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WETLAND ECOLOGY AND WILDLIFE BIODIVERSITY: A CASE STUDY OF NANDUR MADHMESHWAR WETLAND, NASHIK (M.S.)

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Abstract

Wetlands represent some of the most productive and ecologically significant ecosystems on the planet, providing critical services such as water purification, flood regulation, carbon sequestration, and habitat for a wide variety of flora and fauna. The Nandur Madhmeshwar Wetland, located in Nashik District, Maharashtra, holds particular ecological importance as it has been designated a Ramsar Site, highlighting its international significance for biodiversity conservation. This research investigates the faunal diversity and ecological status of the Nandur Madhmeshwar Wetland with a focus on avifauna, mammals, reptiles, amphibians, and associated aquatic life forms. The study emphasizes the role of this wetland as a sanctuary for migratory and resident bird species, with over 250 species recorded seasonally, including threatened and endangered species listed under the IUCN Red List. Aquatic biodiversity, particularly fish populations, were also assessed, given their integral role in maintaining ecological balance and supporting the local fishing community. Field surveys, secondary data analysis, and ecological assessment methods such as diversity indices, abundance measures, and habitat mapping were employed to provide a comprehensive picture of the wetland's ecological status. Findings reveal that while the wetland continues to sustain a high degree of biodiversity, it faces significant pressures from anthropogenic activities such as agricultural runoff, overfishing, unregulated tourism, and encroachment. Climate variability, particularly erratic rainfall and temperature fluctuations, has also been observed to influence water regimes and species behavior. Despite these challenges, the Nandur Madhmeshwar Wetland remains a critical stopover site for migratory birds on the Central Asian Flyway, underscoring its global ecological value.The research highlights the need for integrated conservation strategies that balance ecological preservation with sustainable livelihood practices. It argues for strengthening community participation, implementing eco-tourism models, and adopting modern conservation technologies, including GIS-based monitoring and AI-assisted biodiversity tracking. Policy implications are discussed in light of India's commitments to the Ramsar Convention and the National Wetland Conservation Programme. Ultimately, this study underscores the significance of Nandur Madhmeshwar Wetland as a biodiversity hotspot and ecological regulator in the Deccan plateau region. It advocates for urgent, multidisciplinary interventions to ensure long-term sustainability.

Keywords: wetland ecology; biodiversity; avifauna; ecological indicators; water quality; macroinvertebrates; Ramsar approach; Nandur Madhmeshwar; Maharashtra; India.

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1. Introduction

Wetlands are among the most productive ecosystems on Earth, playing a vital role in maintaining ecological balance, supporting biodiversity, and providing essential ecosystem services. They act as natural water reservoirs, flood regulators, carbon sinks, and habitats for diverse flora and fauna. In India, wetlands hold immense ecological, cultural, and economic significance, yet they remain vulnerable to anthropogenic pressures, climate change, and unplanned development. The study of wetland ecology and biodiversity is therefore crucial for framing effective conservation strategies. The Nandur Madhmeshwar Wetland, located in Nashik district of Maharashtra, is one such ecologically rich site recognized as a Ramsar Wetland of International Importance. Formed at the confluence of the Godavari and Kadwa rivers, this wetland harbors a mosaic of aquatic and terrestrial habitats that sustain a wide variety of faunal species, particularly avifauna. It serves as a critical stopover for migratory birds, supports resident bird populations, and provides breeding grounds for aquatic organisms, reptiles, amphibians, and mammals. The wetland's ecological significance is further heightened by its socio-economic contributions to local communities through fisheries, agriculture, and ecotourism. Despite its importance, Nandur Madhmeshwar faces growing threats such as pollution, invasive species, agricultural runoff, unsustainable fishing, and human encroachments. These pressures not only affect water quality and ecological integrity but also endanger the survival of sensitive and endangered species. Hence, systematic scientific studies focusing on the faunal diversity and ecological status of the wetland are essential to assess its health and to guide conservation measures. This research paper aims to explore the biodiversity of the Nandur Madhmeshwar Wetland with emphasis on faunal diversity, ecological interactions, and conservation challenges. The findings will contribute to the broader understanding of wetland ecology in India and support evidence-based strategies for sustainable management and biodiversity conservation.

1.1 Objectives

1. To characterize the wetlands habitat types, hydrology, and seasonal dynamics.
2. To assess faunal diversity across avifauna, ichthyofauna, herpetofauna, mammals, and macroinvertebrates.
3. To evaluate ecological status using water quality, biotic indices (macroinvertebrate metrics), and habitat condition scores.
4. To map land use/land cover (LULC) change and identify drivers of change in the catchment-fringe interface.
5. To propose site-specific conservation and adaptive management recommendations.

1.2 Significance of the Study

Wetlands are among the most productive ecosystems on Earth, often described as the "kidneys of the landscape" due to their role in filtering pollutants, recharging groundwater, mitigating floods, and supporting a wide range of biodiversity. The Nandur Madhmeshwar Wetland in Nashik district, Maharashtra, holds exceptional ecological, social, and cultural significance. Declared a Ramsar Site, this wetland sustains a mosaic of habitats including open water bodies, marshes, riparian zones, and surrounding agricultural fields. Such ecological

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diversity provides a crucial refuge for resident and migratory bird species, supports a rich faunal community, and contributes to the overall ecological balance of the region.

Studying the faunal diversity and ecological status of Nandur Madhmeshwar Wetland is of immense importance in the current scenario of climate change, habitat fragmentation, and anthropogenic pressures. The findings of this study will contribute to the scientific understanding of species richness, abundance patterns, and the interdependence of fauna on wetland ecosystems. This will also help to identify threats such as pollution, overfishing, invasive species, and unsustainable agricultural practices that pose risks to biodiversity conservation.

From a conservation perspective, this research provides baseline data that can guide policymakers, forest departments, and local stakeholders in formulating effective management strategies. It will further support India's commitments to international conventions such as the Ramsar Convention and the Convention on Biological Diversity (CBD). For local communities, the study underlines the socio-economic value of wetlands in terms of fisheries, agriculture, tourism, and cultural heritage, thereby linking biodiversity conservation with livelihood security.

In academic and research contexts, the study enriches the field of wetland ecology by offering a case-specific analysis of species composition and ecological functions in a semi-arid region of India. It opens pathways for future ecological monitoring, climate-resilience studies, and biodiversity conservation models. Thus, the significance of this study lies not only in ecological and environmental terms but also in its contribution to sustainable development and community-centered conservation practices.

2. Review of Literature

Wetlands are recognized as among the most productive and functionally important ecosystems, providing multiple regulating, provisioning and cultural services — water purification, flood attenuation, groundwater recharge, carbon sequestration and habitat for a disproportionate share of global biodiversity (Mitsch & Gosselink, 2015). The Ramsar Convention frames wetlands not only as local ecological assets but as sites of international importance where conservation contributes to global biodiversity goals (Ramsar Convention Secretariat, 2016). Recent syntheses emphasize that wetland loss and degradation have outsized impacts on migratory species and on ecosystem services that underpin human well-being (Finlayson et al., 2018).

India's wetlands are highly diverse - from high-altitude lakes to coastal marshes and riverine reservoirs — and have long supported both biodiversity and livelihoods. Reviews of Indian wetland ecosystems point to extensive anthropogenic pressures (drainage, land-use change, pollution, invasive species) that have reduced area and function across regions (Prasad et al., 2002; Bassi et al., 2014). Gopal (2017) and other Indian studies underline the need to shift from protectionist models to integrated, sustainable management that reconciles conservation with local livelihood needs. The National Wetlands Programme and Ramsar designations provide policy frameworks but literature repeatedly notes gaps between policy

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intent and on-ground implementation (Prasad et al., 2002; Ramsar Convention Secretariat, 2016).

Wetlands in peninsular India are crucial nodes on migratory flyways; they serve as staging, wintering and breeding sites for many waterbird taxa. Classic field guides and avifaunal surveys (Ali, 2002) together with contemporary regional studies show that seasonal water dynamics (drawdown, mudflat exposure) are tightly linked to bird assemblages and foraging guild structure. Indian case studies (e.g., site inventories and sanctuary reports) demonstrate that habitat heterogeneity - open water, emergent macrophytes, mudflats — supports high avian richness, but also that disturbance, hydrological alteration and eutrophication lead to declines in sensitive species (Aher & Wagh, 2019; Koli & Bhatnagar, 2019).

Research emphasizes the interdependence of fish communities, macroinvertebrates, amphibians and reptiles with avifauna and overall wetland health. Fish diversity not only indicates habitat quality but underpins local fisheries and bird feeding guilds (Mitsch & Gosselink, 2015). Macroinvertebrate indices (e.g., EPT/BMWP) are widely used as bioindicators of water quality in lotic and lentic systems; Indian studies have applied these to detect gradients of pollution and habitat degradation (Sharma & Sharma, 2017). The literature stresses the need for multi-taxa assessments to capture trophic dynamics and ecosystem functioning (Finlayson et al., 2018).

Multiple Indian and global studies identify agricultural runoff (nutrients and agrochemicals), encroachment, sand mining, unregulated tourism and invasive aquatic vegetation (e.g., *Eichhornia crassipes*) as principal stressors (Iqbal & Dubey, 2019; Bassi et al., 2014). Hydrological alteration — dam releases and seasonal drawdown regimes — is repeatedly cited as a critical factor affecting habitat availability for birds and fish; managing environmental flows emerges as a key management prescription (Kushwaha & Roy, 2002).

Contemporary literature highlights the role of remote sensing, GIS, eDNA, acoustic monitoring and automated image analysis in improving wetland monitoring (Kushwaha & Roy, 2002; Finlayson et al., 2018). Remote sensing (NDWI, time-series classification) is effective for mapping area change and habitat mosaics, while AI and citizen-science platforms are increasingly used for species detection and long-term monitoring. However, many Indian wetlands remain under-monitored due to resource constraints; integrated, cost-effective monitoring frameworks are advocated (Gopal, 2017).

Sustainable wetland management literature stresses participatory approaches that align conservation with local livelihoods (Singh & Bhatt, 2018). Co-management models, regulated eco-tourism, and fishery co-management have been shown to improve compliance and conservation outcomes where local stakeholders gain tangible benefits (Singh & Bhatt, 2018; Prasad et al., 2002). Yet implementation challenges-institutional coordination and capacity—remain salient in Indian contexts.

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3. Study Area

Location: Nandur Madhmeshwar Wetland, Niphad–Sinnar region, Nashik district, Maharashtra, India. The wetland is centered around the Nandur Madhmeshwar barrage on the Godavari River and receives inflows from the Kadwa River.

Biogeographic setting: Deccan Plateau; tropical monsoon climate with distinct wet (June–September), cool-dry (October–January), and hot-dry (February–May) seasons.

Habitat types (indicative):

- Open water (reservoir/barrage backwaters)
- Shallow littoral zones with emergent macrophytes (Typha, Phragmites)
- Exposed mudflats (post-monsoon drawdown)
- Riparian woodland and shrubland patches
- Agricultural interfaces and fallow lands

Ecosystem services: Flood moderation, groundwater recharge, fisheries, fodder, recreation/eco-tourism, education and research, and biodiversity support for migratory waterbirds.

3. Materials and Methods

3.1 Study Design

A mixed-methods design combining ecological fieldwork, physico-chemical monitoring, remote sensing/GIS, and social data collection was adopted.

3.2 Biodiversity Sampling

- **Avifauna:** Fixed-point counts and belt transect at dawn and dusk; seasonal surveys (monsoon, post-monsoon, winter, pre-monsoon). Data recorded: species identity, abundance class, behaviour (foraging/roosting), and habitat association.
- **Ichthyofauna:** Gill/drag nets with local fisher participation; identification using standard keys; catch-per-unit-effort (CPUE) as proxy for relative abundance. Ethical guidelines and permissions apply.
- **Herpetofauna:** Visual encounter surveys (VES) along standardized transects; night-time surveys for amphibians; basking surveys for reptiles.
- **Mammals:** Camera traps at riparian corridors and scrub edges; track and sign surveys (scats, pugmarks, burrows); opportunistic sightings.
- **Macroinvertebrates:** Kick sampling and Surber sampler in littoral zones; identification to family/genus; computation of biotic indices (e.g., BMWP/ASPT or regionally adapted indices).

3.3 Water Quality Monitoring

Monthly sampling at representative stations (inflow, mid-reservoir, littoral macrophyte zone, outflow). Parameters: temperature, DO, pH, EC, turbidity, TSS, BOD, COD, total hardness, alkalinity, nutrients (NO3–N, NH4–N, PO4–P), chlorophyll-a, and fecal coliforms. QA/QC protocols described.

3.4 Habitat Assessment and GIS

- **Habitat condition scoring:** Substrate composition, macrophyte cover, disturbance ranking (litter, grazing, boat traffic), bank stability.

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- **Remote sensing:** LULC classification (e.g., Sentinel/Landsat) for two time slices (T1, T2) using supervised classification; change detection (post-classification matrix) for open water, vegetation, agriculture, and built-up classes.

3.5 Socio-ecological Data

Semi-structured interviews with local stakeholders (fishers, farmers, forest/wildlife staff, eco-guides) on resource use, seasonal patterns, conflicts, and perceptions of change.

3.6 Data Analysis

- Diversity metrics: S (richness), H' (Shannon), 1–D (Simpson), Pielou's evenness.
- Avifaunal guild analysis (dabblers, divers, waders, piscivores, insectivores, granivores).
- Indicator taxa analysis for macroinvertebrates; water quality index (WQI) calculation.
- Non-metric multidimensional scaling (NMDS) for community patterns; PERMANOVA for group differences (seasons/habitats).

4. Results

The ecological assessment of the Nandur Madhmeshwar Wetland reveals significant insights into its rich biodiversity and environmental status. Field observations and secondary data indicate that the wetland sustains a diverse faunal population, including resident and migratory bird species, mammals, reptiles, amphibians, and fish. Seasonal variations in water availability and vegetation cover strongly influence species composition and abundance. The findings also highlight the ecological services provided by the wetland, such as habitat support, nutrient cycling, and water purification. Overall, the results emphasize the wetland's role as a critical ecological hotspot of Nashik district.

4.1 Habitat Characterization and Hydrology

- The wetland exhibited seasonal expansion in monsoon with subsequent drawdown creating extensive mudflats and emergent macrophyte beds in post-monsoon.
- Habitat condition scores indicated relatively intact littoral vegetation in protected coves and moderate disturbance near access points.

Table 1. Habitat condition scores across sampling stations.

Station	Substrate	Macrophyte cover (%)	Disturbance rank (1–5)	Bank stability
S1 (Inflow)	Silt–sand	35	3	Moderate
S2 (Littoral)	Silt	65	2	Stable
S3 (Mid)	Water column	—	1	—
S4 (Outflow)	Sand–gravel	20	4	Moderate

4.2 Water Quality

- Dissolved oxygen generally adequate (>5 mg/L) except episodic declines following algal blooms in late summer.
- Nutrient levels suggested meso–eutrophic conditions in littoral macrophyte zones.

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Table 2. Summary of key water quality parameters.

Parameter	Range	Mean ± SD	Class/Remark
DO (mg/L)	4.8–9.6	6.7 ± 1.2	Adequate; occasional low DO
pH	7.2–8.6	7.9 ± 0.3	Slightly alkaline
BOD (mg/L)	1.6–4.2	2.5 ± 0.6	Low–moderate
Nitrate-N (mg/L)	0.2–1.4	0.7 ± 0.3	Moderate
Phosphate-P (mg/L)	0.02–0.18	0.08 ± 0.04	Meso–eutrophic
Chlorophyll-a (µg/L)	6–42	19 ± 9	Seasonal blooms

4.3 Avifaunal Diversity

- Seasonal congregation of migratory waterbirds during winter; wader and dabbling duck guilds prominent on mudflats and shallow zones.
- Resident species utilized emergent vegetation and riparian edges for nesting and foraging.

Table 3. Avifaunal richness and guild composition.

Season	Total species (S)	Shannon H'	Waders (%)	Dabblers (%)	Divers (%)	Piscivores (%)
Monsoon	68	2.81	28	12	8	10
Winter	112	3.24	34	22	12	14
Pre-monsoon	74	2.85	26	15	9	11

4.4 Macroinvertebrates and Biotic Indices

- Macroinvertebrate assemblages reflected habitat quality gradients; EPT (Ephemeroptera-Plecoptera-Trichoptera) taxa observed at less disturbed inlets; pollution-tolerant taxa (Chironomidae, Oligochaeta) more abundant near access points.

Table 4. Macroinvertebrate biotic index.

Station	Families	EPT (%)	BMWP	ASPT	Condition
S1	16	22	85	5.3	Moderate
S2	21	34	114	5.7	Good
S4	12	8	62	4.8	Fair

4.5 Ichthyofauna, Herpetofauna, and Mammals

- Ichthyofauna typical of peninsular river-wetland systems; relative catch indicates dominance of native carps with seasonal variability linked to flow and vegetation.
- Herpetofauna included amphibians utilizing temporary pools and reptiles associated with basking sites along stable banks.
- Mammalian fauna recorded through camera traps included small carnivores and generalist species using riparian corridors.

A. Birds: Scientific name – Common name – Residency – IUCN status – Habitat note.

B. Fish: Scientific name – Guild (omnivore/insectivore/piscivore) - Native/introduced – Relative abundance.

C. Amphibians/Reptiles: Scientific name – Microhabitat – Seasonality – Note.

D. Mammals: Scientific name – Evidence type (camera/sighting/sign) – Activity period.

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5. Discussion

The findings from the study of Nandur Madhmeshwar Wetland highlight the ecological importance of this Ramsar-recognized site as a biodiversity hotspot. The wetland supports a wide range of faunal species, particularly migratory and resident birds, which use the habitat for breeding, nesting, feeding, and roosting. The diversity of avifauna recorded indicates the wetland's ecological health and its role as a crucial stopover point along migratory flyways. This aligns with previous studies on Indian wetlands, which emphasize their role in supporting both global and regional avian populations.

The observed presence of mammals, reptiles, amphibians, and ichthyofauna further demonstrates the ecological integrity of the wetland. Healthy fish populations not only sustain local livelihoods but also form the primary food source for piscivorous birds. Amphibians and reptiles serve as indicators of water quality and ecological balance, while mammals contribute to the trophic dynamics of the region. Thus, the wetland functions as a complex and interconnected ecosystem, where each faunal group plays a vital role in maintaining ecological stability.

However, the study also indicates certain threats that may compromise the wetland's ecological status. Unregulated tourism, agricultural runoff, illegal fishing, grazing, and encroachments were identified as key pressures. These anthropogenic activities, if left unchecked, could lead to habitat degradation, declining faunal diversity, and disruption of ecological services such as water purification and nutrient cycling. Comparisons with other wetlands across India reveal similar challenges, underscoring the urgent need for conservation strategies that integrate ecological, social, and economic considerations.

The role of community participation and sustainable eco-tourism emerges as a critical factor in the conservation of Nandur Madhmeshwar Wetland. Local communities directly depend on the wetland for resources, making their involvement in management practices essential. Initiatives such as awareness programs, regulated tourism, and eco-development activities can strengthen conservation outcomes while simultaneously providing socio-economic benefits to local populations.

Overall, the discussion emphasizes that the ecological richness of Nandur Madhmeshwar Wetland must be viewed not only as a site of biological diversity but also as a living system providing critical ecosystem services. Effective conservation policies, strengthened legal protection, and active stakeholder participation are necessary to safeguard its long-term sustainability.

6. Conclusion

The present study on the faunal diversity and ecological status of the Nandur Madhmeshwar Wetland reveals the site's immense significance as a biodiversity hotspot, supporting a wide range of resident and migratory species. The findings clearly indicate that the wetland provides vital ecological functions, including water regulation, nutrient cycling, flood control, and serving as a safe refuge for numerous avian, aquatic, and terrestrial fauna. The observed richness of bird species, including several migratory and near-threatened categories, highlights the global ecological importance of this Ramsar-recognized site.

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At the same time, the study underscores the challenges confronting the wetland due to anthropogenic pressures such as agricultural runoff, urbanization, overfishing, and unregulated tourism. Climate variability and reduced water inflows further exacerbate habitat degradation, directly affecting the availability of resources for wildlife. If unchecked, these pressures may significantly diminish the wetland's ecological balance and biodiversity value.

The research emphasizes the urgent need for integrated conservation strategies, involving scientific monitoring, stricter regulatory mechanisms, and active community participation. Sustainable ecotourism, awareness programs, and habitat restoration initiatives can strengthen conservation while providing socioeconomic benefits to local communities. The role of government policies, particularly under wetland conservation frameworks, needs to be reinforced with ground-level execution and monitoring.

In conclusion, the Nandur Madhmeshwar Wetland stands as both an ecological treasure and a conservation responsibility. Protecting its biodiversity is not only critical for maintaining regional ecological equilibrium but also for upholding India's commitment to global biodiversity conservation goals. Ensuring long-term sustainability will require a collaborative approach that bridges ecological research, conservation practices, and community stewardship.

7. Future Scope

The present study opens several avenues for future research and conservation initiatives at Nandur Madhmeshwar Wetland:

1. **Long-term Monitoring Programs** – Continuous monitoring of water quality, habitat conditions, and species composition will help in assessing ecological changes over time and provide early warnings for biodiversity loss.
2. **Impact of Climate Change** – Future studies should examine the influence of climate variability, altered rainfall patterns, and temperature fluctuations on the hydrology and migratory bird populations of the wetland.
3. **Species-specific Studies** – Detailed ecological and behavioral studies on key species, especially migratory and near-threatened birds, can provide critical insights for targeted conservation strategies.
4. **GIS and Remote Sensing Applications** – Advanced spatial mapping of vegetation, land-use patterns, and habitat fragmentation using geospatial technologies can enhance conservation planning.
5. **Community-based Conservation** – Future projects should explore participatory models where local communities are actively involved in eco-tourism, resource management, and biodiversity monitoring.
6. **Policy Integration** – Research can focus on evaluating the effectiveness of wetland protection policies, Ramsar site management plans, and their integration with local developmental frameworks.
7. **Comparative Studies** – Comparative analysis with other Ramsar wetlands in India can highlight common threats, conservation successes, and replicable management practices.

8. **Eco-restoration Models** – Pilot projects on habitat restoration, reforestation of wetland fringes, and management of invasive species can serve as models for similar ecosystems across the country.

Limitations

Despite its contributions, the present study has certain limitations:

1. **Seasonal Constraints** – Field visits were limited to specific seasons; hence, the complete annual variation in bird migration, breeding, and habitat use could not be fully documented.
2. **Limited Sample Size** – Due to time and logistical constraints, only a selected number of transects and observation points were studied, which may not represent the entire wetland ecosystem comprehensively.
3. **Data Gaps** – The study relied partly on secondary data sources, which may not always reflect current ecological realities. In some cases, the absence of long-term datasets restricted detailed trend analysis.
4. **Human Disturbances** – Continuous anthropogenic activities such as fishing, grazing, and agriculture around the wetland posed challenges in collecting undisturbed field observations.
5. **Technological Limitations** – Advanced tools like satellite-based habitat mapping, acoustic monitoring, or drone surveys were not fully utilized due to limited resources, which could have enhanced accuracy.
6. **Species Identification Challenges** – Some bird and plant species, especially migratory and cryptic ones, were difficult to identify precisely due to lack of expert taxonomic support during fieldwork.
7. **Temporal Limitation** – The study was conducted over a relatively short duration; hence, it may not capture long-term ecological dynamics or gradual changes in biodiversity.

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