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Application of Science to Aquaculture*

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Introduction

The world production of conventional fish varieties is nearing an almost saturation level and may even exceed the maximum sustainable yield by 2015 A.D. The world marine fish landings is expected to be levelling off somewhere around 90 million tonnes (Mn.t.) per year. The marine fish landings in Europe has started declining from 13 Mn.t. in 1976 to 11.5 Mn.t. in 1985. The increasing fishing pressure, in fishery after fishery, forces to introduce conservation measures such as fixing quota, season, gear restrictions, allocations among competing user groups and even fishery closures as a result of stock failures. India and South-east Asia are no exception to this world-wide trend, on account, among others, of the unprecedented increase in the establishment charges, more especially on capital investment costs, acting as serious constraints on the fishing industry to produce fish at reasonable rates. In certain areas consistent overfishing in traditional fishing grounds has resulted in a noticeable depletion of valuable stocks, very similar to the well known failure of the North-Sea herring fishery during the 1970s.

Advantages of Aquaculture

At the same time, there has been a continuous increase, world wide, in the demand for both fin-fish and shell-fish. This has placed an ever increasing pressure on producer countries to increase their supply. This rapidly escalating fishing pressure especially for high value items such as shrimps would naturally lead to severe over exploitation beyond the maximum sustainable yield leading to virtual stock failures in the sea. Therefore, the only solution for this problem is aquaculture which can give a surprising boost to fish production. Aquaculture also offers considerable advantage over capture fisheries, more especially the trawler fleets. This is because the operator is given exclusive rights to his farm as opposed to an open access fishery enjoyed by all coastal fishermen. The operator can effectively supervise production, harvesting, handling and processing as opposed to managing a fleet, scattered over a wide area.

Furthermore, the natural stock may have to be re-seeded by hatchery reared juveniles through ranching which is becoming a reality in many countries. While the production from capture fisheries is stagnating, the culture fisheries production is expected to increase at a faster rate and occupy a share of 20-25% of world fishery harvest by 2000 A.D. Thus, the fishery scientists are of the opinion that the future major growth in fish production can happen only through aquaculture.

World Supply and Demand for Fish

By 2000 A.D., the projected demand for fish is about 130 million tonnes as against the production of about 90 million tonnes. Aquaculture production is expected to contribute 15 to 20 million tonnes. Therefore, the demand will be

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growing more rapidly than the supply in many cases. The widening gap between supply and market demand will, therefore, have to be met through alternative, usually less desirable products from capture fisheries or traditional seafood items produced through aquaculture. A close scrutiny of the trend in consumption in the U.S.A. reveals that there is a general consumer shift from red meat towards seafood and poultry. This has called for new species and supplies. Health benefits of seafoods are expected to stimulate consumer demand in the U.S. and other developed countries. The per-capita consumption of seafoods is steadily increasing and a one-kilo increase per-capita in the U.S. would need one million tonnes of additional seafood and this market alone will be absorbing a large quantity of seafood in the coming years. Therefore, as Saktivel (1987) of the MPEDA has suggested, we should work out a production and marketing strategy to take full advantage of the expanding marketing opportunities for Indian seafood in countries such as the U.S.A.

The Indian Scenario

The aquaculture technology has advanced to such an extent that fish can be produced where there is light and water. The tropics abound in both these resources in an abundant measure, and here, fresh, brackish and sea water can be effectively utilised for the production of fish through aquaculture. The world aquaculture production has touched 15 million tonnes and is expected to reach 22 million tonnes by the turn of the century. It is interesting to note that Asian countries dominate the scene and account for 60% of the total production in which India and China take a sizeable share in fresh water fish production (nearly 3.2 million tonnes). By virtue of its geographical situation in the monsoonal belt, India is blessed with good rainfall which accounts for extensive fresh and brackish water bodies ideal for aquacultural operations. Lakes in the high altitudes provide suitable conditions for the culture of cold water species such as trouts. Nearly 4 million hectares of water spread area exists as lakes, reservoirs, tanks, ponds and so on. Besides these, there are the shallow, sheltered areas and lagoons along the long coast-line suitable for mariculture. Aquaculture is thus possible in a massive way for shell fishes such as shrimps, prawns, crabs, oysters, clams, mussels etc. a variety of fin fishes and also for several species of very valuable seaweeds. Thus, aquaculture undoubtedly is a boon especially for developing countries such as India with all the vigor and growth potential. It would certainly turn out to be a very lucrative enterprise, at the same time, a cheap source of protein to combat malnutrition. The nutritive qualities of aquaculture products are better than farm animals, with high conversion efficiency. This avocation is important for the development of rural areas and would put to optimum use of fallow and derelict areas lying vacant at present for employment and income generation of the rural folk. Aquaculture could also be effectively used for the re-seeding of over-exploited stock of the sea and other natural bodies of water.

Potentialities for Aquaculture in India and the Concerned Species

Fish culture has been an age old practice in our country, but its importance as a source of food production and to develop it as an industry on scientific lines has been comparatively recent. The establishment of the Central Inland Fisheries station in 1947 to conduct scientific investigations for an appraisal of the inland fisheries resources of the country and for evolving suitable methods directed towards the conservation, development and management has been the first forward step in this direction. In 1961, the status of this station was raised to that of an institute and detailed investigations were initiated on various aspects of management of culture fisheries and emphasis was laid on production and problem-oriented research programmes and

considerable headway has since been achieved in inland fisheries research.

There are extensive swamps in many States of India which are at present lying derelict. Reclamation of such swamps into fish ponds is recognised as an effective means of making them productive. Similarly, a very large number of lakes, tanks and ponds occur all over the country. Three million hectares are available in the form of reservoirs and this area is likely to double by the turn of the century. All these bodies of water could be used for the production of a variety of fin-fish as well as shell-fish using suitable techniques. In order to obtain maximum production through the effective utilisation of every niche available in a body of water, fast-growing compatible species of fish of different feeding habits or different weight classes of the same species could be stocked together in the same pond. Termed as mixed fish farming, composite fish culture or polyculture, such a system using compatible fishes of different feeding habits when stocked together, secure for themselves in the most efficient manner, all life requisites available in the water without harming each other. First developed in China, this system is now widely practiced with great success with different combinations of fishes in many countries.

Air breathing, carnivorous fishes such as murrels, koi, singhi and magur are also economically important and these could be reared in marshy swamps, not quite suitable for other types, since they can survive even in water of low oxygen content.

In paddy fields which retain water for 3 to 8 months in a year paddy-cum-fish culture can provide an additional supply of fish crop. Culture of fish in fields which remain flooded after the paddy is harvested could also serve as an off-season occupation for farmers. In this context the major problem is the introduction of high yielding varieties of paddy which need massive dose of pesticides which are detrimental for fish.

Similarly the fresh-water prawns of the genus *Macrobrachium* has, of late, become a very important group for aquaculture on account of the easy availability in nature of berried females almost throughout the year, high hatching rates, possibilities for mass rearing under controlled conditions and fast growth in confined fresh waters. *M. rosenbergii* and *M. rude* are the most important in this connection. Mixed culture of these prawns with suitable combination of the Indian major carps, minor carps, exotic carps, milk fish, mullets or gourami could be tried with considerable advantage. West Bengal and Kerala have the best potentialities for the culture of *Macrobrachium*. Growing to harvestable size in about 6 months, it has good demand in Europe and U.S.A. It is possible to produce at least 5000 tonnes worth 40 million dollars annually.

The Indian eel (*Anguilla bicolor*) could be cultured in a commercial scale with good prospects for export to Japan and West Europe. We have rich eel-fry resources more especially along the East Coast. The fry occur in fair numbers in all our major river systems and these are excellent for farming. The fry (elvers) fetch US $. 1800/kg. (6000 elvers per kilo) and it takes about an year to reach harvestable size of 200-300 g. Trout culture has recently been initiated in Jammu and Kashmir. A hatchery for the rainbow trout has been set for seed production. The world market for trout is to the tune of $ 70 million (30,000 tonnes).

Our frog population can sustain a regular export. Yet, to maintain the natural population it is desirable to set up frog hatcheries for ranching of tadpoles and also for culture of these amphibians. Brazil has developed the technology for the commercial production of frogs.

The volume of world-trade in ornamental fish and plants is of the order of $ 600 million and India's share is negligible. We have rich resources of both freshwater and marine aquarium fishes. Urgent steps are needed to culture these

ornamental fishes for export which would fetch substantial foreign exchange annually.

The extensive brackish water tracts available along the coasts in the form of estuaries, backwaters, lagoons and salt water lakes could also be effectively used for the culture of a variety of organisms. Fishes such as *Elops* sp., *Megalops* sp., *Chanos* sp., *Mugil* sp., *Polynemus* sp., *Lates* sp., *Etroplus* sp., *Tilapia, Sparus* etc., could be tried. Similarly prawns form an important component of brackish water culture. Only the euryhaline forms which can withstand the fluctuating salinity of brackish water bodies are suitable for culture. In India, the important culturable species are *Penaeus indicus, P. monodon, P. semisulcatus, Metapenaeus dobsonii, M. monoceros, M. affinis, M. brevicornis, Palaemon styliferus, Macrobrachium rosenbergii* and *M. malcolmsonii*. The mud crab *Scylla serrata* occurs in abundance in the backwaters and estuaries. Culture of this species has not been economically viable owing to high feeding costs and low survival rates. The world market for crab is about 200 million US $.

Items that are suitable for mariculture include among others lobsters, edible as well as pearl oysters, mussels, clams, sea urchins, sea cucumbers, and sea weeds. Of these, the Indian lobster (*P. homarus*) found along the rocky coasts of Tamil Nadu is a delicacy. Juveniles collected from the sea could be cultured to good marketable size in about 200 days. Its market prospects are good. The world market is worth 600 million US $. Edible oysters (*Crassostrea madrasensis*) occur all along the coasts. Culture is possible and could develop into a commercial possibility with good demand in Europe. International market is of the order of 47 million US $. India also has the pearl oyster (*Pinctada fucata*). M/s. SPIC, Tuticorin, have undertaken a commercial-scale project. The techno-economic viability is yet to be established. Mussels are well known for their very high productivity. The CMFRI has successfully developed raft culture for mussels (*Perna viridis*). Clams (*Anadara granosa*) occur in the sub-tidal mudflats of the Kakinada Bay. CMFRI has developed the culture technology with a production of 36 tonnes ha^{-1} . The backwater clam *Villorita* and *Meretrix* sp. also occur in large quantities in the coastal zones of Kerala and Karnataka. There is also good possibilities for the culture of sea weeds. The reported annual world production of sea weeds for food and as a source of raw material for the chemical industry has been around 3 million tonnes of which 75% are brown sea weeds. The prospects are good for the production of many species of economic importance through culture.

There is increased recognition of the value of polyculture, integration of agriculture and animal husbandry with fish farming and recycling domestic wastes through fish culture. Controlled breeding and production of seed of cultivable species, feed formulation according to the fishes nutritional requirements, maintenance of proper water quality and control of diseases and pests are also being employed to achieve better production from cultivable waters.

The development of intensive fish culture where a very high rate of production is made possible by rapid waterflow or increased aeration together with high stocking rates and use of rich protein food pellets is likewise significant.

The new type of fish farms have all the characteristics of an industry where the possibilities of development and increase in production seem almost unlimited. It is high time that we adopt these techniques utilising our vast resources and join the aquacultural race which has already started with great enthusiasm and excitement in several countries of the world. The global trade at US$ 30 billion should provide an idea of the tremendous scope for exports.

Table 1 furnishes a list of cultivable species of fin-fish, shell-fish and sea weeds which are of importance from the point of view of export. In

Table 1 *Major cultivable species resources of India for export**

Tubinaria sp. *Sargassum* sp. *Gracilaria edulis* *Gelidiella acerosa*	Sea weeds
Chanos chanos (milk fish) *Mugil* sp. (mullets) *Epinephelus* sp. (groupers) *Lates calcarifer* (sea bass) *Etroplus suratensis* (pearl spot) *Anguilla bicolor* (eel)	Fin fishes
Penaeus indicus (white prawn) *Penaeus monodon* (tiger prawn) *Penaeus merguiensis* (banana prawn) *Penaeus semisulcatus* (flower prawn)	Marine prawns
Macrobrachium rosenbergii	Freshwater prawn
Panulirus sp.	Rock lobster
Scylla serrata	Mud crab
Perna viridis (green mussel) *Perna indica* (brown mussel)	Mussels
Crassostrea madrasensis	oyster
Meretrix sp. *Katelysia* sp. *Villorita* sp. *Paphia* sp.	Clams
Anadara granosa	cockle

*(from Saktivel 1987)

Table 2 *Details of shrimp farming in India*

State	Estimated brackish water area (ha)	Area under Culture(ha)	Estimated Production (tonnes)
West Bengal	4,05,000	34,050	16,300
Orissa	31,600	7,760	4,300
Andhra Pradesh	1,50,000	9,500	12,800
Tamil Nadu	56,000	530	1,100
Pondicherry	800	Negligible	Negligible
Kerala	65,000	13,400	9,750
Karnataka	8,000	2,750	1,150
Goa	18,500	550	350
Maharashtra	80,000	1,980	1,050
Gujarat	3,76,000	360	200*
Total	11,90,900	70,700	47,000*

*Apart from this, 3900 t of freshwater prawns are produced from the farm in Gujarat taking the total production from culture source to about 51,000 t.
+(from Saktivel 1994)

table 2 is given the break up of the area identified to be potentially suitable for prawn farming.

Using capital intensive technologies, fish production has reached high levels. Thus, 600 tonnes per ha. a year of *Tilapia* in cages has been reported from Philippines. At Manhein, Germany carp production systems yield more than 150 tonnes ha^{-1} a year, in two crops. In Thailand the catfish (*Clarias*) production is 208 tonnes ha^{-1} in a year in three crops. Taiwan .farmers achieved more than 20 tonnes ha^{-1} $crop^{-1}$ of tiger prawn. Uruguay and Hawaii are both attaining the same level in fish production. Cage culture of Salmon in Norway produces 150 tonnes in two-year cycles. The average productivity of fresh-water fish from ponds in Israel and China has been around 15 tonnes ha^{-1} $year^{-1}$ (Dehadrai 1992).

There has been impressive growth in fish production in our country during 1991-92. A total production of 41 lakh tonnes was achieved. Out of this 21.4 lakh tonnes were from marine sources and 19.1 lakh tonnes from inland sources. The inland fisheries sector registered an impressive growth rate of 11%. Aquaculture made a major contribution of about 65% to the total production.

India's Shrimp Industry, Possibilities

Of all the aquacultural products, the prawns and shrimps are considered to be the most important by virtue of their high unit value (nearly US $. 26 $kg.^{-1}$) persistent demand and universal appeal among the wealthier nations of the world. Being the fastest moving commodity, it is fondly referred to as the 'darling' of the sea-food industry.

The demand for prawns in the world market is expected to be doubled in the next 10 years. In this context, India has a major role to play and it would be possible to cash in on the lucrative world market to the maximum advantage and improve the economy of the fisher folk in rural areas. India has nearly 1.5 million ha. of brackish water area all along the coast of which nearly 1 million hectares are suitable for aquaculture. Of these, only 44,000 ha. are at present utilised mainly in West Bengal (25,000 ha.), Kerala (6,000 ha.), Karnataka (8,000 ha.) and Goa (5,000 ha.) following traditional practices. The rest of the area in the form of mud-flats, mangroves, lagoons, tidal creeks etc. is at present lying unutilised and serves as dumping places for domestic, industrial and municipal wastes. Even in the areas of culture our production ha^{-1} is distressingly low and it is imperative that we resort to modern techniques and join the world shrimp aquaculture race, introducing vigour and vitality to the profession.

Present Status of Shrimp Farming in India

The Sundarban region of West Bengal (4,05,000 ha.) is one of the most ideal areas for the farming of the tiger prawn (*P. monodon*) on account of the favourable tidal amplitude, salinity ranges, soil conditions and the availability of natural seed. Nearly 34,050 ha. are already under aquaculture and the scope for development in Sundarbans itself is enormous (table 2).

In *Orissa*, the Chilka lake is famous for its prawn and fish fry resources and extensive areas are available in the coastal districts for aquaculture. The prawn-seed resources of the Chilka lake which used to be wasted are being effectively utilised by setting up large farms in the periphery of the lake in the joint sector. There are also plans for setting up hatcheries with foreign collaboration and assistance from MPEDA.

Andhra Pradesh has extensive brackish water bodies with a total water spread area of 150,000 ha. in the 9 coastal districts. The farmers with the aid of subsidies and advise from MPEDA are evincing a keen interest in scientific prawn farming. They are also setting up prawn hatcheries to boost the production of the much needed seed.

In Tamil Nadu efforts are being made to develop suitable areas and allot them to fisher-

men co-operative societies to increase production. The Bay of Bengal Programme of the F.A.O. has proved the economics of pen culture in Killai backwaters. Pulicat lake is also quite suitable for aquaculture.

In Kerala, out of nearly 65,000 ha. of brackish water, an area of nearly 13,400 ha. is under traditional prawn cultivation. Ernakulam District has about 4,600 ha. Paddy-cum prawn culture appears to be the best way of utilising this area for maximum benefit. It should also be possible to introduce suitable technology inputs to improve this age-long method for increasing the production. It is essential that suitable areas be chosen for semi-intensive or intensive culture in the co-operative sector and under self-employment and other such suitable schemes. Hatcheries have to be planned and seed banks and nurseries be developed in all coastal districts. The prawn seed and post-larvae now under-utilised or destroyed, be effectively cultured through proper training of the fishermen and thus provide value addition to this natural resource. For all these, it is imperative that the State Government evolve the needed policy for land allotment.

Nearly 3,76,000 ha. of tidal mud flats with high tidal amplitudes are available in Gujarat. The conditions are quite suitable for brackish water fish-shrimp farming. Urgent measures have to be taken for providing extension services to farmers in shrimp-farming and the State Government should frame the needed land-allotment policy to encourage entrepreneurs including private companies.

Maharashtra State has 80,000 ha. of brackish water area most of which is unutilised for want of technical guidance to undertake the survey of suitable area for farming. For want of local extension service, the enthusiastic entrepreneurs are unable to proceed. No progress has been made in land allotment. The Government has recently set up a prawn hatchery near Bombay and a model farm in Ratnagiri.

Five hundred and fifty ha. of brackish water area is under traditional filtration in Goa. Scientific farming practices are non-existent and virtually unknown to farmers.

In Karnataka nearly 8,000 ha. of brackish water area is available, half of which is under traditional farming. To introduce scientific prawn farming in the traditional farming area adequate infrastructural facilities have to be created for the supply of water. The State Government has yet to take policy decisions to promote prawn farming, starting with land allotment.

The Prevailing Practice

Brackish water shrimp farming as practised in our country today is an age-old practice called 'filtration' or 'trapping' in the inter tidal zone of the coastal belt of India especially in West Bengal ("Bheries") and Kerala ("Pokkali fields"). About 43,000 ha. are reported to be under this traditional farming practice, producing 15,000 - 17,000 tonne of shrimps and about 30,000 tonne of fishes, crabs etc. The farmers use these areas for paddy cultivation during the low-saline monsoon months (June-October) and prawn filtration during the high-saline months (October-May). This trapping in Kerala and West Bengal is undertaken by contract farmers who take the area on lease for about Rs. 6,000/- ha^{-1} for 6 months of the year. The tidal water with natural seed and other fish enter the area during flood tide when they are trapped and are harvested periodically. Shrimps and fish are invariably harvested while still in the juvenile stages since the farmer has to give back the land to the owner in six months time. It should be possible to convert a part of these highly productive areas into intensive, or at least semi-intensive aquaculture farms which could raise the production to at least double the present quantity. This would enable the farmer to increase his earning at least 4-5 times more than what he is earning at present.

How Can We Achieve Bigger Rates of Production?

The estuaries, lagoons and creeks all along our extensive coast-line are rich in natural seed resources. For example the Chilka lake, the Pulicat lake and the Vembanad lake serve as large reservoirs of seed of a variety of species of fishes and prawns. But these vast resources are being destroyed by the fishermen who live in the neighbourhood. Thus, several hundred tonnes of mullet and prawn fry are caught every year, by the fishermen of the Chilka lake; at least, 600 tonnes of juvenile shrimps are filtered out by stake nets and sluice gate operators in the Cochin backwaters and sold either fresh or sun-dried at less than Rs.10 kg^{-1}. The trend is increasing year after year, thereby destroying more and more natural seed resources which would naturally affect the natural recruitment of stocks in the sea and at the same time they are not being rationally used.

In countries such as Japan, Taiwan and others, seed production is done on a massive way in hatcheries and then they are released into the sea to maintain the natural stocks. Quite contrary to this, in our country, it is indeed sad to note that even the ruthless, mass harvesting at the juvenile stage itself goes on unabated. Is it not possible to check this massive destruction of a precious resource being underutilised on account of sheer ignorance? Can't we find alternate employment for these fishermen or divert them to use these catches for further culture, and thus to better utilisation and good profit? It is gratifying to note that some efforts are being initiated in Orissa to develop shrimp farms around the Chilka lake to take advantage of the shrimp fry resources of the lake.

Over exploitation of natural seed resources, itself could lead to difficulties, when large farms are developed based purely on such seed. The alternative is, no doubt the development of suitable shrimp hatcheries for seed production in a massive scale.

In traditional areas of paddy and shrimp cultivation, additional inputs have become imperative. The age old practices have no doubt, their serious drawbacks and at present the contractors take away the major part of the profits. It would, therefore, be desirable to assign land/water areas to the farmer/fishermen and then they should be given training on shrimp-farming under the guidance of the Brackish Water Fisheries Development Agency of the State Government. In this manner the farmer/fisherman get a definitely better earning and the production itself could be considerably enhanced. It is essential, that a financial subsidy of 25-100% be given for the development of land depending on the nature of the scheme. Long-term loans at reduced interest could also be considered. The fishermen be given free training on farm management. Monitoring be done periodically by the Government agency. Such a programme is likely to benefit a very large section of the farmer/fishermen in coastal areas.

There is no doubt of the fact that the only way to increase the shrimp production is through a well planned programme of mass production of seed through carefully planned hatcheries and scientific shrimp farming. In India nearly 300 sea food processing plants are operating at about 25% capacity, this itself mainly during the fishing season chiefly for processing shrimps. India's present annual earning through the export of marine products (90% shrimps) is of the value of about Rs. 3,000 crore. Thus, India is a leader in this area with well established markets all over the world.

World Production of Shrimps

Total world production of shrimps has been showing a steady increase since the 1960s. In 1972, it was recorded at 1.2 million t. live weight which increased by 71% by 1982 totalling 1.69 million t. During the last few years, world pro-

duction stayed at an average between 1.6 and 1.7 million t. The top 20 producing countries accounted for 83% of the world total production with India leading at 0.215 mt. It is noteworthy that 70% of the shrimp-producing countries are developing countries.

In 1983, the four leading producers in the Asia- Pacific region were India, China, Thailand and Indonesia. The other major Asian producers were Malaysia, Japan, Philippines, Vietnam, Korea and Pakistan. Total production from this region was 1,000,500 tonnes, representing 56.9% of the world total.

Latin American countries included in the list of the top 20 major producers are Mexico, Brazil, Ecuador, Argentina and Panama.

World Production of Cultured Shrimps

Reliable figures separately for aquaculture production are not available. More shrimps are steadily entering the world trade channels as a function of the increase in world production. Shrimp trade today is one of the most important foreign exchange earners and thus one of the most profitable enterprises.

The world production of cultured shrimps in 1987 was estimated at 3,40,000 tonnes of which 2,00,000 tonnes were from Asia. The projection is that it would attain one million tonnes per year by the turn of the century. Cultured shrimp production now forms nearly 20% of the total world production. Semi-intensive farming of penaeid shrimps is making rapid strides. The bulk of the production is expected from Taiwan (100,000 t.) Ecuador (75,000 t.), Indonesia (70,000 t.), India (50,000 t.) Philippines (40,000 t.) and Thailand (25,000 t.).

Shrimp Culture in Asia

The Asia-Pacific region is at present the leading shrimp supplier in the world. This region, infact, offers the most favourable conditions for the development of shrimp culture such as (1) the occurrence of highly productive, vast brackish water and mangrove areas for farming, (2) ideal climatic conditions, (3) low labour costs, and (4) the aquacultural traditions prevailing in the region. Undoubtedly these factors are the major exponents to the very steady increase in interest as well as in the phenomenal expansion of shrimp farming and there is no doubt of the fact that this region holds the real promise of becoming the principal source of cultured shrimp in future. At the same time countries rushing their aquaculture production should keep a constant eye on their long-term markets and on their competitors. The future of aquaculture will be a reflection of the extent to which the capture fishery production on shrimp declines.

Indonesia: The success in shrimp culture as already indicated, is mainly a reflection of the rate at which seed can be produced. In Indonesia more than 40 hatcheries are functioning producing nearly 130 million post larvae yr^{-1}. They obtain financial assistance through ADB loans and from NORAD and other sources. They culture species such as *P. monodon, P. merguiensis, P. indicus* and *Metapenaeus* sp. in their traditional "Tambaks" in an area of 1,74,000 ha.

Taiwan: The way in which Taiwan, a tiny country of 36,000 sq. km. has done wonders in the area of shrimp culture is worthy of emulation. Out of a population of 18 million people, 300,000 are engaged in fisheries. There are 1200 hatcheries for seed production as small family business. 20 companies are engaged in feed production. Average productivity of shrimps (*P. monodon*) is 5 mt ha^{-1} yr^{-1} with maximum productivity of 22.4 mt ha^{-1} yr^{-1}. Taiwanese hope to raise their productivity to 40 mt ha^{-1} yr^{-1} in the near future through intensive farming.

What are the techniques they adopt for this spectacular success? They employ:

1. Ultraviolet irradiated sea water for induction of spawning

2. Micro-encapsulated diet for feeding

3. Electrofishing for harvesting and

4. Special techniques for maintenance of water quality.

The spectacular success of the Taiwanese system is attributed to the ideal water supplies, suitable land, hard- working agriculturally minded people who consider this as a family business, a national entrepreneurial spirit, successful research and extension services and substantial encouragement from the Government.

The Taiwanese have shown to the rest of the world that they are capable of excelling in this sphere of activity and may even overtake Japanese in the cost effective aquaculture technology. They are producing shrimps through semi-intensive farming at a much lower rate (dollar 4.6 - 5.2kg^{-1}.) ie. nearly one-fourth of Japanese production costs and sell with 100% profit.

Japan: The Japanese story is somewhat different. Developed in the fifties, the Japanese technology is very sophisticated based on intensive culture. The industry confronted serious constraints owing to shortage of suitable land, climate, disease problems (white turbid mid-gut disease of post larvae) and high cost of production. The M/s Mitsui Corporation achieved a production of 30 tonnes/ha. with 300% water exchange daily, depending on 100% artificial seed production, ultra violet irradiated sea water for induction of spawning at the highest rate (70% as against 20% in natural sea water), artificial feeding at the cost of 2.7 - 3.0 dollars kg^{-1} with a conversion ratio of 1.5: 1.0, micro encapsulated diet to feed all stages of prawns. This sophistication has naturally reflected in the production cost, which amounts upto 25 U.S. $ kg^{-1}.

Thailand: In Thailand, there are 37,000 ha. of shrimp farms managed by 5000 farmers producing 25,000 tonnes. Average productivity has gone up from 170 kg. to more than 400 kg ha^{-1} yr^{-1}. Five hatcheries in the Government sector are producing 32 million post larvae of *P. merguiensis*, 8 mn. post larvae of *P. monodon* and over 1 mn. post larvae of *P. semisulcatus*. The production of the giant fresh water prawn *(Macrobrachium)* is fairly advanced with a production of 3000 mt.yr^{-1}.

The Need to Boost Production

From what has been stated above, it is evident that brackish water shrimp farming has emerged as an industry of significant dimension in Asia. The size of the world market for shrimps at present is valued at 30 billion dollars. The world demand for shrimps in the developed countries is expected to go up by 200,000 tonnes. Asian aquaculture industry is expected to meet this extra demand to a considerable extent. Indonesia is likely to be the leader of Asia on account of the vast area available for farming.

In this context it is imperative that India also should contribute a substantial share in shrimp production by evolving and adopting the needed strategies to boost production with determination. Producing Master and Doctorate degree holders alone will not increase production. Our strategy should be to make a concerted effort towards adopting sophisticated technologies and production techniques as employed in countries such as Taiwan, Ecuador and Indonesia and see that the cultural practices could be employed in suitable identified areas along our long coastal belt thereby generating employment for a very large segment of the poor coastal people and at the same time increasing the production of a very valuable commodity fetching substantial foreign exchange.

With ample brackish water areas and mangrove swamps, we have tremendous potentialities. But what are the restraints? Is it the lack of expertise? Is it the shortage of the needed capital investment?

On account of the large failure rates it would be suicidal to rope in large numbers of entrepreneurs in the initial stages of this practice.

With all our problems, the forecasts for a spectacular increase in production from aquaculture should be treated with caution. Do not forget the fact that the development of shrimp aquaculture in several countries have been slow. Brazil, Venezuela, Columbia etc. have spent large sums of money for developing this resource, but the missing links have been a lack of shrimp seed and technical expertise and their endeavours have ended in total disaster.

Problem of Seed

We should first of all bear in mind that the only solution to the problem of seed availability is the hatchery production of post larvae. Until this basic requirement is met our production is not likely to show any significant improvement.

At present, most of our hatcheries are depending on wild-caught females which are already fertilised or which are subsequently matured and fertilised in the laboratories for spawning. This reliance means that production is limited by the availability and seasonal maturation cycles of the wild-stocks. Often gravid females have to be caught a considerable distance from the hatcheries.

One of the main factors limiting output will be the availability of seed and the ability of offshore populations to sustain the heavy fishing effort of the trawl and post-larval fisheries.

The extensive methods of our present system must be replaced by the development of semi-intensive systems. This combined with the steadily increasing numbers of culture-ponds could result in a sharp increase in the demand for post larvae.

Nutritional Aspects in Aquaculture

Since 50-70 % of the operational cost in aquaculture is expended on feeds, this aspect needs further explanation. It is essential, that the aquaculturist carefully and meticulously manipulate the feed composition to maximise his output without any compromise in quality at an optimal cost.

Towards the realisation of this objective, it is imperative that we have a clear and detailed understanding of the nutritional need of the prawn. Unlike cattle and poultry, there are a large number of prawn species. Their cultural conditions are not very different, yet it is not clear whether their nutritional requirements are the same. This has to be worked out with a view to getting the best results. The species involved are: *Penaeus indicus, P. monodon, P. japonicus, P. merguiensis, P. orientalis, P. aztecus* etc.

A balanced diet containing proper amounts of proteins, lipids, carbohydrates, fibre, minerals and vitamins is essential. The percentage requirements of these components vary from species to species and are also age specific within the same species.

Larval feeds, grow-out feeds and maturation feeds differ in their composition. The essential amino acid requirements and poly unsaturated fatty acid requirements are very specific for achieving high rates of production. Protein-energy ratio for optimal growth will have to be considered. Growth promoting substances also play a very important role. Acceptability, palatability and digestibility are key factors in feed formulations and preparations. Form, size and stability of pelletised feed are the physical factors important in feed preparation. All factors together, water quality aside, contribute to feed conversion ratio (F.C.R.) idealised at 1:1 to 1:1.5 for high energy feeds. Raw material selection, based on a thorough knowledge of their composition, availability and cost with reference to the targeted F.C.R. is, therefore, of primary importance.

Certain feed formulations of penaeid prawns have been developed in India.

A production rate of 1194 kg ha^{-1}. in 3 months for *P. monodon* has been achieved with formulated feed. These are practical diets which have to be further refined and improved with a basic understanding of species-specific and age-specific nutritional requirements. As stated earlier, extensive, semi-intensive and intensive systems will co- exist and hence, feed technology, in terms of cost and F.C.R., will have to be appropriate to each system. Apart from shrimps, fish feed also should receive attention.

Results of some analytical studies indicate that some of the species exhibit differences in terms of proteins, amino acid, fat and mineral composition. Naturally, therefore, their nutritional requirements also are likely to be different. Nutritional benefit of any material in a terrestrial animal is assessed though balance and metabolic studies in addition to the consideration of over all growth and well being of the animal. Such metabolic and balance studies are not performed in prawns on account of the non-availability of suitable methodologies.

There is further complication, since both nutrient and excreta occur in the same medium. What is done is to formulate the feeds which would match the body (tail meat) composition in terms of amino acids and fatty acids of the respective species and this approach is practised currently by prawn nutritionists.

On the basis of broad nutritional principles, an organism requires protein for the building up of the body, fats for body build up, for energy and hormone production and carbohydrates for energy. Vitamins and minerals are important in small quantities for the maintenance of normal physiological functions. For the exoskeleton which is shed periodically, prawns need a continuous supply of calcium, phosphorus, and other minerals apart from chitin. Therefore, they must be provided with appropriate hormonal modulation for absorption and metabolism.

How much of these different components are actually required by the different species of prawns have not been worked out exactly. As a result of this, one could see a wide range of feed formulation even for the same species.

Studies indicate that the different species of penaeid prawns require different protein levels in the diet. On the basis of available information it may be concluded that a protein level ranging from 30 to 40 % may be adequate for different species. It should be possible to bring down the protein level with a better understanding on the amino acid balance required for each species. In fact the actual amino acids requirements for different species have not so far been worked out and such an investigation is warranted. It is known that different species of prawns have different amino acid composition. Therefore, till such time that the amino acid requirement is worked out, it would be advantageous to follow the concept of feeding amino acid as per the body composition of each species.

In the crustacea, carbohydrates are important in the Krebs cycle, glycogen storage, in chitin synthesis, formation of steroids and fatty acids. Different carbohydrates are digested and assimilated differently. The differences in growth may be due to differences in the binding property of the starches. Beneficial effects of feeding glucosamine and chitin has been reported. The turn over of chitin is quite high in the prawns and shrimps. It is required not only for exoskeleton but also for the peritrophic membrane in which the faecal pellets are enveloped. Hence a carbohydrate source will be required or else protein will be used for this purpose. Cannibalism can also be reduced by the incorporation of chitin in the diet. Hence, a level of 30-40 per cent prawn meal will be beneficial.

Crustaceans are unable to tolerate high levels of dietary fat. An optimum level would be around 5-10 % . The fat content of prawn is around 2 per cent and is mainly in the form of phospholipid.

More than half the fatty acids are therefore, poly-unsaturated and mainly linolenic series. Therefore, fish oil is better suited for prawns than vegetable oils. Cholesterol has been implicated in crustaceans as important for various steroids, vitamin D, brain and moulting hormones and for the elaboration of new subcellular membrane associated with rapid growth and moulting of Crustacea.

Our information on mineral requirements in the diet of crustaceans is till incomplete. It has been shown that calcium, sodium, potassium and chloride requirement of prawns might be satisfied by osmoregulation. However, phosphorus has to be delivered through diet as it is deficient in sea water.

As in the case of minerals, our knowledge on the specific requirements of the different vitamins is scanty. Most of the vitamin B group are known to be beneficial in addition to vitamins C and E. The application of vitamin and mineral mix to shrimp feed without adequate knowledge is not only a waste but can also be dangerous. Hence, a proper understanding about the requirement for shrimp could only be achieved through future research.

Very little is known about the significance of fibre in the diet of crustaceans. Yet, it has been shown that the incorporation of fibre from turnip greens up to 5 % in the diet increased the growth, survival and feed conversion in *P. aztecus*.

Presentation of the feed is important in shrimp dietary practice. The form of the feed depends on the stage of growth and different cultural methods. The feeds may be in the form of (1) gels (2) paste (3) steam compressed pellets (4) flakes (5) capsules and (6) spaghetti-like extrusion.

A range of natural and synthetic substance are used as binders. These hold the different components together without loosing the texture for a reasonable time in water. Proper selection of the binder is important.

All these factors indicate that our information on this subject is still fragmentary, and there is the imperative need for further work.

1 There is the urgent need for a detailed scientific investigation to define various nutritional requirements at different stages of growth and the effect of growth and environmental stress on them using different biochemical criteria to meet the specific requirements of the different species.

2. Suitability of using high digestible energy ingredients to spare protein to bring down the protein cost.

3. Identification of appropriate microbes and algae which could be bioengineered to make suitable protein and long chain poly unsaturated fatty acids rich in 3 fatty acids for incorporation into crustacean feed at economical cost.

4. Standardization of experimental conditions for dieting trials.

5. Research is needed to study the nutritional value of natural feeds in nursery and grow out systems.

6. Nutritional requirement will need to be assessed for various life stages of different cultivated commodities for proper feed formulations. Research is indicated in the areas for the assessment of the nutritional value of locally available ingredients for the formulation of cost effective, supplementary and balanced feeds for different life stages of cultivated species.

7. Standard methods need to be developed for nutritional assays, standardisation of nutritional research

methodology and methods of assays.

8. Assessment of the nutritional value of locally available by products from agro-industries for formulating balanced and cost effective feeds.

World Demand for Shrimps and its Consequences

The demand for shrimps in the world market is indicating an upward trend in general with a few erratic fluctuations here and there depending on certain preferences, price movements, production trends and demand cycles.

This continuous and steady demand for shrimp worldwide has, naturally put an ever increasing pressure on producer countries to increase their supply. Consequently, there has been an increase in the size of the trawler fleets and small vessels which engage in shrimp capture fisheries. Thus, most major shrimp fisheries are at present being harvested to full or near-full capacity and there is the real danger of over-exploitation, of this very important marine resource. Indonesia's recent experience is a good illustrative example of this type of over-exploitation. In 1971, the number of vessels based in Cilacap area was 13 as compared to 200 in 1976. In 1980, there were 161 large trawlers and 121 shrimp trawlers in the Malaku and Irian-Java areas. In the straits of Malacca, East Sumatra and the Northern coast of Java, more than 13,000 vessels with in-board engines were concentrated. Naturally, these resulted in an increase of exports from US$. 7 million in 1970 to US$.253.6 million in 1982. Over exploitation has been clearly evident. In the early 1980s trawlers had to be virtually banned in Indonesia !

Major shrimp fishing areas are in the same plight as Indonesia. This places the whole shrimp supply situation in uncertainty. Over exploitation can, in fact, be prevented through careful stock assessment and management, yet there seems to be no real hope for capture fisheries to give higher yields. What is urgently needed is the systematic development and management of our vast brackish water areas available for aquaculture. This would certainly have a salutary effect in generating employment in a variety of ways and at the same time help us to earn substantial foreign exchange. Ancillary industries such as feed manufacturing units, hatcheries, nurseries, seed banks, live feed production units, the engineering, plastics, refrigeration, computer software, transport, packing, aeration equipments, pumps, net manufacturing units etc., could also be developed and these can give valuable support to aquaculture business. To take up scientific farming in about 1,000,00 ha. in our country we would need nearly 1000 hatcheries and 30-35 feed mills.

The question has been asked from time to time, why this shrimp farming since most of it are exported. How could it then help in eradicating malnutrition in a country which is chronically suffering from protein hunger. Here, we should not forget the fact that in these culture systems fin-fish also could be reared, thus assisting in fish production for local consumption. Furthermore, shrimp farming brings substantial earnings which would give the farmer the purchasing power for animal protein which he wants such as chicken, goat, beef and pork.

The Economics of Production

Is shrimp farming beneficial in the long run? One could naturally argue that a mad race for shrimp farming may bring down the unit value to such an extent that it may no longer be economically viable.

At present, production cost kg^{-1} of shrimps through farming varies from 1-2 US$ in India to 4.5$ in Taiwan and 17-25 $ in Japan. The present price is about 15-25$ kg^{-1}. Even if it slumps to a certain extent which is not probable, India could still sell this commodity with a good profit margin. We should also realise that the percentage of people who can afford to buy high priced items such as the shrimp is on the increase all over the developing and developed countries. Since sea foods are considered as health food, the rate of capita consumption is steadily going up every year and therefore, there is an assured market for

aquaculture produce. The success depends, not only on market demand, but also on production cost and availability of suitable farming sites. We could also argue that, in case of a fall in price of shrimps, it is likely that more people can buy and eat shrimp, thereby increasing the world demand. As a matter of fact, these crustaceans have become such a fascinating and most delicious item of food throughout the world that shrimp producing areas have virtually become 'gold mines' and it is up to mankind to exploit them (Saktivel 1985).

Current Problems in Indian Major Carp Culture

Even today carp-culture in India has not absorbed the desired scientific and technical inputs, so essential for its proper development and growth. At present it comprises a package of empirically developed practices known by different names such as the Chinese system, the Indonesian system, Indian system and so on. Naturally, it has to derive the benefit from multidisciplinary systems-oriented research. Even though hypophysation, has been practiced and its benefit utilised to a certain extent, yet the technique has not been perfected to the extent it should. As Jhingran (1986) has rightly observed it is still in a hit and run level rather than a discipline based on cause and effect. Similarly pond manuring and fertilisation still lack a truely chemical basis. The same may be said of the management of hatcheries, rearing practices and stock- pond management. Jhingran (1986) has recently summarised the current problems of Indian major carp culture as follows:

Problems of fish biology and genetics involve gathering of data on genetic traits and characteristics of cultivable and cultivated species of fish from river systems, where they are indigenous, to serve as bench-mark reference data for comparison with forms derived from hybridisation and genetic selection. The bench-mark traits to be recorded are morphometric characters, racial characters as revealed by electrophoretic studies, growth rate, size and age at first maturity, fecundity, reproductive biology, digestive physiology, thermal and salinity tolerance etc.

Under genetic selection and hybridisation are to be developed domesticated strains incorporating desirable culture-performance traits such as enhanced disease resistance, fast growth rate, increased dressed weight, superior nutritive value, agreeable taste and flavour, high quality and texture of flesh, favourable conversion ratio, greater aesthetic appeal, which could be compared with corresponding parameters of identical reference in its wild form studied from riverine sources where the fish is indigenous.

Through careful experiments, it is desirable to develop forms suitable for breeding and those suitable for the table, the former having maximum breeding potential and the latter incorporating desirable qualities of cultivable fish. Under larval and post-larval rearing and stockpond management are to be developed methods of generating soil and water quality characteristics optimum for high survival and fast growth and the culture of live fish food organisms, culture techniques to serve as natural food of low conversion ratio, aeration need of growing fish, methods of disease control etc.

It is also essential that under hatchery and fish farm management study, coordination of various hatchery and fish farm management practices and determination of methods for obtaining highest possible yields from aquaculture systems are assured at an economically viable level. This is because fish production, through aquaculture should serve the community, providing a high protein diet in an abundant measure to ward off malnutrition and hunger especially in the developing countries where these problems exist in an alarming degree.

The Culture Based Fisheries, a New Concept

Considering the worlds increasing demand for shell-fish and fin-fish and such products, culture-based fisheries seem to have a great potential for increasing fish production.

Culture-based fisheries differ from capture fisheries and aquaculture. These are production systems in which man conducts commercial fishery production through a series of processes of raising, nursing and catching living resources, using natural or artificial biotic productivity. These are production systems that consist of a series of combined processes such as production of artificially incubated seed and fry, gathering of natural seed and fry, protection and preservation of released fish in specific farmed areas, management of environmental condition of the farmed areas and regulation of fishery and farmed resources.

This system has been established in Japan for decades; species which have been farmed in this way with varying degrees of success include the Pacific salmon, pilchard, herring, cod, flounder, kuruma shrimp, clams, scallops, crabs, red seabream and abalone.

The advantages of culture-based fisheries are (1) there is a much higher rate of recruitment of harvestable fish from spawners (compared with production in the natural environment), (2) they enable expanded exploitation of the basic productivity of the sea.

One of the basic problems facing development of culture-based fisheries in general is that of jurisdiction or latent ownership of culture-based fishery resources. It is inevitable that the fishing grounds for natural and culture based fisheries production are likely to overlap and that there will be a mixed catch of natural fishery resources and culture based fishery production. In order that culture based fisheries can develop and produce more fishery products in the inshore areas an examination of the existing systems, regulations and facilities in fishery production is urgently required (Hanamura 1979).

Genetically Engineered Organism for Aquaculture

Several new species and fast growing exotic species are being introduced to diversify the product and market, improve profits and decrease reliance on a single product and market. A great amount of work is being carried out in many countries to replace the 'wild' species with genetically engineered organisms, better suited to the culture, environment and the consumer's preference. Our fishery scientists should concentrate on this most exciting and potentially rewarding area.

Re-seeding of the Over exploited Stock by Sea-ranching

Sea-ranching has become a reality to enhance the natural populations in an area. The mass-scale breeding of valuable species has become highly essential for supplying seed to aquaculture and also to renew the natural stock of over-exploited species in the sea, by sea ranching. This naturally involves active research work on mass-scale breeding of several species. The results of studies in countries such as Taiwan, Japan, have been encouraging and they have shown that there is good future for ranching in Asia. India should take up this idea on a large scale at least in the semi-enclosed backwaters and coastal areas. We should set up large hatcheries in the coastal area which are nearer to the large shrimp-grounds.

The Role of Marine Products Export Development Authority (MPEDA)

To augment export production of marine products, more especially shrimps, the MPEDA work in close co-operation with the Fisheries Departments of the respective State Governments. From the selection of site, right through construction and operation of the farm, till harvest, farmers are given technical guidance in the field. Nearly 1,500 farmers are availing the assistance of the

MPEDA. Furthermore the MPEDA, in consultation with the State Fisheries Departments is conducting microlevel surveys in the different States. It has also introduced subsidy schemes from 1985-86 for the development of new areas for farming, to set up seed banks and hatcheries. Besides, supplementary feeding with artificial feed is also encouraged. Farmers are being trained in scientific management practices of shrimp farming.

The Socio-economic Implications of Aquaculture

Technology and the structural changes it brings about have been the major factors for the claims of prosperity in the developed countries. Planners and policy makers naturally recommend these as possible solution to the development and for alleviating poverty elsewhere. Nevertheless, this approach has been criticised for its materialisation and failure to appreciate the socio-cultural differences and the often negative impact technology can have on traditional communities. There is now the willingness to measure development not just solely in terms of total output, worker productivity or monitory value, but also in terms of social feasibility. Smith and Smith (1985) have recently examined the various implications.

Fish supplies are levelling off in many countries as already indicated, as a result of natural limits to fisheries production. Therefore, aquaculture is being viewed as the primary means of achieving the incremental growth in aquatic food supply necessary to keep up with the continued increase in population and the rise in demand. In response to favourable economic conditions created for producers in many countries, aquaculture production is rapidly increasing. This is potentially a gratifying development for both consumers and for export oriented groups since 60% of the people's animal protein requirements are derived from fish.

A major part of these developments emanates from freshwater culture-system more especially for carps and cichlids. Coastal aquaculture systems are also experiencing rapid expansion and increases in production. Important brackish water species include among others milkfish, mullets, shrimps and bivalves. Of these, shrimps are by far the most important economically. This is on account of the fact that shrimps are the source of foreign exchange earned by exporting them to affluent countries such as Japan, N. America and Europe. The social feasibility of extensive coastal aquaculture in the tropics, however, has not been examined critically.

What are the possible repercussions of extensive development of aquaculture in the coastal belt, which itself is a very fragile ecosystem and its impact on coastal resources, the economic, socio-cultural, legal, political and institutional dimensions of this development?

The massive conversion of mangrove swamps to pond aquaculture can cause grave dislocation to traditional coastal communities. Mangroves are important breeding and nursery grounds for many aquatic species that are caught in the near shore areas by capture fisheries. The potential losses to fisheries in this process is under estimated or not assessed at all in cost-benefits studies of coastal pond aquaculture. Others who depend on the mangroves are also ignored in these calculations. The interest of the entire community might be by-passed or even over-run by new aquaculture developments that do not respect traditional uses and claims of the community. Large scale aquaculture enterprises frequently displace small-scale fishermen and aquaculturists through subsidised financing and institutional arrangements that favour the large-scale or corporate investor. Therefore, participation of the local groups and communities must be assured in the development of appropriate technology in these coastal zones.

For the poor coastal communities capital intensive systems such as brackish water pond culture of shrimps or shrimp hatcheries will not be appropriate. The ideal avocations for them are small-scale activities such as (1) stake or raft culture of molluscs, (2) bottom culture of oysters or cockles, (3) culture of seaweeds, (4) cage culture of marine species, (5) integrated systems such as animal-fish culture in small ponds, and (6) managed ranching system such as artificial reefs, pens, or other enclosures. All these have advantages of being amenable to small-scale part-time operation. They can begin at such a level that the other primary occupation of the individual or family such as fishing can continue to provide a steady cash flow to the household while the aquaculture harvest is awaited. Labour requirements are low and could be filled by household labour.

Communities must participate in, and contribute to technology adaptation if aquaculture development in a particular community is to succeed. Partnerships between individual fish farmers or communities, researchers and non-governmental rural development organisations will be necessary to assure that technology developed by researchers will be appropriate for community adoption and modification. The role of rural development organisations is important because they are likely to have the expertise in judging the social feasibility that technicians in research organisations and good extension services lack. Such groups can also assist in training researchers and extension officers to build up the number of professional rural developers who also have an understanding of the technical, financial and managerial aspects of aquaculture.

A successful co-existence of large scale and small scale community activities is possible with careful planning. Many species and system choices exist in aquaculture. These facilitate more specialisation possibilities with wealthier farmers concentrating on higher value (and higher-risk) systems such as shrimp while other lees well off producers concentrate initially upon less complex systems such as bivalve culture for domestic markets. Thus, market competition between systems can also be reduced to a certain extent.

Competition for and demarcation of space within the mangrove and backwater areas are much more difficult to resolve but it can be done. Legislation to address resource allocation and use does not exist. National systems of legislation have generally failed to date to meet basic conservation guidelines and avoid over exploitation. Therefore, a more decentralised approach to coastal zone management is called for. Such an approach is most essential to resolve issues of competition at the local level. Potentially it will generate income for coastal communities.

In any endeavour for the rapid expansion of large scale, capital intensive, export-oriented coastal aquaculture, we must also have a concern for the long-term effects that such development will have on the coastal zone in the tropics. The inhabitants of these areas are poor fishermen who earn a meagre livelihood in a very hard way as gatherers. Otherwise, the damage will be great. It is imperative that some compromise be found between national objectives of increased aquaculture production and foreign exchange on the one hand, and coastal community requirement for increased employment and income on the other.

Participatory development on the part of coastal communities requires conscious efforts to evolve them in the process of aquaculture development. Participatory development will not come about without efforts to decentralise control and decision making over the coastal zone itself and the technologies that are appropriate there. Nor will it come about without efforts of interested researchers, extension workers, rural bankers, non-governmental rural developmental organisations to make certain that communities

are directly involved and supported over the long term. Involvement of these co-operative and supportive groups is also necessary to help individuals and families adjust to the changes and new roles that aquaculture activities bring.

Aquacultural Engineering

Very specific technologies are essential for translating scientific knowledge into practical and economically feasible systems which could produce aquacultural products. Aquacultural engineering concerned with the application of engineering principles and procedures to fisheries and to the culture of aquatic organisms has not received any serious attention in our country. Relatively limited amount of research has been directed towards using available knowledge to develop pilot or commercial scale operating aquacultural systems. This is the place of the engineer and the economist, the translation of the scientific knowledge into practical and economically feasible systems to produce cultured aquatic crops.

Developmental Support

Aquaculture if developed properly is a divine gift for rural farmers, educated unemployed, private entrepreneurs as well as resource-rich large houses. There is support by programmes of the Centre and the States, the welfare agencies, non-government organisations besides several bilateral and international funding sources. Commercial collaborations are possible with foreign companies through subsidies, loans, and equity participation.

The Centre in coordination with State governments is promoting aquaculture through 365 District level Fish Farmer's Development Agencies (FFDA). Similarly the 32 Brackish water Fish Farmer's Development Agencies promote shrimp farming in coastal rural areas. The ICAR has established 187 Krishi Vigyan Kendras many of them imparting training and holding demonstrations on aquaculture.

The Ministry of Rural Development has also several programmes such as DRDA, IRDP, RLEGP and TRYSEM and these in collaboration with the block level administration support aquaculture activities, through subsidies, employment, and training. The Panchayats promote fisheries through the Jawahar Rojgar Yojana for employment and the National Co-operative Department (NCDC) and the lead banks through the NABARD. Refinancing system support fish farming on a large scale.

Research support and other infrastructure development for aquaculture and related activities are provided by several institutions under the ICAR, such as the Institute of Fresh Water Aquaculture, the Central Institute of Brackish Water Aquaculture, National Research Centre on coldwater Fisheries, the National Bureau of Fish Genetic Resources, the Central Inland Capture Fisheries Research Institute, the Central Institute of Coastal Engineering and Fisheries under the Ministry of Agriculture. Research and development activities as well as man-power development are being undertaken by the several Agricultural universities and the C I F E Bombay, (Deemed University) and the technological aspects by the C I F T at Cochin.

New Innovations in India

The new innovations in aquaculture in India have been listed by Tripati (1989) and Dehadrai (1992). Fish culture in our country has come to acquire the status of an organised industry as a result of technological advancements in induced breeding of carps through hypophysation and composite carp culture. Broodstock management for breeding and rearing at present entail activity throughout the year. Brood fish are being bred four times in a season and carp seed can be produced quite independent of the monsoon. They could also be subjected to specialised breeding known as bund breeding-in ditches, paddy fields and even in plastic pools. Seed production of major carps in the country is of the

order of 6000 million now, while fish yields employing semi-intensive systems with low to high inputs range from 2 to 10 tonnes ha^{-1} yr^{-1}.

Inland fish production has been steadily increasing from 2.2 lakh tonnes in 1950 to 13 lakh tonnes in 1987-88 which is about 45% of the total fish production. Fresh water aquaculture production constitutes nearly half of the inland fish production today. Inland capture fisheries have been under serious constraints in recent times, on account of several adverse factors such as increasing loads of pollution, deforestation, siltation of rivers and reservoirs and water abstraction. Therefore, aquaculture assumes great importance. It presents a rich resource potential of more than a million hectares of water area in the form of ponds and tanks.

Mass breeding of carps using pituitary gland extract has become common and alternatives to pituitary are being developed. Human chorionic gonadotropin known by the trade name 'Sumach', an indigenous product available on a commercial scale is being used increasingly, either in isolation or in combination with the pituitary. LH-RH and its analogues preceded by Pimozide or Domperidome which have given excellent results, are likely to replace the pituitary totally.

It is also noteworthy that in larval rearing, high survival rates of 50 to 80 % have been achieved even at high stocking densities. Feeding techniques have been improved by providing natural food organisms through the use of cobalt chloride and manganous sulphate as fertilisers, fish meal as an ingredient, control of predatory species by malathion and by efficient aeration and running water systems.

Seed production on a commercial scale has been developed for many species of catfishes, rainbow trout, masheer, hilsa and mussels. Important species of freshwater, brackish water and marine prawns can now be artificially matured under control and bred with artificial or natural saline water. Maturation of tiger prawn through eye-ablation techniques has facilitated brood stock management. Also rearing techniques have been standardised for prawn seed through the different larval stages leading to the establishment of the much needed commercial hatcheries. The technology of carp polyculture has been continually refined and improved to meet the basic requirements of this system. Low input-high yield operational techniques relevant to semi-intensive aquaculture has been perfected utilising all the ecological niches of the water body, creating a predator free environment, providing suitable fertilisers to increase natural productivity and adding supplementary feed to meet the requirements of the growing fish. This technology promotes up to 15 tonnes a ha. a year with varying input choices. Culture of cat fishes *Clarias, Heteropneustes* and *Anabas* with supplementary feeding could yield 5-7 tonnes a ha. in six months. Production up to 50 tonnes a ha. in five months has also been reported. Fish culture with pig rearing, duck rearing, and paddy cultivation with *Macrobrachium* combinations could bring down the cost of production. Cage culture has also become quite popular.

As Tripati (1989) explains, new inputs and new systems are being developed using locally available materials to reduce the cost such as aquatic and terrestrial weeds as feed for grass carp in small ponds. This gives 4-4.5 tonnes per ha per year. Biogas slurry which is a new fertiliser source in the Indian villages yields up to 5 tonnes ha^{-1} yr^{-1}. Similarly integration of fish culture with agriculture and rearing of livestock has good scope. Paddy-cum fish culture could result in one tonne of fish and 5 tonnes of paddy ha^{-1}. in two crops. Poultry, ceattle, pigs, fish rearing also are economically viable. With proper attention to sanitation, treated sewage effluents can give a production of 3-4.5 tonnes per ha. per year and this system has great potential in our country.

Side by side with these intensification and development of culture systems there are several other improvement in the different components such as the management of water quality through replenishment, aeration and biofiltration, use of compounded, high protein, pelleted diets and prophylactic and control measures for diseases. Running water fish culture which consumes the least energy and has the highest production potential has also been initiated. Cage culture of carps also presents great potential with a production of nearby 200 tonnes per ha in six months. Similarly ranching of Ox-bow lakes or beels by establishing pens could yield, over 4 tonnes per ha. per year. Of late, biotechnological methods are being used for increasing production. Thus, gynogenetic progenies of Indian and exotic carps have been developed using ultraviolet radiation and application of cold/heat shock treatment. Polyploidy, sex reversal and production of monosex populations are some of the genetic engineering tools being employed for increasing fish production. Thus, several intergeneric and interspecific hybrids of the major carps have been produced some of which are endowed with faster growth rates.

These improved technologies for mechanisation and automation demands several ancillary items such as aerators, airlift systems, intake and outlet controls, hatchery designs, seed transport, nets, cages, pens, feeding devices, water management designs, filters, harvesting equipments, pumps, pipes and so on. All these are now available. Considerable experience has also been gained in designing innovative lay outs of fish-shrimp farms suitable for various agro climatic conditions, land profile and water source, keeping in mind the environmental relevance and judicious utilisation of land/water resources through integrated farming systems as well (Dehadrai, 1992).

Conclusions

1. Despite the several new developments mentioned above, India is still lagging behind many other countries in the use of modern aquacultural technologies. We are not fully and effectively using vital information on technology already available, developed and successfully being practiced with great advantage in many Asian countries. This is evident from the fact that while countries like Taiwan are producing upto 20 tonnes ha^{-1} yr^{-1} of prawns through semi- intensive and intensive farming we in India still have not standardised even one tonne production ha^{-1}, which reveals clearly that we are yet to seriously participate in this programme.

2. Water quality studies are important and have been taken up as a key subject in aquaculture. Innovative techniques are available with computer control, systems for continuous water-quality monitoring and feeding. We are yet to understand their importance. Such equipments should be manufactured in India or a few prototypes should be allowed for import without duty. Our research institutions should pay more attention on this very important subject of water quality management, and other related subjects.

3. Since massive production of seed is basic for successful culture, a chain of hatcheries have to be established all over the coastal areas to boost production of seed. At the same time, collection and culture of larvae from natural sources be encouraged and expanded to save this precious resource being wasted or destroyed at present.

4. High energy feed has really boosted the production in aquaculture systems in many countries and we are yet to develop these items in India.

5. Ranching for shrimps, prawns and frogs should be taken up seriously to recoup the natural stock in the major fishing area which are being over exploited at present.

6. Polyculture of fresh water prawn with major carps and other suitable species combinations in brackish water systems should be taken up, West Bengal being ideal for the fresh water culture to increase the production for export.

7. When compared with many developing countries, the progress we have made in aquaculture has not been satisfactory. We should realise that our capture fisheries are showing a distinctive downward trend in catches and that the world aquaculture race has already started with right earnest and we are yet to participate in this. We have rich potentialities and great possibilities for aquaculture. Some positive steps have been taken and these efforts should continue unabated so that our production could cope up with that of other leading countries. We have already wasted several years of our precious time in such basic issues as land allotment to the entrepreneurs and even today a remedy has yet to be found. Both the Central and State Governments should find a way to break this distressing, deadlock.

8. Brackish water areas and similar low-lying wetlands of the coastal belt suitable for aquaculture should not be allotted for other purposes. The indiscriminate draining, filling and unauthorised reclamation and encroachment taking place unabated, in the coastal zone, should be checked at all costs.

9. The dumping of sewage, industrial effluents, municipal wastes etc. should be checked and suitable legislation be introduced to protect and preserve the brackish water and similar areas for fish farming, and avoid further damage.

10. Basic infrastructure facilities such as roads, drinking water, communication, electricity etc. be provided in remote coastal areas to speed up aquacultural developments and police protection assured to maintain law and order against theft of fishes/prawns grown in aquafarms.

11. There is the need for rehabilitating the fishermen who are at present fishing in the inland coastal areas in prawn and fish farming, thereby preventing the destruction of juveniles on a large scale.

12. The State Government should also make adequate investment for the regular supply of inputs such as seed, feed, technology and extension services.

We should realise that aquaculture can produce significant quantities of food, income and employment and if planned and applied effectively can revitalise rural life and supply products of high nutritional value. It can assist in enhancing and maintaining wild aquatic stocks, thereby improving capture fisheries. It is an efficient means of recycling and upgrading low-grade food materials and waste products into high-grade protein-rich food.

A perusal of India's export of fishery products indicates that the major contribution is from capture fisheries, culture fisheries forming only a portion of the total export. This is indeed disappointing since in a vast sub-continent such as ours with excellent water resources, ideal climatic conditions, ancient traditions and knowledgeable people, culture fisheries could contribute substantially. With proper management and the essential inputs, we can certainly develop aquaculture as a major avocation thereby opening up a new frontier for food and wealth for our country.

References

Dehadrai P V 1992 Growth of entrepreneurship vital; *The Hindu Survey of Indian Agriculture* pp. 165-166

Hanamura N 1979 Advances and problems in culture based fisheries in Japan; *Advances in Aquaculture, Fishing* pp. 541-547 eds T V R Pillay and W A Dill (News Books Ltd.)

Jhingran V G 1986 Aquaculture of Indian major carps; in. *Aquaculture of Cyprinid* pp. 335-346 ed. R. Billard and J Marcel (Paris: INRA)

Lourdes M A and Palomares D 1985 Developing countries dominate the shrimp scene; *ICLARM Newsl.* pp. 3-5

Saktivel M 1985 Shrimp farming a boon or bane to India; *ICLARM Newsl.* pp. 6-8

_____ 1987 Present status of aquaculture production of fishery products for export from India; *Mimeographed Report*, MPEDA.

_____1994 Marine Products, Time for diversification; *The Hindu Survey of Indian Agriculture* pp.145-149

Smith Ian R and Rebecca P Smith 1985 Social feasibility of coastal aquaculture; ICLARM *Newsl.* pp. 6-8

Tripati S D 1989 Indian Fisheries. Accent on intensive systems; *The Hindu Survey of Indian Agriculture* pp. 239-241