

**Editorial**

Volume 47 Issue 3 May 2026 pp. i-ii

DOI: <http://doi.org/10.22438/jeb/47/3/Editorial>

*J. Environ. Biol.*, 2026

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## Marine fisheries in India: Opportunities, challenges, and the need for climate-resilient management

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In India, the marine fisheries sector has played a vital role in food security, the coastal livelihoods, and the broader national economy for generations. India has a long coastline (8,118 km, recently revised as 11,098.81 km, based on high-resolution geospatial mapping) and an extensive Exclusive Economic Zone (EEZ) (approximately 2.02 million km<sup>2</sup>). The livelihoods of millions of people depend on this coastline, either directly through fishing or indirectly for exports, logistics, and tourism. In recent years, overall fisheries output has increased due to the rapid growth of inland aquaculture (Zacharia *et al.*, 2025), but marine fish production has remained relatively stable (3.5-4.0 million tonnes annually). Although the pattern is stable, marine capture fisheries appear to be approaching their ecological limits of exploitation, and several stocks already seem to be exploited or overexploited. This current situation alarms the need for ecologically balanced, adaptive management.

The sector offers significant opportunities within the broader framework of India's blue economy. Marine fisheries not only contribute to the nutritional security but also generate considerable foreign exchange earnings, with seafood exports around 8 billion USD annually (MPEDA, 2023). The emerging areas, such as mariculture, which includes cage farming, seaweed cultivation, and integrated multi-trophic aquaculture are the viable pathways for expanding production can be utilised to reduce pressure on wild fish stock. The studies conducted all along the Indian coast by ICAR-Central Marine Fisheries Research Institute have demonstrated the technical feasibility and economic potential of open sea and estuarine cage farming. The successful farming of the high-value fish species such as cobia, Asian seabass, Indian pompano, and silver pompano in cages and brackish water ponds has emphasized the scope for diversification and livelihood enhancement in the coastal regions. In spite of these opportunities, Indian marine fisheries have experienced a series of persistent and emerging challenges. The increased fishing capacity, technological intensification, and open access regimes have led to overfishing, resulting in declining catch per unit effort. In addition, the increased fishing pressure and environmental unreliability lead to pronounced interannual variability in key pelagic resources such as Indian oil sardine (*Sardinella longiceps*) and Indian mackerel (*Rastrelliger kanagurta*) (Rohit *et al.*, 2018; Zacharia *et al.*, 2025). Furthermore, habitat degradation due to coastal developmental activities, destructive fishing practices, and other anthropogenic disturbances continues to compromise the productivity of essential ecosystems such as coral reefs, mangroves, and seagrass beds.

Industrial pollution and marine litter have appeared to be the major concern, which not only impacts the sustainability of marine fisheries but also imposes risks to both ecosystem health and human consumers (Islam and Tanaka, 2004) by degrading water quality and bioaccumulation in marine organisms. Concomitantly, plastic pollution has become a universal issue, with macroplastics and microplastics accumulating across marine environments. The ingestion of this micro and macroplastics by fish and other marine organisms raises serious apprehensions concerning ecological integrity and food safety (Kumar *et al.*, 2020). The collective impacts of the industrial contaminants and plastic debris contribute to habitat degradation, reduced recruitment, and long-term declines in fisheries productivity.

Climate change is altering marine ecosystem dynamics, affecting primary productivity, which in turn impacts marine fisheries.

The rising sea surface temperature, ocean acidification, and shifts in monsoon patterns are the major criteria resulting in increasing frequency of extreme events, including marine heatwaves and cyclonic disturbances, which add further uncertainty to fisheries systems (Dineshbabu *et al.*, 2020). Such environmental inconsistencies have been shown to

influence the distribution and seasonal availability of pelagic fishery resources along the southwest coast of India. These changes often result in spatial and temporal mismatches between fish stocks and fishing operations, increasing operational risks and economic vulnerability for fishers. The environmental changes are particularly more severe on small pelagic fishes. The socio-economic status of small-scale fishermen is severely affected as they are solely dependent on small pelagic fishes inhabited in near shore waters.

Addressing these multifaceted challenges requires an integrated approach to fisheries management. Ecosystem-based fisheries management provides a holistic framework that integrates ecological, economic, and social considerations into decision-making (Garcia *et al.*, 2003). Strengthening stock assessment systems, enhancing monitoring and surveillance, and integrating traditional ecological knowledge with recent advanced scientific tools can improve management efficiency. Technological interventions such as satellite-based potential fishing zone advisories have already demonstrated their value in optimizing fishing operations and reducing fuel consumption. Diversification through mariculture offers a promising pathway for sustainable marine fisheries production. India possesses a significant potential for expanding mariculture activities in coastal and offshore waters. Evidence from extensive successful demonstrations all along the Indian coasts indicates that cage aquaculture and related interventions can serve as viable livelihood options, contributing to income diversification and reducing dependence on capture fisheries. Strengthening value chains, improving post-harvest infrastructure, and promoting value addition are essential for maximizing economic benefits.

Policy and governance frameworks must effectively evolve to address the complex challenges confronting marine fisheries. Co-management approaches involving all the stakeholders involved in the marine fisheries sector can enhance compliance and promote equitable resource use. Regulatory measures such as seasonal fishing bans, gear restrictions, and effort controls need to be implemented rigorously and reviewed periodically. In addition, enforcement of environmental regulations to control industrial discharge and marine litter is equally important.

Future research in Indian marine fisheries must adopt an interdisciplinary and forward-looking approach to address the complex interactions between climate change, pollution, and resource sustainability. There is a pressing need to strengthen long-term monitoring programmes integrating fishery-dependent and fishery-independent data with oceanographic and climate variables to improve predictive capacity. Advanced tools such as remote sensing, ecosystem modelling, artificial intelligence, and genomic approaches should be leveraged to understand shifts in species distribution, stock structure, and ecosystem dynamics under changing climatic regimes. In parallel, focused research on the impacts of microplastics, heavy metals, and emerging contaminants on fish health, trophic transfer, and food safety is essential. Expanding mariculture research towards climate-resilient species, low-impact production systems, and integrated multi-trophic aquaculture will be critical for sustainable intensification. Socio-economic studies assessing vulnerability, adaptive capacity, and livelihood transitions of small-scale fishers must complement biophysical research to ensure inclusive development. Strengthening the science-policy interface through participatory research, co-management frameworks, and real-time decision-support systems will be key to translating scientific knowledge into effective governance and sustainable fisheries management.

In conclusion, marine fisheries in India are at a critical juncture where ecological sustainability, economic development, and social equity must be carefully balanced. While the sector offers substantial opportunities for growth and livelihood enhancement, it is increasingly constrained by overexploitation, climate change, and pollution. A science-based, participatory, and ecosystem-oriented approach, integrated with effective environmental governance, will be essential to ensure the long-term sustainability and resilience of marine fisheries in India.

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