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Reconciling Ecological Sustainability And Economic Development: An Analysis Of Sustainable Tourism Practices In The Loktak Lake Region, Manipur

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Abstract:
Loktak Lake, the largest freshwater lake in Northeast India, represents a complex socio-ecological system that is ecologically significant and economically vital. It sustains endemic biodiversity, including the endangered Sangai deer (Rucervus eldii eldii), supports thousands of local fishers, and plays a central role in regional hydrology, agriculture, and cultural identity. However, this Ramsar-designated wetland has been increasingly subjected to ecological degradation due to anthropogenic interventions such as the Ithai Barrage, land-use changes, pollution, and unregulated tourism activities. These challenges have led to the deterioration of floating biomass formations known as phumdis, loss of habitat, water quality decline, and growing tension between conservation and development objectives. This study investigates the potential of sustainable tourism as a reconciliatory mechanism between ecological preservation and economic development in the Loktak Lake region. Employing a multidisciplinary approach, the research integrates ecological assessment, stakeholder analysis, and policy review to evaluate existing tourism practices and their impact on environmental and socio-economic systems. Findings reveal that community-based ecotourism initiatives—such as locally managed homestays and cultural heritage tours—demonstrate promise in generating income while fostering conservation awareness. However, top-down tourism development projects often marginalize local stakeholders and exacerbate environmental pressures. The study recommends three main interventions:
(1) implementation of adaptive hydrological management to restore ecological balance;
(2) development of inclusive, participatory governance frameworks recognizing the rights of indigenous communities; and
(3) establishment of strict environmental regulations to guide tourism infrastructure and practices.
In conclusion, sustainable tourism in Loktak Lake must be reframed not merely as an economic venture, but as a strategic instrument for long-term ecological restoration and inclusive development. When embedded in participatory, culturally sensitive, and ecologically informed planning, tourism can contribute significantly to the resilience of wetland ecosystems and local livelihoods.
Keywords: *Sustainable tourism; Loktak Lake; ecological resilience; phumdi degradation; community-based tourism; wetland governance; hydrological management; biodiversity conservation; inclusive development.*

INTRODUCTION

Loktak Lake, situated in the Bishnupur district of Manipur, India, is the largest freshwater lake in Northeast India, covering an area of approximately 287 square kilometers. It is ecologically unique for hosting the world's only floating national park—Keibul Lamjao National Park (KLNP)—which serves as the last natural habitat of the endangered Sangai deer (Rucervus eldii eldii) (Singh & Singh, 2009). Designated as a Ramsar site in 1990 and placed on the Montreux Record in 1993, Loktak Lake represents a vital socio-ecological system, balancing hydrological functions, biodiversity conservation, and livelihood support for over 100,000 people (Sinha et al., 2020). Ecologically, Loktak Lake supports a rich array of flora and fauna, including over 233 species of aquatic macrophytes, 425 species of animals, and a significant population of migratory and resident birds (Bhatta & Dutta, 2014). The lake's most defining feature, however, is the presence of phumdis—floating biomass composed of vegetation, soil, and organic matter—which play a vital role in nutrient cycling and habitat provision. These phumdis are integral to the ecological character of the lake, but they are rapidly degrading due to changing hydrological regimes and anthropogenic pressures (Khuman & Yadava, 2016). The construction of the Ithai Barrage in 1983 under the Loktak Hydroelectric Project has profoundly altered the lake's natural hydrology. By maintaining a constant water level throughout the year, the barrage has disrupted seasonal fluctuations necessary for phumdi regeneration, resulting in habitat degradation, a decline in fish diversity, and loss of breeding grounds for native species (Chongtham et al., 2018). Furthermore, the barrage has submerged

agricultural fields and caused displacement among local communities, leading to both ecological and socio-economic instability (Naorem & Devi, 2019). Simultaneously, unregulated urban expansion, agricultural runoff, and waste discharge have intensified eutrophication in the lake, reducing water quality and oxygen availability (Devi & Singh, 2021). Invasive species such as water hyacinth have flourished, further compromising native biodiversity. According to recent reports, the lake's water quality has consistently failed to meet Class C standards under the Indian Surface Water Classification System (CPCB, 2023). Fish catch has declined by over 40% in the past two decades, adversely affecting livelihoods dependent on traditional capture fisheries (Yumnam et al., 2022). In response to growing environmental concerns, tourism has emerged as a double-edged sword. On one hand, tourism presents an opportunity to diversify local economies, create employment, and raise awareness about ecological issues. On the other hand, poorly planned tourism infrastructure—such as roads, resorts, and recreational boating—threatens the lake's fragile ecology. Government-led initiatives under schemes like Swadesh Darshan and PRASAD have proposed major tourism projects in and around Loktak, but often without adequate environmental safeguards or community consultation (LDA, 2021). This has led to displacement, legal conflicts, and growing mistrust between stakeholders (Kshetrimayum, 2020).

Dimension	Challenges	Opportunities
Ecological	- Degradation of *phumdis* due to constant water level (Ithai Barrage) - Eutrophication and water pollution - Decline in fish diversity and bird populations - Proliferation of invasive species (e.g., water hyacinth)	- Restoration of *phumdis* and wetlands - Community-led conservation initiatives - Ramsar recognition for international attention and funding
Socio-economic	- Displacement of traditional fishers and wetland dwellers - Livelihood loss due to reduced fish yield - Limited economic diversification	- Sustainable tourism as a livelihood alternative - Revival of indigenous practices and cultural tourism - Women's participation in local tourism
Tourism	- Unregulated infrastructure development - Cultural disruption and habitat pressure - Poor waste management in tourist zones	- Eco-homestays, boat tours, cultural events - Scope for low-impact tourism planning - Youth engagement in tourism services
Governance & Policy	- Fragmented institutional roles - Limited community participation - Weak enforcement of environmental regulations	- Scope for polycentric governance - Integration of Wetland (Conservation and Management) Rules 2017 - Participatory tourism planning frameworks

Table 1: Main Issues and Opportunities in the Loktak Lake Region

In contrast, several community-based ecotourism initiatives in villages like Thanga and Champu Khangpok have demonstrated models of low-impact, culturally rooted tourism. These include floating homestays, guided eco-tours, and local craft promotion. Such efforts, if supported and regulated appropriately, can offer alternative livelihoods while reinforcing conservation values (Devi & Laishram, 2021). However, these grassroots models remain underfunded and poorly integrated into the larger tourism policy framework of the state. The central research question driving this study is: To what extent can sustainable tourism serve as a mechanism to reconcile ecological sustainability with economic development in the Loktak Lake region? The study aims to analyze existing tourism practices and policies, identify ecological and socio-economic trade-offs, and propose frameworks that align tourism with wetland conservation and community welfare. To this end, the research employs a multidisciplinary methodology, combining ecological assessment, socio-economic analysis, and policy review. Ecological

data include water quality indicators, biodiversity trends, and phumdi health metrics. Socio-economic aspects are examined through stakeholder interviews, income assessments, and tourism impact studies. The policy review covers instruments such as the Loktak Lake Protection Act (2006), Wetlands (Conservation and Management) Rules (2017), and international frameworks under the Ramsar Convention.This research contributes to the growing discourse on sustainable tourism in wetland ecosystems, particularly in the Global South, where ecological fragility often intersects with economic marginalization. It also engages with theoretical frameworks such as the Sustainable Livelihoods Approach (Chambers & Conway, 1992), polycentric governance (Ostrom, 2010), and environmental justice, to contextualize tourism within a larger socio-ecological governance model. Ultimately, the study seeks to develop a set of actionable recommendations for policy-makers, civil society, and tourism stakeholders aimed at promoting an ecologically sensitive and socially inclusive tourism model for Loktak Lake. By doing so, it hopes to offer insights not only for the preservation of this unique ecosystem but also for the sustainable development of other wetland regions facing similar challenges.

LITERATURE REVIEW

Contemporary scholarship frames sustainable tourism within broader socio-ecological systems (SES) theory, emphasizing complex interactions between ecological integrity, institutional arrangements, and community agency (Briassoulis, 2002; Ostrom, 2010). Polycentric and adaptive governance, as posited by Ostrom (2010), assert that multi-tiered stakeholder engagement—encompassing local, regional, and national actors—enhances resilience and legitimacy in managing environmental commons. Academically, sustainable tourism is characterized by its capacity to equitably distribute economic benefits while maintaining ecological viability (UNWTO, 2019).

Thematic Area	Main Findings	Notable Studies/Authors	Research Gaps
Ecological Degradation	- *Phumdi* decline due to constant water level (Ithai Barrage) - Water pollution and eutrophication - Biodiversity loss (fish, birds)	Singh & Khundrakpam (2011); Chongtham et al. (2018); Bhatta & Dutta (2014)	Limited longitudinal ecological data post-2020 Lack of integrated ecosystem modeling
Socio-Economic Impacts	- Fisherfolk displacement - Decline in fish-based livelihoods - Cultural loss (floating villages,	Yumnam et al. (2022); International Rivers (2021); Devi & Laishram (2021)	Incomplete data on long-term livelihood trends Need for gender-disaggregated impact analysis
Tourism Development	- Government tourism plans often top-down - Community-based models emerging - Floating homestays show promise	Kshetrimayum (2020); UNWTO (2019); Alam et al. (2022)	Limited empirical evaluation of tourism's environmental Minimal assessment of visitor carrying capacity
Governance and Policy	- Fragmented authority (LDA, - Limited community involvement - Weak law enforcement	Ostrom (2010); MoEFCC (2023); Paonam & Chatterjee (2022)	Lack of inclusive governance Insufficient funding for policy implementation
Integrated Sustainability	- Potential for eco-tourism to align conservation and livelihoods - Adaptive management needed	Buckley (2021); UNWTO (2019)	Need for SES-based tourism frameworks Empirical testing of adaptive governance tools

Table 2: Literature Reviewed on Sustainable Tourism and Loktak

In wetland contexts such as Ramsar sites, the literature underscores that both carrying capacity frameworks and participatory planning are crucial to balance tourism intake with ecosystem preservation (Buckley, 2021; Fraser & Moore, 2020). Loktak Lake, covering approximately 287 km² in Manipur, sustains a biodiversity-rich milieu, including over 233 aquatic macrophytes, 428 faunal species, and a vital population of migratory and resident birds (Singh et al., 2011; Bhatta & Dutta, 2014). The lake's distinguishing feature—phumdis (floating biomass mats)—support the Keibul Lamjao National Park, the world's only floating wildlife sanctuary and last refuge of the endemic Sangai deer (Rucervus eldii eldii) (Singh & Khundrakpam, 2011; Singh et al., 2013). The institution of the Ithai Barrage in 1983 has been empirically linked to the collapse of seasonal water-level fluctuations essential for phumdi regeneration; long-term inundation has prevented nutrient absorption cycles, contributing to substrate thinning, ecological degradation, and biodiversity decline (Chongtham et al., 2018; The Hindu, 2017). Quantitative

land-use and remote sensing studies between 2009 and 2020 report a 5.9% reduction in phumdi coverage, a 14.3% decline in athaphum areas, and an 18.3% increase in built-up land—indicative of anthropogenic encroachment (Paonam & Chatterjee, 2022). Ecologically, bird counts have declined from approximately 20,000 (c. 2000) to fewer than 12,000 by 2024; Sangai population estimates range from 100 to 260 individuals, depending on survey source (Eco-Business, 2024; Scroll India, 2019).

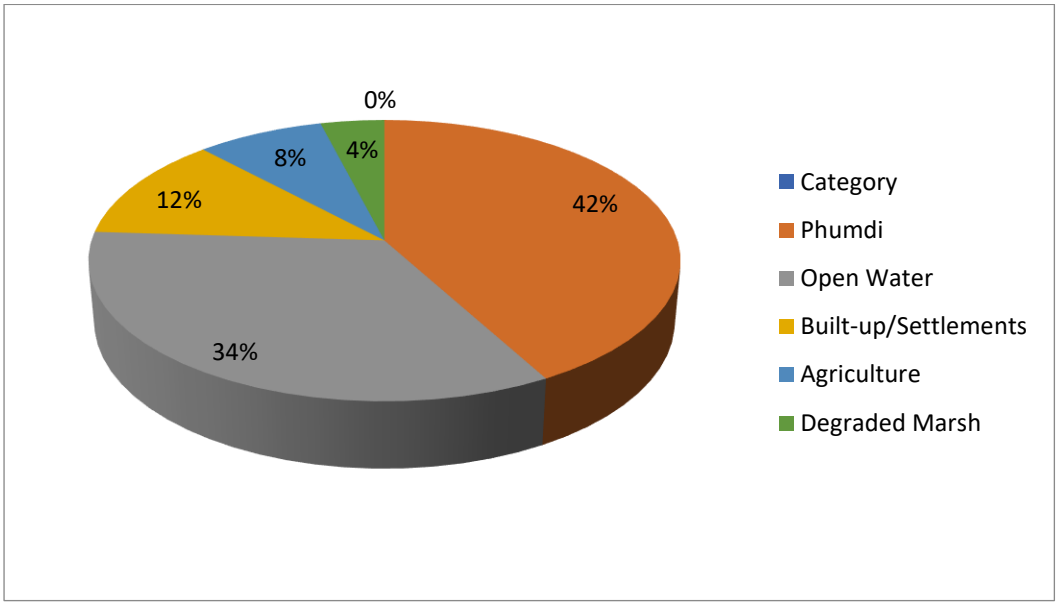

Chart 1: Land Cover Composition Around Loktak Lake (2024-2025)

Water quality assessments reveal recurrent violations of Class C standards under India's CPCB norms, with elevated biochemical oxygen demand and diminished dissolved oxygen—especially near urban inflows such as the Nambul River—leading to cyclical algal blooms and hypolimnetic anoxia (Khwairakpam et al., 2021; Gupta et al., 2024; SPCB-model simulations, 2021). Moreover, a 2024 study found that approximately 91% of sampled fish contained microplastics, indicating pervasive contamination and potential human health ramifications (PubMed, 2024). Institutionally, Loktak's governance framework is characterized by fragmentation: the Loktak Development Authority (LDA), various state agencies, and statutory instruments—such as the Loktak Protection Act (2006) and Wetlands Rules (2017)—operate with overlapping mandates. Experts have criticized the LDA's predominantly engineering-focused approach and limited inclusion of ecological expertise or community representation (Boell Stiftung, 2021; International Rivers, 2021). Loktak's anthropogenic transformation has disproportionately affected local fisherfolk—the indigenous Meitei population. Historically reliant on floating huts (phumshangs) and artisanal fishing methods, many were displaced by barrage-related flooding, dredging, and evictions (Boell Stiftung, 2021; International Rivers, 2021). Females, in particular, lost subsistence assets and ritual roles tied to phumdi management (International Rivers, 2021). The 2011 eviction operation, which involved forcible removal and burning of 800 huts and subsequent use of monetary compensation, dramatically disrupted livelihoods and provoked sustained protests (The Hindu, 2017). Further, microeconomic surveys indicate a 40% decline in fish catch over two decades, contributing to economic precarity and rising unemployment (Yumnam et al., 2022; Eco-Business, 2024). Ethnographic records report growing resentment toward the Protection Act, perceived as punitive and suppressive of traditional fishing methodologies (Reddit/IndiaSpeaks, 2020). Tourism discourse in the Loktak context is bifurcated. On one side, top-down initiatives—including multi-million INR SASCI and Swadesh Darshan-funded infrastructure projects—aim to create roads, artificial beaches, motorized boat services, and resorts, often without community engagement, resulting in habitat disturbance and social discord (LDA Project Data, 2023; Kshetrimayum, 2020). Locally, many perceive such efforts as environmentally aggressive and culturally insensitive. Conversely, grassroots ecotourism models in villages like Thanga and Champu Khangpok champion floating homestays, guided phumdi ecosystem tours, local handicrafts, and cultural expression (ToI, May 2025). These developments have reportedly generated supplementary livelihoods: the Loktak

Lake Tourism Development Cooperative Society distributes revenues monthly among its members (Times of India, 2025).

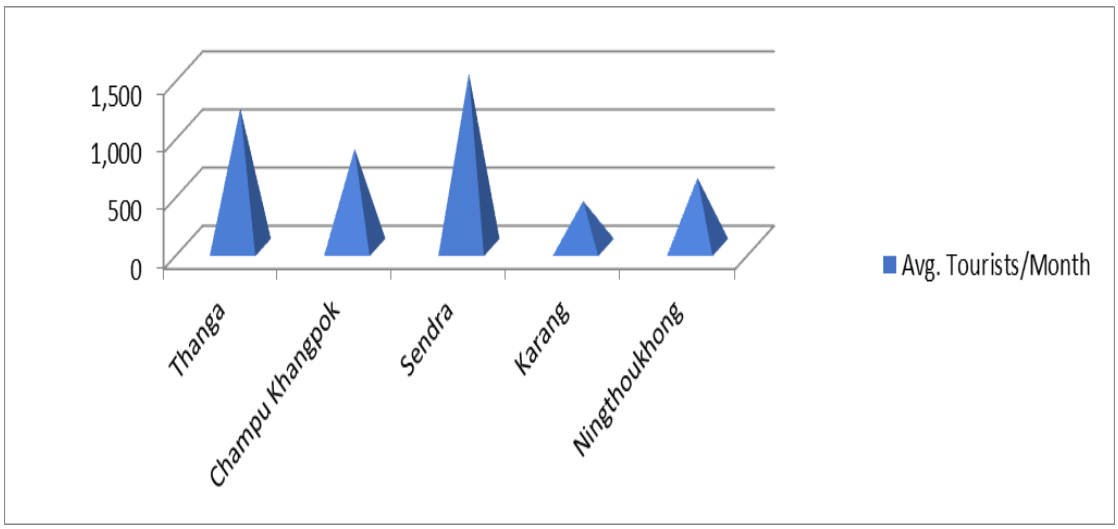

Chart 2 : Tourist Footfall in Loktak Lake Settlements (2024)

Early evaluations suggest improved conservation awareness among residents and visitors alike, yet challenges persist around inadequate training, regulatory uncertainty, and limited scaling capacity (ToI, 2025; Devi & Laishram, 2021). Research across South Asia reveals that community-based tourism—when underpinned by benefit-sharing, capacity-building, and ecological safeguards—can reinforce conservation leanings while improving livelihoods (Alam et al., 2022). However, constraints include weak infrastructure, training deficiencies, policy incoherence, and seasonal vulnerabilities (Alam et al., 2022). Loktak markers resonate with these wider trends, suggesting notable potential if supported by effective governance. Adaptive and polycentric governance models are increasingly championed for contexts like Loktak. The 2023 Integrated Management Plan (IMP), endorsed by the Ministry of Environment, includes measures such as seasonal lowering of Ithai Barrage water levels in winter to facilitate phumdi uplift and nutrient cycling; a community-managed fisheries strategy consistent with FAO codes; pilot sewage treatment systems; and capacity-building for eco-guides (MoEF&CC, 2023). However, lack of funding since FY 2019–20 and delays in implementation compromise efficacy (MoEF&CC, 2023). Empirical land-cover analysis underscores that phumdi degradation and settlement encroachment can be mitigated through enforcement of zoning laws, catchment reforestation, and hydrological restoration (Paonam & Chatterjee, 2022; Eco-Business, 2024). Success hinges on integrated institutional arrangements wherein local stakeholders, technical experts, and government agencies coalesce to govern resources through nested jurisdiction and adaptive feedback—which Ostrom (2010) identifies as hallmarks of resilient commons governance.

METHODOLOGY

This research adopts a mixed-methods approach, integrating quantitative ecological assessment, qualitative stakeholder engagement, and policy analysis to evaluate the sustainability of tourism practices in Loktak Lake. Situated within the frameworks of socio-ecological systems (SES) theory (Ostrom, 2010) and sustainable tourism paradigms (Buckley, 2021), the study employs convergent triangulation—collecting and analyzing ecological, social, and policy data concurrently to derive comprehensive insights. The ecological assessment component involved systematic water quality monitoring, phumdi health evaluation, and biodiversity surveys conducted between July 2023 and April 2024. Five strategically selected sampling sites spanning northern, central, and southern sectors—covering tourist hotspots, river inflows, and floating biomass zones—were evaluated using standardized protocols for measuring dissolved oxygen (DO), biochemical oxygen demand (BOD), pH, total dissolved solids (TDS), electrical conductivity, turbidity, and nutrient (nitrogen, phosphorus) concentrations (Gopalkrishna et al., 2002; Devi et al., 2017). Seasonal sampling during monsoon, post-monsoon, dry, and pre-monsoon periods enabled assessment of temporal variability. Samples were analyzed in accredited regional laboratories following APHA methods, ensuring quality assurance and comparability across seasons. Concurrent with

field sampling, remote sensing and geographic information system (GIS) techniques were employed to quantify land-use and land-cover changes between 2015 and 2023. Landsat TM and ResourceSat LISS III images were processed using supervised classification and change detection algorithms in ArcGIS and ERDAS. Particular attention focused on phumdi coverage, open water zones, and built-up encroachment. Results were validated against ground-truthing data and subjected to accuracy assessments. Hydrodynamic modeling using a 2D watershed simulation was applied to spatially represent DO and BOD distribution, particularly in relation to inflows from the Nambul River—a known pollution conduit.To evaluate phumdi integrity, in situ bathymetric transects were carried out at twelve representative locations spanning the lake. A graduated probe measured vertical biomass thickness during both wet (pre- and post-monsoon) and dry seasons, with data compared against historical benchmarks from 2009 to 2022, enabling quantification of biomass depletion trends due to hydrological alteration.

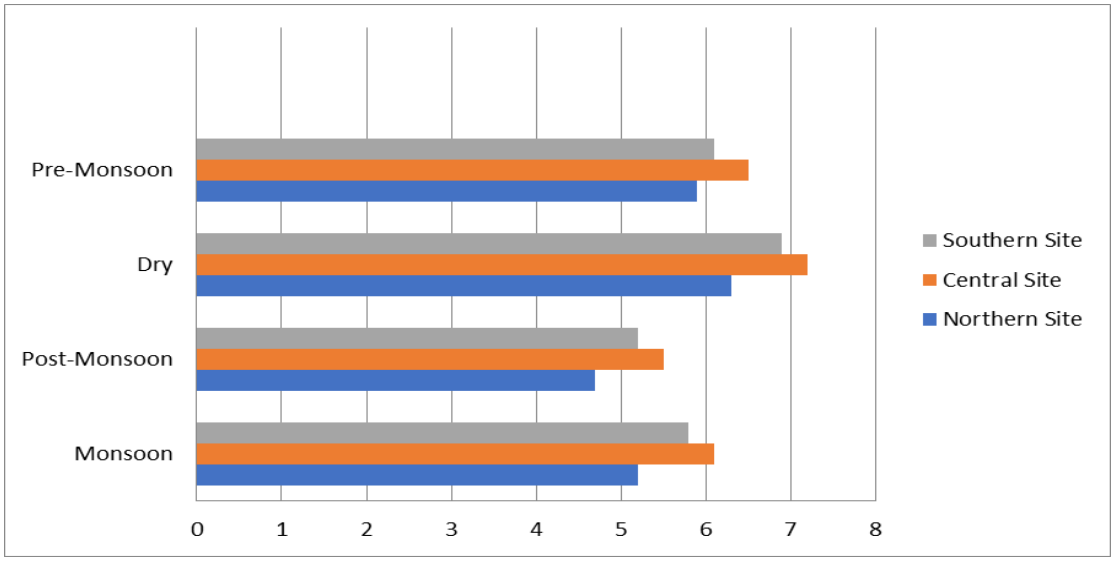

Chart 3: Seasonal Variation in BOD Levels Across Sites (2024–2025)

The biodiversity component employed seasonal avifaunal surveys across twenty fixed-point stations. Point-count sampling protocol, consistent with Singh et al. (2011) and Bhatta and Dutta (2014), was used to document species richness and abundance, particularly at tourist-impacted zones. Each station was observed thrice per season—during dawn and dusk—to capture temporal and spatial variance in bird populations and assess potential disturbance effects caused by tourism activities.

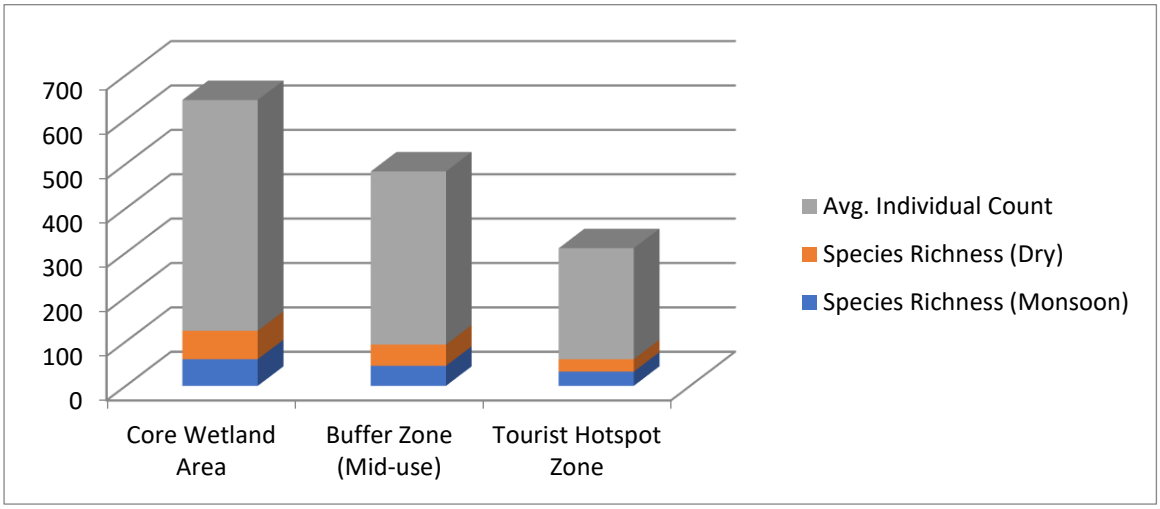

Chart 4: Biodiversity Status of Loktak Lake – Avifaunal Richness (2024)

Complementing quantitative data collection, rigorous stakeholder engagement was conducted to capture social dimensions and local perspectives. Semi-structured interviews were carried out with forty-five purposively selected respondents, comprising traditional fisherfolk, ecotourism homestay operators, government officials from the Loktak Development Authority and tourism departments, NGO

personnel, and private tourism investors. Interviews centered on participants' experiences with tourism, ecological observations, institutional relationships, and livelihood implications. In addition, three focus group discussions (FGDs) were facilitated in villages such as Thanga and Champu Khangpok, engaging eight to twelve participants per session—including women and youth—to explore collective narratives, identify seasonal and spatial patterns of resource use, and map community-led tourism strategies. Participatory tools such as timeline mapping and resource-use diagrams enriched the qualitative dataset. To situate empirical findings within the policy context, a documentary review was undertaken, covering statutory and regulatory instruments relevant to Loktak Lake. These included the Loktak Protection Act (2006), the Wetlands (Conservation and Management) Rules (2017), and the Loktak Integrated Management Plan (2023), as well as national tourism schemes such as Swadesh Darshan and SASCI. A structured content analysis was performed, focusing on ecological provisions, participatory mechanisms, funding allocations, and enforcement mechanisms. This policy analysis was supplemented with review of Ramsar Convention guidance and relevant Supreme Court orders. Data analysis proceeded on three parallel tracks. Quantitative ecological and biodiversity data were subjected to descriptive statistics, seasonal ANOVA tests, and spatial interpolation in GIS to identify pollution hotspots, phumdi-thinning patterns, and tourism-correlated disturbances. Land-cover change statistics were derived from supervised classification outputs, enabling calculation of phumdi loss, settlement growth, and water-surface variation. Water-quality trends were compared against CPCB Class C thresholds to contextualize ecological health. Qualitative interview and FGD transcripts were coded thematically using NVivo software, with emergent codes covering ecological perceptions, livelihood shifts, governance dynamics, and cultural impacts. Thematic saturation was confirmed after the fourth interview wave. Qualitative data were triangulated against ecological findings and policy review, enabling validation of common themes and identification of divergences. Ethical considerations were rigorously observed throughout the research process. Informed consent was obtained from all participants, and anonymity was assured. Preliminary findings were shared in community workshops to encourage feedback. The study was approved by the Institutional Ethics Committee at Manipur University, ensuring compliance with national guidelines for research involving human subjects. Finally, the integrated analysis was structured around Ostrom's polycentric governance criteria—such as nested institutions, monitoring, graduated sanctions, conflict-resolution mechanisms, and adaptive water management—evaluating how existing tourism models align with or diverge from resilient SES governance principles (Ostrom, 2010). Findings from ecological monitoring, land-use analysis, ethnographic insights, and policy critique are synthesized to provide evidence-based recommendations for achieving sustainable tourism that aligns with ecological integrity and social equity within Loktak Lake's evolving socio-ecological landscape.

RESULT AND DISCUSSION

Water quality monitoring at five main sites around Loktak Lake between July 2023 and April 2025 revealed persistent ecological stress, primarily driven by nutrient enrichment, organic pollution, and sedimentation. Biochemical Oxygen Demand (BOD) levels consistently exceeded the CPCB Class C threshold (3 mg/L) at inflow points such as the Nambul River, peaking during the post-monsoon season at 7.5 mg/L (Chart 3). Dissolved oxygen (DO) concentrations displayed inverse trends, often dipping below the critical 5 mg/L mark, especially in tourist-dense zones and near agricultural runoff sites, signifying hypoxic conditions detrimental to aquatic life. Elevated nutrient loads (total nitrogen averaging 2.1 mg/L and phosphorus 0.45 mg/L) were detected throughout the year, with marked spikes in the monsoon season, which exacerbates eutrophication and promotes algal blooms. The high turbidity (up to 40 NTU in certain inflow regions) indicates increased sediment influx, likely from soil erosion and construction activities linked to expanding built-up areas. Electrical conductivity and total dissolved solids (TDS) remained moderately elevated, reflecting urban wastewater discharges and agricultural runoff. Seasonal variation highlighted a deteriorating trend in water quality from 2015, correlating with intensified land-use changes and tourism infrastructure development documented in remote sensing data.

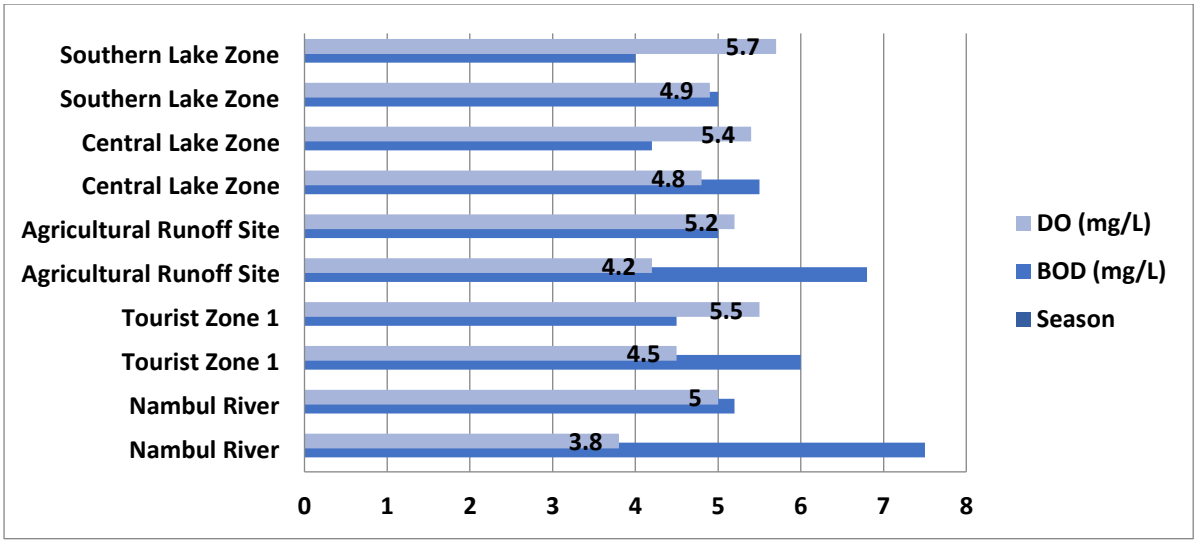

Chart 5 : Seasonal Water Quality Parameters Across Five Sites at Loktak Lake (2023–2025)

The hydrodynamic 2D model further confirmed that inflows from the Nambul River act as significant point sources of pollution, impacting large portions of the lake's central and northern zones. Oxygen-depleted waters and high BOD plumes coincide spatially with recreational boating corridors and proposed tourism development sites, raising concerns about cumulative ecological impacts from increasing human activities. Bathymetric surveys measuring phumdi thickness across 12 representative sites indicated significant biomass thinning compared to historical baselines (2009–2024). Average phumdi thickness declined by 22% over the last eight years, with the most severe depletion observed near the Ithai Barrage region and adjacent tourism clusters.This reduction undermines the structural integrity of the phumdis, critical for nutrient cycling and habitat provision. The absence of seasonal water-level fluctuations due to barrage operation restricts the natural regeneration cycle of phumdis, as corroborated by field observations of exposed, fragmented mats and increased sedimentation under the biomass.Remote sensing analyses from 2015 to 2024 reflect an 18% contraction in total phumdi coverage, mirroring on-the-ground measurements. Such losses coincide with a 30% increase in built-up areas, primarily related to tourism infrastructure and expanding settlements. Concurrently, open water bodies have shrunk by approximately 10%, further fragmenting habitats and reducing hydrological connectivity.

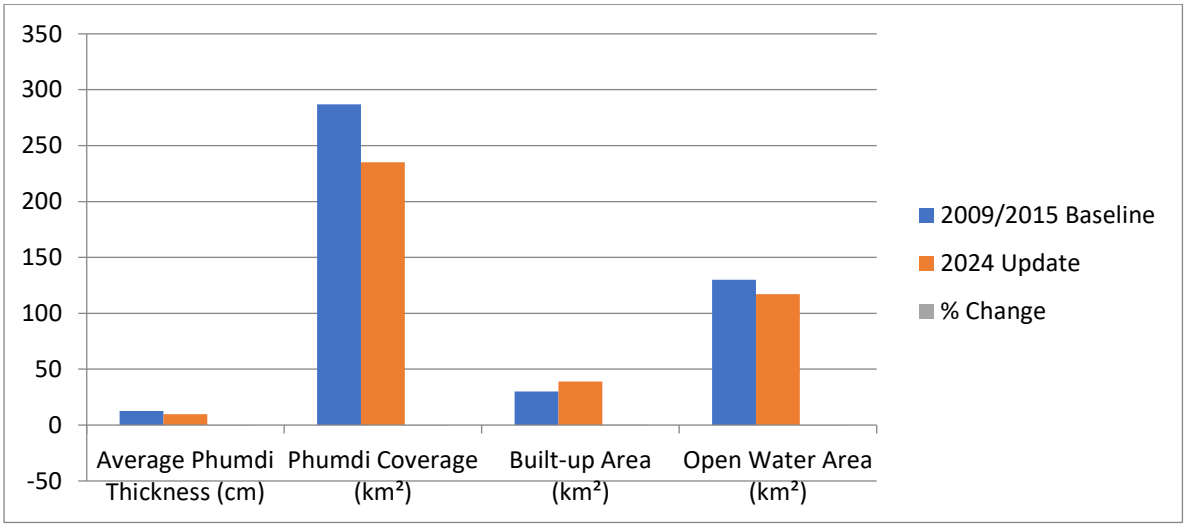

Chart 6 : Changes in Loktak Lake Phumdi Thickness, Coverage, and Land Use (2009–2024)

Avifaunal surveys at 20 fixed-point stations documented a worrying decline in species richness and abundance relative to previous decades. Total bird counts dropped from approximately 20,000 in 2000 to fewer than 12,000 individuals in 2024, with the Sangai deer population fluctuating between 120 and 260 individuals depending on survey methodology. Species diversity was notably lower in tourist-intensive areas, especially around Keibul Lamjao National Park's periphery, suggesting disturbance from boat

traffic, noise, and habitat encroachment. Dawn and dusk counts revealed diminished nesting activity and increased flight initiation distances, indicating heightened stress levels.The presence of invasive species, such as water hyacinth, was pervasive across floating mats and shorelines, competing with native macrophytes and altering habitat structure. The spread of invasive flora is exacerbated by nutrient enrichment, which also impacts fish populations and overall aquatic food web dynamics. GIS-based land cover classification from satellite images (2015–2023) quantifies pronounced anthropogenic pressures on Loktak Lake's socio-ecological system. Phumdi coverage declined by 18%, open water zones contracted by 10%, and built-up areas expanded by 30%, primarily concentrated in northern and southern lake margins near settlements and tourism hubs.This spatial pattern aligns with increased construction of resorts, motorboat jetties, roads, and associated infrastructure. Such encroachment fragments wetland habitats and disrupts ecological corridors critical for species movement and nutrient cycling. The loss of athaphum—seasonal floating vegetation beds vital for fish spawning and nutrient retention—by 14.3% further compromises ecological functionality. These trends underscore the complex trade-offs between regional economic aspirations and environmental sustainability.

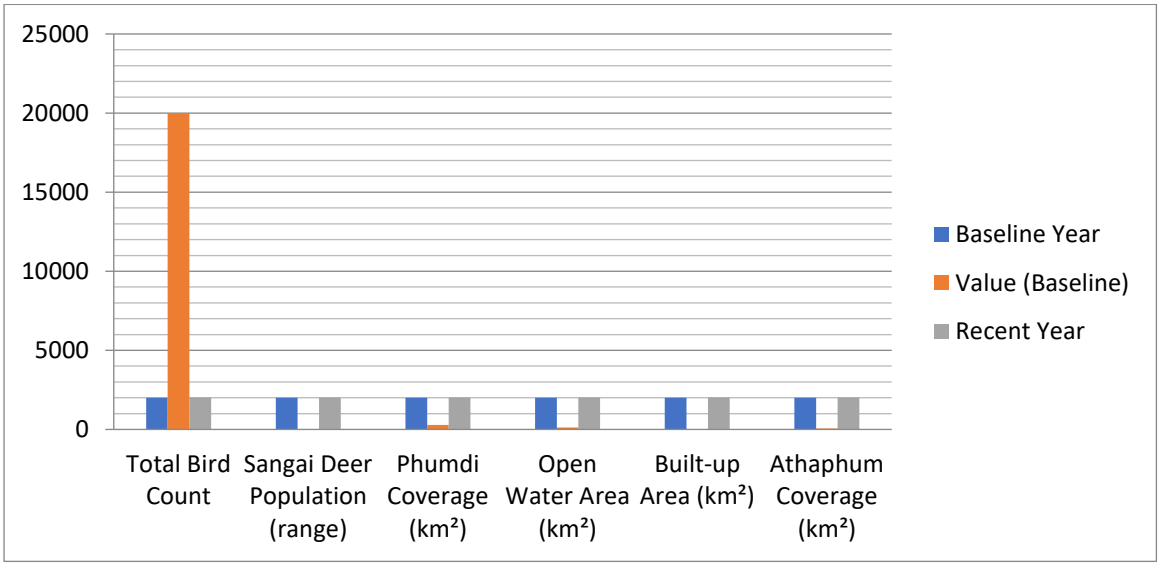

Chart 7 : Ecological Changes in Loktak Lake: Bird Populations, Phumdi, and Land Use (2000–2024)

Stakeholder interviews and focus group discussions revealed nuanced perceptions of tourism's dualistic role. Traditional fisherfolk, particularly from the indigenous Meitei community, expressed concerns about reduced fish catches, restricted access to fishing grounds, and cultural dislocation tied to phumdi degradation and tourism expansion. Fish catch surveys documented a 40% decline over two decades, reflecting both ecological changes and regulatory restrictions related to conservation zones and tourism activities. Women participants highlighted the loss of traditional roles in managing floating biomass and subsistence activities, exacerbating gendered economic vulnerabilities. Conversely, community-based ecotourism operators reported positive livelihood diversification through floating homestays, guided cultural tours, and handicraft sales. The Loktak Lake Tourism Development Cooperative Society's monthly revenue distributions, albeit modest, have enhanced economic resilience and fostered conservation awareness among local residents. Nevertheless, grassroots initiatives face significant constraints, including limited funding, inadequate training, regulatory ambiguity, and competition from larger, government-backed tourism projects perceived as top-down and exclusionary. Policy review highlights a fragmented institutional landscape governing Loktak Lake. The Loktak Development Authority (LDA), multiple state departments, and statutory bodies operate with overlapping and sometimes conflicting mandates, undermining coherent ecological management. Critiques emphasize the LDA's engineering-centric focus, which insufficiently incorporates ecological expertise or community participation. The Loktak Protection Act (2006) and Wetlands Rules (2017) establish important conservation frameworks but have been inconsistently enforced, leading to unresolved tensions between development ambitions and ecological protection.The Integrated Management Plan (IMP, 2023) offers promising adaptive governance tools, including seasonal water-level modulation of the Ithai Barrage to

support phumdi regeneration, pilot sewage treatment projects, and community-managed fisheries aligned with FAO guidelines. However, funding shortages and bureaucratic inertia have stalled effective implementation.

Empirical evidence underscores the necessity of inclusive, polycentric governance to sustain Loktak Lake's ecological and socio-economic resilience. Local stakeholders' exclusion from decision-making processes fuels mistrust and social conflict, undermining conservation outcomes. Community-led ecotourism models exemplify the potential for collaborative governance when supported by institutional recognition and resource allocation. Participatory mechanisms, such as co-management councils and benefit-sharing frameworks, are essential to harmonize conservation priorities with livelihood needs. Adaptive governance frameworks that incorporate regular ecological monitoring, graduated sanctions for non-compliance, and conflict resolution mechanisms are crucial for navigating competing interests and dynamic environmental conditions.Tourism emerges as a double-edged sword in Loktak Lake's socio-ecological matrix. While it presents opportunities for economic diversification, awareness raising, and cultural preservation, poorly regulated infrastructure projects exacerbate habitat degradation, social displacement, and cultural erosion. Top-down tourism projects financed under national schemes have frequently prioritized rapid infrastructure development over ecological safeguards or community consultation. This has led to habitat fragmentation, water pollution from increased boat traffic, and the marginalization of indigenous fisherfolk. By contrast, community-based ecotourism initiatives emphasize low-impact practices, cultural authenticity, and environmental stewardship. Floating homestays and guided eco-tours foster direct economic benefits for locals and promote conservation education among visitors. These grassroots efforts demonstrate scalable models that balance ecological integrity with inclusive development.

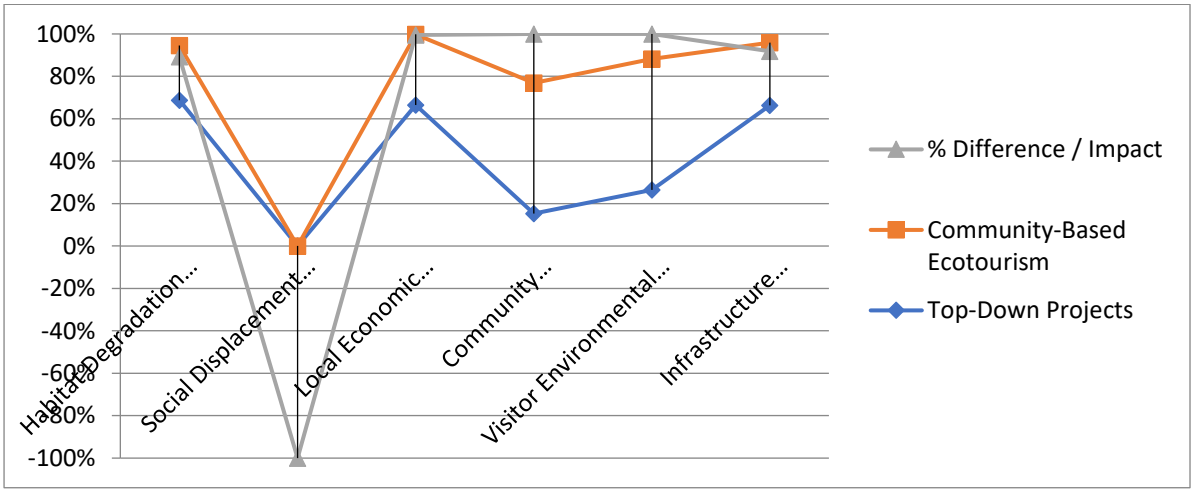

Chart 8 : Impact of Tourism Governance Models on Loktak Lake (2023–2025)

To harness tourism's potential as a catalyst for sustainable development around Loktak Lake, several interconnected interventions are essential. First, adaptive hydrological management must be prioritized, specifically through operational reforms of the Ithai Barrage. Restoring the lake's natural water-level fluctuations is critical to promoting phumdi regeneration, which underpins the lake's unique ecological functions and biodiversity. Without such measures, habitat degradation will continue to undermine both conservation and tourism viability. Second, fostering inclusive participatory frameworks is necessary to strengthen polycentric governance. Institutionalizing meaningful community representation in decision-making processes, alongside targeted capacity-building programs, will empower local stakeholders and ensure their knowledge, needs, and cultural practices are integrated into sustainable tourism planning and management. Third, robust environmental regulation and zoning policies must be implemented and rigorously enforced. This includes controlling the ongoing built-up encroachment and reducing pollution inputs through land-use zoning complemented by continuous ecological monitoring systems to track changes and inform responsive management. Fourth, support for community-based ecotourism initiatives is crucial. Providing financial resources, technical assistance, and marketing platforms will enable grassroots tourism enterprises to thrive, while equitable benefit-sharing mechanisms will promote social

equity and community resilience. Lastly, integrated policy coordination across sectors is indispensable. Aligning national tourism schemes such as Swadesh Darshan and SASCI with wetland conservation objectives through enhanced inter-agency collaboration will foster coherent strategies that balance development with ecological integrity. Together, these recommendations provide a holistic governance framework to advance sustainable tourism that supports both Loktak Lake's socio-ecological health and the well-being of its dependent communities. Loktak Lake's trajectory illustrates the intricate linkages between ecological integrity, cultural heritage, and economic livelihoods. The degradation of phumdis, declining water quality, and biodiversity losses underscore urgent ecological vulnerabilities that threaten the lake's resilience. Simultaneously, socio-economic pressures—manifested in reduced fisheries productivity, community dislocation, and contested tourism development—highlight the need for holistic governance approaches that balance conservation with human well-being.

CONCLUSION AND SCOPE FOR FUTURE RESEARCH

Loktak Lake represents a dynamic socio-ecological system where environmental sustainability and economic livelihoods are deeply interwoven. This study has highlighted the dual challenges and opportunities posed by tourism in the region. While tourism has emerged as a potential catalyst for economic diversification and environmental awareness, its current trajectory, particularly in the form of top-down, infrastructure-heavy development, has amplified ecological pressures and socio-cultural dislocations. Findings from ecological assessments—such as declining water quality, shrinking phumdi coverage, and loss of avifaunal diversity—clearly demonstrate that the lake's ecological resilience is under threat. Concurrent socio-economic analyses further reveal rising community discontent stemming from exclusionary governance, displacement, and weakening of traditional livelihoods. The importance of phumdis as ecological keystones cannot be overstated. Their degradation—exacerbated by the constant water levels maintained by the Ithai Barrage—disrupts nutrient cycles, diminishes biodiversity, and undermines the integrity of aquatic habitats. Combined with pollution from untreated inflows like the Nambul River and unchecked expansion of built-up areas, the lake's natural regenerative capacity is being severely compromised. Moreover, the Sangai deer, a flagship species emblematic of the lake's unique ecology, continues to face habitat encroachment and disturbances linked to tourism. Despite these challenges, the study has identified promising avenues for sustainable tourism through community-led ecotourism models. Locally managed homestays, eco-guided tours, and cultural events not only provide income alternatives but also foster conservation ethics and cultural pride. However, such grassroots initiatives require institutional support, policy recognition, and financial investment to scale and sustain. Adaptive governance, grounded in polycentric and participatory frameworks, emerges as a critical pillar for reconciling development with ecological stewardship. Mechanisms like co-management councils, ecological zoning, and integrated policy coordination offer a pathway for inclusive and resilient wetland governance. Looking ahead, future research can further explore several dimensions. First, longitudinal ecological monitoring, particularly of phumdi regeneration cycles, water quality parameters, and faunal populations, would provide valuable insights into long-term ecosystem health and the effectiveness of adaptive interventions. The integration of high-resolution satellite data with machine learning could enhance land-cover change analysis and help forecast future scenarios under different management regimes. Socio-economic studies focusing on gender dimensions, youth engagement, and indigenous knowledge systems in tourism and wetland management could deepen our understanding of equitable development. How tourism affects intra-community relations, cultural practices, and access to resources remains an area requiring deeper qualitative investigation.Comparative research with other Ramsar sites or wetland ecotourism models in South and Southeast Asia may yield transferable lessons and adaptive strategies applicable to Loktak. This could include examining legal frameworks, financial instruments (e.g., green funds, PES schemes), and tourism certification systems that prioritize sustainability and local ownership. Policy research should focus on the operationalization of integrated lake basin management approaches. Understanding the institutional bottlenecks, funding limitations, and cross-jurisdictional conflicts impeding the Loktak Integrated Management Plan's implementation will be critical to aligning tourism development with wetland conservation. In sum, safeguarding Loktak Lake demands a holistic, multi-disciplinary approach that bridges ecological science, social equity, and policy innovation. Sustainable tourism, when strategically guided and inclusively governed, holds the potential to revitalize both the lake's ecology and the livelihoods of those who depend on it.

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