

INDIAN FISHERIES AND AQUACULTURE: PRESENT STATUS AND FUTURE PROSPECTS

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Global fish production from capture has remained relatively stable over the past two decades while fish production through aquaculture has progressively increased. The Indian fisheries sector has come a long way since independence (Figure 1) and has contributed immensely to the food basket of the country, with annual production levels of over six million tonnes of fish and shellfish from capture fisheries and aquaculture. India is the fourth largest producer of fish and is playing an important role in global fisheries. Furthermore, with production over 3.1 million metric tonnes, the country occupies second position in the world from the inland fisheries sector. In the last five decades, Indian fisheries have made great strides, with the annual production increasing from 0.75 million tonnes of fish and shellfish in 1950 to about 6.1 million tonnes in the year 2002, indicating an increase of over eight fold. The share of inland fisheries sector, which was 29% in 1950-51, has gone up to over 50% at present (Table 1). While capture fisheries have solely contributed production from the marine sector, aquaculture contribution in the inland fisheries sector has been significant in recent years. The production from capture fisheries in the last two decades has grown by only 72% i.e. from 2.08 million tonnes in 1980 to 3.59

million tonnes in 2000, but the aquaculture sector has shown a growth of 468% in the same period, i.e. 0.37 million tonnes in 1980 to 2.1 million tonnes in 2000. The country has also emerged as one of the major in exports, recording a peak during the year 2000-2001, earnings Rs. 5957 crores (US \$ 1.25 billion). However, there has been a decline of 7.56% during 2001-2002 due to economic recession and steep decline in prices of black tiger prawns in the international market. Fish production (inland and marine) in major fish producing states is shown in Figure 2.

Inland Fisheries

India is blessed with huge inland water resources (29,000 kms of rivers, 0.3 million ha of estuaries, 0.19 million ha of backwaters and lagoons, 3.15 million ha of reservoirs, 0.2 million ha of floodplain wetlands and 0.72 million ha of upland lakes). It has been estimated that about 0.8 million tonnes of inland fish is contributed by different types of inland open water systems. Though, the production breakup of these water bodies is not available, it is believed that capture fisheries production from rivers and estuaries contribute only a small share of the total inland catch. The bulk of the production comes from reservoirs and floodplain wetlands, which are managed on the basis of culture-based fisheries or various other forms of enhancement. The 14 major rivers, 44 medium rivers and innumerable small rivers of the country with a combined

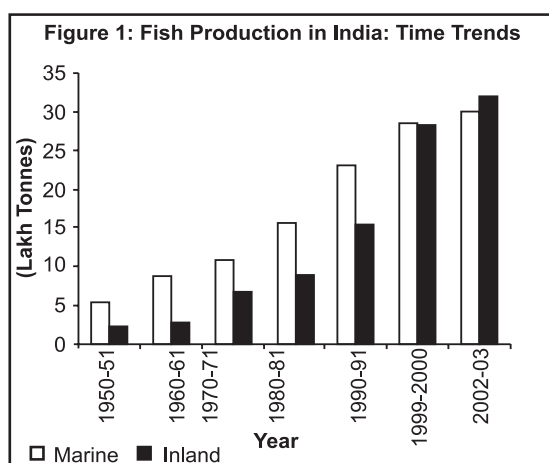
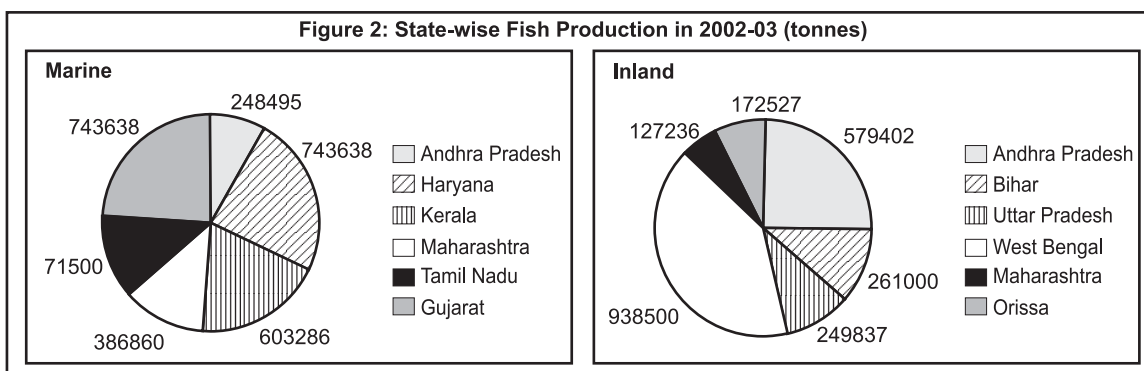


Table 1: Indian Fisheries

Potential Production	8.4 mmt
Present Fish Production	6.18 mmt
Inland	3.16 mmt
Marine	3.02 mmt
Fish seed production	18500 million fry
Hatcheries	1070
FFDA	422
BFDA	39
Export	Rs. 6,800 crores



length of 29,000 kms provide for one of the richest fish faunistic resources of the world. While production figures from different riverine systems are not available, estimates made for major rivers showed yield varying from 0.64 to 1.64 tonnes per km with an average of 1 tonne per km. The average estimated yield in different estuaries range from 45-75 kg/ha.

Reservoirs form the largest inland fisheries resources in terms of resource size with 56 large reservoirs (>5000 ha), 180 medium reservoirs (1000-5000 ha) and 19,134 small reservoirs covering a water area of 1.14 million ha, 0.527 million ha and 1.485 million ha, respectively, with substantial areas added year after year due to construction of new impoundments created through erection of dams over rivers, streams or any other water course. In India, management of medium and large reservoirs can be considered akin to enhanced capture fisheries and their fisheries largely depend on natural recruitment. On the other hand, the fish catch of the small reservoirs depends on stocking and management and is termed as culture-based fisheries. Stocking in such small reservoirs is not merely a simple matter of releasing appropriate species into the ecosystem, but an important management option which needs evaluation of an array of factors, like biogenic capacity of the environment, the growth rate of the desired species, fishing condition, shallowness of the reservoirs and natural recruitment. In general, stocking of advanced fingerlings (10-15 cm) of Indian major carps at density of 400-500 numbers/ha is the option suggested for small reservoirs. However, the average national production levels obtained from the small reservoirs of the country have a productivity of

about 50 kg/ha, and is low when compared to other Asian and Latin American countries.

Efforts on scientific management by CIFRI in several small reservoirs have shown that it is possible to improve the yield, for example 102 kg/ha in Baghla, 140 kg/ha in Bachhra, 150 kg/ha in Markonahalli (all are in Uttar Pradesh), 194 kg/ha in Aliyar, 182 kg/ha in Tirumoothly (both are in Tamilnadu), 108 kg in Meenkara and 316 kg/ha in Chulliar (both are in Kerala). It has been estimated that the 1.5 million ha of small reservoirs can produce at least 0.15 million tonnes against the present levels of less than 0.07 million tonnes. The medium and large reservoirs can yield another 0.15 tonnes through proper species and stock enhancement. Thus, greater thrust is warranted to exploit the fisheries potential of these water bodies through culture-based fisheries in coming years.

Floodplain wetlands or beels are other potential fishery resources in the states of Assam, West Bengal and Bihar. They offer tremendous scope for both culture and capture fisheries. These water bodies play vital role for recruitment of fish stocks of the riverine system and provide nursery grounds for commercially important finfishes and shellfishes. It has been estimated that these beels possess potential to yield as much as 1000-1500 kg/ha/year, while the present level remains at only 100-150 kg/ha. The rich nutrients load and availability of fish food organisms make water bodies ideal for culture-based fisheries leading to higher growth of stocked fish species compared to the reservoirs. The marginal areas of the beels can be utilised for construction of ponds or pens of suitable sizes for raising the required fingerlings for stocking the beels.

Table 2: Marine Fish Production Trends (000' tonnes)

State/Dts	2000-01	2001-02	2002-03	2003-04	2004-05 (Target)
Andhra Pradesh	182	204	224	297	29
Goa	67	66	72	90	110
Gujarat	620	650	743	609	700
Karnataka	175	128	180	187	190
Kerala	566	593	603	608	not received
Maharashtra	402	414	386	400	400
Orissa	121	113	115	116	125
Tamil nadu	367	370	379	373	374
West Bengal	181	184	181	181	181
A&N Island	27	27	28	31	32
Daman & Diu	16	21	11	10	not received
Lakshadweep	12	13	7	10	15
Pondichery	38	39	39	42	45
TOTAL	2780	2829	2991	2958	

Considering the present threat of increased pollution levels and siltation of open water resources like rivers, estuaries and lagoons and also the over-exploitation of these resources leading to stagnation of fisheries production, thrust on culture-based fisheries in reservoirs and floodplain wetlands holds the key for future of the inland fisheries development in India.

Marine Fisheries

Marine fisheries have played a pivotal role in ensuring food and nutritional security of the growing population, employment generation, enhanced income and foreign exchange earnings. India has vast resources in terms of a 8,129 kms long coastline, 0.5 million sq. km of continental shelf and 2.02 million sq. km of exclusive economic zone. It is only after the establishment of Central Marine Fisheries Research Institute in 1947, that the marine fisheries development was put on sound footing. Major thrust areas include research on biology of commercially important species and monitoring their stocks for proper management; judicious exploitation and conservation; conducting exploratory surveys and mapping of the productive fishing grounds, locating new areas and resource; and carrying out environmental studies related to fisheries. Marine fish production trend in major coastal states between 2000-2004 is given in table 2. In the first two Five Years Plans, emphasis on marine fishery sector was on the

mechanizations of indigenous crafts, introduction of mechanized fishing boats, improvements in fishing gears, establishment of infrastructure facilities such as processing plants, ice plants, cold storages and landing and berthing facilities. These programmes, backed by the discovery of rich fishing grounds in inshore waters paved the way for establishment of Sea Food Exports Industries. In the next three Five-Year Plans, the above programmes were continued with greater emphasis on introduction of mechanized fishing boats and adoption of synthetic materials for fishing gears. Research on various aspects of marine fisheries and exploration of their resources was intensified (Text Box 1). With the declaration of an Exclusive Economic Zone of 200 miles in 1976, the programmes relating to deep-sea fishing were intensified. While in fifties and sixties, mechanized boats with trawl nets and motorized indigenous crafts were introduced for efficient harvests from the inshore region, in seventies, purse-seines were introduced along the south-west coast. These developments resulted in expansion of fishing areas and increase in production. Improved harvesting technologies coupled with increasing demand of fish for domestic and export market have resulted in significant increase of production over the last fifty years, i.e., from 0.53 mmt in 1951 to 3.0 mmt in 2001-2002. However, the intense exploitation of resources in coastal areas up to 50 meters by artisanal and small-mechanized

Text Box 1	
Marine Fisheries Resource Management	
➤	Intensification of exploitation in offshore grounds.
➤	Enhancement of coastal stocks through sea-ranching.
➤	Creating of artificial fish habitats in the inshore grounds.
➤	Regulation of fishing efforts, effort rationalisation and closed fishing season.
➤	Gear, area and temporal restrictions and mesh size regulation to prevent growth over fishing and recruitment over fishing.
➤	Fishery forecasts linked to biotic and abiotic features.
➤	Promoting tuna long lining, purse seining and oceanic squid jigging.
➤	Monitoring ecosystem health.
➤	Utilisation of bycatch by conversion into value added products.
➤	Development of infrastructure for production and post-harvest.
➤	Human resource development.
➤	Creation of environmental awareness.
➤	Organization of extension programmes and inter-institutional linkages.

fishing sector resulted in the annual catch plateauing, with a decrease in catch per unit effort. While the contribution of the artisanal sector to the total production was significant in the sixties, their contribution at present is low (only 13%) and mechanized and motorized sector contribute 87% of total production.

Technological research in fisheries did not receive much attention in India until the establishment of Central Institute of Fisheries Technology (CIFT); which gave a foundation for research in the design of various fishing crafts, gears, fishing techniques, methods of handlings and post-harvest processing and utilization. Initially motorization of indigenous crafts was taken up as a first step of mechanized fishing. Subsequently, several designs of small, medium and larger sized mechanized boats were introduced into the fishing industry. Fish detection facilities were introduced in large boats with facilities for proper gear handling for enhancing their efficiencies. Various designs and sizes of mechanized crafts were introduced besides specialized fishing vessels like trawling-cum-fish carrying, trawler-cum-purse-seiner, boats for long line fishing and trolling.

Gear designing was given greater emphasis for enhancing the production from the mechanized vessels and diversification of fishing activities. This led to development of different gears, introduction which were stern trawling, outrigger trawling, mid-water trawling, purse seining and long lining. Introduction of gears like four-seam trawl and bulged-belly trawl could increase the catching efficiency by about 30%. Specialized gill nets were fabricated for lobster fishing. The use of non rotting synthetic fibre in fishing gears was another significant development. Of late, the use of mechanical fishing accessories, ancillary fishing equipment and electronic testing devices of practical value in fishing operation have also added a new dimension for enhancing the catch per unit effort of a specific gear and craft.

An increase in fishing intensity, declining stocks, conflict between the fishing sectors, decreasing catch rate, decreasing recruitment, inappropriate exploitation pattern, habitat degradation and resource degradation have been identified to be the major problems of coastal fisheries, presently. Several regulatory measures like regulation of mesh size, regulation of fishing areas, seasonal closure of fishing, ban of the destructive gears, promotion of marine sanctuaries, promotion of artificial reefs and sea ranching, effecting code of conduct for responsible fishing have to be implemented to ensure sustainable growth in this sector.

Freshwater Aquaculture

Indian aquaculture has shown significantly higher growth rates than those of capture fisheries in the last decade, with the quantity increasing from 1.01 million tonnes in 1990 to 2.10 million tonnes in 2000. Freshwater aquaculture has continued to form a major share of the aquaculture production, with a contribution of over 95% in terms of quantity. It is only the three Indian major carps, which share as much as 1.6 million tonnes. On the other hand, shrimp forms the main component of brackish water aquaculture sector with production crossing a lakh tonne mark, recently. Freshwater aquaculture in India has made notable strides in recent years with a growth trend similar to that of the world. With an annual

growth rate of over 6% during the last decade, the sector possesses higher growth rates than other food producing sectors. The sector has evolved from the stage of a domestic activity in the East Indian states of West Bengal and Orissa to that of an industry in recent years, with states like Andhra Pradesh, Punjab, Haryana and Maharashtra taking up fish culture as a trade. With technological inputs, entrepreneurial initiatives and financial investments, the pond productivity has gone up at a national level from 500-600 kg/ha/yr to over 2000 kg/ha/yr, with several farmers and entrepreneurs achieving higher production levels of 6-8000/ha/yr. Carps is the mainstay of culture practice in the country, which is supported by strong traditional knowledge base and scientific inputs in various aspects of management. Carps contribute 87% of the total aquaculture production. Though the country possesses a large number of potential cultivable carp species, it is only the three Indian major carps; catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*), that contribute a lion's share with production (0.546, 0.567 and 0.517 million tonnes, respectively recorded during the year 2000). Scientific interventions in the last five decades have led to the development of a host of carp culture technologies with varied production potentials depending on the type and level of inputs. Further, other produce like catfishes, freshwater prawns and molluscs for pearl culture have also been brought into the culture systems. In addition, a range of other non-conventional culture systems, like sewage-fed fish culture, integrated farming systems, cage and pen culture, running water fish culture have made freshwater aquaculture a growing activity across the country. Being mainly organic-based, the freshwater aquaculture practices are also able to utilise and treat a number of organic wastes including domestic sewage, enabling eco-restoration.

Carp breeding and seed production

Seed being the basic input in any culture systems, its production has been accorded highest priority in terms of broodstock management, establishment of hatcheries, refinement of induced breeding techniques, rearing and production of quality seed across

the country. The technology of induced breeding of carps under control condition has become a common practice of the farmers today. The breakthrough of induced breeding through hypophysation is, undoubtedly, the most important aspect that led to the growth of freshwater aquaculture sector. The technology has made mass production of quality seed under control condition possible, thereby, reducing the dependence on natural seed collection. Development of several ready-to-use synthetic inducing agents, as alternative to pituitary hormone, made the technology of induced breeding easier and more farmer friendly. Besides Indian major carps, the technology of breeding of Chinese grass carp and silver carp has also been domesticated all over the country. Various carp species are domesticated to breed before and after the monsoon. The technology of multiple breeding of carps has been able to demonstrate 2-3 fold higher spawn recovery from a single female during season through 3-4 times breeding within an interval of about 45 days. The technological evolution of hatchery design and operation from initial earthen pits to double-walled hapa and subsequently to glass-jar and circular eco-hatchery provided scope to produce and handle mass quantities of eggs during hatching. Carp hatcheries in the public sector have contributed to an increase in seed production from 6,321 million fry in 1985-86 to over 18,500 million fry at present. Even states like Assam and West Bengal are producing seeds much beyond their requirement, showing the prospects of export trade and its economical viability. However, in the wake of increased emphasis on diversification of carp culture, greater research thrust is warranted for commercial production of important medium and minor carp species.

Despite the domestication of induced breeding technology and production of carp seed to the tune of over 18,500 million fry in the country, the availability of stocking materials of desired species and size still remains a constraint. Raising of seed in the initial two stages is associated with high rates of mortality due to several management problems. Packages of practices have been developed and standardized for raising fry and fingerlings with higher growth and survival levels. Higher

survival levels of fry of over 40-60% through intensive rearing during nursery stage have been demonstrated at stocking densities of 5-10 million/ha in earthen ponds and up to 30 million in ferro-cement tanks. A farmer is now able to harvest 3-4 crops of fry even in a season of 3-4 months i.e., during June-September. Further, at 2-3 lakh/ha stocking densities the technology of fingerlings rearing can result 60-80% survival, with mean fingerlings size of 100 mm in a rearing period of 3 months.

Grow-out culture of carps

Research and development efforts in the last five decades have greatly enhanced average fish yields in the country making carp culture an important economic enterprise. The three major Indian carps were the principal species cultured by the farmers in ponds since ages and production from these systems remained significantly low till the introduction of carp polyculture technology. Introduction of exotic species like silver carp, grass carp and common carp into the carp polyculture system during early sixties also added new dimension to the aquaculture development of the country. It is the Pond Culture Division of the erstwhile CIFRI, Cuttack that was responsible for the development and refinement of scientific carp culture in India through its research in several centres under the All India Coordinated Research Project on Composite Fish Culture and Fish Seed Production. With the adoption of technology of carp polyculture or composite carp culture, production levels of 3-5 tonnes/ha/year could be demonstrated in different regions of the country. It is the technology of carp polyculture that has revolutionized the freshwater aquaculture sector and brought it from a level of backyard activity to that of a fast growing organized industry. Research over the years has led to the development, refinement and standardization of a host of technologies with varied production levels depending on the input use. The technology of intensive carp culture has demonstrated higher production levels of 10-15 tonnes/ha/yr.

The necessity of bringing more species of promise into the carp culture practice is being emphasized. Species like *Labeo calbasu*, *L. gonius*, *L. bata*, *Puntius pulchellus*, *P. sarana*,

P. kolus and *Cirrhinus cirrhosa* are considered to be important candidate species due to their production potential, consumer preference and high market price, and there is a need for greater research thrust for diversification of carp culture sector.

Culture of catfishes

Though catfishes possess considerable commercial importance, their culture in the country is yet to make any mark. *Clarias batrachus* (magur) and *Heteropneustes fossilis* (singhi) are the two air-breathing catfishes, which are well adapted to adverse ecological conditions. While the technology of induced breeding and seed production of these two important catfish species has been perfected, their large-scale production is yet to be taken up. With more or less similar pond management measures as that of carp culture practices and stocking with 20,000-50,000 fingerlings/ha, production levels of 3-5 tonnes/ha are achieved in grow-out culture of magur, which attain 100-200 g in 6-8 months. These groups of fishes can suitably be cultured both in monoculture and polyculture systems. In spite of the availability of huge potential resources in the form of swamps and derelict waters that could be effectively used for commercial farming and huge market demand of these species, large scale culture of these species is yet to receive due attention. Development of balanced supplementary feed owing to its carnivorous feeding habits and availability of desired quantity of seed of right size are the two critical aspects, which have to be addressed. Research with regard to development and standardization of induced breeding and grow-out technologies of several other non-air breathing catfishes like *Mystus seenghala*, *M. aor*, *Pungasius pungasius*, *Wallago attu*, *Ompak pabda* are also being envisaged in view of the high consumer preference for these in different parts of the country.

Culture of freshwater prawn

The giant freshwater prawn, *Macrobrachium rosenbergii* is the largest and fastest growing species among freshwater prawns. The technology of hatchery of the species has been developed and standardized for obtaining

commercial production seed with an average survival level of 60% from zoea I to PL. The development of hatchery technology for *M. rosenbergii* and later the technology of seed production of Indian riverine prawn, *M. malcolmsonii* has opened up possibilities for diversification of freshwater aquaculture. There are about 35 freshwater prawn hatcheries established mainly in the states of Andhra Pradesh, Tamil Nadu and Kerala producing about 200 million seeds per annum, as against the projected demand of 10,000 million seed for development of at least 0.2 million ha water area in coming years.

During the last five years, freshwater prawn farming sector has witnessed overwhelming growth with as much as 24,000 ha additional area, thus bringing total area coverage of the country to about 37,000 ha achieving production over 30,000 tonnes. Monoculture of freshwater prawn at stocking densities of 30,000-50,000/ha has shown production levels of 1.0-1.5 tonnes/ha in a culture period of 7-8 months. Further, polyculture of freshwater prawn along with carps has also demonstrated to be a technologically sound culture practice and economically viable option for enhancing the farm income of the farmers. With the increased thrust of the farming practice in last few years, inadequacy of seed has become a major constraint. Establishment of a chain of commercial hatcheries in the coastal states of the country to meet this need should receive due attention.

Freshwater pearl culture

While marine pearl culture in India had its beginning in the early seventies, freshwater pearl culture remained an unexplored area till late eighties until the research programmes by the Central Institute of Freshwater Aquaculture, Bhubaneswar were initiated. The investigations by the institute in last one and half decades have not only led to development of the base technology of surgical implantation by using three commonly available freshwater mussel species, viz., *Lamellidens marginalis*, *L. corrianus* and *Parreysia corrugata*, but also standardized different steps involved for the production of cultured pearls. Three different surgical procedures that is, mantle cavity

insertion, mantle tissue implantation and gonadal implantation techniques have been standardized for obtaining different kinds of pearl products. In mantle cavity insertion method, the products obtained are shell attached, half round or design pearls depending upon the shape of nuclei implanted. While in mantle tissue implantation procedure the products are unattached, irregular to oval graft pearls or small round nucleated pearls, in gonadal implantation the pearls produced are unattached and slightly larger round pearls.

In spite of fact that freshwater pearl culture possesses several advantages in terms of commercial-scale availability of natural stock of pearl mussels with over 50 species; wider area of farming, even in non-maritime regions; operational ease in management of freshwater culture environment; absence of natural boring and predatory organisms; traditional pearl marketing environment; availability of economically viable indigenous technology; overall cost effectiveness of operations; and most importantly the availability of cheap labour force, which can be trained for taking up the pearl culture, commercial farming of the freshwater pearl mussel is yet to be established in the country. Emphasis on entrepreneurship development through institutional backup for technology transfer; assistance by financial institutions for credit; Governmental interventions for greater technology dissemination and subsidies; and organized and coordinated effort for market promotion are the aspects that need serious attention for the future development of the sector.

Integrated fish farming

Integrated fish farming is the combination of two or more normally separate farming systems where byproduct i.e., waste from one sub-system is utilized for sustenance of other; for example fish-pig/poultry/duck farming. Though organized integrated farming systems are not very common in the country, use of organic manures in the form of cattle wastes and poultry droppings are common in most of the farms of the country, especially, in carp culture farms. Production levels 3-5 tonnes/ha/year have been demonstrated by the integration of fish with poultry/duck/pig, with waste derived from these

farm animals as principal input and without provision of any supplementary feed. The system is not only found to provide considerable potential and scope for augmenting production, but also offer enormous scope for employment generation, betterment of rural economy and improving the socio-economic status of rural community.

Cage and pen culture

Commercial fish farming in cages is almost non-existent in the country, even though the practice is widely accepted globally. The information on cage culture in the country is limited to a few experimental trials with major carps and catfishes, with a maximum-recorded production of 3.3 kg/m³/month during grow-out culture of grass carp. With over 3 million ha potential area under reservoirs, which are otherwise either unutilized or under utilized, the emphasis on cage culture is inevitable in coming years to meet the ever-increasing demand of fish. Further, cages can also be used for nursing fry in reservoirs where transportation of desired quantity and size of seed from distant places are difficult.

Pens are usually constructed in shallow margins of reservoirs, tanks and ox-bow lakes. They can effectively be utilized for raising fry and fingerlings, which has been demonstrated in several trials carried out all over the country. The system possesses great potentials considering the availability of large extent of the water resources in terms of reservoirs, swamps and ox-bow lakes in the country.

Sewage-fed fish culture

The practice of recycling sewage through agriculture, horticulture and aquaculture is in vogue traditionally in several countries, including India. Sewage-fed fish culture in *bheries* of West Bengal is an age-old practice. Though the area of coverage is gradually reducing, about 5700 ha is still utilized for growing fish by intake of raw sewage into the system and as much as 7000 tonnes of fish, mainly contributed by carps, are produced annually from these water bodies. Experimental result has shown high potential productivity of the system with record of over 9 tonnes of fish/ha within a culture period of one

year. As sewage arising out of domestic wastes content high level of nutrients, emphasis on this practice has been on the recovery of nutrients and raising protein rich fish from the filth. To overcome from the concern of public health relating to consumption of fish cultured in sewage water, depuration measures by keeping the harvested fish in clear freshwater at least a fortnight before marketing has been suggested. Recently aquaculture has also been employed as a major option for treatment of domestic sewage. The Central Institute of Freshwater Aquaculture has evolved an aquaculture-based sewage treatment system incorporating duckweed and fish culture for treatment of domestic sewage.

Ornamental fish culture

Ornamental fish form an important commercial component of fisheries with world trade of over US\$ 7 billion. The relatively minimum requirement of space or attention compared to other pet animals is the reason for growing interest in keeping aquaria in household levels. In spite of India possessing a rich diversity of ornamental fishes with over one hundred varieties of indigenous species, in addition to similar number of exotic species that are bred in captivity, the export of ornamental fishes from the country is only about Rs. 10 million; the potential of the country has been estimated to be US\$ 30 million. The export at present is mainly confined to a few indigenous species from northeastern states and few varieties of exotic species. In spite of having vast potential domestic and international demand the sector has not received due attention either from research or by the industry and calls for systematic cataloguing of potentially important ornamental varieties, detailed study on their biology and behaviour, breeding and husbandry. The sector possesses great potential for growth by the establishment of commercial breeding and culture farms as a cottage activity with minimum levels of investments in different locations of the country.

Coldwater fisheries development

The country possesses significant aquatic resources in terms of upland rivers/streams, high and low altitude natural lakes, manmade

reservoirs, both in Himalayan region and western ghats, which hold large populations of both indigenous and exotic cultivable and non-cultivable fish species. Important food fishes in the region are mahseers and schizothoracids among the indigenous species and trouts among the exotic varieties. Research efforts over the years have led to development of technology of seed production of important cultivable species like trout, mahseers and snow trout. High survival rates of hatchery seed in case of trout along with successes in production of mahseer seed under control conditions have led to possibilities of farming. Breeding of different species of snow-trout viz., *Schizothorachthys niger*, *S. esocinus*, *S. micropogon* and *S. planifrons* and *Schizothorax richardsonii* has also become possible and the technology has been perfected for mass production of the seed under controlled farm conditions.

Brackishwater Aquaculture

Brackishwater aquaculture in India is an age-old practice in *bheries* of West Bengal and *pokkali* fields of Kerala. The modern and scientific farming in the country is only about a decade old. The country possesses huge brackishwater resources of over 1.2 million hectares suitable for farming. However, the total area under cultivation is just over 13% of the potential water area available i.e. 157,400 ha in 2001-2002. Shrimp is the single commodity that contributes almost the total production of the sector. The production levels of shrimp recorded marked increase from 28,000 tonnes in 1988-89 to 127,170 tonnes in 2001-2002. Moreover, the black tiger prawn, *Penaeus monodon*, also contributes the lion's share. The other shrimp species being cultivated are *P. indicus*, *P. penicillatus*, *P. merguensis*, *P. semisulcatus* and *Metapenaeus* sp. Culture of crab species like *Scylla serrata* and *S. tranquebarica* has also been taken up by few entrepreneurs. There are several other finfish species like *Mugil cephalus*, *Liza parsia*, *L. macrolepis*, *L. tade*, *Chanos chanos*, *Lates calcarifer*, *Eetroplus suratensis* and *Epinephelus tauvina* which possess great potential for farming, but commercial production of these species is yet to be taken up in the country.

The studies on induced breeding of shrimps were initiated by the Central Marine Fisheries Research Institute in the early 70s'; an experimental hatchery was established by the Institute in 1975 at Narakkal, Kerala, MPEDA took the lead for establishment of two large-scale hatcheries viz., TASPARC and OSPARC in 80's that gave a boost for the establishment of a number of commercial hatcheries in the private sector. The technology of hatchery production of shrimp seed involving broodstock development, induced maturation and spawning, larval-rearing and post-larval (nursery) rearing has been standardized. At present about 226 shrimp hatcheries are operational with a total production capacity of 10.5 billion PL20/year.

Though brackishwater farming in India is an age-old practice, the scientific and commercial aquaculture of the country at present is restricted to shrimp farming owing to the high export potential of the shrimps. The development of shrimp farming in the country took place only during early 90s with several industrial units joining the sector. Semi-intensive culture practices mainly with black tiger prawn have demonstrated production levels of 4-6 t/ha in a crop of 4-5 months. The high return coupled with credit facilities from commercial banks and subsidies from MPEDA have helped in the development of shrimp farming in the country to a multi-billion dollar industrial sector. In spite of disease problem that has been plaguing the sector since 1994-1995 the industry has learnt to live with certain modifications in pond management, which has resulted in sustaining the shrimp production of the country during last two years. During the year 2000-2001 the shrimp production of the country from aquaculture has witnessed a record production of 97,100 tonnes valued as Rs. 3,620 crores. Further, Mulletts and milkfish are important cultivable brackishwater herbivorous fish, with high growth potential. Seed production technology of seabass, *Lates calcarifer* is available for commercialization.

Mariculture

Intensive researches during last two decades by the Central Marine Fisheries Research

Institute have led to the development of several viable technologies with regard to seed production and culture of important marine crustaceans, molluscs and seaweeds. Several programmes on sea ranching of exploited stocks such as pearl oyster, *Xancus pyrum*, *Trochus* sp., *Turbo* sp. and giant clam have been taken up in the country.

Mussel culture

Green mussel, *Perna viridis* and brown mussel, *Perna indica* are the two important mussel species available in the country. The culture technology of these has been standardized. Mussel farming is carried out either in rafts or by long line methods. While long line system is very flexible and can withstand turbulent sea, raft system is more rigid and suited for more calm seas. Mussels attain harvestable size of 70-80 mm in 6-7 months of culture period; production levels of 12-14 kg mussels/meter of rope have been reported. In a raft size of 8 m x 8 m as many as 100 ropes can be suspended and the culture is done at about 5-10 m depth. Economic analysis of the mussel farming made based on pilot scale studies on raft culture by CMFRI showed over 40% profit margins on investment of about Rs. 24,000 per raft of 8 m x 8 m during a culture period of 6-7 months.

Edible oyster culture

The culture of edible oyster in India was initiated as early as the beginning of this century. However, intensive researches on various aspects of the culture were taken up only during seventies. The technique of oyster farming consists of two items, collection of spat and growing the spat to adult stage. *Crassostrea madrasensis* is the only species that is found to be important for commercial farming. The species reach harvestable size (80 mm) in a culture period of 7-8 months and production levels of 8-10 tonnes of shell on oysters/ha are obtained. Estimated economics of the culture of edible oysters in a unit area of 300 sq. m with rack and ren method showed over 44% of profit over an initial investment of about Rs. 21,000 including Rs. 16,000 as fixed cost. Technology has been developed for hatchery production of seed, which has opened up scope for establishment of large-scale commercial farms.

Pearl culture

The success of marine pearl culture in India was achieved in 1973 by the Central Marine Fisheries Institute at its Tuticorin Regional Centre. Raft culture techniques are followed for culture of pearl oysters and the important species being *Pinctada fucata*. Oysters of over 20 g at its post-spawning recovery stage are used for nucleus implantations. The oysters after thorough washing in cleaned seawater are narcotized by using menthol, which helps in relaxation of adductor muscles within 45-60 minutes. The surgery involves grafting of a piece of mantle of the donor oyster in the gonad of the oyster, followed by implantation of a spherical shell-bead nucleus of about 3-7 mm diameter. Multiple implantations are also done depending on the size of nucleus. The post-operative culture period for the implanted oyster is usually 3 months to 18 months depending on the size of nucleus implanted.

Seaweed culture

Seaweed forms an important component of the marine living resources, available largely in shallow seas, wherever, suitable substratum is available. Agar agar and algin are two principal industrial products of seaweeds. Seaweed is also used as food, fodder, fertilizers and in several other industrial and pharmaceutical products. The seaweed resources of the country are mainly confined to the coasts of Tamil Nadu and Gujarat. Since 1972, CMFRI is involved in experimental culture of different seaweed species and developed technologies for important agarophytes like *Gracilaria edulis*, *G. corticata* and *Gelidiella acerosa*. Both net and rope culture technologies have been standardized. Fragments of seaweeds are inserted in the twists of the coir rope nets of 4 m x 2 m in size for culture of *G. edulis* and the nets are fixed at about 1 m depth in near-shore water with the help of wooden poles. Into this method 1 kg of seed material would yield on an average 3 kg of *G. edulis* in a culture period of 60 days. 1000 such nets can be fixed in one-hectare area and production of 30 tonnes/ha can be obtained. With a minimum of four crops a total of 120 tonnes of fresh *G. edulis* can be produced in one year. In case of *G. acerosa* both coral stone method and net culture method

have been standardized. Culture practices of several other species are on experimental scale.

Governmental support and assistance from public financing institutions with an element of risk coverage in the initial stages are necessary for establishment of commercial mariculture farms. Ownership or leasing right with protection against navigation, traditional fishing and encroachment are other pre-requisites for development of farming, which must be addressed by the Governmental interventions. Taking into account the potentials of production of fish and shellfish from different areas of the fisheries sector, following strategies for enhancing production have been evolved (Annexure).

Conclusions

Possessing 2.4% of the global land area India sustains 16% of the world population. Increasing per capita fish availability from the present level of only 8 kg to 11 kg (as recommended by World Health Organization) is the primary challenge before the country. Considering the limited scope of the capture fisheries from coastal waters and natural inland waters like rivers and estuaries, emphasis on aquaculture and culture-based fisheries from reservoirs and floodplain wetlands to meet the targeted fish requirement of 8.3 million tonnes by 2020 is appropriate considering the availability of vast water resources, rich cultivable species diversity and sound technological base.

Annexure : Action Plan for Enhancing Production

<p>Coastal Aquaculture Brackishwater area available 1.2 million ha. Presently under utilization 0.1 million ha. Present Production 0.9 lakh tonnes Projected potential production 0.5 million tonnes</p> <p>Strategies</p> <ul style="list-style-type: none"> ➤ Increasing water area under aquaculture practices ➤ Increasing productivity of existing water bodies ➤ Diversification of candidate species ➤ Research support for sustainable, eco-friendly and techno-economically viable hatchery & culture systems ➤ Fish health management and disease diagnostics ➤ Fish nutrition and feed formulation ➤ Fish genetics and selective breeding ➤ Utilization of inland saline soils for aquaculture <p>Capture Fisheries Present annual production 0.5 million tonnes Estimated production potential 0.8 million tonnes</p> <p>Strategies</p> <ul style="list-style-type: none"> ➤ Management of stocks in reservoirs ➤ Stocking and selection of right species ➤ Maintaining proper harvesting schedules ➤ Fishery regulations, closed seasons, mesh regulation, fishing efforts. ➤ Culture based fisheries ➤ Pen & Cage culture technologies 	<ul style="list-style-type: none"> ➤ Resources specific harvesting techniques ➤ Management models for culture based fisheries ➤ Hill fishery resources assessment and management ➤ Development of sport fisheries in hill areas <p>Culture Fisheries Present annual production 2.3 million tones Estimated production potential 4.5 million tonnes</p> <p>Strategies</p> <ul style="list-style-type: none"> ➤ Increase in the coverage of areas of ponds and tanks for aquaculture practices ➤ Increasing productivity of existing water bodies ➤ Diversification and Intensification of culture practices ➤ Research support for sustainable, eco-friendly and techno-economically viable hatchery & culture systems ➤ Fish health management and disease diagnostics ➤ Fish nutrition and feed formulation ➤ Fish genetics and selective breeding ➤ Aquaculture technologies for hill fisheries <p>Harvest and Post-harvest sector</p> <p>Strategies</p> <ul style="list-style-type: none"> ➤ Fuel-efficient and resources specific craft and gear ➤ Eco-friendly and responsible fishing techniques for EEZ ➤ Post harvest value addition, waste utilization and by products from un-conventional fish species ➤ Biomedical, pharmaceutical and industrial products from aquatic organisms ➤ Expansion of domestic and international marketing network
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