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Wetland Ecosystems of Uttar Pradesh and Uttarakhand: A Comprehensive Review of Avifaunal Richness and Conservation Strategies

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ABSTRACT

Wetland ecosystems are among India's most biologically productive habitats, offering critical ecosystem services and supporting exceptional avifaunal diversity. In northern India, the wetlands of Uttar Pradesh (UP) and Uttarakhand (UK) together form an ecologically interconnected landscape that includes the Gangetic floodplains, terai–bhabar zones, Himalayan foothill wetlands, oxbow lakes, marshes, reservoirs, and high-altitude lake systems. These diverse environments serve as vital breeding, feeding, roosting, and migratory stopover sites for a large proportion of India's bird species, including several threatened and globally important migrants. This review synthesizes current knowledge on avifaunal richness, ecological significance, threats, and conservation needs across major wetland sites in UP and UK. Uttar Pradesh supports an extensive network of riverine and floodplain wetlands associated with the Ganga and Yamuna basins. Important sites such as Nawabganj, Sandi, Sarsai Nawar, Parvati Arga, and Sur Sarovar-many of them Ramsar-listed-host large congregations of migratory birds each winter. Species such as the Sarus Crane, Bar-headed Goose, Northern Shoveler, and numerous waders depend heavily on these habitats. Uttarakhand's wetlands, including the Asan Conservation Reserve, Nainital Lake, Bhimtal, Sattal, and various reservoirs and high-altitude lakes, support rich assemblages of waterbirds, raptors, passerines, and trans-Himalayan migrants. Both states form essential components of the Central Asian Flyway (CAF) by providing habitat connectivity critical for the survival of migratory avifauna. The review highlights ecological factors that regulate bird diversity in these wetlands, including hydrological cycles, vegetation composition, food availability, and human disturbances. Research across both states shows significant species richness and pronounced seasonal variation, reflecting the ecological sensitivity of these wetlands. To address these challenges, the review recommends integrated conservation approaches centred on community participation, habitat restoration, catchment management, and strengthened protected area networks. Enhancing Ramsar Site management, improving hydrological regulation, and adopting modern monitoring tools including satellite tracking, drone-based surveys, and citizen science databases like eBird can greatly support data-driven decision-making. Policy priorities identified include stronger implementation of the Wetland (Conservation and Management) Rules 2017, improved cross-state coordination between UP and UK, and greater support for long-term ecological research and bird monitoring programs.

Key words: *Wetlands, India, Uttar Pradesh, Uttarakhand, Avian Biodiversity.*

Introduction

Wetlands are among the most productive, ecologically significant, and economically valuable ecosystems on the planet, yet they remain one of the most threatened natural resources due to escalating anthropogenic pressures and climate change. Defined as transitional zones between terrestrial and aquatic environments, wetlands are characterized by water saturation, hydric soils, and specialized vegetation adapted to periodically or permanently flooded conditions (Mitsch and Gosselink, 2015). Globally, wetlands encompass a wide range of habitats-including marshes, swamps, peatlands, bogs, mangroves, floodplains, and coastal lagoons-each exhibiting complex biophysical processes and supporting rich biodiversity. Their unique hydrological dynamics, nutrient cycling abilities, and biological productivity make wetlands critical regulators of ecological balance and providers of indispensable ecosystem services.

Wetlands serve as natural sponges that moderate water flow, reduce flood intensity, and recharge groundwater, thereby playing a pivotal role in hydrological regulation (Davidson *et al*., 2018). During periods of high rainfall or extreme weather events, wetlands absorb excess water and gradually release it, reducing the risk of downstream flooding. In arid and semi-arid regions, wetlands contribute significantly to water storage and maintenance of local microclimates. Furthermore, wetland vegetation-comprising reeds, sedges, mangroves, and other moisture-loving species-facilitates sediment stabilization and shoreline protection by reducing erosion and enhancing soil accretion (Barbier *et al.*, 2011). This natural buffering function is especially important in coastal wetlands, where rising sea levels and increased storm frequencies threaten millions of lives and livelihoods.

Another central ecological function of wetlands involves nutrient cycling and water purification. Wetlands are sometimes referred to as the "kidneys of the landscape" because their soils and biota possess a remarkable capacity to filter pollutants, trap sediments, and transform excess nutrients through microbial processes such as denitrification (Vymazal, 2018). Phosphorus retention, heavy metal sequestration, and the degradation of organic pollutants are facilitated by the anaerobic conditions and high biological activity characteristic of wetland ecosystems. These natural purification functions are increasingly being harnessed in the design of constructed wetlands, which are engineered systems used worldwide for wastewater treatment. The integration of wetland-inspired technologies into urban water management exemplifies the growing recognition of wetlands as cost-effective, sustainable, and ecoliterate solutions for improving water quality.

Wetlands are also biodiversity hotspots that support a multitude of plant, animal, and microbial species. They provide critical habitats for migratory birds, amphibians, fish, and invertebrates, many of which rely on wetlands for breeding, feeding, or shelter (Ramsar Convention Secretariat, 2016). Peatlands, for example, store vast amounts of carbon while harboring unique flora such as Sphagnum mosses. Mangrove wetlands, distributed along tropical and subtropical coastlines, sustain diverse fish and crustacean populations while offering nursery grounds essential for commercial fisheries (Alongi, 2008). The intricate interdependence between wetland species and their environment reflects the ecological integrity and evolutionary uniqueness of these habitats, making their conservation vital for maintaining global biodiversity.

Despite their immense ecological value, wetlands are experiencing rapid degradation worldwide. According to global assessments, more than 35% of wetlands have been lost since the 1970s due to agricultural expansion, urbanization, industrial development, and infrastructural encroachment (Darrah *et al*., 2019). Pollution from agricultural runoff, untreated wastewater, and industrial effluents further exacerbates wetland decline. Additionally, climate change poses severe threats to wetland hydrology and species composition through alterations in precipitation patterns, increased evapotranspiration, and sea-level rise. These pressures collectively undermine the resilience of wetlands, jeopardizing the ecosystem services upon which millions of people depend for water security, fisheries, agriculture, and cultural practices.

India is endowed with one of the world's richest and most diverse wetland systems, making it a true geographical haven for biodiversity. Spread across a vast ecological spectrum-from the towering Himalayas to the tropical coasts, from arid desert wetlands to the lush floodplains of the Ganga and Brahmaputra, India's wetlands represent an extraordinary variety of landscapes and biological communities. These ecosystems include rivers, lakes, marshes, lagoons, mangroves, estuaries, coral atolls,

peat lands, floodplains, backwaters, reservoirs, and high-altitude glacial lakes. Such diversity in wetland types arises from India's varied topography, climate gradients, and hydrological processes, allowing the country to host an astonishing range of flora and fauna.

India's wetlands are biodiversity hotspots that support thousands of species of plants, fish, birds, reptiles, amphibians, and microorganisms. They provide essential habitats for nearly 20% of India's known biodiversity and act as critical breeding, feeding, and nesting grounds. Many migratory bird species especially those traveling along the Central Asian Flyway depend heavily on Indian wetlands such as the Chilika Lagoon, Keoladeo National Park, and the wetlands of the Sundarbans. But very recently Jena *et al* (2025) studied how wetland degradation in India reduces avian biodiversity and affects local livelihoods of Sundarvan and near ny villages. Each winter, millions of birds from Europe, Central Asia, and Siberia arrive in India's wetlands, transforming these landscapes into vibrant seasonal refuges. The presence of rare and endangered species like the Gangetic dolphin, gharial, Indian skimmer, and several endemic fish further highlights the ecological importance of these ecosystems.

One of the unique features of India's wetlands is their wide geographical spread across contrasting climatic zones. In the Himalayan region, high-altitude wetlands like Pangong Tso and Tso Moriri support specialized cold-adapted species in fragile alpine environments. In central India, floodplain wetlands formed by the Ganga, Yamuna, Narmada, and Brahmaputra rivers nourish fertile agricultural lands while sustaining rich aquatic biodiversity. In peninsular India, mangrove wetlands especially the Sundarbans and Godavari-Krishna mangrove systems act as natural barriers against cyclones and support diverse marine and estuarine life. Even the Thar Desert, one of the driest regions in the country, hosts remarkable wetlands such as Sambhar Lake and Tal Chhapar, attracting thousands of flamingos and other birds.

The ecological value of India's wetlands extends beyond biodiversity. They play vital roles in flood regulation, groundwater recharge, nutrient cycling, shoreline stabilization, and climate moderation. Wetlands also support millions of people through fisheries, agriculture, livestock rearing, tourism, and cultural practices. In many parts of India, wetlands hold deep spiritual significance and are linked with festivals, traditional livelihoods, and local conservation efforts.

However, despite their immense ecological and economic importance, many Indian wetlands face increasing threats from pollution, land conversion, encroachment, upstream hydrological changes, and climate variability. Recognizing this, India has designated 82 wetlands as Ramsar Sites wetlands of international importance and continues to expand conservation initiatives through national and state-specific programs.

International frameworks such as the Ramsar Convention on Wetlands (1971) have played a significant role in raising global awareness and fostering conservation efforts. Ramsar-designated Wetlands of International Importance now cover over 250 million hectares, reflecting a commitment to sustainable wetland management (Ramsar Convention Secretariat, 2016). Yet, the gap between policy and implementation persists in many regions, especially in developing countries where economic demands often overshadow ecological priorities. Effective wetland conservation requires integrated management approaches that address environmental, economic, and socio-cultural dimensions. Community-based stewardship, ecological restoration, sustainable agriculture, and nature-based solutions are increasingly recognized as essential components of wetland management strategies (Zedler and Kercher, 2005).

Recent scientific advancements have also improved our understanding of wetland processes and their responses to environmental stressors. Remote sensing technologies, for instance, enable large-scale wetland mapping and monitoring, while biogeochemical studies provide insights into carbon sequestration, greenhouse gas emissions, and nutrient dynamics (Junk *et al*., 2013). Such research is crucial for developing adaptive management frameworks capable of safeguarding wetlands in a rapidly changing world. Moreover, interdisciplinary studies that integrate hydrology, ecology, social sciences, and policy analysis are essential for addressing the multifaceted challenges associated with wetland conservation and restoration.

Given the global decline of wetland ecosystems and the growing recognition of their ecological, economic, and cultural importance, a comprehensive review of current knowledge, emerging trends, and ongoing challenges is both timely and necessary. This review aims to synthesize the latest research on

wetland ecology, ecosystem services, threats, conservation strategies, and technological innovations. By examining global patterns alongside regional case studies, the paper seeks to provide an integrative understanding of wetland dynamics and highlight future directions for research, policy, and sustainable management. In doing so, the review underscores the urgency of protecting wetland ecosystems as vital assets for biodiversity conservation, climate regulation, and human well-being.

Materials and Method

The list of Ramsar sites in India is maintained by the Ministry of Environment, Forest & Climate Change and the details of each site are also documented on the Ramsar Sites Information Service (RSIS). According to the RSIS, there are 93 Ramsar Sites in India. These wetlands are crucial for migratory waterbirds along the Central Asian Flyway and for sustaining local livelihoods. However, encroachment, pollution, rapid urbanisation, and invasive plants are key threats to these areas.

The study covers major wetlands in the Indian states of Uttar Pradesh and Uttarakhand, located in the Gangetic plain and the lower Himalaya foothills respectively. Wetlands included in the analysis comprise nationally and internationally important sites (Ramsar-designated and NWIA-mapped wetlands), representative riverine floodplain lakes, oxbow lakes, reservoirs, marshes, and high-altitude wetlands (where present within state boundaries).

The local and nearby field survey was conducted in and around the aquatic habitat and their adjoining forest areas from January 2023 to February 2024. The wetland observations were carried out by using a traveller binocular and Canon point shoot camera. Taxonomical identification of birds on the ground was based on Grimmett *et al*. (1998). Birds are classified with help of field guide books (Ali *et al*., 1987; Grimmett *et al*., 1998; Grimmett *et al*., 2016). During the field survey birds were counted by two standards methods i.e. line transect method and point count method.

Results

Convention on Wetlands of International Importance was established in 1971 to promote their conservation and wise use. India became a signatory to the Ramsar Convention in 1982 and has since emerged as one of the countries with the largest number of designated Ramsar Sites in the world. As of 2024, India hosts 85 Ramsar Sites, covering more than 1.35 million hectares, representing a wide array of wetland types, ecological zones, and cultural landscapes.

The Ramsar Sites in India include a remarkable diversity of ecosystems, coastal lagoons, mangroves, marshes, floodplain wetlands, high-altitude lakes, estuaries, peat lands, reservoirs, and riverine stretches. These sites are distributed across the Himalayan region, Indo-Gangetic plains, peninsular plateau, Western Ghats, eastern coastal plains, and the islands of Andaman and Nicobar. Each Ramsar Site possesses unique hydrological characteristics and ecological functions, supporting habitat for migratory birds, endemic flora and fauna, threatened species, and complex biogeochemical processes. Iconic wetlands such as Chilika Lake in Odisha, Keoladeo National Park in Rajasthan, Loktak Lake in Manipur, Sundarbans Wetland in West Bengal, and Uttar Pradesh and Uttarakhand are the exceptional ecological value of India's wetland network.

Ramsar Wetlands in Uttar Pradesh

Bakhira Wildlife Sanctuary

Bakhira Wildlife Sanctuary is located in the Sant Kabir Nagar district of Uttar Pradesh, approximately 44 km west of Gorakhpur city. It is the largest natural floodplain wetland in eastern Uttar Pradesh, situated west of the Rapti river. This freshwater marsh is kwown for Endangered Avifauna: Egyptian Vultures, Greater Spotted Eagle, Common Pochard, Swamp Francolin.

Haiderpur Wetland

It is a wetland in Hastinapur WLS (wildlife sanctuary) formed by the construction of the Madhya Ganga Barrage. This human-made wetland was formed in 1984 by the construction of the Madhya Ganga Barrage on a floodplain of the River Ganga. It is located within the boundaries of Hastinapur Wildlife Sanctuary. Haiderpur Wetland provides habitat for numerous animal and plant species, including more than 30 species of plants, over 300 species of birds including 102 waterbirds, more than 40 fish and more than ten mammal species. This diverse habitat supports more than 15 globally threatened species, such as the critically endangered gharial (*Gavialis gangeticus*) and the endangered hog

deer (*Axis porcinus*), black-bellied tern (*Sterna acuticauda*), steppe eagle (*Aquila nipalensis*), Indian skimmer (*Rynchops albicollis*) and gold mahseer (*Tor putitora*).

Nawabganj Bird Sanctuary

It is a shallow marshland near Lucknow in Uttar Pradesh. It was renamed Chandra Shekhar Azad BS. It is an important destination for over 250 species of birds flying in from Northern Europe, Tibet, China and Siberia (Figure 1). The major migratory birds are Greylag Goose, Pintail, Red-crested Pochard, Gadwall, Coot and Mallard. Resident birds include a mixed Heronry of the Sarus Crane, Painted Stork, Black-crowned Night Heron, Open-billed Stork and White stork, Peacocks, White Ibis, Dabchick, Whistling Pheasant-tailed Jacana, Bronze-winged Jacana, Purple Moorhen, Lapwing, Tern, Vulture, Wigeon, King Crow, Indian Roller and the Bee-eater.

Fig. 1. Nawabganj Bird Sanctuary

Parwati Arga Bird Sanctuary

It is a permanent freshwater environment consisting of two oxbow lakes. Parwati Arga Bird Sanctuary is situated in Gonda District at a distance of 22 Kms from Ajodhya of District Faizabad and about 45 Kms. from Gonda city on Mankapur Nawab Ganj road and Mankapur Faizabad Railway line. The biggest attraction of the sanctuary is the presence of varieties of avian found. At least 153 Species of avifauna belonging to 33 families have been identified in the Parwati Arga wetland.

Saman Bird Sanctuary

Saman Bird Sanctuary is located in Bhogav, on Agra-Mainpuri-Farrukhabad. It is well connected from Agra & Aligarh by Road. Spread over just about 5.25 sq kms of area, the sanctuary today remains one of the best places in the state to view the majestic Sarus Cranes. Saman sanctuary is also a haven for several species of migratory birds like the Common Teal, Northern pintail, Great White pelican and species of Storks (Figure 2). The resident population of Storks in the sanctuary includes Painted Stork, Block-necked Stork, Open-billed Stock and Woolly-necked Stork.

Fig. 2. Saman Bird Sanctuary

Samaspur Bird Sanctuary

This sanctuary was established in the year 1987. Exact location of the sanctuary is Rohaniya block of the district and far located at 122 kilometers from Lucknow to the city. In this sanctuary more than 250 bird's species are naturally habited. Having a fleet of more than 250 species, this sanctuary is one of the best and most liked birding destination. Vulture, Kingfishers, Spot Bill Teel common and Teel Whis-

tling etc. have made the sanctuary as their permanent habitat. In this sanctuary, resident and domestic bird Surkhab is also found in large population. Accept the birds, more than 11 fish species are also find in the lake situated at Samaspur. Migratory birds come from more than 5000 kilometers far to spend some time in pleasant weather.

Sandi Bird Sanctuary

Sandi Bird sanctuary having an area 3,09 hectares is situated in Hardoi district on Hardoi- Sandi Road around the Deher Jheel and the Garra river. In 1991, Sandi wetlands were declared as Sandi Bird Sanctuary. The Bombay Natural History Society, Mumbai (BNHS) has also listed this Sanctuary as one of the 'Important Bird Area' sites. The aim of the Sanctuary is protection and conservation of the wetland with special emphasis to the local and migratory birds, conservation of their natural habitat including aquatic plants and animals.

Sarsai Nawar Jheel

Sarsai Jheel, also known as Sarsai Nawar Jheel, is a permanent marsh and important wetland located in the Etawah district of Uttar Pradesh. It covers an area of about 161 hectares and is part of the Indo-Gangetic floodplain, sustained mainly by monsoon rainfall. In winters, almost more than 40,000 migratory birds from northern arcvisit Sarsai Nawar wetland (Figure 3). Ten Sarus Crane pairs breed here regularly, which is more than twice the number of breeding pairs in the bird sanctuary of Bharatpur in Rajasthan.

Fig. 3. Sarsai Nawar Jheel

Sur Sarovar (Keetham Lake)

Soor Sarovar Bird Sanctuary is conveniently situated on the Delhi-Agra highway in Uttar Pradesh. Initially covering a modest are of 4.03 sq kms, the Forest Department later expanded the sanctuary area to cover 8 sq kms by planting trees around the lake to increase the green cover for its wild animals. Keetham Lake, a haven for waterfowl, was declared a wildlife sanctuary in 1991. The lake is home to over 126 species of migratory and resident waterfowl (Figure 4). Here, one can hear the rustle of the leaves, the muffled sounds of wild animals moving and even the occasional hiss of snakes. Hog deer, Spotted Deer, Nilgai and Monitor Lizards can be easily seen in the woods.

Fig. 4. Sur Sarovar (Keetham Lake)

Maharana Pratap Wetland (Richa wetland,) Bareilly

The main wetland near Bhuta, Bareilly is the Maharana Pratap Wetland, located in the Richa area of the Bhuta Block of Bareilly district in western Uttar Pradesh (Figure 5). This wetland is a popular local spot, sometimes referred to as the Richa wetland. The wetland has been part of a multi-stake-

Fig. 5. Maharana Pratap Wetland (Richa wetland,) Bareilly

holder initiative to restore wetlands in the area, which also included the Aril River. This wetland is known for breeding area for Sarus crane.

Ramsar Wetlands in Uttarakhand

Asan Barrage

It is formed by the damming of the Asan River near its confluence with the Yamuna River in the Dehradun district. The Asan Barrage is a barrage in the Uttarakhand-Himachal Pradesh border region in Doon Valley (Dehradun district), northern India, situated at the confluence of the Eastern Yamuna Canal and the Asan River and about 11 km from Dakpathar, and 28 km. northwest of Dehradun in Uttarakhand. The barrage is 287.5m long and has water throughout the year which is fed from the river Asan and the discharge channel of the river Yamuna. Since 2020 it has been declared as Uttarakhand's first Ramsar site. Endangered Avifauna: Red-Headed Vulture (Indian Black Vulture), White-Rumped Vulture, Baer's Pochard.

Uttarakhand has been active in identifying many important local/sacred water bodies (e.g., a recent state inventory of sacred natural sites), but identification at state level is different from a formal Ramsar nomination requires a formal submission to the Ramsar Secretariat via the central government Ministry of Environment, Forest and Climate Change (MoEFCC).

Discussion

This review synthesizes current knowledge on the wetland ecosystems of Uttar Pradesh and Uttarakhand, highlighting their central role for avian biodiversity, the mounting threats they face, and pragmatic conservation strategies. Overall, the two states harbour a mosaic of wetland types, riverine marshes, oxbow lakes, reservoirs, high-altitude lakes and seasonal floodplain wetlands, that together support high avian richness, including breeding residents, wintering migrants along the Central Asian Flyway, and several globally or nationally threatened species. Regional field surveys and targeted assessments confirm that many wetlands in Uttarakhand and the Gangetic plains of Uttar Pradesh act as critical stopovers and wintering grounds that sustain both waterfowl and shorebird assemblages.

Empirical surveys in the western Himalaya and the Gangetic floodplain report substantial species lists encompassing waterfowl, waders, herons, raptors and passerines closely tied to wetland integrity. Local studies in Uttarakhand have recorded diverse water bird communities across riverine and reservoir wetlands, demonstrating seasonal changes in composition driven by hydrology and resource pulses. These findings underscore wetlands' outsized role in regional bird conservation and in maintaining ecosystem services, nutrient cycling, fisheries, groundwater recharge and flood mitigation, which in turn sustain human livelihoods. Multiple, interacting drivers are degrading wetland habitat quality and reducing their capacity to support birds (Arya *et. al*., 2021).

Land-use change and drainage: Conversion of marshes to agriculture, encroachment for housing and infrastructure, and channel modifications fragment habitat and reduce available foraging and roosting areas.

Hydrological alteration: Upstream flow regulation, irrigation withdrawals and reservoir operations alter seasonal inundation regimes critical for many water bird life cycles.

Pollution and eutrophication: Untreated sewage, agricultural runoff (fertilizers, pesticides) and aquaculture effluents lead to eutrophication, fish kills and shifts in food-web structure.

Invasive species and biological change: Proliferation of invasive macrophytes (e.g., water hyacinth) and non-native fishes can reduce habitat heterogeneity and prey availability.

Climate change: Changes in precipitation patterns, earlier snowmelt in the Himalaya and increasing temperature extremes modify wetland hydrology and phenology, potentially decoupling migratory timings from resource peaks. Recent continental analyses indicate linked declines in water bird abundance where primary productivity and hydrology are changing, implying serious risks for inland wetlands in South Asia. The experience from other Indian wetlands cautions that legal designation alone does not guarantee recovery without active management and community engagement.

National and state-level policy instruments (e.g., Wetlands (Conservation & Management) Rules, Ramsar designations) and recent schemes (such as the Amrit Dharohar initiatives and centrally supported wetland mapping/monitoring programmes) have improved the institutional visibility of wet-

lands and mobilized resources for select sites. The Government of India's Ramsar listings and the updated national inventory provide a policy framework for prioritizing sites for conservation and restoration. However, case studies show mixed outcomes: where governance is weak, deteriorating local practices.

From the evidence surveyed, a multifaceted conservation strategy is required that combines landscape planning, local stewardship, science-led management and policy reform. Key recommendations are; Integrated hydrology management to preserve seasonal habitats used by migrants and breeders, Targeted habitat restoration to remove or control invasive macrophytes and Pollution control and sustainable livelihoods for retrofit sewage treatment for urban and peri-urban wetlands. Community engagement and co-management also empower local communities and fishers with formal roles in conservation planning, benefit-sharing, and monitoring.

Conclusion

Uttar Pradesh and Uttarakhand contain wetland networks of high conservation value for avifauna, but they are increasingly threatened by land-use change, pollution, hydrological alteration and climate change. Recent policy attention and site designations (including Ramsar listings) are important first steps, but conservation gains will depend on integrated hydrological management, active restoration, pollution control, community co-management and sustained scientific monitoring. Prioritizing climate-resilient wetlands and scaling successful local governance models will be critical to preserve the region's avian richness into the coming decades.

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Conflict of Interest- None

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