Introduction to Mariculture

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Background Information

Fish is a comparatively cheap source of animal protein and can be considered as the rich food for the poor. It constitutes the major source of animal protein in regions where animal protein in diets is below world average. It is also a source of essential fatty acids, vitamins and minerals; some fish are high in calcium, zinc, vitamin A and iron. The global production of food fish amounts to 177.8 million tonnes in 2020 inclusive of both captures and culture fisheries (FAO, 2022). The demand for fish has increased at twice population growth over last 50 years. Global consumption of aquatic foods (excluding algae) increased at an average annual rate of 3.0 percent from 1961 to 2019, a rate almost twice that of annual world population growth (1.6 percent) for the same period, with annual per capita consumption reaching a record high of 20.5 kg in 2019. Rising incomes and urbanization, improvements in post-harvest practices and changes in dietary trends are projected to drive a 15 percent increase in aquatic food consumption, to supply an average 21.4 kg per capita in 2030.

At a global level, the major source of seafood production is through marine capture fisheries. The marine capture fisheries scenario reveals that 80% of the world's fish stocks for which assessment information is available are reported as fully exploited and thus requiring effective and precautionary management As reflected in the global scenario of marine capture fisheries, the current marine capture fisheries scenario in India is also characterized by increased and excessive fishing effort, overexploitation of certain resources from the inshore grounds and increased conflicts among the different stakeholders in the sector. Due to the larger dependency on inshore fisheries over the years, the production from inshore waters has reached asymptotic level and hence ensuring sustainability is inevitable in our marine fisheries policy. It is evident that increasing marine fish production from capture is not a practical option in future and it is also necessary to implement management measures to sustain the capture fisheries production in the coming years.

It is generally well accepted that aquaculture is the only way forward to meet the additional requirement of fish in future. Aquaculture is the fastest growing food production sector globally with an annual average growth of >6% in the last two decades. It increased from <1 million tonnes in 1950 to 87.5 million tonnes in 2020 and is still showing a steady increasing trend. It is projected that in India we need to produce about 18 million tonnes of fish by 2030, as compared to 14 million tonnes we produce today. In this case, we need an additional production of about 4 million tonnes in the next 8 years and we have to focus on aquaculture for meeting the increased requirement of fish in future. While we have done comparatively well in the case of freshwater and brackishwater aquaculture we are still in the primary stages of development in marine aquaculture (mariculture) and hence there is an urgent need to develop it into a substantial contributor of fish production.

Mariculture- Global and Indian Scenario

Mariculture is a specialised branch of aquaculture involving the cultivation of economically important marine plants and animals in the sea or any other water body having tidal influence and includes onshore facilities like hatcheries, nursery rearing and grow out systems using seawater. It is well established that mariculture presents an opportunity for increasing seafood production in the scenario of growing demand for seafood and the limited scope for expanding wild fishery harvests. Mariculture is the fastest growing subsector of aquaculture and has very high growth potential. At global level, mariculture produces many high value finfish, crustaceans, and molluscs *viz.* oysters, mussels, clams, cockles and scallops. In 2020 mariculture has contributed around 33.1 million tonnes of foodfish globally which formed about 37.8% of the foodfish aquaculture production. (World food fish aquaculture production was 87.5 million tonnes in 2020). In addition about 35.0million tonnes of seaweeds were also produced by mariculture. The total mariculture production including the sea weeds was 68.1 million tonnes in 2020 which constituted 55.5% of the total aquaculture production during the year (Global aquaculture production including the aquatic plants was 122.6 million tonnes in 2020). Algae dominated the global mariculture production (51.4%) followed by molluscs (25.8%) followed by finfish (12.2%), crustaceans (9.9%) and others (0.7%) (FAO,2022). It has also been estimated at a global level that the development potential for mariculture far exceeds the space required to meet the foreseeable seafood demand. The current total landings of all wild-capture fisheries could be produced using less than 0.015% of the global ocean area. The projected mariculture production based on area available in the Indian Region is 8 to 16 million tonnes whereas the current mariculture production is less than 0.05 million tonne (Rebecca *et al*.2017). In addition, the development of a mariculture sector also strengthens the Blue Revolution policy of GOI.

Overview of Mariculture Technologies developed by CMFRI

Mariculture activities in India were initiated by the research and development made by CSIR-CSMCRI 1970s by near shore culture of seaweed *Gracilaria edulis* in Krusadi Island, followed by the Indian Council of Agricultural Research-Central Marine Fisheries Research Institute (ICAR-CMFRI) in the early 1980s by initiating small scale commercial culture of bivalves. Additionally, in 1990s, Central Institute of Brackish water Aquaculture (ICAR-CIBA), National Institute of Ocean Technology (NIOT) and the Marine Products Export Development Authority (MPEDA) also significantly contributed to the development of mariculture. Subsequently ICAR-CMFRI has become the pioneering institution in the country which has been developing appropriate mariculture technologies in India (James, 1996, Devaraj *et al*, 1999, ICAR, 2000, Pillai and Menon, 2000, Pillai *et al*, 2003, Mohan Joseph 2004, Modayil *et. al.* 2008, Gopakumar *et. al.* 2007, Gopakumar, 2010). Open sea mariculture was initiated for the first time in India by ICAR-CMFRI in 2005 by establishing the first open sea floating cage in Visakhapatnam with funding support from the Department of Animal Husbandry, Dairying and Fisheries (DADF), Ministry of Agriculture, Government of India. Further refining technologies and adoption have led to rapid spread of cage mariculture along both coasts in near shore waters by self-help groups, fisher societies and small entrepreneurs. Available technologies include seed production and farming of finfishes such as cobia, pompano, sea bass, groupers, snappers, breams and ornamental fishes, shell fishes such as mussels, oysters, clams, green tiger shrimp, blue swimmer crab and ornamental shrimps. Technologies for marine pearl production, seaweed farming, Recirculation Aquaculture System (RAS), and Integrated Multitrophic Aquaculture (IMTA), live feed production and sea ranching are also available.

Marine Finfish culture

In India, much research attention was not given for developing seed production methods for high value finfishes suited for sea farming. Till recently we had commercial level seed production technology of only one marine finfish – the Asian sea bass (*Lates calcarifer*). Subsequently it was realised that unless an intensified research on the development of commercial level seed production technologies is taken up, sea farming cannot emerge as a significant seafood production sector in the country. In the recent past, CMFRI has been intensifying its research activities on the breeding and seed production of high value marine finfish and success was achieved in the breeding and seed production of cobia (*Rachycentron canadum*), silver pompano (*Trachinotus blochii*), the Indian pompano *T.mookalee*, the orange spotted grouper *Epinephelus coioides* and the Pink Ear emperor *Lethrinus lentjan* for the first time in the country. Recently CMFRI achieved initial success in the breeding of fanged seabream, *Sparidentex jamalensis*, picnic seabream, *Acanthopagrus berda*, John's snapper, *Lutjanus johnii* and *Siganus vermiculatus* for the first time in India (CMFRI, 2020).

Marine ornamental fish culture

On a global basis a lucrative marine ornamental fish trade has emerged in recent years which are a low volume high value industry. A long term sustainable trade of marine ornamental fishes could be developed only through hatchery produced fish. The CMFRI has pioneered in the development of techniques for breeding, seed production and culture of more than a dozen species of marine ornamental fishes which are in heavy demand in the national and international trade. Recently CMFRI has successfully raised hybrid clown fishes or designer clowns. The designer clowns such as Picasso, platinum, snowflake, etc are highly sought-after varieties in the domestic as well as international markets.

Sea cage farming

The sea cage farming has been expanding in recent years on a global basis and it is viewed by many stakeholders in the industry as the aquaculture system of the millennium. Cage culture has made possible the large-scale production of commercial finfish in many parts of the world and can be considered as the most efficient and economical way of rising fish.

When compared to many countries in the Asia-Pacific Region, India is still in its infancy in sea cage farming. For the first time in India as part of R &D a marine cage of 15 m diameter with HDPE frame was successfully launched in 2007and operated at Visakhapatnam, in the east coast of India by CMFRI (Mohan Joseph, M, 2005). Since then, a lot of innovations on designing and fabrication of cages and mooring systems were made which led to the development of better designs of cages of 6m diameter with improved mooring systems that can withstand rough sea conditions. Subsequently demonstrations of cage farming were undertaken along different parts of the Indian coast under a participatory mode with the local coastal fishermen. Successful sea cage farming demonstrations were conducted at Kanyakumari, Vizhinjam, Kochi, Mangalore, Karwar, Veraval, Mandapam, Chennai and Balasore. Cobia, Sea bass and spiny lobsters were the major groups employed for farming. These demonstrations have created an awareness regarding the prospects of sea cage farming in India. Many entrepreneurs, fishermen and farmers are coming forward to take up this venture (Syda Rao, 2012, Philipose *et.al.* 2012, Syda Rao *et.al.* 2013). Recently small-scale cage farming in lakes and other saline water bodies has become an alternate livelihood option for many fishermen (Imelda, 2012, Imelda, 2016).

Mussel Farming

In the wild, mussels are mostly found in the littoral and sub littoral zone in clusters on various substrates. The two mussel species found along Indian seas are *Perna viridis* and *Perna indica*. *P.viridis* is distributed along the north and south of east coast and the south west coast of India. The brown mussel *P.indica* species is found along the south west coast. The Institute has developed technologies for culture of bivalves *viz.*raft method (in bays, inshore waters), rack method (in brackishwater, estuaries) or long line method (open sea). These methods are commonly adopted for mussel farming. When mussel farming is taken up on a larger scale, depending on the wild seed may not be practicable because it may affect the wild mussel fisheries. Hence low value high volume seed production technologies are needed for hatchery production of mussel seeds for farming. CMFRI has already succeeded in the low cost production of mussel seeds in hatchery. The carrying capacity and environmental assessments are also needed for sustaining the farming.

Edible Oyster Farming

CMFRI has developed methods for edible oyster (*Crassostrea madrasensis*) culture and has produced a complete package of technology, which is presently being widely adopted by small scale farmers in shallow estuaries, bays and backwaters.

Pearl Oyster Farming and Pearl Production

In India, the marine pearls are obtained from the pearl oyster, *Pinctada fucata*. Success in the production of cultured pearls was achieved for the first time in 1973 by CMFRI. Raft culture and rack culture in nearshore areas are the two methods commonly adopted for rearing pearl oysters and subsequently attempts have been made to develop onshore culture. The technology for mass production of pearl oyster seed has also been developed. Research is also directed towards development of a technology for *in vitro* pearl production using mantle tissue culture of pearl oyster. The pearl production technology still remains to be commercialised in India (Jagadis *et. al*, 2015).

Designer Pearl Production

CMFRI successfully developed and standardised a simple technique for value added marine pearls, called mabe pearls. A mabe pearl is a dome shaped or image pearl produced by placing a miniature image against the side of the oyster shell interior. The result is an exquisite pearly nacre coated image. The main advantage is the very short gestation period (2 months) and the superior quality of the nacre of Indian pearl oyster *Pinctada fucata* (Anil *et. al*, 2007).

Abalone Culture

Abalones are marine gastropods of the genus *Haliotis*. They are known for the production of gem quality pearls and also for their succulent meat. *Haliotis varia* is the commercially important species along the Indian coast. CMFRI has developed methods for the seed production and culture of this species.

Cephalopod Culture

CMFRI has developed methods for the culture of the cuttlefish *Sepiella inermis*, *Sepioteuthis lessoniana* and *Sepia pharaonis* at an experimental level. However, scaling up of the methodologies for commercial level production remains to be demonstrated.

Lobster Fattening

Increasing demand for live lobsters in the export market led CMFRI to demonstrate the farmers and entrepreneurs to collect under sized lobsters from the commercial catches and grow to marketable size in ponds and tanks by feeding trash fishes and other discards.

Crab fattening

Live mud crabs (*Scylla serrata)* being a much sought after export commodity, its fattening is considered very lucrative and methodologies were developed for the same.

Sea cucumber culture

More than 200 species of sea cucumber are found in Indian waters, mainly in the Gulf of Mannar, Palk Bay and the Andaman and Nicobar Islands. The most important commercial species is *Holothuria scabra*, whose continuous exploitation has led to depletion of natural populations. Seed of *H. scabra* was produced in the hatchery for the first time in India in

1988 through induced spawning using thermal stimulation, and this technique has been widely used since then to produce seed for stock enhancement programmes (James, 2004).

Seaweed Culture

Around 60 species of commercially important seaweeds with a standing crop of one lakh tonne occur along the Indian coast. Seaweed products like agar, algin, carrageenan and liquid fertilizer are in demand in global markets and economically viable seaweed cultivation technologies have been developed in India. CMFRI has developed technology to culture seaweeds by either vegetative propagation using fragments of seaweeds collected from natural beds or spores (tetraspores/ carpospores) (Kaliaperumal *et.al*,2003, Kaladharan, 2018). .It has the potential to develop in large productive coastal belts. Recently the culture of the carageenan yielding sea weed *Kappaphycus alvarezii* has become very popular due to its fast growth and less susceptibility to grazing by fishes and is being cultivated extensively along the Ramanathapuram, Pudukkottai, Tanjore, Tuticorin and Kanyakumari districts of Tamil Nadu (Johnson and Gopakumar, 2011).

Integrated Multitrophic Aquaculture (IMTA)

At a global level, the mariculture practices are dominated by intensive monocultures which have led to sustainability problems, environmental degradation and consequent disease problems. In this context, the idea of bio-mitigation of the environment along with increased biomass production integrating commercially important species of different trophic levels is emerging as an innovation in aquaculture. Integrated Multi trophic aquaculture (IMTA) is the practice which combines in appropriate proportions the cultivation of fed aquaculture species (finfish / shrimp) with organic extractive aquaculture species (shellfish / herbivorous fish) and inorganic extractive aquaculture species (e.g. seaweed) to create balanced systems for environmental stability (bio-mitigation) economic stability (product diversification and risk reduction) and social acceptability (better management practices). IMTA is well recognized as a mitigation approach against the excess nutrients / organic matter generated by intensive aquaculture activities especially in marine waters, since it incorporates species from different trophic levels in the same system. In addition, it is also relevant in the implementation of ecosystem approach to aquaculture (EAA) propagated by FAO. IMTA can also increase the production capacity of a particular site. It is well understood that the increasing use of coastal waters worldwide coupled with rapid growth and expansion of mariculture demand for more sustainable practices and hence the concept of IMTA has much relevance and scope (Soto, D.2009). CMFRI has done many successful front line demonstrations at selected areas to popularise this technology.

Recirculating Aquaculture System (RAS)

Closed-system aquaculture presents a new and expanding commercial opportunity. Recirculating aquaculture systems (RAS) are tank-based systems in which fish can be grown at high density under controlled environmental conditions. They are closed-loop facilities that retain and treat the water within the system. In an RAS, water flows from a fish tank through a treatment process and is then returned to the tank, hence the term recirculating aquaculture systems. Recirculation systems use land-based units to pump water in a closed loop through fish rearing tanks and consist of a series of sub-systems for water treatment which include equipments for solids removal, biological filtration, heating or cooling, dissolved gas control, water sterilization and photo-thermal control (Jacob Bregnballe. 2015). CMFRI has successfully demonstrated the use of RAS in seed production and nursery rearing of different species.

Live feed Technology

Live feed refers to small microscopic living organisms which are employed to feed the larvae of fish especially during the early larval stages. It is the major constraint in the larviculture of many commercially important finfish and shellfish in aquaculture. The culture technologies of live feeds such as different species of microalgae, rotifers and copepods are standardised by CMFRI. Recently a breakthrough was achieved in the mass production copepods as live feed. Santhosh *et al.(*2018) reported the mass production of four species of calanoids *viz. Temora turbinata, P. seudodiaptomus serricaudatus, Acartia spinicauda* and *Parvocalanus arabiensis*.

Sea ranching for stock enhancement

It refers to the release of hatchery reared young ones of marine organisms of commercial or conservation importance into selected areas of marine habitats to enhance the natural stock. The protocols for sea ranching of green tiger shrimp, *Penaeus semisulcatus* are standardised and successfully carried out to enhance the shrimp productivity in the Gulf of Mannar and Palk Bay.

Way Forward

The business opportunities that can be developed based on the available technologies include (i) broodstock centres for cobia, silver pompano, Indian pompano, orange spotted grouper and seabass (ii) hatcheries for production of seed of cobia, silver pompano, Indian pompano, orange spotted grouper and seabass (iii) nursery rearing centres for production of ready to stock fingerlings of cobia, silver pompano, Indian pompano, orange spotted grouper and sea bass to supply stockable size fingerlings (iv) development of cage/pond farms for cobia, silver pompano, Indian pompano, orange spotted grouper and seabass (v) production of grow out feeds for cobia, pompanos grouper and seabass (vi) fabrication of site specific and cost effective cages and mooring systems(vii) establishment of hatcheries for green mussel, edible oyster and pearl oyster (viii) farming systems for green mussel, edible oyster and pearl oyster (ix) hatcheries for marine ornamental species (x) production of seaweeds through farming (xi) commercial level production of designer pearls (xii) development of commercial level IMTA systems (xiii) grow out production through Recirculation Aquaculture Systems (xiv) mass scale live feed production for supplying to hatcheries and (xv) Large scale seed production of *P.semisulcatus* for stock enhancement.

There are a few priorities/ challenges/constraints which need to be addressed before commercialisation of mariculture. Seed availability is the major constraint for the initiation of commercial level farming of marine finfishes and shellfishes. The huge demand for sea bass, cobia, pompano and grouper seeds from fish farmers and entrepreneurs is indicative of the need of the sector. Hence there is an urgent need to establish marine finfish and shellfish hatcheries by fisheries development agencies/ private sector to ensure the seed availability. In addition, it is required to intensify research programmes for the development of seed production techniques for many more species of high value marine fishes. The recent achievement in the mass production technology of marine copepods can facilitate the larviculture of species with comparatively small sized larvae. If seed production technologies of more species are available, the farmers will be able to select the species as per the demand of the locality.

The requirements in commercialisation of marine ornamental fish culture include (i) establishment of commercial level production units and trade development including marketing channels (ii) the broodstock development, breeding and larviculture techniques developed for some species need to be scaled up for commercial production and (iii) R & D to be intensified on seed production of many more lucrative species. The technologies for hatchery production of ten species of clownfishes are standardised and hence can be scaled up for commercial level production and a hatchery produced marine ornamental fish trade could be developed in the country. Hatchery production of marine ornamental fishes can be a lucrative additional source of income for the coastal fishermen below poverty line The immediate way forward for the development of a hatchery produced marine ornamental fish trade in the country include imparting necessary training to prospective entrepreneurs, supplying of brooders/ newly hatched larvae to the trained entrepreneurs, promoting the establishment of a few small-scale hatcheries and establishing appropriate marketing channels. In this regard, a joint programme involving Marine Products Export Development Authority (MPEDA), National Fisheries Development Board (NFDB), CMFRI, State Fisheries Departments of maritime states/Lakshadweep, Andaman –Nicobar Islands is the need of the hour. Development of required broodfishes of the different species in broodbanks and production of larvae and early juveniles in pilot hatcheries is needed for initiating the entrepreneurship. Imparting necessary hands on training to prospective entrepreneurs and capacity building is to be taken up. Simultaneously establishment of a few small-scale hatcheries to groups of farmers has to be accomplished. Initially supplying of just metamorphosed young ones for rearing to marketable size, subsequently after the initiation of live feed culture providing newly hatched larvae for rearing and finally providing brooders for breeding and seed production to the small-scale hatcheries in a phased manner and hand holding till the hatcheries are able to function independently are needed. Developing appropriate marketing channels both domestic and export should also receive priority attention so that the enterprise becomes sustainable (Gopakumar, 2017).

The commercial level farming of lucrative shellfish species like the sand lobster, *Thenus unimaculatus* and the blue swimmer crab *Portunus pelagicus* can also be practiced if hatchery produced seeds are available. CMFRI is able to succeed in the seed production of both the species and these methodologies need to be standardized for consistent production. Similarly seed production techniques which are already developed by the Institute for edible oyster, pearl oyster and green mussel need to be scaled up to commercial level production as per the requirement of the sector.

The development of farming systems especially the sea cage farming deserves prime attention. To promote sea cage farming in the country, identification of suitable sites with proper depth, water quality and water current are required. Site selection survey and identification of suitable sites for cage farming deserves urgent attention. Availability of logistic support for cage farming including seed, feed, and market outlets should be given careful consideration if a profitable business is to be established. Cage farming has to be promoted away from the human settlements, discharge points of industrial and municipal waste, so as to maintain ideal water quality for sea farming. Further, policy for leasing the suitable sites, bank finance, and governmental support through subsidy assistance are the needs of the hour.

The bivalve farming which is already being practiced at a few locations can be further expanded. The carrying capacity assessment, low value availability of hatchery produced seed and the feasibility of open sea farming of bivalves require attention by the R&D sector. Similarly, the expansion of sea weed farming offers immense scope. A concerted effort by the developmental agencies for popularization of seaweed farming is warranted.

The biomitigation impact of IMTA is away forward in sustainable aquaculture and needs to be expanded. The innovative technology of RAS needs to be popularised. In addition, it is also relevant in the implementation of ecosystem approach to aquaculture (EAA) propagated by FAO.

Of prime significance is the development of appropriate mariculture policies. Recently as per the demand from NFDB, CMFRI has drafted a mariculture policy. In this draft the strategies to be adopted for mariculture site selection, leasing policy, mariculture systems and species, precautionary approach to environmental sustainability, seed and feed , food safety and health management, capacity building and extension, ecolabelling and certification, insurance and financial support, market support, institutional mechanisms, legal framework and future areas of mariculture research are given. Fisheries being a state subject, the lead role in mariculture development need to be taken up by the concerned maritime states and Union Territories with the active involvement of central agencies like ICAR-CMFRI, NFDB and MPEDA. The maritime states have the jurisdiction upto 12 nautical miles off the coastline towards the sea as per the Marine Fisheries Regulation Acts since 1980. Hence the role of the state is very vital in developing mariculture. The immediate way forward is an integrated approach by linking up the entrepreneurs, fisheries development agencies, state fisheries departments and marine aquaculture research institutions. In this regard, a mission mode approach headed and co-ordinated by the State Fisheries Departments with the active support of fisheries research institutions and other fisheries development agencies is the need of the hour to take forward mariculture into a substantial contributing sector of seafood production in the country.

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