



Balancing Industrial Development and Fisheries in Coastal Water Bodies: A Case Study of Tamil Nadu, India

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The intersection of rapid industrial development and traditional fisheries in coastal water bodies presents a complex socio-ecological challenge. This article examines the environmental impacts of industrialization on marine ecosystems, utilizing the coastal state of Tamil Nadu, India, as a primary case study. By analyzing critical zones such as the Ennore Creek and the Gulf of Mannar, the paper highlights the detrimental effects of heavy metal pollution, thermal discharges, petrochemical spills, and anthropogenic marine litter on aquatic biodiversity and fisherfolk livelihoods. To mitigate these impacts, the article advocates for the adoption of Ecosystem-Based Fisheries Management (EBFM) and rigorous enforcement of regulatory frameworks like the Coastal Regulation Zone (CRZ) notifications. Furthermore, it underscores the necessity of extension support and community-led initiatives, demonstrating how capacity-building programs and international partnerships can foster sustainable coastal resilience and plastic circularity.

Introduction

Coastal zones are highly dynamic ecotones that serve as the interface between terrestrial and marine environments, offering immense ecological productivity and socio-economic value. In India, maritime states such as Tamil Nadu and Kerala, characterized by extensive coastlines and dense fishing populations, rely heavily on marine fisheries for employment, trade, food security, and local consumption. However, the contemporary paradigm of the "Blue Economy" has accelerated industrial encroachment into these sensitive habitats. The proliferation of thermal power plants, petrochemical complexes, commercial ports, and unregulated coastal real estate has precipitated a severe marine ecological crisis in the Bay of Bengal and the Indian Ocean region. The depletion of fish stocks, driven by warming oceans, habitat destruction, and industrial pollution, forces artisanal fishermen into increasingly precarious situations, threatening both their livelihoods and cultural heritage. Balancing the imperatives of industrial and infrastructural development with the sustainability of coastal fisheries requires a paradigm shift from exploitative resource extraction to holistic, science-based governance. This article explores the multifaceted environmental impacts of industrialization on Tamil Nadu's coastal water bodies and evaluates the critical need for ecosystem-based management, stringent policy enforcement, and community-centric extension support.

Environmental Impacts of Industrial Development on Coastal Water Bodies

The degradation of coastal ecosystems is driven by a confluence of anthropogenic stressors. In Tamil Nadu, specific industrial clusters have become focal points for severe environmental degradation, directly impacting marine trophic dynamics and the communities dependent upon them.

Industrial Effluents and Heavy Metal Bioaccumulation: The Ennore Creek Crisis

Ennore Creek, situated in North Chennai, exemplifies the devastating consequences of "toxic industrialization". Once a fertile wetland and a thriving hub for artisanal fishing, the extended North Chennai coastline has been systematically transformed by industrial infrastructure since the 1960s. The region is currently dominated by the North Chennai Thermal Power Station (NCTPS), Kamarajar Port, and various fertilizer and cement industries. The continuous discharge of fly ash slurry and industrial effluents has drastically altered the creek's hydrology, reducing its depth and water-carrying capacity, thereby exacerbating flood risks and destroying local mangrove vegetation (Story of Ennore, 2017; Land Conflict Watch, 2025).

The ecological toll is most evident in the bioaccumulation of toxic trace elements in marine life. A recent quantitative analysis utilizing Inductively Coupled Plasma Mass Spectrometry (ICP-MS) assessed heavy metal concentrations in commercially important fish species (*Nemipterus japonicus*, *Oreochromis mossambicus*, and *Lates calcarifer*) from the Chennai coast. The study detected alarming levels of Arsenic, Cadmium, Chromium, Mercury, Lead, Strontium, and Vanadium. Notably, the muscle tissues of *Oreochromis mossambicus* exhibited the highest contamination, with Chromium concentrations reaching up to 12.399 $\mu\text{g}/\text{kg}$ (dry weight). While the calculated Hazard Index (HI) for both children (0.238) and adults (0.136) remained below the critical threshold of 1, the chronic exposure to these metal(loid)s poses a latent public health risk and signifies severe disruption of the aquatic food web (Ray et al., 2025).

Petrochemical Pollution and Thermal Discharges

Thermal power plants require massive volumes of water for boiler cooling, subsequently discharging heated effluents back into the coastal waters. This thermal pollution induces chemical and thermal stress, depriving the immediate marine environment of dissolved oxygen and causing localized mortality of fish and benthic organisms (Poornima et al., 2005; Climate Connection, 2020).

Furthermore, the Ennore-Manali industrial cluster, recognized as the densest concentration of fossil-fuel industries in South India, is highly susceptible to petrochemical disasters. In December 2023, exacerbated by the floods following Cyclone Michaung, a massive oil spill originating from the Chennai Petroleum Corporation Limited (CPCL) inundated the Buckingham Canal and Ennore Creek. The spill coated approximately 60 hectares of mangroves in toxic sludge, inflicting acute environmental harm and paralyzing the local fishing economy (Land Conflict Watch, 2025). Such incidents underscore the inherent incompatibility of dense, red-category industrial zoning with fragile coastal wetlands.

Marine Litter and Ghost Fishing in the Gulf of Mannar

The Gulf of Mannar, a globally significant marine biodiversity hotspot and UNESCO Biosphere Reserve, faces immense pressure from both land-based industrial pollution and marine-based anthropogenic activities. The region hosts nearly 30 industries along its coast, contributing to habitat destruction and water quality degradation.

A pervasive and escalating threat in this region is Anthropogenic Marine Litter (AML), predominantly plastics. Mangrove ecosystems, such as those in Tuticorin, act as efficient traps for macro-litter due to their intricate root architecture. A systematic assessment across the Tuticorin mangroves recorded an average surficial litter abundance of 12.88 items/ m^2 , leading to the asphyxiation of pneumatophores, structural deformities in seedlings, and altered sediment properties (Ponmani et al., 2026).

Compounding this is the crisis of Abandoned, Lost, or otherwise Discarded Fishing Gear (ALDFG), commonly known as "ghost gear." The modernization of fisheries has seen a shift from biodegradable natural fibers to highly durable synthetic plastics. In the coral reef ecosystems of the Gulf of Mannar and Palk Bay, ghost nets entangle marine mammals, sea turtles, and commercially vital fish species, while simultaneously causing physical

fragmentation and disease susceptibility in coral structures. This continuous "ghost fishing" severely depletes fish stocks, directly undermining the economic returns of traditional fishers.

The Need for Ecosystem-Based Fisheries Management (EBFM)

The traditional approach to fisheries management, which predominantly focuses on maximizing the yield of single target species, has proven inadequate in the face of complex, multi-dimensional stressors such as climate change, industrial pollution, and habitat loss. To achieve a sustainable balance, there is an urgent need to transition toward Ecosystem-Based Fisheries Management (EBFM).

EBFM is a holistic paradigm that recognizes the physical, biological, economic, and social interactions within a marine ecosystem. It aims to ensure the health and ecological integrity of marine living resources while maximizing economic opportunities (Hornborg, 2019). Research indicates that implementing EBFM measures can effectively forestall future declines in fish populations driven by climate change, outperforming non-EBFM approaches by maintaining ecosystem resilience (Holsman et al., 2020).

In the context of Tamil Nadu, EBFM requires the integration of Marine Spatial Planning (MSP) to clearly delineate zones for industrial activity, aquaculture, and traditional fishing. It necessitates cross-sectoral coordination to regulate land-based industrial effluents before they reach estuaries and coastal waters, thereby protecting critical nursery habitats like mangroves and seagrass beds that sustain offshore fish populations.

Policy Framework and Regulatory Challenges

India possesses a robust legislative framework designed to protect coastal ecology; however, the efficacy of these laws is frequently undermined by poor implementation, institutional apathy, and prioritization of commercial interests over environmental conservation.

The Coastal Regulation Zone (CRZ) Notifications

The CRZ notifications were established to restrict commercial activities, waste dumping, and industrial expansion within ecologically sensitive coastal stretches. Despite these clear mandates, violations are rampant. A damning 2024 report by the Comptroller and Auditor General (CAG) of India exposed severe lapses by the Tamil Nadu State Coastal Zone Management Authority (TNSCZMA). The audit revealed that between 2015 and 2022, the TNSCZMA incorrectly granted CRZ clearances to 114 out of 175 scrutinized projects (65%) without forwarding them to the Ministry of Environment, Forest and Climate Change (MoEF&CC) or the State Environmental Impact Assessment Authority (SEIAA).

Furthermore, the CAG identified 90 unauthorized constructions within the No Development Zone of CRZ III (areas within 200 meters of the High Tide Line). Clearances were frequently granted without mandatory No Objection Certificates (NOCs) from the Tamil Nadu Pollution Control Board regarding effluent discharge. The report also criticized the systemic exclusion of local traditional coastal communities from District Coastal Zone Management Authorities (DCZMAs), a direct violation of the CRZ mandate that marginalizes the very stakeholders most affected by coastal degradation.

Marine Fishing Regulation Acts (MFRA)

The Tamil Nadu Marine Fishing Regulation Act of 1983 was enacted to protect the living resources of the sea by prohibiting destructive fishing practices and regulating the operational zones of mechanized vessels to protect traditional artisanal fishers. While the Act provides a legal basis for sustainable harvesting, its success is heavily dependent on rigorous Monitoring, Control, and Surveillance (MCS) mechanisms, which often lack adequate funding and personnel, leading to overcapacity and the continued use of unsustainable gear in territorial waters.

Extension Support and Community-Led Initiatives

Addressing the dichotomy between industrialization and fisheries requires more than top-down regulation; it demands active stakeholder engagement, capacity building, and targeted extension support to foster grassroots resilience.

Community-Centric Debris Management and Upcycling

A prime example of successful extension support is observed in the Ramanathapuram district, bordering the Gulf of Mannar. Supported by the UNDP-Global Environment Facility (GEF) Small Grants Programme and implemented by the M.S. Swaminathan Research Foundation (MSSRF), local fishing communities have initiated a movement to combat ghost gear. The project trained underwater retrieval teams to safely remove abandoned nets from coral reefs. Crucially, the initiative placed women at the forefront of the solution; 123 fisherwomen were trained to upcycle the recovered plastic nets into durable, marketable products such as bags, mats, and baskets. This not only mitigates a severe marine threat but also generates a supplementary monthly income of INR 2,000 to 5,000 for the women, transforming an environmental hazard into a sustainable livelihood.

Institutional Capacity Building: The TN-SHORE Project

At the macro-institutional level, the Government of Tamil Nadu, supported by the World Bank, has launched the Strengthening Coastal Resilience and the Economy (TN-SHORE) project. Spanning 14 coastal districts, the project is structured around critical components: strengthening institutions for integrated coastal management, executing shoreline protection and conservation, improving livelihoods for natural resource-dependent communities, and enhancing plastic circularity and marine pollution management. By integrating Stakeholder Engagement Plans (SEP) and focusing on vulnerable groups, TN-SHORE represents a comprehensive approach to mitigating industrial impacts while bolstering the socio-economic fabric of coastal populations.

The Tamil Nadu Ocean Commitment

Aligning with the United Nations Sustainable Development Goal 14 (Life Below Water), the Tamil Nadu Ocean Commitment is a voluntary initiative aimed at marine biodiversity conservation, sustainable fisheries management, and pollution reduction. By fostering collaboration between government agencies, research institutions (like the National Centre for Sustainable Coastal Management), and NGOs, it seeks to implement nature-based solutions to strengthen coastal resilience against both climate change and industrial encroachment (SDGs UN).

Conclusion

The pursuit of industrial development in coastal water bodies must not come at the cost of irreversible ecological collapse and the disenfranchisement of traditional fishing communities. The case of Tamil Nadu vividly illustrates the severe consequences of unchecked industrialization from the heavy metal contamination and petrochemical spills in Ennore Creek to the proliferation of marine litter and ghost gear in the Gulf of Mannar. Balancing these competing interests requires a definitive move away from fragmented governance toward Ecosystem-Based Fisheries Management (EBFM) and Integrated Coastal Zone Management (ICZM). It is imperative that regulatory bodies strictly enforce environmental laws, such as the CRZ notifications, and eliminate the loopholes that permit unauthorized industrial expansion in sensitive zones. Simultaneously, empowering local communities through extension programs, alternative livelihood training, and participatory governance ensures that those who bear the brunt of environmental degradation are active agents in coastal restoration. Only through a synergistic approach combining rigorous policy enforcement, scientific management, and community empowerment can India secure the ecological integrity of its coastal waters and the sustainable future of its fisheries.

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