

Avian Diversity and Habitat Use in Kolleru Lake Wetlands, Andhra Pradesh, India

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Abstract - Kolleru Lake, one of India's largest freshwater wetlands and a designated Ramsar Site, supports a diverse assemblage of resident and migratory waterbirds. This review synthesizes decades of ecological research to assess avian diversity, habitat utilization, and the impacts of anthropogenic pressures on the lake's ecological integrity. Studies conducted between 1980 and 2020 report over 230 bird species across 17 orders, including six globally threatened and twenty near-threatened species. However, large-scale habitat transformation caused by aquaculture expansion, agricultural runoff, and hydrological alteration has led to significant fluctuations in species richness and habitat availability. Remote sensing analyses reveal extensive conversion of open-water zones to fishponds, resulting in eutrophication, weed proliferation, and fragmentation of breeding and feeding habitats. Conservation initiatives such as "Operation Kolleru" temporarily restored wetland conditions and enhanced migratory bird populations, yet unregulated land use continues to threaten long-term stability. The synthesis highlights the importance of maintaining habitat heterogeneity, enforcing conservation regulations, and promoting community-based management. Sustained monitoring of avian diversity, coupled with habitat restoration and integrated watershed management, is crucial to preserving the ecological and ornithological significance of Kolleru Lake.

Keywords: Kolleru Lake; avian diversity; habitat utilization; Ramsar wetland; aquaculture impact; land-use change; migratory birds; conservation management.

I. Introduction

Wetlands represent some of the most biologically productive ecosystems on Earth, providing crucial ecological services such as flood control, nutrient retention, groundwater recharge, and serving as critical habitats for numerous species of flora and fauna. Among the diverse life forms inhabiting wetlands, avian species serve as vital ecological indicators because their diversity and abundance reflect the overall health and functionality of the ecosystem (Ali & Ripley, 1968;

Roth, 1976). The Kolleru Lake Wetland, located between the Krishna and Godavari deltas of Andhra Pradesh, stands out as one of India's most important freshwater ecosystems and a globally recognized Ramsar Site of international significance (Azeez *et al.*, 2011; Dutt, 1982). It acts as a refuge for thousands of migratory and resident birds, offering feeding, nesting, and breeding habitats throughout the year (Anjaneyulu & Ramana Rao, 1985; Vasudeva Rao *et al.*, 2014).

Kolleru Lake occupies an area of approximately 901 km² at its maximum flood level of +10.7 meters above mean sea level (MSL), with a normal water spread of about 300 km² at +5 MSL (Vasudeva Rao *et al.*, 2014). The catchment area, covering nearly 4,763 km², is fed by fifteen irrigation canals and fifteen drainage channels, primarily the Budameru and Tammileru rivers, which drain the Krishna and Godavari deltas (Rao *et al.*, 2014). Seasonal hydrological variations cause large fluctuations in water level and habitat distribution, expanding during the monsoon and contracting during the dry season. This hydrodynamic variability sustains a mosaic of ecological zones, including open waters, submerged macrophytes, floating vegetation, and emergent marshlands (Seshavataram & Venu, 1982).

Historically, Kolleru Lake was celebrated as a "bird paradise" due to its extraordinary richness in migratory and resident waterfowl (Neelakantan, 1949; Balakrishna, 1984). Early ornithological observations recorded thriving pelicanries, heronries, and abundant populations of storks, ibises, and ducks. However, since the 1980s, the ecosystem has undergone dramatic transformations due to unchecked anthropogenic pressures such as the spread of aquaculture, paddy cultivation, nutrient loading, hydrological alteration, and pollution (Azeez *et al.*, 2011; Taher & Taher, 1996). The construction of bunds and conversion of wetland areas into fishponds caused large-scale habitat fragmentation and a decline in open water zones, resulting in the loss of breeding and foraging grounds for many avian species (Rao & Ramana Rao, 1985).

Kolleru supports over 230 species of birds across 17 orders, including approximately 100 migratory species that visit seasonally along the Central Asian Flyway (Vasudeva Rao *et al.*, 2014; Bharatha Lakshmi *et al.*, 2015). Among these are several globally threatened species such as the Spot-billed Pelican (*Pelecanus philippensis*), Painted Stork (*Mycteria leucocephala*), and Oriental Darter (*Anhinga melanogaster*), which signify the wetland's international conservation value (Bharatha Lakshmi *et al.*, 2015). Yet, this ecological richness is under severe stress from anthropogenic disturbances, notably the proliferation of fish tanks within the sanctuary boundaries and degradation of hydrological connectivity. The Government of Andhra Pradesh launched "Operation Kolleru" in 2006 to remove illegal fishponds and restore the lake's natural hydrology, leading to a temporary resurgence in migratory bird numbers (Azeez *et al.*, 2011). Despite this, pressures from renewed aquaculture and agricultural intensification persist, emphasizing the need for long-term, integrative management.

The present review discusses available literature on the avian diversity, habitat utilization, and conservation status of Kolleru Lake. It aims to consolidate findings from several decades of ecological surveys, evaluate the effects of land-use and hydrological changes on bird communities, and highlight strategies for sustainable conservation of this Ramsar wetland.

II. Study Area and Environmental Setting

Kolleru Lake is situated between 16°32'–16°47' N latitude and 81°05'–81°22' E longitude, extending across the districts of Krishna and West Godavari. Geomorphologically, it occupies a depression formed by deltaic and fluvial deposits that act as a natural receptacle for floodwaters. The region experiences a tropical monsoon climate, with mean annual rainfall between 850 and 900 mm. The lake's water balance depends heavily on the monsoon regime and the inflow from irrigation canals and agricultural runoff (Azeez *et al.*, 2011; Vasudeva Rao *et al.*, 2014). Hydrological variations produce alternating cycles of expansion and contraction, which in turn influence vegetation patterns and the spatial distribution of bird habitats.

The lake's basin supports dense aquatic vegetation dominated by *Eichhornia crassipes*, *Typha angustata*, *Nymphaea nouchali*, and *Hydrilla verticillata* (Seshavaram & Dutt, 1978). These macrophytes provide nesting materials, camouflage, and abundant invertebrate food resources essential for waterfowl. The periphery of the lake is interspersed with agricultural lands, aquaculture ponds, and human settlements, creating ecotonal transitions between terrestrial and aquatic habitats. The overall landscape structure

thus supports both aquatic-dependent species like ducks, jacanas, and coots, as well as open-country birds like kites and lapwings (Rao *et al.*, 2014).

Although declared a Wildlife Sanctuary in 1999 and recognized as a Ramsar Site in 2002, Kolleru's ecological integrity remains compromised by widespread encroachment and unregulated aquaculture (Azeez *et al.*, 2011). Continuous sediment deposition, weed infestation, and pollution have gradually reduced the area of open water, with substantial ecological consequences for bird diversity and trophic interactions.

III. Avian Diversity and Temporal Trends

Over the decades, Kolleru Lake has exhibited remarkable variability in its avian assemblages, reflecting both natural hydrological oscillations and anthropogenic disturbances. Early ornithologists such as Neelakantan (1949) and Balakrishna (1984) reported extensive colonies of pelicans, storks, and herons. By the late 20th century, however, bird counts had declined sharply, coinciding with the spread of aquaculture and reduction in open-water habitats (Nagulu & Ramana Rao, 1983). During the 1980s and 1990s, the lake's avian diversity dropped from over 200 species to nearly 160 (Taher & Taher, 1996).

A revival was observed after the implementation of "Operation Kolleru," when extensive fishpond demolitions restored natural hydrology. Bharatha Lakshmi *et al.* (2015) recorded 232 bird species representing 138 genera and 57 families, including six globally threatened species and twenty near-threatened ones. Vasudeva Rao *et al.* (2014) similarly observed a resurgence of migratory ducks and waders following habitat restoration. This rebound highlights the resilience of avian communities when suitable habitat conditions are reinstated. Nonetheless, more recent surveys suggest that illegal aquaculture expansion continues to erode habitat quality, threatening long-term stability (Kolli *et al.*, 2020).

Species richness is closely linked to hydrological fluctuations; wet years with widespread inundation support higher diversity, while dry years restrict foraging zones and increase competition among waterbirds. The richness and abundance patterns of key families such as Ardeidae, Anatidae, Scolopacidae, and Laridae are directly influenced by the extent of open water and aquatic vegetation cover (Figure 1) (Rao *et al.*, 2014).

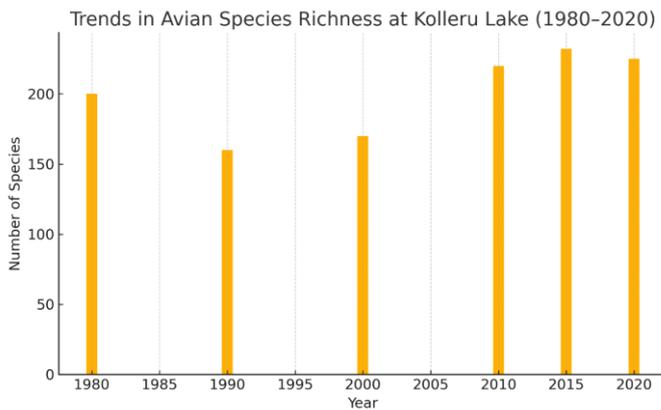


Figure 1: Trends in Avian Species Richness at Kolleru Lake (1980–2020)

IV. Land-Use Change and Habitat Transformation

The ecological condition of Kolleru Lake has been drastically reshaped by changes in land use and land cover over the last four decades. Remote sensing analyses conducted by Kolli, Opp, Karthe, and Groll (2020) using Landsat imagery documented that fishponds occupied nearly 30% of the lake area in 1999, declining after restoration measures in 2008 but expanding again by 2018. The conversion of wetlands into aquaculture ponds, often beyond the legal +5 ft contour, has fragmented habitats and diminished ecological connectivity. Kareddula (2011) reported that between 1988 and 2004, aquaculture increased by 44% while open-water zones decreased by 36%, drastically altering habitat availability for aquatic fauna.

The proliferation of aquaculture infrastructure not only modified land cover but also disrupted the hydrological regime by impeding natural inflow and outflow channels, reducing flood retention capacity, and encouraging eutrophication. Nutrient loading from fertilizers and feed residues has promoted excessive growth of *Eichhorniacrassipes* and *Ipomoea aquatica*, which obstruct light penetration and deplete dissolved oxygen, impacting invertebrate and fish communities. Consequently, the prey base for piscivorous birds has declined, leading to shifts in foraging behavior and habitat use (Seshavataram & Venu, 1982; Sabesh, 2010).

The intensification of agriculture along the periphery contributes additional chemical pollutants through runoff, while sedimentation reduces water depth and further constrains habitat heterogeneity. These cumulative pressures have altered the trophic structure of the lake, affecting both food availability and nesting habitats for wetland-dependent birds (Figure 2).

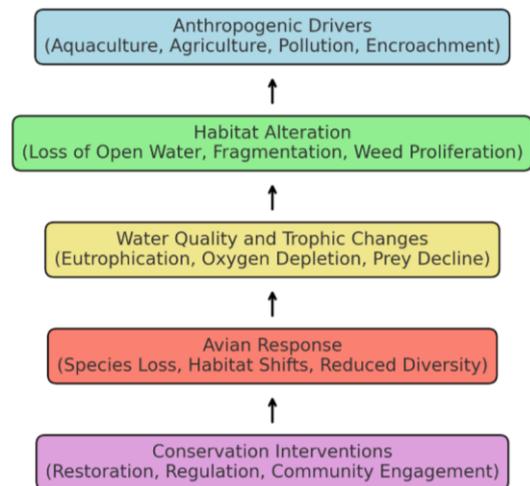


Figure 2: Flowchart of Ecological Drivers and Avian Response at Kolleru Lake

V. Habitat Utilization Patterns

The habitat mosaic of Kolleru Lake supports a broad spectrum of avian ecological guilds. Open-water areas serve as feeding zones for diving ducks, pelicans, and cormorants, while submerged vegetation zones are utilized by dabbling ducks and herbivorous species such as whistling teals. Floating vegetation supports jacanas, moorhens, and grebes, whereas reed beds and marshes offer nesting and roosting grounds for herons, egrets, and bitterns. Agricultural fields adjoining the lake are used seasonally by storks, cranes, and ibises, which forage on invertebrates and amphibians exposed in shallow soils (Vasudeva Rao *et al.*, 2014).

Quantitative analyses indicate that approximately 22% of bird observations occur over open water, 18% in submerged vegetation zones, 17% in fishponds, 16% in agricultural fields, and 15% in floating vegetation, with the remaining proportion distributed across marshes and reed beds (Rao *et al.*, 2014). These findings highlight the importance of maintaining habitat heterogeneity for sustaining the diverse avian community. Birds' seasonal habitat selection is influenced by water depth and vegetation cover, with migratory waterfowl concentrating in deeper zones during winter and waders utilizing receding shorelines during the dry season.

Functional guild analysis reveals that piscivores dominate the community, followed by insectivores, omnivores, and herbivores. Seasonal migration patterns also influence species composition, as the arrival of northern migrants from the Palearctic region significantly enhances richness during the post-monsoon and winter months (Bharatha Lakshmi *et al.*, 2015).

VI. Anthropogenic Pressures and Ecological Stressors

Anthropogenic disturbances have profoundly affected Kolleru's ecological stability. Unregulated aquaculture has transformed vast wetland areas into artificial ponds, disrupting natural hydrology and fragmenting habitats. Studies estimate that over 50,000 hectares of wetland were encroached upon by aquaculture by the early 2000s (Azeez *et al.*, 2011). Pollution is another major concern, as pesticide and heavy metal accumulation in sediments and fish tissues pose secondary poisoning risks to piscivorous birds (Amaraneni, 2002). The obstruction of the Upputeru outlet, combined with siltation, has reduced water exchange and caused stagnation, particularly during dry seasons, thereby affecting nutrient balance and oxygen availability (Rao *et al.*, 2014).

In addition to pollution and hydrological disruption, human disturbance, grazing, and bird hunting remain pervasive. Poaching for meat and feathers, especially targeting large waterfowl, has been reported despite the legal protection under the Wildlife (Protection) Act (Taher & Taher, 1996). Furthermore, unregulated tourism and fishing activities disturb breeding colonies and reduce reproductive success. Collectively, these pressures exert cascading effects on avian diversity and habitat use.

VII. Conservation and Management Perspectives

To counteract the rapid degradation, "Operation Kolleru" was initiated in 2006 by the Government of Andhra Pradesh, resulting in the demolition of 1,776 illegal fish tanks and the reclamation of approximately 44,725 acres of wetland (Azeez *et al.*, 2011). Post-restoration surveys indicated an increase in migratory bird populations, particularly pelicans, storks, and ducks, confirming the positive impact of habitat recovery (Bharatha Lakshmi *et al.*, 2015). However, weak enforcement and socioeconomic dependencies on aquaculture have led to the gradual resurgence of illegal fishponds in subsequent years (Kolli *et al.*, 2020).

Long-term conservation success will depend on balancing ecological restoration with local livelihoods. The promotion of eco-friendly aquaculture practices, establishment of vegetative buffer zones, and creation of artificial nesting islands can provide sustainable alternatives. Hydrological restoration through desiltation of the Upputeru channel and reconnection of feeder canals can reinstate natural water dynamics, crucial for wetland renewal. Regular monitoring using remote sensing and ground surveys should be institutionalized to track habitat change and avian population dynamics (Kareddula, 2011).

Community participation is vital in ensuring compliance with conservation regulations. Integrating local fisherfolk and farmers through awareness campaigns, eco-tourism initiatives, and compensation schemes can align conservation objectives with socioeconomic incentives. Such participatory approaches, supported by strong policy frameworks, are essential for sustaining Kolleru's ecological and cultural heritage.

VIII. Conclusion

Kolleru Lake stands as one of India's most ecologically significant freshwater wetlands, supporting a rich diversity of avian species. Despite its Ramsar and Wildlife Sanctuary status, it continues to face persistent challenges from aquaculture expansion, pollution, hydrological alteration, and human encroachment. While interventions like "Operation Kolleru" demonstrated the potential for ecological recovery, long-term sustainability requires integrated watershed management, effective law enforcement, and community-based conservation. Future research should emphasize continuous avian monitoring, trophic link studies, and modeling of hydrological and climate change impacts on habitat dynamics. Strengthening collaboration among governmental agencies, researchers, and local communities will be critical for safeguarding the ecological integrity of Kolleru Lake and ensuring its role as a sanctuary for India's wetland avifauna.

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