

Mangroves as Coastal Guardians- Protecting Shores, Sustaining Biodiversity, Supporting Coastal Communities

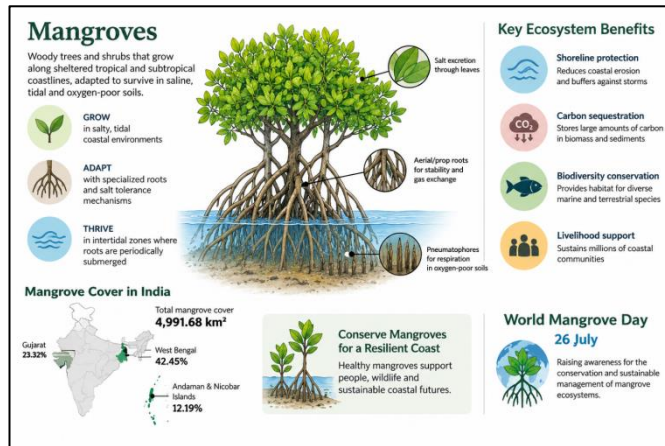
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Mangroves are highly productive coastal ecosystems that play an important role in protecting shorelines from erosion, storing carbon, supporting biodiversity, and sustaining the livelihoods of millions of coastal communities. India has approximately 4,991.68 km² of mangrove cover, representing about 3% of the world's mangrove forests and 8% of Asia's mangrove area.



Conserving this ecosystem requires active participation from local communities along with sustainable livelihood opportunities that encourage their involvement in the protection and management of mangrove resources. In recognition of their ecological and socio-economic importance, World Mangrove Day is observed annually on 26 July to promote the conservation and sustainable management of mangrove ecosystems. Officially known as the International Day for the Conservation of the Mangrove Ecosystem, the day was proclaimed by UNESCO at its 38th General Conference in 2015. The date commemorates the sacrifice of Hayhow Daniel Nanoto, a young environmental activist from Guinea who lost his life in 1998 while campaigning for the conservation of mangrove ecosystems. Since its establishment, the observance has helped raise awareness and strengthen conservation, restoration, and sustainable management efforts among governments, organizations, and coastal communities worldwide.

What Is A Mangrove?

Mangroves are woody trees and shrubs that grow along sheltered coastlines in tropical and subtropical regions. Although mangrove species are not necessarily closely related, they share the remarkable ability to survive in saline coastal environments that are regularly influenced by tides. Some species grow very close to the shoreline, where their roots are submerged in seawater during high tide. Mangroves possess several specialized adaptations that allow them to tolerate high salinity and low-oxygen conditions in coastal soils.

India has made considerable progress in mangrove conservation through regulatory measures and targeted conservation initiatives. West Bengal has the largest share of the country's mangrove cover, accounting for 42.45% of the total, followed by Gujarat (23.32%) and the Andaman and Nicobar Islands (12.19%). The distribution of mangrove cover across India is presented in Figure 1.

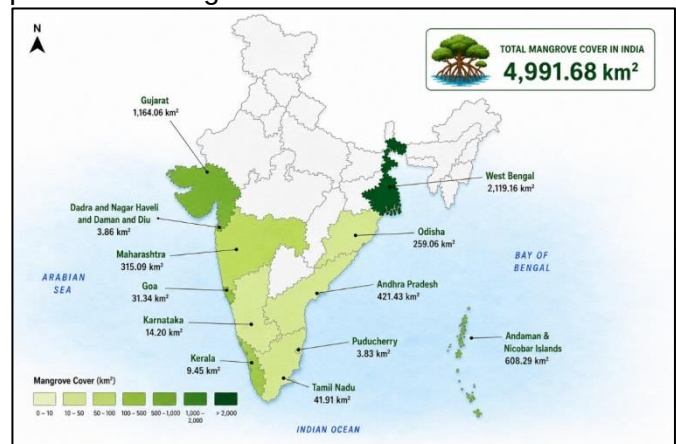


Figure 1: Total mangrove cover of India

Mangrove Ecosystem Characteristics

Mangrove Diversity

Indian mangroves comprise approximately 59 species across 41 genera and 29 families. Of these, 34 species belonging to 25 genera and 21 families are found along the west coast. Among these, nine species are globally significant as

'species of conservation importance', namely *Sonneratia griffithii*, *Heritiera fomes*, *Excoecaria indica*, *Aglaia cucullata*, *Aegialitis rotundifolia*, *Brownlowia tersa*, *Ceriops decandra*, *Phoenix paludosa*, and *Sonneratia ovata*. In addition, 188 mangrove-associated species often extend their distribution into back-mangrove environments. India records the highest mangrove-associated biodiversity in the world, with 4,107 species documented, of which 23% are floral and 77% are faunal species. Bhitarkanika in the state of Odisha is considered the 'Mangrove Genetic Paradise' of the world, comparable to the Baimaru mangroves of Papua New Guinea.



Figure 2: Intertidal coastal habitat within a marine landscape, Mirya mangrove ecosystem (Ratnagiri)

Mangrove waters support diverse faunal communities, including planktonic and benthic species that play a vital role in the ecosystem alongside their terrestrial counterparts. India is home to 105 fish species that are typical mangrove dwellers, represented by mudskippers, carangids, clupeids, serranids, mullets, hilsa, seabass, and milkfish. Crustacean species such as *Penaeus indicus*, *P. merguensis*, and *P. monodon* also inhabit these waters, while crabs are represented by genera including *Uca*, *Scylla serrata*, and *Thalassina*.

How Do Mangroves Strengthen Ecosystem Resilience To Climate Change?

Mangroves strengthen coastal ecosystem resilience to climate change by serving as highly productive wetlands that sequester carbon in both soil and aboveground biomass. They are estimated to store between 6.23 billion and 11 billion tons of carbon globally, ranking them among the world's richest carbon-storing ecosystems. Beyond carbon storage, mangroves improve water quality, act as buffers against coastal erosion, storms, and flooding, and provide physical resistance to shoreline degradation. Mangrove trees anchor themselves in soft, unstable mud and provide physical resistance to coastal storms and erosion. However, the United Nations Environment Programme (UNEP) has estimated

that climate change could cause a 10–15% loss of global mangroves by 2100. Disturbed mangroves retain significantly less carbon approximately 95 Mg ha⁻¹, which represents about 11% of the carbon held in intact mangroves and potentially correspond to emission rates of 2,244 to 3,799 Mg CO₂ ha⁻¹. Therefore, mangrove restoration can contribute substantially to carbon sequestration.

Key Threats to Mangrove Ecosystem

- **Coastal Development and Urbanization:** The expansion of cities, ports, industries, roads, tourism infrastructure, and other development projects leads to the clearing of mangrove forests. Urban encroachment fragments habitats, alters natural water flow, and restricts the landward migration of mangroves.
- **Climate Change and Sea-Level Rise:** Sea-level rise is considered the greatest global threat to mangroves. Under current climate projections, nearly 25% of the world's mangrove area could be submerged within the next 50 years.
- **Extreme Weather Events:** The increasing frequency and intensity of cyclones, storms, floods, and prolonged droughts damage mangrove vegetation, alter hydrological conditions, and reduce the resilience of these ecosystems, making recovery increasingly difficult.
- **Aquaculture Expansion:** Large areas of mangrove forests are converted into shrimp farms- a conversion that destroys nursery habitats for fish and crustaceans, reduces biodiversity, and disrupts coastal ecological balance. The waste generated from shrimp farms and the use of antibiotics severely affect the mangrove ecosystem.
- **Oil and Gas Exploration:** Exploration, drilling, pipelines, and associated infrastructure disturb mangrove habitats, while oil spills and leakages cause long-term damage to soils, water, and marine biodiversity.
- **Sand Mining, Dredging, and Land Reclamation:** These activities disturb mangrove sediments, alter tidal flow, increase erosion, and destabilize root systems.
- **Pollution:** Mangroves are exposed to pollution from plastics, industrial effluents, untreated sewage, agricultural runoff, and oil spills. These pollutants degrade water quality, reduce biodiversity, and impair ecosystem functioning.
- **Soil Acidification and Heavy Metal Contamination:** Construction activities disturb mangrove soils rich in pyrite and sulphur minerals. Their oxidation produces sulfuric acid, causing soil acidification, heavy metal

release, fish mortality, forest degradation, and corrosion of nearby infrastructure.

- **Biodiversity Loss and Livelihood Impacts:** Nearly 50% of the world's mangrove ecosystems are classified as threatened. Continued degradation endangers coastal biodiversity, fisheries, food security, and the livelihoods of millions who depend on these ecosystems.

Institutional Framework For Mangrove Ecosystem Conservation

Mangrove conservation in India is supported by a diverse network of institutions operating at the national, state, international, and community levels, including central government agencies, ICAR research institutions, state departments, international organizations, NGOs, academic institutions, and community-based organizations. Collectively, they contribute to policy formulation, scientific research, habitat restoration, biodiversity conservation, climate resilience, sustainable fisheries, livelihood enhancement, and participatory management. The major institutions and their key roles in mangrove conservation are summarized in Table 1.

Table1: Agencies and their key roles in Mangrove conservation

Agency/Institution	Key roles with respect to mangrove conservation
Central level	
Ministry of Environment, Forest and Climate Change	Policy formulation, notification and management of mangroves, coastal biodiversity conservation, implementation of Mangrove Initiative for Shoreline Habitats & Tangible Incomes (MISHTI), and CRZ Notification, 2019 in which there is special mention for mangroves as Ecologically Sensitive Areas (CRZ-IA), enforcing a 50-meter buffer zone protection.
Ministry of Earth Sciences	Mangrove conservation through coastal research, ecological restoration drives, and blue carbon assessments.
National Biodiversity Authority	Protects mangrove ecosystems by regulating biological resource access, funding local conservation through Biodiversity Management Committees, and implementing the Biological Diversity Act.
National Centre for Sustainable Coastal Management	Manages mangroves through scientific research, ecosystem mapping, and capacity-building training programs.
Zoological Survey of India	Documenting faunal biodiversity, publishing comprehensive assessment guides, and monitoring estuarine wildlife health
Botanical Survey of India	Conservation and documentation of marine and coastal flora, including mangroves and seagrasses.
National Institute of Ocean Technology	Actively supports mangrove and coastal ecosystem conservation through collaborative restoration drives,

community engagement, and climate resilience projects.

Indian National Centre for Ocean Information Services Supports mangrove conservation by providing ocean data, hazard warnings, and climate impact assessments. These tools help protect coastal wetlands, which act as natural green buffers against rising sea levels and extreme weather.

Coastal Aquaculture Authority Prohibits converting natural mangrove forests into commercial shrimp or fish ponds. Operating under the Coastal Aquaculture Authority Act (2005), the agency regulates coastal farming to protect ecologically sensitive wetlands.

Indian Coast Guard Actively protects coastal mangrove ecosystems through direct cleanup drives, pollution response operations, and partnerships with local green groups.

National research institutes

ICAR-Central Marine Fisheries Research Institute Mangrove conservation through coastal plantation drives, captive breeding of dependent species like the mangrove clam, and educational outreach programs.

ICAR-Central Institute of Fisheries Education Scientific research, educational outreach, and biodiversity mapping

ICAR-Central Institute of Brackishwater Aquaculture Initiatives tied to mangrove ecosystems, focusing on sustainable coastal livelihood activities and eco-friendly aquaculture that protect these habitats from destructive practices.

National Institute of Oceanography Scientific research, ecosystem mapping, public clean-up drives, and collaborative national conferences.

State government departments & institutes

State Forest Departments Several Indian State Forest Departments actively manage and conserve coastal mangrove ecosystems, led prominently by the Maharashtra Forest Department through its specialized Mangrove Cell and Mangrove and Marine Biodiversity Conservation Foundation, alongside the Gujarat Forest Department and the Goa Forest Department.

Mangrove and Wetland Cells Conservation and restoration of mangroves, wetlands and coastal ecosystems.

International & multilateral agencies

Food and Agriculture Organisation Tracking global forest data, leading community projects, and promoting sustainable coastal use

International Union for Conservation of Nature Biodiversity assessments and conservation policy support and initiatives such as Global Mangrove Alliance.

United Nations Development Programme Financial and technical assistance for biodiversity conservation and coastal livelihood projects.

United Nations Environment Programme Protects and restores global mangrove ecosystems by tracking forest changes, funding field projects, and promoting natural regeneration strategies. Key efforts include the Global Mangrove Watch, the Blue Forests Project, and recognizing successful local restoration

World Bank	as World Restoration Flagships. Funding support for blue economy, coastal resilience and mangrove conservation projects.
NGOs & civil society organisations	
Dakshin Foundation	Research in blue carbon potential, publishing educational resources on mangrove ecology, and supporting community-based coastal protection campaigns
WWF-India	Protect and restore coastal ecosystems through community engagement, citizen science, and direct restoration projects. Key initiatives include the Mangrove Mitras program, the Magical Mangroves campaign, and local field restoration projects.
Wildlife Trust of India	Protects coastal wetlands through community stewardship, habitat restoration, and its flagship Kannur Kandal Project in Kerala.
M. S. Swaminathan Research Foundation	Mangrove conservation, community participation, innovative 'fishbone' tidal canals, and integrated livelihood programs.
Bombay Natural History Society	Restores coastal wetlands, Biodiversity research, awareness generation and conservation advocacy.
Mangrove Foundation of India	Focused on community-based mangrove restoration, wetland conservation, and climate adaptation and sustainable livelihood activities.
Community-based & grassroots institutions	
Fisheries Cooperatives	Promote sustainable fishing practices within mangrove ecosystems by organizing fishers into formal groups that protect nursery grounds and adopt eco-friendly gear.
Self-Help Groups	Drive livelihood diversification and raise community awareness regarding mangrove and coastal conservation by providing microcredit and skill development for alternative livelihoods such as apiculture, ecotourism, and crab fattening, thereby reducing dependence on destructive mangrove resource extraction.
Eco-Development Committees	Foster community participation in mangrove conservation and eco-development by involving local communities in patrolling, habitat restoration, plantation drives, and benefit-sharing to build ownership and stewardship.
Joint Coastal Management Committees	Facilitate participatory coastal governance by bringing together government agencies, local communities, researchers, and NGOs to jointly plan, implement, and monitor mangrove conservation and sustainable resource use.
Traditional Fisher Associations	Integrate indigenous knowledge of fish and shellfish species in mangroves by documenting and applying traditional practices such as community-defined fishing grounds, customary seasonal closures, and sacred mangrove groves that have historically sustained fish and shellfish populations.
Community	Lead grassroots conservation of

Conservation Groups	mangrove ecosystems through environmental education, clean-up drives, habitat and wildlife monitoring, and reporting of illegal activities such as poaching and encroachment to authorities.
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India has implemented several national and state-level initiatives to strengthen mangrove conservation, including Mangrove Initiative for Shoreline Habitats and Tangible Incomes (MISHTI), Integrated Coastal Zone Management (ICZM), Green India Mission, Compensatory Afforestation Fund Management and Planning Authority (CAMPA) and the National Coastal Mission. These programmes promote restoration, habitat protection, biodiversity conservation, and climate resilience, supported by scientific research, NGOs, and local community participation. However, lasting conservation requires stronger inter-agency coordination, effective policy implementation, enhanced scientific monitoring, increased investment, and greater community involvement.

Effective Mangrove Restoration Techniques

Restoration Technique	Main Approach	Advantages	Limitations	Suitable Conditions
Natural Regeneration	Remove disturbances to allow natural recovery	Low cost; maintains natural diversity	Slow; depends on nearby seed source	Intact hydrology with natural seed supply
Ecological Mangrove Restoration (EMR)	Restore ecological processes, especially hydrology	High survival; resilient ecosystem	Requires expertise and monitoring	Degraded sites with restorable ecology
Hydrological Restoration	Re-establish tidal flow	Supports natural regeneration	Can be costly	Areas with altered hydrology
Direct Planting	Plant seedlings or propagules	Simple and rapid	High mortality if site unsuitable	Severely degraded sites
Nursery-Based Restoration	Raise seedlings before transplanting	Healthy planting stock	Higher cost and labour	Large-scale restoration projects
Assisted Natural Regeneration (ANR)	Protect and support natural regeneration	Cost-effective	Depends on natural propagules	Moderately degraded sites
Sediment Restoration	Improve sediment conditions	Better seedling survival	Requires sediment management	Eroded or subsided areas
Coastal Engineering	Reduce wave energy and stabilize shoreline	Controls erosion	Expensive; maintenance needed	High-energy coastlines
Community-Based Restoration	Involve local communities	Long-term protection; livelihood benefits	Needs sustained participation	Community-dependent mangrove areas

Mangrove Conservation

Mangrove conservation in India is deeply rooted in a legacy of traditional coastal stewardship, now reinforced by modern legal and policy instruments.

The Indian Forest Act, 1927, the Wildlife Protection Act, 1972, and the Coastal Regulation Zone (CRZ) Notification, 2019 provide the statutory backbone for protecting mangrove habitats from unchecked exploitation and unregulated development. India's commitment to international environmental goals, including the Sustainable Development Goals (SDGs) and the Paris Agreement on climate change, has lent additional urgency to mangrove restoration as a nature-based solution for carbon sequestration and coastal resilience. The involvement of corporate entities through Corporate Social Responsibility (CSR) initiatives has also emerged as a promising avenue for funding large-scale mangrove plantation and livelihood generation projects. Furthermore, the integration of mangrove conservation into disaster management planning, especially in cyclone-prone states, has highlighted the protective function of mangroves as bio-shields against storm surges and coastal flooding. Moving forward, the success of mangrove conservation in India will depend on harmonizing ecological restoration with the socio-economic aspirations of coastal communities, strengthening local governance institutions, and leveraging technology for real-time monitoring and adaptive management.

Conclusion

The fragmentation of habitats due to coastal infrastructure has weakened their natural resilience to both environmental and anthropogenic pressures. Despite decades of restoration efforts, shifting hydrological regimes and salinity patterns driven by sea level rise, intense storms, and freshwater extraction continue to threaten mangrove stability. Sustaining mangrove ecosystems requires an integrated strategy that balances ecological restoration with the livelihood needs of coastal communities. Restoration approaches using micro and macro propagation, including volunteer recruitment, direct seeding, and transplanting nursery raised seedlings have proven effective when matched to appropriate hydrological conditions. Countering the mounting pressures from development, pollution, and climate change demands stronger inter agency coordination, expanded community stewardship, and reliable financing. Recognized as both a biodiversity priority and a livelihood safeguard, mangroves can endure as resilient natural barriers and productive ecosystems for future generations.

References

- Kathiresan, K. & Bingham, B.L. (2001). Biology of mangroves and mangrove ecosystems. *Advances in Marine Biology*, 40, 81–251. [https://doi.org/10.1016/S0065-2881\(01\)40003-4](https://doi.org/10.1016/S0065-2881(01)40003-4).

- Friess, D.A., Rogers, K., Lovelock, C.E., Krauss, K.W., Hamilton, S.E., Lee, S.Y., Lucas, R., Primavera, J., Rajkaran, A. & Shi, S. (2019). The state of the world's mangrove forests: Past, present, and future. *Annual Review of Environment and Resources*, 44, 89–115. <https://doi.org/10.1146/annurev-environ-101718-033302>.
- Forest Survey of India (2023). India State of Forest Report 2023. Forest Survey of India, Ministry of Environment, Forest and Climate Change, Government of India.
- Feller, I.C., Lovelock, C.E., Berger, U., McKee, K.L., Joye, S.B. & Ball, M.C. (2010). Biocomplexity in mangrove ecosystems. *Annual Review of Marine Science*, 2, 395–417.