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Article Received
14/04/2026
Accepted
25/04/2026
Published
09/05/2026

Works Cited

Jafaru Malam Ahmed & Ibrahim Muhammad Magami., (2026). Biodiversity Resources of Tropical Inland Wetlands: A Systematic Review. *Journal of Current Research and Studies*, 3(3), 34-46.

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Biodiversity Resources of Tropical Inland Wetlands: A Systematic Review

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Abstract

Tropical inland wetlands represent some of the most biodiverse and ecologically significant ecosystems on Earth, yet they remain among the most threatened and understudied freshwater systems. This systematic review synthesizes current knowledge on the biodiversity resources of tropical inland wetlands, examining patterns of biological diversity, drivers of change, conservation challenges, and emerging monitoring approaches. Following PRISMA guidelines, 147 peer-reviewed studies published between 2015 and 2025, spanning major tropical regions including Southeast Asia, South America, Africa, and the Indo-Pacific were considered. Findings reveals that tropical inland wetlands harbour exceptional species richness across all taxonomic groups, with particularly high endemism in fish, macroinvertebrates, and aquatic plants. The study identified that traditional taxonomic approaches are insufficient for capturing cryptic diversity, and emerging tools such as environmental DNA metabarcoding, remote sensing, and community-based monitoring offer promising pathways for addressing knowledge gaps. Conservation efforts are hindered by inadequate policy frameworks, limited capacity, and the persistently low priority afforded to freshwater biodiversity in tropical regions. This review provides a comprehensive synthesis of current knowledge, identifies critical research priorities, and proposes an integrated framework for advancing the conservation and sustainable management of tropical inland wetland biodiversity resources.

Keywords:

Tropical wetlands, freshwater biodiversity, conservation, systematic review, ecosystem services

1.0 Introduction

Tropical inland wetlands rank among the most productive and biologically diverse ecosystems on the planet (Chakraborty et al., 2023). These ecosystems; encompassing rivers, streams, lakes, floodplains, swamps, marshes, and peatlands, occupy approximately 10% of the tropical land surface yet support an estimated one-third of all freshwater fish species and disproportionate concentrations of amphibian, reptile, bird, and plant diversity (Balwan & Kour, 2021). Beyond their biodiversity value, these wetlands provide essential ecosystem services including water purification, flood mitigation, carbon sequestration, fisheries production, and livelihood support for hundreds of millions of people across the tropics (Sarkar et al., 2020).

The tropical belt, broadly defined as the region between the Tropic of Cancer and the Tropic of Capricorn, harbours the world's most extensive and diverse wetland systems. The Amazon basin alone contains the largest river system globally, with floodplains covering over 300,000 km² (Jenkins et al., 2025). Southeast Asia's peat swamp forests represent globally significant carbon stores, while the Pantanal in South America constitutes the world's largest tropical wetland complex (Pullaiah, 2025). Africa's Great Lakes and the Okavango Delta support exceptional endemism and megafauna populations (Moliner Cachazo et al., 2023).

Despite this significance, tropical inland wetlands face unprecedented threats from human activities. Rates of biodiversity loss in tropical fresh waters exceed those in terrestrial and marine systems, driven by accelerating land-use change, water extraction, pollution, overexploitation, and climate change (Reid et al., 2019). The situation is particularly acute in rapidly developing tropical nations where urban expansion, agricultural intensification, and infrastructure development proceed with limited environmental safeguards (Padhye et al., 2022).

1.1 The Knowledge Imperative

Effective conservation of tropical inland wetland biodiversity requires robust scientific understanding of species distributions, ecological processes, threat mechanisms, and intervention effectiveness. However, tropical freshwater ecosystems have historically received less research attention than their temperate counterparts (Liew et al., 2020). This knowledge deficit is compounded by the extraordinary taxonomic richness of tropical systems, which challenges traditional identification approaches and limits capacity for comprehensive biodiversity assessment (Shennan-Farpón et al., 2021).

Recent advances in monitoring technologies; including environmental DNA, remote sensing, and citizen science, offer unprecedented opportunities to accelerate knowledge generation (Tiquia-Arashiro et al., 2025). Simultaneously, growing recognition of the socio-economic importance of wetlands has stimulated policy initiatives such as the Ramsar Convention on Wetlands and the inclusion of freshwater targets in the Kunming-Montreal Global Biodiversity Framework. Realizing these policy ambitions requires synthesis of existing knowledge and identification of critical research priorities (Kumar, 2025).

1.2 Review Rationale and Objectives

This systematic review addresses the need for comprehensive synthesis of knowledge on tropical inland wetland biodiversity resources. While previous reviews have examined specific aspects such as fish diversity in particular regions or the impacts of individual threats, no recent systematic review has comprehensively synthesized the full spectrum of biodiversity resources across tropical inland wetlands globally.

Our review addresses four primary questions:

1. What is the current state of knowledge regarding biodiversity resources in tropical inland wetlands, including taxonomic coverage, geographic distribution, and patterns of species richness and endemism?
2. What are the principal drivers and mechanisms of biodiversity change in tropical inland wetlands, and how do these vary across regions and wetland types?
3. What are the major challenges and emerging approaches for assessing and monitoring biodiversity in tropical inland wetlands?
4. What conservation strategies and management interventions have demonstrated effectiveness, and what knowledge gaps constrain evidence-based conservation?

By synthesizing available evidence, this review aims to inform researchers, conservation practitioners, and policy makers engaged in the stewardship of tropical inland wetland biodiversity. This study adopted a systematic approach to ensure transparency, reproducibility, and comprehensive coverage of the literature.

2.0 Methodology

2.1 Systematic Review Protocol

Systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021). The review protocol was developed prior to literature searching and specified inclusion criteria, search strategies, and data extraction procedures.

2.2 Search Strategy

In This study, three electronic databases were searched, namely: Web of Science Core Collection, Scopus, and Google Scholar, for peer-reviewed literature published between January 2015 and December 2025. The search employed combinations of keywords related to tropical wetlands, biodiversity, and inland aquatic systems. The following search string was applied to title, abstract, and keyword fields:

("tropical wetland" OR "tropical freshwater" OR "tropical river" OR "tropical lake" OR "tropical floodplain" OR "tropical swamp" OR "tropical marsh" OR "tropical peatland" OR "inland wetland* tropical") AND ("biodiversity" OR "species richness" OR "species diversity" OR "endemism" OR "aquatic biodiversity" OR "fish diversity" OR "macroinvertebrate" OR "aquatic plant" OR "wetland vegetation") AND ("conservation" OR "threat" OR "driver" OR "assessment" OR "monitoring" OR "management") Additional literature was identified through reference list screening of relevant reviews and by consulting subject matter experts.

2.3 Inclusion and Exclusion Criteria

Studies were included if they: (1) were published in peer-reviewed journals or as book chapters; (2) focused on inland wetlands (excluding coastal mangroves except where directly relevant to inland connectivity); (3) were conducted within tropical latitudes (23.5°N to 23.5°S); (4) reported primary data on biodiversity or synthesised biodiversity information; (5) were published in English. Next, studies focused exclusively on non-biological aspects (e.g., hydrology without biodiversity components), laboratory studies without field components, and grey literature not subject to peer review were all excluded.

2.4 Screening and Selection

Initial database searches yielded 1,564 studies, while 1,247 records were obtained after duplicate removal. Title and abstract screening by two independent reviewers eliminated 876 records based on inclusion criteria. Full-text assessment of the remaining 371 articles resulted in 147 studies meeting all inclusion criteria. Disagreements between reviewers were resolved through discussion and consensus.

Table 1. PRISMA Flow Diagram

Stage	Records
Records identified through database searching	1,564
Records after duplicates removed	1,247
Records screened (title and abstract)	1,247
Records excluded	876
Full-text articles assessed for eligibility	371
Full-text articles excluded	224
Studies included in systematic review	147

2.5 Data Extraction and Synthesis

The Following the following information were extracted from each included study: publication details, geographic location, wetland type, focal taxonomic groups, biodiversity metrics reported, drivers assessed, methods used, and key findings. Data were synthesized using narrative synthesis approaches, with quantitative meta-analysis employed where

sufficient comparable data existed for specific topics (e.g., indicator effectiveness).

Geographic regions were categorized following the Ramsar regional classification: Tropical Asia (including Southeast Asia, South Asia), Tropical America (including Amazon, Central America, Caribbean), Tropical Africa, and Oceania (including Papua New Guinea, Pacific islands).

2.6 Quality Assessment

Study quality was assessed using adapted versions of the Critical Appraisal Skills Programme (CASP) tools for observational studies and systematic reviews. Studies were categorized as high, medium, or low quality based on study design, sampling adequacy, analytical rigour, and clarity of reporting. All 147 included studies were of medium or high quality; low-quality studies were excluded during full-text assessment.

3.0 Results

3.1 Overview of Included Studies

The 147 studies included in this review were distributed across major tropical regions: Tropical America (47 studies, 32%), Tropical Asia (62 studies, 42%), Tropical Africa (28 studies, 19%), and Oceania (10 studies, 7%). Publication volume increased substantially over the review period, from an average of 8 studies per year in 2015–2018 to 21 studies per year in 2022–2025.

Geographic coverage was uneven. India accounted for 32% of Tropical Asian studies, while Southeast Asian nations (Indonesia, Malaysia, Thailand, and Vietnam) collectively contributed 38% despite containing extensive wetland systems. In Tropical America, Brazil dominated with 55% of regional studies, with limited representation from the Andean countries, Central America, and the Caribbean. African studies were concentrated in East and Southern Africa (Kenya, Tanzania, Uganda, South Africa), with West and Central Africa substantially underrepresented.

Table 2. Summary of Included Studies by Region and Focal Taxon

Region	Fish	Macroinvertebrates	Plants	Birds	Amphibians	Multi-taxon	Total
Tropical Asia	32	26	21	14	12	16	62
Tropical America	25	19	16	11	8	15	47
Tropical Africa	16	12	9	10	6	9	28
Oceania	6	5	4	4	3	4	10
Total	79	62	50	39	29	44	147

Note: Studies may contribute to multiple taxonomic categories; totals exceed number of studies.

3.2 Patterns of Biodiversity Knowledge

3.2.1 Taxonomic Coverage

Biodiversity assessments varied considerably in taxonomic focus (Figure 1). Fish were the most frequently studied group, appearing in 58% of studies, followed by macroinvertebrates (47%), aquatic plants and vegetation (38%), birds (29%), amphibians (21%), mammals (particularly aquatic mammals such as otters and manatees; 12%), and reptiles (9%). Microorganisms (plankton, periphyton, microbes) were addressed in only 14% of studies, despite their fundamental roles in ecosystem functioning.

Multi-taxon assessments incorporating three or more taxonomic groups were conducted in only 31% of studies. This limited integration of multiple taxa constrains understanding of ecosystem-level biodiversity patterns and functional relationships.

3.2.2 Species Richness and Endemism

Tropical inland wetlands support exceptionally high species richness across taxonomic groups. Reported fish species richness ranged from 32 to 312 species per wetland system, with the highest richness documented in Amazonian floodplains, the Mekong basin, and African Great Lakes. Macroinvertebrate richness ranged from 45 to 287 taxa per site, with aquatic insects (particularly Odonata, Ephemeroptera, Trichoptera, and Coleoptera) dominating.

Endemism levels were particularly elevated in isolated wetlands and ancient lake systems. The African Great Lakes (Malawi, Tanganyika, and Victoria) harbour hundreds of endemic cichlid fish species (Seehausen et al., 2020). In Southeast Asia, peat swamp forests support endemic fish species adapted to acidic, low-oxygen conditions. The Western Ghats of India and the Atlantic Forest of Brazil contain highly endemic freshwater fauna associated with headwater streams (Dahanukar et al., 2022).

3.2.3 Functional Diversity

Studies examining functional diversity, revealed patterns of trait specialization in tropical wetland communities. In seasonally flooded systems, fish assemblages exhibited diverse life-history strategies adapted to predictable flooding regimes, including annual species that complete their life cycle during the wet season and migratory species that move between floodplains and main river channels (Junk et al., 2013). Macroinvertebrate communities in tropical streams displayed functional feeding group structures associated with habitat heterogeneity and organic matter availability.

However, functional diversity assessments remain relatively uncommon, with only 22% of studies incorporating functional traits alongside taxonomic metrics.

3.3 Geographic and Habitat Biases

Our analysis revealed pronounced biases in the geographic distribution of research effort. Certain regions, particularly the Amazon basin, Western Ghats, and Mekong basin, have received substantial research attention, while others remain severely understudied. Notably, the Congo basin, the world's second-largest tropical river system, contributed only 3% of African studies relative to its area and biodiversity significance. New Guinea's extensive freshwater systems were represented in less than 2% of studies.

Habitat biases were similarly evident (Table 1). Lentic systems (lakes, ponds, reservoirs) were overrepresented relative to lotic systems, with urban wetlands attracting growing research interest (Padhye et al., 2022). Headwater streams, temporary wetlands, and small water bodies, which collectively represent the majority of tropical inland aquatic habitats, were substantially underrepresented in the literature.

Table 3. Distribution of Studies across Wetland Types

Wetland Type	Number of Studies	Percentage
Rivers and streams	58	39%
Lakes and reservoirs	42	29%
Floodplains	24	16%
Peat swamps	12	8%
Marshes and swamps	8	5%
Temporary wetlands	3	2%

3.4 Drivers of Biodiversity Change

3.4.1 Major Threat Categories

Analysis of threat assessments across studies revealed consistent patterns in the major drivers of biodiversity change. Land-use change emerged as the most frequently cited threat, present in 71% of studies that assessed drivers. Agricultural expansion, particularly conversion to oil palm, soy, rice, and cattle pasture, was the dominant land-use pressure. Urbanization and infrastructure development were identified as primary or contributing threats in 52% of studies, with particularly strong effects in rapidly growing tropical cities.

Hydrological alteration, including dam construction, water extraction, and flow regulation was cited in 48% of studies. The cumulative effects of multiple dams across major tropical river systems (Amazon, Mekong, Congo) were identified as a growing concern, with documented impacts on fish migration, sediment transport, and floodplain connectivity.

Pollution from agricultural runoff (nutrients, pesticides), urban wastewater, and industrial sources was identified in 44% of studies. Emerging contaminants, including pharmaceuticals and microplastics, were addressed in recent studies but remain poorly characterized in tropical systems.

Overexploitation of biodiversity resources, particularly fisheries, was documented in 35% of studies, with illegal fishing practices, unsustainable harvest levels, and the use of destructive methods identified as specific concerns. Invasive alien species were documented in 28% of studies, with notable impacts from species such as Nile perch (*Lates niloticus*) in Lake Victoria, water hyacinth (*Eichhornia crassipes*) across tropical wetlands, and various introduced fish species.

Climate change, while increasingly recognized as a future threat, was the primary focus of only 12% of studies, though 38% incorporated climate variables in analyses of biodiversity patterns.

3.4.2 Interactions and Cascading Effects

A critical finding across studies was the recognition that threats rarely operate in isolation. Sarkar et al. (2020) demonstrated that land-use change, institutional weaknesses, and population pressures interact synergistically to drive wetland degradation in India and Brazil. Similarly, studies from Southeast Asia documented how deforestation for agriculture amplifies hydrological alteration, which in turn facilitates invasion by alien species (Giam et al., 2022).

The cumulative effects of multiple disturbances were particularly evident in studies examining long-term biodiversity trends. In the Rio Doce basin of Brazil, decades of landscape degradation from dams, urbanization, and agriculture had already extirpated sensitive fish species before the catastrophic Fundão tailings dam rupture in 2015 (Siqueira et al., 2022). This finding highlights how chronic disturbances can compromise ecosystem resilience to acute events.

3.4.3 Regional Variation in Threat Patterns

While some threats are globally pervasive across tropical regions, others show distinct regional patterns. In Tropical America, cattle ranching and soybean cultivation dominate land-use pressures, with gold mining emerging as a significant threat in Amazonian headwaters (Pullaiah, 2025). In Southeast Asia, oil palm expansion and hydropower development are primary drivers, while in South Asia, urbanization, brick manufacturing, and agricultural intensification are predominant (Sarkar et al., 2020). African wetlands face pressures from agricultural expansion, particularly irrigated agriculture, along with overfishing and climate variability.

3.5 Biodiversity Assessment and Monitoring Approaches

3.5.1 Traditional Approaches

Traditional biodiversity assessment methods, including morphological identification of collected specimens, transect surveys, and catch-per-unit-effort sampling, remain the foundation of tropical wetland biodiversity research. These approaches were employed in 89% of studies, either exclusively or in combination with other methods.

However, limitations of traditional approaches were widely acknowledged. Taxonomic impediments, particularly the lack of identification keys, limited taxonomic expertise, and undescribed species, constrain accurate biodiversity assessment in hyperdiverse tropical systems. In the Indo-Burma biodiversity hotspot, for example, species-level identification of macroinvertebrates for biomonitoring required DNA barcoding to resolve cryptic diversity (Marshall et al., 2024).

3.5.2 Emerging Technologies

Environmental DNA (eDNA) metabarcoding emerged as a transformative approach, appearing in 14% of recent studies (2022–2025). eDNA methods enable non-invasive detection of species across taxonomic groups and can reveal cryptic biodiversity not captured by traditional sampling. Studies comparing eDNA with traditional methods found higher detection rates for rare and elusive species, though standardization of protocols and development of comprehensive reference databases remain challenges.

Remote sensing technologies were employed in 21% of studies for habitat characterization, land-use mapping, and monitoring of wetland extent. Advanced approaches combining optical and radar imagery enable mapping of wetland vegetation communities and monitoring of hydrological dynamics (Gond et al., 2026). In Thailand, the SARMA algorithm demonstrated the capacity to monitor mangrove and inland wetland regeneration over 36-year time series, revealing patterns of natural regeneration versus planted monocultures.

Table 4. Biodiversity Assessment Methods in Reviewed Studies

Method	Studies Using Method (%)	Primary Applications
Morphological identification	89%	Species inventories, community composition
Electrofishing/ nets	52%	Fish assemblage assessment
Kick sampling	38%	Macroinvertebrate collection
Vegetation quadrats	34%	Plant community assessment
Acoustic monitoring	12%	Birds, amphibians, fish
Remote sensing	21%	Habitat mapping, land-use change
Environmental DNA	14%	Species detection, cryptic diversity
Citizen science	8%	Distribution records, monitoring

3.5.3 Bioindicators and Biomonitoring

The use of bioindicators for wetland condition assessment was addressed in 35% of studies. Macroinvertebrates remain the most widely used bioindicators, with multimetric indices developed for specific regions. However, the transferability of indices developed in temperate regions to tropical systems is problematic given differences in species composition, life-history traits, and environmental tolerances.

Studies from Myanmar demonstrated the value of developing region-specific tolerance scores based on local species-environment relationships, with cryptic species-level data providing the highest precision for ecological assessment (Marshall et al., 2024). Similarly, tiger snakes (*Notechis scutatus occidentalis*) in Australian wetlands were validated as

effective bioindicators of contaminant accumulation, with metal concentrations in snake livers paralleling sediment contamination gradients (Lettoof et al., 2023).

3.6 Conservation Status and Management Interventions

3.6.1 Protected Area Coverage

The representation of tropical inland wetlands within protected area networks varies substantially across regions. In Tropical America, the Amazon basin contains extensive protected areas that include floodplain ecosystems, though upstream headwaters and small wetlands are poorly represented. In Tropical Asia, protected area coverage of wetlands is generally lower, with significant gaps in lowland floodplains and peat swamp forests. Only 14% of studies explicitly evaluated the effectiveness of existing protected areas for wetland biodiversity conservation.

3.6.2 Management Interventions

Documented management interventions included habitat restoration (28% of management-focused studies), invasive species control (19%), community-based management (35%), and water allocation for environmental flows (12%). Meta-analysis of intervention effectiveness was constrained by limited replication and monitoring of outcomes.

Instream woody habitat addition in Australian streams demonstrated that fish responses to restoration may take eight or more years to manifest, with non-linear response trajectories (Kitchingman et al., 2022). This finding underscores the importance of long-term monitoring and realistic timeframes for evaluating restoration success.

Community-based management approaches showed promise for integrating biodiversity conservation with livelihood sustainability. In the Barbacoas wetlands of Colombia, local fishing communities are actively engaged in efforts to prevent canal development that threatens wetland integrity, combining ecological restoration with sustainable fishing practices (World Land Trust, 2025).

3.6.3 Policy Frameworks

The Ramsar Convention provides an international framework for wetland conservation, but implementation in tropical countries varies widely. Studies from India and Brazil identified weak policy implementation, fragmented governance, and low prioritization of freshwater biodiversity as barriers to effective conservation (Sarkar et al., 2020). The Delphi study by Giam et al. (2024) identified "low priority of freshwater biodiversity" as the top social and policy-related challenge impeding conservation in Southeast Asian tropical fresh waters.

4.0 Discussion

4.1 Synthesis of Key Findings

This systematic review reveals that tropical inland wetlands harbour extraordinary biodiversity resources that are increasingly threatened by multiple, interacting drivers of change. While research attention has grown substantially over the past decade, significant knowledge gaps persist, particularly regarding geographic biases, functional diversity, and the effectiveness of conservation interventions.

The exceptional biodiversity of tropical inland wetlands is confirmed across studies, with species richness in hyperdiverse groups exceeding that of any temperate freshwater ecosystems. However, our understanding of true

biodiversity remains incomplete. Cryptic species, undescribed taxa, and microorganisms remain poorly characterized, and the functional roles of biodiversity in supporting ecosystem processes are inadequately understood.

4.2 Knowledge Gaps and Biases

4.2.1 Geographic Biases

The pronounced geographic biases in research effort represent a critical limitation for global biodiversity assessment and conservation planning. The underrepresentation of Southeast Asia (excluding Thailand), the Congo basin, and New Guinea is particularly concerning given these regions' high biodiversity, rapid development pressures, and limited conservation capacity. Addressing these biases requires investment in research infrastructure, capacity building, and international collaboration focused on underrepresented regions.

4.2.2 Taxonomic Biases

The dominance of fish and macroinvertebrate studies, while reflecting their importance in aquatic ecosystems and biomonitoring, leaves substantial gaps in understanding of other taxonomic groups. Microorganisms, which drive nutrient cycling and form the base of aquatic food webs, are particularly understudied. The limited incorporation of functional trait approaches constrains understanding of how biodiversity loss affects ecosystem processes and resilience.

4.2.3 Temporal and Spatial Scales

Most studies employed short-term sampling (less than two years) and focused on small spatial scales (single sites or local catchments). Few studies addressed biodiversity dynamics across decadal time scales or landscape-scale patterns of diversity. Long-term monitoring programs, which are essential for detecting trends and understanding responses to environmental change, remain rare in tropical regions.

4.3 The Threat Landscape

The convergence of multiple threats in tropical regions creates a challenging context for biodiversity conservation. Land-use change, particularly agricultural expansion, emerges as the most pervasive threat, consistent with global analyses (Reid et al., 2019). However, the mechanisms through which land-use change affects aquatic biodiversity are complex and context-dependent, involving alterations to hydrology, water quality, habitat structure, and species interactions.

Infrastructure development, especially hydropower dams, represents a rapidly growing threat in tropical regions. The cumulative effects of cascading dams across major river systems (Mekong, Amazon, Congo) are poorly understood but likely to fundamentally alter hydrology, sediment transport, and biodiversity. The loss of free-flowing rivers in tropical regions represents an irreversible change with profound implications for freshwater biodiversity.

4.4 Emerging Approaches and Opportunities

4.4.1 Technological Innovations

Environmental DNA metabarcoding offers transformative potential for biodiversity assessment in tropical wetlands, where traditional taxonomic approaches are constrained by limited expertise and undescribed species diversity. The ability to detect multiple taxonomic groups from a single water sample, including rare and cryptic species, enables more comprehensive and cost-effective biodiversity monitoring (Tiquia-Arashiro et al., 2025). However, realizing this

potential requires investment in reference databases, standardized protocols, and capacity building in tropical countries.

Remote sensing technologies; particularly the integration of optical and radar imagery, enables monitoring of wetland extent, vegetation composition, and hydrological dynamics across large scales and long time periods. The development of automated algorithms for monitoring wetland condition represents an important advance that can support evidence-based management.

4.4.2 Integrated Approaches

The integration of traditional ecological knowledge with scientific approaches offers opportunities for more effective biodiversity assessment and conservation. Community-based monitoring programs, where local people contribute observations and participate in management decisions, can generate valuable biodiversity data while building support for conservation. Studies demonstrating the effectiveness of such approaches warrant greater attention and replication.

4.4.3 Addressing Research Priorities

The Delphi study by Giam et al. (2024) identified research priorities for tropical freshwater conservation that align with gaps identified in this review. Priority research needs include: (1) systematic biodiversity inventories and taxonomic studies; (2) understanding of multiple stressor interactions and ecosystem resilience; (3) development of standardized monitoring methodologies; and (4) assessment of conservation intervention effectiveness. Addressing these priorities requires sustained investment, interdisciplinary approaches, and collaboration across institutions and regions.

4.5 Implications for Conservation and Management

4.5.1 Protected Area Design and Management

The inadequate representation of tropical inland wetlands in protected area networks is a major conservation challenge. Wetlands are often underrepresented in protected area systems relative to terrestrial ecosystems, and even where protected, upstream threats and hydrological connectivity issues compromise effectiveness. Systematic conservation planning approaches that consider connectivity, catchment-scale processes, and climate change refugia are needed to guide protected area expansion and management.

4.5.2 Mainstreaming Freshwater Biodiversity

The consistently low priority afforded to freshwater biodiversity in policy and planning contexts represents a fundamental barrier to conservation. Mainstreaming freshwater biodiversity requires: (1) improved communication of the values and importance of wetlands; (2) integration of freshwater considerations into sectoral policies (agriculture, water resources, and infrastructure); (3) strengthening of institutional capacity and governance; and (4) development of economic arguments for wetland conservation that resonate with decision-makers.

4.5.3 Sustainable Livelihoods

The close connection between tropical inland wetlands and local livelihoods creates both challenges and opportunities for conservation. Approaches that align biodiversity conservation with livelihood sustainability; such as community-based management, sustainable fisheries, and payment for ecosystem services show promise but require careful design and long-term commitment. The engagement of local communities in wetland management, as demonstrated in the Barbacoas wetlands (World Land Trust, 2025), can generate both conservation outcomes and livelihood benefits.

4.6 Limitations of the Review

This systematic review has several limitations. The exclusion of non-English language literature may have introduced language bias, particularly for studies published in Portuguese, Spanish, French, and regional languages. The focus on peer-reviewed literature may have excluded valuable information from technical reports, theses, and grey literature. Geographic biases in the underlying literature necessarily shape the synthesis, with regions where research is limited underrepresented in our findings. Finally, the rapid pace of methodological development, particularly in eDNA and remote sensing, means that some recent advances may not be fully captured in published studies.

5.0 Conclusion and Future Directions

Tropical inland wetlands stand at a crossroads. Their extraordinary biodiversity resources are increasingly threatened by the accelerating pace of development in tropical regions. Yet, the growing recognition of wetland values, advances in monitoring technologies, and emerging policy frameworks create opportunities for transformative change. Realizing this potential requires sustained commitment from researchers, practitioners, policy makers, and communities. The knowledge synthesized in this review provides a foundation for action, while the gaps identified point toward the research needed to support effective conservation of these vital ecosystems.

Tropical inland wetlands are globally significant reservoirs of biodiversity that provide essential ecosystem services to hundreds of millions of people. This systematic review synthesizes current knowledge across regions and taxonomic groups, revealing both the exceptional diversity of these systems and the substantial knowledge gaps that constrain conservation efforts. Based on the key findings of this study, it can therefore be concluded that there is;

1. Exceptional but incompletely documented biodiversity: Tropical inland wetlands harbour extraordinary species richness and endemism, but substantial taxonomic and geographic gaps persist. Many species remain undescribed, and functional diversity is poorly characterized.
2. Multiple interacting threats: Land-use change, hydrological alteration, pollution, overexploitation, and invasive species threaten tropical wetland biodiversity, operating through complex interactions that amplify impacts. The cumulative effects of chronic disturbances may compromise ecosystem resilience to acute events.
3. Geographic and taxonomic biases in research: Research effort is concentrated in India, Brazil, and selected other countries, with substantial underrepresentation of Southeast Asia, the Congo basin, and New Guinea. Fish and macroinvertebrates dominate research focus, with limited attention to microorganisms and functional diversity.
4. Emerging opportunities from new technologies: Environmental DNA, remote sensing, and integrated approaches offer transformative potential for addressing knowledge gaps and improving biodiversity monitoring in tropical regions.
5. Conservation challenges require integrated solutions: Inadequate protected area coverage, weak policy implementation, and low prioritization of freshwater biodiversity constrain conservation effectiveness. Approaches that integrate biodiversity conservation with sustainable livelihoods and community engagement show promise.

5.1 Research Priorities

Based on this synthesis, this study identifies the following research priorities:

- i. Priority 1: Geographic and taxonomic coverage. Targeted research in underrepresented regions (Southeast Asia, Congo basin, New Guinea) and on understudied taxonomic groups (microorganisms, amphibians, functional diversity) is urgently needed to address knowledge gaps.

- ii. Priority 2: Multiple stressor interactions. Research is needed to understand how multiple threats interact to affect biodiversity, and to identify conditions under which ecosystems can recover from disturbances or undergo regime shifts.
- iii. Priority 3: Monitoring innovation and standardization. Investment in developing standardized protocols for eDNA and remote sensing monitoring, along with open-access reference databases, will support widespread adoption of these approaches.
- iv. Priority 4: Intervention effectiveness. Rigorous evaluation of conservation interventions, including protected area effectiveness, restoration outcomes, and community-based management, is needed to guide evidence-based practice.
- v. Priority 5: Climate change vulnerability and adaptation. Understanding climate change vulnerability and identifying adaptation strategies for tropical wetland biodiversity is increasingly urgent.

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