POLICY PAPER 138

Climate Adaptive Conservation of Fisheries Resources

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CONVENER : Dr. U.K. Sarkar, Former Director, ICAR-National Bureau of Fish Genetic Resources, Lucknow

REVIEWERS : Dr. A. G. Ponniah, Former Director, ICAR-Central Institute of Brackishwater Aquaculture, Chennai

: Dr. B. K. Das, Director, ICAR-Central Inland Fisheries Research Institute, Barrackpore

EDITORS : Dr. V.K. Baranwal

Dr. R.K. Jain

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NASC, Dev Prakash Shastry Marg, New Delhi - 110 012, India
Tel: (011) 25846051-52; Fax: (011) 25846054
Email: naas-mail@naas.org.in; Website: www.naas.org.in

Preface

There has been remarkable growth in fisheries sector, particularly in inland fisheries. However, it faces a great threat from climatic changes such as escalating temperatures, shifting rainfall, and occurrences of extreme weather events, which impact species distributions, reproductive cycles, and fish physiology. The tropical regions of Asia and Africa are more prone to the impacts of climate change. The aquatic resources of India support a rich diversity of more than 3,250 species contributing to about 9% of the global fish diversity. Therefore, it is important to understand the impacts of climate change to safeguard the fish genetic resources and fisheries sector. Addressing the challenges, which include the identification of optimal climatic conditions for natural recruitment, development of climate-resilient adaptation strategies and techniques, modelling the distribution and abundance of fish under the future changing climatic conditions, and community approach to equip the stakeholder to cope with extreme events is vital at this juncture. A Brainstorming Session on “Climate Adaptive Conservation of Aquatic Genetic Resources” was organised by the Academy to discuss the intricate linkages between climate change, aquatic ecosystems, and global biodiversity. The deliberations assessed the multifaceted impact of climate change on fish reproduction and other biological attributes across ecosystems and in-depth exploration of fish ecological, physiological, and behavioural responses to changing environmental conditions. I take this opportunity to compliment the Convener (Dr. U.K. Sarkar), Reviewers (Dr. A.G. Ponniah & Dr. B.K. Das), and Editors (Dr. V.K. Baranwal & Dr. R.K. Jain) for bringing out this document. I am sure this will be useful to all the fellows and stakeholders.

September 2025
New Delhi

(Himanshu Pathak)
President, NAAS

Climate Adaptive Conservation of Fisheries Resources

INTRODUCTION

The fisheries sector in India supports the livelihood of about 30 million people in coastal and rural areas and holds immense potential for rural development and economic growth (DoF, 2023). Recognised as a "sunrise sector", it is poised to play a pivotal role in strengthening the Indian economy in the coming years. It has witnessed remarkable growth over the years and presently contributes to ≈8% of the global fish production. The fish production in India has increased from 2.44 million tonnes (Mt) in 1980-81 to 18.4 Mt in 2023-24 (DoF, 2025) with an average annual growth rate of 7.33% (Fig. 1). India's fisheries sector significantly contributes to both domestic and global food and presently India ranks as the third-largest fish producer, second-largest aquaculture nation (after China) and leading producer of shrimp worldwide (PIB, 2024).The sector has seen a significant shift from marine-dominated production to inland fisheries systems contributing about 70% of the country's output. The culture-based fishery in India is supported by the vast network of lentic waterbodies including tanks and ponds which cover ≈2.36 million hectares (Mha). The natural aquatic resources including the vast network of rivers, estuaries, wetlands, reservoirs and cold-water resources support rich fish diversity and potentially contribute to the country's fish production.

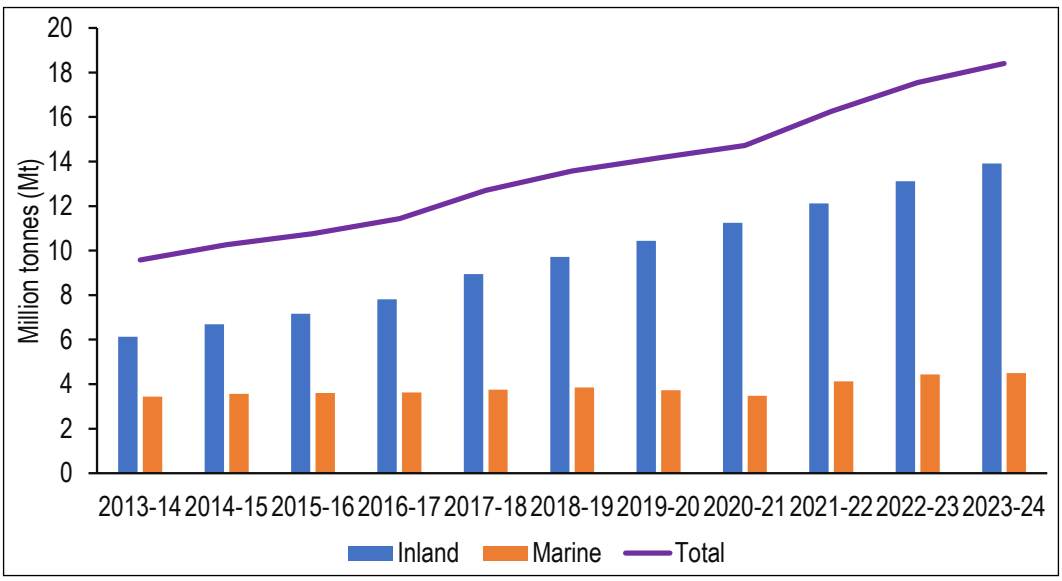

Fig. 1: Fish production trend in India (Source: DoF, 2025)

The aquatic ecosystems in India face unprecedented threats due to accelerating anthropogenic activities and the escalating demands of a growing population. Alongside anthropogenic factors, climate change is exerting substantial impacts on ecosystems globally, affecting species distributions, reproductive cycles, and fish physiology. In Indian waters, the consequences of climate change are increasingly evident, with potential repercussions for fish populations and the communities reliant on them for sustenance and livelihoods (Sarkar *et al*., 2024b). A critical facet of this complex issue lies in its profound effects on fish reproduction across freshwater, brackish water, and marine habitats. As the earth undergoes unprecedented shifts in temperature, precipitation patterns, and sea levels, aquatic environments are experiencing alterations that significantly influence the reproductive strategies and success of fish populations. Understanding this intricate interplay between climate change and fish reproduction is urgent to better comprehend, mitigate, and adapt to the consequences of a changing climate.

In freshwater ecosystems, rising temperatures are disrupting the delicate balance governing fish reproduction, potentially leading to mismatches in critical life history events and decreased reproductive success. Brackish water environments, influenced by temperature shifts and sea-level rise, face challenges in sustaining suitable spawning and nursery grounds for diverse fish species. Marine habitats, affected by rising sea surface temperatures, changed water currents and ocean acidification, experience shifts in reproductive dynamics that can impact the survival of developing fish embryos and larvae.

With climate change posing a considerable threat to global biodiversity, it is essential to assess the response of genomic insights to invasive species to changing environmental conditions. Invasive species, due to their adaptability and rapid spread, can out compete native fishes, thereby threatening stability of the ecosystem. This underscores the need for a comprehensive framework that integrates biological and ecological linkages, vulnerability assessments, and guide stakeholders in formulating specific mitigation measures suitable to the specific fish species and ecosystems.

Recognizing the need, a brainstorming session on “Climate Adaptive Conservation Aquatic Genetic Resources” was organised by the Academy. The deliberations clearly highlighted the need to preserve and protect valuable fish genetic resources against the backdrop of changing climatic conditions. The major challenges to be addressed in the context of climate change are as follows :

- ✦ Strengthening climate-resilient conservation strategies for fish genetic resources
- ✦ Utilising the genomic and biotechnological approaches to understand species adaptability under climate stress
- ✦ Formulating practical climate adaptation measures in fisheries and aquaculture
- ✦ Problem of Anti-Microbial Resistance (AMR) in microbes in the context of climate change

- ✦ Emerging pollutants in aquatic ecosystem in the context of climate change
- ✦ Developing robust policy guidelines to mitigate climate change impacts and ensure sustainable management of aquatic ecosystems

2. AQUATIC RESOURCES & BIODIVERSITY

India is endowed with vast aquatic resources spread across the coastline which includes the 2.02 million km^2 Exclusive Economic Zone and continental shelf area of 0.53 million km^2 in the Indian Ocean and support rich fish diversity and potentially contribute to the country's fish production. The vast coastline of 11,098.81 km is also dotted with unique ecosystems including estuaries, coastal lagoons, creeks, and mangroves. The estuaries formed by major rivers along the east coast, including the Hooghly–Matlah, Mahanadi, Godavari, Krishna, and Cauvery, as well as the Narmada and Tapti along the west coast, constitute important brackish water resources in India. The pristine coastal waters in the Andaman and Nicobar Islands and Lakshadweep Archipelago further support diverse marine ecosystems. India's mangroves, covering 4992 $km^{2,}$ is steadily expanding and sustain rich floral and faunal diversity. The deep sea, Earth's largest biome, remains largely unexplored in terms of its resources.

The diverse lotic and lentic freshwater ecosystem with dynamic habitat characteristics including the rivers and canals (252,431 km), floodplain lakes (0.812 Mha), ponds and tanks (2.41 Mha), reservoirs (4.03 Mha), and beels/oxbow lakes (0.48 Mha) supports wide variety of fish species. India's cold-water resource comprises of streams & rivers in the upland, high & low altitudinal lakes and reservoirs located in different hilly regions, mostly 900 m above mean sea level with water temperature ranging from 10 to 20°C.

India boasts expansive aquatic ecosystems, encompassing rivers, lakes, wetlands, and coastal regions, characterized by both ecological richness and cultural significance. The country harbours remarkable biodiversity, with 3,250 finfishes, 3,271 molluscs, 2,934 crustaceans, 765 echinoderms, and more than 200 coral species. Globally, the number of valid species is 37,273, of which 19,013 are specific to freshwater habitats (Fricke *et al*., 2025). India is home to a total of 3,500 native finfish species belonging to 1,046 genera, 257 families, and 57 order which includes ≈1500 marine and ≈950 freshwater species besides brackish water habitats (AqGRISI, 2025; https://aqgrisi.nbfgr.res.in/#/). The marine fish diversity comprises 2,492 species, distributed across 941 genera and 240 families. India's coldwater habitats support 258 species across 21 families and 76 genera, with the highest diversity (255 species) recorded in the Northeast Himalayan region (Singh and Akhtar, 2015).

According to the IUCN Red List (2025), worldwide under the class Actinopterygii, there are 772 critically endangered species, 1,341 endangered species, 1,507 vulnerable species, 885 near-threatened species, 17,655 species of least concern, and 5,220 data-deficient species. In India, as reported by the IUCN in 2024, 18 species

are critically endangered, 96 endangered, 116 vulnerable, 44 near-threatened, 2,150 of least concern, and 333 data-deficient. Continuous exploration and cataloguing of India's fish genetic resources by various research organizations have led to the discovery of 268 new finfish species and 70 new distributional records during 2013–2022 (Sarkar *et al*., 2024a).

3. CLIMATE CHANGE CONCERNS

Globally, the fisheries sector is increasingly challenged by climate change, natural disasters, water scarcity, pollution, biodiversity loss, and other anthropogenic pressures (FAO, 2024). The susceptibility of fish species in Indian waters to climate change has been extensively studied through frameworks that consider factors such as temperature, ocean acidification, habitat loss, and life history traits (Makwana and Patnaik, 2021; Chakraborty *et al*., 2024).

The effects of climate change on inland fisheries have gained utmost importance in recent times owing to their immediate as well as long-term impacts on fishery resources, aquatic ecosystems, and the livelihoods of fishing communities (Panikkar *et al*., 2022). Climate change disturbs the farming and fishing operations in the inland open water resources impacting the production and thus livelihood of the dependent communities (Sarkar and Das, 2021). Specifically, it alters the hydroecology and resilience of the floodplain wetlands causing the loss of fish diversity and abundance, seasonal shift in the reproductive activity and disease occurrence (Kumari *et al*., 2021; Debnath *et al*., 2021; Puthiyottil *et al*., 2021; Sarkar *et al*., 2022). Climate change significantly impacting the riverine ecosystem causing water scarcity and temperature rise, shift in the flow dynamics. The river water temperature in the Indian catchments is expected to rise by >3.0°C for the period 2071–2100 (Rehanaand Rajesh, 2023). The rise in the minimum water temperature in the river and increased rainfall has already been linked to breeding failure of the Indian Major Carps which was evident through the subsequent decrease in fish spawn abundance in the Ganga River. Further, a spatial shift in the distribution of warm water fish species *Glossogobius giuris* and *Xenentodon cancila* to the colder stretch recorded in the Ganga River (Vass *et al*., 2009).

In addition, climate change is having intense and complex effects on marine species, driven primarily by factors like rising sea temperatures, ocean acidification, sea level rise, and changes in ocean currents. These environmental shifts are reshaping marine ecosystems and the species that inhabit them, causing disruptions in biodiversity, species behaviour, and ecosystem functioning. The impacts on marine fisheries are widespread and deeply concerning. Many marine fishes are highly sensitive to changing environmental conditions such as temperature and ocean chemistry, which can directly affect their reproductive success. The horizontal and vertical range expansion of *Sardinella longiceps* and *Rastrelliger kanagurta*, respectively, together with the shift in the peak spawning period of *Nemipterus japonicus* and *N. mesoprion* towards cooler months, have been linked to rising seawater temperatures (Vivekanandan, 2011).

Rising seawater temperatures have also been associated with the faster growth rate in *S. longiceps* (Indian oil sardine), *R. kanagurta* (Indian mackerel) and *N. japonicus* (Japanese threadfin bream); decrease in length at first maturity in *R. kanagurta*, *Penaeus* (*Fenneropenaeus*) *indicus*, *Metapenaeus dobsoni* and *M. monoceros*; and reduction in mean length in fishery of *N. Japonicus* (Vivekanandan, 2013).

Thus, climate change is having significant impacts on aquatic ecosystems and biodiversity, which are crucial to economy, food security, and overall environmental health of the country. Major climate change concerns are water crisis & flow modification, fish physiology & health, spread of exotics, extreme weather events, eutrophication, sea level rise, ocean acidification and global warming.

4. NEED FOR CLIMATE ADAPTIVE CONSERVATION & STRATEGIES

Understanding the climate change vulnerability of fish species is essential for safeguarding India's fisheries and aquatic biodiversity. Assessing biological, ecological, and genetic resilience will help identify priority species and ecosystems for targeted conservation and adaptation measures, ensuring sustainable fisheries and community livelihoods in the face of changing climatic conditions. Strengthening the adaptive capacity is essential to ensure sustainability of fisheries, maintain food security, and support livelihoods. Adaptive strategies allow fisheries to respond to the changing climate while ensuring resilience and continued productivity. As adaptation strategies become imperative to mitigate climate impacts on aquatic ecosystems, reliable scientific information on the impacts of climate change on aquatic biodiversity and genetic resources is essential to guide evidence-based policies and targeted interventions.

Prioritizing fish species based on ecological and economic significance is crucial for effective conservation, with studies highlighting the importance of commercially valuable and ecologically significant species (Johnson *et al*., 2020). Integrating vulnerability assessment through the biological and ecosystem approaches with transcriptomic analysis emerges as a promising approach, linking ecological vulnerability with molecular-level responses for a holistic understanding of fish population adaptation. While policy guidelines are lacking, initiatives like the National Innovations in Climate Resilient Agriculture (NICRA) aim to enhance agriculture, fisheries, and natural resource management resilience to climate change through strategic research and technology demonstration, reflecting a cross-disciplinary commitment to climate resilience.

4.1. Marine Fisheries

Climate adaptive conservation in marine fisheries is essential to protect marine biodiversity, sustaining the livelihoods of fishing communities, and ensuring food security in the face of climate change. Through a combination of ecosystem-based management, flexible fisheries quotas, habitat restoration, and stakeholder involvement, marine conservation efforts can help build resilience and protect the future of global fisheries. However, these efforts must be complemented by urgent measures to mitigate

climate change through reductions in greenhouse gas emissions, thereby ensuring the long-term sustainability of ecosystems and fisheries (Chavez-Molina *et al*., 2023).

Combating climate change impacts on marine ecosystems and fisheries requires integrated strategies, including social networking, skill development, welfare awareness, ecotourism, sustainable fishing, climate research, and fisheries enhancement. Building stakeholder resilience and adopting citizen science–based resource management are also vital to reducing climate vulnerability in coastal wetlands in India and globally (Kathirvelpandian *et al*., 2024). The key climate adaptive conservation strategies for marine fisheries are:

- **Ecosystem-Based Management (EBM):** It is a holistic approach that considers the entire ecosystem, including the interconnections between species, habitats, and human activities. It emphasizes the need for integrated management across multiple sectors (e.g., fisheries, tourism, shipping) to ensure ecosystem health and resilience.
- **Climate-Resilient Marine Protected Areas (MPAs):** To adapt to climate change, MPAs need to be designed with flexibility in mind, considering the movement of species and the impacts of climate change. MPAs may need to be expanded, connected, or adjusted as species shift their ranges or as ecosystems change.
- **Climate-Integrated Fisheries Research:** Understanding how climate factors - such as temperature, acidification, and ocean circulation can interact with marine ecosystems is critical. Research should focus on the potential for species to adapt to these changes and how to protect vulnerable groups.

4.2. Inland Fisheries

Climate change poses significant challenges to inland fisheries by altering water availability, quality, and ecosystems. Climate adaptive conservation is necessary to help these ecosystems and the communities that depend on them become more resilient to these changes, ensuring their continued sustainability while preserving the livelihoods of local communities. Strategies such as wetland and riparian habitat conservation and restoration, adaptive species management, flexible water resources, and fisheries management are critical to ensure sustainability of inland fisheries in a changing climate. By incorporating local knowledge, ongoing research, and long-term monitoring, adaptive conservation can help safeguard both freshwater biodiversity and the livelihoods of millions of people who rely on these vital resources. An ecosystem-based fisheries management approach, combined with capacity building among stakeholders and fishing communities, constitutes an essential mitigation strategy for sustainable riverine fisheries development.

Conservation efforts can focus on maintaining genetic diversity in wild fish populations, which helps improve their resilience to changing conditions (e.g., temperature fluctuations). Selectively breeding or introducing fish species that are more tolerant

to climate change impacts (warmer water temperatures) can help sustain fisheries. Identifying climate-resilient species and strengthening ecological resilience are essential steps in prioritizing conservation efforts. Policymakers should emphasize the development of climate-smart villages and waterbodies to support mitigation and adaptation of vulnerable aquatic resources through an integrated, multiscale approach. Active collaboration among fishing communities, researchers, managers, policymakers, government agencies, and non-governmental organizations (NGOs) is vital to addressing the adverse impacts of climate change on fisheries (Panikkar *et al*., 2022). Fishing communities and farmers should adopt climate-resilient fishing and aquaculture practices, participate in resource co-management and apply Indigenous Traditional Knowledge (ITK) in climate adaptation planning. Researchers should conduct a species/ecosystem level vulnerability assessment, predict the climate change impacts, and provide scientific evidence to support decision making. Resource managers should enforce management measures, build the capacity of resource users towards sustainable utilisation and support habitat restoration initiatives. Government agencies and NGOs should mobilise resources for climate adaptation projects, deliver capacity-building and awareness programs, and promote income diversification through alternative livelihoods. Policymakers should formulate climate responsive fisheries policies, integrate adaptation strategies into all levels of fisheries management and ensure sustainable funding for long-term resilience-building initiatives.

5. POLICY SUPPORT/ INITIATIVES/ SCHEMES

The Government of India has launched several programs and initiatives aimed at supporting climate adaptation in fisheries. These programs are designed to address the challenges posed by climate change, including shifting fish populations, changing aquatic ecosystems, and the vulnerability of coastal and inland communities that rely on fisheries for their livelihoods. Some of the major government programs and policies that focus on climate adaptation in the fisheries sector are as follows:

- **Fisheries and Aquaculture Infrastructure Development Fund (FAIDF):** It supports climate-resilient fisheries by promoting sustainable aquaculture, cold-chain, and modern infrastructure to reduce post-harvest losses. It plays a key role in adapting the fisheries sector to climate change impacts while enhancing livelihoods and the blue economy.
- **Blue Revolution:** This emphasizes sustainable intensification of fisheries and aquaculture, integrating climate-smart practices to enhance productivity while conserving aquatic ecosystems. It addresses climate change by promoting resource-efficient technologies, biodiversity conservation, and resilient livelihoods in coastal and inland communities.
- **Pradhan Mantri Matsya Sampada Yojana (PMMSY):** This integrates climate-smart fisheries and aquaculture practices to enhance resilience against changing temperature and water regimes. It promotes sustainable resource use, eco-friendly

infrastructure, and adaptive strategies to mitigate climate change impacts on the sector.

- **National Innovations in Climate Resilient Agriculture (NICRA):** Research on climate-resilient aquaculture systems, such as polyculture and integrated multi-trophic aquaculture (IMTA), has been promote to facilitate climate adaptation among fish farmers to strengthen food security.
- **National Adaptation Fund for Climate Change (NAFCC):** It supports projects aimed at climate adaptation, including those related to the fisheries sector. The fund finances projects that enhance the resilience of fisheries communities and improve the sustainability of marine and inland fisheries in the face of climate change.
- **Indian Council of Agricultural Research (ICAR):** The Council through the Central Marine Fisheries Research Institute (CMFRI), National Bureau of Fish Genetic Resources (NBFGR), Central Inland Fisheries Research Institute (CIFRI) and other research bodies, conducts extensive research to understand the impacts of climate change on fisheries and develop strategies for adaptive management.
- **Fish Stock Monitoring and Climate Modeling:** Monitoring fish populations and using climate models to predict the future distribution of marine species helps adjust fisheries management practices and set appropriate catch limits based on climate projections.
- **Ministry of Environment, Forests, and Climate Change (MoEFCC):** This has been involved in establishing Marine Protected Areas (MPAs) to conserve critical marine habitats. These MPAs help increase biodiversity resilience by providing safe spaces for marine species to thrive despite the pressures of climate change, overfishing, and habitat loss.
- **State-level Initiatives and Schemes:** Several states in India, particularly those with extensive coastlines like West Bengal, Kerala, Tamil Nadu, and Andhra Pradesh, have developed their climate adaptation programs tailored to local contexts. These initiatives typically include fisheries management plans, climate adaptation training for fishers and disaster management and risk reduction.

6. RECOMMENDATIONS

1. Efforts to be made to utilise the increased rainfall predicted in future for fisheries development incorporating fisheries aspect in the district agricultural contingency plan for effective planning and implementing climate resilient fish farming practices.
2. Initiate targeted research on carbon sequestration potential in fisheries and aquaculture systems to enable carbon credit mechanisms, alongside studies on inland heat wave impacts and the development of heat-resistant fish strains for climate adaptation.

3. Formulate a mega project on climate smart fisheries and aquaculture by sourcing the required funds from international agencies such as Climate Investment Fund and creating a corpus from the available funding sources.
4. Monitoring the impact of climate change on fish health and aquatic animal pathogens.
5. Strengthen climate change research to develop adaptation and mitigation strategies. It should include developing research programmes on studying the impact of climate change on important indigenous and endemic species using state fish as model fish species in each state of the country.
6. The natural deep pool habitats in the large rivers are highly affected due to sedimentation. Ensure the intact status of existing critical riverine habitats including the deep pools which are necessary to sustain the fish populations during the extreme summer seasons.
7. Assess the seasonal water budgets and climate risks of Ramsar sites, considering biodiversity values and stakeholder needs, while integrating them with existing risk-reduction models for wetland restoration. Evaluate the environmental flows (e-flows) of selected critical river stretches to safeguard threatened and sensitive fish species that face extinction or local extirpation under changing climatic conditions.
8. Develop climate-smart villages through training and resource support for fishers and farmers in vulnerable areas, enabling them to adapt to the impacts of the climate crisis.
9. Identify climate resilient genetic fish stocks and devise stock specific and region-specific management measures alongside developing brood stocks with resistance to changing climatic conditions.
10. Encourage innovations in greening the fisheries sector by reducing fuel usage through advanced navigation techniques and applying innovative approaches like harnessing solar energy in aquaculture .
11. Devise regional data grid and adaptation strategies based on regional climate change evidence which can be used to assess climate change impacts on inland fisheries.

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