructing a bamboo rack by involving fishermen. In August 1996, more than 100 tonnes of full-grown oysters were harvested. This motivated several farmers to arrogate edible oyster farming leading to the establishment of a number of commercial oyster farms in this large estuarine system.

A proud farmer holding fully-grown oysters in a farm in Ashtamudi Lake (Kerala)

The farmers were advised to collect oyster spat by placing rens of oyster shell from the bamboo/ wooden racks constructed in the estuary during the post-monsoon period. The intensity of spatfall has been observed to be as high as 125 spat per cultch. The rens are suspended from the same grow out structure and harvested after a period of 5 to 6 months. The heat-shucked meat in the frozen form was sold in the internal market. Later, the institute refined on the technology by introducing seasonal and perennial oyster farming depending on the estuary's physico-chemical characters. In Kerala, the BFFDA now gives financial assistance to farmers to set up oyster farms. This confirms the fact that the end users and the planners have recognized oyster culture as a viable project ideal for rural development and income generation.

Fully grown edible oysters on rens after harvest

Cultchless oysters grown in a cage from an oyster farm along the East Coast

Table 7: **Impact of demonstration programmes in oyster culture**

	Scientific outcome	*Social impact*
Perennial Farms	• Information on spatfall • Spat collection two to three times from the same site • Possibility of making more than one harvest per year • Replacement of bamboo pole with concrete filled PVC pole to avoid woodborers • Low fouling in the estuarine region	• Establishment of oyster farms • Employment opportunities for women - ren making and heat shucking of oysters • Market improvement for oyster meat • Oyster farming becomes a source of additional income to fishers
Seasonal Farms	• Possibility of integrated farming with mussel • Crop holiday during monsoon period to avoid large scale mortality of farmed oysters • Fast growth and high meat yield just before monsoon	• Employment opportunities for women - ren making and heat shucking of oysters • Market improvement for oyster meat • Oyster farming becomes a source of additional income to fishers

By the year 1997, oyster farming became increasingly popular, and a progressive farmer took up oyster farming on a large scale producing annually 10 to 15 tonnes of oyster. Being an agriculturist, he made use of material from his own agriculture farm for construction of rack. The fuel for heat shucking of farmed oysters was also taken from his own coconut grove. This hard working 60-year-old farmer received the 'Best Farmer' award from the Government of Kerala for his integrated farming approach.

Similarly, in other estuaries also the farming methods were demonstrated. In addition to creating awareness on the profitability of oyster farming, the demonstrations in the states of Karnataka, Tamil Nadu and Andhra Pradesh, gave valuable information on the spatfall, growth, and optimum period of

harvest, etc. Though the level of technology adoption varied from place to place, the overall impact was acceptance of the farming method as a part time avocation for additional income to rural fishers.

Integrated Farming of Finfish and Shellfish

To further improve the profit margin, integrated farming of edible oyster and mussel (which enjoys a better market value) from the same rack structure was introduced in the Ashtamudi

An integrated farming system with edible oysters suspended on rens, estuarine food fishes in cages and mud crabs in bamboo boxes. (A farm in Ashtamudi Lake)

The use of cement filled PVC poles in an oyster farm. This has allowed farmers to avoid the less durable wooden poles

Cage farming of food fish in estuarine farms. Note the submerged hapa.

Lake ecosystem. Similarly, preliminary experiments are being conducted for testing the feasibility of growing finfishes, shrimp and crabs in cages suspended in the same farm and it has given encouraging results.

BIVALVE SEED PRODUCTION

Development of Seed Production Technology

Availability of seed is recognized as one of the major requirements for farming. Aquaculture industry throughout the world has experienced the unpredictability of natural seed collection. In India, in the Gulf of Mannar, interference by man and unfavourable environmental conditions led to near absence of pearl oyster stocks for decades at a stretch. The development of hatchery technology for the Indian Pearl oyster was motivated by the question posed by the Indian fishery managers: Of what use is the technology for pearl culture, if there are no pearl oysters in the natural beds? The answer for this problem was the development of a full-fledged hatchery technology (Fig. 10) for seed production in 1982. This was on the same process of induced spawning and larval rearing followed for bivalves throughout the world. The fertilized egg hatches into a trochophore larva, which in due course transforms into umbo, pediveliger and finally settle to the bottom as spat. Seed production for commercially important mussels, oysters and clams was also carried out in CMFRI along similar lines.

The 'cultch less' or the free spat of edible oyster produced in the hatchery is used for the production of the highly priced individual oysters. For the present, the requirement of spat of edible oyster and mussel is met from the nature, although, the hatchery technology is perfected. However, with the growth of pearl culture industry, entrepreneurs have realized the importance of producing pearl oyster spats in areas where natural resources do not exist, by adopting the pearl oyster hatchery technology.

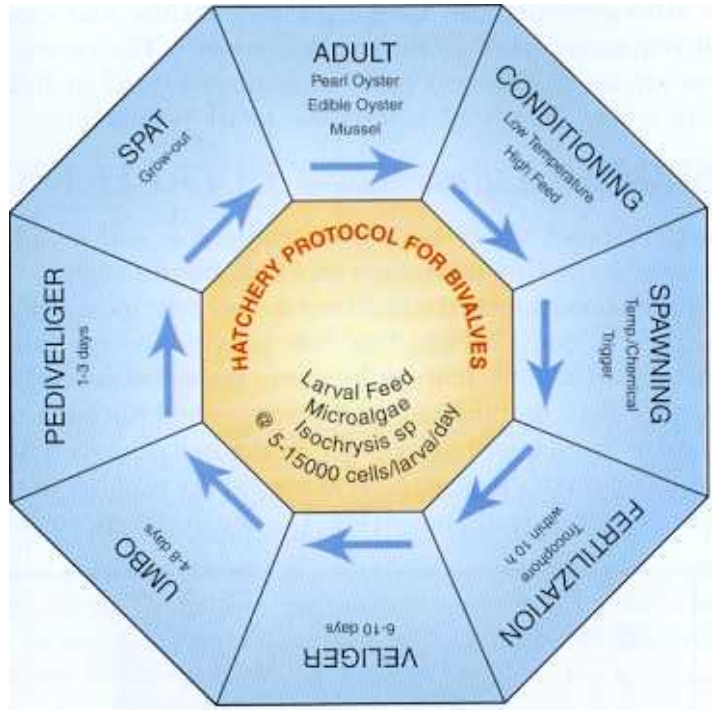


Fig. 10: Bivalve induced breeding and larval rearing in a typical bivalve hatchery

Results of the stock enhancement programme undertaken by CMFRI in the Gulf of Mannar showing a heap of pearl oysters picked by divers during 1998. The beds were totally overexploited during sixties and seventies

The entrepreneurs also have their own facility that caters to their requirements of adult (mother) oysters. The recent pearl farms set up in different parts of southeast coast of India do not face any dearth of oysters for pearl production.

Stock Enhancement of Pearl Oysters

Revival of pearl oyster beds from extinction and creation of new beds in the Gulf of Mannar and Palk Bay through ranching of the seed produced in the hatchery is one of the most significant objectives of the CMFRI. The first programme on ranching was launched in 1985. In the subsequent years, this was continued and more than one million spat were ranched during a period of 5 years. Subsequent dives made in the beds clearly indicated replenishment of the pearl beds as seen in the number of oysters collected in one diving hour (Fig. 11). Stock enhancement (sea

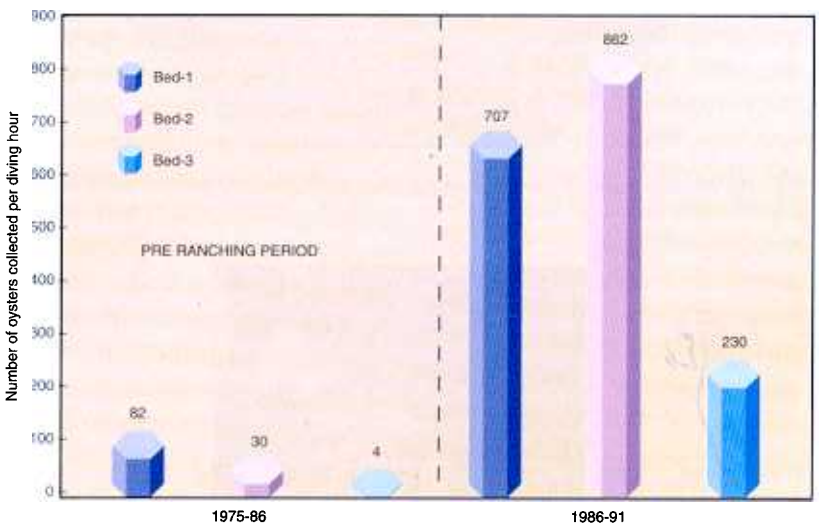


Fig. 11: Graph showing revival of pearl oyster beds along the Southwest Coast of India after sustained ranching (stock enhancement) of spat

ranching) of captive reared pearl oysters is a technique, which aims at rebuilding the wild population from its destruction/ catastrophe by man-made and natural causes.

POST-HARVEST AND MARKETING

Pearls

Post-Harvest Technology

Pearls have a premium on quality. The quality differences are so subtle and discrete that even professionals in the pearl trade can make wrong judgements. Gross production of pearls obtained during harvest is comprised of from the finest pearl to trash. Some of the pearls may be of outstanding colour and with perfectly round shape, many are inferior and some are totally valueless as gems or jewels. Such composition is common to pearl culture anywhere in the world.

The cultured pearls are subjected to different processing steps before they reach the consumer. Size, shape, colour, lustre, and surface quality are used to sort out the pearls. Besides size, lustre is considered the most important factor in evaluating pearls. If lustre and refraction are good, it indicates that the nacre is made up of pure aragonite and it is thick and durable. The pearls are classified into the following three grades, A, B, and C. In India, composition of pearls produced were Class A (best quality or with one minor flaw) 37.6%, Class B (those with minor flaws which can be corrected with processing) 37.6% and Class C (trash pearls, misshapen and heavily pockmarked) 24.8% (Alagarswami, 1991). In the pearl trade, it is a common practice to improve the quality of the pearl through bleaching and dyeing.

By-products

In terms of volume, the by-product is the total mass of the oysters after extraction of the cultured pearl. The seed pearls, shell and the flesh form the by-products of culture (Table 8). The tiny seed pearls, which are not used as gems or jewels, are used in the preparation of medicines. The Indian system of medicine use pearl powder and pearl liquid as important ingredients in several preparations. Large shells are used in shell craft for their mother-of-pearl layer. The shell of *Pinctada margaritifera*, the black lip pearl oyster found in the Andaman and Nicobar Islands is widely used by the shell craft industry. In recent years, sale of spat produced in the hatchery has also been identified as a source of trade and income to pearl farmers.

Edible Bivalves (Mussels and Edible Oysters)

Post-Harvest Technology

The edible bivalves like the mussel and the oysters are harvested when the condition index is high i.e., when the gonad is ripe and the meat occupies the entire shell cavity. In temperate countries, mussel and oyster harvest is mechanized while in India the 'mussel ropes' and oyster strings are collected manually and brought to the shore. Mussels are normally marketed shell-on. Harvested oysters, which are kept under moist and cool conditions, survive for several days. However, it is desirable that they reach the consumer within three days of harvest. Studies indicate that oysters packed in wet gunny bags can be safely transported for 25-30 hours without mortality and in good condition. Oysters are eaten in fresh condition in the half shell in many countries. Removal of meat from the shell is termed shucking. Live mussels and oysters are shucked easily using stainless steel knives or by gently heating to open the shell. Remnants of mussel byssus thread if any are removed before marketing the meat. The post-harvest procedures for mussel and oysters are shown in Fig 12.

Unloading harvested edible oysters for cleaning

Jet washing of harvested edible oysters to remove grit and slit

By-products and Value Addition

A variety of products have been developed in India from mussels and oysters (Table 8). These products have been developed by the R&D activities of the Central Institute of Fisheries Technology (CIFT), Cochin.

- ***Icing***: Fresh oysters and mussels can be preserved in ice in organoleptically acceptable condition up to 9 days. Fresh frozen oyster and mussel meat remains acceptable for 40 weeks.
- ***Canning***: Cleaned meat after blanching in 5% brine for 5 minutes can be canned. The blanched meat with medium

Table 8: **Value added mussel and oyster products from India**

Mussel products	*Pearl Oyster products*	*Oyster products*
• Iced and frozen mussel • Canned mussels • Smoked mussels • Dried mussels • Marinated mussels • Mussel pickle • Mussel chutney powder	• Pearl powder • Pearl liquid • Seed pearls • Mother-of-pearl shell	• Frozen oysters • Canned oysters • Smoked oysters • Oyster stew

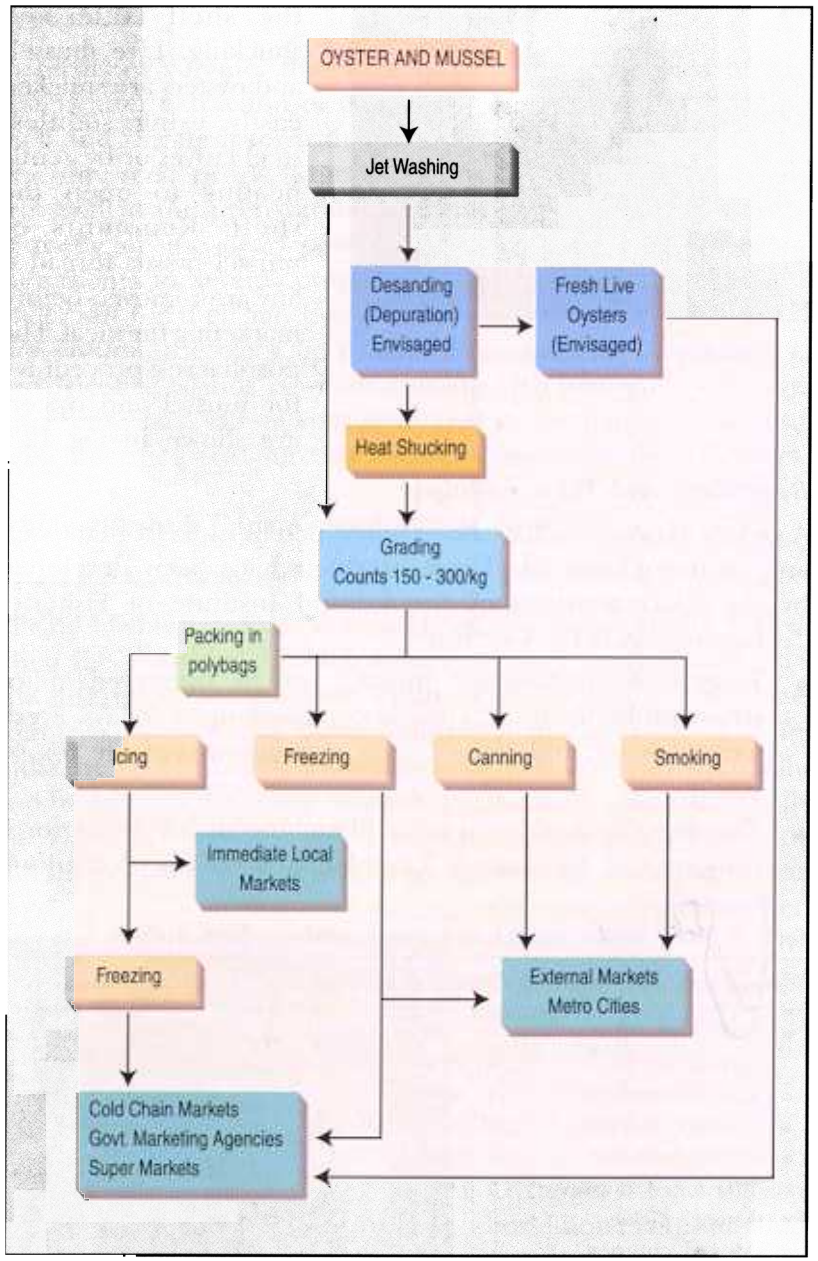


Fig. 12: Bivalve post-harvest procedures/processing

is canned by heat processing in steam at 115°C for 20 minutes.

- ***Smoking***: Smoking improves flavour of the meat. The blanched bivalve meat after drying to a moisture level of 40-45% is smoked at 80-90 °C for 30 minutes. It is then dried further to bring the moisture level to 10%. The shelf life of smoked oyster and mussel in room temperature is six months.
- ***Drying***: Blanched meat can be sun-dried or dried in an electrical dryer to bring down the moisture content to 10-15%. Shelf life of the dried meat is six months in room condition.

For further economic utilization, value added products of mussels like seafood cocktails are also prepared and marketed by many seafood export firms from India. The export of these items from India has by and large, been showing an increasing trend. Fig.13 points to the export figures in quantity and value between 1993 and 1996.

The two shell valves constitute about 85% of the total weight of oyster and contain about 52-55% calcium oxide. They are used in the manufacture of calcium carbide, lime, fertilizers and cement. Larger oyster shells are useful spat collectors in oyster culture. The shells are broken to pieces and also used as poultry grit. The mussel shell finds use as a liming agent in coconut plantations. Another important economic use of

Shucking of edible oyster meat by women farmers

bivalve shell is in the making of curios, a small-scale industry which is rapidly developing along the east coast of India, and in the Andaman and Nicobar Islands.

Shucking fresh mussels for immediate sale at Nadakkavu fish market near Calicut

Marketing

India is presently a net importer of cultured pearls and the pearl trade is centred in the city of Hyderabad. Export of Indian cultured marine pearls is of recent origin (Fig. 13) and the main country to which it exports is Hong Kong (@ US $ 8.5 per gram). Besides, there is a growing internal market for cultured marine pearls.

The edible bivalve market channel is relatively straightforward and fresh and frozen farmed mussels and oysters have a healthy and growing domestic demand in maritime regions of the

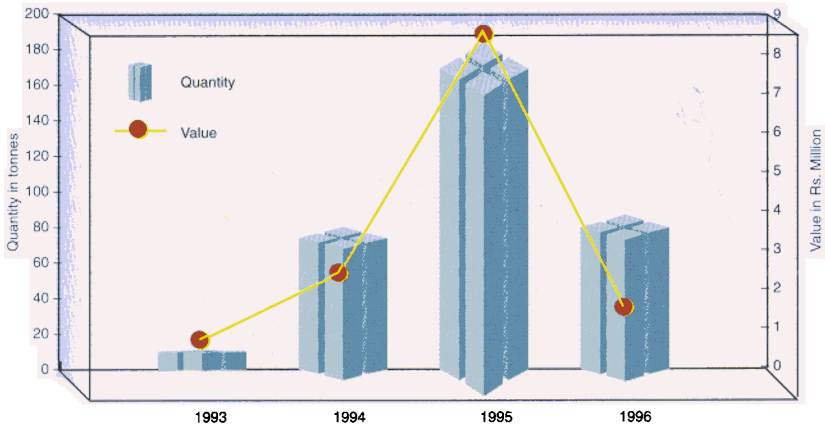


Fig. 13: Graph showing trends in mussel export in quantity and value from India (Source: MPEDA, Cochin)

Farmed mussel and oyster value added products prepared by Integrated Fisheries Project, Cochin, for metropolitan markets

A spoon set made out of pearl oyster shell by craftsmen in Rameswaram, Tamil Nadu

A variety of molluscan shell products displayed in curio shop in Rameswaram, Tamil Nadu

'Arikadukka' a traditional mussel delicacy from North Malabar

Half shell mussels, a product displayed for export promotion by MPEDA, Cochin

country. There is now increasing appreciation of the fine texture and taste of mussel and oyster meat and these comparatively new products look set to captivate the urban connoisseurs. New strategies need to be developed to fully exploit the domestic markets. On the export front, in the case of mussels, Indian products have found a place in the markets of UAE, Germany and Republic of South Africa, and the list is growing. Although live oysters are an expensive gourmet food in Europe and America, they have not found such a niche in India. Markets are limited to few isolated pockets like the Parsi community in Mumbai, who have a specific preference to smoked oysters marketed in cans.

FACTORS UNDERLYING THE SUCCESS STORY

The following factors played a key role in the evolution of bivalve mariculture in India as a nascent industry, which could develop the coastal ecosystems and rural economy.

- Pearl culture, although technologically intensive, has caught the imagination of the entrepreneurs (including large corporate bodies), because of the location specific demonstrations carried out by the CMFRI and also because pearls are natural gems which fetch a very high price.
- Pearl oysters were a limited natural resource with government imposed restrictions on its use, but, with the development of a reliable hatchery technique for pearl oyster seed production, the institute was able to overcome these restrictions and many entrepreneurs were able to start ventures in states other than Tamil Nadu and Gujarat.
- The mussel and edible oyster culture technologies developed by CMFRI are simple and easy, well suited as a part-time avocation to fishers, especially women, and having high reproducibility in different locations.
- The demonstration farms set up by CMFRI with fishers participation convinced them about the economic feasibility of the mussel and oyster culture technologies.
- The easy availability of required inputs and virtually no expenditure for feed and maintenance motivated the fishers to start their own mussel and oyster culture ventures.
- Easy disbursement of loans and subsidies from the developmental agencies like DWCRA, IRDP, TRYSEM and local farmer's cooperative banks helped the farmers to initiate

mussel culture. Timely repayment of loans by the farmers encouraged the developmental agencies to sustain the loans in subsequent years.

- The tropical environment that India has and the sound ecofriendly technology that CMFRI developed for bivalve culture, ensured that the period of culture was short thereby maximizing profits for the ventures.

EPILOGUE

India has gained practical experience in commercial production of cultured pearls, mussels and oysters through institutional research work carried out by the CMFRI, an important institute of the Indian Council of Agricultural Research (ICAR). These R & D efforts, especially the location specific demonstrations with direct involvement of farmers, have been instrumental in providing thrust and an insight into the travails of the relatively new industry. Although the general growth of bivalve mariculture from mid seventies to early nineties had been less dramatic, the present picture is one of vibrant growth.

To make bivalve culture more popular, the following aspects need to be given importance in both the public and private sector.

- Adequate financial support in the form of loans at concessional rates and subsidies should be made available to farmers as incentives.
- For the development of quality and maintenance of hygiene, suitable depuration units should be set up by governmental agencies/entrepreneurs.
- Bivalve products suitable for domestic as well as export market should be developed and simultaneously product awareness among consumers should be created through publicity.
- Framing the legal aspects of farming bivalves in open access areas.

Bivalve mariculture is suitable for rural development programmes in coastal ecosystems since the different culture activities like seed collection, seeding, farm construction,

harvesting, shucking and marketing provide employment opportunities. Farming of bivalves in the estuaries is less expensive and provides scope for effective utilization of the water resources. Thus overall development would require increased focus on participatory, bottom up approach with full involvement of village communities.

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