MARICULTURE ADVANCEMENTS IN INDIA: TOWARDS A NEW EPOCH

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Until recently, monoculture of either Penaeus monodon or Litopenaeus vannamei was the major mariculture species in India. However, due to disease setbacks, there was an extensive push from national R&D institutions to develop new-age mariculture technologies. This led to the first successful demonstration of open sea cage farming along the south-east coast of India, and subsequently, various marine finfish and shellfish mariculture sites were set up along the country's coastline. A few bottlenecks remain, particularly regarding commercial seed production, species-specific feed formulations and comprehensive sea space management plans, but R & D on breeding and seed production technologies for candidate species continues apace to support the imminent expansion of sustainable mariculture in the country.

View of maiden sea cage installed at Bay of Bengal, Visakhapatnam

Mariculture is one of the fastest growing sub-sectors of aquaculture, making an important contribution to the global food basket and nutritional security. Apart from augmenting seafood production, mariculture also provides sustainable alternative livelihood avenues and employment opportunities for coastal communities. Traditionally, mariculture practices in India have been limited to brackishwater bodies following capture-based rearing of juvenile finfish and shrimp species in an extensive manner. These sites have been confined to the coastal states of West Bengal, Kerala, Karnataka and Goa in natural water logging/flooding areas like "Bherries" and "Pokkali" fields, with varying degree of management practices.

The first scientific attempt at developing various mariculture technologies was initiated in India during the 1960s by the ICAR-Central Marine Fisheries Research Institute (CMFRI). Initially the focus was largely on marine molluscan species such as oyster, mussel, clam, etc. As a result of these efforts, Kerala become the first state in the country to recognise the potential of mussel farming technology for rural development. For the next two decades, research concentrated on commercially important bivalve culture, breeding and seed production technology developments and popularisation. The species highlighted during this era were *Pinctada fucata, P. margeretifera, Crassostrea madrasensis*, etc.

In the 1970s, the country realised the importance of shrimp farming and its role in the national economy. During this period, breeding protocols, seed production and rearing technologies for important marine shrimp species like *P. indicus, P. monodon, Metapenaeus monoceros, M. affinis, M. dobsoni,* and *Parapenaeopsis stylifera* were standardised. The rapid gain in shrimp production through coastal mariculture took place during the late 1980s with the establishment of commercial shrimp hatcheries by the Marine Products Export Development Authority (MPEDA) in Andhra Pradesh and Odisha. The Indian shrimp industry witnessed phenomenal growth during the late 1990s. Tiger shrimp *(P. monodon)* contributed the most towards the farmed shrimp production from the country. However, due to the White Spot Syndrome Virus (WSSV) in India during 1994, the shrimp farming industry suffered heavy losses which necessitated the need for alternative species to *P. monodon* and diversification in shrimp farming protocols. Consequently, the exotic shrimp species *L. vannamei* was introduced in 2009, accompanied by the government's strict control and monitoring measures.

India, as a key player in global seafood supplies, now ranks second after China in aquaculture production, and Indian seafood products are being exported to more than 100 countries around the globe. Farmed shrimp (*L. vannamei)* largely makes up the bulk of the production.

A new mariculture era in India

Coastal aquaculture, in particular, monoculture shrimp farming has increasingly become unpredictable in terms of success and there is the danger of the industry being over-dependent on shrimp. Taking into consideration the risks associated with monoculture in shrimp farming, the emphasis on diversification efforts in culture systems and species increased. It was in this context that India explored the options for promoting mariculture in the open seas. In 2006 with funding support from the Ministry of Agriculture and Farmers Welfare, ICAR-CMFRI successfully developed and tested the first ever open sea cage farming system in the country at Visakhapatnam, Andhra Pradesh, and the species demonstrated was Asian seabass *(Lates calcarifer)* (Rao *et al.*, 2013).

During 2006-2009, pivotal progress was made in sea cage farming technology in India due to the pioneering efforts of ICAR-CMFRI. The indigenously designed HDPE sea cage (17.8 metres in diameter) which was initially launched at Visakhapatnam underwent a number of modifications and refinements for standardisation purposes (Mojjada, 2015). This resulted in a 6m diameter HDPE sea cage system with a 140 mm floating collar and 90 mm handrail (Mojjada *et al.,* 2013). The culture net cages ranged between 4-8 m depth with varying production volumes. The installations and mooring were based on a single point mooring (SPM) system anchored with a dead weight combination. The self buoyant floating sea cages were flexible, dynamic and proved their technical feasibility and seaworthiness by being used successfully for raising various commercially important candidate finfish and shellfish species along the Indian coast.

However, to reduce the cost and for ease of management, a cheaper cage system with similar dimensions was looked into. Galvanised Iron (GI) sea cage designs having a diameter of 6m were developed to meet the requirements of small-scale farmers (Rao *et al.,* 2013). In order to prevent rusting, the welded GI cages were coated with fibreglass reinforced plastic (FRP)/epoxy. These cages were fitted with floating barrels of 200 litre capacity filled with 30lbs of air. The GI cages were able to withstand 20-25 persons on-board which facilitated manual farming operations. Mooring structures and other necessary components were modified according to the environment and requirement of the farmers. Preference was given to this cage design since it was more cost effective for small-scale farmers and could reach breakeven with a single successful crop.

Credit: Karwar Regional Station, ICAR-CMFRI

View of sea cage farm established at Karnataka coast.

Later on, demonstrations were carried out along the coastal states of the country with locally available commercially important species along with needful social engineering, to bring awareness among fisher folks and various stakeholders including governmental and non-governmental institutions. This initiative gained wide popularity among the targeted groups and has proven to be a highly successful model for mariculture production in India. It has enabled small-scale fishermen and stakeholders to have a dependable source of livelihood through a low capital investment, environment friendly and sustainable mariculture system.

Increasingly diverse candidate species

The development of culture technologies for different marine finfish species has been spearheaded by various R&D organisations, primarily ICAR-CMFRI, ICAR-Central Institute of Brackish water Aquaculture (CIBA) and the Rajiv Gandhi Centre for Aquaculture (RGCA). Today, seed production technologies for cobia, silver pompano, orange-spotted grouper, Indian pompano, Asian sea bass, mullet, milkfish and crab species have been perfected in the country. Further, several commercially important finfish and shellfish species have been prioritised for mariculture practices in India (Ranjan *et al.*, 2008).

Apart from hatchery produced seeds, there remains potential for capture based mariculture (CBM) in India with regard to specific species. Spiny lobster fattening in sea cages in Gujarat, Tamil Nadu, Kerala, and Maharashtra; as well as Asian seabass culture along Odisha, West Bengal, Andhra Pradesh, Tamil Nadu, and Kerala are prominent examples of CBM in India (Rao et al., 2013). Dependency on CBM in cages may not be a long-term sustainable solution; nevertheless, the bigger species basket along with the popularity of sea cage farming has increased the demand for commercially important marine fish species in the country.

Mariculture in India is slowly moving towards public private partnership enterprises. However, a full-fledged take-off of mass scale seed production by entrepreneurs is yet to happen. With technical support from the R&D institutes and government encouragement, it is anticipated that this too will be achieved shortly to support the expansion of the sector in India.

Seaweed farming and IMTA systems

Most of the farmed seaweed in India consists of *Kappaphycus alvarezii,* which is one of the main integrated species in raft, net-tube and Integrated Multi-Trophic Aquaculture (IMTA) systems whereas other species such as *Gracilaria* are at the experimental stage. However, unlike other Asian countries, seaweeds in India are not as popular for consumption as food but rather, utilised for phycocolloid production. ICAR-CMFRI and CSIR-Central Salt and Marine Chemicals Research Institute (CSMCRI) have made considerable efforts in the farming of seaweeds and their value addition as a livelihood alternate for coastal communities. In Tamil Nadu, around

800-1 000 families are benefitting from seaweed farming. Moreover, nearly 5 000 families are involved in seaweed collection from the wild *(Sargassum, Turbinaria, Gracilaria* and *Gelidiella spp.)*. Most of those involved in the seaweed farming and collection are women; hence it is a women-friendly technology and leads to women empowerment. Despite these efforts, seaweed resources have been largely underutilised and communities have yet to harness the potential of seaweed farming in the country.

Seaweed cultivation by using bamboo rafts off the Mandapam coast of Tamil Nadu has been a successful model for cooperative farming in the last two decades (Johnson and Ignatius, 2020). Another method of seaweed *(K. alvarezii)* integration along with cage reared finfish (cobia) is practiced along the Tamil Nadu coast where it has proven to be successful. Bamboo rafts (12 × 12 feet) carrying 60 kg of seaweed per raft are integrated for a duration of four cycles along with 6m diameter sea cages stocked with cobia. This method not only increases the farmed fish production, but also boosts the growth of seaweeds too.

Drone view of seaweed rafts integrated with cobia cage, Tamil Nadu

Seaweed growth in net-tube system after two weeks of stocking in sea cage IMTA

Several such models have been tested and standardised in the Indian mariculture context, primarily by ICAR-CMFRI. Integration of seaweed *(K. alvarezii)* and bivalve *(Pinctada fucata)* along with finfish (Asian seabass, *Lates calcarifer)* in open sea cages is another successful example. Experiments were conducted along the Andhra Pradesh coast where all the tested groups performed well during culture. Other trials carried out along the Gujarat coast implemented a cost effective method of seaweed integration using net tubes made from discarded fishing/culture nets of suitable sizes along with lobster and finfish sea cages. The net tubes with seaweeds were tied inside the lobster cages and along the farm margins for finfish cages. This net tube methodology was widely accepted by the fishers since it is cost effective and economically viable due to enhanced production and survival of stocks from the lobster and finfish cages. The net tubes protected the farmed seaweeds, and retained the broken pieces inside the tube nets if any such damage occurred due to rough weather conditions.

Spatial management tool developed

Coastal and Marine Spatial Planning (MSP) is a science-based tool that can address specific ocean management challenges and fix targets for economic development and conservation. Unplanned and poor management of coastal resources could lead to stakeholder conflicts and degradation of the coastal environment, in addition to severely affecting marine flora and fauna.

In this regard, ICAR-CMFRI has developed an innovative decision support model for identifying potential mariculture sites by using the Geographical Information System (Divu *et al.,* 2020). Various parameters/factors related to the coastal region are considered, such as topographic, physical oceanographic, chemical oceanographic, biological oceanographic and socio-infrastructural analyses to obtain a final model which identifies suitable sites for mariculture operations. This methodology is based on a defined criterion that assesses the structural suitability of the culture system and biological suitability for fish farming in open waters all along the coast.

Presently, the model has been developed for the coastal waters of Gujarat. However, this tool can be useful to other maritime states in India, and will help to address spatial management in coastal regions, resolve conflicts between stakeholders for resource utilisation, aid decision-makers to formulate strategies for sustainable ecosystem-based marine environment management, and initiate marine spatial planning (MSP) in India.

An awakening blue revolution giant

India has a huge potential for mariculture with 2.2 million km^2 of Exclusive Economic Zone (EEZ), 0.5 million km^2 of continental shelf, 8.129 km of coastline, 1.2 million hectares of brackishwater and 20 million hectares for marine farming. The country is still at an early stage in world marine and coastal finfish production with just about 3.08% contribution during 2018 (FAO, 2020).

In order to address critical gaps in fish production and productivity, quality, technology, post-harvest infrastructure and management, modernisation and strengthening of the value chain, traceability, enforcement of a robust fisheries management framework and fishers' welfare, the Government of India has come up with an umbrella scheme called "Pradhan Mantri Matsya Sampada Yojana (PMMSY)". Backed by a total estimated investment of Rs. 20 050 crores for the growth and development of the fisheries sector in India, the Government provides various schemes/programmes and facilities to small and medium scale farmers for pisciculture. The Centrally Sponsored Scheme (CSS) on Blue Revolution provides funding for the improvement of basic infrastructure for culture practices such as fish brood banks, hatcheries, construction of ponds, rearing ponds, installation of cages in reservoirs and open seas, fish feed mills; development of post-harvest infrastructure like ice plants, cold storages, ice plants-cum-cold storages; and development of fish landing centres and harbours for the smooth operation, handling and transportation of fishery species and their products. Technological developments like sea cage farming, breeding and seed production of candidate marine species, intercropping of finfish in coastal mariculture systems and site selection models (Divu *et al.,* 2019, 2020). in mariculture in India provide opportunities to augment production from farming. At the same time, they also offer options for supplementing output from marine capture fisheries and employment opportunities for coastal fisher folk while substantiating the blue economy goals of the nation.

The newly drafted National Mariculture Policy-2019 (NMP-2019) particularly focuses on entrepreneurship opportunities by utilising the available resources in a sustainable manner so as to ensure the food and nutritional security of the country and enhance the quality of life of the population. With the enabling atmosphere provided by effective Government policy support, it is hoped that the blue revolution through mariculture will be successful in the country and transform the sector in a holistic manner.

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