MARINE FARMING : COUNTRY ANALYSIS – INDIA

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1. Marine Aquaculture Products Demand, Trade and Markets

Among the Asian countries, India ranks second in culture and third in capture fisheries production and is one of the leading nations in marine products export. The present marine fisheries scenario is characterized by declining yields from the inshore waters and increasing conflicts among different stakeholders, whereas the increasing demand for fish in domestic and export markets indicate good prospects for large scale sea farming and coastal mariculture.

Contribution of fisheries to Indian GDP is about 1.2 % (2002-03) which forms about 5.2 % of the agricultural GDP. The mariculture potential of India is vast as there is great scope for developing farming of shrimps, pearl oysters, mussels, crabs, lobsters, sea bass, groupers, mullets, milkfish, rabbitfish, sea cucumber, ornamental fishes, sea weeds etc. Although about 1.2 million ha is suitable for land based saline aquaculture in India, currently only 13 % is utilized. In India till date mariculture activities are confined only to coastal brackishwater aquaculture, chiefly shrimp farming. Shrimp is the most demanded product from coastal aquaculture and India is the 5th top most shrimp producer from culture. Farmed shrimp contributes about 60% by volume and 82% by value of India's total shrimp export. Share of cultured shrimp export is 78, 700 t valued at INR[i]. 3,3000 million. The area under shrimp farming is about 135,000 ha and average production is about 80,000 t /year. In recent years, the demand for mussels, clams, edible oysters, crabs , lobsters, sea weeds and a few marine finfishes is continuously

[i] US$ 1 = INR 45 approx.

increasing and brings premium price in the international market. The other activities which can be categorized as artisanal mariculture include green mussel farming, lobster fattening, crab farming, edible oyster culture, clam farming and seaweed culture. Farming of green mussel yields about 4500 t and farmed oysters 800 t, farmed seaweeds about 1000 t while quantities produced are not significant for crabs, lobsters, mullets and milkfish. A flourishing international trade of marine ornamental fishes is also in vogue which offers scope for the culture of marine ornamental fishes.

The farming of shrimp is largely dependant on small holdings of less than 2 ha, as these farms account for over 90% of the total area utilized for shrimp culture. Coastal aquaculture is mainly concentrated in the states of Andhra Pradesh, Tamil Nadu, Orissa and West Bengal. The long coast line of 8129 km along with the adjacent landward coastal agro climatic zone and the sea-ward inshore waters with large number of calm bays and lagoons offer good scope to develop mariculture in the country. Although the techno economic feasibility of several mariculture technologies are already available, lack of adequate infrastructure and lacunae in legislation block their take off.

1.1 Products demand, trade and market trends locally and internationally

The mariculture related development in infrastructure, technology, processing, value addition and trade in India are almost entirely targeted at and anchored on the prospects for export and earning of foreign exchange. It is explicitly evident from the fact that 50 % of the gross earnings generated from Indian marine fisheries is accounted for by crustaceans and cephalopods. Further, more than 90 % of the aquaculture shrimp production is meant for the export markets. The overall average unit value realized for all fish in the domestic marketing system is about INR. 70 per kg as against INR. 148 per kg in export marketing (2003-04). Export of marine products set an ever time record of US $ 1.48 billion in 2004-05. Exports increased by 11.97 % in volume, 9.11 % in rupee value and 11.10 % in US $ realization. The European Union emerged as the largest market for Indian marine products accounting for 27 % of the total exports and USA came in the second position with 23 % share in exports. Frozen shrimp continued to be the main item in terms of value (64 % in the total export value) and frozen fish continued to be the largest item in terms of volume (35 % in the total export). India’s share in the booming world trade of fish is less than 2 percent, which is very low considering the huge export potential for exports. The ever expanding internal market also recorded highest increase for fish and fishery products among all the food products. The dwindling catch rates in capture fisheries and rampant disguised unemployment in the coastal region focus towards the development of mariculture and coastal aquaculture as a remunerative alternate occupation.

1.2 Role of aquaculture *vs.* fisheries as supply

Fisheries production pattern in India is presented in the Table 1.

Table 1 Fish Production and Average Annual Growth Rate, India

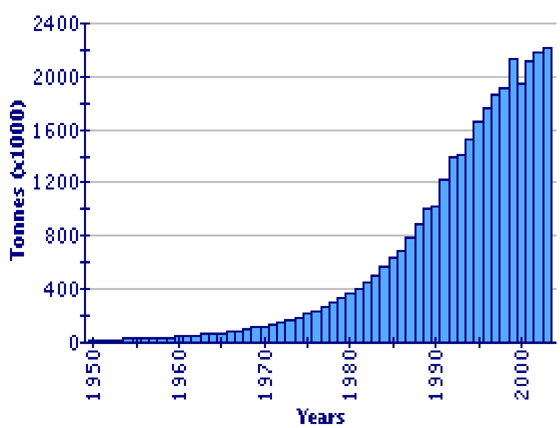
Year	**Fish Production in '000 tons**			**Average Annual Growth Rate (%)**		
	Marine	**Inland**	**Total**	**Marine**	**Inland**	**Total**
1950-51	534	218	752	……..	…….	……..
1960-61	880	280	1160	5.12	2.53	4.43
1970-71	1086	670	1756	2.13	9.12	4.23
1980-81	1555	887	2442	3.65	2.85	3.35
1990-91	2300	1536	3836	3.99	5.64	4.62
1991-92	2447	1710	4157	6.39	11.33	8.37
1992-93	2576	1789	4365	5.27	4.62	5.00
1993-94	2649	1995	4644	2.83	11.51	6.39
1994-95	2692	2097	4789	1.62	5.11	3.12
1995-96	2707	2242	4949	0.56	6.91	3.34
1996-97	2967	2381	5348	9.60	6.20	8.06
1997-98	2950	2438	5388	-0.57	2.39	0.75
1998-99	2696	2566	5262	-8.61	5.25	-2.34
1999-2000*	2834	2823	5657	5.12	10.02	7.51

* Provisional figure Note: The growth rates prior to 1992-93 represents annual average compound growth rates

Source: Tenth Plan Document (Fisheries) Govt. of India, Fig from CMFRI, Kochi upto 1970-71, State Govts / UT figure after 1970-71

The total fish production during the four decades (1950-51 to 1990-91) showed an annual average compound growth rate that varied between 3.35 to 4.62 percent. In the early nineties there was a boom in total fish production followed by sluggish trend due to decreasing pattern of marine production towards the end of the decade. It may be noted from the analysis that the marine fisheries sector witnessed a slack production trend in most of the years whereas the inland production was found growing throughout. It can be broadly stated that marine fish production was growing with a compound annual growth rate of 3.54 percent over the five decades since independence. On similar basis, growth of inland fish production is dynamic over the same period with a growth rate of 5.84 percent.

Fig. 1 Aquaculture production in India (from 1950 - 2003)



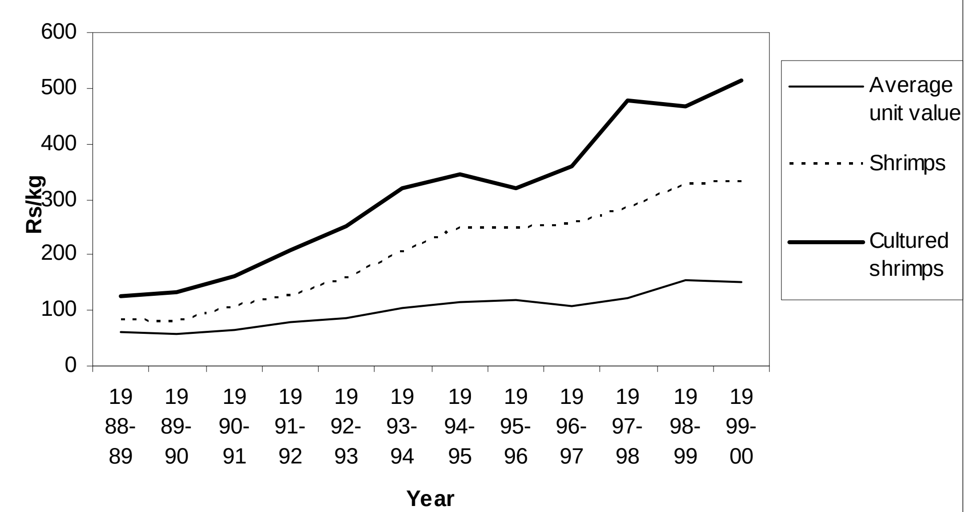
Source: FAO Fishery Statistics, Aquaculture production, 2003

In 2003, aquaculture alone contributed to one third of the total fish production in India. Of the total aquaculture production of 22.2 million mt, production of carp was 1.87 million mt, giant river prawn was 30,000 mt and the marine shrimp *P. monodon* was 1,15,000 mt.

Aquaculture production from India in 2000 was 2,095 thousand mt worth US $ 2,166 million. The shrimp exports from India during 2001-02 was 1,27,656 mt worth INR. 4,1320 million. The cultured shrimp production during 2001-02 was 1,27,170 mt in which 74,826 mt was exported fetching INR. 3,6450 million. The cultured shrimp contributed about 60 % in terms of quantity and about 86 % in value of the total shrimp exports during 2001- 02.

In the seventies and early eighties, shrimp exports have been stagnating around 50,000 tonnes per annum and the export earnings were below INR. 3500 million. Before 20 years the price of white prawn was INR.8/kg and that of tiger shrimp INR.13/kg (George, 1974). During the same period brown varieties had only INR.2-3/kg. Sathiadhas *et al.* (1989) reported that the unit price for white prawns during 1986-88 was INR.40/kg. The price of tiger and brown were only INR.60/kg and INR.10/kg respectively. During the last few years the prices of all aquaculture products have increased considerably. However, with the development of shrimp culture since the mid eighties, the shrimp exports began to rise significantly, both in terms of quantity and value. The growth in value terms has been more spectacular, because the cultured shrimps fetched more unit value, in comparison to the marine captured shrimps (Fig. 2).

Figure. 2: Contribution of aquafarmed shrimps in the unit value realisation of marine exports



The total shrimp exports and contribution by cultured shrimps to it are given in Tables 2 and 3. The share of aquafarmed shrimps in total shrimp exports has been continuously increasing since the mid eighties. In 1988-89, the share of cultured shrimp was only 33% by quantity. But at the end of 2000 it increased to 59%. Though the percentage of cultured shrimps by quantity is half of India's total shrimp exports, its contribution by value is much more than that. The value, at INR. 2293.0 million in 1988-99 increased to INR 38,700 million in 2000-01, which is 86% of the total shrimp exports in that year. This value realization is mainly resorted to the bigger and uniform size composition of the cultured shrimps. There was a decline in contribution of cultured shrimps in 1994-95 and the subsequent two years, which was due to the disease outbreaks and the stoppage of culture activities in the Coastal Regulatory Zone (CRZ) area and the resultant decrease in production from aqua farms. During the three years (1998-99 to 2000-01) however, the culture production increased and the contribution also showed significant rise, registering an all time high of 58.8% in terms of volume and 86.4% in terms of value to the total shrimp exports.

The quantity of shrimp exports increased to 1,28000 mt in 2001-02 and 1,35000 mt in 2002-03. The value realized by the aquaculture shrimps has also gone beyond 80 % of the gross earnings of shrimp exports.

Table 2: Contribution of cultured shrimps (quantity) to the total shrimp exports from India

Year	Total quantity of shrimp exports (mt)	Quantity of cultured shrimp exports (mt)	% contribution to shrimp exports
1987-88	55,736	--	--
1988-89	56,835	18,300	33.00
1989-90	57,819	19,500	33.72
1990-91	62,395	23,075	36.98
1991-92	76,107	26,000	34.16
1992-93	74,393	30,550	41.06
1993-94	86,541	40,300	47.14
1994-95	1,01,751	53,853	52.92
1995-96	95,724	47,922	50.96
1996-97	1,05,426	45,945	43.58
1997-98	1,10,318	43,712	42.90
1998-99	1,02,484	53,712	52.41
1999-00	1,10,275	54,000	48.96
2000-01	1,11,874	65,894	58.90
2001-02	1,27,709	1,02,940	58.80
2002-03	1,34,815	1,15,320	60.08

(Source: Ganapathy and Viswakumar, 2001) Source: NGK Pillai & Pradeep K. Katiha, 2004)

Table 3: Contribution of cultured shrimps (value) to the total shrimp export earnings from India

Year	**Total value of shrimp exports (INR. Crores)**[ii]	Value of cultured shrimp exports **(INR.Crores)**	**% Contribution to export value**
1987-88	425.78	--	--
1988-89	470.33	229.30	48.78
1989-90	463.31	259.74	59.57
1990-91	663.32	376.40	56.77
1991-92	966.16	544.76	55.81
1992-93	1,180.26	766.25	64.93
1993-94	1,770.73	1,288.93	72.79
1994-95	2,510.27	1,866.23	74.35
1995-96	2,356.00	1,531.69	64.09
1996-97	2,701.78	1,642.56	60.80
1997-98	3,140.56	2,086.00	66.42
1998-99	3,344.97	2,511.00	75.07
1999-00	3,645.22	2,782.00	76.32
2000-01	4,481.51	3,870.00	86.35
2001-02	4139.92	3845.00	85.63
2002-03	4608.31	3793.86	82.33

(Source: Ganapathy and Viswakumar, 2001) Source: NGK Pillai & Pradeep K. Katiha, 2004)

Coastal aquaculture is a significant contributor to marine fish production, constituting mainly the shrimps like *Penaeus monodon* and *P. indicus.* However, vast water bodies highly suitable for aquaculture and the varied biodiversity that has the potential to capture new markets with a wide range of seafood products, have prompted consideration of other candidate species like oysters, mussels, crabs, lobsters, scampi, sea bass, groupers, sea cucumber, ornamental fishes and seaweeds in the new aquaculture scenario in the country. Hatchery and rearing techniques have also been standardised for many of these organisms. Coastal aquaculture in India is mainly confined to shrimp culture. Considering the vast domestic market with huge demand for fish, there is enough scope for diversification with other cultivable species like mud crabs, fin fishes, oysters, mussels, sea cucumber, pearl oyster etc. Although India does

[ii] One Crore = ten million INR

not have the advantage of extensive shallow seas with calm waters, there exists many potential mariculture sites which are still unutilized, offering tremendous scope for mariculture. Low cost user friendly bivalve mariculture practices provide seasonal vocation for the rural folk. Polyculture of different compatible species also offer a viable alternative to shrimp farming. They require less input compared to shrimp culture and are economically viable. Hence the promotion of location oriented, resource specific mariculture is ideal for maintaining sustainable production without endangering the existing environmental equilibrium of natural resources.

The major molluscan product exports from India include frozen mussel meat, snail meat, freeze dried clam meat, boiled clam/whelk meat, seashells and dried clam meat. South Africa became the largest market for frozen clam meat during 1999-2000, with an import of 32 t worth INR.18.90 lakhs of clam meat (MPEDA). *Katelysia opima, Meretrix meretrix* and *M. casta* were the major clam species exported from India. Among the molluscan products freeze dried clam fetches the high unit value of INR.430/kg. (see Table 4). Two kilograms of cultured pearls also were exported during 1996 which fetched a value of Rs3,57,000/kg of pearls. The scope for the export of cultured pearls is enormous, which fetches high unit value. Hence, there is bright future for sea farming of pearl oysters in India to produce export quality pearls.

Table 4. Frozen mussel meat exported from India along with revenue realised from 1996 to 2003..

Year	**Quantity (kg)**	**Value (INR)**	**Unit value INR / kg**
1996	**12133**	**8179938**	**67**
1997	24773	1739989	70
1998	20513	1273226	62
1999	35989	1807231	50
2000	106445	7493917	70
2001	482097	29007630	60
2002	106937	9226164	86
2003	74982	4975491	66

(Source: MPEDA)

Substantial quantity of crabs and crab products are also being exported from India. The details of the live crab export from India are given in Table 5. The unit value realized for live crabs increased from INR. 119 /kg in 1996 to INR. 195/kg in 2003 showing a steady increase in demand for live crabs in the international market.

Table 5: Live Crab trade

Year	**Quantity (kg)**	**Value (INR)**	**Unit value INR/ kg**
1996	2028430	240692690	119
1997	1482659	191712499	129
1998	1777198	306427388	172
1999	1503454	261008303	174
2000	1579704	260923450	165
2001	1190214	197306436	166
2002	1958748	400060486	204
2003	1455454	284341287	195

(Source: MPEDA)

Exports from crabs and crab products from India were mostly confined to four types of products till recently. During 2000, the total number of crab products in India's export basket rose to 11, indicating there is an increasing demand for diversified crab products. The different items in the export basket are crab shells, frozen cut swimming crab, frozen mud crab, frozen crab claws, frozen whole crab, frozen soft shell crab, frozen stuffed crab, frozen pasteurized crab, frozen crab meat, frozen cut crab with claws and live crabs. Total crab exports were 1.1 % of the total marine exports in terms of quantity in 1996 increased to 1.47 % in 2000. The crab exports stood 6197 mt in 2000 and the value realized was US $ 5.5 million in 2000 indicating their enormous scope in the export market.

Annual yield from crab fattening was significantly higher than crab culture. About 5-6 crops could be obtained annually through crab fattening as against only 2 crops from crab culture. Average yield from crab culture was 2800 kg/ha/crop and that from fattening was 3100 kg/ha/crop. Average Body Weight (ABW) of the crabs obtained through culture was 800g, whereas that of fattening was 850 g. The weight increase after 30-40 days of fattening was very little, ranging 50-100g. Average Feed Conversion Ratio (FCR) calculated for 4-5 months culture was 4.9, which was higher compared to that of other aquaculture species cultures locally.

The international demand for lobster is continuously increasing over the years and the targeted fishing has led to over fishing of the same in our coastal waters. Although the unit value realized for each products of lobsters enhanced, the overall value has come down as more and more small sized lobsters were caught from our open sea. It is a highly advisable to go for mariculture of lobsters wherever possible.

Table 6: Frozen Lobster exports (1999-2003)

Year	**Quantity (kg)**	**Value (INR)**	**Unit value INR / kg**
1999	1363594	661542732	485
2000	1555166	802049638	516
2001	1125666	654731490	582
2002	1008394	575601161	571
2003	806290	380467756	472

Similarly demand for finfish also recorded a steady growth both in exports and domestic markets over the last few years. Mariculture of mullets, groupers, *Chanos chanos* etc is quite possible in view of their increasing unit value realization (Table 7)

Table 7: Frozen Finfish exports (1996-2002)

Year	**Quantity (Tons)**	**Value (INR.million)**	**Unit value INR/ kg**
1996	**10093**	**3722.6**	**37**
1997	173005	6369.2	37
1998	188029	7267.3	39
1999	126474	5257.7	42
2000	188822	7697.2	41
2001	185457	7614.9	41
2002	217195	9064.5	42

The World Fish Centre and National Centre for Agricultural Economics and Policy Research (NCAP) estimated the supply demand projections under different scenarios. Accordingly, the annual production of inland fish in the year 2005 will be in the range of 3.6 - 3.7 mmt, and will reach to 4.6 – 5.5 mmt in 2015, with an annual growth rate of 2.9 – 4.0 percent under different scenarios. The share of inland fish in total production, which was about 50 percent in the year 2000, will increase to 61 percent in 2015. The production of marine fish is likely to be in the range of 2.9 – 3.0 mmt in 2005, and 3.2 – 3.6 mmt in 2015. The fish production will grow at the annual rate of 2.9 – 4.0 percent for inland and in the range of 1.2 to 1.8 percent a year for marine fish. The share of marine fish in the total fish production will decline from 50 percent in 2000 to about 40 percent in 2015.

Varying estimates quantify the per capita fish consumption to around 8 to 10 kg. per annum. However, demand for fish and fish products in future will substantially grow due to escalating population growth. The domestic demand of fish will be in the range of 5.9 – 6.0 mmt in the year 2005. It is likely to grow to 6.7 – 7.7 mmt in 2015. The consumption of fish is projected to increase from 5.2 mmt. in 1998 to 6.0 mmt in 2005 and 7.7 mmt in 2015. Out of this, in-home consumption will be about 66 percent, while the rest will be consumed away from home and enter industrial processing. The annual per capita consumption of fish is expected to increase to 16.7 kg by 2015.

Changing Consumer Preferences and Buying Patterns

The demand for fish is determined by factors such as increase in the number of consumers and increasing preference for seafood backed by growing purchasing power. The consumer preferences and patterns have shifted from sticking to cereals and other items to more nutritive yet affordable animal products like fish. According to NSSO figures, the per capita cereal consumption is declining, recording 0.52 % decline in rural areas and by 0.23 % per annum in urban areas during the period of 1970-71 to 1991-92. The shift in the dietary pattern may be attributed to diversification in the food basket in favour of non cereal food items like egg, meat and fish. There is considerable product diversification and market expansion of fishery products over the last three decades. There is increasing demand for “ready to cook” or “ready to serve” type seafood, hygienically prepared and attractively packed convenience foods to match the changing needs of urban population. The seafood processing and marketing has become competitive all over the world and exporters are switching over to value addition to increase profitability.

Aquaculture production and marketing are very closely inter-linked. Efficient marketing along with sufficient infrastructure facilities to handle the products without spoilage can ensure the sustenance of aquaculture production in the long run. (Chidambaram, 1988). Amongst other marketing factors, role of intermediaries, share of producer in consumer rupee and marketing expenses in each distribution channel are the major determinants which decide the ultimate profitability of any aquaculture project (Gupta *et al.*, 1984). Hence, the present level of trade through different marketing channels of different farming systems, price spread at various stages of its movement and share of producer in consumer's rupee should be evaluated to evolve and formulate further strategies for the development of aquaculture industry.

The aquaculture products especially shrimps are undergoing a lot of changes during peeling and processing. The head-on raw material is converted into either Headless (HL) product by removing the Head (35%) or into Peeled and Un-deveined (PUD) and Peeled and De-veined (PD) products by removing Head, Shell and the gut contents (50%). At various stages of the marketing system a unit weight of shrimp undergoes considerable weight loss and corresponding price increase.

Export quality prawns are graded based on their size, weight and quality. Domestic market products are graded into 2-3 groups based on their size. Marketing of value added products of prawns and other aquaculture products like live crab export, edible oyster and pearl oyster are gaining importance in recent years. The flow of aquaculture products can be broadly divided into two categories depending on the ultimate destination of the product. High unit value products like prawns are reaching the export market and the low unit value products like finfishes and small crabs reach the domestic market.

The Marine Products Export Development Authority of India (MPEDA) has listed about 65 value added products, suitable both for export and domestic markets. Product diversification always promote price discrimination and enable us to realize maximum foreign exchange earnings. It further helps us to enhance the employment opportunities of coastal and rural women. The emergence of value added products are accelerated by the current demand pattern of the major seafood markets in exporting countries. People have become more selective in their food choice and they are ready to spend more for food. All over the world, the tendency now is to take convenience foods such as assembled meals rather than preparing from basic ingredients. The most advisable and viable alternative to maximize our shrimp exports is through value added ready to eat products. An additional export of almost 100,000 tons of value added products in our marine products could easily corner about INR. 15000 million foreign exchange earnings and generate regular employment opportunity to about 35,000 fisherfolk.

Market chain organization

Trade Flows and Market Chains

Fish passes through a number of hands before it reaches the ultimate consumers. Both domestic and export marketing have entirely different flow of products through different marketing channels. The flow of aquaculture products from producer to consumer on export and domestic market are given in Figure 3. The export marketing system has five main marketing channels where the products pass from one to four intermediaries. The domestic marketing system can also be classified into five channels. There is considerable variation in the unit price of products moving through export and domestic marketing channels. Export marketing channels have five times higher unit price than the products moving through the domestic channels. There is interrelationship between the different intermediaries involved in the marketing flow.

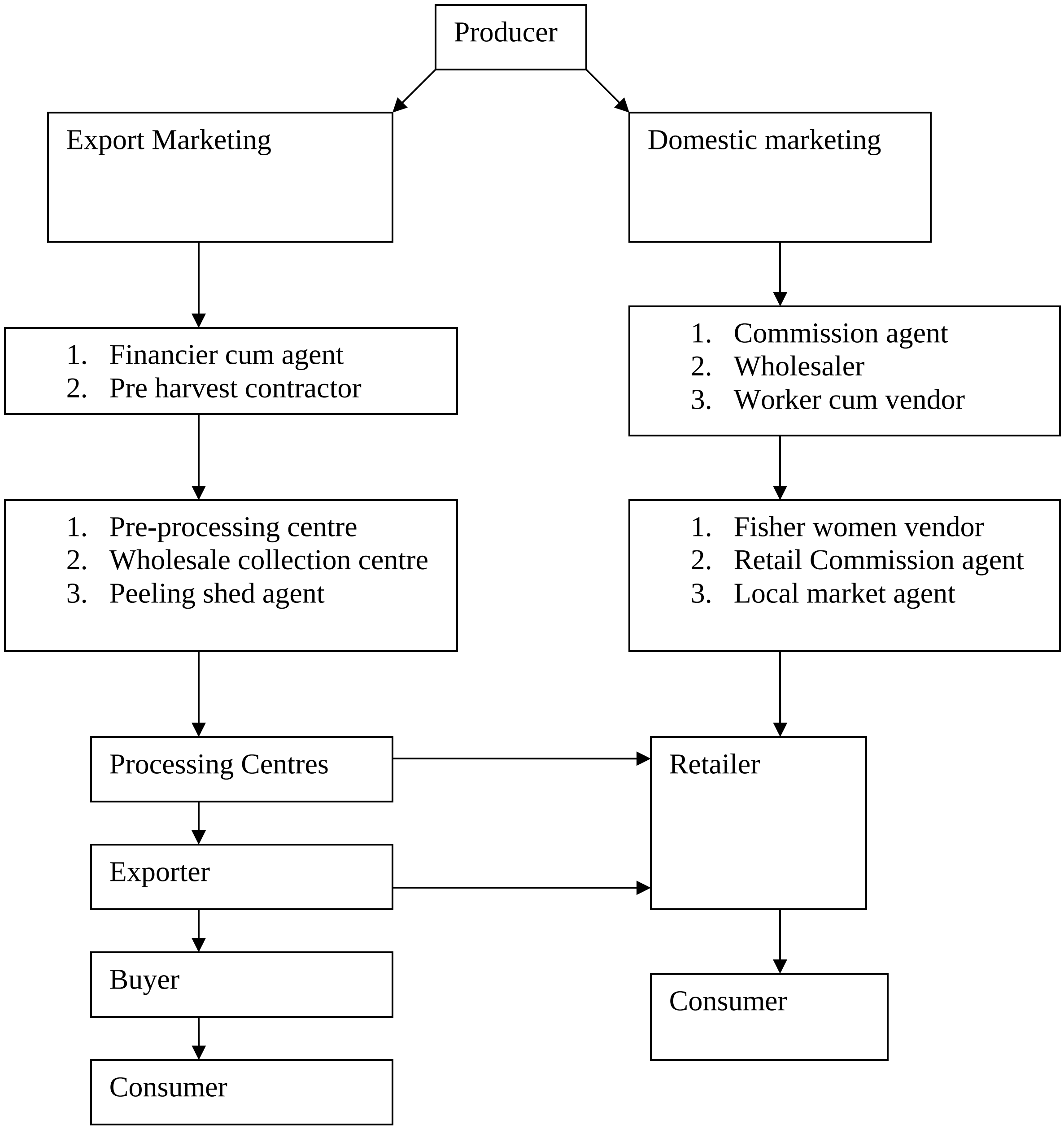


Fig. 3. Marketing channels in domestic and export marketing in India

Price spread is bound to increase within the proliferation of marketing agents performing the service of procurement, assembling, storage, transportation, peeling, processing, packaging, holding, clearing formalities and exporting. It will be influenced by the degree of marketing control exercised by the government policies. An increase in price spread will soon be resulted in the rise of consumer price.

In the best export marketing channel involves a maximum of two intermediaries such as exporters and buyers between the producer and the consumer. This is the best marketing channel for the producer, available in India under the present system of aquaculture product marketing. This system of marketing is available mainly for the commercial semi-intensive farms of Nellore, Guntur and Tuticorin. Here the exporter owns a shrimp farm or he gives consultancy to other entrepreneurs through a buyback agreement. Hence the exporter gets a regular supply of the product according to the demand of the buyer. The harvested prawns are reaching the processing unit in the best possible quality form. Here the producers are getting the maximum price for all grades of prawns.

A marketing channel involving only the essential intermediaries such as exporter cum processor and foreign buyer is the most suitable marketing system. A system of well organized co-operative marketing along with financial assistance from MPEDA, BFFDA, NABARD and state banks can enhance the producer's share and reduce the role of financier cum agents and money lenders.

The successful experiment of mussel farming in Padanna demonstrates parallel development of domestic marketing system is very essential for the introduction and growth of any new product. Domestic consumption of mussel is very conspicuously noticeable in Northern Kerala. Farmers have to harvest the fully grown mussels in May itself and sell before the onset of monsoon to avoid mortality due to low salinity. At present only few companies are purchasing mussel from farmers and the bargaining power from the farmers side is very much restricted. There had been an instance in which entire produce was made as value added products. The growth of Women Self Groups and vertical integration for export marketing through ABAD group in 2003-04 is highly responsible for the spread of mussel farming in this region.

Vulnerability Issues in Marketing

Uncertainty in supply and demand

Price fluctuations

HACCP and Quality issues

Changing International Trade Regulations

Perishable nature of the products

Too many varieties and too many demand patterns

Assembling the products from too many distant and remote centres

Too many intermediaries in the marketing channel

Inadequate storage facilities

Lack of refrigerated transporting system

Lack of vertical and horizontal integration of markets

In the case of marine fish domestic marketing fish travels long distances from coastal areas to interior parts of the country. The usual marine fish marketing channels prevailing in India are as below:

1. Fisher - > Auctioneer–> Agents of freezing plants –> exporters
2. Fisher –> Auctioneer – >Processor(Dry fish) –> Wholesaler –> Retailer –> Consumer
3. Fisher–> Auctioneer–> Wholesaler (Primary market) –> Wholesaler (Retail market) -> Retailer –> Consumer
4. Fisher –> Auctioneer –>Commission Agent –> Wholesaler –> Retailer –> Consumer
5. Fisher –> Auctioneer –> Retailer –> Consumer
6. Fisher –>Auctioneer -> Consumer

The major portion of the internal fish marketing takes place through 3rd to 6th channels. The auctioneers of the primary market and commission agents of the secondary market are also involved in the process without taking possession of the fish. The fish marketing in India can be divided into two groups- domestic fish marketing and export marketing. In India fish marketing has not developed fully on modern lines. There is a gradual transformation from traditional to modern method of marketing with the advent of improved transport, processing and storage facilities. The involvement of a number of middlemen in the marketing chain adversely affects the interest of both fishermen and consumers.

2. Livelihood Opportunities related to Mariculture Development

2.1 Poverty status and livelihood vulnerability of coastal communities

The emerging economic growth, shifting dietary patterns in favour of fish consumption and continuous price rise for different species of fish have increased the demand for fish production, consequence of which constant improvements in technologies are on vogue in order to increase the catch rate by introducing improved craft and gear combinations and to preserve the quality of catch. The negative effects of these new technologies include over exploitation of resources and inter-sectoral conflicts. Apart from these, the socio economic scenario of the fisher folk is deplorable, as they form one of the under privileged section of the community, affected by a number of problems including inadequate employment, food security, closed seasons, dwindling catch rates, problems in production, post harvest and marketing and indebtedness.

Increasing Poverty among Coastal Fisherfolk

The cornerstones of development agenda of a nation is based on the strategies that rests on economic growth, poverty and inequality. The postulates of development paradigm presume rapid elimination of poverty, equitable distribution policies and faster economic growth between which a linkage may be derived. Poverty reduction in a country is directly proportional to the rate of growth of income as well as equitable distribution. The most thought provoking issue in this connection is of defining and assessing what is the level of poverty; whether absolute or relative poverty has to be considered. Absolute poverty is defined in reference to a poverty line that has a fixed purchasing power determined to cover needs that are physically and socially essential. The relative definition of poverty is based on the fixed proportion of some income standard of the population. In India, the poverty estimates are based upon the absolute poverty and according to NSSO 55th round data, the rural poverty line is defined as of INR. 327 per month in 1999-2000 corresponding to 2400 Kcal per capita per diem and for urban India it was INR 454 per month corresponding to 2100 Kcal per capita per diem.

In India rising poverty is of great concern and the official estimates of poverty tend to vary very sharply from year to year. According to the results of the 55^{th} round of the National Sample Survey, the percentage of people below poverty line in India decreased from 36% in 1993-94 to 26 % in 1999-2000. The vast majority of India's poor, estimated to be anywhere between 320-400 million, live in rural areas. A study by the International Food Policy Research Institute (IFPRI) notes that while overall economic growth has been impressive since the start of reforms in the early 1990s, positive impact on rural poverty was not observed. The failure to reduce rural poverty is attributed to declining public investment in agriculture, which provides a livelihood to 70% of Indians. Trade liberalization in recent years has also led to extreme price volatility in many agricultural products that has hurt poor farmers. Agriculture growth has declined in recent years, from 5.0% in 1994-95 to a negative 0.9% the following year to a positive growth of 9.6% in 1996-97 and a negative 1.9% in 1997-98 and is expected to decline over the years.

The incidence and persistence of poverty in fisheries sector can be attributed mainly to open access nature of marine fisheries, slow pace of aquaculture/ mariculture development and unconstrained labour mobility (FAO, 2005). At times labour mobility to fisheries is accentuated by social factors such as caste system prevailing in India. Notwithstanding the above factors there is considerable growth of population within the fishing community and the newer technologies are adopted that pave way to biological and economic over fishing, lesser per capita production stressing the need for efficient fisheries management essentially directed towards sustainable development ensuring distributive justice. The economics of different craft gear combinations and per capita earnings of fishing labour clearly indicates that the people living below poverty line is not less than 60 percent in the coastal rural sector. It is explicitly clear that the coastal rural people could not get much of the benefits of the economic development taken place in our country since independence. It is researchable issue that the sustainable development of FAO does not throw light on the factor of alleviating poverty. The Code of Conduct for Responsible Fisheries as well as FAO's definition of sustainable development, both do not call explicitly for giving special attention to combating poverty.

The policies for alleviating poverty in fisheries sector should focus on certain specific points in addition to common measures adopted. The marine inshore fisheries resources are already over exploited and this result in loss of potential resource rents. The capture of these resource rents by appropriate management efforts can add to the economic growth in long run. Further the increasing adoption of newer technologies coupled with inadequate use of property rights is an important cause of sectoral disparity and inequitable income distribution. The policies pertaining to advent of alternative avocations to fishers by providing the awareness, training and initial resource capabilities can do better in the way of providing mobility to other sectors

Employment of the primary capture fisheries and aquaculture production sectors in 1998 is estimated to have been about 36 million people, comprising about 15 million full-time, 13 million part-time and 8 million occasional workers. Employment in aquaculture (inland and marine) has been increasing and is now estimated to account for about 25 percent of the total.(Govt. of India, 2001).

In spite of regional dimensions of economic growth in India, sectoral disparity, inequality in income and poverty incidence in fisheries sector have been increasing over the years. This information is important owing to the fact that inequality cumulated over a period of time has substantial impact on the standard of living of people (Barro and Sala-i-Martin, 1995). Further inequality in every respect pave way for unequivocal negative effects on subsequent growth and development, thus upsetting the socio economic fabric of the society resulting in conflicts in resource sharing and distribution. The subject of income distribution is one of the most critical issues of development economics and the conventional classical theories postulate inverse relationships between inequality and growth. The recent resurgence of the issues concerning equity and income distribution is closely related to emphasis on poverty reduction as the most important goal for development effort (Kakwani, Khandkar and Son, 2004).

In spite of the planned economic development in the country aimed at reducing spatial and sectoral disparities in income, one may notice that it has been rising over time. Large disparities and negative growth rates undermine the integration of the economies and social stability hampering long term economic growth of which fisheries and aquaculture sectors are no exception. It can be observed that the physical productivity of worker per unit of capital invested has declined steeply which is a phenomenon characteristic of the open access resources subject to increased commercialization (Kurien and Paul, 2001). The recent measure of liberalization of transition economies, India being on list of the late adopters, aggravated the problem of disparities owing to the measures introduced that curtails the supportive measures offered to fisheries sector.

The rise in inequality in the fisheries sector is resultant of the following factors.

i) Shift to capital intensive technologies and labour saving devices.
ii) Technological innovations leading to marginalization.
iii) Drop in the rate of labour absorption in the capture/mariculture
iv) Disguised unemployment.
v) Failure of coastal aquaculture/mariculture to emerge as an alternative avocation.
vi) Lack of integration of mariculture with inshore capture fisheries.
vii) Lack of legislations for open sea mariculture.

2.2 Current experiences and better practice

The success story of IVLP by CMFRI

The Institution Village Linkage Programme (IVLP) for Technology Assessment and Refinement (TAR) is one of the most important segments of National Agricultural Technology Project (NATP) for testing, improving and refining technologies prevailing at or generated for diverse production systems. Central Marine Fisheries Research Institute (CMFRI) has implemented the programme in a coastal village, viz., Elamkunnapuzha in Ernakulam District of Kerala, since August 2000 to April 2005. Altogether 31 techno-interventions are assessed and refined in farmer's fields (13 fisheries, 5 livestock and 13 agriculture). A total number of 687 farm families have participated in these interventions and the total population covered under this programme is 3435. The programme has been successful in building instantaneous linkages among farmers, fisherfolk, research institutions, agricultural universities and the local extension system. It has imparted diverse packages of technical knowledge through 15 field level training programmes in which 576 farmers, out of which 318 females, are participated. The overall impact of this intervention is highly promising and is termed as 'Elamkunnapuzha Model of Development'.

The most important impact of IVLP is the adoption of diversified aquaculture practices by the farmers. The comparative yield levels of different fish culture under recommended practices have shown marked improvements. Hitherto the farmers are mostly concentrating only on shrimp-oriented aquaculture in the region. High price of shrimp coupled with export potential lead them blindly to go for this culture irrespective of its suitability and cost of production. Shrimp culture for most of the farms is not ideal but also less profitable than other fish/crab culture practices. Least cost combination of factors of production coupled with high suitability of ponds for monoculture of crabs, *Mugil cephalus, Chanos chanos* and polyculture of different types of finfishes has shown profitability ranging from INR.2,00,000/ha for monoculture of milk fish to INR.7,00,000 / ha for monoculture of juvenile crabs. The only constraint in the spread effect of crab culture is the non-availability of hatchery-produced seeds.

Farmers have shown much enthusiasm in continuing their efforts in commercializing the ventures. As far as fisheries-based interventions are concerned, around 30 percent of the farmers are using leased ponds. The lease rate of ponds has increased from INR.8500/ha during 2000-01 to INR.10,000/ha during 2003-04 in view of the diversified utilization pattern and consequent increase in demand for ponds. The seasonal employment pattern of fish/crab seed collectors also increased from about 80 to 120 labour days per annum. In the project village alone an area of 22.3ha, so far unutilized, has been brought under different fish culture practices.

The livestock interventions proved as the most ideal supplementary avocation suitable for the coastal agro ecosystem. The benefit-cost ratios of various animal husbandry practices clearly indicate the need for adopting scientific management practices. It provides maximum opportunity for optimum utilization of backyards of homesteads and provides employment mostly to women. The annual household income could be enhanced by INR.2,150 by growing 10 *Gramalakshmi* birds and to INR.10,000 by growing 5 broiler rabbits of Grey giant variety. The cultivation of paragrass in the unutilized marshy lands has shown a potential yield of 10t/ha, indicating higher prospects for the fodder-deficient Island ecosystem.

In agriculture-based interventions, cultivation of vegetables of improved variety yielded better returns as mono-crop and inter-crop along the embankment of fishponds and also along homesteads. Although the yield of snake gourd *(Kaumudi)* cultivation is better than all other vegetables, the net earnings (INR.1,28,325/ha) are more for bitter gourds (*Preethi*). The impact of nutrient management in coconut plantation has shown an average increase of 30 nuts per annum per tree. This practice of nutrient management for all coconut trees in the entire village may bring far reaching impact on the rural economy. Since there are about 100,000 coconut trees in the study area alone, the impact of this single management practice alone could fetch additional revenue of about INR.10 million in Elamkunnapuzha village, even if we assume an additional 20 nuts per tree per year with an average price of INR. 5 per nut.

The IVLP model has ensured the active participation of stakeholders throughout the process of technology assessment and refinement. Participatory Rural Appraisal and Livelihood Analysis have identified the location specific problems, potential solutions and the extent of blending the prevalent indigenous knowledge with the scientific practices to optimise the yield and earnings. Economic feasibility and high profitability in on-farm and verification trials are visible and farmers have largely adopted the improved farming practices. Integration of aquaculture with agriculture and animal husbandry practices has shown potential of generating additional employment opportunities and enhancement of disposable household income.

Comparative Economics of Mariculture practices

Table 8 : A comparison of economic indicators for different aquaculture practices.

Key economic Indicators	**ET**	**EW**	**CC**	**CF**	**MC**	**EO**	**MF**
Net profit/ha(INR)	92,986	1,23,407	43,982	5,38,237	37,544	4,401	12,989
Net operating profit/ha (INR)	1,47,877	1,61,812	64,319	5,87,557	47,146	6,018	14,928
Cost of production /kg (INR)	197	47	210	174	42	2.74	3.58
Profit/kg (INR)	92	63	55	99	22	1.25	1.92
Input Output Ratio	1.46	2.33	1.26	1.57	1.51	1.46	1.54
Breakeven production (kg)	693	846	640	3459	1160	2393	4411
Break even production as % of total production	68	43	79	64	66	69	65

ET- Extensive tiger shrimp culture system;EW- Extensive Indian white shrimp culture system

CC- Crab culture system;CF- Crab fattening system; MC- Milkfish culture system

EO- Edible Oyster culture system; MF- Mussel farming system

A comparative picture of the various economic indicators of different aquaculture practices are given in Table 8. Cost of production was maximum for crab culture system followed by extensive tiger shrimp culture system. When profit per kg was compared across the different culture systems, crab fattening system topped the list, followed by extensive tiger shrimp culture system and extensive Indian white shrimp culture system. Net profit and net operating profit were higher for crab fattening system. Although profit realized per/kg was maximum for crab fattening system, the inconsistent supply of crab seeds prevents their large scale adoption. Although profit realized per kg was higher for the extensive culture system of tiger shrimp, the high production costs indicated the possible risk involved in case of a crop failure. Net operating profit of disease affected tiger shrimp extensive culture system was negative whereas all other shrimp culture systems affected by disease could manage a positive net operating profit. Extensive Indian white shrimp culture system on the other hand had moderate profit per kg and comparatively less production cost than the extensive tiger shrimp culture system.

Crab culture system was the first to achieve break even production, followed by extensive tiger shrimp culture system and extensive Indian white shrimp culture system. When the percentage of break even production to the total production was compared among the different culture systems, extensive Indian White shrimp culture system came first followed by crab fattening system. The economic indicators clearly show mussel culture to be profitable than edible oyster farming. Although production cost per kg and break even production was low for edible oyster farming system, all other indicators favoured mussel farming.

2.3 Role of mariculture in poverty reduction as an alternative to potentially destructive extractive fisheries

In the context of heightening demand for fisheries products, importance of aquaculture has increased seemingly. Freshwater and brackish water fish culture forms the main types of aquaculture activities in India. Mariculture, in spite of its vast potential both on the landward and seaward side of the coastal line has not developed with the exception of shrimp farming. Technological developments like pearl oyster culture, edible oyster culture, mussel culture, lobster farming, crab culture, seaweed culture, sea cucumber culture and culture of fin fishes have been developed by research institutes like CMFRI. Adoption of these techniques on a scientific basis can add to the income of the farmer and thus raise the standard of living.

One of the most adaptable alternative systems that can be offered to the coastal community is that of mariculture. The need of the hour is to organise proper development, extension and training programmes on mariculture to the coastal community. Also this effort should be backed up by effective institutional finance linkages and forward and backward marketing linkages so as to ensure effective and proper implementation of the programme.

Depending on the geographical and ecological diversities of the country, there are vast differences in the availability and suitability of areas that can be developed for mariculture and also in the candidate species available for cultivation. Species like shrimps and the finfish like grey mullets, milkfish, pearl spot, seabass, groupers, redsnapper, breams and pompanos are suitable for farming all along the Indian coast especially along the south west and south east coasts. Other varieties like sea cucumber could be cultured along the coasts of Tamil Nadu and Lakshadweep: pearl oyster along the coasts of Tamil Nadu (Gulf of Mannar & Pak Bay), Kerala, Gujarat, Lakshadweep & Andaman Islands: edible oyster in Andhra Pradesh , Tamil Nadu, Kerala, Karnataka and Gujarat: mussels in Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Goa and southern Maharashtra: windowpane oyster and red clam in Andhra Pradesh: clams in Kerala, Karnataka, Goa and Maharashtra: and the sea weeds in the Gulf of Mannar , Gulf of Kutch, Kerala Backwaters, Chilika Lake, Pulikat Lake and the lagoons and lakes in Lakshadweep and Andaman & Nicobar Islands (Devaraj *et. al*, 1999).

The natural living resources of the Indian seas are rich, diverse and are distributed in a variety of ecosystems/habitats ranging from the estuaries, saline lagoons, low lying saline inundated marshes, inter tidal and sub tidal belt to beyond shallow coastal shelf waters and have immense value and use of humanity. There has been an uninterrupted hunt for the flora and fauna in most of the maritime countries to quench the hunger as well as curiosity. Slowly but steadily the irrational anthropogenic destruction coupled with several other activities like dumping of pollutants, land reclamation, destruction of mangroves have ultimately caused environmental maladies, resource depletion, habitat degradations and even in some cases denudations. Much of these have taken place in the easily accessible coastal waters, fragile sensitive ecosystems and have badly hit the more vulnerable and wanted target species and a wide spectrum of low-value-high –volume bottom biota forming part of the marine food.

2.4 Successful and unsuccessful examples of introduction of mariculture into coastal communities

Mussel farming in Cheruvathur and Padanna in Kasargod District in Kerala: A success story

Kasargod, the extreme northern district of Kerala is particularly notable for mussel farming as it has been successfully accomplished by the women's Self Help Groups (SHGs) for the past few years. These groups were given financial assistance in the scheme namely, SGSY (*Swarnajayanthi Gramaswa Rosgar Yojana*) by the state government which takes care of economic empowerment of weaker sections. Subsidies, bank loans etc are the part and parcel of it and it essentially focuses attention on poverty alleviation through organized Self Help Groups. This programme looks into training, credit, marketing, technical knowledge and basic facilities necessary for the upliftment of the poor. This study was undertaken in two major *Panchayaths*[iii] namely Cheruvathur and Padanna in Kasargod district. Six Self Help Groups of women (three each from both *panchayats*) were selected for the study.

The major expenditure required for mussel farming is for the materials such as bamboo, nylon rope, coir, cloth, seed, etc. and labour costs essentially cover construction, seeding, harvesting etc. The women's' groups constituted in the scheme DWCRA started mussel farming as early as 1996-97 and are assisted by loan amount worth INR. 8800 per member with a subsidy amount worth INR. 4400. The duration of the loan is 5 years and the rate of interest is 12.5 % per annum. In addition to this, a revolving fund of INR. 5000 was also provided without interest. When the SHGs are economically empowered with the provision of loan facilities, the returns from mussel farming help them to repay the loan slowly.

The loan was granted through Farmers' Service Cooperative Banks and North Malabar Gramin Banks in Cheruvathur and Padanna *panchayaths* of Kasargod district. Majority of the SHGs' showed considerable progress in repayment of the loans interpreted as indication of the profitability of Mussel farming. The expenditure details of the selected SHGs in the initial year of mussel cultivation are shown in the Table 1.

[iii] *Panchayat* is the tiniest elected empowered body of people's representatives in the local administrative set up

The Net Operating Profit in all the six SHG's was computed and found as substantially good which proves the profitability of Mussel farming in the initial trial itself and since during the subsequent years, material costs such as those of bamboo, rope, cloth and labour cost in construction etc. are negligible, this ensures reasonable profit as a major consequence of adoption of Mussel farming enterprise bringing about economic empowerment of rural women through organized Self Help Groups. The BC ratio for all the six SHG's was above 1 indicative of considerable economic viability and potential in mussel farming.

The loan sanctioning, utilization, accounts maintenance and timely repayment of loans etc. are all perfectly accomplished with proper maintenance of the documented records by the group members. This ascertains the fulfillment of norms and standards of the SHG leading to economic empowerment of the members.

An unsuccessful attempt in mariculture:

Case study of Mussel Farming in Karwar and Bhatkal of Karnataka State

Self Help Groups (SHGs') of fisherfolk were mobilised in *Karwar* and *Bhatkal* locations of Karnataka coastal belts. Three SHG's of 15 members each comprising a total of 45 were mobilized in Majali (Open Sea) of Dhandebag and three SHG's of 15 members each comprising a total of 45 were mobilized in Sunkeri of Kali estuary in Karwar coastal belts in Uttar Kannada district of Karnataka state. Initially, two training and demonstration programmes in these two sites in Karwar were undertaken, one for *raft culture* in open sea in *Majali* of *Dandebag* and one for *rack culture* in *Sunkeri* of *Kali* estuary. The training was imparted to 45 members of three Self Help Groups, each possessing 15 members in 2 sites separately comprising a total of 90 participants. Similarly In *Mundalli* river of *Bhatkal* estuary in Karnataka, 4 Self Help Groups of 15 members each exclusively of women fisherfolk mobilized under the NGO, *' Snehakunja '* comprising a total of 60 participants were trained on mussel farming.

The major expenditure required for mussel farming is for the materials such as bamboo, nylon rope, coir, cloth, seed, etc. and labour costs essentially for construction, seeding, harvesting etc. The SHGs' of *Majali* and *Sunkeri* were mobilized by the project team of CMFRI and the SHG's of *Bhatkal* were mobilized by a NGO namely *Snehakunja.* The first two trials and demonstrations were under the funding of CMFRI and for the last one, only the technical helps during the training and demonstration were offered by CMFRI. The yield particulars in all the ten SHG's was noted and found as substantially good which proves the profitability of mussel farming in the subsequent trials because the material costs such as those of bamboo, rope, cloth and labour cost in construction etc. are negligible, this ensures reasonable profit as a major consequence of adoption of Mussel farming enterprise bringing about economic empowerment of rural women through organized Self Help Groups.

Mussel farming faces a number of impediments like water salinity, seed availability, selection of location / site, climatic vagaries, identification of proper beneficiaries and proper monitoring opportunities. The major problems and constraints faced by the fisherfolk in mussel cultivation are as follows

- Unpredictable seed availability.
- Mortality of seeds during transportation.
- Reduced growth during certain years.
- Lack of depuration facilities.
- Lack of storage, cold room, cold chain
- Marketing of mussels.
- Social dynamics at the village level based on caste, politics.

The open sea mussel culture in this particular case met with the impediment of unfortunate sabotage of the seeded mussel by some miscreants. It was rectified by reseeding, but the yield was not that much conspicuous compared to the trials undertaken in estuaries. All the SHG members are of unanimous opinion that the government should come forward with suitable legislations for the allotment of water spread area for open sea mussel culture and improved marketing facilities. Provision of loans with reduced interest rates and freezer facility for storage of harvested mussels can bring about a breakthrough in this sector in the near future.

Sea weed culture of *Kappaphycus* promoted by Pepsi Company is also an example of vertical integration due to the big profit reaped into it as 100 times of the production cost. Similar scope is there for Ornamental Fish culture

2.5 Markets and coastal community development linkages

Forward and backward linkages are essential for the sustenance of any development initiative. Market oriented production rather than production oriented marketing is to be opted to ensure efficiency in marketing and to overcome problems in marketing. A need-based linkage building would certainly help in sustaining the marine aquaculture initiatives. Linkages that need to be developed are with that of consumers, middlemen, agricultural/fisheries office, NABARD, banks and other financial institutions, *panchayat* functionaries, NGO's, marketing outlets, local organizations, researchers and input suppliers.

Another linkage that is to be developed, though in the present vista is not much emphasized is the consumers changing needs and wants. Though it is highly relevant in the modern marketing contexts of branded consumer products, the idea can be very much adopted in the fisheries marketing also. Consumers can be educated about new products and can be encouraged to use new items of fisheries products. This is possible through information dissemination through media. By the time the demand for these items are generated, production can also be initiated by marine aquaculture activities. As earlier stated adoption of this strategy can promote market oriented production.

A linkage that is essential in any development initiative is that of finance. An activity that is not supported by financial assistance in the form of subsidy, credit and grants are not sustainable. Hence adequate backward linkages from the financial institutions/Government agencies have to be provided to ensure successful implementation and continuation of the programme. Mariculture is not yet commercially exploited on a large scale and adequate support and extension is required to extent its adoption.

3. Existing and potential mechanisms of technology transfer

There are no mechanisms exclusively targeted at extension in the field of mariculture**.** The Department of Fisheries of the state governments have extension officers who look in to the specific extension agenda of the state department. The Brackishwater Fisheries development Agency in maritime states also have some mechanisms for guiding farmers and entrepreneurs. The Marine Products development Authority has officers specially trained for the extension of shrimp farming. There are training programmes at the state level and farmer level conducted by the state departments and MPEDA. State Agricultural Universities in the maritime states through the Colleges of Fisheries also have extension training and dissemination of information to farmers.

3.1 Training centres of excellence

There are no exclusive training centres in India for mariculture inIndia except for a training hatchery established in CMFRI at Cochin. CMFRI is the nodal agency in the country which conducts Masters and Ph.D level courses in Mariculture in India. It has hatcheries in Mandapam, Vizakhapatnam, Tuticorin, Calicut and Cochin which are used as training hatcheries. A centre of excellence in Mariculture is being developed at its regional centre in Mandapam Camp where there is an extensive farm area to be developed in to a large marine farm. A modern hatchery is under construction at Mandapam. There is need for technical support and for organizing regular training programmes in Mariculture as being done in SEAFDEC. CMFRI is also the NACA centre for mariculture, with no programme ongoing at present. CMFRI is also the Centre of Advanced Studies in Mariculture of the Cochin University of Science and Technology

There is great potential for developing a regular training programme here and updating it in to a centre of excellence. CMFRI has a Division on Mariculture located at Mandapam. The centre has over 14 scientists and over 100 technical and supporting staff, guest house, running seawater facilities, laboratories etc. The MPEDA has a hatchery at Vallarpadom for shrimp which was used for imparting training till a few years back, but is not functional now. Some trainings are imparted by NGOs and VAs, with the help of scientific organizations, but their impacts are low.

3.2 Existing mechanisms of technology transfer and proposed alternative mechanisms for effective dissemination of R & D for farmers and other stakeholders

The transfer of technology (TOT) basically depends upon three systems i.e. the Knowledge Generating System (KGS), the Knowledge Disseminating System (KDS) and Knowledge Consuming System (KCS). The members of the KGS are Research Institutes, the members of KDS consists of extension personnel and other transfer of technology agencies. Besides this the KDS also includes the Input Supply Agencies (ISA) such as Lead Banks, Fertiliser Corporations and Seed Suppliers'. The main function of KDS is to transfer the technology to KCS and collect feed back and pass it on to KGS. The KCS consists of farmers and actual users of technology. The most effective transfer of technology is possible when all the three systems i.e. KGS, KDS & KCS work in close co-operation. There should be an effective interaction and desired relationship between all the three systems.

The Indian Council of Agricultural Research though basically a KGS has also taken up the task of transfer of technology by launching various schemes in collaboration with State Govts. (KDS) and agriculture Universities and voluntary agencies. The various transfer of technology programmes launched by ICAR, are, All India Coordinated Research Projects, National Demonstration Programme, Operational Research Projects and Krishi Vigyan Kendra Trainers' Training Centres and Lab-to-Land Programme. The scientists of the ICAR are actively engaged in these transfer of technology programmes. This will develop the desired linkage between the KGS (ICAR & Agricultural University KDS (State Govt., Voluntary and other Extension Agencies) and the KCS (the farmers and users of the technology). This is a step in the right direction and will narrow the gap between the research and the extension systems.

Systems of Extension in India

In Indian context, broadly there are 4 major organizational streams to TOT work for fisheries and rural development.

1. The first line extension system comprising mainly the ICAR institutes and state agricultural universities.
2. Extension system of Ministry of Agriculture / Fisheries and the State Dept. of Fisheries.
3. Extension System of Ministry of Rural development and State Development Departments.
4. Development work by The NGOs, business houses etc.

SCHEMES FOR TRANSFER OF COMPOSITE FISH CULTURE TECHNOLOGY

In India both Govt. and non-Govt. organisations are presently engaged in dissemination of the technology of Composite fish culture through their various transfer of technology schemes. Some of the important schemes are given below:

1 All India Coordinated Research Project on Composite Fish Culture.

2 National Demonstration.

3 ICAR/State Govt./Agricultural University Demonstration.

4 Voluntary Organization Demonstration

5 Operational Research Project.

6 CIFRI/IDRC Rural Aquaculture Project & CMFRI Mariculture projects.

7 Fish Farmers' Development Agencies.

8 World Bank Project.

9 Krishi Vigyan Kendra.

10 Trainers' Training Centre.

11 Lab-to-Land Programme.

12 Agricultural Technology Information Centre (ATIC) of ICAR institutions and SAUs

3.3 Present training activities and likely future requirements

Present training activities are limited to M.F.Sc and Ph.D. Courses in Mariculture at CMFRI, Cochin. For a country if the size and scope as that of India, this is far too low. There is need to upgrade the technical manpower, training capacities and infrastructure with funding support for regular training in mariculture for farmers and entrepreneurs at its Mandapam, Visakhapatnam and Calicut centres. India could develop as a major player in mariculture by diversifying in to farming of finfish, mollusks, sea cucumber, crabs, lobsters, seaweeds etc. Great potential exists and there is urgent need to develop at least one centre of excellence in Mariculture with technical and operational support from FAO/ NACA at CMFRI as it already has infrastructure, farm, hatchery and some scientists working on research issues in Mariculture. At least 100 persons could be trained every year in various mariculture technologies at this centre. Also, the MPEDA's Vallarpadam hatchery could be converted to a training centre by collaborating with CMFRI. The hatchery at CIBA, Chennai could also be used for shrimp hatchery training. CMFRI is upgrading its hatcheries at the other centres and establishing a national Fish Seed Facility in Cochin for supplying fish seed to farmers. CMFRI also has commenced an Open Sea Cage Demonstration Farm at four sites , two on the east coast and two on the west coast. All these efforts together will help in developing the mariculture activities in India in the next 5 years.

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4.0 Existing Major Mariculture Species and farming Technologies

4.1 Status of farming of selected species

Details of the mariculture potentials of the country are presented below in Table 9.

Table 9.Mariculture Potential in India

Sl. No.	Area	TA (Million ha)	PCA (million ha)	CCA (million ha)	CAP (tons)
1	Coastal land based	2.5	1.2	0.14	85,000 (mainly shrimps)
2	Hinterland saline soil aquifer based	8.5		100	200 (milkfish, mullets, pearl spot, scampi)
	Sea Farming				
	(a)Open sea (EEZ)	202	1.8 (inshore 0-50m depth)	20	1500(mussel)
	(b) Bays, coves and gulf	-	10700	-	-
	(c) Estuaries and backwaters	-	2050	5	800(oysters)
	(d)Island lagoons/lakes				
	Stock Enhancement Programme	35,000	-	-	-
	(a)Sea ranching	18(0-50m depth)	18	Nominal	Nominal(shrimp, pearl oyster,clams,sea cucmber)
	(b) Artificial reef Habitat	-	-	50 reefs	10
	(c)Bottom Artificial reefs (FAD)	-	-	150 FAD	

TA = Total area; PCA = Potential cultivable area; CCA = Current cultivated area;CAP = Current Annual Production.

Source : Devaraj *et al*. 1999

Table 10.
Marine organisms of aquaculture importance in India

Species	Hatchery Techniques	Rearing Technique
Fishes		
Mugil cephalus, *Liza parsia*,*L. macrolepis*, *Valamugil seheli*,*Chanos chanos, Etroplus suratensis*, *Epinephelus tauvina*, *E. dussumieri, Lethrinus* spp., *Sillago sihama*, *Anguilla bicolor* and *Siganus* spp.	X	X
Anemone fish, *Chromis* sp**.** and *Lates calcarifer*	XX	XX
Crustaceans		
Penaeus monodon, *P. indicus* and *P. semisulcatus*	XXX	XXX
Scylla serrata	X	XXX
Portunus pelagicus	XX	XX
Panulirus homarus, *P. ornatus* *P. polyphagus* and *Thenus orientalis*	X	X
Molluscs		
Perna viridis, *P. indica*, *Pinctada fucata, Crassostrea madrasensis*, *Anadara granosa*, *Meretrix meretrix, M. casta*and *Paphia malabarica*	XXX	XXX
Trochus radiatus, *Xancus pyrum*, *Sepia pharaonis* and*Loligo duvaucelli*	X	X
Seaweeds		
Gracilaria edulis, *Gelidiella acerosa*, *Porphyra* sp., *Sargassum* spp., *Ulva* spp. and *Euchaemia sp.*	XX	XX
Seacucumber		
Holothuria scabra	X X	X X

X = Techniques under development
xx = Techniques developed
Xxx = Techniques developed and commercialized

Existing major mariculture species and farming technologies

Shrimp culture:

Shrimps being a highly valued export commodity, shrimp farming is considered a lucrative industry. The current shrimp aquaculture production of India is around 100000 tons from an area of 0.12 million ha. spread over West Bengal, Kerala, Andhra Pradesh, Tamil Nadu and Karnataka. Production-wise *Penaeus monodon* contributed 75% and *P.indicus* 20%. Depending on the area of the pond; inputs like seed, feed and management measures like predator control, water exchange through tidal effects or pumping, etc., farming systems have been classified into four groups: extensive, modified extensive, semi-intensive and intensive. According to Marine Products Export Development Authority (MPEDA), which is the main agency promoting shrimp farming through its various schemes and subsidies, during 2000-01, about 1,45,900 ha was under shrimp culture, with an average production of 0.7 tons/ha/y. Currently, 80 percent of the shrimp production comes from small and marginal holdings, with farms of less than 2 ha constituting 49.2 percent of the total area under culture, between 2-5 ha (15.8 percent), 5-10 ha (13 percent) and the rest >10 ha. Presently, there are about 200 operational shrimp hatcheries with a total annual production capacity of 10.8 billion seeds (PL 20), most of them located on the east coast, with state-of-the-art facilities. There are also 33 feed mills with a total installed capacity of 1,50,000 tons to cater to shrimp industry. Fluctuating marine fish production combined with increased demand for shrimp in global market, successful demonstration of semi-intensive shrimp culture and establishment of commercial hatcheries along the east coast of India have led to rapid development of intensive/semi-intensive shrimp farms with a production of 5-10 tons/ha/crop in 4-5 months. Farmed shrimp production increased from 40,000 tons in 1991-92 to 82,850 tons in 1995-96 but subsequently, slumped to about 70,000 tons between 1995- 97 as the fast pace of development failed to look at sustainability which resulted in disease outbreak, crop failures, environmental degradation and social tensions . Presently, most of the large farms run by corporate bodies have closed down due to disease problems, public litigations and protests by environmental groups over issues like salination of land and fresh water aquifers adjacent to shrimp farms, through seepage. The farming community has now become more responsive to the concepts of environment-friendliness and sustainable aquaculture. Disease problems are being overcome through adoption of closed system of farming (recirculation system, zero water exchange) in grow outs, application of probiotics, secondary aquaculture of selected fishes like mullets, milkfish, molluscs and seaweeds in reservoirs and drain canals, adoption of indigenous, good quality seed and feed and reduction in stocking density to 5-6 nos./sq. m in the farms. Preliminary trials of culture of *P. monodon* in freshwater have shown fast growth and high production and have been adopted in many farms along the Andhra Pradesh and Kerala coasts. Advanced molecular techniques like Polymerase Chain Reaction (PCR) for early and rapid detection of viral pathogens, which cause disease outbreaks, are also being used to prevent disease problems in the grow out system.

Socio-economic development through integrated farming systems and group farming experiments

In the coastal low lands (*Pokkali* fields in Kerala, *Khar* lands in Goa, *Khazans* in Karnataka State and *Bheri* in West Bengal) along the west coast of India, there is a traditional practice of shrimp farming in rice fields, which is done as a rotational crop after rice harvest giving production up to 0.5 ton/ha/year. Fragmented holdings and poor socio-economic conditions of these small farmers, for whom the aquaculture is a livelihood activity, prevent the adoption of advanced technologies. Group farming approach, which relies on synchronized farming operations and collective management by the farmers of a locality is found to help increase production by improving the farmers' access to required inputs and reducing the cost of cultivation. As part of its action, research project on empowerment of rural communities through extension, the Central Marine Fisheries Research Institute initiated group farming approach using shrimp (*P. indicus*) – rice rotation culture through its Institute-Village-Linkage Programmes (IVLP), designed to transfer technologies efficiently from lab to field and improve rural economy. Besides achieving social and economic gains for the farmers, it was especially useful in empowering women farmers, where women for the first time directly participated in an area entirely dominated by men and production of scientifically developed shrimp feed was taken up by women on a commercial basis . Unemployment is a serious issue, especially in rural areas of India. Consequent upon the establishment of shrimp farms , employment is reported to have increased by 2-15 percent and the average income of farm labourers has increased by 6-22 percent . The average labour requirement for paddy cultivation was found to be 180 labour days/crop/ha compared to shrimp farming where 2 crops were taken and labour requirement was 600 labour days/crop/ha . Ancillary industries like hatcheries, feed mills, processing and ice plants have also generated employment opportunities and boosted the rural economy. It has also helped in the development of indigenous technologies, especially with regard to feed and seed production. Imported shrimp feed is expensive and beyond the reach of small farmers and special low pollution diets which cost half the imported feeds and yet with an FCR of 1.5:1 has been developed indigenously and widely adopted by small farmers in improved extensive farming ventures. In addition, production of this scientifically formulated ecofriendly feed, *Mahima,* on a commercial basis, has been taken up by women in certain villages, which has also aided in empowering them. In shrimp hatcheries, a regular supply of healthy broodstock is necessary. However, the supply of spawners from the wild is limited. Until recently, eyestalk ablation was the widely adopted method to induce rapid maturation and spawning. Presently, the technology has been developed to induce maturation and repetitive spawning using environmental and nutritional manipulation strategies in shrimps like *P. indicus* and *P. semisulcatus* .

Issues in shrimp farming

While extensive farming methods are sustainable and produce little waste, intensive operations discharge effluents carrying nitrogenous excretory waste, uneaten food, residues of chemicals and drugs that cause damage to the ecosystem. The quality of effluent water from different systems of shrimp farming in India is generally believed to be low without any serious impact on biodiversity .The Ministry of Agriculture (GOI) has prescribed standards for shrimp farm waste water which is in the interest of the aquaculturist to adhere and ensure sustainable production system. The MPEDA is also extending assistance for setting up effluent treatment units in shrimp farms of 5 ha or more water area, either singly or in a group. Conversion of mangroves and agricultural lands are also serious reasons for conflicts arising out of competitive utilization of limited natural resources, although such practices have been minimal and mainly fallow and unproductive agricultural lands have been converted.

There are also reports of salinization of ground water and agricultural land through seepage from aquaculture ponds. Wild seed capture rampant before establishment of hatcheries and the blocking of access to sea by large farms were also causes for conflict with the capture fisheries sector, which has been resolved to a large extent now.

In view of the numerous conflicts that arose and litigations by environmental groups, the Coastal Regulation Zone (CRZ) notification, 1991 under the Environment (Protection) Act, 1986, restricts construction of shrimp farms a landward boundary up to 500 m from high tide line (HTL) and has put an end to the construction of coastal farms. While aquaculture development is controlled by local state governments, its overall supervision is done by the Central Ministry of Agriculture, which in 1995, issued guidelines for sustainable development and management of brackishwater aquaculture. It seeks to discourage conversion of agriculture lands, mangroves and other ecologically sensitive wetlands for aquaculture. Also, Environmental Monitoring and Management Programme (EMMP) and Environment Impact Assessment (EIA) have been made mandatory for shrimp farms of 10-40 ha and >40 ha, respectively, which require a ‘No Objection Certificate’ from the State Pollution Control Boards for all the qualifying aquaculture units. A National Aquaculture Authority has also come into force, which consists of representatives of Pollution Control Boards, Revenue Authorities, Fisheries Departments, Developmental bodies and Research Institutions, who have been assigned the role of regulating shrimp culture in a sustainable manner in the country. The code of practices for shrimp hatcheries and farms are also being issued by MPEDA. Shrimp farming being more economical and rewarding than any other agricultural farming (Table 3), suitable areas may be marked out for shrimp farming by an identified Integrated Coastal Area Management Authority and coastal aquaculture may be suitably integrated in an eco-friendly manner with other activities in the coastal region to reap maximum benefits. In general, there is a greater awareness of the need to adopt sustainable aquaculture methods like low stocking density, minimum usage of chemicals and feeds and prevention of conflicts at most of the major shrimp farming centres.

Table 11. Economics of shrimp aquaculture / hatchery

Enterprise	Shrimp farm	Shrimp hatchery	Broodstock / nauplii Facility
Area and production	1ha	0.3 ha	0.1 ha
Capacity	1.0-2.0 t/ha/crop	40 million PL20/year	200 million nauplii/ year
Species	*P. monodon* *P. indicus* *P.semisulcatus*	*P. monodon* *P. indicus* *P.semisulcatus*	*P. monodon*
Farming method	Modified extensive	Broodstock Development induced maturation, larval and post larval rearing.	Indoor tanks
Duration	4-4 ½ months	30 days /run	15 days
Economics (in Rs)			
Initial investment	18,000	7, 60,000	38,500
Recurring cost	9,000	90,000	13,750
Total cost	27,000	3, 80,000	52,250
Production	3.12t (2 crops)	40 million PL20/yr	200 million nauplii/yr
Revenue	97,000	2, 62,000	50,000
Net profit	22,250	65,500	18,000

Source : ICAR 2000

Lobster farming and Fattening

Increasing demand for live lobsters and crabs in the export market led the farmers and entrepreneurs to collect juvenile lobsters and crabs from the wild and grow to marketable size in ponds and tanks by feeding trash fishes and other discards. In many maritime states juvenile lobsters, *Purulei* of *Panulurus homarus, P. ornauts, P. poyphagus* and *Thenus orientalis* are grown in captivity and the eyestalk ablated lobsters attained 180 – 200 g in 5 – 6 months period. This type of lobster fattening at a stocking density of 10 – 15 young ones per square meter yielded appreciable growth rates with a profit margin of INR.50, 000/- from a pond of 70 m^2. Recently major breakthrough in breeding and hatchery production of two species of scyllarid lobsters, *Thenus orientalis* and *Scyllarus rugosus* was achieved by CMFRI. Successful hatchery production of seeds of *T.orientalis* was accomplished for the first time in India and is the second instance globally. Completion of larval cycle of *T.orientalis* was achieved in 26 days and *S.rugosus* in 32 days.

Crab farming / fattening

Live mud crabs (*Scylla serrata*, *S. tranquebarica)* being a much sought export commodity, mud crab fattening was considered the best alternative. Seed stock consist of freshly moulted crabs (water crabs) of 550 g which are stocked in small brackishwater ponds at a stocking density of 1/sq. m or in individual cages for a period of 3-4 weeks while being fed thrice daily with trashfish @ 5-10 percent of their biomass. Selective harvesting is done according to size, growth and demand and the venture is profitable because of low operating costs and fast turnover. Monoculture (with single size and multiple size stocking) and polyculture with milkfish and mullets are being carried out on a small scale, as the seed supply is still mainly from the wild. Experiments on breeding and seed production of *S. tranquebarica* have given 20 percent survival rate from egg to first instar stage and attempts are on to improve the survival rate for an economically viable hatchery technology. Hatchery technology for breeding and seed production of the blue swimming crab, *Portunus pelagicus*, has also been developed and four generations of crabs have been produced by domestication. The hatchery seed is being mainly utilized for stock enhancement programmes along the east coast.

Table 12.Economics of three systems of mud crab farming

Culture Method	Monoculture	Polyculture	Fattening
Species	*Scylla tranquebarica* *S. serrata*	*S. tranquebarica* *S. serrata*	*S.tranquebarica* *S. serrata*
Culture Period, days	120	138	30
Expenditure, INR. (seed, feed, pond, Preparation, labour)	43,860	48,400	56,200
Production, t crabs	0.78	1.14 and 0.7 tonne milkfish	0.56
Income, INR.	1,57,200	2,61,200	1,22,850
Net profit /crop INR.	1,13,340	2,12,800	66,650

Source : ICAR 2000

Edible Oyster Farming

CMFRI has developed methods for edible oyster (*Crassostrea madrasensis*) culture and has produced a complete package of technology, which is presently being widely adopted by small scale farmers in shallow estuaries, bays and backwaters all along the coast. In the adopted rack and ren method, a series of vertical poles are driven into the bottom in rows, on top of which horizontal bars are placed. Spat collection is done either from the wild or produced in hatcheries, on suitable cultch materials. Spat collectors consist of clean oyster shells (5-6 Nos.) suspended on a 3 mm nylon rope at spaced intervals of 15-20 cm and suspended from racks, close to natural oyster beds. Spat collection and further rearing is carried out at the same farm site and harvestable size of 80 mm is reached in 8-10 months. Harvesting is done manually with a production rate of 8-10 tonnes/ha. Oyster shells are also in demand by local cement and lime industry and culture production has increased to 800 tonnes in the year 2000.

Mussel Farming

Raft method (in bays, inshore waters), rack method (in brackishwater, estuaries) or longline method (open sea) are commonly adopted for mussel farming *Perna indica* and *P.viridis*). Mussel seeds of 15-25 mm size collected from intertidal and subtidal beds are attached to coir/nylon ropes of 1-6 m length and enveloped by mosquito or cotton netting. Seeds get attached to rope within a few days while the netting disintegrates. The seeded ropes are hung from rafts, racks or longlines. A harvestable size of 70-80 mm is reached in 5-7 months and production of 12-14 kg mussel (shell on) per metre of rope can be obtained. Attempts to demonstrate the economic feasibility of mussel culture has led to the development of group farming activities in the coastal communities (especially rural women groups) with active support from local administration and developmental agencies like Brackishwater Fish Farmers Development Agency (BFFDA) and State Fisheries Department. Cultured mussel production has increased from 20 tonnes (1996) to 4500 mt in 2004 mainly through the rack system in estuarine area. Molluscan culture technologies and their economics are given in Table 13.

Table 13. Molluscan culture technologies and economics

Technology	Edible oyster farming	mussel farming	Pearl oyster culture
Species	*Crassostrea Madrasensis*	*Perna viridis* *P. indica*	*Pinctada fucata*
Farming method	Rack and Ren (30 X 10m)	Raft (8 X 8m)	Cages suspended from rafts / racks
Culture Period	8 months	5-7 months	12-15 months
Unit area	300 sq.m	64 sq.m	Open sea; 6 rafts
		And 600 box cages.	
Economics (US$)			
Initial investment	371	203	10,000
Recurring cost	139	357	4,419
Total cost	510	560	
Production	5.83 tonnes shell - on (0.48 tonne meat)	0.8 t shell- on	

Revenue percentage	736	934	Depends on pearl production and market value of pearl
Profit	226	303	30% (at 25% pearl production.

Source: ICAR 2000

Pearl Oyster Farming and Pearl Production

In India, the marine pearls are obtained from the pearl oyster, *Pinctada fucata*. Success in the production of cultured pearls was achieved for the first time in 1973 by CMFRI Raft culture and rack culture in nearshore areas are the two methods commonly adopted for rearing pearl oysters and recently attempts have been made to develop onshore culture methods. Shell bead nucleus (3-8 mm) implantation is done in the gonads of the oyster through surgical incision while graft tissues are prepared from donor oysters of the same size and age group. Implanted oysters are kept under observation for 3-4 days in the labs, under flow through system and then shifted to the farm in suitable cages for rearing. Periodic monitoring is done and harvest is carried out after 3-12 months. Pearls are categorized into A, B and C types depending on colour, luster and iridescence. 25 percent pearl production has been successfully demonstrated in a series of farm trials at various locations along the Indian coast. Research is also directed towards development of a technology for *in vitro* pearl production using mantle tissue culture of pearl oyster. The technology for mass production of pearl oyster seed and pearl production has paved the way for its emergence as a profitable coastal aquaculture activity at certain selected centres along the coast. Village level pearl oyster farming and pearl production, through direct involvement of small scale fishermen have been carried out successfully as part of technology transfer programme along the Valinokkam Bay on the east coast (Table 14). Pearl oyster farming has already generated income worth US $ 26,000 and several young women who are trained in pearl surgery in pearl farms are finding ready employment in this developing industry. The

CMFRI also imparts training on pearl culture to trainees in neighbouring Asian countries, and various Memorandum of Understanding (MoU) have been signed with entrepreneurs, desirous of pearl culture since 1996. Recently success has been obtained in the production of Mabe pearls and tissue culture of pearls. Success was achieved in the organ culture of mantle of pearl oyster and abalone. A breakthrough has been achieved by developing a tissue culture technology for marine pearl production using the pearl oyster *Pinctada fucata* and abalone *Haliotis varia* for the first time in the world. This technology can be easily extended to other pearl producing molluscs and gives ample scope for manipulation of pearl quality and also increased pearl production. Mabe pearl production was standardized for production of base images with ten different types of moulds .Technology for production of jewelry from Mabe pearl was also standardized.

Table 14. Economics of pearl culture programme at Valinokkam Bay – A group farming success

Number of oysters implanted	9414
Total expenditure incurred, US$	1571
Rate of Return, %	56.7
Total pearls harvested	1849
Revenue earned from sale of pearls, US$	2178
Pearls is distributed to fisherman	250
Revenue earned from sale of pearls	US# 2178

Raft	Cages	Pearl oyster (For implementation)	Pearl oyster (for graft tissue)	Shellbead nuclei	labour	Miscellaneous
24	18	24	2	17	6	9

Clam Culture

Package of clam culture practices has been developed for the blood clam *Anadara granosa* and *Paphia malabarica*, where production of 40 tonnes/ ha/6 months and 15-25 tonnes/ha/4-5 months have been achieved in field trials. Induced spawning and larval rearing to setting of spat has been perfected for clams like *P. malabarica*, *Meretrix meretrix* and *Marcia opima*.

Sea Cucumber Culture

More than 200 species of sea cucumbers are found in Indian waters mainly in the Gulf of Mannar, Palk Bay and Andaman and Nicobar Islands. The most important commercial species is *Holothuria scabra*, whose continuous exploitation has led to depletion of natural population . Seed of *H. scabra* was produced in the hatchery for the first time in India in 1988 through induced spawning using thermal stimulation and has been used widely since then to produce seed for stock enhancement programmes. Water quality is the most important parameter in hatcheries with ideal conditions being temperature, 27-29^{o}C; salinity 26.2 – 32.7 ppt, dissolved oxygen 5-6 ml/l; pH, 6-9; and ammonia content, 70-430 mg/cubic metre . Larvae require different diets at different developmental stages and algae like *Isochrysis galbana*, *Chaetoceros calcitrans*, *Tetraselmis chuii* and *Sargassum* are used. Seed produced in hatcheries are grown in velon screen cages (2 sq.m area), netlon cages (1.65 sq.m area, 5 mm mesh net), concrete rings (70 cm dia x 30 cm height) and also at the bottom of prawn farms. Artificial diets prepared with soyabean powder, rice bran and prawn head waste is used for feeding juveniles and results are encouraging. Juveniles have been stocked @ 30,000/ha and grown along with shrimps (*P. monodon*) in farms . Sea cucumbers being detritus feeders, feed on waste shrimp feed and organic matter on the pond bottom, reducing the organic pollution load in the farm. Being an eco-friendly practice, which also provides an additional income to the farmer, it is expected to become popular among farmers who have been facing problems of shrimp disease outbreaks in the recent past.

Marine Finfish Culture

In the area of marine fish culture, the country is still in the experimental phase only. Attempts are being made to develop suitable hatchery and farming technology for mullets (*Mugil cephalus*, *Liza macrolepis*, *V. seheli*), groupers (*Epinephelus tauvina*), seabass (*Lates calcarifer*), milkfish (*Chanos chanos*) and pearlspot (*Etroplus suratensis*). The Central Institute of Brackishwater Aquaculture (CIBA) has developed an indigenous hatchery technology for seabass using captive broodstock which were stocked in large RCC tanks (12 x 6 x 2 m) with 70-80 percent water exchange daily. Maturation process was accelerated using LHRH hormone injection and larvae were maintained with rotifers and *Artemia* nauplii. Cooked and minced fish meat is used for nursery rearing and survival rates up to 14 percent in larval rearing phase and 84 percent in the nursery phase have been recorded. Hormonal induction of Broodstock development was achieved in groupers.

Ornamental Fish Culture

There are a wide variety of ornamental fishes in the vast water bodies and coral reef ecosystems along the Indian coast, which if judiciously used, can earn a sizeable foreign exchange. A long term sustainable trade of marine ornamental fishes could be developed only through hatchery produced fish. Hatchery technology for clownfish (*Amphiprion sebae*), damsel fishes (*Pomacentrus caeruleus*, *Neopomacentrus nemurus, N. filamentosus*, *Dascyllus trimaculatus*) and the sea horse (*Hippocampus kuda*) has been developed, which can be scaled up for mass production of these species.

Seaweed Culture

Around 60 species of commercially important seaweeds with a standing crop of 100,000 tons occur along the Indian coast from which, nearly 880 tonnes dry agarophytes and 3,600 tons dry alginophytes are exploited annually from the wild . Seaweed products like agar, algin, carragenan and liquid fertilizer are in demand in global markets and some economically viable seaweed cultivation technologies have been developed in India by CMFRI and Central Salt and Marine Chemical Research Institute (CSMCRI). CMFRI has developed technology to culture seaweeds by either vegetative propagation using fragments of seaweeds collected from natural beds or spores (tetraspores/ carpospores). It has the potential to develop in large productive coastal belts and also in onshore culture tanks, ponds and raceways . Recently the culture of the carageenan yielding sea weed *Kappaphycus alvarezii* has become very popular and is being cultivated extensively along the Mandapam coast. To make the seaweed industry more economically viable, research aimed at improvement of strains of commercially important species by isolating viable protoplasts and somatic hybridization techniques, is being carried out. The rate of production of *Gelidiella acerosa* from culture amounts to 5 tonnes dry weight per hectare, while *Gracilaria edulis* and *Hypnea* production is about 15 tonnes dry weight per hectare. Pilot scale field cultivation of *Kappaphycus alvarezii* carried out in the nearshore area of Palk Bay and Gulf of Mannar showed maximum increase in yield of 4.3 fold after 30-32 days in Palk Bay and 5.7 fold after 22-34 days in Gulf of Mannar.

4.2 Priorities for development and research

Research thrust on seed production of crabs, lobsters, cephalopods and marine finfish

The major constraint for the development and expansion of mariculture in India is the lack of availability of seed for commercial level farming. Hence maximum research thrust is required for the development of commercial level seed production technologies for the suitable species of crabs, lobsters and marine finfishes. Eventhough seed production of the swimming crab *Portunus pelagicus* is achieved , the survival rate to seed stage is only about 5%. Technology upgradation is required to achieve commercial level seed production. Similarly the success in the seed production of the sand lobster *T.orientalis* also remains to be scaled upto commercial level production. In the case of spiny lobsters, the larval rearing phyllosoma VIII still remains as a challenge due to the prolonged larval phase of spiny lobsters. The experimental success obtained in the seed production of squids and cuttlefishes (*D. singhalensis, S.pharaonis , S.lessoniana* and *S.inermis*)have to be scaled up. Massive research input is required for development of seed production technologies for many species of marine finfishes which are suitable for open sea cage farming.

Open sea cage culture

The open sea cage culture has been expanding in recent years on a global basis and it is viewed by many stake holders in the industry as the aquaculture system of the millennium. Cage culture has made possible the large scale production of commercial finfish in many parts of the world and can be considered as the most efficient and economical way of rising fish. It has now been realized that further conversion of wetlands and mangroves into traditional aquaculture farms has to be limited. Cage culture has several advantages over other culture systems. The cage culture system can optimize the carrying capacity per unit area since the flow of current brings in fresh water and removes metabolic wastes, excess feed and faecal matter. Simple cage designs for inshore waters are relatively easy to construct with minimal skilled labour. Cage culture is a low input farming practice with high economic return. The Indian coast offers many ideal locations for cage farming. Potential sites include bays in Ratnagiri, Goa, Karwar, Palk Bay, Larsons Bay, Gulf of Mannar, Lakshadweep islands and Andaman and Nicobar Islands. The potential fishes for cage culture include groupers, snappers, seabass, rabbit fish and Cobia. A few modern demonstration farms could be set up at suitable sites by entrusting the work with developmental agencies of central / state governments. The materials for cage farm and the technology for installation of floating cage farms could be imported. Floating cage farming can be further expanded after the techno-economic viability under Indian conditions is established through the demonstration farms. The traditional practice of artisanal cage farming can also be improved and expanded by extension and training programmes to the fisherman by central / state govt. developmental agencies.

Popularisation of Bivalve Mariculture

Being in the lower part of the food chain, bivalves are energy efficient and cause least pollution to the culture system and the environment. It can be carried out as an artisanal mariculture programme and also as a large scale mariculture enterprise oriented towards export market. Artisanal mariculture of mussels, edible oyster and clams is being practiced on a small scale in certain parts of our coast. There is scope for bivalve farming along Kerala, Karnataka and Konkan coast. State / Central government developmental agencies can be entrusted for the expansion of bivalve farming in the suitable areas of the coast by giving training and extension programmes. Mass scale industrial farming of bivalves can also be taken up with an export oriented market.

Expansion of seaweed culture

The seaweed industry provides a wide variety of products that have an estimated total annual production value of US$5.5–6 billion. Food products for human consumption contribute about US$5 billion to this figure. Substances that are extracted from seaweeds – hydrocolloids – account for a large part of the remaining billion dollars, while smaller, miscellaneous uses, such as fertilizers and animal feed additives, make up the rest. The industry uses 7.5–8 million tonnes of wet seaweed annually, harvested either from naturally growing (wild) seaweed or from cultivated (farmed) crops. The farming of seaweed has expanded rapidly as demand has outstripped the supply available from natural resources. Commercial harvesting occurs in about 35 countries, spread between the northern and southern hemispheres, in waters ranging from cold, through temperate, to tropical. In this context, mariculture of seaweeds in the suitable areas of the coast has to be promoted to industrial level production. Suitable areas for seaweed culture include Tamil Nadu coast, Orissa coast, Okha Veraval coast and Konkan coast. Demonstration programmes for artisanal seaweed culture could be organised by developmental agencies in this area. Large scale culture of seaweed can also be demonstrated at Palk Bay to asses the techno-economic viability for industrial level production of seaweeds. Production of good quality agar/Carrageenan and development of appropriate marketing system have to be taken up as priority programmes for the development of seaweed industries in India.

Demonstration farms for pearl culture

The techno-economic viability of pearl culture still remains to be demonstrated in India. Hence establishment of one or two demonstration farms through Central / State developmental agencies is the immediate requirement before commercialization of this programme.

Development of artisanal mariculture programmes

Since the marine fish catch in recent years has been declining alternate small scale livelihood programmes have to be evolved for coastal fisherman. In this context, artisanal mariculture can play a vital role as an additional source of income. Artisanal mariculture of bivalve molluscs, seaweeds, crab and lobster fattening are being practiced in certain parts of the coast. Extensive training programmes could be organized along Kerala, Tamil Nadu, Karnataka, Konkan and Orissa coasts for promoting the artisanal mariculture practices.

Marine ornamental fish trade through hatchery production

In recent years, the marine ornamental fish trade is a global multimillion dollar industry worth an estimated US$ 200-330 million annually and operated throughout the tropics. Even though India is bestowed with food ornamental fish resources, wild collection from coral reefs can lead destruction of the reef habitat. Hence development of trade through hatchery production of fish offers wide scope. In the recent past, CMFRI has developed technologies of hatchery production techniques for clownfish and few species of damsel fishes. However the techno-economic viability of commercial level production is yet to be demonstrated. Hence establishment of one or two demonstration units at suitable areas like Lakshadweep, Andaman Nicobar and Gulf of Mannar coast through State/ Central developmental agencies is the immediate requirement. In addition, research on development of seed production technologies for suitable species of marine angelfishes, gobiids and cardinal fishes deserve attention.

Establishment of seed banks for mariculture

The availability of seed is the basic requirement for any commercial level mariculture enterprise. At present except for a few species pf shrimps, commercial level seed availability is lacking for other suitable species for mariculture. Hence the establishment of seed banks at appropriate locations is the basic requirement for the development of mariculture. Seed banks for all the mariculture candidate species can be developed at appropriate locations. For those species in which hatchery produced seed is not economically viable (Bivalve molluscs) and for those species in which hatchery production technologies are not available (many species of marine finfishes), seed banks could be developed from wild collected seeds. Lack for commercial level hatchery production technologies is the major constraint for the development of marine aquaculture in India. Hence research on seed production of species having culture potential should be strengthened through research institutions.

Integrated farming of finfish and shellfish with seaweed

Integrated farming of fish and shellfish with seaweed can reduce the environmental impact of industrialized mariculture and at the same tine add to its income. Plants counteract the environmental effects of the heterotrophic fed fish and shrimp and restore water quality. A one hectare land based integrated sea bream – shellfish – seaweed farm can produce 25 tons of fish, 50 tons of bivalves and 30 tons fresh weight of seaweeds annually. Hence modern integrated systems are bound play a major role in the sustainable expansion of mariculture. A few front –line demonstration farms on integrated farming of fish and shellfish with seaweed can be established at suitable locations through Central/State developmental agencies to assess the techno-economic viability.

Installation of artificial reefs and FADs

Artificial reefs and Fish aggregating Devices are known to attract fish. Hence installation of artificial reefs and FADs at suitable areas of the coast can enhance fish production. A few artificial reefs and FADs can be installed at suitable locations by Central/State developmental agencies by involving fisherfolk participation. Regular assessment of the impact of artificial reefs and FADs on enhancing fish production can be done with the involvement of research institutions.

Large scale sea ranching for stock enhancement.

It is well known that many of our marine fisheries resources are overexploited leading to reduction of the concerned wild stock. In this context, large scale sea ranching programmes can play ital role in the natural stock enhancement. Already sea ranching of *Penaeus semisulcatus* is being carried out by CMFRI at Mandapam area. Massive sea ranching programme for *Penaeus semisulcatus* can be taken up along the east coast by developmental agencies through fisher folk participation. Regular impact assessments of the sea ranching have to be conducted by involving research institutions.

Development of Capture Based Aquaculture

Capture-based aquaculture (CBA) has been defined as the practice of collecting "seed" material – from early life stages to adults – from the wild, and its subsequent grow out to marketable size in captivity, using aquaculture techniques. This category of farming includes the rearing of some species of finfish, most molluscs, and certain forms of the extensive culture of marine shrimp. It has been estimated that it accounts for about 20 percent of the total quantity of food fish production through aquaculture. Using FAO data from 2001, this is equivalent to over 7.5 million tons per year, principally molluscs. The production of finfish, especially carnivorous species (including milkfish, groupers, tunas, yellowtails and eels), through CBA, is currently receiving the most attention. CBA is an interface between capture fisheries and true aquaculture and provides an alternative livelihood for local coastal communities in developing countries and several industrialized countries. In India since the seed production technologies of many species are either not standardized or commercially viable, the practice of CBA can be developed with proper management.

Conservation Mariculture

The populations of many marine species are constantly declining and are in the process of getting endangered. These include species of *Trochus, Turbo,* chank, sea cucumber and sea horse. Stock replenishment through large scale seed production and sea ranching will be a positive step towards the conservation of these species. CMFRI has successfully developed hatchery techniques for some of the species. However future research thrust in this sector is very much warranted.

4.3 Identification of better management practices and systems to mitigate environmental impacts

The following better management practices are suggested for shrimp culture, bivalve culture and seaweed culture.

(a) Shrimp Culture

1. Scientific extensive and semi-extensive farming
2. Two tons ha^{-1}. $year^{-1}$ production for extensive and five tons ha^{-1}.$year^{-1}$ from semi-extensive in two crops.
3. No construction within the natural mangrove area or ecologically sensitive wetlands swamps etc.
4. Conversion of agricultural land / mangroves for aquaculture should be discouraged.
5. Environmental impact assessment (EIA) should be made at the planning stage itself for farms above 40 ha.
6. Stocking density should be less than 5 PL sq m^{-1} and 15 PL sq m^{-1} for semi-extensive farms
7. Use of wet diets to be avoided
8. Use of inorganic fertilizers pesticides hormonal growth promoters and antibiotics in the farm should be avoided.
9. Introduction of imported shrimp seed and use of exotic seed should be prohibited.
10. About 10% of the total pond area to be provided for wastewater treatment.

(b)Bivalve Farming

Plants counteract the environmental effects of the heterotrophic fed fish and shrimp and restore water quality. Hence integrated farming of finfish and shellfish with sea weeds will prove to be more ecologically sustainable in addition to being more productive.

(c) Seaweed Farming

Seaweed culture is presently carried out in coastal waters using bamboo rafts. If these rafts are deployed in the same area, it would not only adversely affect the nutrient availability and phytoplankton production, but also fisheries, movement of boats, fishing operations, traditional rights etc. Thus areas are to be identified for seaweed farms. Also, the culture ropes can be integrated with the mussel culture rafts as already done by the mussel farmers in the Kasargod area. This will help to great extent in preventing the mussel farms adversely affecting the culture sites as the high nutrient load consequent to the mussels' mantle cavity outputs. The growth rates of seaweeds in such farms also have been found to be several folds higher. A package can be developed on these lines to have an environmental friendly mussel-oyster-seaweed farm along the coasts.

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