MARICULTURE IN INDIA: AN OVERVIEW

V. V. R. Suresh, Rajesh, N., Boby Ignatius and Gopalakrishnan, A.
ICAR-Central Marine Fisheries Research Institute, Kochi- 682 018, India
E-mail: sureshvr5644@gmail.com

Introduction

The world is projected to require a 50% increase in food production by 2050 to sustain an anticipated global population of 9.7 billion (FAO, 2017). Accomplishing this task poses considerable challenges, given the existing scarcity of land and freshwater resources, coupled with the looming threats of climate change and geopolitical impacts. In the global landscape, aquaculture has established itself as the fastest-growing sector in food production, boasting an annual growth rate exceeding 6% over the last two decades. Within aquaculture, mariculture stands out as the most rapidly expanding subsector, holding immense growth potential. The year 2020 witnessed mariculture contributing a substantial 33.0 million tonnes of food fish, constituting approximately 27% of the global food fish aquaculture production. The overall mariculture production, inclusive of seaweeds, reached an impressive 68.1 million tonnes, representing a significant 55.6% of the total world aquaculture production during the same year. India, with its burgeoning demand for seafood, is positioned to harness the considerable potential of mariculture, recognizing that reliance on the capture fisheries sector alone cannot meet this growing demand. The National Policy on Marine Fisheries (NPMF, 2017) underscores the pivotal role of mariculture in enhancing fish production from coastal waters. The government, in alignment with this policy, is committed to addressing the institutional and commercial requirements of the emerging mariculture sector. This commitment encompasses the formulation of leasing rights policies, spatial planning, provision of technological inputs such as husbandry, seed, feed, and health management, as well as addressing environmental and social impacts. Moreover, there is a concerted effort towards capacity building for local fishers and entrepreneurs to actively participate in mariculture.

Mariculture and its genesis in India

Mariculture, as defined by the Food and Agriculture Organization (FAO, 1997), involves the cultivation of marine organisms in seawater, enclosed sections of the ocean, or in tanks, ponds, or raceways filled with seawater. Responsible mariculture plays a vital role in supplementing land-based economies and conserving marine capture fisheries, thereby contributing to global food and nutrient supply (Schubel and Thompson, 2019). In the context of India, the demand for seafood is rapidly increasing, and it cannot be met solely through capture fisheries. The genesis of mariculture development in India can be traced back to the 1970s when ICAR- Central Marine Fisheries Research Institute (CMFRI) initiated pioneering efforts in Mandapam and Tuticorin, focusing on seaweed and bivalve culture. Subsequent endeavours included induced maturation and breeding of the Indian white shrimp and the promotion of semi-intensive shrimp farming. Capitalizing on technology development, such as seed production and farming techniques, holds the key to unlocking the vast mariculture potential, involving the cultivation of finfishes like cobia, silver pompano, Indian pompano, sea bass, groupers, snappers, and breams, along with ornamental fishes. Shellfish species, including mussels, oysters, clams, green tiger shrimp, and blue swimmer crab, are also

integral components of this strategy. Additionally, technologies for marine pearl production and seaweed farming have already made strides in the country, presenting further opportunities for sustainable growth in the mariculture sector. Mariculture emerges as a crucial frontier with immense potential along India's 8,118 km coastline and the Exclusive Economic Zone covering over 2.3 million km^2. Despite the significant mariculture production potential of 4 to 8 million tonnes annually, the current output is only a meagre »0.1 million tonnes (Gopalakrishnan et al., 2023), indicating substantial untapped opportunities for blue economic growth. To harness India's blue economy potential through mariculture, it is imperative to establish a strategic mission. This mission should address mariculture species prioritization, the development of hatchery technologies, scaling up grow-out technologies, and identifying potential sites for mariculture. Additionally, the implementation of enabling factors and policies is crucial for the successful growth of mariculture in India. This comprehensive approach is essential to unlock the full potential of mariculture and contribute to sustainable economic development.

Prioritization of mariculture species

The strategic selection of target species for mariculture and the development of hatchery technologies represent pivotal elements in advancing the blue economy. This selection process necessitated a comprehensive evaluation based on factors such as market demand, ecological sustainability, biological attributes, and economic viability. In 2017, a meticulous initiative led to the thoughtful prioritization of 76 diverse species for mariculture development. This selection comprised 23 finfish species, 7 molluscs, 6 crustaceans, and 31 ornamental species, supplemented by 4 region-specific species and 5 species of conservation interest (Ranjan et al., 2017). Such strategic prioritization underscored a nuanced approach aimed at fostering sustainable and diversified mariculture practices.

Captive breeding and seed production

Standardization and demonstration of breeding and seed production technologies constitute significant advancements in bolstering India's capability to tap into its marine economic resources. Across diverse taxa, including finfish species, shellfish, and seaweed, these technologies have undergone rigorous scientific processes to ensure reliability and efficiency. The standardization of breeding methods involves meticulous control and optimization of environmental conditions to encourage successful reproduction and genetic diversity. Concurrently, seed production technologies focus on the systematic cultivation of juvenile organisms, ensuring their healthy development for subsequent transfer to grow-out facilities. This scientific progress not only signifies a leap forward in the sustainable management of marine resources but also opens avenues for the commercialization of mariculture ventures, contributing to the broader goals of India's blue economy. Currently, captive breeding technologies are available for not less than 12 finfish species, several molluscs and shellfishes, besides a host of live feed organisms. To meet the additional requirement for seeds of cultivable species in future, innovative measures are being taken to establish hatcheries, seed banks, rearing units and SPF/SPR/genetically improved brood banks. A system of seed certification is also being planned to ensure the supply of quality seed. To augment mariculture production, CMFRI has established the National Brood-bank Facility for Cobia and Silver Pompano in the country. The All India Network Project on Mariculture (AINP(M)), headed by CMFRI, is another significant ongoing initiative addressing technological constraints in mariculture. Research efforts have successfully yielded mature technologies for year-round seed production of six marine finfishes (Cobia, Silver pompano, Indian pompano, Orange-spotted grouper, Pink ear sea bream, and John's snapper) and 27 species of expensive marine ornamental species, including five crossbreeds.

Mapping of potential mariculture sites

As India advances its ambitious blue economy agenda, a critical imperative emerges in the meticulous delineation of potential areas for diverse mariculture activities. This includes hatcheries, nurseries, cage farming, bivalve farming, pen culture, and seaweed culture. This strategic delineation is grounded in scientific criteria, considering environmental, socio-cultural attributes, and logistical considerations. Globally, the quest for additional areas to expand aquaculture to meet growing local and export markets necessitates an exploration of activities farther off the coast. A cornerstone of this approach is the implementation of marine spatial planning, ensuring the harmonious coexistence of various ocean activities, including mariculture while preserving ecosystems. The CMFRI has undertaken comprehensive efforts in this realm. Successfully mapping and identifying 317 potential seaweed farming sites covering an extensive 23,970-hectare area (Johnson et al., 2020), and geo-referenced 146 potential sites for sea cage farming within 10 km of the coastline, projecting a substantial production potential of 2.13 million tonnes of fish per year (Business Standard, 2023). Such meticulous mappings and identifications underscore a commitment to data-driven planning and establishing a robust foundation for the sustainable and efficient development of mariculture in India's coastal regions.

Mariculture systems

Prominent mariculture systems include sea cage farming, Integrated Multitrophic Aquaculture (IMTA), Recirculating Aquaculture System (RAS), culture of seaweeds, and bivalve farming. These methods emphasize sustainable cultivation, efficient resource use, and environmental conservation, showcasing a dynamic approach to the growth of the mariculture sector.

Sea cage farming

Sea cage farming, a milestone in intensive finfish production along India's coast since 2007, has seen progress in cage design, mooring systems and species involved. Collaborative demonstrations with Fisher Cooperatives, have played a pivotal role in popularizing cage culture. ICAR-CMFRI has played a pivotal role in developing and standardizing comprehensive guidelines and best practices for sea cage farming (NFDB, 2018), Good Aquaculture Practices in sea cage farming (Sekar et al., 2022), marine finfish hatchery (Ranjan et al., 2022), good mussel farming practices (Mohamed et al., 2019), and good seaweed farming practices (Johnson et al., 2023). CMFRI introduced indigenous 6-meter diameter cages of GI and HDPE make, which are widely adopted, yielding 2-3 tonnes of fish per cage per cycle. With an economic return of Rs. 1.5-2.5 lakh per crop, sea cage farming operates successfully in Maharashtra, Tamil Nadu, Kerala, Karnataka, and Odisha, transforming coastal aquaculture (Johnson et al., 2023).

Integrated Multitrophic Aquaculture (IMTA)

The idea of bio-mitigation of environmental pollution along with increased biomass production integrating commercially important species of different trophic levels is emerging as an innovation in aquaculture. IMTA is the practice which combines in appropriate proportions the cultivation of fed aquaculture species (*e.g.* finfish/shrimp) with organic extractive aquaculture species (*e.g.* shell/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). This concept is being adopted in cage aquaculture wherein appropriate proportions of finfishes/shrimp with shell/herbivorous fish are integrated with seaweed farming. This system can mitigate the potential negative externalities of sea cage farming with simultaneous enhancement in seaweed

yield. This technique (16 rafts of 12ft x 12ft size installed around a 6m dia. cage) has proven to double the yield in one cycle (45 days) of seaweed farming (additional 176 kg per cycle/raft of 12ft x 12 ft size) with commensurate income enhancement (Gopalakrishnan et al., 2023). The technology is currently adopted by more than 150 farmers in the Palk Bay region with the support of CMFRI.

Recirculating Aquaculture System

Recirculating aquaculture systems (RAS) represent onshore facilities designed to cultivate fish at high density within controlled environmental conditions. In these systems, water is continuously pumped through fish-rearing tanks in a closed-loop configuration, comprising a series of sub-systems for routine water treatment processes. These facilities serve the dual purpose of seed production and grow-out for various species, even accommodating exotic temperate varieties like the Atlantic salmon, all within a precisely regulated environment. The CMFRI has developed and implemented a cost-effective RAS facility. This facility is employed for year-round maturation of broodstock, seed production, and nursery rearing for seven species of marine finfish. The success of this RAS facility has gained popularity among stakeholders in different coastal states, showcasing its efficacy in advancing sustainable aquaculture practices.

Seaweed farming

Seaweed farming offers significant opportunities for livelihoods and diverse by-products. Its key advantage is the low capital input, functioning as a primary producer with minimal external requirements. In the past decade, Palk Bay, Tamil Nadu, has witnessed economically viable seaweed farming by self-help groups (SHG) using a 3.7 x 3.7 m raft system with a 45-day farming cycle for 270 days/year. This environmentally friendly practice holds the potential for enhancing coastal community livelihoods. Despite the potential to generate carbon credits, the current industrial demand surpasses supply from both farmed and wild-collected seaweeds. Addressing this CMFRI is attempting production of seaweed planting material through micropropagation, along with the development of processing and marketing strategies, crucial for the future expansion of seaweed farming in India.

Farming of bivalves

Cultivation of mussels and oysters has expanded in India along Kerala, Karnataka, Goa, and Maharashtra's backwater belts due to high profitability. Methods like stake culture, on-bottom culture, long-line culture, raft culture, and rack culture are employed. The rack culture of green mussels in North Kerala, especially in Padanna estuary areas, involves around 2000 farmers, contributing three-quarters of India's green mussel production. The CMFRI successfully implemented commercial farming along the West Coast, yielding 10,000 tonnes annually, benefiting about 6000 women self-help groups (Gopalakrishnan et al., 2019).

Other supporting processes

Beyond the fundamental processes of mariculture, key supporting processes are essential for the industry's holistic and sustainable development. Feed management, aquatic animal health management, green certification for marine ornamental species, marketing strategies and value chain development are integral components, in the promotion of mariculture products.

Mariculture feed management

Fish meal, a crucial protein component, determines feed cost-effectiveness in mariculture. Increasing demand, particularly from poultry and shrimp farming, escalates feed prices, challenging mariculture's economic viability. Global concerns about fish meal sourced from low-value fishes consumed by humans

prompt the exploration of alternative protein sources. We endeavour to target species-specific feeds, including micro feeds for larval nutrition, tailored to growth patterns of prioritized mariculture species, ensuring efficient and economically viable production.

Aquatic animal health management

In the Indian mariculture context, bacterial diseases primarily stem from opportunistic pathogens like *Vibrio* sp., *Photobacterium* sp., and *Streptococcus* sp., leading to substantial economic losses. Bivalve farming faces a significant threat from diseases caused by *Perkinsus olseni* and *P. beihaiensis*. CMFRI has developed diagnostic tools for detecting these pathogens. Given the susceptibility of fish farming to infectious diseases, robust investments in disease management are imperative. To address this, the National Surveillance Programme for Aquatic Animal Diseases (NSPAAD) was initiated in India in 2013. This nationwide program monitors aquatic animal diseases, including those affecting marine finfish and shellfish species.

Green certification of marine ornamental species

CMFRI has standardized the breeding and seed production of 27 high-value marine ornamental fish species, including four designer varieties of Percula clown fishes. The potential for ornamental fish trade in India is vast, identified by the government as a thrust area for export development. This trade has witnessed growth in the collection, culture, and marketing of marine ornamental fishes in recent years. However, the trade's prosperity hinges on three prerequisites: quality, quantity, and sustainability. Therefore, raising awareness among local communities and stakeholders to discourage unlawful and illegal practices is crucial. Recognizing the importance of environmental and socioeconomic sustainability, CMFRI is in the process of developing guidelines for Green certification for Indian marine ornamental fishes.

Marketing and value chain development

The seasonality of mariculture production systems may lead to a market glut during harvest, necessitating efficient value chains for the timely and cost-effective clearance of highly perishable produce. The mariculture produce value chain involves intermediaries such as auctioneers, wholesalers, commission agents, retail outlets, and processors, extending from the farm to the consumer. Ensuring quality requires efficient market logistics, including insulated trucks, refrigerated containers, cold storage, and packaging. Post-harvest processing and value addition are crucial elements. The government has initiated efforts for the comprehensive development of mariculture value chains, addressing infrastructure requirements for marketing on a priority basis. Financial assistance, capacity building, technical guidance, and institutional support are also being ensured for stakeholders in the value chain.

Policy support for mariculture development

Recent years have witnessed significant efforts by the Government of India to advance mariculture development. The National Fisheries Development Board (NFDB) formed a committee to draft the National Mariculture Policy (Gopalakrishnan et al., 2019). This policy focuses on sustainable expansion, optimized leasing and licensing practices, mariculture systems, species selection, environmental health, seed and feed resources, animal health management, certification standards, insurance mechanisms, and market initiatives. Currently under consideration within the Ministry of Fisheries, Animal Husbandry, and Dairying, the policy aims to harvest around 4.1 million tonnes of marine fish annually through cage culture alone by 2050, with 1% of the country's extensive coastline dedicated to mariculture. To achieve this, India is mulling establishing dedicated mariculture parks and leasing marine areas to local fisher groups, cooperatives, and entrepreneurs through stakeholder consultations. A crucial aspect involves ensuring the availability

of approximately 2,460 million seeds and around 6.15 million tonnes of feed to meet the sector's expanding demands. The Government of India, particularly the NFDB and CMFRI, has taken various measures to promote and regulate mariculture.

References

Business Standard. 2023. CMFRI identifies 146 sites along the Indian coastline for sea cage farming. https://www.business-standard.com/article/economy-policy/cmfri-identifies-146-sites-along-indian-coastline-for-sea-cage-farming-123020700952_1.html

FAO. 2017. The future of food and agriculture: Trends and challenges. Food and Agriculture Organization of the United Nations, Rome.

FAO. 1997. Mariculture Development: A New Challenge. FAO Fisheries Circular No. 928 FIIU/C928. FAO., Rome. http://www.fao.org/docrep/w6602e/w6602e00.htm

Johnson, B., D. Divu, Reeta Jayasankar, L. Ranjith, Gyanaranjan Dash, et al. 2020. Preliminary estimates of potential areas for seaweed farming along the Indian coast. *Marine Fisheries Information Service Technical & Extension Series* No. 246: 14-28.

Johnson, B., Tamilmani, G., Divu, D., Mojjada, S. K., Megarajan, S. et al. 2023. *Good Management Practices in Seaweed Farming*. CMFRI Special Publication (148), 30p.

Gopalakrishnan, A., Kirubagaran, R., George John, Ponniah, A.G., Gopakumar, G., Sunilkumar Mohamed K., Krishnan, Imelda Joseph, Boby Ignatius, Abdul Nazar, A.K., Jayakumar, R., Raju, M.S., Sreepada, R.A., Shinoj, P. and Rajesh N. (2019). Draft National Mariculture Policy 2019 (NMP2019); Report of the Committee constituted by the National Fisheries Development Board (NFDB), Ministry of Fisheries, Animal Husbandry & Dairying, Govt. of India. CMFRI Marine Fisheries Policy Series No.17/2020, 22p.

Gopalakrishnan, A., Boby Ignatius and VVR Suresh. 2023. Mariculture Development in India: Status and Way Forward. *Indian J. Plant Genet. Resour.* 35(3): 317–321.

Mohamed K. S., P. K. Asokan, G. Sasikumar, P. Kaladharan, V. Kripa, et al. 2019. Guidance for Good Mussel Farming Practices in India based on a Case study from Kerala. CMFRI Mar. Fish. Policy Series 10, 64p.

NFDB. 2018. Guidelines for Sea Cage Farming in India. National Fisheries Development Board, Hyderabad. 22p.

NPMF, National Policy on Marine Fisheries (2017) Ministry of Agriculture and Farmers Welfare (Department of Animal Husbandry, Dairying and Fisheries), Government of India, The Gazette of India Notification, Extraordinary, Part 1, Section 1, No. 121, New Delhi, the 1st May, 2017, F. No. 21001/05/2014-FY (Ind) Vol. V.

Ranjan, R., Muktha, M., Ghosh, S., Gopalakrishnan, A., Gopakumar, G., Joseph, I. (Eds.). 2017. Prioritised species for mariculture India. ICAR-Central Marine Fisheries Research Institute, Kochi, 450p.

Ranjan, R., Megarajan, S., Xavier, B., Avadhanula Ravi K, Ghosh, S., Gopalakrishnan, A. 2022. Good Aquaculture Practices for Marine Finfish Hatchery. CMFRI Special publication No. 142, 34p.

Schubel, J. R., Thompson, K. 2019. Farming the Sea: The only way to meet humanity's future food needs. GeoHealth, 3, 238-244. https://doi.org/10.1029/2019GH000204

Sekar Megarajan, Ritesh Ranjan, Biji Xavier, Biswajit Dash, Shubhadeep Ghosh, A. Gopalakrishnan. 2022. Good Aquaculture Practices (GAP) in Sea cage farming of Indian pompano and Orange spotted grouper. ICAR-Central Marine Fisheries Research Institute Special Publication No. 143, 72p.