# Indian Agriculture by 2047

## A Roadmap for Research, Education and Extension

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# 5 Fisheries Sector



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## 1. Context

India's fisheries sector has exhibited remarkable growth and resilience over the years, evolving into a pivotal component of the country's agriculture and food industry. From a modest production of 24.42 lakh tons in 1980, the sector has experienced a rapid rise, reaching an astounding 162.48 lakh tons by 2022-23. This remarkable expansion is characterized by a significant shift towards inland and coastal production, which now stands at 121.21 lakh tons and exceeds marine production at 41.27 lakh tons (FAO, 2024a). The sector has maintained a robust average annual growth rate of 10.34%, reflecting its dynamic adaptation to changing environments and market demands. This surge in production has had a considerable impact on the country's economy, contributing 6.44% to the Gross Value Added (GVA) in the agriculture sector (GoI, 2020a). Additionally, the fisheries sector has marked its prominence in the global market, with the export of 13 lakh tons of fish and fishery products generating revenue of over Rs. 60,000 crore and witnessing an annual growth rate of 31.71%. Beyond its economic contributions, the fisheries sector is a vital source of employment, providing livelihood opportunities to approximately 28 million people nationwide (DoF, 2020). This includes many jobs spanning from fishing, processing, and marketing, highlighting the sector's pivotal role in socio-economic development and community welfare.

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India's fisheries sector provides enormous potential in extending its reach to hitherto underexploited resources in both marine and inland waters; sizeable hikes in production and productivity from aquaculture; productive integration with other farming sectors such as agriculture, horticulture, poultry, and livestock; expansion of non-food fisheries such as ornamental; and in enhancing the availability of nutritious fish protein rich in omega-3 fatty acids to the nation's growing population. On the environmental front, ponds, tanks and floodplains can play a very important role in harvesting and holding rainwater and serving as a valuable ameliorative agent for recharging groundwater.

Despite the progress, India still lags behind in per capita fish consumption (7.89 kg/year) compared to the global average (20.25 kg/year) (FAO, 2024a, NAAS, 2024a). With the growing population of the country and the increasing requirements for fish protein, the need to produce an adequate quantity of fish at a reasonable price is more compelling than ever before. To match such demands and ensure a growth trajectory that fulfils the requirements of today and leaves an equally better fishery for tomorrow, it is necessary for the country to develop a sound National Fisheries Policy framework. The Policy will provide the blueprint to optimally harness the capture and culture of fishery resources that would help sustain the desired production and productivity levels. This policy framework is also expected to guide similar initiatives at the State and Union Territory levels in the coming period.

## 1.1. Marine fisheries

The potential of the fisheries sector in general and the marine fisheries sub-sector in particular was recognised quite early in India's development planning. Marine fisheries play an important role in trade and commerce and promote employment and livelihoods of coastal communities. After the declaration of the EEZ in 1976, the sea area available to India is estimated at 2.02 million $km^2$, a shelf area of 0.372 million $km^2$, and a coastline of 8118 km (ICAR, 2015b). With sovereign rights on the EEZ, India has also acquired the responsibility to conserve, develop and optimally harness the marine living resources within this area. The marine fisher population in India is estimated at 3.77 million, of which 0.93 million are active fishers (ICAR, 2018). About 0.52 million people are engaged in fishing and allied activities, of which 69% are women (ICAR, 2018). Women are especially active in fish marketing, constituting about 86% of the participants. About 14,000 women are also engaged in fish seed collection, and an equal number in the shell collection activities

(ICAR, 2018). The predominance of small-scale fisheries characterises the marine fisheries sector as a whole.

### 1.2. Inland fisheries

The inland capture fisheries resources are as vast and varied as the marine fisheries resources, and their importance as a source of livelihoods, food, and nutrition for the population has been no less than their marine counterpart. The riparian communities along the major river systems of India have been as old and traditional as the marine fishers. However, with the changing scenario in the inland sector, their migration to other sources of livelihoods is more prominent than any other food production sector.

The inland capture fisheries resources include a riverine length of 2,01,496 km (including the tributaries and irrigational canals), 3.52 million ha of small and large reservoirs, 1.2 million ha of floodplains, etc (NAAS, 2016). The total area available for the inland fishery is estimated at 8.24 million ha, excluding rivers and canals (NAAS, 2016). The total inland fisher population is approximately 24.29 million (DoF, 2020).

## 2. Challenges and Opportunities

### 2.1. Global challenges and opportunities

According to the recent FAO's Global State of Fisheries and Aquaculture (SOFIA, 2022) report, aquatic food production is forecast to increase by a further 15% by 2030, mainly by intensifying and expanding sustainable aquaculture production. Such growth should preserve aquatic ecosystem health, prevent pollution, and protect biodiversity and social equality. However, it also predicts that aquaculture production's average annual growth rate will slow over the next decade to less than half the rate observed in the previous decade, dropping from 4.2% (2010-2020) to 2% (2020-2030) (FAO, 2024a). Several factors are expected to contribute to this slowdown. These are broader adoption and enforcement of environmental regulations; reduced water availability and suitable production locations; increasing outbreaks of aquatic animal diseases related to intensive production practices; and decreasing aquaculture productivity gains.

The opportunity would still lie with the Asian countries, including India, as they are expected to continue to dominate the aquaculture sector, maintaining their share of 88% of 2030 global aquaculture production, and be responsible for more than 88% of the increase in production by 2030. The report further predicts that all farmed groups of species will continue

to increase. Still, rates of growth will be uneven across groups, and the quantitative importance of different species will change as a consequence. In general, species that require larger proportions of fishmeal and fish oil in their diets are expected to grow more slowly owing to higher prices and reduced availability of fishmeal.

FAO envisages a "Blue Transformation" strategy to steer the sector during the next decade with four specific goals: (i) increase the development and adoption of sustainable aquaculture practices; (ii) integrate aquaculture into national, regional and global development strategies and food policies; (iii) expand and intensify aquaculture production to meet the growing demand for aquatic food and enhance inclusive livelihoods; and (iv) improve capacities at all levels to adopt innovative technology and management practices for a more efficient and resilient aquaculture industry.

The burden on the aquatic environment is increasing due to continued urbanization, industrialisation, and climate change (FAO, 2020, World Bank, 2013). Coastal areas face pressures from development activities, while urban and industrial effluents impact inland water bodies. Climate change is causing warming temperatures, sea level rise, ocean acidification, and changes in precipitation patterns, which can have severe consequences for aquatic ecosystems and the fisheries they support (FAO, 2020).

Many of the world's fish stocks are over-exploited, with fish stocks declining at unsustainable rates due to excessive fishing pressure. Restoring and maintaining healthy fish populations is crucial. Activities such as coastal development, pollution, and destructive fishing practices are degrading critical habitats like coral reefs, mangroves, and estuaries that serve as nurseries for many fish species. With growing populations and increasing demand for seafood as a vital source of protein and nutrients, sustainable fisheries management is essential to ensure food security and nutrition, especially in developing coastal communities.

Illegal, Unreported, and Unregulated (IUU) fishing undermines conservation efforts, distorts market competition, and threatens the livelihoods of legitimate fishers. Combatting this illicit activity is a global priority. The unintended catch of non-target species, including marine mammals, turtles, and seabirds, is a significant conservation concern, as is the wasteful practice of discarding edible fish at sea.

Climate change-related risks pose one of the major challenges for the fisheries sector globally. IPCC's recent sixth assessment report reiterated the acceleration of global warming and placed unprecedented emphasis

on adaptation, highlighting the urgency of scaling up adaptation actions. Fisheries and aquaculture make a minor contribution to global carbon emissions. But there are opportunities for decarbonisation along the fisheries and aquaculture value chain, increasing its efficiency by reducing fish waste and losses, including for small-scale fishers and fish farmers. Decarbonisation technologies already exist; however, access and upscaling remain challenging due to the high costs.

Emerging and frontier technologies like artificial intelligence (AI), internet of things (IoT), blockchain, and nanotechnology provide opportunities to develop high-tech aquaculture systems (UNDP, 2025). These advanced technologies can enable precision farming, automation, real-time monitoring, and optimization of production processes, leading to improved efficiency, sustainability, and profitability in aquaculture operations worldwide. However, the concerns raised about these emerging technologies, such as displacement of labor and growing unemployment, digital divide and inequity between small-scale and large-scale operators, etc., need to be taken into account. Leveraging precision fishing technology can help reduce fishing operations' carbon footprint and promote sustainable resource utilization. Advancements in areas such as fuel-efficient vessels, selective fishing gear, real-time catch monitoring, and electronic monitoring can contribute to developing a green and responsible fishing industry.

There is a growing demand for the development of antibiotic-free fish production systems, driven by concerns over antimicrobial resistance and consumer preferences for safer, more sustainable food products. This requires innovations in disease prevention, alternative treatments, and improved biosecurity measures in aquaculture facilities. Consumers, particularly in developed nations, are becoming increasingly aware of the need for safe, nutritious, and fortified fish products produced through eco-friendly and sustainable practices. This presents an opportunity for aquaculture and fisheries businesses to differentiate their products and capture premium market segments by adopting responsible and traceable production methods.

## 2.2. National challenges and opportunities

The fisheries sector in India faces several challenges, including minimal technology application and productivity levels that are less than optimal compared to Southeast Asian countries. Genetic selection has been limited to 1-2 traits in carps, while countries like Europe and East Asia have advanced to selecting for 5-6 traits in species like salmonids and

tilapia. There is limited access to and exchange of globally available technologies for open water and precision aquaculture and inadequate knowledge of genomic diversity. The lack of vaccines, therapeutics, on-farm diagnostics, and efficient delivery systems poses a significant hurdle. Moreover, there is an absence of long-term aquatic ecosystem change studies and understanding of human-ecosystem interactions, compounded by inadequate R&D infrastructure for high-throughput genome analysis and mining given India's rich aquatic species diversity.

Non-transparent, data-deficient fisheries, characterized by poor monitoring, control, and surveillance, as well as inadequate knowledge of stock identities and fishing grounds, impede effective management. The excessive use of fossil fuels leads to an increased carbon footprint and reduced productivity, while the dependence on conventional fishing systems persists due to the non-adoption of available technologies. In the post-harvest sector, there is a low integration of frontier technologies, high dependence on capital-intensive imported machinery, low adoption of farm-to-fork traceability technologies, and poor integration among supply chain nodes. Inadequate post-harvest fish handling and cold chain management further exacerbate the challenges.

A significant issue is the unrecognised contribution of small-scale fishers, women, and fish workers due to the non-availability of sex-disaggregated data. The predominance of traditional, input and energy-intensive technologies with high environmental footprints and low adoption rates, such as the lack of miniaturisation of analytical/processing equipment and bio-refinery, poses a challenge. Limited availability of indigenous processing machinery and inadequate implementation of food safety and traceability measures across the value chain further hamper progress.

A significant limitation is the lack of synergies in terms of interdisciplinary and multispecialty human capital and R&D teams. Additionally, there is a substantial gap between the demand and supply of professional (4500 vs. 1500) and paraprofessional (28000 vs. 3500) human resources in fisheries and aquaculture. Limited mobility and exchange of human resources and partnerships within Asia, as well as an incoherent science (R&D)-policy interface in informing fisheries management, further impede progress in the sector.

The supply chain is the weakest link in the entire series of operations in the fisheries sector in India. It results in considerable losses to the operators and the national economy. Improving the supply chain from 'boat to plate' and 'farm to fork' can benefit fish harvesters, farmers, processors,

and consumers. This one area has remained grossly neglected and needs to be improved significantly to reduce post-harvest losses, provide safe food to people, and improve the economy of the participants in the chain. Improvements in the supply chain would necessitate the following major policy initiatives.

While the country has modern processing infrastructure catering to the export market, the same is true for domestic marketing. Fish is sold most unhygienically at the landing sites and/or wholesale/retail markets. Despite substantial assistance being made available by the Government for setting up/improving fish handling centers (FHCs) and fish landing centers FLCs and fish markets, the situation has not improved. This is one of the reasons why India has been witnessing a slower growth rate in fish consumption over the years compared to many Asian countries such as Thailand, Vietnam, Malaysia and even Sri Lanka. Unfortunately, there has also been little consumer resistance to purchasing fish handled in the most unhygienic manner.

The environment in both marine and inland waters in India is under stress due to pollution and is probably one of the reasons for the decline in fish stocks. With the increasing anthropogenic activities on land and inadequate mechanisms for effluent treatment, the abundance of solid waste and in particular plastics (especially micro-plastics) has increased manifold in the sea as well as in the inland waters, resulting in negative impacts on the fauna and flora. There are also several alarming reports that indicate the movement of microplastics back to human beings through the fish food cycle.

Wanton and un-wanton dumping of fishing nets in the oceans also contributes to micro-particles, besides the nets engaging in ghost fishing, which affects fish stocks. The policy directives will strengthen regulatory mechanisms to control pollutants to ensure that land and sea-based pollution is effectively controlled and the ecosystems are monitored. Fishers will make all-out efforts to ensure that fishing vessels do not contribute to marine pollution by considering the required measures, in the design and construction of fishing vessels and subsequently in the use of gear.

## 3. Vision and Mission

### 3.1. Vision

By 2047, India will emerge as a global leader in sustainable, climate-resilient, technologically advanced fisheries and aquaculture. The sector

will be transformed into a state-of-the-art, green, resource-sensitive, equitable, and competitive industry, underpinned by scientifically managed and well-sustained aquatic ecosystems and biodiversity.

### 3.2. Mission

Aquaculture will achieve technological self-reliance and global eminence, driven by cutting-edge genetics, biotechnology, precision farming, and renewable energy integration innovations. Genetically improved and technology-augmented aquaculture systems will optimize productivity, quality, and resilience, ensuring all food, nutrition, and livelihood security.

Capture fisheries will be sustainable, monitored, assessed, regulated, and traceable, safeguarding marine, coastal, and inland ecosystems. Advanced stock assessment, monitoring, control, and surveillance systems will promote transparency and traceability, enabling informed management decisions and ecosystem conservation.

Indigenous technologies and machines with low environmental footprints will facilitate the zero-waste utilization of aquatic resources, yielding safe, nutritious, and consumer-friendly products. Blockchain-enabled traceability, intelligent fish handling, and modern retail chains will ensure food safety, quality assurance, and fair value realisation for all stakeholders.

Interdisciplinary research and development will drive innovation, harnessing advances in genomics, biotechnology, artificial intelligence, nanotechnology, and renewable energy. A robust ecosystem of incubation centers, skill development programs, and policy research will nurture a globally competitive workforce, positioning India as a thought leader in sustainable fisheries and aquaculture development.

Through international cooperation, inclusive stakeholder engagement, and evidence-based policymaking, India will champion the sustainable management of shared resources, ecosystem restoration, and climate change adaptation and mitigation strategies, fostering resilient aquatic ecosystems and conserving biodiversity for future generations.

## 4. Priority Areas

### 4.1. Genetically improved, technology augmented, resilient & responsible aquaculture systems (GITA-RAS)

The GITA-RAS program aims to utilize genetic and genomic diversity for a 20% increase in productivity and quality enhancement in aquaculture

systems. It involves upscaling ready-to-adopt technology packages for seed, feed, health, and grow-out of freshwater, marine, ornamental, seaweed, and aquaculture in open water and degraded land areas. The program focuses on developing hi-tech aquaculture systems (utilizing advances in AI, ICT, space technology, nanotechnology, etc.) for four high-value species in open sea/reservoir automated cages, biofloc, and recirculating aquaculture systems (RAS). It also explores viable technologies for *in-vitro* fish meat production and marine microalgae culture. Additionally, the program aims to use renewable energy (up to 30- 40%) in hi-tech culture systems and establish cellular fish culture and marine microalgae parks in suitable marine hubs (ICAR, 2015a).

### 4.1.1. Mariculture

The Government of India, recognizing that the demand for seafood will be increasing year after year and also realizing that marine capture fisheries alone might not be able to meet the additional seafood demands, has initiated the development of mariculture in the country's coastal areas. Based on the potential areas available for mariculture development in the country, the annual production of 4-8 Mt has been projected.

As mariculture development in the country is in nascent stage, the policy initiatives would be manifold, starting with developing a blueprint of suitable sites/areas along the Indian coastline with a leasing policy following a Marine Spatial Planning (MSP) approach. This would allow the selection process of identifying suitable species for farming in a particular area and allocation of space on a priority basis to small and traditional fishers for open sea cage farming. Commercial-scale production of seed of potential species and their cage farming may be promoted in specifically identified ocean spaces, in particular in waters beyond 12 nautical miles, but with adequate safeguards and without affecting regular fishing, shipping and other maritime activities.

On the Indian coastline, which is almost straight with large areas exposed to surf and tidal influence, cages have to be set up in open waters, exposing them to the elements of nature, as well as in sites located in bays, coves, and sheltered areas and are less vulnerable to high winds and currents. Therefore, one of the key requirements to popularize mariculture would be the availability of sturdy cages and moorings that can withstand the harsh marine environment.

While sufficient progress has been made in the development of technologies for breeding and larval rearing of a number of candidate species (*e.g.*

cobia, silver pompano, Indian pompano, orange-spotted grouper, emperor sea-bream, John's snapper and vermiculated spinefoot, green and brown mussels and edible oyster), the availability of quality seed in sufficient quantities would kick-start the activities on a larger-scale and also make farming cost-effective. The role of R&D and industry is prime in this regard to cater to the needs of the mariculture farmers and entrepreneurs. Policy initiatives will provide the required support for promoting commercially viable seed production technologies and developing brood banks for candidate species and hatcheries to scale up seed production and availability to meet the requirements of farmers. The PPP will also be important in the entire mariculture developmental process (ICAR, 2015b).

### 4.1.2. Seaweed farming

Like aquaculture and mariculture, urban farming in the country is also untapped, and demand for seaweed is increasing for hydrocolloids, cosmetics, supplements, and as a potential biofuel source. This sub-sector offers immense scope for value creation along the value chain and can contribute significantly to the economy in the coastal country. There are about 844 seaweed species in India with a standing stock of about 58,715 tons (NAAS, 2024b). Seaweeds are abundant along the Tamil Nadu, Gujarat and Diu coasts and around the Lakshadweep and Andaman & Nicobar Islands. Rich seaweed beds occur around Mumbai, Ratnagiri (Maharashtra), Goa, Karwar (Karnataka), Varkala, Vizhinjam (Kerala) and Pulicat (Tamil Nadu), East Godavari to Srikakulam coast (Andhra Pradesh) and Chilka (Odisha). However, indiscriminate and unorganized harvesting has resulted in the depletion of natural resources.

While the initial trial of seaweed farming was carried out during the early and mid-1980s, the activity has yet to popularize. Unlike other fisheries activities, local demand for seaweed for food purposes is minimal. Nearly all domestic seaweed production is used in the industrial sector, and, therefore, the production would necessitate strong backward and forward linkages. The policy would ensure that such linkages are developed while ready-to-use technologies and other inputs are made available.

Suitable areas for seaweed farming have been identified along the coastline of Gujarat, Diu, Lakshadweep, Tamil Nadu, and Andhra Pradesh by the research institutions in the country. To promote seaweed farming and attract the fishers, initially, seaweed seedbanks using sexual reproduction methods, complementing the presently adopted widely popular vegetative/asexual propagation methods, can be set up on the Tamil Nadu coast, where maximum seaweed farming is currently being

carried out. Later, it can be extended to the coasts of Gujarat and other places along the coastline. The species that can be promoted on a larger scale is *Kappaphycus alvarezii* and potential varieties of indigenous seaweeds (agarophytes and alginophytes).

Offshore waters also offer opportunities for raising seaweeds, especially through Integrated Multi-Trophic Aquaculture Systems (IMTA), where finfish species such as cobia can be raised along with seaweeds. While moving towards large-scale seaweed farming, the harvesting of seaweed from the wild would be discouraged unless sustainable management plans are in place.

Seaweed farming would be instrumental in creating livelihoods for fishers and rural women. Women would be encouraged to form self-help groups/ cooperatives/producers' associations to undertake seaweed production and processing through training, access to public finance, and marketing support.

### 4.1.3. Ornamental fish farming

Ornamental fish are a relatively small but active component of the international fish trade. Maintaining an aquarium is a popular hobby, and the global trade of ornamental fish is estimated at US$ 18-20 billion annually. Due to its diverse biological resources, India has many commercial and potent ornamental fish resources. About 374 freshwater species and over 300 marine species are suitable for the ornamental fishery.

While the value of the domestic market for the ornamental fishery is estimated at about Rs. 500 crores, the activity is limited to some specific areas in West Bengal, Tamil Nadu, Maharashtra, North-eastern States and the Islands. The policy would encourage setting up domestic units to enhance ornamental fish production, develop an end-to-end supply chain, and maintain habitats to boost rural livelihoods. The policy would also encourage consumer education, the benefits of maintaining an aquarium, and promote the installation of aquaria in public institutions. Women and youth will receive focus through appropriate interventions.

It is estimated that about 85% of ornamental species are harvested from the wild, chiefly from the hill streams of the Northeastern States or the prime coral habitats located along specific stretches of the coastline and the two Island Territories. As these wild-sourced species command higher prices, the pressure on their harvesting is substantial and increasing. Policy interventions will ensure that such resources are optimally harvested, and

necessary controls will be implemented to ensure the sustainable use of the wild ornamental germplasm.

### 4.1.4. Productive and sustainable utilization of inland saline soils

The area under salt-affected soils in the country is estimated to be about 6.73 million ha (Mha) with the States of Gujarat (2.23 Mha), Uttar Pradesh (1.37 Mha), Maharashtra (0.61 Mha), West Bengal (0.44 Mha) and Rajasthan (0.38 Mha) together accounting for almost 75% of the saline and sodic soils in the country (ICAR, 2015a). The other States where such resources exist include Punjab and Haryana. Irrational use of canal water is a major cause of soil salinisation. Saline soils bring down productivity and render the soil unsuitable for agriculture and other purposes such as construction. However, field-tested technologies are available for utilizing such lands through farming finfish and shellfish. Such technologies have already shown potential in saline areas of Haryana, Punjab, Rajasthan and UP, where farmers have successfully raised black tiger shrimp (*Penaeus monodon*) and Pacific whiteleg shrimp *Litopenaeus vannamei*. Unlike coastal saline areas, there is also a negligible environmental impact as the inland saline areas have few alternate uses. However, wastewater disposal from aquaculture needs due consideration to prevent any long-term consequences.

The key policy initiative would entail the identification of potential areas and their allocation for aquaculture; imparting best technologies to the farmers, including the sustainable use of groundwater wherever required; extension support and hand-holding; introduction of potential finfish species such as sea bass and mullets for risk reduction; sound mechanisms for treatment and disposal of wastewater from aquaculture; and establishing forward and backward linkages for the supply of seed and feed of species such as Pacific white leg shrimp, mullets and sea bass and subsequent assistance in the marketing of the produce. Where larger areas suitable for farming in saline soils are available, the development of Special Aquaculture Zones through PPP arrangements would also be considered (DoF, 2020).

## 4.2. Fisheries for blue economy: sustainable, monitored, assessed, regulated & traceable fisheries (S.M.A.R.T.)

The S.M.A.R.T. Fisheries for Blue Economy program involves remote sensing and GIS-based assessment of all major aquatic ecosystems and valuation of ecosystem services consisting of marine, coastal and inland

resources. It aims to develop predictive tools to project and identify expected tipping points of the ecosystems and prospect climate-resilient aquatic germplasm and allele mining for abiotic stress management. The program focuses on transparent and traceable marine fisheries through advanced stock assessment and effective monitoring, control, and surveillance (MCS) systems, such as smart tokens, digital trip sheets, real-time catch data logs, and deep learning-based species detection to exclude non-target fish. It promotes energy-efficient fishing vessels using hybrid energy and partially replacing fossil fuels (ICAR, 2015b).

The program also involves developing a national blueprint for an inclusive spatio-temporal plan for marine conservation and management, complete genome sequencing of 500 species, and IoT and AI-based automated catch monitoring and genetic stock assessment methods using a structured ecosystem approach to fisheries management (EAFM). It aims to develop energy-smart industrial fishing fleets driven by renewable energy sources, AI-embedded selective gear systems, innovative ecosystem restoration programs using improved artificial propagation (including seed ranching), artificial fish habitats, and drone-based seed disseminations. The program also accelerates coral reef resilience through heat-evolved symbionts and cell line-based propagation, promoting healthy and climate-resilient freshwater and marine ecosystems, sustaining fish species diversity and ecosystem services. It involves live mapping of ecosystem changes in marine/freshwater hotspots for preparedness, mitigation, and adaptation to extreme event impacts. The program aims to establish a global repository of aquatic germplasm and genomic data, including genetically engineered stress-tolerant strains, and achieve real-time knowledge of the fishery footprint in the Indian Exclusive Economic Zone (EEZ), aiding safe, efficient, and sustainable catch of 5 Mt per year, as well as precision AI-enabled green fishing with total replacement of fossil fuels for fishing operations.

### 4.2.1. Marine spatial planning

India's coastal and marine environment is one of the world's richest ecosystems with high productivity. The Blue Economy provides an excellent opportunity to access these natural resources and ensure food security and gainful employment, but only if the resources are sustainably harvested and well-managed. India has developed a working definition of Blue Economy: "it refers to exploring and optimizing the potential of the oceans and seas, which are under India's legal jurisdiction for

socio-economic development, while preserving the health of the oceans. The Blue Economy links production and consumption to capacity and envisages an integrated approach to economic development and environmental sustainability. It covers both the marine, that is offshore resources, as well as the coastal, that is onshore resources".

The fisheries and aquaculture sector are emerging as a dynamic segment of the Indian economy and is positioned towards a significant growth trajectory in the coming period. Fisheries and aquaculture are also important constituents of Blue Economy initiatives. These initiative aims to promote investment and innovation in support of food security, poverty reduction, and the sustainable management of aquatic resources. The initiative takes an overall approach towards improving sustainable growth and management of aquatic resources, with special attention provided to the seafood value chain.

However, considering the competing demands for ocean space, the need for Marine Spatial Planning (MSP), which is an essential tool for implementing the Blue Economy, assumes significance. With the growing demand for mineral and oil exploration/extraction from the seas, the increasing volumes of maritime commercial traffic and the reservation of spaces for strategic defence purposes, the available space for fisheries is diminishing. Keeping these contemporary developments in view, the policy will emphasize the need for sound MSP to ensure that all economic activities get their due space and, in the process, reduce conflicts. Where required, necessary research support would also be solicited from the Research Institutions.

### 4.2.2. Regulating the sustainable and wise use of inland and marine resources

Considering the developments in exploiting the resources in waters beyond 12 nm, there is an urgent need to enact comprehensive legislation for fishing regulation by the national fleet in the EEZ and the ABNJ. Comprehensive legislation is also required because it would clearly set the agenda for the nodal agency responsible for the management of EEZ, and it would be easier for the fishers to follow a set of clear regulations and for the MCS agencies to implement them.

Similarly, a Model Bill for Inland Fisheries and Aquaculture is needed, which the States/UTs can use to repeal their existing Acts or amend them to make them contemporary and comply with the topical requirements.

### 4.2.3. Regulating fish meal production and wild collection of juveniles

India is a new entrant in fishmeal production. All these years, fish meals have been imported, but now, after meeting the domestic requirements, India is a net exporter of fish meals. A policy direction on fishmeal production and seed collection is also an urgent requirement for sustaining the sector. While usually concerned with aquaculture, fish meal and seed production happen at the crossroad of capture and culture fishery and can affect both. The seed collected from the wild for stocking in farm ponds or mariculture affects the population of many other discarded species while retaining the target species. Fish meal production units, while on one hand have helped in productive utilization of 'trash fish' but in the process of proliferation of such units, fishing vessels are now using destructive gear to ensure that large catches irrespective of size and conservation status are harvested to meet the increasing requirements of the fish meal plants. Large quantities of fish meal are produced using small-sized sardines, which has a negative impact on the sustainability of the sardine population. Policy initiatives will discourage the use of edible fish species for such conversion. Further, R&D on producing fish meal from alternative sources and sustainably harvested fisheries will be encouraged, and the total fish meal requirement for all sectors (poultry, aquaculture, etc.) will be estimated to ensure a steady supply of quality fish meal.

## 4.3. Technology-mediated value chain for safe and nutritious aquatic food/fish products (TVC-4-SNAP)

The TVC-4-SNAP program focuses on developing cost-effective and indigenous machineries with low environmental footprints for producing novel health foods, nutraceuticals, cosmeceuticals, and pharmaceutical products from aquatic resources. It involves establishing ICT-mediated fish market grids with blockchain-enabled traceability systems and cold chains for price integration and waste management. The program explores alternative strategies for producing antibiotic-free fish and develops expert systems for traceability, quality assurance, and safety. It aims to create a geo-coded and gendered occupational database of all actors across fish/aquatic product value chains and integrate circular economy principles in fish processing. The program promotes the establishment of intelligent fish landing centers and markets with stable price regimes, optimal market intermediation, and the production of fortified fish (2 species) and modern retail market chains with quality certification, niche

labelling, and branding. It conducts market studies to widen the markets (export/domestic) and products, and provides R&D-based support systems for technology adoption, incubation centers, skill development, and regulatory frameworks. The program aims to develop indigenous technology-driven production of safe and high-value products from aquatic resources, ensuring better price/value realisation for fishers and their human development. It strives to double the domestic consumption of safe and fortified fish and triple the exports of high-value products targeted at specific market segments, with at least one-third being value-added products.

### 4.3.1. Improving the supply chain and value chain

***Zero wastage:*** To reduce fish wastage in terms of physical and quality loss, policy initiatives will be directed towards improving the handling and storage of fish in the vessel. The deck is the first point of contact, and if the fish is handled and stored properly, the chances of contamination are minimized. The use of clean ice and/or provision of Refrigerated seawater/ slurry ice facilities is paramount, and it would be ensured that the fishing vessels are provisioned with clean ice and/or other such cooling facilities onboard.

Once the catch is landed, policy initiatives will aim at well-developed distribution channels and cold chain arrangements to move the harvest to the consumers in the shortest possible time. Reducing the number of nodal points in the supply chain and minimising the distribution channels is also important. Establishing a partnership of actors in the value chain is the key to realising the best product values. Appropriate revenue structures, which ensure adequate compensation to fishers and farmers and protect their livelihoods, are also necessary to ensure their participation in the value realisation.

With production from marine capture fisheries plateauing and wastage of fish across the supply chain not decreasing, there could be a scarcity of raw material for export in the coming years. Trade policies, including tariffs, also significantly shape fish production and international trade. The policy measures required for improving the value chain in the domestic market (as well as for exports) would include establishing a well-organized supply chain and making adequate facilities available at the landing sites, such as clean water, clean ice and proper storage. For implementing the Hazard Analysis Critical Control Point (HACCP) System based on the recognition that microbiological hazards exist at various points of the supply chain, policy measures will be implemented to control them.

***Value-addition:*** Value-addition can start when the fish is out of water. Proper on-board handling, as mentioned earlier, can substantially reduce wastage and on-board gilling and gutting, and placing the fish in crates with adequate ice further enhances the value. On landing at the FH or the FLC, further value-addition can occur by dressing the fish, vacuum packing, etc. and then moving it to the retail markets. As we move up the value addition, values can be enhanced by adding specialized ingredients to increase nutritional value, increase shelf life, and realize the convenience of using fish products. There is also immense scope to develop non-food, pharmaceutical, and nutraceutical products.

***Value-creation:*** Certification and labelling schemes and traceability for environmentally and socially responsible production will create new markets, and these products can be traded globally. These measures also focus on environmental concerns and strive to achieve sustainability in fisheries. Certification can also offer other benefits to producers in the form of improved market access and potential price improvements. Effective MCS and a 'blockchain' approach could boost transparency of the sector by providing means to trace and record the entire fish supply chain, and convince the public, industry and consumers about sustainability and food safety.

### 4.3.2. Developing domestic markets

Despite the immense health and nutrition benefits of fish, the slow pace of increase in fish consumption in the country has been raised occasionally, but the real pinch has been felt since the spread of the COVID-19 pandemic. With the closure of export markets, producers have felt the need to develop domestic markets to reduce dependence on exports. Fish may be included in the mid-day meal program to improve the nutritional requirements of school children.

The growth of online fish marketing has now created ample opportunities for the supply of processed fish to many consumers profitably. This shortening of the value chain will be remunerative for fishers as they will have an increasing share of the consumer's rupee. The processor can also ensure better value chain governance owing to the direct linkage with the fishers. Over time, if fishers can develop the required skills, they can establish captive value chains with end-to-end connectivity (DoF, 2020).

### 4.3.3. Promoting trade and food safety

India's fish trade remains heavily dependent on shrimps. It comprises about 40% of exports in quantity terms and 68% in value terms. In this scenario, the matter of concern is that during the last 24 years, while trade has

increased by 13 times and quantity by 5 times, the nature of India's export basket remains the same. For long-term development, it is essential that India's export potential is diversified and the capture and culture fishery is fully realized. Further, it is also necessary for the Indian processing sector to move to higher-order value addition, considering key market requirements.

India has consolidated the US market but failed in the EU market. India has also successfully opened new markets in China, the Middle East, and Southeast Asia. A competitive and diversified offering will help India further consolidate its market position.

However, global trade is becoming increasingly subject to different barriers and filters. The high-value markets of the US, EU, and Japan are especially subject to increasing constraints, mainly on account of safety and hygiene and biodiversity conservation (*e.g., protection of* turtles and mammals). Therefore, focusing on quality control and maintaining traceability throughout the supply chain is necessary for ensuring competitiveness. It is important for India to be competitive through cost-effective technologies to capture new emerging markets.

## 4.4. Professional fisheries human resource for global knowledge leadership (HR-4-GloKeL)

The HR-4-GloKeL program aims to bridge the demand-supply gap in professional human resources by 50- 60% and partner with Agricultural Universities (AUS) to bridge the para-professional supply gap. It establishes a Center of Excellence (CoE) in Policy Research for data-driven decision-making. It aims to produce at least 10% of the global supply of smart and specialized fisheries professionals. The program strives to emerge as a leading think tank driving evidence-based policymaking and development interventions (ICAR, 2015a).

### 4.4.1. Data-base development

Sound data is a key prerequisite to sound policy formulation. With the fisheries sector growing manifold in the last four decades, mechanisms for data collection and their collation have lagged behind. While data on marine fish landings is collected regularly following internationally accepted methodologies and protocols, the same is not happening in other sectors. Except for the five-year census carried out for the marine fisheries sector, similar information is also unavailable for inland fisheries, including aquaculture. New tools related to Information Technology may be tapped to access, store and disseminate the data. Also, an integrated fisheries

statistical system that covers all the states and UTs needs to be developed and hosted by the Department of Fisheries, Ministry of Fisheries, Animal Husbandry and Dairying, with a necessary support system for the states.

***Building community institutions:*** A prerequisite for successful resource management is the appropriate specification of property rights, *i.e.* who owns the resource, who is responsible for conservation, who receives the gains from resource use, etc. In India, the issue of ownership is *de facto* ambiguous. While the Government, as a as a custodian of the people owns, owns the resource, the community also asserts its traditional right to ownership. One way to legitimise both positions is through co-management. The States of Kerala and Tamil Nadu and the UT of Puducherry have now set up co-management structures at different administrative tiers (village, district, state), including a charter of their rights, and duties and have also provided the legal/administrative support. Such models need to be upscaled to other inland and coastal States/UTs.

***Developing a single-window system:*** A new department under the Ministry of Fisheries, Animal Husbandry & Dairying needs to be created as an umbrella agency focusing on governance, coordination and policy setting (in its area of Business) and harmonization amongst the States/UTS for effective fisheries governance. It will require establishing specialized agencies to carry out focused activities covering R&D, MCS, Trade, International relations, development, etc. The National Fisheries Development Board (NFDB) may give the mandate.

The fisheries sector deals with a range of institutions that fall within the purview of coastal State/UT Governments (DoF), Central Government (MFAH&D, MA&FW, MHAS, MCI, MEFCC, MWRRD&GR, MP, MD, MES, etc.) and scientific bodies. This pluralistic governance structure necessitates strong coordination between the MoFAH&D and the Coastal States/UTs on one hand, and different Ministries/Departments of the Union Government on the other. Further, similar cooperation between the States/UTs and within the State/UT will also be essential to ensure that fisheries and aquaculture are sustainably managed.

## 5. Roadmap during *Amrit Kaal*

### 5.1. Reforms in fisheries research

Research on sustainable fishing practices should be prioritized to prevent overexploitation and ensure long-term resource viability. Research efforts should also increase to develop efficient and environmentally friendly

aquaculture techniques. This includes selective breeding programs for improved fish stock, disease-resistant varieties, and alternative feeds.

Allocate greater resources towards fisheries research to support infrastructure development, acquire advanced equipment, and attract skilled researchers. Modernize existing research facilities and establish new ones strategically to address regional challenges and diverse fish species. Encourage partnerships with international research institutions and organizations to share knowledge, access advanced technologies, and address global challenges like illegal fishing and transboundary resource management.

More specifically, the following research efforts need to be strengthened[5]:

- ***Sustainable fisheries management***: Balancing economic growth with environmental preservation to ensure a sustainable future for the fisheries sector.
- ***Technological advancements***: Developing and implementing innovative fishing, aquaculture, and post-harvest processing technologies to enhance efficiency and productivity.
- ***Resource efficiency***: Promoting resource-efficient aquaculture systems and practices to minimize environmental impact and maximize resource utilization.
- ***Ecosystem health***: Recognizing that fish and fisheries are part of a larger ecosystem, and managing them holistically to ensure the health and sustainability of the entire marine and freshwater environment.
- ***Post-harvest value addition*:** Promoting value-added processing of fish and other marine products to increase economic returns and create new opportunities.
- ***Market intelligence*:** Providing market intelligence and information to fishers and stakeholders to enable informed decision-making and optimize market access.
- ***Climate resilience:*** Developing climate-resilient fish species and culture systems to mitigate the impacts of climate change on fisheries.
- ***Data repository:*** Promoting the adoption of innovative technologies like remote sensing, data analytics, and underwater monitoring systems to improve stock assessment, resource management, and track illegal fishing activities.

[5] Drawn from Vision 2050 documents of various fisheries research institutions of ICAR.

## 5.2. Human resource development

### 5.2.1. Curriculum redesign and modernization

Introducing courses on emergent areas such as Blue Economy, Blue Transformation, climate change adaptation strategies for fisheries, cultivated fish meat and cloning, disruptive technologies like IoT, AI/ML, NLP, block chain technology, robotics, big data analytics, etc. as well as incorporating modules on sustainable fishing practices, responsible aquaculture techniques, ecosystem management, and certification & traceability within fisheries education programs need to be given a priority (ICAR, 2015a).

### 5.2.2. Multi-disciplinary approach

Creating a regional HRD consortium enabling seamless knowledge, capacity and facility sharing (with India as the hub), connecting the network of HRD institutions in India with the institutions in the South and South East Asian region would foster and strengthen collaboration between fisheries science with related fields like marine biology, environmental science, economics, and business management in the region to provide students with a holistic understanding of the sector. Facilitate student exchange programs with international institutions to promote knowledge sharing and adoption of best practices in fisheries education (GoI, 2020b).

### 5.2.3. Technology integration

Develop and utilize online learning platforms to provide students in remote locations with access to educational resources, recorded lectures, and interactive learning modules. To enhance student learning and engagement, equip classrooms with modern technology like virtual reality simulations, modelling tools, and data visualization software. Provide training on using technology relevant to the fisheries sector, such as GPS navigation systems, fish finders, and data analysis tools.

### 5.2.4. Capacity development and training

Organize capacity-building programs for existing faculty members to equip them with the latest knowledge on advancements in fisheries science, pedagogy, and effective teaching methods. Invite industry professionals to conduct guest lectures, workshops, and share their practical experience with students. Facilitate exchange programs for faculty members with international institutions to promote knowledge sharing and adoption of best practices in fisheries education.

### 5.2.5. Entrepreneurship development

Fishers and other stakeholders (both upstream and downstream) have not developed entrepreneurial skills as the sector has grown over time. The sector's activities and organization remain sticky and resist change. Steps need to be taken towards training, capacity building, and upgrading the technological skills of traditional fishers and fish farmers to move from artisanal fishing/farming to more economic and efficient means of carrying out their profession.

To fully gain from the benefits of commercializing fisheries and aquaculture, entrepreneurial skills of fishers and fish farmers will be developed, encouraging them to increase their reach in the fisheries value chain and other requirements of a modern fishery's sector. The Colleges of Fisheries established nationwide can play a role in this. Besides, some R&D institutions can also take up dedicated programs to build the entrepreneurship of stakeholders at different levels.

## 5.3. Reorient fisheries extension

Extension system in fisheries has certain unique features/challenges compared to crop and livestock sectors:

### 5.3.1. Delivering knowledge and extending technical support

India has one of the most extensive networks of fisheries R&D institutions in the world. The eight Fisheries Institutions under the ICAR umbrella; the six R&D Institutions under the MFAH&D, including a quasi-judicial body, the Coastal aquaculture Authority; three institutions under the Marine Products Export Development Authority; four Institutions under the Ministry of Earth Sciences; and the 40+ Colleges of Fisheries located in different States/UTs concerned with marine fisheries provide an unparalleled mass of experienced human resource for fisheries and aquaculture development in the country. Their coverage with respect to the disciplines and geography is extensive.

The fisheries Institutions of ICAR have been at the forefront of fisheries research and developmental initiatives since their establishment. Popularization of composite fish farming of the IMC and exotic species (silver carp, grass carp and common carp) and seed production technologies leading to the first 'Blue Revolution' in the country during the late seventies owes mainly to the extension services and hand-holding made available to fish farmers through the All India Coordinated Research Project of the ICAR and the setting up of the Fish Farmers

Development Agencies (FFDAs) by the then Ministry of Agriculture and Cooperation throughout the country. Similar developments occurred in farming air-breathing fishes, brackish water aquaculture and reservoir fisheries development. In the marine sector too, the ICAR Institutions are playing a stellar role, including the regular provision of marine fisheries data through a dedicated sampling methodology, setting benchmarks for the minimum-legal size of commercial species that can be harvested, stock assessments, completing the life-cycle of many commercially viable fish species for mariculture, five-yearly census of the marine fisheries sector, improved post-harvest technologies, new boat designs and quality control.

However, when major hikes are envisioned from the aquaculture sector, and capture fish production needs to be sustained at optimum levels, the expected role of the fisheries institutions assumes greater significance. Technologies that meet the immediate needs of the practitioners at the grassroots level are the need of the day. A balance between basic science and adaptive research is necessary. The need for extension services and hand-holding is felt much more than before. In other words, research should move ahead of development to absorb the outcomes in the developmental process, as it happened in the past. The R&D Institutions also have to forge a stronger relationship with the private sector and work in tandem to optimize the resources and shorten the technology transfer period from lab to land.

Knowledge dissemination up to the last mile will be one of the key objectives of the policy. With increasing literacy rates and the ever-increasing use of the internet and smartphones, knowledge dissemination will be primarily carried out through virtual platforms, making it fast and cost-effective and ensuring that no one is left behind. There is a need to establish IT-based knowledge 'hubs and spokes' for collecting, collating, and processing information that could be made available in real time to the fishers and fish farmers. It would also be ensured that such information provided to the end-users is in the vernacular so that assimilation becomes easier. In the marine sector, the provision of 'Sagar Mitras' promoted by the Department of Fisheries would be a valid contact point for the stakeholders.

## 6. Epilogue

The roadmap outlined in this document lays out an ambitious yet achievable vision to transform India's fisheries and aquaculture sector into

a global leader in sustainability, innovation, and inclusive growth during the *Amrit Kaal* period, leading up to 2047. Guided by the principles of the Blue Economy, this comprehensive strategy aims to optimize the immense potential of India's aquatic resources through a harmonious balance between socio-economic development and environmental conservation. By prioritizing research and development, integrating cutting-edge technologies, and capacity building, the sector will be poised to achieve technological self-reliance, climate resilience, and competitive advantage on the global stage. Implementing this roadmap will not only bolster food and nutritional security for the nation. Still, it will also generate significant employment opportunities and drive inclusive socio-economic progress in coastal and rural communities. The emphasis on empowering small-scale fishers, women entrepreneurs, and youth will foster a more equitable and sustainable development trajectory. This vision underpins a strong commitment to ecosystem restoration, biodiversity conservation, and sustainable resource management. Through innovative approaches such as marine spatial planning, ecosystem-based fisheries management, and climate change adaptation strategies, India will emerge as a torchbearer for the responsible stewardship of its rich aquatic ecosystems. The successful realization of this roadmap hinges on collaborative efforts, forging strategic partnerships with diverse stakeholders, including research institutions, industry, civil society, and international organizations. By harnessing collective expertise and fostering a culture of evidence-based policymaking, India can effectively navigate the complex challenges and seize the opportunities that lie ahead.

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