Mariculture in India: An Overview

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Introduction

By 2050, the world is projected to need a 50% increase in food production to sustain an anticipated global population of 9.7 billion (FAO, 2017). Meeting this demand presents considerable challenges due to the existing scarcity of land and freshwater resources, along with the looming threats of climate change and geopolitical impacts. Within the global food production landscape, aquaculture has emerged as the fastestgrowing sector, with an annual growth rate exceeding 6% over the past two decades. Among the various segments of aquaculture, mariculture is the most rapidly expanding sub sector, holding immense growth potential. In 2020, mariculture contributed a substantial 33.0 million tonnes of food fish, approximately 27% of the global food fish aquaculture production. The overall mariculture production, including seaweeds, reached an impressive 68.1 million tonnes, accounting for a significant 55.6% of the total world aquaculture production that year. With its growing demand for seafood, India is well-positioned to harness the significant potential of mariculture, recognizing that reliance on the capture fisheries sector alone cannot meet this increasing demand. The National Policy on Marine Fisheries (NPMF, 2017) highlights the pivotal role of mariculture in enhancing fish production from coastal waters. In line with this policy, the government is committed to addressing the institutional and commercial requirements of the emerging mariculture sector. This commitment includes formulating leasing rights policies, spatial planning, providing technological inputs such as husbandry, seed, feed, and health management, and addressing environmental and social impacts. Additionally, there is a concerted effort to build capacity among 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), encompasses the cultivation of marine organisms in seawater, either in enclosed ocean sections or in tanks, ponds, and raceways filled with seawater. Practiced responsibly, mariculture is crucial for supplementing land-based economies and conserving marine

capture fisheries, thus contributing significantly to the global food and nutrient supply (Schubel and Thompson, 2019).

In India, the demand for seafood is rapidly rising and cannot be met solely through capture fisheries. The origins of mariculture development in India date back to the 1970s, when the ICAR-Central Marine Fisheries Research Institute (CMFRI) began pioneering efforts in Mandapam and Tuticorin, focusing initially on seaweed and bivalve culture. These efforts soon expanded to include induced maturation and breeding of the Indian white shrimp and the promotion of semi-intensive shrimp farming.

Advancing technology, particularly in seed production and farming techniques, is key to harnessing the vast potential of mariculture. This includes the cultivation of finfishes such as cobia, silver pompano, Indian pompano, sea bass, groupers, snappers, and breams, as well as ornamental fishes. Shellfish species like mussels, oysters, clams, green tiger shrimp, and blue swimmer crab are also integral to this strategy. Furthermore, technologies for marine pearl production and seaweed farming have already seen significant progress in India, offering additional opportunities for sustainable growth in the mariculture sector.

Mariculture represents a critical frontier with vast potential along India's 8,118 km coastline and within the Exclusive Economic Zone spanning over 2.3 million km^2. Despite an estimated annual mariculture production potential of 4 to 8 million tonnes, current production stands at a mere approximately 0.1 million tonnes (Gopalakrishnan *et al*., 2023), highlighting substantial untapped opportunities for blue economic growth.

To fully realize India's blue economy potential through mariculture, it is essential to establish a strategic mission. This mission should focus on prioritizing mariculture species, developing hatchery technologies, scaling up grow-out technologies, and identifying suitable sites for mariculture. Additionally, implementing enabling factors and policies is crucial for the successful expansion of mariculture in India. A comprehensive approach is vital to unlocking the full potential of mariculture and contributing to sustainable economic development.

Prioritization of mariculture species

Advancing the blue economy hinges on the strategic selection of target species for mariculture and the development of hatchery technologies. This selection process requires a thorough evaluation of factors such as market demand, ecological sustainability, biological characteristics, and economic feasibility. In 2017, a detailed initiative led to the careful prioritization of 76 different species for mariculture

development. This prioritized list included 23 finfish species, 7 molluscs, 6 crustaceans, and 31 ornamental species, along with 4 region-specific species and 5 species of conservation interest (Ranjan *et al.*, 2017). This strategic prioritization highlights a nuanced approach aimed at promoting sustainable and diversified mariculture practices.

Captive breeding and seed production

The standardization and demonstration of breeding and seed production technologies are crucial advancements in enhancing India's ability to utilize its marine economic resources. These technologies, applied across various taxa such as finfish, shellfish, and seaweed, have been rigorously developed to ensure their reliability and efficiency. Standardizing breeding methods involves meticulous control and optimization of environmental conditions to promote successful reproduction and genetic diversity. Concurrently, seed production technologies focus on the systematic cultivation of juvenile organisms, ensuring their healthy development for later transfer to grow-out facilities.

This scientific progress not only represents a significant step forward in the sustainable management of marine resources but also creates opportunities for the commercialization of mariculture ventures, thereby contributing to India's blue economy goals. Currently, captive breeding technologies are available for at least 12 finfish species, several molluscs and shellfish, as well as a variety of live feed organisms. To meet future demand for seeds of cultivable species, innovative measures are being implemented to establish hatcheries, seed banks, rearing units, and SPF/SPR/genetically improved brood banks. Additionally, a system for seed certification is being planned to ensure the supply of quality seed.

To boost mariculture production, CMFRI has established the National Brood-bank Facility for Cobia and Silver Pompano. Another significant ongoing initiative is the All-India Network Project on Mariculture (AINP(M)), led by CMFRI, which addresses technological constraints in mariculture. Research efforts have successfully developed mature technologies for the year-round seed production of six marine finfish species (Cobia, Silver Pompano, Indian Pompano, Orange-spotted Grouper, Pink Ear Sea Bream, and John’s Snapper) and 27 species of valuable marine ornamental species, including five crossbreeds.

Mapping of potential mariculture sites

As India advances its ambitious blue economy agenda, meticulously delineating potential areas for diverse mariculture activities becomes a critical imperative. 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 exploring 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-referencing 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 steadfast commitment to data-driven planning, establishing a robust foundation for the sustainable and efficient development of mariculture in India's coastal regions.

Mariculture systems

Prominent mariculture systems encompass sea cage farming, Integrated Multitrophic Aquaculture (IMTA), Recirculating Aquaculture Systems (RAS), seaweed culture, and bivalve farming. These methods highlight sustainable cultivation, efficient resource use, and environmental conservation, showcasing a dynamic approach to the sector's growth.

Sea cage farming

Since 2007, sea cage farming has become a milestone in intensive finfish production along India's coast, marked by advancements in cage design, mooring systems, and species involved. Collaborative demonstrations with Fisher Cooperatives have been crucial in popularizing cage culture. ICAR-CMFRI has been pivotal 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 techniques (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 made of GI and HDPE, 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 has successfully transformed coastal aquaculture in Maharashtra, Tamil Nadu, Kerala, Karnataka, and Odisha (Johnson *et al*., 2023).

Integrated Multitrophic Aquaculture (IMTA)

The concept of bio-mitigation of environmental pollution, coupled with increased biomass production by integrating commercially important species from different trophic levels, is emerging as an innovation in aquaculture. IMTA is the practice that combines 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) in appropriate proportions 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, where 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 while simultaneously enhancing seaweed yield. This technique (16 rafts of 12ft x 12ft size installed around a 6m diameter cage) has been proven to enhance seaweed yield by about 122% 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) are onshore facilities designed for highdensity fish cultivation within controlled environmental conditions. These systems continuously pump water through fish-rearing tanks in a closed-loop configuration, incorporating various sub-systems for routine water treatment processes. Serving the dual purpose of seed production and grow-out for various species, they can even accommodate exotic temperate varieties like Atlantic salmon, all within a precisely regulated environment. The CMFRI has developed and implemented a cost-effective RAS facility, utilized 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, demonstrating its efficacy in advancing sustainable aquaculture practices.

Seaweed farming

Seaweed farming presents significant opportunities for livelihoods and diverse byproducts, with its key advantage being low capital input and functioning as a primary

producer with minimal external requirements. Over the past decade, Palk Bay, Tamil Nadu, has witnessed economically viable seaweed farming by self-help groups (SHGs) 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 to enhance coastal community livelihoods. Despite the potential to generate carbon credits, the current industrial demand surpasses supply from both farmed and wild-collected seaweeds.

To address this issue, 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

Due to high profitability, the cultivation of mussels and oysters has expanded in India along the backwater belts of Kerala, Karnataka, Goa, and Maharashtra. Various methods such as stake culture, on-bottom culture, long-line culture, raft culture, and rack culture are employed. The rack culture of green mussels in North Kerala, particularly in the Padanna estuary areas, involves 2000 farmers and contributes threequarters of India's green mussel production. The CMFRI successfully implements commercial farming along the West Coast, yielding 10,000 tonnes annually and benefiting 6000 women self-help groups (Gopalakrishnan *et al*., 2019).

Other supporting processes

In addition to the fundamental processes of mariculture, key supporting processes are crucial for the industry's holistic and sustainable development. These include feed management, aquatic animal health management, green certification for marine ornamental species, marketing strategies, and value chain development, all integral components in promoting mariculture products.

Mariculture feed management

In mariculture, fish meal, a crucial protein component, plays a pivotal role in determining feed cost-effectiveness. The rising demand, especially from poultry and shrimp farming, leads to an escalation in feed prices, posing challenges to the economic viability of mariculture. Given global concerns about fish meal sourced from low-value fishes consumed by humans, there is a push to explore alternative protein sources. Our endeavor is to develop species-specific feeds, including microfeeds for larval nutrition,

tailored to the growth patterns of prioritized mariculture species, ensuring efficient and economically viable production.

Aquatic animal health management

In the Indian mariculture context, bacterial diseases primarily arise from opportunistic pathogens such as *Vibrio* sp., *Photobacterium* sp., and *Streptococcus* sp., resulting in significant economic losses. Bivalve farming is particularly threatened by diseases caused by *Perkinsus olseni* and *P. beihaiensis*. CMFRI has developed diagnostic tools to detect these pathogens. Given the susceptibility of fish farming to infectious diseases, robust investments in disease management are imperative. To address this issue, 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 clownfishes. The potential for the ornamental fish trade in India is vast, identified by the government as a thrust area for export development. In recent years, this trade has witnessed growth in the collection, culture, and marketing of marine ornamental fishes. However, the trade's prosperity relies 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 result in 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. Efforts initiated by the government focus on 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

In recent years, the Government of India has made significant efforts to advance mariculture development. The National Fisheries Development Board (NFDB) formed a committee to draft the National Mariculture Policy (Gopalakrishnan et al., 2019), which 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 goal, India is contemplating the establishment of 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.

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