

Assuring fish demand of India by 2030

through aquaculture development: issues and strategies

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Fish is known to provide high-value protein and a wide range of essential micronutrients, including various vitamins, minerals and polyunsaturated omega-3 fatty acids. Thus, even with supply in low quantity in the meal, fish is able to provide nutritional requirements for a large mass of the rural poor at an affordable price, besides satisfying the higher income group and the connoisseurs. At present fish constitute 16.6% of animal protein supply globally and 6.5% of all protein for human consumption. Popularity of fish in India has also been increasing significantly day-by-day. With availability of a rich fish faunal biodiversity of about 3,000 species, Indian population has been able to relish eating of diverse fish varieties in their meals. The total fish production in the country, together from marine and inland sector, has reached to the tune of 11.4 million tonnes in 2016-17, an almost 31.6% increase than the production level of 2010-11. This has placed the country as the 2nd largest global fish producer. The export earnings from the sector reached a new high of US \$ 7.08 billion (₹ 45,107 crore) during the financial year 2017-18, with shipment of 1.38 mmt of seafood, mostly frozen shrimp and frozen fish as the flagship items.

Key words: Aquaculture, Demand, Development, Fish, Strategies

THE marine capture fisheries production of 3.64 mmt (2016-17) of the country from the 8,129 km long coast line is primarily being exploited through small-scale fishing. Although the country is the third largest producer of captured fish from the marine sector, the efforts on harnessing the potential of these coastal resource for mariculture were initiated only in recent years. Considering the contribution in terms of quantity, the production from freshwater aquaculture was growing over years, with carp contributing major share of about 75 to 80% of the total aquaculture production. With adoption of semi-intensive carp polyculture practice, production levels of 5-6 tonnes/ha/yr is generally achieved, although several progressive farmers succeed higher production levels of 10 to 15 tonne/ha/yr. Further, the effective utilization

of only about two-thirds of the available pond resources and corroborated national average production of about 4.0 tonne/ha from these provide enormous scope for both horizontal and vertical expansion of the aquaculture in coming years, catering the future demand of both domestic and international markets. The sector contributes about 0.9% to the National Gross Value Added and 5.43% to the agricultural GVP (2015-16). With per caput current fish availability at 9.6 kg in the country, the country is yet to match the global fish consumption level of 20.3 kg. Further, with the addition of over 15 million population every year and gradual shift in the food habit oriented towards fish- a safe protein source, it is evident that the demand-supply gap is going to grow in the years to come.

According to an estimate by the World Bank (2013), 12.73 million tonne of fish is required for India by 2030 indicating deficit of 1.3 million tonne from its current production. At the same country has set its ambitious target of production of about 17 million tonne by 2030. Although the marine production after long period of stagnancy showed little sign of improvement, the entire additional supply has to be catered largely by aquaculture. Bridging the deficit fish supply, particularly when the marine capture has reached a plateau, is definitely a challenging task. This is particularly important as the increase in the production has to be made against the odds of emerging challenges which include water scarcity, reducing per caput land holding, climate change, and increased competition from other sectors particularly for inputs such as

feed and fertilizers, labour, etc. and also environmental issues.

Freshwater aquaculture

The country possess 2.414 million ha of ponds and tanks of which about 1.6 million ha of water area was brought under aquaculture. The freshwater aquaculture in the country has remained as the carp centric, with the three Indian major carps (catla, rohu and mrigal), and three exotic carps (grass carp, silver carp and common carp) contributing the bulk. Although, of late, the culture of the exotic pangas, *Pangasianodon hypophthalmus* received attention of aquaculture producer of the country, especially in Andhra Pradesh, the largest share of about 6.0 million tonne of freshwater aquaculture production today hitherto comes from carps only. However, higher growth potential of the pangas at higher stocking density has placed the species as the most important alternative species for the present aquaculture, both in pond and cage aquaculture systems. Some of the other diversified species those received attention over these years mainly include different species of minor carps and catfishes having regional preference, murrels and freshwater prawn. Use of these species in monoculture and polyculture in different combination showed to improve the fish production and farm income. Apart from these, with the development of breeding and seed production technologies, several other species showed their potential to be brought into the culture systems.

The R&D efforts of last seven decades have led to development of several epoch-making technologies, whose reach was far and wide. Development of technologies pertaining to the breeding and seed production of over 50 finfish and shellfish species, grow-out culture systems with varied production levels, genetic improvement of important cultivable species, nutrition and feed development, and fish health management including surveillance, prediction and control, have virtually led to the Blue Revolution in the country. The

phenomenal average annual growth rates of over 6% registered in last three decades is enough testimony of the large-scale adoption of different technologies and scientific farming practice by our farmers. There has been a quest in the sector for development of newer methods of fish farming, production of genetically improved variety, disease-resistant breed, nutritionally efficient balanced feed and therapeutics for emerging diseases.

Realization of fish as a safe protein and fish farming as a profitable venture has promoted the aquaculture activity in the country. Extensive support is now being extended by the Government for the sectorial development and there is positive response from the farmers' side also. However, bringing the second 'Blue Revolution' in the country requires systematic planning and strategic development of the sector.

STRATEGIES FOR AQUACULTURE DEVELOPMENT

The freshwater aquaculture sector in India today is considered as a well-organized industrial enterprise. While at hand the sector poised for great production prospect, on the other it is marred with several challenges. Therefore, it is necessary that such issues are analyzed and appropriate strategies are developed for overcoming these issues and realizing the growth potential of aquaculture sector.

Enhancing productivity: Adoption of sound scientific technologies, entrepreneurial initiatives and financial investments in several parts of the country, especially in the Koleru Lake region of Andhra Pradesh, although have led to achieving higher production levels of 6 to 10 tonne/ha/yr in carp polyculture system and 10 to 20 tonne/ha/yr in exotic pangus culture by the famers on a continuous basis, the culture practice in large parts of the country by and large has remained extensive. Although a number of reasons for such low productivity are often flagged, it is apt for taking pragmatic corrective

measures for keeping the growth pace of aquaculture production from the freshwater sector.

Effective resource utilization: Availability of suitable resource plays a key role for the success of culture. While ponds with 2.0 to 2.5 m water depth are usually considered optimum for grow-out farming, a considerable pond resources in the country do not comply with this requirement. Seasonal nature of the ponds retaining water only for 4-6 months are quite common in Jharkhand, Chhattisgarh, Odisha and Madhya Pradesh. Further, due to rainfed nature of the ponds, an erratic or reduced rainfall increases the risk of drying up or critical reduction in water depth in several areas, often force the farmers for premature crop harvest. The community-owned ponds, those constitute a major share of available resource, have inherent social and ownership problems which hinders adoption of scientific fish farming and even restrict stocking of fish seed. Many ponds also lose depth due to poor maintenance and thereby reducing water-holding capacity and fish production. Considering the fact that the resource renovation was included as an integral part in various schemes launched by the State Fisheries Departments in recent years, it is expected that large areas under shallow ponds would be brought under the scheme and thereby effectively utilized for productive farming.

The entire carp farming operation constitute components of nursery rearing of fry, production of fingerling and juveniles, and grow-out production. Despite availability of pond resources with varied depth, invariably most of these water-bodies in the country are used for grow-out purpose, leading to their in-effective use. Considering the water depth requirements for different activities vary greatly, these ponds can be allocated accordingly based on their depth and period of water retention.

Assuring seed availability and quality: The country at present produces over 45 billion of fry, mostly of carps, and is considered self-sufficient. But, the fingerling production process is often marred

with shortage of rearing space, besides the problem of long distance transportation. As a result, availability of fingerling, the recommended size for grow-out stocking, has remained a constraint and most of the resources are stocked with seed at fry stage, which often leads to poor survival and low production. In view of increasing deficit of fingerlings and juveniles of all cultivable species, it is necessary that more farmers are encouraged for taking up fingerlings and yearlings production. The concept of seed village development, especially in areas of low rainfall, need to be given greater thrust. Further, considering increasing thrust on diversification, it is necessary that seed production of these new species are intensified through incentivizing new hatchery establishment and their seed production chain. 'Mission Fingerling', the programme launched recently by the National Fisheries Development Board, and varied promotional schemes of the State Fisheries Departments encouraging fingerling production are important steps forward for increasing assured fingerlings supply.

Seed production in the freshwater sector was an unregulated activity. Unlike some other countries, where 'Seed testing and certifying laboratory' are established to monitor genetic purity of seed, in India such provision is non-existent except in case of brackishwater shrimp. Captive breeding of same population over the years in several hatcheries reported to result in poor genetic base, leading to inbreeding depression, retarded growth, poor disease-resistance and severe quality degradation of seed of important cultivable species. Many hatcheries do not find to comply to the required facilities for broodstock maintenance and also necessary hatchery facilities, and resort to large-scale hybridization.

Necessity of hatchery accreditation and seed certification although is emphasized time and again, strict action is necessary for their effective implementation to ensure the seed quality and its traceability. Genetic stock improvement through selective breeding has demonstrated to be an

effective tool for increasing production potential of the fish species. In this direction, apart from the successful production of improved rohu 'Jayanti', efforts are on for improving catla and freshwater prawn. Therefore, it is appropriate that similar programmes are undertaken in other potential fish species, although they require substantial investments. Gamete cryo-preservation technique proved to be another effective brood improvement protocol for quality seed production. The technology was standardized to store fish spermatozoa of major carps for years which are being used to fertilize fresh eggs and improve gamete quality. It is necessary that such technique is popularized among the hatchery owners to overcome the inbreeding issue.

Ensuring appropriate nutrition and feed: Supplementary feeding is an integral part of fish culture operation, constituting over 60 % of the input cost. However, the use of supplementary feed in freshwater aquaculture systems was in low key, mostly due to inadequate awareness on its benefit and reluctance among the practitioners for the investment. Despite the availability of floating pellet feed in adequate quantity, their use is mostly restricted to the progressive farmers, and mainly those undertaking farming of pangus catfish. The use of these feed in carp polyculture is limited, and farmers continue to use raw feed mixture of oil-cake and rice bran to safeguard the profit margin. The farmers often compare the cost of the conventional mixture with that of pellet feed without considering FCR. Though realization of better nutrition and higher biomass yield with balanced diet is a well-known fact, the practice is yet to be popularized in the carp farming sector. Expansion of aquaculture activity, therefore, needs promotion of use of concentrated feed through large-scale demonstration in different regions. Aquaculture sector is currently using about 20% of total concentrate feeds of 44 million tonne produced in the country. While promoting establishment of feed mill, efforts should also be made to encourage in finding alternate ingredients. The

small farmers also need to be encouraged resorting to the farm-made feed using local ingredients, which not only can reduce the cost of production, but also minimize pressure on conventional feed ingredients.

Fish health management: Health management during culture operation was a low key activity barring the preventive measures like use of lime and few chemicals. Only except in case of outbreak of certain fish epidemics like EUS, which are attended by the farmers, the other health problems as well as poor growth and mortality due to water quality issues are often ignored in culture ponds. Intensification of the aquaculture practice in recent years, however, have increased the incidence of disease, and thereby necessity of disease surveillance, prevention and remedial measure. Study of the crop loss due to infection/disease was initiated to assess the magnitude of economic loss. In a study on crop loss due to argulosis, the estimated loss was ` 30,000/ha. Systematic research efforts over last few decades have led to greater understanding of host, pathogen and environment relationship in the freshwater fish and shellfish species, generating wide range information on systematic aetiology of a large number of diseases. The national programme on fish disease surveillance, being implemented in large parts of the country over last five years, has been able to tackle the problem of new and emergency disease situation, besides keeping a close eye on the endemic disease issues. Remedies in the form of prevention through scientific inputs and environmental management, development of disease diagnostic tools, therapeutics for control of infection, immunostimulants, chemical formulation etc. were the key developments during recent years, which is expected to support the aquaculture sector in the wake of any disease threat.

Aquaculture diversification

Pond culture system in India largely involves carp polyculture involving 3-6 species or monoculture of catfish, despite the fact that

inclusion of more species into the system ensures better utilization of ecological niches of the pond and also the supplied inputs. Further, the culture system mostly uses cropping of single stocking single harvest and hence the productivity potential remains underutilized initially. Practice of multiple cropping, and multiple stocking and multiple harvest demonstrated to be advantageous in reducing input levels, investment and also multifarious risks involved in long-duration farming. Intercropping of minor carps in the initial six months of culture in the major carp based polyculture system was also proved to yield over 20% higher yield. Though major carp farming is an indispensable system in our country, the farmers need to be encouraged to take up farming of alternative species like murels, freshwater prawn and regionally important species having higher market value. Species diversification can also be an effective tool for conservation of our species. Besides, it could also serve for responsible aquaculture through effective utilization of the inputs, rural nutrition security and effective utilization of the seasonal ponds.

Unscrupulous addition of alien species into the culture system emerged as a big concern in recent years. Although certain exotic species like *Pangasius hypophthalmus* and paku, *Piaractus brachipomus* are doing well in the culture systems, lesson learnt from the introduction of African catfish *Clarius gariepinus* and accidental entry of the sucker mouth fish (devil fish) (*Hypostomus plecostomus*) warrants the need of cautious approach in introducing newer species in to our ponds.

Diversified aquaculture systems was developed to utilize varied type of water resources. Some of the systems include waste-fed aquaculture, weed based aquaculture, etc. Cage aquaculture in reservoirs proved to be an important farming practice to utilize vast open-water resources of the country. *In situ* seed rearing in reservoirs in pens and subsequent grow-out culture in cages can be an important step forward for increasing production. In recent year,

the need for re-circulatory aquaculture system has often been stressed for intensive production in smaller areas. Such closed system with zero water discharge can be popularized, thereby reducing environment consequence.

Ornamental fish farming is an important intervention which can be taken up in large-scale as well as a backyard activity, thereby, can play a major role for rural livelihood improvement. With successful captive breeding of several important high valued indigenous species, besides the exotics, its trade is likely to be intensified as small-scale and also commercial enterprise, especially in places adjoining to cities and towns.

Enhancing the technology reach

Growth of fish in a pond is a biological process and thus the fish crop needs continuous attention with regard to environmental health, nutrition and disease management. Although the scientific fish farming technology offers a range of full proof practices, an insight into the practice followed in field condition revealed completely different picture. The disperse nature of the pond resources and their difficult accessibility and poor knowledge of the farming community about the scientific know how are some of the factors those are hindering the effective communication and learning. As a result, major portion of the resources is yet being utilized under traditional and extensive system without following systematic stocking density, species ratio and supplementary feeding.

Over the years, a lot of efforts were made to increase the skill level and technical efficiency of the humane resource engaged in the sector through extension mechanisms of ICAR, Fisheries Departments of the states, state agricultural universities and several other organizations. The benefit of carp polyculture was demonstrated throughout the country through a vast network of 429 FFDA established in all potential districts covering 0.83 million ha water area. Besides institutional frameworks of ICAR, it has also been organizing regular trainings through its vast

network of 700 Krishi Vigyan Kendras. However, besides intensifying the training activities in all relevant aspects of farming, it is necessary that large-scale demonstrations of new farming practice of diversified species and systems are also undertaken throughout the country to curtail the time span of technology dissemination process. Necessity of skill development in all the relevant areas is an important aspect of effective farming operation. Realizing the need to enhance skills of people employed in the sector and to empower youth to enhance employment opportunities, the Agriculture Skill Council of India (ASCI) in collaboration with other organization took initiative in various areas of capacity building by bridging gaps and upgrading skills of local workers in different fields of aquaculture and fisheries. The Fisheries Skill Advisory Board recommended that 'Skill India Mission' should act as an enabler to 'Blue Revolution'. It is expected that the skill development programme in the value chain would definitely lead to competent manpower development, ultimately leading to enhanced adoption of scientific farming practice and thereby enhanced fish production.

Infrastructure and market facilities

Fish is a highly perishable commodity and needs an organized cold chain and quick delivery system from the farm gate to the consumers to maintain the quality and hygiene. Therefore, it requires storage facilities, ice plants, cold chains, roads and transportation in identified aquaculture areas to provide quality fish to the consumer. While availability of these infrastructures are negligible at present in the sector, adequate governmental investments required for creation of other facilities such as feed mills and ancillary industries (aerators, feed dispensers), organized hygienic market, post-harvest fish processing factories, etc. Development of infrastructure all along this cold chain would not only secure and increase the profit margin of the producer, but

also would support excellent employment opportunity at every stage of the cold chain.

Increasing fish production can be intrinsically linked to increase in popularity of fish. Popularity of processed fish products such as fillets, chunks, sticks and many other value added products in supermarkets is a new avenue for the freshwater sector to explore. Establishment of processing industry for production of value added products would develop the economy of the sector besides creating the employment opportunity. Fish waste constitute nearly 40% of the freshwater fish which usually goes unused. Although technologies were developed to utilize these wastes for production of silage and high grade nutrient concentrate that could be used to fertilize agriculture crop as well as pond to boost productivity, it is necessary that appropriate mechanisms are developed for their collection, especially from city markets, and further utilization.

The fish produced from the freshwater sector in India has not yet reached an effective export market unlike other south-east Asian countries. While an effective planning, infrastructure and financial support can facilitate development of export oriented freshwater fish production system with stringent quality control measures, the advantage of the strong information technology can be utilized to support the product promotion and formulation of appropriate marketing strategies as per needs of the international markets.

Financial support and crop insurance

The requirement of high capital investment to start an aquaculture farm often acts as a deterrent for entrepreneurs to venture into this business. Although many state governments have initiated schemes to support fish culture projects, those are often insufficient. Involvement of the financial institutions for the aquaculture is abysmally low, especially for the resource poor farmers. Only vertical increase in the productivity of culture pond cannot cater to the fish demand in 2030. The

horizontal expansion of the culture area is required to be extended in the country for which financial support mechanism is required for establishment of new farm. Fortunately, many governments support schemes extended are being implemented to create new water-bodies with an aim for water harvesting, which can be effectively utilized for fish production. With the water issues becoming more acute over the years in several regions, it is envisaged that further more water-bodies would be created area under such schemes, resulting in higher fish production too.

The aquaculture sector, particularly the brackishwater prawn farming was widely supported by insurance companies in its boom time in the mid-1990s. But due to the incidence of disease outbreak, all these supports gradually faded away from the sector. Since freshwater aquaculture is subjected to many natural calamity (flood, drought, disease incidence etc.), insurance coverage of the crop is earnestly required to provide adequate safety nets. A secure crop would definitely attract increased investments to this sector and, therefore, introduction of the insurance scheme for aquaculture crop would help the development process.

Strengthening research base to address water and climate challenges

The per caput availability of water in India has declined from 5,300 m³ in 1955 through 2,500 m³ in 1990 and estimated to be 1,500 m³ by 2025. Against a declining water availability, our gross irrigated area needs to be increased to ensure increased food grain production of 450 to 500 mmt to feed the 1,620 million population by 2050. Similarly, water requirement from livestock sector is expected to increase. Further, there has been shrinkage of water-table, frequent drought situation, changes in climatic and rainfall pattern which are important particularly in context of fish farming. Although the consumptive water use is low, the total water requirement is high for freshwater aquaculture and adequate

quantity of quality water is a prime requisite. In such situation, increasing aquaculture production in the country through competition for water share with agriculture and allied sectors is going to be the most important challenge in the future.

Budgeting water requirement in the different types of fish seed and grow-out production system was a long pending research issue in the freshwater sector. In the context of expected water scarcity, budgeting and its judicious use of water is a primary requisite towards development of protocols for the best water management practice. Climatic condition, soil type, height of water-table are the major factors determining the water requirement for fish culture besides other controllable factors like pond depth, seepage etc. Varying nature of these factors from place to place makes the water requirement a dynamic and there is a need to identify production system with low water requirement. Therefore, consideration of water availability can be the major deciding factor in future for determining the level of intensification in fish farming while ensuring the environmental sustainability.

Climate change and bio-risk cause adverse impact on production target due to several factors viz., cyclone, flood and drought etc. caused by global warming, that is likely to create favourable climate conditions for the growth of non-targeted organisms and thus increased ambient water temperature is likely to cause a rise in the responses of disease occurrences spread by vectors. Shifting of the breeding season was experienced in major freshwater cultured species due to the climate change effect. Similarly, alterations in other sensitive water quality parameters such as ammonia, air and water temperature would have pronounced effect on the breeding behaviour, feed utilization efficiency, disease outbreaks and even on the sensory qualities of the cultured fish species. Thus, climate change is going to be major future challenge for increasing the fish production from the sector through aquaculture. To tackle the challenges of water scarcity

and possession of climate resilient technologies, it is necessary that our research programmes on these unconventional subject areas are intensified.

Other technical and policy interventions

Significant focus is given at present to promote scientific pen and cage farming in reservoirs to improve productivity in open waters. The State Fishery Departments with support from National Fisheries Development Board are promoting large-scale cage farming in reservoirs. In recent years, cage farming is popular in Chhatisgarh and Jharkhand. It is high time that such proven technology is extended to utilize the vast reservoir resources all over the country. The pen culture technology can be adopted in many of the *chaurs* and *mauns* resources in Bihar, Chhatisgarh, Jharkhand and the floodplain wetlands of Asom and West Bengal, which would directly help in raising the income of the fisher households and their livelihood security.

Due to the dispersed nature and difficult access of freshwater resources in the country, development of a strong data base was a continuous problem. Further, majority of the ponds and tanks in the country belong to the private ownership and fish production data from these ponds are usually goes unaccounted. Similar is the case for the community tanks and minor irrigation projects. Non-availability of physical and social information on the resources has always hindered effective planning and also in implementation of the various development schemes brought to the sector. An organized country-wide survey on the resource use and other production characteristics, at least at five yearly intervals, would definitely help in developing appropriate policy directions, implementation of governmental schemes and increased investments.

Allocation of agricultural land for aquaculture purpose has limited scope in the face of decreasing per caput land holding and increasing need for food grain production. Therefore, it is essential that those of

about 40% of tank/pond resources which have remained underutilized/unutilized, need effective strategies for their utilization and also investment. Further, the community owned ponds/tanks require to have appropriate leasing policy by different states. The demonstrated advantage of long duration leasing for 5-10 years, over short-term leasing policy, need appropriate policy direction equally by the central and state governments.

Fish farming in ponds and tanks until now is a freelance activity in most part of the country, with farmers resorting to use of any materials and inputs. Unscrupulous use of many chemicals and antibiotics are in vogue in the sector with little care about the ecological consequence and food chain perturbation. This has led to irresponsible aquaculture practice, mostly oriented towards profit making. Close vigilance and appropriate policy guidelines, therefore, is essential for ensuring quality of the produce and safety of the consumers.

Brackishwater aquaculture

India possesses 1.2 million ha of potential brackishwater area, spread across its nine coastal states. Besides, there are more than 7 million ha inland saline areas in Punjab, Haryana, Uttar Pradesh and Rajasthan, a large part of which is suitable for brackishwater farming. Shrimp farming at present is almost synonymous with the brackishwater farming in our country contributing to the tune of about 6.0 lakh tonne production and also constitute the major share in the ₹ 45,000 crore seafood export earnings. The farming in the sector, however, is going through a paradigm shift in diversification of the system with different candidate species of shellfish and finfish.

Strategies for development

The brackishwater farming till recent years was confined to farming few species of shrimp and mostly oriented towards export market. Since the investment in such shrimp farming is large, the activity was

mostly confined to farmers/entrepreneurs with substantial investment capacity. Study revealed at least 10 species of shrimp, 8 species of finfish and 2 species of crab have potential for commercial cultivation.

Farming of shrimps: The shrimp farming in India at present is largely confined to the exotic Pacific white shrimp, *Litopenaeus vannamei*, that has almost replaced the black tiger prawn, *Penaeus monodon* which was ruling the industry about a decade back. Introduction of *L. vannamei* has not only revived the shrimp culture industry after the setback in tiger shrimp culture, but its huge production also has pushed the shrimp farming to a new height in the country. Due to ease in farming even at higher stocking density and its hardiness against environmental perturbation, the species have expanded opportunity for the small- and marginal-farmers for its farming. Successful demonstration of farming of Indian white shrimp, *Penaeus indicus* in recent years in several coast states, with impressive production levels of 4-5 tonne/crop/year is a significant milestone, which provides huge possibility for their large-scale farming as alternate species. The proposal for initiation of selective breeding programme for its growth improvement must be brought into action at the earliest possible. Considering the fact that only about 15% of the potential brackishwater resource is being utilized for farming at present, the sector is expected for a huge horizontal growth in future years.

Concept of organic farming has also become popular in the brackishwater sector. Farmers started producing shrimp and fish following organic farming practices and the products are well accepted by the consumers despite higher price. The relatively lower production in this farming method gets compensated due to the higher market price of the product and thereby safe guard the profit margin. Investment to promote such organic farming in brackishwater has enormous scope to increase the farm income.

Species and system diversification: Despite heavy demand for certain

species of brackishwater finfishes in the domestic market, their supply in the country is mostly confined to the estuarine and marine catches. Non-availability of seed of cultivable finfishes has remained as the major issue for their large-scale farming, although certain farmers resort to their farming through natural seed collection. Development of the technology of breeding and seed production of seabass (*Lates calcarifer*), milkfish (*Chanoschanos*) and pearl spot (*Etroplus suratensis*) in recent years has widened the scope for species diversification to certain extent. However, expansion of farming of these species in coming years would largely depend on the assured availability of their quality seed, for which it is necessary that the breeding and mass-scale seed production technologies are taken up by both public and private sectors. Greater research impetus is also necessary for brining other species of promise through development of seed production technologies of other diversified species like Grey mullet, *Mugil cephalus* and others. Further, to give a boost in commercial farming, it would be necessary to create a complete value chain, including availability of relevant packages of practices of grow-out farming, assured supply of right kind of feed, required health management measures and assured market. It may be ideal also to recommend the shrimp farmers for resorting to crop cycling with intermittent farming of finfishes, which can greatly help in ecological restoration and also disease management.

Farming and fattening of crab has become popular among small-to marginal-farmers as well as a group activity by many self-help groups. The mud crab, *Scylla serrata* is an important candidate for brackishwater aquaculture. The success in developing seed production technology of the species has opened up avenues for commercialization of its culture technology. Similarly, integration of bivalve farming with shrimp and fish was recognized as an important intervention for increasing the production while ensuring

environmental upkeep. Culture of sea weeds in brackishwater ponds as well as a secondary aquaculture in discharge water treatment system offers scope to produce raw materials for the production of a wide range of pharmaceuticals. Brackishwater ornamental fishes have great demand in domestic as well as international markets. With the scalability of the enterprise, it can be adopted from backyard to commercial level involving individual to group activity. Therefore, breeding and culture of brackishwater ornamental fish can be a good intervention for farmers as well as a group activity for self-help groups, besides ensuring excellent scope to empower the rural women.

Supplementary feed and health management: To make the enterprise economically viable, due support through development of cost effective feed and appropriate disease management is considered to be most important. The adoption of intensive farming technologies led the culture systems to rely largely on the exogenous feed supply. This necessitated the basic understanding of nutrition and dietary requirements of cultured species, leading to formulation of several cost-effective diets. With the substantial investment by the private industries over the years, a large number of feed plants were established in the country. It is expected that with the increase in demand the more and more feed plants would also be established in coming days.

The real research thrust on health management in brackishwater farming sector was provided only with the outbreak of white spot syndrome virus in shrimps in the early 1990s. Further, with the shift in culture systems from extensive to semi-intensive and intensive practice favoured the incidence of a large number of emerging and transboundary diseases of viral, bacterial, fungal and parasitic origin either in acute outbreak forms or as latent infections. Development of diagnostic and control methods against these diseases were taken up. It is also necessary that the present programme of national disease surveillance is intensified further to

have a close vigil on any health issues and also tackling any emerging disease threat.

Mariculture

The marine resource of the country comprises 8,129 km of coastline and 2.2 million km² of Exclusive Economic Zone. The coastal fish stocks in India is optimally fished and in some cases, over fished. With present harvest of about 3.8 million tonne, the gap between present production and estimated marine fisheries potential of 4.412 million tonne reduced substantially, thereby offering little scope for further increase in production from the open seas in coming years. Unlike other south Asian countries, farming of fish in marine environment is a recent activity in India. It has long been confined to culture of seaweeds, pearl oysters, edible oysters and mussel only in a few patches of the south-east and south-west coast of India. Except in supporting livelihood of small-and marginal-farmers and farmers' group, it has not yet developed into any commercial enterprise.

Strategies for development

The strategies and development include Captive seed production and grow-out cage farming of important fish species, Production of marine ornamental fish, and farming of oyster, and mussels seaweed.

Captive seed production and grow-out cage farming of important fish species: Although marine cage farming has enormous potential for fish production, our country has not yet made major headway due to the constraint of non-availability of captive seed production technology. Development of technologies of controlled breeding and mass-scale seed production of a few important marine finfish species viz., cobia (*Rachycentron canadum*), silver pompano (*Trachynotus blochii*) and grouper (*Epinephelus tauvina*) in recent years are significant breakthrough, which is expected to boost the grow-out sea-cage farming in the country. There is also a need for development and standardization

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of seed production and farming techniques for at least two dozen more species of high value marine finfish within next decade. The seed production technology of these species would have major components such as hatchery production of larvae, rearing of the seed and production of the microscopic organisms and live feed for the seed, offering enterprising opportunity at each stage.

With the development of packages of practices of open-sea cage aquaculture of different finfish species viz. cobia, seabass, pompano, grouper and also lobster, and their successful demonstration all along the Indian coast in last one decade, the mariculture in the country is expected to provide a new dimension of commercial enterprise in coming years. To transform the present state of cage farming from just over 1,500 cages to level of organized industry, it is necessary that the major issue of leasing of coastal waters are resolved through agreed terms between the Central and State Governments of all coastal states.

Production of marine ornamental fish: It is another immense opportunity in the marine sector. Breeding and seed production of many important ornamental fishes including high-valued clown and damsels developed over these years. Establishment of small-scale ornamental fish hatcheries of these species can lead to income generation for rural communities as well as the self-help groups. Further, adoption of this intervention in varied scale by individuals and groups can prove to be an efficient investment opportunity and export earner.

Farming of oyster, mussels seaweed: The farming of edible Indian backwater oyster, *Crassostrea madrasensis* is confined only to the south Indian coast, with major production coming from Kerala, where well established commercial edible oyster farms were established

around Ashtamudi, Kayamkulam and Vembanad estuaries. With encouraging entrepreneurship, it is possible that the farming is expanded to other maritime states, viz., Karnataka, Goa, Maharashtra, Tamil Nadu, Pudduchery and Andhra Pradesh.

Marine mussels is another preferred group of shellfish cultured in the Indian coast. Of the two species viz., green mussel, *Perna viridis* and the brown mussel, *P. indicus*, the former is accepted as the favorite candidate species for mariculture in the open coastal waters. Like edible oyster farming, mussel farming is also largely confined to Kerala, Karnataka and Goa. Greater adoption of edible oyster as well as mussel needs supply of assured seed, and thus, can create opportunity for seed production as enterprise.

Seaweed farming is another avenue of mariculture that has not yet reached to its potential in our country despite having standardized farming technologies for many species, good resources, opportunity and heavy demand from the industry. The country at present produce a good amount of seaweed from the traditional farming in the coastal waters. These seaweeds have wide-scale use, from food industry to pharmaceutical and marine biomolecule production. The low capital investment requirement makes seaweed farming a preferred choice for the coastal farmers with small-and marginal-investment capacity. It is also suitable to be undertaken as group activity. Additionally, in future years seaweed farming can earn carbon credits to the farmers.

to have greater focus to harvest more through open-sea farming, which has remained almost unexplored. This should be adequately supported with suitable policies, flow of appropriate technology, increased awareness and infrastructural development across the coasts. Such practice can be an alternate livelihood support for the coastal local communities and can also help in reducing pressure on capture fisheries. Similarly, cautious approach should also be adopted in intensifying the existing aquaculture production systems in both freshwater and brackishwater. Though the current level of utilization of the pond productivity is well below the carrying capacity, there is a need to devise fish farming methods that are more productive, energy efficient, environment friendly, less water consuming, climate resilient and economically efficient. To complement this, there is also a necessity to expand the aquaculture sector horizontally so as to meet the burgeoning fish demand in the future. Considering the present strength of aquaculture sectors, in terms of resource availability, possession of scientific know-how on different aspects of seed production and farming, readiness of the supporting industries for supply of critical inputs, and increased gap between production potential and present production levels, the aquaculture sector in India is not only expected to meet the increasing demand of ever-growing population of the country by 2030, but also likely to boost its export earnings through increased production of high-valued shellfish and finfish species.

SUMMARY

The need to fulfill the increasing demand of fish as the animal protein source is expected to witness increased fishing pressure on the natural fish stocks and also increased intensification of the existing aquaculture activity. There is a need

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