India

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Modayil, M.J., Sathiadhas, R. and Gopakumar, G. 2008. India. In A. Lovatelli, M.J. Phillips, J.R. Arthur and K. Yamamoto (eds). FAO/NACA Regional Workshop on the Future of Mariculture: a Regional Approach for Responsible Development in the Asia-Pacific Region. Guangzhou, China, 7–11 March 2006. *FAO Fisheries Proceedings.* No. 11. Rome, FAO. 2008. pp. 145–171.

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 inshore waters and increasing conflicts among stakeholders, whereas the increasing demand for fish in domestic and export markets indicates good prospects for large-scale sea farming and coastal mariculture.

The contribution of fisheries to Indian gross domestic product (GDP) is about 1.2 percent (2002–2003), which forms about 5.2 percent 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, seabass, groupers, mullets, milkfish, rabbitfish, sea cucumber, ornamental fishes, seaweeds, etc. Although about 1.2 million ha is suitable for land-based saline aquaculture in India, currently only 13 percent is utilized. Mariculture activities are presently confined to coastal brackishwater aquaculture, chiefly shrimp farming. Shrimp is the most demanded product from coastal aquaculture, and India is the fifth largest producer of cultured shrimp. Farmed shrimp contributes about 60 percent by volume and 82 percent by value of India's total shrimp export. The share of cultured shrimp export is 78 700 tonnes valued at Rs 33 000 million.[1] The area under shrimp farming is about 135 000 ha and average production is about 80 000 tonnes/year. In recent years, the demand for mussels, clams, edible oysters, crabs, lobsters, seaweeds and a few marine finfishes has been continuously increasing and many of these commodities bring premium prices in the international market. The other activities that can be categorized as artisanal mariculture include green mussel farming, lobster fattening, crab farming, edible oyster culture, clam farming and seaweed culture. The farming of green mussel yields about 4 500 tonnes, farmed oysters 800 tonnes, and farmed seaweeds about 1 000 tonnes, while quantities produced are not significant for crabs, lobsters, mullets and milkfish. A flourishing international trade in marine ornamental fishes is also in vogue that offers scope for their culture.

Shrimp farming is largely dependent on smallholdings of less than 2 ha, as these farms account for over 90 percent of the total area utilized for shrimp culture. Coastal aquaculture is concentrated mainly in the states of Andhra Pradesh, Tamil Nadu, Orissa and West Bengal. A long coastline of 8 129 km, along with an adjacent landward coastal agro-climatic zone and seaward inshore waters with a large number of calm

[1] US$1 = Rs 45 approx.

bays and lagoons offers good scope to develop mariculture in the country. Although the techno-economic feasibility of several mariculture technologies has already been demonstrated, lack of adequate infrastructure and lacunae in legislation block their implementation.

Local and international product demand, trade and market trends

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

Role of aquaculture vs. fisheries as supply

The fisheries production pattern in India is presented in Table 1.

TABLE 1

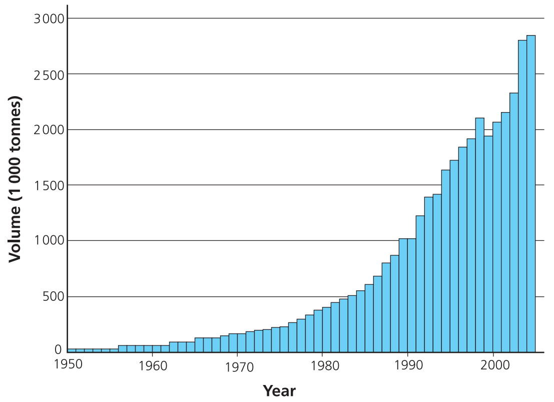
Fish production and average annual growth rate for India (Source: Tenth Plan Document (Fisheries) Government of India; figures from Central Marine Fisheries Research Institute (CMFRI), Kochi up to 1970–71; State government figures after 1970–71) [1]

Year	Fish production (1 000 tonnes)			Average annual growth rate (%)		
	Marine	Inland	Total	Marine	Inland	Total
1950–51	534	218	752	-	-	-
1960–61	880	280	1 160	5.12	2.53	4.43
1970–71	1 086	670	1 756	2.13	9.12	4.23
1980–81	1 555	887	2 442	3.65	2.85	3.35
1990–91	2 300	1 536	3 836	3.99	5.64	4.62
1991–92	2 447	1 710	4 157	6.39	11.33	8.37
1992–93	2 576	1 789	4 365	5.27	4.62	5.00
1993–94	2 649	1 995	4 644	2.83	11.51	6.39
1994–95	2 692	2 097	4 789	1.62	5.11	3.12
1995–96	2 707	2 242	4 949	0.56	6.91	3.34
1996–97	2 967	2 381	5 348	9.60	6.20	8.06
1997–98	2 950	2 438	5 388	-0.57	2.39	0.75
1999–2000[2]	2 834	2 823	5 657	5.12	10.02	7.51

[1] Growth rates prior to 1992–93 represent annual average compound growth rates.

[2] Provisional figure.

Figure 1
Aquaculture in India, 1950–2003
(Source: FAO, 2003)



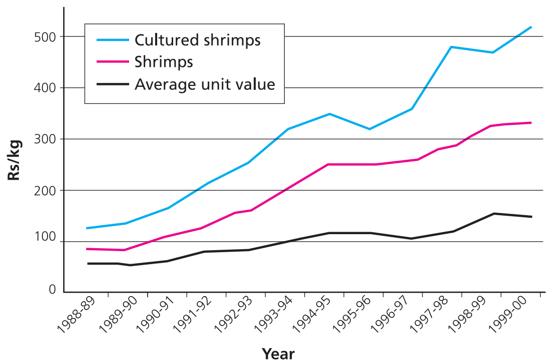
The total fish production during the four decades between 1950–51 and 1990–91 showed an annual average compound growth rate that varied between 3.35 and 4.62 percent (Figure 1). In the early 1990s, there was a boom in total fish production followed by a sluggish trend due to a pattern of decreasing marine production towards the end of the decade. It may be noted from the analysis that the trend for the marine fisheries sector was towards slack production in most of the years, whereas inland production grew throughout. It can be broadly stated that marine fish production has grown at a compound annual growth rate of 3.54 percent over the five decades since independence, while the growth of inland fish production has been dynamic over the same period, with a growth rate of 5.84 percent.

In 2003, aquaculture alone contributed one-third of the total fish production in India. Of the total aquaculture production of 2.3 million tonnes, production of carp was 1.87 million tonnes, giant river prawn was 30 000 tonnes and marine shrimp (*Penaeus monodon*) was 115 000 tonnes.

Aquaculture production from India in 2000 was 2 095 000 tonnes worth US$2 166 million. The shrimp exports from India during 2001–02 were 127 656 tonnes worth Rs 41 320 million. The cultured shrimp production during 2001–02 was 127 170 tonnes, of which 74 826 tonnes was exported, fetching Rs 36 450 million. Cultured shrimp contributed about 60 percent in terms of quantity and about 86 percent in terms of value to total shrimp exports during 2001–02.

In the 1970s and early 1980s, shrimp exports stagnated at around 50 000 tonnes per annum and the export earnings were below Rs 3 500 million. Twenty years ago, the price of white prawn was Rs 8/kg and that of tiger shrimp was Rs 13/kg. During the same period, brown varieties fetched only Rs 2–3/kg. Sathiadhas et al. (1989) reported that the unit price for white prawns during 1986–88 was Rs 40/kg. The price of tiger shrimp and brown varieties was only Rs 60/kg and Rs 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-1980s, the shrimp exports began to rise significantly, both in terms of quantity and value. The growth in terms of value has been more spectacular, because the cultured shrimp fetched more unit value in comparison to marine captured shrimp (Figure 2).

Figure 2
Contribution of farmed shrimps to marine exports



Total shrimp exports and the contribution of cultured shrimp to it are given in Tables 2 and 3. The share of farmed shrimp in total shrimp exports has been continuously increasing since the mid-1980s. In 1988–89, the share of cultured shrimp was only 33 percent by quantity; however, by the end of 2000 it had increased to 59 percent. Although the percentage of cultured shrimp by quantity is half of India's total shrimp exports, its contribution by value is much more. The value of Rs 2 293 million in 1988–99 increased to Rs 38 700 million in 2000–01, which was 86 percent of the total shrimp exports in that year. This value realization was mainly the result of the larger and more uniform size composition of cultured shrimp. There was a decline in the contribution of cultured shrimp in 1994–95 and in the subsequent two years that was due to disease outbreaks and the stoppage of culture activities in the Coastal Regulatory Zone (CRZ) area. During the years 1998–99 to 2000–01, however, the culture production increased and the contribution also showed a significant rise, registering an all time high of 58.8 percent in terms of volume and 86.4 percent in terms of value to the total shrimp exports. The quantity of shrimp exported increased to 128 000 tonnes in 2001–02 and to 135 000 tonnes in 2002–03. The value realized by cultured shrimp has also gone beyond 80 percent of the gross earnings of shrimp exports.

TABLE 2
Contribution of cultured shrimp (quantity) to total shrimp exports from India (Source: Ganapathy and Viswakumar, 2001; Pillai and Katiha, 2004)

Year	Total quantity of shrimp exports (tonnes)	Quantity of cultured shrimp exports (tonnes)	Contribution to shrimp exports (%)
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	101 751	53 853	52.92
1995–96	95 724	47 922	50.96
1996–97	105 426	45 945	43.58
1997–98	110 318	43 712	42.90
1998–99	102 484	53 712	52.41
1999–00	110 275	54 000	48.96
2000–01	111 874	65 894	58.90
2001–02	127 709	102 940	58.80
2002–03	134 815	115 320	60.08

TABLE 3
Contribution of cultured shrimp (value) to the total shrimp export earnings from India (Source: Ganapathy and Viswakumar, 2001; Pillai and Katiha, 2004)

Year	Total value of shrimp exports (Rs Crores)[1]	Value of cultured shrimp exports (Rs 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	4 139.92	3 845.00	85.63
2002–03	4 608.31	3 793.86	82.33

[1] 1 Crore = 10 million Rs.

Coastal aquaculture is a significant contributor to marine fish production, which is comprised mainly of shrimp such as *Penaeus monodon* and *Litopenaeus indicus*. However, vast water bodies highly suitable for aquaculture and a 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, seabass, groupers, sea cucumber, ornamental fishes and seaweeds in the new aquaculture scenario in the country. Hatchery and rearing techniques have also been standardized 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 to other cultivable species such as mud crabs, finfishes, oysters, mussels, sea cucumber, pearl oyster, etc. Although India does not have the advantage of extensive shallow seas with calm waters, there exist many potential mariculture sites that are still unutilized, offering tremendous scope for mariculture. Low-cost user-friendly bivalve mariculture practices provide seasonal vocation for rural folk. Polyculture of compatible species also offers a viable alternative to shrimp farming. Both require fewer inputs than 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 tonnes worth Rs1 890 000 (MPEDA data). *Katelysia opima*, *Meretrix meretrix* and *Meretrix casta* were the major clam species exported from India. Among the molluscan products, freeze-dried clam fetches the highest unit value (Rs 430/kg) (Table 4). Two kilograms of cultured pearls were also exported during 1996, fetching a value of Rs 357 000/kg. The scope for the export of cultured pearls is enormous. Hence there is a 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 realized from 1996 to 2003 (Source: MPEDA)

Year	Quantity (kg)	Value (Rs)	Unit value (Rs/kg)
1996	12 133	8 179 938	67
1997	24 773	1 739 989	70
1998	20 513	1 273 226	62
1999	35 989	1 807 231	50
2000	106 445	7 493 917	70
2001	482 097	29 007 630	60
2002	106 937	9 226 164	86
2003	74 982	4 975 491	66

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

TABLE 5
Live crab trade (Source: MPEDA)

Year	Quantity (kg)	Value (Rs)	Unit value (Rs/kg)
1996	2 028 430	240 692 690	119
1997	1 482 659	191 712 499	129
1998	1 777 198	306 427 388	172
1999	1 503 454	261 008 303	174
2000	1 579 704	260 923 450	165
2001	1 190 214	197 306 436	166
2002	1 958 748	400 060 486	204
2003	1 455 454	284 341 287	195

Exports of crabs and crab products from India were mostly confined to four types of products until recently. During 2000 the total number of crab products in India's export basket rose to 11, indicating that 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 softshell crab, frozen stuffed crab, frozen pasteurized crab, frozen crab meat, frozen cut crab with claws and live crabs. Total crab exports were 1.1 percent of total marine exports in terms of quantity in 1996 and increased to 1.47 percent in 2000. In 2000, crab exports stood at 6 197 tonnes and the value realized was US$5.5 million, indicating their large potential for the export market.

The annual yield from crab fattening was significantly higher than that of crab culture. About five or six crops can be obtained annually through crab fattening as compared to only two crops from crab culture. Average yield from crab culture was 2 800 kg/ha/crop and that from fattening was 3 100 kg/ha/crop. Average body weight of the crabs obtained through culture was 800 g, whereas that of those from crab fattening was 850 g. The weight increase after 30–40 days of fattening was very little, ranging 50–100 g. Average food conversion ratio (FCR) calculated for 4–5 months culture was 4.9, which was higher than the FCRs of other local aquaculture species.

The international demand for lobster has continued to increase over the years, and targeted fishing has led to over-fishing in Indian coastal waters. Although the unit value realized for each product derived from lobster has increased, the overall value has declined, as more and more small-sized lobsters are caught from our open sea. It is highly advisable to promote the mariculture of lobsters wherever possible. Data for frozen lobster exports from India during 1999–2003 are shown in Table 6.

TABLE 6
Frozen lobster exports from India, 1999–2003

Year	Quantity (kg)	Value (Rs)	Unit value (Rs/kg)
1999	1 363 594	661 542 732	485
2000	1 555 166	802 049 638	516
2001	1 125 666	654 731 490	582
2002	1 008 394	575 601 161	571
2003	806 290	380 467 756	472

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

TABLE 7
Frozen finfish exports from India, 1996–2002

Year	Quantity (tonnes)	Value (Rs million)	Unit value (Rs/kg)
1996	10 093	3 722.6	37
1997	173 005	6 369.2	37
1998	188 029	7 267.3	39
1999	126 474	5 257.7	42
2000	188 822	7 697.2	41
2001	185 457	7 614.9	41
2002	217 195	9 064.5	42

The WorldFish Center and the National Centre for Agricultural Economics and Policy Research (NCAP) have 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 million tonnes and will reach to 4.6–5.5 million tonnes 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 million tonnes in 2005 and 3.2–3.6 million tonnes in 2015. Fish production is predicted to grow at an annual rate of 2.9–4.0 percent for inland fish 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 is expected to decline from 50 percent in 2000 to about 40 percent in 2015.

Varying estimates quantify the per capita fish consumption at around 8–10 kg per annum. Future demand for fish and fish products will grow substantially due to escalating population growth and increasing per capita fish consumption. The consumption of fish is projected to increase from 5.2 million tonnes in 1998 to 6.0 million tonnes in 2005 and to 7.7 million tonnes in 2015. Out of this, in-home consumption accounts for about 66 percent, while the rest will be consumed away from home or enter industrial processing.

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. Consumer preferences and patterns have shifted from cereals and other items to more nutritive yet affordable animal products like fish. According to National Sample Survey Organization (NSSO) figures, the per capita cereal consumption is declining, recording a decline of 0.52 percent per annum in rural areas and of 0.23 percent per annum in urban areas during the period 1970–71 to 1991–92. This shift in dietary pattern may be attributed to diversification in the food basket in favour of non-cereal food items like eggs, meat and fish. There has been 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 populations. Seafood processing and marketing have 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. The present level of trade through different marketing channels of different farming systems, the price spread at various stages of movement and the share of the producer in the consumer's rupee should be evaluated to formulate further strategies for the development of the aquaculture industry.

Aquaculture products, especially shrimp, undergo 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 percent) or into peeled and un-deveined (PUD) and peeled and deveined (PD) products by removing head, shell and the gut contents (50 percent). 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 two or three groups based on their size. Marketing of value-added products of prawns and other aquaculture products such as live crab, edible oyster and pearl oyster are gaining importance. 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 export markets, while low-unit-value products like finfishes and small crabs reach the domestic market.

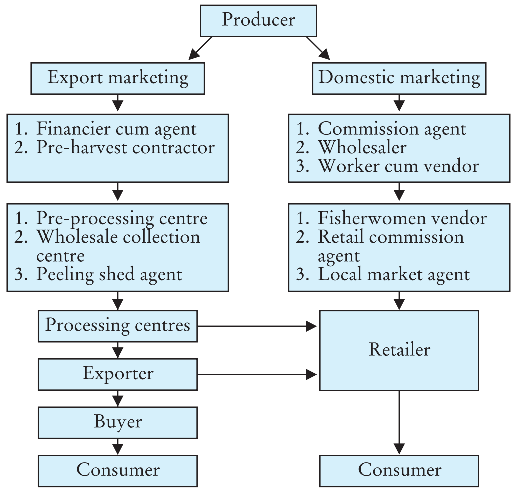
The Marine Products Export Development Authority of India (MPEDA) has listed about 65 value-added products suitable both for export and domestic markets. Product diversification helps promote price discrimination and enables realization of maximum foreign exchange earnings. It also helps to enhance the employment opportunities of coastal and rural women. The emergence of value-added products is 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 current tendency is to purchase convenience foods such as assembled meals rather than preparing them 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 100 000 tonnes of value-added products in our marine products could easily generate about Rs 15 000 million in foreign exchange earnings and provide regular employment 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 several entirely different flows of products through different marketing channels. The flow of aquaculture products from producer to consumer on export and domestic market is shown 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, the products moving through export marketing channels having five times higher unit price than those moving through the domestic channels. There is an interrelationship between the different intermediaries involved in the marketing flow.

Figure 3
Marketing channels in domestic and export marketing in India



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

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 gives a contract 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 shrimp are usually also able to reach the processing unit in a better condition, and producers get a maximum price for all size grades.

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 cooperative marketing, along with financial assistance from such agencies as MPEDA, the Brackishwater Fish Farmers Development Agency (BFFDA), the National Bank for Agriculture and Rural Development (NABARD) and state banks can enhance the producer's share and reduce the role of financier-cum-agents and money lenders. Vulnerability issues in marketing are listed in Box 1.

BOX 1
Vulnerability issues in marketing

These include:

- Uncertainty in supply and demand
- Price fluctuations
- HACCP and quality issues
- Changing international trade regulations
- The perishable nature of the products
- Too many varieties and too many demand patterns
- Assembling the products from too many distant and remote centers
- Too many intermediaries in the marketing channel
- Inadequate storage facilities
- Lack of refrigerated transporting system
- Lack of vertical and horizontal integration of markets

The successful experiment of mussel farming in Padanna demonstrates that parallel development of a domestic marketing system is essential for the introduction and growth of any new product. Domestic consumption of mussel is very noticeable in northern Kerala. Farmers have to harvest the fully grown mussels in May and sell them before the onset of monsoon to avoid mortality due to low salinity. At present only a few companies are purchasing mussels from farmers, and thus the farmers' bargaining power is very restricted. The growth of women's Self Help Groups (SHGs) and vertical integration for export marketing has helped the spread of mussel farming in this region.

Market chain

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 given 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 domestic fish marketing takes place through the 3rd to 6th channels. The auctioneers of the primary market and commission agents of the secondary market are also involved in the process, although without taking actual possession of the fish. Fish marketing in India can be divided into two categories – domestic fish marketing and export marketing. In India, fish marketing has not developed fully on modern lines. There has been a gradual transformation from traditional to modern methods of marketing with the advent of improved transportation, processing and storage facilities. The involvement of a number of middlemen in the marketing chain adversely affects the interest of both fisherfolk and consumers.

LIVELIHOOD OPPORTUNITIES AND MARICULTURE

Poverty status and livelihood vulnerability of coastal communities

Emerging economic growth, shifting dietary patterns in favour of fish consumption and continuously rising prices have resulted in increased pressures on wild fish stocks and associated inter-sectoral conflicts in coastal areas. Among the people living around coastal and inland waters, fisherfolk are one of the most underprivileged groups, being affected by such problems as inadequate employment; food insecurity; closed seasons; dwindling catch rates; problems in production, post-harvest and marketing; and indebtedness.

Increasing poverty among coastal fisherfolk

In India, poverty is of great concern. Although data vary, the results of the 55th round of the National Sample Survey show that the percentage of people below the poverty line in India decreased from 36 percent in 1993–94 to 26 percent 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, a positive impact on rural poverty has not been observed. The failure to reduce rural poverty is attributed to declining public investment in agriculture, which provides a livelihood to 70 percent of Indians. Trade liberalization in recent years has also led to extreme price volatility in many agricultural products that has hurt poor farmers. Agricultural growth has declined in recent years, a trend that is expected to continue. In 1994–95, agriculture grew at a rate of 5.0 percent, followed by a negative growth of 0.9 percent the subsequent year, then a positive growth of 9.6 percent in 1996–97 and then negative growth of 1.9 percent in 1997–98.

The incidence and persistence of poverty in the fisheries sector can be attributed mainly to the open access nature of marine fisheries, the slow pace of aquaculture/mariculture development and unconstrained labour mobility (FAO, 2005). Labour mobility to fisheries is accentuated by social factors such as the caste system prevailing in India. There is considerable growth of population within the fishing community, and newer technologies are being adopted that pave the way to biological and economic overfishing and reduced per capita production, which emphasizes the need for efficient fisheries management directed primarily towards sustainable development and equitable distribution of benefits. The economics of different craft/gear combinations and per capita earnings of fishing labour clearly indicate that not less than 60 percent of people in the coastal rural sector live below the poverty line. It is clear that coastal rural people have not received much of the benefit of economic development since India became independent.

Employment within the primary capture fisheries and aquaculture production sectors in 1998 was estimated to be 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 (Government of India, 2001).

In spite of the regional dimensions of economic growth in India, sectoral disparity, inequality in income and poverty incidence in the 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 a substantial impact on the standard of living of people (Barro and Sala-i-Martin, 1995). Income distribution is one of the most critical issues of development economics and is closely related to emphasis on poverty reduction as the most important goal for development (Kakwani, Khandkar and Son, 2004).

In spite of India's planned economic development that is aimed at reducing spatial and sectoral disparities in income, such disparities have been increasing over time. Large disparities and negative growth rates undermine the integration of the economies and social stability, hampering long-term economic growth, the fisheries and aquaculture sectors being no exception. The physical productivity of worker per unit of capital invested has declined steeply, which is a phenomenon characteristic of open-access resources subject to increased commercialization (Kurien and Antonyto, 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 introduction of measures that curtail the supportive measures offered to the fisheries sector. The rise in inequality in the fisheries sector results from the following factors:

- shift to capital-intensive technologies and labour-saving devices;
- technological innovations leading to marginalization;
- drop in the rate of labour absorption in the capture/mariculture sectors;
- disguised unemployment;
- failure of coastal aquaculture/mariculture to emerge as an alternative vocation;
- lack of integration of mariculture with inshore capture fisheries; and
- lack of legislation for open-sea mariculture.

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 the National Agricultural Technology Project (NATP) for testing, improving and refining technologies prevailing at or generated for diverse production systems. The Central Marine Fisheries Research Institute (CMFRI) has implemented the programme in the coastal village of Elamkunnapuzha in Ernakulam District of Kerala from August 2000 through April 2005. Altogether 31 techno-interventions were assessed and refined in farmer's fields (13 fisheries, 5 livestock and 13 agriculture). A total of 687 farm families participated in these interventions, and the total population covered under this programme was 3 435. The programme has been successful in building 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, of which 318 were female, participated. The overall impact of this intervention is highly promising and is termed the "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 types of fish culture under recommended practices have shown marked improvements. Hitherto the farmers mostly concentrated on shrimp-oriented aquaculture. The high price of shrimp coupled with its export potential attracted farmers to this type of aquaculture irrespective of its suitability and cost of production. Shrimp culture was not ideal for most of the farms and was also less profitable than other culture practices such as fish and crab. A least-cost combination of production factors coupled with the high suitability of ponds for monoculture of crabs, mullet (*Mugil cephalus*) and milkfish (*Chanos chanos*) and the polyculture of different finfishes has shown profitability ranging from Rs 200 000/ha for monoculture of milkfish to Rs 700 000/ha for monoculture of juvenile crabs. The only constraint limiting the expansion of crab culture is the unavailability of hatchery-produced seed.

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 Rs 8 500/ha during 2000–01 to Rs10 000/ha in 2003–04, an increase caused by diversified utilization and a 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 22.3 ha that was previously unutilized has been brought under different fish-culture practices.

Livestock interventions have proved to be the most ideal supplementary avocation suitable for the coastal agro-ecosystem. The benefit-cost ratios of various animal husbandry practices clearly indicate the need to adopt scientific management practices. Such practices provide maximum opportunity for optimal utilization of homestead backyards and employment, mainly to women. The annual household income can be enhanced by Rs 2 150 by growing ten Gramalakshmi birds and by Rs 10 000 by growing five broiler rabbits of the grey giant variety. The cultivation of paragrass in the unutilized marshy lands has shown a potential yield of 10 tonnes/ha, indicating good prospects for the fodder-deficient island ecosystem.

In agriculture-based interventions, cultivation of improved varieties of vegetables yielded better returns as mono-crops and inter-crops along the embankment of fish ponds and also along homesteads. Although the yield from snake gourd (*kaumudi*) cultivation was better than that for all other vegetables, the net earnings (Rs 128 325/ha) are higher for bitter gourds (*preethi*). The impact of nutrient management in coconut plantations has shown an average increase of 30 nuts per tree per annum. The practice of nutrient management for all coconut trees in the entire village may have far-reaching impacts on the rural economy. Since there are about 100 000 coconut trees in the study area alone, adopting this single management practice could fetch additional revenue of about Rs 10 million in Elamkunnapuzha Village, even if we assume an additional 20 nuts per tree per year with an average price of Rs 5 per nut.

The IVLP model has ensured the active participation of stakeholders throughout the process of assessment and refinement of technology. Participatory Rural Appraisal and Livelihood Analysis has identified the location-specific problems, potential solutions and the extent of blending of the prevalent indigenous knowledge with scientific practices to optimize both 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 has shown potential for generating additional employment opportunities and enhancing disposable household income.

Comparative economics of mariculture practices

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

TABLE 8
A comparison of economic indicators for different aquaculture practices

Key economic indicators	ET[1]	EW	CC	CF	MC	EO	MF
Net profit/ha (Rs)	92 986	123 407	43 982	538 237	37 544	4 401	12 989
Net operating profit/ha (Rs)	147 877	161 812	64 319	587 557	47 146	6 018	14 928
Cost of production/kg (Rs)	197	47	210	174	42	2.74	3.58
Profit/kg (Rs)	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
Break-even production (kg)	693	846	640	3 459	1 160	2 393	4 411
Break-even production as % of total production	68	43	79	64	66	69	65

[1] 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.

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

Role of mariculture in poverty reduction as an alternative to fisheries

In the context of heightening demand for fisheries products, the importance of aquaculture has increased. Fresh and brackishwater fish culture are the main types of aquaculture activity in India. With the exception of shrimp farming, mariculture, despite its vast potential on both the landward and seaward sides of the coastal line has not developed. Technological developments like pearl oyster culture, edible oyster culture, mussel culture, lobster farming, crab culture, seaweed culture, sea cucumber culture and finfish culture have been developed by research institutes like CMFRI. Adoption of these techniques on a scientific basis can add to farmers' incomes 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 immediate need is to organize proper development, extension and training programmes for mariculture in the coastal communities. Also this effort should be supported 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. Shrimps and finfish like grey mullet, milkfish, pearl spot, seabass, groupers, red snapper, breams and pompanos are suitable for farming all along the Indian coast, especially along the southwest and southeast coasts. In addition, sea cucumber could be cultured along the coasts of Tamil Nadu and Lakshadweep; pearl oyster along the coasts of Tamil Nadu (Gulf of Mannar and Pak Bay), Kerala, Gujarat, Lakshadweep and the 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 seaweeds in the Gulf of Mannar, Gulf of Kutch, Kerala backwaters, Chilika Lake, Pulikat Lake and the lagoons and lakes in Lakshadweep and the Andaman and 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 ranging from estuaries, to saline lagoons, low-lying saline inundated marshes, and the intertidal and subtidal belt to beyond the shallow coastal shelf waters and have immense value and use for humanity. Slowly but steadily aquatic resources have been depleted and habitats damaged by activities such as dumping of pollutants, land reclamation and destruction of mangroves. Many of these problems have taken place in easily accessible coastal waters that are fragile, sensitive ecosystems and have badly hit the more vulnerable and desirable species, as well as a wide spectrum of low-value, high-volume bottom biota forming part of the marine food chain.

Examples of introduction of mariculture into coastal communities

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

Kasargod, the extreme northern district of Kerala, is notable for mussel farming, as it has been successfully accomplished by women's Self Help Groups (SHGs) for the past few years. These groups were given financial assistance by the Swarnajayanthi Gramaswa Rosgar Yojana (SGSY) scheme by the state government, which takes care of economic empowerment of weaker sections of society. Subsidies, bank loans and other support are provided for poverty alleviation through organized SHGs. This programme looks into training, credit, marketing, technical knowledge and the basic facilities necessary to uplift the poor. This study was undertaken in two major *panchayaths*[2], namely Cheruvathur and Padanna in Kasargod District. Six SHGs of women (three each from both *panchayaths*) were selected for the study.

The major expenditure required for mussel farming is for materials such as bamboo, nylon rope, cloth, seed, etc. and labour costs essential to cover construction, seeding, harvesting, etc. The women's groups constituted under the Development of Women and Children in Rural Area (DWCRA) scheme started mussel farming as early as 1996–97 and were assisted by a loan amount worth Rs 8 800 per member with a subsidy amount worth Rs 4 400. The duration of the loan was five years and the rate of interest was 12.5 percent per annum. In addition, a revolving fund of Rs 5 000 was also provided without interest. When the SHGs are economically empowered with the provision of loans, the returns from mussel farming help them to slowly repay the loan.

The loan was granted through Farmers' Service Cooperative Banks and North Malabar Gramin Banks in Cheruvathur and Padanna *panchayaths* of Kasargod District. The majority of the SHGs showed considerable progress in repayment of the loans, which was interpreted as an indication of the profitability of mussel farming.

The net operating profit shown by all six SHGs confirmed the profitability of mussel farming during the initial trial. Since in subsequent years, material costs such as those of bamboo, rope and cloth and the cost of labour for construction, etc. are negligible, a reasonable profit as a major consequence of adoption of mussel farming is assured.

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

The benefit-cost ratio for all six SHGs was above 1, indicative of considerable economic viability and potential in mussel farming.

The loan sanctioning, utilization, accounts maintenance and timely repayment, etc. are all perfectly accomplished with proper maintenance of the documented records by the group members. This ascertains the fulfilment 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, Karnataka State

SHGs of fisherfolk were mobilized in the Karwar and Bhatkal areas of the Karnataka coastal belts. Three SHGs of 15 members each were mobilized in Majali (open sea), Dhandebag, and three SHGs of 15 members each were mobilized in Sunkeri, Kali Estuary in the Karwar coastal belts, Uttar Kannada District, 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 and one for rack culture in Sunkeri. The training was imparted to the 45 members of the two SHGs, each possessing 15 members (a total of 90 participants). Similarly in Mundalli River of Bhatkal Estuary in Karnataka, four SHGs of 15 members each (total of 60 participants) comprised exclusively of women fisherfolk were mobilized under the nongovernmental organization (NGO) "Snehakunja" and trained in mussel farming.

The major expenditures required for mussel farming are for materials such as bamboo, nylon rope, cloth, seed, etc. and labour costs for construction, seeding, harvesting, etc. The SHGs of Majali and Sunkeri were mobilized by the project team of CMFRI, and the SHGs of Bhatkal were mobilized by the NGO Snehakunja. The first two trials and demonstrations were under the funding of CMFRI, while for the last trial only technical help during the training and demonstration were offered by CMFRI. The yield particulars for all SHGs were noted and considered to be quite good.

Mussel farming faces a number of impediments involving such variables as water salinity, seed availability, location/site selection, 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 seed during transportation;
- reduced growth during certain years;
- lack of depuration facilities;
- lack of storage, cold room and cold chain;
- marketing of mussels; and
- social dynamics at the village level based on caste and politics.

The open-sea mussel culture in this particular case met with the impediment of sabotage of the seeded mussel by some miscreants. This was rectified by reseeding, but the yield was not comparable to that produced during the trials undertaken in estuaries. All the SHG members are of unanimous opinion that the government should come forward with suitable legislation for the allotment of water areas for open-sea mussel culture and improved marketing facilities. Provision of loans with reduced interest rates and freezer facilities for storage of harvested mussels could bring about a breakthrough in this sector in the near future.

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 should be promoted to ensure marketing efficiency and to overcome marketing problems. A need-based building of linkages would help in sustaining mariculture initiatives. Linkages that need to be developed include links among consumers, middlemen, agricultural/fisheries offices, NABARD, banks and other financial institutions, *panchayat* functionaries, NGOs, marketing outlets, local organizations, researchers and input suppliers.

Another linkage that should be developed is one that recognizes the consumer's changing needs and wants. Although highly relevant within the modern marketing context of branded consumer products, this idea can also be applied to fisheries marketing. Consumers can be educated about new fisheries products and encouraged to use them through information dissemination via the media. By the time the demand for these items is generated, production can also be initiated by mariculture activities. Adoption of this strategy can promote market-oriented production.

Financial linkages are essential in any development initiative. An activity that is not supported by financial assistance in the form of subsidies, credits or grants is 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. Because mariculture is not yet commercially exploited on a large scale, adequate support and extension are required for its adoption.

EXISTING AND POTENTIAL MECHANISMS OF TECHNOLOGY TRANSFER

There are no mechanisms exclusively targeted at mariculture extension. The departments of fisheries of each state government have extension officers who support the extension agenda of their state. The Brackishwater Fisheries Development Agencies in maritime states also have some responsibilities and mechanisms for guiding farmers and entrepreneurs. MPEDA has officers specially trained for the extension of shrimp farming and some other mariculture techniques. There are training programmes at the state and farmer level that are conducted by the state fisheries departments and MPEDA. State agricultural universities in the maritime states through their colleges of fisheries also have extension training and disseminate information to farmers.

Training centres of excellence

There are no training centres in India exclusively devoted to mariculture except for a training hatchery established in CMFRI at Kochi. CMFRI is the country's nodal agency that conducts post-graduate level courses in mariculture. It has hatcheries in Mandapam, Vizakhapatnam, Tuticorin, Calicut and Kochi that 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 into 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 elsewhere in the region, such as at the Southeast Asian Fisheries Development Center (SEAFDEC). CMFRI is also the Network of Aquaculture Centres in Asia-Pacific (NACA) National Seafarming Centre, although there is 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 at CMFRI and updating it into a Centre of Excellence. CMFRI has a Division on Mariculture located at Mandapam, where there are more than 14 scientists and over 100 technical and support staff, a guest house, running seawater facilities, laboratories, etc. MPEDA has a hatchery at Vallarpadom for shrimp that was used for imparting training until a few years back, but it is no longer functional. Some training is provided by NGOs and volunteer agencies (VAs), with the help of scientific organizations, but their impacts are low.

Existing and proposed mechanisms of technology transfer

The transfer of technology (TOT) 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, while the members of KDS consist of extension personnel and other TOT agencies. Besides this the KDS also includes the Input Supply Agencies (ISA) such as lead banks, fertilizer corporations and seed suppliers. The main function of KDS is to transfer the technology to KCS and collect feedback and pass it on to KGS. The KCS consists of farmers and other actual users of technology. The most effective TOT is possible when all three systems (i.e. KGS, KDS and KCS) are working in close cooperation. Thus there should be effective interaction and good relationships among all three systems.

The Indian Council of Agricultural Research (ICAR), though basically a KGS, has also taken up the task of technology transfer by launching various schemes in collaboration with state governments (KDS), agricultural universities and voluntary agencies. The various TOT programmes launched by ICAR include the All India Coordinated Research Projects, National Demonstration Programme, Operational Research Projects and the Krishi Vigyan Kendra Trainers' Training Centres and Lab-to-Land Programme. ICAR's scientists are actively engaged in these TOT programmes. This approach will develop the desired linkage between the KGS (ICAR and agricultural university), KDS (state government, voluntary and other extension agencies) and the KCS (the farmers and other 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 the Indian context, there are four major organizational streams to TOT work for fisheries and rural development. These are:

- the first line extension system, comprising mainly the ICAR institutes and the state agricultural universities (SAUs);
- the extension system of the Ministry of Agriculture/Fisheries and the State Department of Fisheries;
- the extension system of the Ministry of Rural Development and the State Development Departments; and
- the development work done by the NGOs, business houses, etc.

Schemes for transfer of composite fish culture technology

In India, both the government and NGOs are presently engaged in dissemination of the technology of composite fish culture through various TOT schemes. Some of the important schemes include:

- All India Coordinated Research Project on Composite Fish Culture;
- National Demonstration;
- ICAR/State Government/Agricultural University Demonstration;
- Voluntary Organization Demonstration;
- Operational Research Project;
- Central Inland Capture Fisheries Research Institute (CIFRI)/IDRC Rural Aquaculture Project and CMFRI Mariculture projects;
- Fish Farmers' Development Agencies;
- World Bank Project;
- Krishi Vigyan Kendra;
- Trainers' Training Centre;
- Lab-to-Land Programme; and
- Agricultural Technology Information Centre (ATIC) of ICAR institutions and SAUs.

The approach is an example of a widespread TOT programme to promote one technology, the lessons from which might be adapted for other aquaculture technologies.

Present training activities and likely future requirements

Present training activities are limited to MFSc and PhD courses in mariculture at CMFRI, Kochi. This is far too low for a large country such as India. There is a 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 into farming of finfish, molluscs, sea cucumbers, 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 mariculture research. 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 into a training centre via collaboration with CMFRI. The hatchery at the Central Institute for Brackishwater Aquaculture (CIBA), Chennai could also be used for shrimp hatchery training. CMFRI is upgrading its hatcheries at other centres and establishing a national Fish Seed Facility in Kochi for supplying fish seed to farmers. CMFRI has also commenced an Open Sea Cage Demonstration Farm at four sites, two on the east coast and two on the west coast. All these efforts will help to develop mariculture in India over the next five years.

EXISTING MAJOR MARICULTURE SPECIES AND FARMING TECHNOLOGIES

Status of farming of selected species

Details of the mariculture potentials of the country are presented in Tables 9 and 10.

TABLE 9

Mariculture potential in India (Source: Devaraj *et al.*, 1999)

Area	TA[1] (million ha)	PCA (million ha)	CCA (million ha)	CAP (tonnes)
Coastal land-based	2.5	1.2	0.14	85 000 (mainly shrimp)
Hinterland saline soil aquifer-based	8.5	-	-	200 (milkfish, mullet, pearl oyster, scampi)
Sea Farming				
Open sea (EEZ)	202	1.8 (inshore 0–50 m depth)	-	1 500 (mussel)
Bays, coves & gulf	-	10 700	-	-
Estuaries & backwaters	-	2 050	5	800 (oysters)
Stock Enhancement Programme				
Sea ranching	18 (0–50 m depth)	18	Nominal	Nominal (shrimp, pearl oyster, clams, sea cucumber)
Artificial reef habitat	-	-	50 reefs	10
Bottom artificial reefs (FAD)	-	-	150 FAD	-

[1] TA = total area, PCA = potential cultivable area, CCA = current cultivated area, CAP = current annual production.

TABLE 10
Marine organisms of aquaculture importance in India

Species	Hatchery techniques[1]	Rearing technique
Fishes		
Mugil cephalus, Liza parsia, L. macrolepis,		
Valamugil seheli, Chanos chanos, Etroplus suratensis,		
Epinephelus tauvina, Lethrinus spp.	X	X
Sillago sihama, Anguilla bicolor & *Siganus* spp.		
Anemone fish, *Chromis* sp. & *Lates calcarifer*	XX	XX
Crustaceans		
Penaeus monodon, Litopenaeus indicus & *P. semisulcatus*	XXX	XXX
Scylla serrata	X	XXX
Portunus pelagicus	XX	XX
Panulirus homarus, P. ornatus		
P. polyphagus & *Thenus orientalis*	X	X
Molluscs		
Perna viridis, P. indica, Pinctada fucata		
Crassostrea madrasensis, Anadara granosa		
Meretrix meretrix, M. casta &		
Paphia malabarica	XXX	XXX
Trochus radiatus, Xancus pyrum,		
Sepia pharaonis, Loligo duvaucelli	X	X
Seaweeds		
Gracilaria edulis, Gelidiella acerosa, Porphyra sp.		
Sargassum spp., *Ulva* spp. & *Euchema* sp.	XX	XX
Sea cucumber		
Holothuria scabra	XX	XX

[1] X = techniques under development; XX = techniques developed; XXX = techniques developed and commercialized.

Existing major mariculture species and farming technologies

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 them to marketable size in ponds and tanks by feeding trash fish and other discards. In many maritime states, juvenile lobsters (*Panulirus homarus*, *P. ornatus*, *P. polyphagus* and *Thenus orientalis*) are grown in captivity, eyestalk-ablated lobsters attaining 180–200 g within 5 to 6 months. This type of lobster fattening, when conducted at a stocking density of 10–15 juveniles per m^2, yielded appreciable growth rates with a profit margin of Rs 50 000 from a pond of 70 m^2. Recently a major breakthrough in breeding and hatchery production of two species of scyllarid lobster, *Thenus orientalis* and *Scyllarus rugosus,* was achieved by CMFRI. Successful hatchery production of seed of *T. orientalis* was accomplished for the first time in India. Completion of the larval cycles of *T. orientalis* and *S. rugosus* was achieved in 26 days and 32 days, respectively.

Crab farming/fattening

Live mud crabs (*Scylla serrata*, *S. tranquebarica)* are a much sought-after export commodity; thus mud crab fattening was considered a good opportunity (Table 11). Seed stock consist of freshly moulted crabs ("water crabs") of 550 g that are stocked in small brackishwater ponds at a stocking density of 1/m^2 or in individual cages for a period of 3–4 weeks while being fed thrice daily with trash fish at 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 being made 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 utilized mainly for stock enhancement programmes along the east coast.

TABLE 11
Economics of three systems of mud crab farming (Source: ICAR, 2000)

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 (seed, feed, pond, preparation, labour) (Rs)	43 860	48 400	56 200
Production (tonnes)	0.78	1.14 (and 0.7 milkfish)	0.56
Income (Rs)	157 200	261 200	122 850
Net profit /crop (Rs)	113 340	212 800	66 650

Edible oyster farming

CMFRI has developed methods for edible oyster (*Crassostrea madrasensis*) culture and has produced a complete package of technology that is presently being widely adopted by small-scale farmers in shallow estuaries, bays and backwaters along the coast. In the adopted rack method, a series of vertical poles are driven into the bottom in rows, on top of which horizontal bars are placed. Spat are either collected from the wild or produced in hatcheries, on suitable cultch materials. Spat collectors consist of clean oyster shells (5–6 shells) 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 a harvestable size of 80 mm is reached in 8–10 months. Harvesting is done manually and the production rate is 8–10 tonnes/ha. Oyster shells are also in demand by local cement and lime industry and culture production had increased to 800 tonnes in the year 2000.

Mussel farming

The raft method (in bays and inshore waters), rack method (in brackishwaters and estuaries) or longline method (in the open sea) are commonly adopted for farming mussels (*Perna indica* and *P. viridis*). Mussel seed 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. Seed attach 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 a production of 12–14 kg of mussel (shell on) per meter of rope can be obtained. Attempts to demonstrate the economic feasibility of mussel culture have led to the development of group farming activities in the coastal communities (especially by rural women's groups) with the active support of local administration and developmental agencies like the Brackishwater Fish Farmers Development Agency (BFFDA) and the State Fisheries

Department. Cultured mussel production has increased from 20 tonnes in 1996 to 4 500 tonnes in 2004, mainly through use of the rack system in estuarine areas. Molluscan culture technologies and their economics are given in Table 12.

TABLE 12
Molluscan culture technologies and economics (Source: ICAR, 2000)

Technology	Edible oyster farming	Mussel farming	Pearl oyster culture
Species	*Crassostrea madrasensis*	*Perna viridis, P. indica*	*Pinctada fucata*
Farming method	Rack (30 x 10 m)	Raft (8 x 8 m)	Cages suspended from rafts/racks
Culture period	8 months	5–7 months	12–15 months
Unit area	300 m^2	64 m^2 & 600 box cages	Open sea; 6 rafts
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 tonnes shell on	
Revenue	736	934	Depends on percentage pearl production & market value of pearl
Profit	226	303	30% (at 25% pearl production)

Pearl oyster farming and pearl production

In India, 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 laboratory under a water flow-through system and then shifted to the farm in suitable cages for rearing. Periodic monitoring is done and harvesting is carried out after 3–12 months. Pearls are categorized into A, B and C types depending on colour, luster and iridescence. Twenty-five 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 the emergence of pearl oyster farming as a profitable coastal aquaculture activity at certain centres along the coast. Village-level pearl oyster farming and pearl production, through direct involvement of small-scale fishermen, have been successfully carried out as part of a technology transfer programme along Valinokkam Bay on the east coast (Table 13). 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. CMFRI also imparts training on pearl culture to trainees in neighbouring Asian countries, and since 1996 several Memoranda of Understanding (MoU) have been signed with entrepreneurs interested in pearl culture. Recently success has been obtained in the production of Mabe pearls and the 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 *P. fucata* and the 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 jewellery from Mabe pearl was also standardized.

TABLE 13
Economics of the pearl culture programme at Valinokkam Bay – a group farming success

Number of oysters implanted	9 414
Total expenditure incurred (US$)	1 571
Rate of return (%)	56.7
Total pearls harvested	1 849
Revenue earned from sale of pearls (US$)	2 178
Pearls distributed to fisherman	250

Clam culture
A package of clam (cockle) culture practices has been developed for blood clam (*Anadara granosa* and *Paphia malabarica*), where production of 40 tonnes/ha in six months and 15–25 tonnes/ha in four to five months has been achieved in field trials. Induced spawning and larval rearing to setting of spat have been perfected for clams like *P. malabarica*, *Meretrix meretrix* and *Marcia opima*.

Sea cucumber culture
More than 200 species of sea cucumber are found in Indian waters, mainly in the Gulf of Mannar, Palk Bay and the Andaman and Nicobar Islands. The most important commercial species is *Holothuria scabra*, whose continuous exploitation has led to depletion of natural populations. Seed of *H. scabra* was produced in the hatchery for the first time in India in 1988 through induced spawning using thermal stimulation, and this technique has been widely used since then to produce seed for stock enhancement programmes. Water quality is the most important parameter in hatcheries, with ideal conditions being a temperature of 27–29 °C, salinity of 26.2–32.7 ppt, dissolved oxygen of 5–6 ml/litre, pH of 6–9 and ammonia content of 70–430 mg/m^3. The larvae require different diets at different developmental stages, and algae like *Isochrysis galbana*, *Chaetoceros calcitrans*, *Tetraselmis chuii* and *Sargassum* sp. are used. Seed produced in hatcheries are grown in velon screen cages (2 m^2 area), netlon cages (1.65 m^2 area, 5 mm mesh net), concrete rings (70 cm diameter x 30 cm height) and also at the bottom of shrimp ponds. Artificial diets prepared with soybean powder, rice bran and prawn-head waste are used for feeding juveniles and results are encouraging. Juveniles have been stocked at 30 000/ha and grown along with shrimp (*Penaeus 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 that 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 only in the experimental phase. Attempts are being made to develop suitable hatchery and farming technology for mullets (*Mugil cephalus*, *Liza macrolepis*, *Valamugil seheli*), groupers (*Epinephelus tauvina* and other species), Asian 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 that were stocked in large reinforced concrete cement (RCC) tanks (12x6x2 m) with 70–80 percent water exchange daily. The maturation process was accelerated using luteinizing hormone-releasing hormone (LHRH) injection and

larvae were maintained with rotifers and *Artemia* nauplii. Cooked and minced fish meat is used for nursery rearing, and survival rates of up to 14 percent in the 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 fish in the vast waterbodies and coral reef ecosystems along the Indian coast that, if judiciously used, can earn a sizeable foreign exchange. A long-term sustainable trade of marine ornamental fishes can be developed only through hatchery-produced fish. Hatchery technology for clownfish (*Amphiprion sebae*), damsel fishes (*Pomacentrus caeruleus*, *Neopomacentrus nemurus, N. filamentosus*, *Dascyllus trimaculatus*) and sea horse (*Hippocampus kuda*) has been developed and could be scaled up for mass production.

Seaweed culture

Around 60 species of commercially important seaweeds with a standing crop of 100 000 tonnes occur along the Indian coast, from which nearly 880 tonnes of dry agarophytes and 3 600 tonnes of dry alginophytes are exploited annually from the wild. Seaweed products like agar, algin, carrageenan and liquid fertilizer are in demand in global markets; and some economically viable seaweed cultivation technologies have been developed in India by CMFRI and the Central Salt and Marine Chemical Research Institute (CSMCRI). CMFRI has developed technology to culture seaweeds by either vegetative propagation using fragments of seaweed collected from natural beds or by spores (tetraspores/carpospores). Seaweed culture has the potential to develop in large productive coastal belts and also in onshore culture tanks, ponds and raceways. Recently the culture of the carrageenan-yielding seaweed *Kappaphycus alvarezii* has become very popular and this species 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 ha, while *Gracilaria edulis* and *Hypnea* production is about 15 tonnes dry weight per ha. Pilot-scale field cultivation of *K. 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 of 5.7 fold after 22–34 days in the Gulf of Mannar.

PRIORITIES FOR DEVELOPMENT AND RESEARCH

Seed production of crabs, lobsters, cephalopods and marine finfish

The lack of availability of seed for commercial-level farming is the major constraint to the development and expansion of mariculture in India. Hence maximum research thrust is required for the development of commercial seed production technologies for the suitable species of crabs, lobsters and marine finfishes. Even though seed production of swimming crab (*Portunus pelagicus*) has been achieved, the survival rate to the seed stage is only about 5 percent. Improvement of technology is thus required to achieve commercial-level seed production. Similarly, success in seed production of the sand lobster (*Thenus orientalis*) also remains to be scaled up to commercial level. In the case of spiny lobsters, the larval rearing to phyllosoma VIII still remains a challenge due to the prolonged larval phase. The experimental success obtained in the seed production of squids and cuttlefishes (*Loligo singhalensis, Sepia pharaonis, S. lessoniana* and *S. inermis*) has to be scaled up. Massive research input is required for development of seed production technologies for the many species of marine finfish that are suitable for open sea-cage farming.

Open-sea cage culture

Open-sea cage culture has been expanding on a global basis and is viewed by many stakeholders in the industry as the aquaculture system of the future. 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 raising fish. It is now recognized 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, although the risk of self pollution must be reduced through good management and site selection. Simple cages for inshore waters are relatively easy to construct with minimal skilled labour. The Indian coast offers many ideal locations for cage farming, potential sites including bays in Ratnagiri, Goa, Karwar, Palk Bay, Larsons Bay, Gulf of Mannar, Lakshadweep islands and the Andaman and Nicobar Islands. Potential fish for cage culture include groupers, snappers, seabass, rabbitfish and *Cobia*. A few modern demonstration farms could be set up at suitable sites by entrusting the work to developmental agencies of the central and state governments. The materials for cage farms and the technology for installation of floating cages could be imported. Floating cage farming can be further expanded after its 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 fishermen by central and state government developmental agencies.

Popularization of bivalve mariculture

Being in the lower part of the food chain, bivalves are energy efficient and cause minimal pollution to the culture system and the environment. Bivalve culture can be carried out as an artisanal activity and also as a large-scale mariculture enterprise oriented towards the export market. Artisanal mariculture of mussels, edible oysters and clams is being practiced on a small scale in certain parts of the Indian coast. There is scope for bivalve farming along the Kerala, Karnataka and Konkan coast. State and central government developmental agencies can be entrusted with the expansion of bivalve farming in suitable coastal areas by providing training and extension programmes. Large-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 suitable coastal areas has to be promoted to industrial-level production. Suitable areas for seaweed culture include the Tamil Nadu coast, Orissa coast, Okha Veraval coast and Konkan coast. Demonstration programmes for artisanal seaweed culture could be organized by developmental agencies in this area. Large-scale culture of seaweed can also be demonstrated at

Palk Bay to assess the techno-economic viability for industrial-level production of seaweeds. Production of good quality agar/carrageenan and development of an appropriate marketing system have to be taken up as priority programmes for the development of the 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 can proceed.

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 fishermen. In this context, artisanal mariculture can play a vital role as an additional source of income. Artisanal mariculture of bivalve molluscs and seaweeds, and crab and lobster fattening are being practiced in certain parts of the coast. Extensive training programmes could be organized along the coasts of Kerala, Tamil Nadu, Karnataka, Konkan and Orissa for promoting artisanal mariculture practices.

Marine ornamental fish trade through hatchery production

In recent years, the marine ornamental fish trade has become a global industry worth an estimated US$200–330 million annually and operated throughout the tropics. Even though India is bestowed with good ornamental fish resources, wild collection from coral reefs can lead to destruction of the reef habitat. Hence development of trade through hatchery production of fish offers potential. In the recent past, CMFRI has developed hatchery production techniques for clownfish and a few damsel fish species. 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, the Andaman and Nicobar Islands and the Gulf of Mannar coast is required through state and central developmental agencies. In addition, research on development of seed production technologies for suitable species of marine angelfishes, gobiids and cardinal fishes deserves attention.

Establishment of seed banks for mariculture

The availability of seed is a basic requirement for any commercial mariculture enterprise. At present, except for a few species of shrimp, commercial-level seed availability is lacking for species suitable for mariculture. Hence the establishment of seed banks at appropriate locations is the basic requirement for the development of mariculture. For those species for which hatchery production of seed is not economically viable (e.g. bivalves) or hatchery production technologies are not available (many species of marine finfish), seed banks could be developed from wild-collected seed. Lack of commercial-level hatchery production technologies is the major constraint for the development of marine aquaculture in India. Hence research on seed production for species having culture potential should be strengthened.

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 time add to its income. Plants counteract the environmental effects of the heterotrophic-fed fish and shrimp and restore water quality. A 1 ha land-based integrated seabream – shellfish – seaweed farm can produce 25 tonnes of fish, 50 tonnes of bivalves and 30 tonnes fresh-weight of seaweeds annually. Hence modern integrated systems are bound to play a major role in the sustainable expansion of mariculture. A few 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 (FADs) are known to attract fish. Hence their installation in 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 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

As the overexploitation of many of our marine fisheries resources has lead to a reduction of wild stocks, large-scale sea ranching programmes may play a vital role in natural stock enhancement. Sea ranching of *Penaeus semisulcatus* is already being carried out in the Mandapam area by CMFRI. A massive sea-ranching programme for *P. semisulcatus* can be taken up along the east coast by developmental agencies through fisherfolk participation. Regular impact assessments of 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 and molluscs and certain forms of extensive shrimp culture. It is estimated to account for about 20 percent of the total quantity of foodfish production through aquaculture. Using FAO data from 2001, this is equivalent to over 7.5 million tonnes per year, and is principally molluscs. The production of finfish, especially carnivorous species (including 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 nations. In India, since the seed production technologies of many species are either not standardized or are not commercially viable, CBA might be developed, with proper management.

Conservation mariculture

The populations of many marine species are in decline and are in the process becoming 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 on such approaches is very much warranted.

Identification of better management practices (BMPs) and systems to mitigate environmental impacts

The following BMPs are suggested for bivalve culture and seaweed culture. Extensive information has been generated on BMPs for shrimp farming, and is therefore not included here.

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 seaweeds will prove to be more ecologically sustainable, in addition to being more productive.

Seaweed farming
Seaweed culture is presently carried out in coastal waters using bamboo rafts. If many rafts are deployed in the same area, it would not only adversely affect nutrient availability and phytoplankton production, but also fisheries, movement of boats, fishing operations, traditional rights, etc. Thus proper siting needs to encouraged, and suitable areas should be identified for seaweed farms. Also, the culture ropes can be integrated with the mussel culture rafts, as is already done by mussel farmers in the Kasargod area. This approach will help to a great extent in preventing mussel farms from adversely affecting the culture sites, as nutrient output from mussels can be absorbed. The growth rates of seaweeds in such farms are several folds higher. A package should be developed along these lines to establish environmentally friendly mussel-oyster-seaweed farms along the coasts.

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MARINE AQUACULTURE PRODUCTS DEMAND, TRADE AND MARKET

Indonesia has 5.8 million km^2 of marine area, with 17 504 islands and 81 000 km of coastline, and a population of 217 million people. National export of fisheries product in 2004 was 902 358 092 kg valued at US$1 780 million (about 2.69 percent of total export value), while national import of fisheries product in the same period was about 136 040 149 kg with a value of US$154 million (about 0.28 percent of total import). Export volume and value of fisheries product by commodity are shown in Table 1.

TABLE 1
Export volume and value of fisheries product by commodity in 2004

Commodity	Volume (kg)	Value (US$)
Fresh shrimp, frozen, canned	139 450 184	887 127 117
Fresh tuna, frozen, canned	94 220 950	243 937 896
Other live, fresh, frozen, dried, canned	522 831 403	354 446 044
Fresh crab, frozen, canned	20 902 586	134 354 913
Frog leg	3 388 995	11 515 497
Dried jellyfish	4 598 934	4 994 686
Snail	1 886 462	2 762 606
Shrimp crisp	5 535 502	7 539 046
Fish oil	2 141 066	637 748
Dried seaweeds	51 010 828	25 296 399
Coral and shell	3 125 494	1 411 077
Pearl	1 711	5 866 158
Ornamental fish	3 516 060	15 809 284
Dried anchovy	3 202 761	18 571 267
Other product	46 545 156	66 563 069
Total	902 358 092	1 780 832 807

Total production of capture fisheries is about 4.07 million tonnes/year, and total production of aquaculture in 2004 was 1.47 million tonnes (Table 2) (about 26 percent of total fishery production).

TABLE 2
Indonesian aquaculture production in 2004

Aquaculture system	Production (tonnes)
Marine-based aquaculture	420 919
Coastal brackishwater pond	559 612
Inland pond	286 182
Freshwater cage culture	53 695
Freshwater floating net	62 371
Rice field integrated farming	85 832
Total	1 468 610

The contribution of mariculture to fisheries production in 2004 was about 0.42 million tonnes (Table 3) or about 28.6 percent of total aquaculture.

TABLE 3
Indonesian mariculture production by commodity in 2004

Commodity	Production (tonnes)
Grouper	6 552
Asian seabass	1 748
Mussel	12 953
Seaweeds	397 964
Other	1 702
Total	420 919

Almost all Indonesian mariculture products are produced for export. Grouper, Asian seabass and other finfish are commonly exported as live fish. They are transported from the farm by live-fish transport with seawater circulation. Seaweed products for carageenan extraction are exported as dried raw materials. The trading of this bulky product involves several marketing intermediaries before export.

The cost of transport from farming sites to buyers remains a marketing constraint for seaweed. A collector is needed who is able to bring together sufficient quantities of seaweed and transport them efficiently to the larger buyers. Some intermediate steps require quality and price adjustment before seaweed is ready to export. Quality assurance along the trading chain is also required, with reasonable prices for farmers and traders.

LIVELIHOOD OPPORTUNITIES RELATED TO MARICULTURE DEVELOPMENT

Indonesia has identified 12 139 042 ha of area available for marine aquaculture (excluding coastal ponds); however, as of 2004 only about 1 227.49 ha (0.01 percent) was used. If the effective area (based on receiving capacity) is about 10 percent of the available area, the optimal area is about 1.2 million ha of potential farming area.

The Indonesian Archipelago has tropical characteristics with various rainfall patterns. The western part of Indonesia has an annual rainfall of more than 2 000 mm with a longer rainy season and lower solar radiation. The eastern part of Indonesia is rich with solar radiation and has lower precipitation and shorter periods of rain. The western part is therefore considered to have higher suitability for agriculture and brackishwater aquaculture, while the eastern part is considered suitable for mariculture. The potential area available for mariculture development in Indonesia is given in Table 4, along with data on the distribution of poverty in the country.

TABLE 4
Poverty distribution and suitable mariculture area available in Indonesia

Province	Number of poor (x1 000)	Population (%)	Available mariculture area (ha)	2004 area (ha)
Nangroe Aceh D	1 157.2	28.47	129 318	-
Sumatera Utara	1 800.1	14.93	99 642	0.24
Sumatera Barat	472.4	10.46	54 139	15.14
Riau	744.4	13.12	118 377	0.55
Jambi	325.1	12.45	290 205	-
Sumatera Selatan	1 379.3	20.92	614 834	-
Bengkulu	345.1	22.39	9 258	-
Lampung	1 561.7	22.22	388 351	0.51
Bangka-Belitung	91.8	9.07	255 175	9.95
DKI Jakarta	227.1	3.18	2 825	2.40
Jawa Barat	4 654.2	12.10	35 933	11.00
Jawa Tengah	6 843.8	21.11	1 134	-
D.I. Yogyakarta	616.2	19.14	0	-
Jawa Timur	7 312.5	20.08	31 937	30.00
Banten	779.2	8.58	60 768	9.28
Bali	231.9	6.85	8 140	421.00
Nusa Tenggara Barat	1 031.6	25.38	139 523	251.00
Nusa Tenggara Timur	1 152.1	27.86	160 922	3.01
Kalimantan Barat	558.2	13.91	853 640	0.21
Kalimantan Tengah	194.1	10.44	659 754	-
Kalimantan Selatan	231.0	7.19	199 467	5.86
Kalimantan Timur	318.2	11.57	409 314	2.62
Sulawesi Utara	192.2	8.94	43 105	304.00
Gorontalo	486.3	21.69	65 836	0.27
Sulawesi Tengah	1 241.5	14.90	551 235	0.31
Sulawesi Selatan	418.4	21.90	43 028	-
Sulawesi Tenggara	259.1	29.01	183 911	149.30
Maluku	397.6	32.13	1 065 983	9.85
Maluku Utara	107.8	12.42	429 154	0.18
Papua	966.8	38.69	5 234 074	0.8
Total	36 146.9	16.66	12 139 042	1 227.49

The total number of poor is about 36.14 million (16.7 percent of the population), while the potential area used for mariculture is about 0.01 percent. This raises the question, “Is mariculture able to reduce poverty?” The Government of Indonesia strives to provide the proof that the answer is an optimistic, “yes”.

The area used for mariculture has increased annually by an average of about 19.4 percent since 2000, while the annual increase in the number of farmers over this period has averaged 30.7 percent (Table 5). There seems to be significant mariculture development; however, the area utilized is still very low compared to that available.

TABLE 5
Number of farmers involved in mariculture and total area utilized, 2000–2004

Year	Number of farmers	Total area utilized (ha)
2000	29 604	614
2001	39 800	713
2002	65 624	951
2003	67 735	981
2004	81 377	1 227
Average annual increment	30.7 %	19.4%

The range of species cultured in the Indonesian mariculture sector is still limited and is dominated by export-oriented commodities. The oldest commodity is seaweed, which has been exported since 1985 from several areas around the country. In 2004 the quantity of dried seaweeds (*Eucheuma cottonii* or *Kapaphycus alvarezii*) exported was about 400 000 tonnes from around 3.2 million tonnes of farm-harvested product. The development of seaweed farming has been successful, but its expansion is also limited by factors such as the need to identify suitable areas and a lack of information about value, culture techniques, markets and capital. The area suitable for seaweed culture has been recognized only after some on-site trials; however, there is still a lack of systematic analysis of suitable locations. Spatial and temporal variation in environmental conditions is not always detectable by conventional analyses without year-round sampling.

The development of seaweed farming has helped reduce poverty in several areas of Indonesia and provides several lessons for successful mariculture:

- The target location should be feasible for farming of commercial strains/species on a commercial scale. Site suitability is only recognizable after on-site trials.
- The introduction of farming requires a "candidate farmer" who should be able to work successfully under the conditions found in coastal areas.
- The seed (initial stock) and other facilities provided to farmers should be provided as a "loan" that should be paid back after a certain period of successful harvests.
- Supervision should be provided to the farmer and continued until marketable quality seaweed is produced in sufficient quantity.
- Farmers should be "connected" with a "generous" trader or exporter.

Government, through so-called "Technical Implementation Units" (TIUs), has started to facilitate initial seaweed stock plantations in several regions, in order to ensure farmers that the initial stock is available and can be obtained at a reasonable price. The Marine Aquaculture Development Centre of Lombok has also built up a multistrain stock of seaweeds.

The other aquaculture commodity that has shown significant recent growth is finfish, particularly grouper. This commodity is considered harder to develop for poverty alleviation, as poor farmers are limited by technology, capital and market information.

Grouper seed became available from commercial hatcheries in 1999, along with commercial pelleted feed in 2003. Although farmers produced 6 552 tonnes of marine fish in 2004, considerable problems still remain. Unsuccessful examples of grouper development have been experienced in Indonesia, providing the following lessons:

- Risks due to mortality and market are now considered as major constraints.
- There is a lack of practical management practices and demonstrations to help farmers in controlling mortality due to diseases caused by parasites and other pathogens.
- It takes a long time for tiger grouper and humpback grouper to reach marketable size (about 10 months and 16 months, respectively). This long culture period increases investment risk.

- Trading live fish is difficult and risky and needs a large production scale.
- High capital investment is unattractive to investors.

The culture of pearl oyster is also one of the established mariculture activities in Indonesia. The Indonesian Pearl Culture Association has 39 registered pearl oyster company members. Excluded from the association are more than 100 small companies or smallholders involved in pearl farming. The pearl farms are located in Lampung (Sumatera), Madura (East Java), Bali, West Nusa Tenggara, Sulawesi, Maluku and Papua. As of September 2005, they produced 3 800 kg of pearl. The species available in Indonesia are: *Pinctada maxima, P. margaritifera, P. fucata, P. lentiginosa* and *Pteria penguin.* So far, the wild broodstock appears to be sufficient to fulfil the hatchery requirements.

Pearl farms employ plenty of labour, contributing to poverty alleviation, but the employment is not socially secure. Security risks are one of the main problems faced by pearl farming. The rearing activity in open water is hard to control. Security problems may indicate social problems with the local community. Companies should seek to involve the local community to minimize such problems, and business interdependency between the local community and the company should be created through mutual collaboration.

Pearl farming requires several independent processes including:

- hatchery operations for producing spat;
- nursery operations to raise spat to young oysters (5 cm shell length) at 6 months after stocking;
- rearing to produce adult oysters (10 cm length), that are ready for nucleus insertion; and
- insertion and incubation of inserted oysters to produce pearls.

It is recommended that spat production usually be conducted by government hatcheries, which are able to supply sufficient spat; nursery operations and rearing to adult oysters can be conducted by the local community and supervised by the company or government. Insertion of nucleus and incubation to produce pearls is conducted by the company. Such arrangements are advantageous to the company, as they minimize hired labour and assure protection of the company's investment by the community because there is a mutual interest in success. There are working examples of such collaboration in Indonesia.

EXISTING AND POTENTIAL MECHANISMS FOR TECHNOLOGY TRANSFER

Indonesia has institutions for mariculture development that are spread from the west to the eastern part of the country. They are called Technical Implementation Units (TIUs), and are part of the Directorate General of Aquaculture. Such institutions include:

- Center for Marine Aquaculture Development, Lampung (Sumatera)
- Marine Aquaculture Development Center, Batam (Riau)
- Marine Aquaculture Development Center, Ambon
- Marine Aquaculture Development Center, Lombok (West Nusa Tenggara)
- Brackish Water Aquaculture Development Center, Jepara (Central Java)
- Brackish Water Aquaculture Development Center Takalar (South Sulawesi)
- Brackish Water Aquaculture Development Center, Situbondo (East Java)
- Brackish Water Aquaculture Development Center, Aceh

The mission of the TIUs is to conduct technology propagation/extension and develop applied technology. They have facilities such as commercial-scale experimental facilities (hatchery, nursery and grow-out facilities), training facilities, dormitories and laboratory services. The technology transfer by these institutions usually involves:

- on-the-job training, where participants stay, learn and work with the staff in charge for a certain period, depending on the subject and level;
- publication of posters and leaflets;
- on-farm supervision; and
- pilot projects, prototype testing and modelling.

For example, one of the current activities conducted at the Marine Aquaculture Development Center in Lombok is training on abalone culture for vocational schools involved with marine aquaculture. The training involves teachers from seven provinces with the purpose of accelerating abalone spat production.

EXISTING MAJOR MARICULTURE SPECIES AND FARMING TECHNOLOGY

Indonesian mariculture involves the culture of seaweeds, grouper, lobster and abalone. Seaweeds (*Eucheuma* spp.), as one of the established species, is recognized as a strategic commodity. Its culture involves large numbers of people, applies simple techniques and provides short-term returns to farmers for small investment. The existing seaweed producers are located in seven provinces, i.e. Sulawesi Utara, Sulawesi Tenggara, Sulawesi Selatan, Jawa Timur, Bali, Nusa Tenggara Barat and Nusa Tenggara Timur. Both floating and off-bottom farming methods are used. Seaweed farming areas produce 40 tonnes of harvest per ha per month. The Indonesian government supports development of this commodity by encouraging cooperation among capital sources (banking) for credit, companies for marketing and processing and the coastal community as a seaweed producer.

The technology for grouper (tiger and humpback) farming was first established in 1999 and has developed rapidly since then. Hatchery seed is now available from Lampung, East Java and Bali. Private companies entered the business in 2002 and are mainly located at Lampung, Nusa Tenggara, Bali and Riau. Fish-farming companies located close to a source of trash fish have a comparative advantage, with feed provided by fishers at lower prices and in relatively fresh condition. The main problems with grouper production relate to trading and marketing. The main markets for grouper (People's Republic of China and China, Hong Kong SAR) require live fish. The high risk and transportation costs influence the competitiveness of the product from Indonesia. Diseases due to parasites and other pathogens are also a problem.

Grouper farming has been introduced to small households by government in several provinces, but with limited success due to technical and non technical constraints. Major concerns appear to be the long grow-out period and the need for regular investment by farmers in trash fish for feed without returns from fish sales.

Lobster is a mariculture commodity that can generate income within a short period. Floating cages stocked with 50-g adolescent lobster (*Panulirus* spp.) and fed with trash fish can reach 250 g within 6 months. Lobster culture is conducted by smallholders located close to the source of wild seed. However, the capture of wild lobster seed needs to be controlled to preserve broodstock and limit overharvesting. At present, wild seed of 2–3 cm are collected by fisherman using artificial aggregators (settling media) made of fibre sack or cotton cloth. Wild seed can easily be collected during the period of settling. The collected juveniles are nursed in concrete tanks or floating nets and fed with trash fish until they reach a length of 5 cm, after which they are transferred to grow-out facilities. Lobster mariculture, including the nursery step, shows potential for further development and is currently under experimentation.

Abalone, especially tropical abalone (*Haliotis asinina*), is another commodity with potential for further development. Experiments show that the animal can be raised in floating cages, obtaining a marketable size (7 cm shell length) in 12 months. They are fed with seaweeds (*Gracilaria* spp. and *Ulva* spp.) and show a survival rate of about 50 percent and a food conversion ratio (FCR) of 1:15. The technique to produce seed (spat) in hatcheries is available, but there are no private hatcheries as yet in Indonesia to provide sufficient spat. The government should invest or encourage private investment in hatcheries to produce abalone seed. Abalone culture also has potential for integration with grouper or seaweed farming.

Green mussel (*Perna viridis*) culture is established around the Gulf of Jakarta, with about 10 000 tonnes produced annually. Farmers use bamboo sticks to settle the spat. The main problems are poor water quality and toxic algae in coastal waters arising from urban pollution. The Indonesian government is concerned about these problems and is involved in transplantation of mussel spat to less polluted areas. The Centre for Mariculture Development at Lampung has also successfully produced hatchery spat.

Islamic Republic of Iran

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Besharat, K. and Rezvani, S. 2008. Islamic Republic of Iran. In A. Lovatelli, M.J. Phillips, J.R. Arthur and K. Yamamoto (eds). FAO/NACA Regional Workshop on the Future of Mariculture: a Regional Approach for Responsible Development in the Asia-Pacific Region. Guangzhou, China, 7–11 March 2006. *FAO Fisheries Proceedings.* No. 11. Rome, FAO. 2008. pp. 181–188.

BACKGROUND

The Islamic Republic of Iran has a great potential for fisheries development activities, with some 1 850 km of coastline in the south (the Sea of Oman and Persian Gulf) and over 900 km of coastline in the north (the Caspian Sea). Iran IR comprises a land area of 1.64 million km^2 and is located in the northern part of the temperate zone between latitudes 25^{o}00 and 39^{o}47' north and longitudes 44^{o}02' and 63^{o}02' east. The average altitude is over 1200 m. The Islamic Republic of Iran is bordered by Turkmenistan, the Caspian Sea, Azerbaijan and Armenia on the north; Afghanistan and Pakistan on the east; the Sea of Oman and Persian Gulf on the south; and Iraq and Turkey on the west. The country has three main climatic zones where several different fish and shrimp species can be grown:

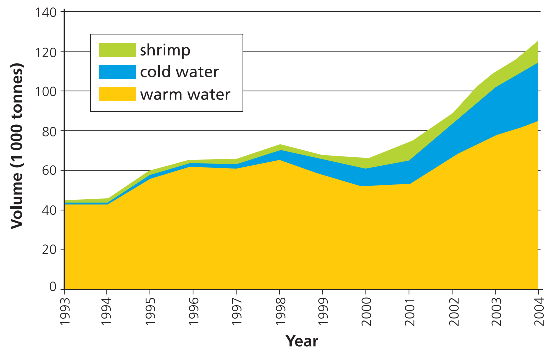
- arid and semi-arid regions of the interior and far south, characterized by long, warm and dry periods, lasting sometimes over seven months, covering nearly 90 percent of the country and having an annual precipitation rate of between 30 and 250 mm;
- Mediterranean climate (mainly in the western Zagros Mountains, the high plateau of Azerbaijan and the Alborz Mountains), characterized by warm, dry summers and cool, damp winters, with annual rainfall between 250 and 600 mm, and covering about 5 percent of the land surface; and
- humid and semi-humid regions (mainly in the Caspian, but also in west Azerbaijan and the southwest Zagros), with an annual precipitation rate of 600 to 2 000 mm, also covering about 5 percent of the land surface.

Although aquaculture in Asia dates back thousands of years, there has been limited attention to its development in Iran IR until the last four decades. The first aquaculture experiment was conducted with rainbow trout culture near Tehran in Mahisara (Karaj) in 1959. The first farm for warmwater aquaculture was established in Giulan Province and by the Abzi Company in Khuzestan Province (Shooshtar) in 1971. Shrimp culture in Iran IR has a short history, occurring only since 1991. The industry has developed very rapidly over the past seven years and great progress has been made (Shakouri, 2003).

STATUS OF IRANIAN AQUACULTURE

The Government of Iran considers the fisheries sector as important for job creation, food security and poverty alleviation in the 4th National Five-Year Development Plan (NFDP). In 2003 some 144 600 employees were directly involved in the sector. Fisheries products provide 2.7 g/day per capita of animal protein supply in the country (Abdolhay, 2005). While fisheries production exceeded 440 000 tonnes in

Figure 1
Aquaculture production, 1993–2004



2003, the government has targeted a production of 763 000 tonnes in 2009. This means that the fish supply will increase from 6.1 to 10 kg per capita and will provide 4.5 g of animal protein. Fish is an expensive, high-status food item in the Islamic Republic of Iran. The consumption in the Islamic Republic of Iran is 6.1 kg per capita (Shilat, 2003), and the main goal of the government is to increase fish consumption to 7 kg (for comparison, world per capita fish consumption is 13.5 kg). Faced with population trends and the decline of some capture fisheries, the government is increasingly looking at aquaculture as an alternative source of fish and shellfish products, and a contributor of animal protein to food security by raising fish consumption to 13.5 kg per capita.

The total fisheries and aquaculture production in 2003 was 442 000 tonnes (Shilat, 2003). The goal of the government is to achieve a production of 100 000 tonnes of farmed marine fish in the Persian Gulf, Oman Sea and the Caspian Sea. Since 1990 the Islamic Republic of Iran has increased shrimp farming, which now has a yearly production of 4 000 tonnes. There are plans for increasing shrimp production to 47 000 tonnes by 2009 from an area of 22 000 ha.

Fingerlings of several species are produced and stocked in the Caspian Sea and Persian Gulf. In 2004 a total of 235 million fingerlings were released into these seas (Abdolhay, 2005). There are currently no selection or breeding programmes on any of these species for restocking purposes, although there are plans for such a programme for both shrimp and the Caspian trout (*Salmo trutta caspius*). The total aquaculture production trends are shown in Figure 1.

CULTURE SPECIES

Warmwater fish culture includes the extensive rearing of four Chinese carps, namely common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalmichthys molitrix*), and bighead carp (*Aristichthys nobilis*). The species were introduced from Romania, Hungary and the People's Republic of China. Coldwater fish farming includes rearing of rainbow trout (*Oncorhynchus mykiss*) in tanks and raceways. Rainbow trout were introduced from several countries, including the United Kingdom, Italy and Norway.

Shrimp-farming systems are semi-intensive, aiming at a production of 3 tonnes/ha in rectangular, earthern ponds. *Fenneropenaeus indicus* is the main species cultured because of the availability of wild spawners, its easy maturation in captivity and its tolerance of various environmental conditions (salinity in particular). Several experiments have shown that green tiger shrimp (*Penaeus semisulcatus)* and banana shrimp (*F. merguiensis)* are not reliable species for pond culture. Slow growth of *P. semisulcatus* and high mortality of *F. merguiensis* are main disadvantages of these species.

Farming of freshwater prawn (*Macrobrachium rosenbergii)*, beluga (*Huso huso*), common bream (*Abramis brama*), milkfish (*Chanos chanos*), barb (*Mesopotamichthys sharpeyi*) and pike-perch (*Sander lucioperca*) has been introduced to farmers for diversification of production and to provide more flexibility in marketing.

Shrimp culture

In 2002, the Islamic Republic of Iran produced 5 960 tonnes of shrimp in 246 farms. Compared to the previous year, the production and number of farms showed a 20 percent and 12 percent decrease, respectively. The reason for this decline was the low price of shrimp in the world market and a disease outbreak in one farm complex (Choebdeh farm complex, Khuzestan) (Table 1). In spite of the control of disease in Khuzestan, the farms are still closed. Production of pond-reared shrimp in 2004 was 8 902 tonnes. Table 2 shows the number of shrimp postlarvae that have been produced in shrimp hatcheries from 1994–2004.

TABLE 1
Number of farms, pond area and annual production of shrimp, 1992–2004

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Number of farms	2	11	12	37	40	60	79	138	207	278	207	249	310
Pond area (ha)	2	31	47	179	181	440	612	1 336	2 461	3 618	2 647	3 589	4 098
Production (t)	3	16	53	135	159	518	865	1 827	4 005	7 606	5 960	7 500	8 902

TABLE 2
Production of shrimp postlarvae (millions), 1994–2004 (Source: Shilat, 2003)

Species	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
F. indicus	282.0	18.0	24.7	57.0	114.0	306.0	532.0	828.0	683.0	764.3	900.8

STOCK ENHANCEMENT

Fish stock enhancement

One of the main goals for Shilat is to preserve and maintain the diversity of species in the Caspian Sea and Persian Gulf. In the last 10–20 years, severe stock depletion for several species has led to restocking programmes, with annual releases of about 250 million fry and fingerlings into the Caspian Sea and Persian Gulf (Table 3). The releases are an important event for the whole community (Abdolhay, 2005).

TABLE 3
Releases of fingerlings (millions) to the Caspian Sea and Persian Gulf for stock enhancement, 1994–2005

	Species	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Caspian Sea	Sturgeon	4.66	8.05	11.0	18.8	22.6	19.1	18.3	20.0	19.6	20.0	21.1	10.0
	Kutum	142.7	117.9	142	154	143	148	147	232	225	155	179	229
	Caspian salmon	0.64	0.80	0.42	0.34	0.51	0.50	0.64	0.36	0.34	0.33	0.31	0.3
	Bream	10.4	11.2	8.40	12.9	13.8	14.2	14.3	15.5	16.5	17.0	16.3	27.1
	Perch	2.88	2.27	2.41	5.43	3.61	4.00	4.00	7.40	5.50	11.0	7.54	10.2
	Sea carp	0	0	0	6.50	24.0	9.00	32.0	17.9	7.60	2.00	0.0	0.3
	Caspian roach	0	0	0	15.8	13.9	10.7	16.2	19.1	12.2	12.0	10.4	3.8
Persian Gulf	Yellow seabream	-	-	-	-	-	-	-	-	-	-	0.05	0.6
	Gray grouper	-	-	-	-	-	-	-	-	-	-	-	0.1
Total (rounded)		161	140	164	214	221	206	233	312	287	217	235	282

The decrease of some species in 2005 compared with the previous year is a result of the lack of wild broodstock.

Shrimp stock enhancement

Table 4 shows the number of shrimp postlarvae released in the northern part of the Persian Gulf and the Oman Sea during the years 1997–2005.

TABLE 4
Number of shrimp postlarvae released into the Persian Gulf and Oman Sea, 1997–2005

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
Number (x1 000)	7 049.5	2 085	4 200	1 998.5	4 630	5 750	13 696.7	72 703	9 095.7	121 208.4

MARINE CAGE CULTURE

With the assistance of the Refa Company (a Norwegian company), Shilat studied the feasibility of marine fish farming in the northern coast of the Persian Gulf, Oman Sea and the southern coast of the Caspian Sea. The results show a good potential for cage culture in various areas.

The major candidates for cage culture are silver pomfret (*Pampus argenteus)*, milkfish (*Chanos chanos)*, cobia *(Rachycentron canadum)*, Asian seabass (*Lates calcarifer*), rabbitfish (*Siganus* sp.) and gilthead seabream (*Sparus aurata*) in the Persian Gulf and Oman Sea. For the Caspian Sea, major candidates are considered to be beluga (*Huso huso*), rainbow trout and the local trout (*Salmo trutta caspius*).

The study estimated the potential for cage culture as 200 000 tonnes for the central, 10 000 tonnes for the western and 40 000 tonnes for the eastern part of the Caspian Sea. The potential for Persian Gulf cage culture was estimated as 150 000 tonnes (excluding Khouzestan Province).

There is significant potential for the development of a viable marine fish culture industry based on sea-cage production systems in Iran IR. Application of available technical and financial resources to establish pilot and commercial cage-farm facilities is a priority to meet the ambitious goal of developing the sea-cage industry. In the long term, the production of large volumes of high and medium-value marine fish for world markets is likely to provide the greatest potential for sea-cage culture in Iran IR. This will be attained through investments by large companies or by vertical integration by companies contracting smaller producers, as is happening within the salmon industry in some countries today. Sea-cage culture can develop into a major industry in Iran IR, perhaps second only to the oil and gas industry.

The Iranian government has decided to establish four pilot farms during the fourth National Five Year Development Plan. At present, the first sea-cage farm with a capacity of 180 tonnes is installed between Queshm and Hengam islands in the Persian Gulf. This project will be carried out for a three year period of pilot-scale production of selected species.

HUMAN RESOURCES

The total employment from fisheries was estimated in 1994 as 97 381, with aquaculture and related activities providing employment for 10 921 (11.2 percent of total fisheries employment). In 2003 employment from fisheries, and from aquaculture and related activities reached 156 470 and 17 095 jobs, respectively (Shilat, 2003) (Table 5).

TABLE 5
Employment in aquaculture and related activities (Source: Shilat, 2003)

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Aquaculture	10 921	11 004	11 630	10 250	16 661	19 872	23 581	20 150	20 240	17 095
Total	97 381	11 848	108 398	112 181	122 170	122 961	143 148	144 398	144 584	156 470

Shrimp culture has an important role to play in poverty alleviation and creating job opportunities along the southern coasts of the country. It has already created over 4 000 direct, full-time jobs in farms and hatcheries and an equal number of indirect full-time job opportunities in feed mill plants, processing units and other activities. Part-time employment generated in related sectors (construction, transport, equipment services, etc.) is also important.

MARKET

The Islamic Republic of Iran currently exports several fish products, the most important one, of course, being Iranian caviar, which is recognized as the best in the world. Farmed shrimps are European Community-approved and also exported. In addition, canned tuna, kilka (*Clupeonella* spp.) (Thai/Japanese market) and some by-products from sturgeon caviar production (fish meat, swimbladder, gel-products from skin) are also exported.

The Islamic Republic of Iran is one of the main food producers in the region, and export to all Arabic countries is possible. With the adoption of high standards such as ISO 14000, the potential for export to the rest of the world is also very high. The export of cultured species that do not fit the Iranian eating customs, such as eel, shellfish, etc. also has a huge potential.

Fish consumption per capita in the Islamic Republic of Iran is estimated based on the total fish supply and has increased from 4.5 kg in 1998 to 6.1 kg in 2003. Increased fish supply to the community has great significance for the government as a key issue in the development of the fisheries sector.

Based on the 4th NFDP, fisheries production will exceed 760 000 tonnes, including 280 000 tonnes of freshwater fishes that do not penetrate the international market. So the producers have to rely on the domestic market. Iranians eat some 23.1 kg of beef and lamb and 11.8 kg of poultry each year. The government has been actively promoting changes in Iranian food consumption habits towards fisheries products, such as through fish-cooking training courses for housewives, fisheries products shows and direct selling around the country, release of booklets and books for children and entertainment and documentary programmes.

Marine fish and shrimp have a good demand in international markets. In 2003 the Islamic Republic of Iran exported some 20 647 tonnes of fisheries products, including caviar, marine shrimp and fish, and value-added products such as canned tuna and smoked fish, with a value of US$87.4 million. Caviar has the highest value, while shrimp has the highest contribution by volume. Considering the huge potential for shrimp culture in southern Islamic Republic of Iran, it is estimated that shrimp production will increase to 46 000 tonnes in 2009, which will need further development of international markets (Shakouri and Safiyary, 2004).

Fisheries imports are mainly tuna and fishmeal. According to the Iranian customs authority, fishery import in 2003 was estimated as 69 000 tonnes with a value of US$60 million.

APPLIED RESEARCH, EDUCATION AND TRAINING

Applied research

Several institutes and organizations have responsibility for applied research. The Iranian Fisheries Research and Training Organization (www.ifro.org) affiliated to Shilat is the major source of applied research and training on fisheries and aquaculture. It has ten research centres and two training centres in the country as follows:

- four centres located by the Persian Gulf and Oman Sea (Khuzestan, Bushehr, Hormozgan and Sistan-Baluchestan provinces);
- five fisheries research centres located by the Caspian Sea (Giulan, Mazandaran and Golestan provinces);
- the International Institute of Cold Water in Mazandaran and the International Institute of Sturgeon in Giulan; and
- the Artemia Research Center, located by Urmia Lake (works on *Artemia* and live feed).

The Supreme Committee of Research is the highest reference group and is responsible for approving fisheries research projects. University professors, representatives of executive departments of Shilat, and some experienced researchers and other experts are members of the committee.

Results of the research are submitted to Shilat as a basis for pilot projects and modification. They are then transmitted to farmers through short training courses and manuals. Shilat's training and demonstration centres play a significant role in this process. It should be mentioned that since 2005, all research departments affiliated to the Ministry are organized into one department, the Deputy of Research, Training and Extension.

Universities have a huge capacity for research activities. However, there is no effective link between industry and university. According to law, 1 percent of the total income derived from industrial activity should be invested in research and development (R&D). Agriculture is not included in this category. When there is support from IFRO and/or Shilat, interesting and valuable applied research has been made by university students and lecturers.

The Scientific and Industrial Research Organization is another agency involved in fisheries research. Researchers can submit proposals to the organization, and an accepted proposal can benefit from financial support. The organization's priority is basic and long-term research such as improving broodstock selection and breeding programmes for existing aquaculture species. The organization is expanding cooperation with other international organizations to exchange a wide range of experiences, especially on implementation of breeding programmes for fish and shrimp.

Training programmes are needed for mariculture to develop the skilled people needed for pilot projects and commercial farms. As aquaculture technology is developing rapidly, there must be a continuous process of learning new techniques. For Iran IR to be able to develop further and establish its own self-sustaining aquaculture businesses, resources should be put into a mariculture R&D centree.

Education and training

Since the 1970s, the Ministry of Science, Research and Technology has put a fisheries science course in the programme of Iranian universities. At present, some eight state and 12 open universities offer BSc courses and four state and two open universities offer MSc and PhD courses in various fields of fisheries and aquaculture science. Tehran and Chamran (Khuzestan) and Gorgan (Golestan Province) universities are the oldest of Iran's universities.

In addition the University of Applied Sciences offers fisheries training courses in two faculties located by the Caspian Sea (Rasht) and the Persian Gulf (Bushehr). The university gives priority to practical topics, aiming to meet the human resource needs of industrial aquaculture/fisheries units.

Training and Extension Services centres affiliated to Shilat are other sources for training of skilled manpower. These centres implement several short-term training courses in various fields and at various levels for both illiterate and literate farmers, as well as the educated.

TRENDS, ISSUES AND DEVELOPMENT

The third National Five Years Development Plan targeted a production of 230 000 tonnes for the aquaculture subsector, but the output in 2002 was only 76 816 tonnes (Figure 2). Besides the optimistic planning, factors affecting the low performance relative to target include:

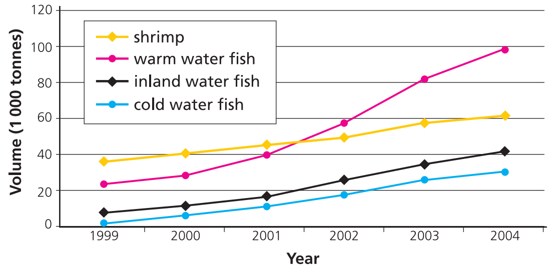
- The occurrence of dry years and low precipitation in the country. For example, compared to 1998, the total area of inland water bodies had decreased by 25 percent in 2001.
- Technology and productivity are inadequate. Compared to some other countries, the productivity derived from inputs is lower than average. For instance, the average production of carp is minimal. The main reasons for low productivity are lack of current knowledge and equipment. The efficiency of short-term training courses is reasonable, but they cannot meet the requirements of industry.

- Improvement is needed in the quantity and quality of applied research and postgraduate courses are required in all aspects of aquaculture, including farming systems, management, feed production, etc.

More investment is needed in the sector, and international and regional collaboration can assist in building skills and sharing experiences to improve the sustainability of the industry.

Establishment of fish-farm complexes is one of the Iranian government's major plans for increasing fish production. Azadegan (12 040 ha in Khuzestan Province) and Ghasreshirin (3 000 ha in Kermanshah Province) are examples where projects are ready for operation.

Figure 2
Projection for aquaculture in the 3rd National Five Years Development Plan



There are more than 40 000 rivers, springs and wells in the Islamic Republic of Iran. Some 379 of them have a capacity of more than 500 litres/sec and are located in mountainous and cold areas that offer good potential for trout farming. Studies have also indicated a huge potential for shrimp culture in the southern and northern parts of the country. Since 1992 some 45 000 ha of land in four provinces neighbouring the Persian Gulf and Oman Sea and Golestan (in the north) have been allocated to investors. Out of this, some 20 000 ha is under construction and 6 000 ha is ready for operation.

Shilat, in line with local governments countrywide, developed its 4th Five-Year Plan for Fisheries for 2005–2010 (Table 6). This plan gives attention to:

- food security through increased domestic fish production;
- quality improvement and waste reduction in fisheries;
- fish export promotion;
- market improvement;
- fish conservation and enhancement;
- deep-sea fisheries development;
- improved aquaculture productivity;
- sea-cage culture development;
- expansion of applied research; and
- increased fish consumption.

TABLE 6
Aquaculture production projections (tonnes) in the 4th Five-Year Plan for Fisheries, 2005–2009 (Source: Shilat, 2004)

	2003	2005	2006	2007	2008	2009
Shrimp farming	7 492	14 110	23 800	32 300	40 500	47 200
Coldwater fish farming	23 138	35 000	40 000	46 000	51 000	59 000
Warmwater fish farming	79 545	106 527	129 158	153 806	173 314	208 206
Sea-cage culture	0	180	800	1 500	2 900	4 400
Total	110 175	155 817	193 558	233 606	267 714	318 806

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