

Food Security in India: *Is Aquaculture a Solution in the Offing?*

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Abstract: Food security has become the prime concern with the increasing trend of population growth in the country. Increasing fish production to meet the challenges of nutritional security has drawn the attention of the planners and policy makers. In this context, aquaculture is considered as a promising food production sector for high quality protein food and providing livelihood to the rural populace. The near stagnated capture fisheries is struggling to meet the demand for fish protein, especially in the context of the rising proportion of fish eating population. Because aquaculture has immense potential to provide food for the poor, it is essential to make it more efficient and cost-effective. However, there is multitude of challenges associated with the growth of this industry. Thus, systematic and technological interventions backed by adequate policy support are very vital for making the aquaculture operations sustainable and economical. Here, we discuss the status, potential, strategies, approaches and the way forward for achieving the targeted fish production through fish farming in India.

Keywords: Aquaculture, food security, freshwater, brackishwater, mariculture

1. Introduction

Food security refers to access to quality food for everyone at every time. In India, where one third of its population is believed to be absolutely poor, the issue of food security needs to be closely studied and mitigated. The second largest populated country in the world (with more than 1.2 billion people) will not be able to feed herself unless improvement is made in the availability and access to food. The effort of the government of India in this direction has resulted in the implementation of the National Food Security Bill in the year 2013.

The objective of the National Food Security Bill is to provide legal rights, to selected strata of population, for food and nutritional security. The bill which seeks to provide food to a major chunk of the population at subsidized rates, however, is not free from apprehensions. The challenges faced were the lack of acceptable measures of food needs and lack of consensus while identifying the number of people below poverty line (BPL) at the state level. The ever-

growing Indian population may also act as a barrier for the success of the bill in the years to come.

The rapidly growing population in India is affecting the percapita availability of food grains. Over the last fifty years, the foodgrain production has increased considerably. The advantage of this increase in foodgrain production is, however, not visible in the percapita availability of food grains. The annual percapita availability of food grains, which was 171.1 kg in 1961 has come down to a level of 169 kg in 2011 (Fig. 1). Rising population is nullifying the effect of growth in food grain production, not forgetting several other factors which determine the access to food grains. Percentage change and Compound Annual Growth Rate (CAGR) in human population, foodgrain production and percapita availability of food grains is given in Table 1. The human population and food grain production had grown up by 2.09% and 2.36% respectively from 1961 to 2011. However, the annual percapita availability of food grain had increased only by 0.04% during this period.

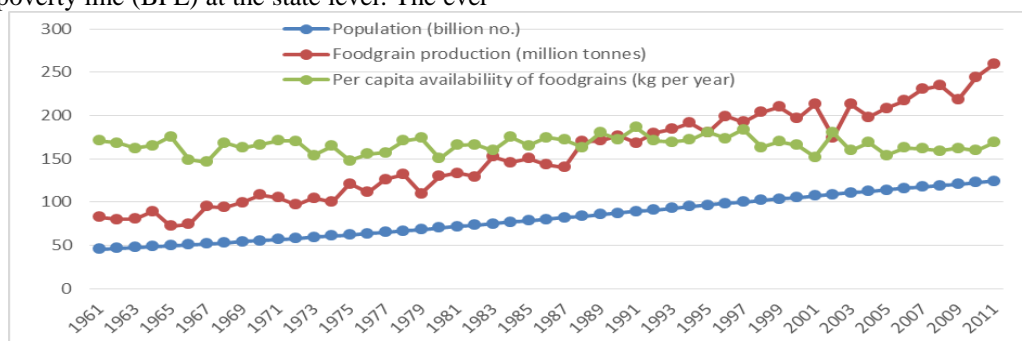


Figure 1: Growth in human population, foodgrain production and annual percapita availability of foodgrains from 1961 to 2011

Table 1: Percentage change and CAGR in human population, foodgrain production and per capita availability of foodgrains

Decade	Population (billion no.)		Foodgrain production (million tonnes)		Per capita availability of foodgrain(kg per year)	
	% change	CAGR	% change	CAGR	% change	CAGR
1961-1970	21.21	2.16	31.08	3.03	-2.92	-0.51
1971-1980	23.54	2.19	23.22	3.76	-12.21	0.06
1981-1990	21.95	2.22	32.33	3.51	3.92	0.51
1991-2000	18.16	2.24	16.88	3.49	-10.90	0.12
2001-2011	15.88	2.27	21.82	3.59	11.26	0.30
Overall	171.69	2.09	213.49	2.36	-1.22	0.04

Source: Authors' calculation based on GoI 2013.

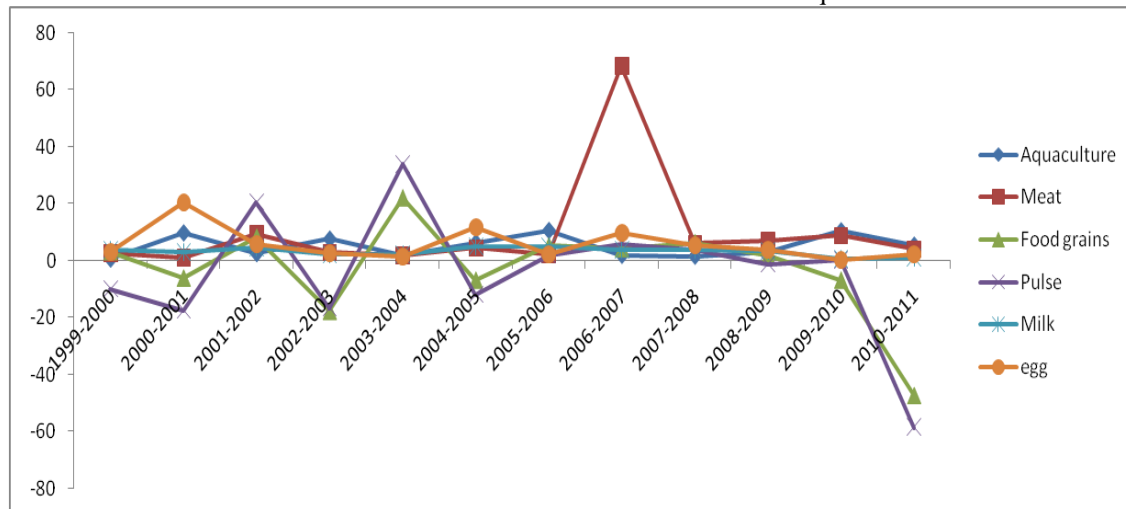
Human population projections by United Nations indicate an addition of 0.3 billion people to India's present population by 2045. Thus, the number of mouths that the country has to feed will be increased to 1.5 billion in the next three decades. The annual percapita availability of foodgrains as well as nutrients may suffer a further decrease unless corrective measures are taken immediately. The trends in nutritional intake, provided by National Sample Survey signify the importance of consumption diversification into high value nutrient rich food items. The average calorie and protein intake at all India level has declined, and the share of cereals in total calorie and protein intake has also fallen. In India, the daily percapita protein intake has declined from 60.2 g to 55.0 g in the rural households and from 57.2 g to 53.5 g in the urban counterparts between 1993-94 and 2009-10 (NSS 66th Round). Interestingly, the percentage share of protein intake from milk and milk products, egg, fish and meat has increased over the past and that of cereals and pulses has declined.

Table 2: Percentage break-up of protein intake from various sources in rural and urban households

Year	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	All
Rural						
1993-94	69.42	9.76	8.81	3.66	8.35	100
1999-2000	67.43	10.91	9.19	4.04	8.43	100
2004-05	66.37	9.47	9.28	3.98	10.84	100
2009-10	64.87	9.06	10.02	4.04	12.01	100
Urban						
1993-94	59.41	11.54	11.66	5.29	12.1	100
1999-2000	57.03	13.1	12.43	5.98	11.46	100
2004-05	56.16	11	12.33	5.47	14.98	100
2009-10	56.39	11.31	13.75	5.59	12.96	100

Source: NSS, 2012

Cereals and pulses alone cannot be relied up on to meet the dietary protein requirement for the rising population. Area expansion to increase the production of cereals and pulses may also not befit to India. The policy makers are hoping for a second green revolution to increase the foodgrain production to the level which can support the population surge. Thus, it is right time that we tap the potential of livestock and fisheries to meet our dietary protein demand and other nutrient requirements.



Source: NSS, 2012

Figure 2: The comparison of percentage growth for different food groups

Fisheries sector, especially aquaculture, can be an important contributor in the supply of animal protein in the future albeit the proportion of fish in the diet of the Indians is significantly less. Presently, cultured fish is the fastest expanding agricultural commodity in comparison to other agricultural commodities like meat, food grains, pulses, milk and eggs (Fig. 2), and there is little scope to enhance its

production of marine fisheries which is already stagnated. Aquaculture therefore, has an important role to play in ensuring food and nutritional security of country.

2. Fish as a Health Food

Health food refers to specific food items having beneficial effect on human health in addition to the normal nutritional role that they perform. Fish contains proteins and other nitrogenous compounds, lipids, minerals and vitamins and very low levels of carbohydrates. The biochemical composition (Table 3) of fish shows that it is a good source of protein and essential fatty acids. Animal proteins are generally superior to plant proteins and fish is one of one of the cheapest sources of animal protein. Fish proteins are of superior quality owing to the higher proportion of myofibrillar proteins and essential amino acids. Apart from this fish lipids provide health promoting omega-3 poly unsaturated fatty acids (PUFAs) like highly unsaturated (with 5-6 double bonds) fatty acids which are beneficial to heart and aid in the prevention of atherosclerosis, cancer and Alzheimer's disease etc.

Table 3: Biochemical composition of fish

Component	Quantity (%)
Moisture	65-80
Protein	15-20
Fat	5-20
Ash	0.5-2

Source: Gopakumar, 2002

The proximate compositions of some major species presented in Table 4 indicate that the fish is also a good source of vitamin B complex. The species with good content of liver oil is a good source of fat soluble vitamins such as A and D. Fish is also enriched with adequate concentrations of calcium, phosphorus, iron, copper and trace elements like selenium, iodine and zinc. In short, fish is a good source of all nutrients except carbohydrates and vitamin C. For children, small fish can be a source of calcium and phosphorous for bone and teeth development. The challenge, however, is to develop acceptable fishery products which can be used as a complementary food (paste or powder form) for children. According to dietary guideline of National Institute of Nutrition (NIN), we have to take fish more frequently (at least 100-200g fish in a week) and have to prefer it over meat and poultry.

Table 4: Proximate composition of commonly available fishes of India

Species	Proximate composition (%)				mg/100 g				
	Moisture	Protein	Fat	Ash	Na	K	Ca	Fe	P
<i>Catla catla</i>	76.30	19.60	1.30	0.90	58	161.7	495.2	1.0	245.0
<i>Labeo rohita</i> (rohu)	76.90	19.10	0.20	0.90	112.2	132.2	86.3	1.4	128.7
<i>Cirrhinus mrigala</i> (mrigal)	77.10	19.00	1.10	1.40	69.5	170.5	352.1	1.1	283.2
<i>Clarias batrachus</i> (magur)	78.70	18.20	1.42	0.97	-	-	-	-	-
<i>Mugil cephalus</i> (mullet)	74.90	20.80	5.10	0.60	136.4	252.8	136.9	4.4	175.0
<i>Chanos chanos</i> (milk fish)	70.90	23.50	3.60	1.40	83.2	251.4	9.3	1.3	179.5
<i>Etropolis suratensis</i> (pearl spot)	75.30	22.50	2.40	0.90	126.9	296.7	315.3	1.8	251.0
<i>Oreochromis mossambicus</i> (tilapia)	77.30	20.47	0.58	0.90	-	-	585.2	1.5	235.0
<i>Macrobrachium rosenbergii</i> (Fresh water prawn)	78.29	21.17	0.27	0.37	182.2	298.6	74.0	1.2	179.9
<i>Penaeus indicus</i> (shrimp)	76.80	17.50	0.58	1.46	209.0	382.0	32.3	5.3	268.0
<i>Perna viridis</i> (mussel)	76.69	12.55	2.57	2.06	180.1	251.1	54.3	0.9	102.4

Source: Gopakumar, 2002

3. Role of aquaculture

Indian fisheries sector has been contributing significantly to the protein supply and food security of the country since 1950. The current average annual growth rate of this sector is 4.7%. The fisheries sector contributed Rs 80, 000 crores to the GDP (at current prices), which is 0.96% of the total GDP during 2012-13. During 2012-13, the export of marine products reached 9, 83,756 tonnes valued at Rs. 30, 213.26 crores and US \$ 5.007 billion. Fish production in India has followed an increasing trend from 0.72 million metric tonnes (mmt) in 1950-51 to reach 10 mmt in 2013-14. This comprises 4 mmt from marine sources (capture) and 6 mmt from inland fisheries (including aquaculture). Thus it is evident that, aquaculture leads the blue revolution in the country as there is no considerable growth of fisheries from open water sources. About 6-7% annual growth rate of aquaculture in last two decades has made India the second largest producer of farmed fish in the world after China. Aquaculture, which was mainly an extensive activity in the

1970s and 1980s, has evolved continuously and at present, it is mainly considered as a commercial enterprise. Fresh water aquaculture contributes majorly to lead the total aquaculture production in India, since the mariculture sector is still in infancy.

4. Status and Scope of Inland Aquaculture

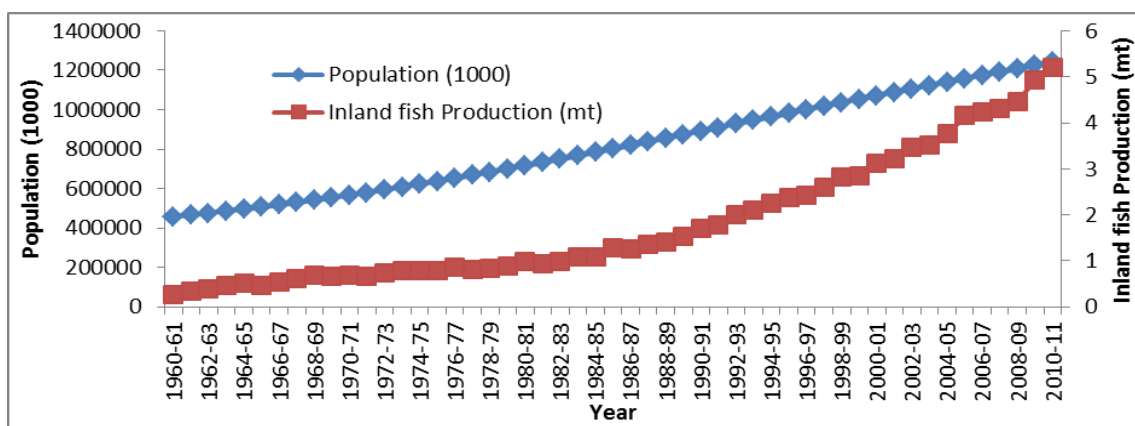
Fresh water aquaculture

The major resource for freshwater aquaculture in the country is 2.41 million ha of ponds and tanks. The other resources where fish farming can be undertaken include floodplain wetlands, lakes, reservoirs, irrigation canals and paddy fields. In India, more than 75% of the aquaculture production is being contributed by carps (Indian Major Carps (IMC), exotic carps and medium carps). Recently, a catfish, *Pangasius* species which is becoming popular among aqua farmers and interestingly, India is now the third largest producer of this species after Vietnam and Thailand. The inland fisheries resources provide full time vocation to

1.24 million fishers, and contribute approximately 6.0 mmt to annual fish production in India. In inland capture fish production, India occupies third position after China and Bangladesh. It provides nutritional and livelihood security to the rural people through fishing and ancillary activities like fish processing, value addition and fish marketing. However, reports say that only about 40% of the available ponds are utilised for fresh water fish culture activities. The rapid growth in the inland fish production since 1984-85 clearly depicts its scope to serve the cheapest protein source to growing population of our nation in future (Fig. 3). Reservoir fishery in India has enormous potential for further development with the incorporation of suitable management techniques. The total area of the reservoirs is estimated as 3.15 million ha out of which large and medium reservoirs comprise 1.6 million ha. The total and partial utilisation of this resource potential under reservoirs will generate about 0.98 mmt and 0.24 mmt of fish respectively with an average

productivity of 0.25 tonnes/ha. Another important resource is the flood plain wetlands which hold a potential for 0.3 mmt of fish and an area of 0.35 million ha with an average productivity of 0.85 tonnes/ha.

The farming of freshwater prawn primarily the giant fresh water prawn, *Macrobrachium rosenbergii* (the largest and fastest growing species), is another area for generation of fishery resources in which the culture can be practiced as monoculture or polyculture with major carps. Annually, about 30,000 tonnes of fresh water prawn is produced from an area of 43,433 ha with an average productivity of 990 kg/ha/year. Seed production has been adequately addressed through hatcheries in coastal states and demonstrations in inland states using artificial sea water or ground saline water.



Source: (Handbook of Fisheries and Aquaculture, 2011, Authors' calculation based on Agricultural Statistics at a Glance 2013)

Figure 3: The comparison of trends in Indian population and inland fisheries production

Seed production

Production of quality fish seed is vital for the development of aquaculture and culture-based fisheries in inland fishery resources. The present total fish seed production (mainly carps) from major fish seed producing states of India amount to 26, 276 million fry and 11,736 million fingerlings. Out of this, the state of West Bengal contributes 84% and 50% respectively to fingerling and fry production of our country. Hence, there should be rigorous initiatives from other states to augment the seed production and ensure year round supply. In this regard, reservoirs can be utilised as a good resource for production of fish fingerlings through cage culture technique. Considering the infrastructure facilities for seed production, the production and collection centres should be located near to the farming sites in order to reduce the cost in logistics, transportation and seed mortality. The annual fish seed requirement for stocking in inland resources is presented in table 5.

Table 5: Annual fish seed (Fingerlings) requirement during the Twelfth Five-Year Plan

Resource/fish	Area(mha)	stocking rate (fingerlings/ha)	requirement (million eggs)
Ponds and tanks (carps)	2	8000	16000
Reservoirs (carps)	3	1500	4500
wetlands (carps)	0.35	3000	1050
scampi farming	2	2000	4000

Source (Draft report for the Twelfth Five Year Plan, 2012)

Feed and Nutrition

Freshwater fish farmers follow the crude mixture of rice bran and oil cakes to feed the fishes. Though these traditional feed recipes have been useful in semi-intensive culture practices, their role in sustainable intensification of aquaculture is confined. It is estimated that the demand for feed from the freshwater aquaculture sector by the end of the twelfth Five Year Plan would be approximately 10 mmt. If we improve the water stability of the prepared feed in 50% of the aquaculture farms, the Feed Conversion Ratio (FCR) can be reduced from 4 to 1.5, which will significantly reduce the feed ingredient requirement. Considering the infrastructure facilities, the development of fish feed mills and scaling up of production from the existing feed mills is the need of the hour. Further, familiarization of extruded

feed based aquaculture among the farmers through awareness, trainings and demonstrations can be carried out to improve the sustainable production from aquaculture. The major protein source of fish feed is fish meal itself, The availability of fish meal, the major protein source of fish feed is getting limited due to the stagnation or down growth of capture fisheries as well as increasing demand for fish consumption. Hence, there should be evaluation of alternate protein sources of animal and plant origin in order to meet the feed requirements for sustainable intensification of aquaculture.

Health management

Following the intensification of aquaculture and introduction of exotic species, the disease outbreaks are frequent in the culture systems of our country. This possesses a serious hindrance to the development of aquaculture and disease outbreaks will result in considerable economic loss in aquaculture, reduction of income for farmers and finally reduced fish supplies. Basically, the awareness level of aquaculture farmers on the aquatic animal health management is poor. Further, the farmer's knowledge on infrastructure facilities for disease surveillance, early warnings, diagnostics and field-level treatments is also inadequate. Therefore, there is an urgent requirement of an effective programme to improve the health and hygiene in aquaculture through setting up of quarantine facilities, steady surveillance, epidemiological studies and early warning systems, disease diagnostic laboratories and hands on training of field-level staff to assist the farmers in early diagnosis of the problem. Further, networking amongst national-level institutions and laboratories on scientific investigations, establishment of standard protocols for diagnosis, risk assessments and contingency planning in the event of disease outbreaks would also be essential.

Species diversification

India is a country where carp aquaculture (IMC. exotic and medium carps) provides major share (approximately 75%) of the cultured fish production both in terms of quantity and area of farming. The remaining aquaculture production comes from *Pangasius* sp., other catfishes and air breathing fishes. Therefore, species diversification in aquaculture is another vital aspect in freshwater aquaculture. The diversification of fish species in Indian aquaculture is limited just to 15 species in comparison with 29 species in China. The diversification of fish species in aquaculture will help to supply many fish resources pertaining to regional preferences. Besides, this will contribute to the conservation of species diversity in long run. Hence, there should be pragmatic efforts to encourage the utilization of the locally available and marketable species in aquaculture operations. There are many cultivable species with local demand viz. *Labeo calbasu*, *L. fimbriatus*, *L. gonius*, *L. dussumieri*, *L. bata*, *Cirrhinus reba*, *Systemus sarana* and *Puntius jerdoni* etc. Therefore, presently there is concerted effort for mass scale breeding and seed production to ensure the seed supply of these species and their inclusion as a part of carp polyculture on the basis of local demand. Moreover, experimental culture trials are also carried out for several species such as murrels, other air breathing fishes and

mahseers on the freshwater side and cobia, seabass, groupers, pompano, red snapper, lobster and seabream on marine side. Besides, sustainable and eco-friendly culture operations can be performed with the eco-friendly exotic species with rigorous monitoring to improve the production.

Water resource management

Water is turning as a scarce resource since there is heavy demand and competition for this resource among various sectors and users. This situation addresses the need for harvesting the rain water and optimizing its usage in aquaculture. Emergence of recirculatory system in aquaculture is a good initiative to cope-up with the increasing demand for water resources. Thus, modern engineering techniques have to be applied for the efficient utilisation of water in aquaculture. In this line, technologies are required for enhancing water use efficiency which may include systems for removal of metabolites and microbial load, maintenance of higher oxygen regime, minimizing water loss through seepage and percolation etc. Apart from this, conservation of existing water resources is also very important for increasing the availability of water in future.

Inland saline aquaculture

There are large tracts of salt affected land in the semi-arid and arid eco-regions of northern plains and central high lands in the states of Haryana, Rajasthan, Uttar Pradesh and Gujarat. These inland saline areas comprise a large volume of surface and sub-soil brackish water, with a slight difference in ionic composition with respect to sea water of same salinity. There are about 7.3 mha of salt and alkalinity affected soils exist, which are unfit for agriculture and these areas can be promoted for brackish water aquaculture. Experimental aquaculture trials in inland saline waters were initiated by the Central Institute of Fisheries Education, Mumbai at its Sultanpur and Rohtak Centres in Haryana. The studies suggest that fish species such as *Chanos chanos* (milk fish), *Mugil cephalus* (striped grey mullet), and *Etroplus suratensis* (pearl spot); shrimp species such as *Litopenaeus vannamei* (whiteleg shrimp) and *Penaeus monodon* (tiger shrimp) were found to be encouraging for inclusion in monoculture, polyculture and integrated farming in the salt affected areas. It is proposed that suitable schemes may be incorporated to promote utilization of these salt-affected areas during the twelfth plan period.

Ornamental fish culture

Ornamental fish farming holds good scope in the future since India is blessed with rich diversity of marine and fresh water ornamental fishes. The export potential of ornamental is about \$30 billion which is not fully utilised. At present, the export is restricted to a few species of indigenous fishes from north-eastern states and some exotic species and thus share of the country in Asia's ornamental fish exports is just 2%. However, the trade from the country is expanding at an annual rate of 20% though it amounts only 15 crores presently. Around 350 species of attractive indigenous and endemic freshwater ornamental fishes are available in India, especially in the biodiversity rich Western Ghats and the North Eastern Hills (e.g. loaches, barbs, etc). Similarly, a

large number of marine ornamentals are also sourced from the wild for exports. Ninety five per cent of our ornamental fish export is based on wild collection. Development of culture technologies is the answer to a long-term sustainable trade of ornamental fish, which reduces the insistence on wild populations. Intense efforts are being carried out by Central Marine Fisheries Research Institute and Central Institute of Freshwater Aquaculture for standardization and commercialization of the seed production techniques. The initial experimental results are encouraging and a great future is ahead for ornamental fish culture in the country.

Database on inland fisheries sector

Database on inland fisheries and aquaculture is a weak spot in the progress of Indian fisheries. The resources under inland fisheries and aquaculture are highly dispersed and mostly located in inaccessible and difficult terrains. Therefore, a focused effort would be necessary in various aspects such as resource mapping through GIS, regular building and updating of the data-base, manual survey of water resources, etc. Similar to marine fisheries, census may also be undertaken for inland fisheries during the Twelfth Five Year Plan. The NGOs and co-operative societies can be used in coordinating and undertaking the task at the district-level. The state and central level institutions can compile the same at their respective levels.

Diversified practices

There are several other non conventional practices of aquaculture including the sewage fed fish culture in Bheries of West Bengal, which is an example of efficient waste management. Cage cultures for *Etroplus* and mullets have also been tried in these regions other than the conventional carp culture. Region specific models have been developed in order to improve the management of aquaculture in different regions. The manipulations are associated with species, size, stocking density, biology and the seed availability. Integrated farming practices are coming up with the synergistic systems in which fish will be integrated with cattle, rice, horticulture crops, duck, pig and in various combinations.

5. Status and scope of mariculture and brackish water aquaculture

Brackish water aquaculture

The brackish water area with potential for shrimp culture is estimated between 1.2 and 1.4 mha. Presently, an area of about 1, 84,115 ha are under farming with an average production of about 0.11 mmt of shrimp annually. The average fish productivity has been estimated as 1,000 kg/ha/year. About 0.3 million persons received direct employment in shrimp farming and about 0.6 million people are employed under ancillary activities. Presently *L. vannamei* contribute about 80 percent of the total shrimp exports, leaving behind the other species, *Penaeus monodon*. About 91% of the shrimp growers in the country have a holding between 0 to 2 ha, 6% between 2 to 5 ha and the remaining 3% have an area of 5 ha and above. The infrastructure facilities like hatcheries and laboratories for

disease diagnosis are established over the years in both private and public sector. The culture of introduced species, Whiteleg shrimp (*Litopenaeus vannamei*), has been successful in the country and the production and productivity from brackishwater resources have increased. However, the availability of specific pathogen free (SPF) or specific pathogen resistant (SPR) seed stock is still a major constraint in expanding shrimp farming and this requires serious attention.

Mariculture

The long coastline of 8017 km of the country along with large number of calm bays and lagoons offer good scope to develop mariculture/sea farming. Presently, sea farming is confined to green mussels practiced along the Malabar region of Kerala producing with an average annual production of 20,000 tonnes. Seaweed farming is successfully carried out along the Ramanathapuram and Tuticorin coasts of Tamil Nadu producing about 5000 tonnes of seaweed annually. Keeping in view the available potential that exists for coastal aquaculture and mariculture, developmental initiatives are urgently required to make these activities significant contributors in seafood production. Moreover, recently cage farming of cobia, seabass, groupers, red snapper, breams and lobsters are introduced experimentally by CMFRI and yielded progressive results. Thus, there is a good scope for improvement of finfish and shellfish cage culture in near future.

Seed production

In coastal aquaculture, quality seed of *P. monodon* has emerged is a major bottleneck. Interestingly, the introduction of *L. vannamei* has reduced the pressure on tiger shrimp wild stocks. However, *L. vannamei* farming is completely dependent on import of SPF seeds which may turn in to a critical chokepoint in the future. A full-fledged brood stock development programme including brood banks for tiger shrimp is the need of the hour and it should be executed through the research institutions. Similarly, the availability of required quantities of quality seed is a major concern in the development of marine finfish cage culture in our country. In this regard, a national-level facility for raising brood stock can be developed research institutes like CMFRI and juveniles produced by this facility can be used for supplying to fishermen for cage culture operations.

Species and culture system diversification

Mariculture development in our country needs paradigm shift in both farming practices and cage construction technology. The successful experimental trails carried out by the research organisations should be forwarded in the form of front line demonstration to convince the fish farmers on the economic viability. The scientific and commercial aquaculture of the country at present is largely dependent on shrimp farming. The production levels of shrimp recorded an increase from 28,000 tonnes in 1988-89 to 2.9 lakh tonnes in 2012-13. Shrimps contribute 64.12% of total marine export earnings in 2013-14 and about 80 % of the shrimp export is contributed by *L. vannamei* using only 13%

of the available potential water area. The semi-intensive culture can result in promising production levels of 4 to 6 t/ha in a crop of 4-5 months. The growth of the sector however was hindered subsequently by several factors including the regulation of farming in the CRZ, white spot disease and the depressions in export market. However, the industry has made certain modifications in pond management like moderate stocking densities, good farm management and health management to control the disease outbreaks and mass mortalities. With respect to species diversification, no other species has come up as a potential species in the culture systems. Culture of crab species say *Scylla serrata* and *S. tranquebarica* is also taken up by some entrepreneurs. Finfish species viz., *Mugil cephalus*, *Liza parsia*, *L. macrolepis*, *L. tade*, *Chanos chanos*, *Lates calcarifer*, *Etroplus suratensis* and *Epinephelus tauvina* are identified as potential candidates for farming in coastal regions. Nevertheless, the farming has been restricted only to the seabass, *Lates calcarifer* due to issues in the availability of technology for seed production and farming.

Successful breeding of cobia, *Rachycentron canadum* and silver pompano, *Trachinotus blochii* has been achieved recently at CMFRI. These experimental trials should be focused further for diversifying the culture practices. In this line, the coastal cage culture trials are now initiated with cobia, seabass, silver pompano, groupers, red snapper, breams, lobsters and mussels and showed encouraging results. The efforts on technology development for mariculture over last three decades have led to development of technologies for farming of mussels, oysters, seaweeds and crab and lobster fattening. With the rack, longline and raft culture technologies for green mussel, *Perna viridis* and brown mussel, *P. indica*, the cultured mussel production of the country has increased from about 20 tonnes in 1996 to around 20,000 tonnes in 2011. Further, the farming of edible oyster, *Crassostrea madrasensis* has shown high growth potential in recent years. These technologies can be strengthened and transferred to different coastal regions of the country to augment the coastal fish production and to provide the livelihood security to the coastal people.

6. Sustainability and Biodiversity Issues In Aquaculture

Aquaculture is also under public scrutiny because of its possible impacts on biodiversity. The critical aspect seems to be the exploitation of wild populations for culture operations as well as on the negative impact caused by cultured animals on the environment. Aquaculture is very much essential in the coming future to provide fish protein for ascertaining food security, to ensure socio-economic wellbeing through the generation of livelihood opportunities. However, we may have to consider the aspects of aquaculture that are expected to affect the biodiversity and their quantification in terms of impact. In the initial phases of aquaculture sector, there was a greater dependence on wild seeds of fish, especially for shrimp and marine finfish culture. This have resulted in a high degree of loss of biodiversity through the overexploitation of larval stages of undesired species as well as diminished the recruitment to capture fisheries. With the development of artificial propagation techniques for most of the major cultured

species, the dependence on wild stock has reduced. On the other hand, the artificial methods were promised to augment conservation of depleted species. The development and commercialization of the artificial propagation technologies of the candidate species would be rather an adequate solution to all these problems.

7. Planning and Policies

Indian aquaculture has emerged with less scientific input and is also lacking promising inputs in terms of seed, feed, health management and marketing support. To optimize production from aquaculture, the programmes should be focused to improve commercial production and supply of quality seed and feed, management of culture environment and efficient utilisation of available water resource for culture. The miserable performance of FFDA's and Brackish water Fish Farmer's Development Agencies (BFFDAs) and inefficient extension methods has reduced the expected output from aquaculture. Therefore, these two field-level agencies have combined to form a single unit called as Fisheries and Aquaculture Development Agency (FADA). This agency is anticipated to modulate the fishery extension system and undertake extension of new technologies, promote networking among farmers and fishermen. This unit can also act as link between farmers and developmental agencies such as the Krishi Vigyan Kendras (KVKs) and the Agriculture Technology Management Agencies (ATMA). The Centrally Sponsored Scheme on 'Development of inland fisheries and aquaculture' during the Eleventh Plan was aimed at enhancing inland fish production, creation of employment opportunities, diversification of aquaculture practices, provide hands on training to farmers through the FFDA's and BFFDAs. As a result of this scheme during this period there was a significant improvement in the area brought under fish cultivation and training for farmers.

The treatment of aquaculture on par with agriculture must be the first concern while developing policies. This will help the aquaculture farmers to avail the benefits of taxation, water and power tariff, allocation of resources, leasing of water bodies for aquaculture and mariculture purposes, etc. Inland fisheries and aquaculture bill can be focused on the sustainable development of the sector. To achieve the targeted production of 11.58 mmt during the Twelfth Five Year Plan period, an amount of Rs. 6000 crores is required for HRD, institutional strengthening, policy reforms and overall improvement in the management and governance aspects. The improvement of production from freshwater, brackish water and coastal waters is necessary for achieving the targeted production. Some of the measures recommended for the sector wise development of aquaculture are the following

- 1) **Fresh water aquaculture: The fish food security of the country in future lies in the augmentation of fresh water aquaculture. A growth rate of 8% per year is expected which will supply 7.5 mmt of fish to the country. We should focus on the following points for achieving this target.**
 - Utilisation of more water area under ponds and tanks for aquaculture and increase the area availability through reclamation of weed choked waters.

- Diversification of species and diversification of farming systems such as integrated farming, ornamental fish culture and waste water aquaculture.
- Customized cold chains for marketing support
- Public private partnerships for culture operations and marketing the fish

2) Mariculture: Expected production in 2020- 0.2 mmt. We should focus on the following aspects to achieve the same.

- Identification of suitable culture sites and appropriate leasing policy
- Brood bank and hatchery facilities for high value fish and shellfish, ornamental fish and sea weeds
- Cage culture in open seas and island ecosystems through public-private partnerships and effective market linkages

3) Coastal aquaculture: Expected production in 2020- 0.3 mmt. The focus should be on following points.

- Increased area utilisation for culture through species diversification
- Adequate quantity of quality seed and feed
- Inland saline aquaculture for selected candidate species
- Public private partnerships and market linkages

8. Conclusion

Increased demand for food grains and protein will cause a price hike in a country like India, where population is quite high. Aquaculture can undoubtedly serve as a cheap protein source of fish in the future to feed the 1.5 billion people. The different sectors of aquaculture have to be strengthened in demand based manner to approach the target levels of production. India can play a major role in the production and distribution of the farmed fish around the world. The planet will have a reduced space for farming in the coming future. The vertical and horizontal expansion of the farming practices including the IMTA (Integrated Multi Trophic Aquaculture) should be initiated without compromising the biodiversity and germplasm. The strategies can be increased area utilization, improved status of feed, seed and supplements, Institutional strengthening, demand based production, disease control and surveillance, species diversification, efficient utilization of water resource, generation of database on cultivable areas and species, creation of demand for domestic and export markets, diversification of the culture practices, utilization under-utilized areas like inland saline waters, proper policy options for the management and the initiation of public-private partnerships. The future demand can be met sustainably, if the aquaculture will go hand in hand with the environment. The focus for the future should be producing more per drop of water and within the spatial limits.

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