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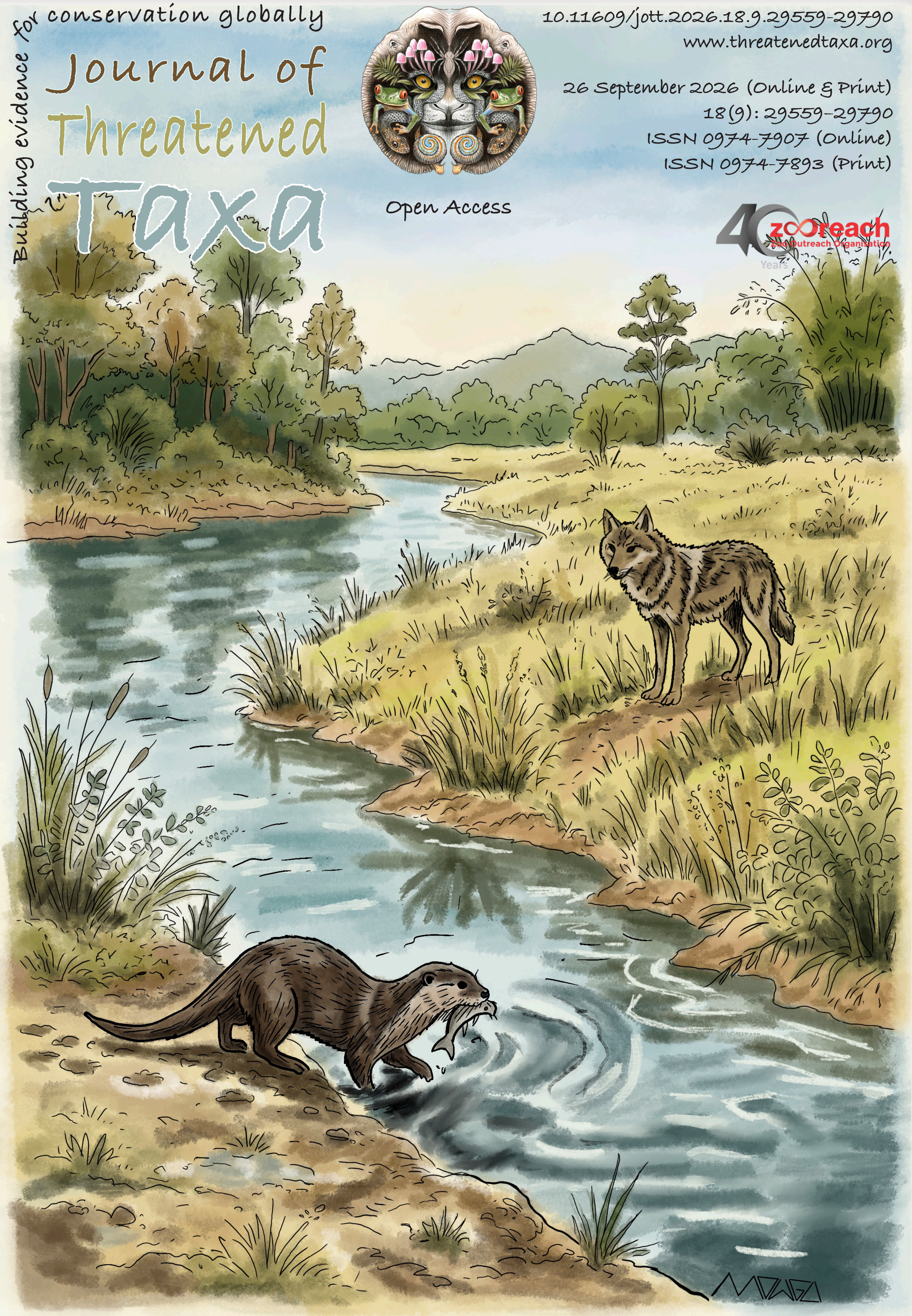

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Cover: Indian Grey Wolf *Canis lupus pallipes* and Smooth-coated Otter *Lutrogale perspicillata* sharing the territory in Chambal basin. Digital art on Procreate by Aakanksha Komanduri.

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ARTICLE

Long-term dynamics of breeding waterbirds in relation to habitat structures in a tropical irrigation wetland: evidence from Vettangudi Bird Sanctuary, Tamil Nadu, India

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Abstract: Wetlands are critical habitats for breeding waterbirds, yet many are undergoing rapid ecological change due to hydrological alteration, land-use changes, and increasing anthropogenic pressures. We assessed long-term changes in breeding waterbird assemblages in Vettangudi Bird Sanctuary, an irrigation tank in Tamil Nadu, using data from eight breeding seasons (2012–2026). Total breeding waterbird abundance showed high interannual variability with no significant long-term trend. Nest abundance declined over time, from 396 nests in 2012–13 to as low as 163 in 2018–19, with only partial recovery to 190 in 2025–26. Breeding species richness declined, from 11 nesting species in 2016–17 to three species in 2025–26. The breeding community was dominated by Asian Openbill and Black-headed Ibis, while several species, like egrets and herons, showed declining trends or zero nesting in later years. In land-use and land-cover (LULC) analysis, water extent showed a significant negative relationship with breeding diversity during nest initiation (August: $\rho = -0.74$, $p = 0.035$), while no significant associations were observed during peak nesting (December). Nesting abundance showed a weak positive association with dense vegetation cover in both August ($\rho = 0.43$, $p = 0.30$) and December ($\rho = 0.52$, $p = 0.20$). Despite recent increases in water extent and vegetation cover, nesting abundance and species richness declined, suggesting that habitat extent alone does not determine breeding suitability. The observed declines are likely linked to changes in habitat quality, nesting substrate availability, particularly the removal of mature *Parkinsonia aculeata* trees, coupled with the increasing dominance of *Neltuma juliflora*. Hence, prioritising targeted conservation, long-term monitoring and management of stable hydrological conditions and nesting trees, and minimising disturbance during the breeding period, are key to sustaining breeding waterbird populations in such vulnerable, human-influenced wetlands.

Keywords: Colonial nesting, conservation management, habitat change, heronry, irrigation tanks, land use land cover, LULC, protected area, Sivagangai, wetland ecology.

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Author contribution: BH: Conceptualisation, writing, editing and supervision; MH: writing, editing, data management and maps; RN: data collection and curation; RV: writing.

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INTRODUCTION

Globally, wetlands play a critical role in maintaining ecological balance by supporting diverse biological communities. Colonial and solitary waterbirds depend on wetlands for feeding, roosting, nesting substrates, and suitable hydrological conditions throughout the breeding cycle. Consequently, changes in wetland condition can directly influence breeding success, population persistence, and community composition of waterbirds. Despite their ecological importance, wetlands globally are declining at an alarming rate due to human-driven land-use changes, altered hydrological regimes, and climate-related impacts, which collectively contribute to waterbird population decline (Wang et al. 2023; Kundu et al. 2024).

In India, these pressures are further intensified by agricultural expansion and development, resulting in the loss and fragmentation of wetland habitats (Rashiba et al. 2022; Kundu et al. 2024). Such changes directly influence waterbird assemblages by altering habitat availability and suitability, ultimately affecting their distribution and breeding success (Charalambous et al. 2024).

The breeding ecology of waterbirds is particularly sensitive to habitat conditions. Hence, habitat selection, especially during breeding cycles, is largely shaped by hydrological conditions, availability of food resources, and access to suitable nesting sites (Li et al. 2019). Hydrological regimes influence prey accessibility, colony isolation, and nest survival, while vegetation structure determines the availability and suitability of nesting sites for colonial breeding species (Frank et al. 2021). In tropical regions, rainfall patterns further influence these processes, which regulate water levels, vegetation growth, and resource availability, leading to inter-annual variability in breeding populations (Byju et al. 2025a; Gonzalez & Fletcher 2025). Recent studies increasingly emphasize that habitat quality and structural heterogeneity may be more important determinants of breeding success than habitat extent alone (Mott et al. 2023; Charalambous et al. 2024).

Advances in remote sensing have enabled the quantification of long-term wetland habitat dynamics through land-use and land-cover (LULC) analyses (Pontieri et al. 2025). Open-water extent, vegetation structure, and canopy structure, which are directly relevant to nesting and foraging requirements of waterbirds, are important habitat variables that, with long-term breeding data, enable the assessment of how changes in water availability and dense vegetation cover relate to variation in waterbird abundance and nesting patterns (Wani et al. 2021; Zhang et al. 2023).

In peninsular India, irrigation tanks, which were originally constructed for water storage and agriculture, have evolved into significant ecological habitats sustaining diverse avifaunal assemblages (Mathibalan et al. 2026). In Tamil Nadu, several studies have highlighted the importance of such wetlands in supporting breeding colonies of waterbirds, particularly heronries consisting of mixed-species nesting aggregations (Frank et al. 2021; Byju et al. 2025b). Nevertheless, long-term assessments of waterbird breeding in these systems remain scarce, particularly studies linking breeding patterns with habitat change.

Vettangudi Bird Sanctuary, located in the Sivagangai District of Tamil Nadu, is one such irrigation tank system. Despite its ecological importance, studies on avifauna in Vettangudi have been limited to documenting species occurrence and breeding records (Subramanya 2005; Chandrasekaran et al. 2014; Mahesh et al. 2018), with no specific works on long-term changes in breeding waterbird assemblages in relation to vegetation and water extent. Understanding these relationships is particularly important because the sanctuary has undergone substantial habitat modifications over recent decades, including changes in vegetation composition, water availability, and management interventions.

Hence, the present study aimed to: 1. assess the breeding assemblage of waterbirds and species composition over the long term; 2. evaluate temporal trends in species richness and nesting abundance of breeding waterbirds; 3. examine the relationship between nesting patterns and habitat characteristics, particularly changes in LULC. We hypothesized that breeding waterbird assemblage structure and nesting abundance are influenced not only by the extent of water and vegetation, but also by habitat quality attributes such as vegetation heterogeneity, nesting substrate availability, hydrological stability, and anthropogenic disturbance. Therefore, increases in habitat extent alone may not necessarily translate into greater waterbird breeding population or nesting abundance.

MATERIALS AND METHODS

Study area

Vettangudi Bird Sanctuary in the Sivaganga District, Tamil Nadu (10.098° N, 78.539° E), covers approximately 40 ha and comprises three village freshwater irrigation tanks— Periyakollukudi (13.5 ha), Chinnakollukudi (6.2

ha), and Vettangudi (14 ha). Our study was conducted in the main waterbird-breeding tank of Periyakollukudi Tank, hereafter referred to as the Vettangudi Sanctuary.

The tank is largely rain-fed from the north-east monsoon (October–December; 330–390 mm), with supplementary rainfall from the south-west monsoon (June–September; up to ~300 mm). The adjacent paddy fields and the Vaigai River provide additional foraging habitats. Vegetation within the tanks is dominated by *Neltuma juliflora*, *Acacia nilotica*, *Parkinsonia aculeata*, and parts of the surrounding area are also invaded by *Neltuma chilensis* (BirdLife International 2026).

Data collection

Waterbird surveys were conducted over eight breeding seasons from July to January (2012–13, 2015–16, 2016–17, 2017–18, 2018–19, 2019–20, 2021–22, and 2025–26). The peak breeding season of colonial waterbirds in Tamil Nadu coincides with the northeast monsoon (Byju et al. 2025a). The study site was visited once a month during morning hours (0700–1100 h). Data collection was conducted following both direct count and block count methodologies (Bibby et al. 2000). Waterbirds were surveyed from three selected vantage points, chosen based on waterbird presence and nesting within the tank (Image 1). The perimeter counting method was employed to enumerate visible nests and to monitor foraging flights from the colony edge for nest counts (Dodd & Murphy 1995). Observations were performed using binoculars (10×50 Nikon) and spotting scopes (14 × 70 Vanguard).

Statistical analysis

We considered peak seasonal nest counts and waterbird abundance counts for data analysis. Temporal trends were assessed using the non-parametric Mann–Kendall test (MK) (Mann 1945; Kendall 1975). The magnitude of change was estimated using Sen's slope estimator, which provides the median rate of change per unit time (Sen 1968). Trend analyses were conducted for (i) total breeding waterbird abundance (summed peak counts) and (ii) species-wise counts. Only species with ≥5 observations were included in species-level analysis. Statistical significance was evaluated at $\alpha = 0.05$.

Interannual variation in species composition was assessed using hierarchical cluster analysis based on Bray–Curtis dissimilarity (Bray & Curtis 1957). Clustering was performed using the agglomerative average linkage (UPGMA) method (Sokal & Michener 1958). A combined dendrogram and heatmap were used to visualize

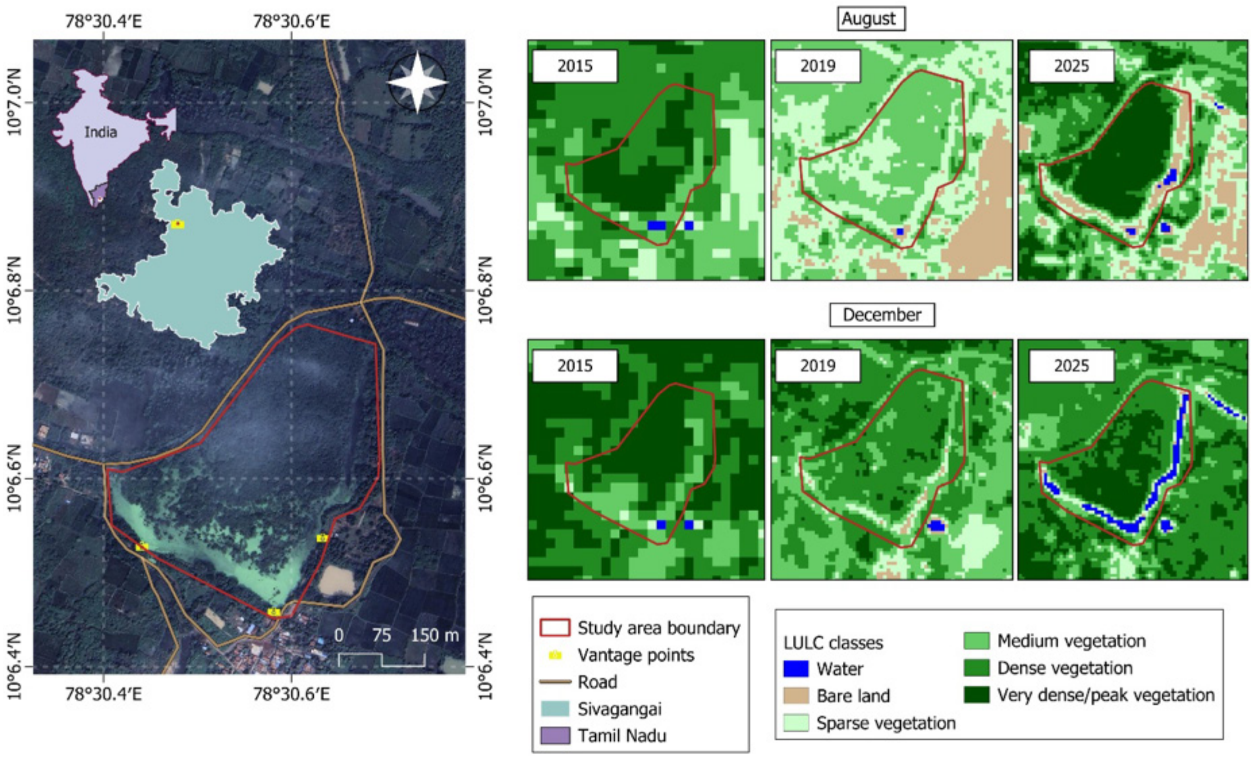

Image 1. Map showing the vantage points in the study area with the representative LULC maps of the early (2015), mid (2019) and recent (2025) study years.

similarity patterns across years.

All statistical analyses and plots were performed using R software version 4.5.1 (R core team 2026).

Land use/Land cover analysis

LULC classifications of the study area were derived from satellite imagery for August (nesting initiation) and December (peak breeding) across the study years 2012, 2015, 2016, 2017, 2018, 2019, 2021, and 2025 (which corresponds to the breeding season, as 2012 August and December are 2012–13 and similar for the other years). Surface reflectance imagery from Landsat 7 ETM+ (30 m resolution) was used for 2012, while Landsat 8 OLI/TIRS Collection 2 Level–2 data (30 m resolution) were used for 2015, 2016, 2017, and 2018. Sentinel–2 MSI Level–2A data (10 m resolution) were used for 2019, 2021, and 2025. Due to limited image availability, scenes with up to 80% cloud cover were included where necessary. Cloud, shadow, and cirrus pixels were masked using the QA_PIXEL band. Supervised classification was performed separately for each dataset in QGIS (version 3.44.1) to derive five classes: water, bare land, sparse vegetation, medium vegetation, and dense vegetation. These variables were selected because they represent key habitat attributes known to influence colonial breeding waterbirds. Water extent was defined as the total surface area (ha) classified as open water within the study area. Vegetation extent was defined as the total area (ha) occupied by moderate and dense vegetation classes. Water extent reflects hydrological conditions and potential foraging habitat; moderate vegetation represents habitat heterogeneity with shrubs, small trees, and developing nesting substrates, while dense vegetation represents mature nesting trees used by colonial nesting species. Class-wise area was calculated using pixel-based area estimation. The total area for each class was derived by summing pixel areas and converting to hectares. Based on functional relevance to breeding waterbirds, three variables— water extent, moderate vegetation, and dense vegetation were selected for subsequent statistical analysis.

Representative LULC maps were generated for 2015, 2019, and 2025 using surface reflectance imagery from Landsat 8 OLI/TIRS Collection 2 Level–2 (2015; 30 m resolution) and Sentinel–2 MSI Level–2A (2019 and 2025; 10 m resolution). Years were selected based on data availability and minimal cloud cover (less than 10%), with intervals of 3–4 years to represent early, mid, and recent periods. The classified outputs for LULC analysis were clipped to the study area boundary and validated using satellite imagery and field data.

Breeding waterbird diversity was quantified using the Shannon diversity index (H'), which incorporates both species richness and relative abundance (Shannon 1948; Magurran 2004).

To evaluate the relationship between habitat characteristics and breeding waterbird species diversity and nest abundance, Spearman's rank correlation coefficient (ρ) was used. This non-parametric method was selected due to the small sample size and the absence of normality assumptions in ecological datasets (Zar 2010). Analyses were conducted separately for August and December to distinguish between habitat influences on breeding patterns.

Limitations of the study

The analysis is based on non-continuous sampling years due to logistical constraints and restricted field access during the COVID–19 period, which restricts the ability to capture continuous interannual variability. Nest and breeding waterbird abundance was derived from single peak counts per season and therefore does not account for turnover or failed nesting attempts within the breeding period. In the LULC analysis, differences in spatial resolution between Landsat (30 m) and Sentinel–2 (10 m) imagery may influence the detection of fine-scale features, with coarser Landsat data more likely to contain mixed pixels in heterogeneous areas.

RESULTS

Waterbird and nest abundance patterns

A total of 25 waterbird species were recorded in the sanctuary. Among them, 11 waterbird species nested in the first year and reduced to three species in the last year of study. Total waterbird abundance increased from 2012–13 (n = 648) to 2016–17 (n = 990), followed by a sharp decline in subsequent years and again reached higher values in 2025–26 (n = 967) (Image 2). Total waterbird nests showed an overall declining trend. The highest number of nests was recorded in 2012–13 (396 nests), decreased to 190 in 2025–26, with inter-annual fluctuations in between (Image 3).

Species-wise abundance showed an overall increase in Asian Openbill *Anastomus oscitans* (n = 500 in 2025–26), the highest among all species. Black-headed Ibis *Threskiornis melanocephalus* abundance also increased, with a peak in 2025–26 (n = 300). Little Egret *Egretta garzetta* reached a peak of 150 individuals in 2016–17, followed by a sharp decline in later years. Species like Indian Cormorant *Phalacrocorax fuscicollis* and Little

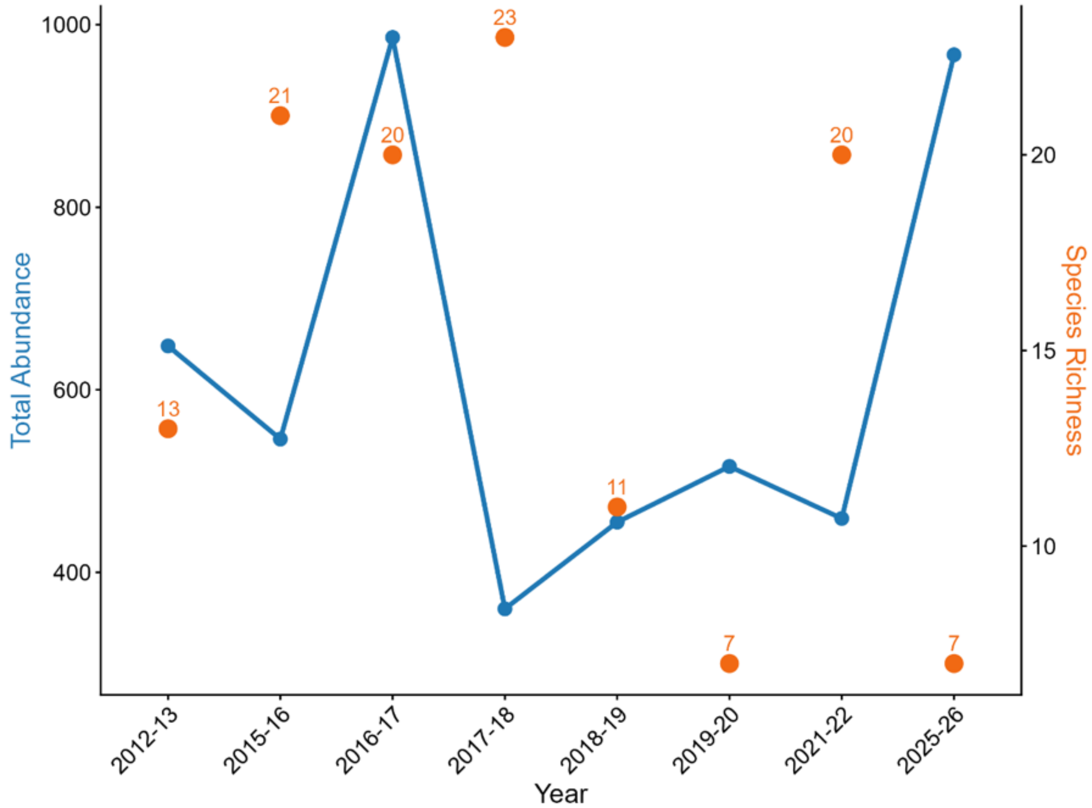

Image 2. Total waterbird abundance and overall waterbird species richness across study years in Vettangudi Bird Sanctuary.

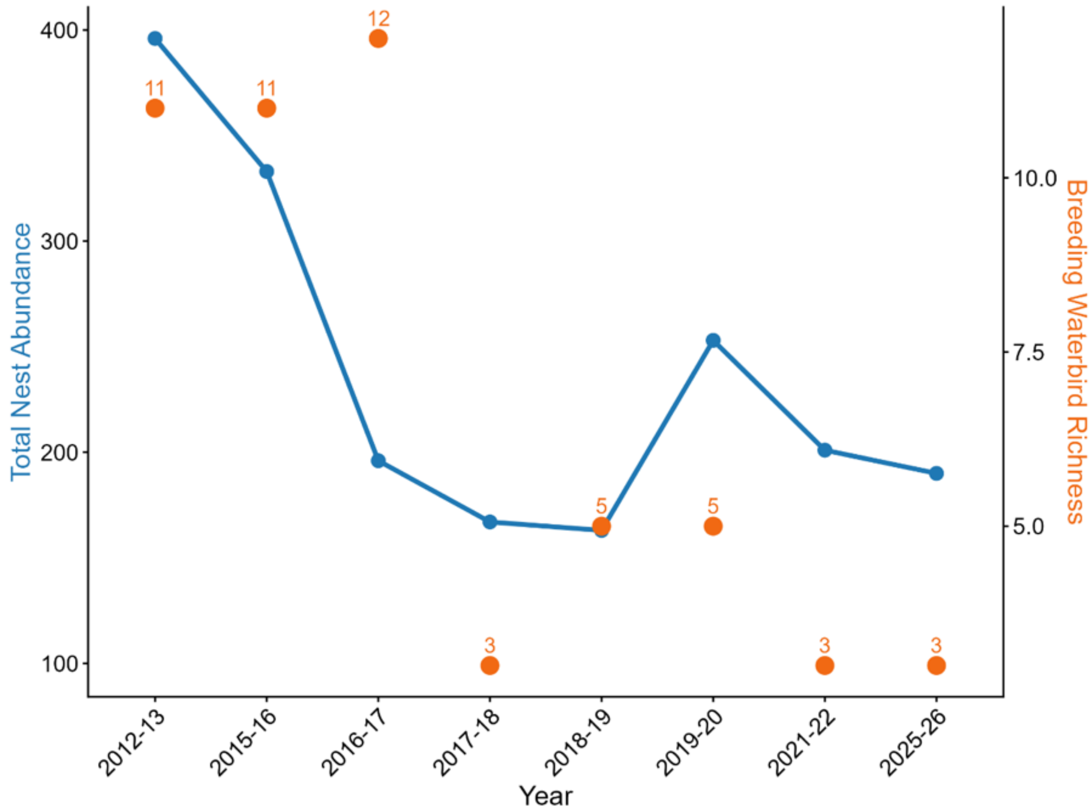

Image 3. Total nest abundance and richness of breeding waterbirds across study years in Vettangudi Bird Sanctuary.

Table 1. Shannon-Weiner diversity index values calculated for the breeding waterbirds.

Year	Shannon index
2012–13	1.701
2015–16	1.320
2016–17	1.772
2017–18	0.376
2018–19	1.310
2019–20	0.984
2021–22	0.532
2025–26	0.878

Table 2. Spearman correlation analysis of nest abundance and breeding waterbird diversity with the habitat characteristics.

Nest abundance	August		December	
	Rho	p value	Rho	p value
Water	-0.061	0.884	-0.282	0.498
Moderate vegetation	0	1	-0.595	0.132
Dense vegetation	0.428	0.299	0.523	0.196
Breeding waterbirds diversity	August		December	
	Rho	p value	Rho	p value
Water	-0.741	0.035	-0.245	0.557
Moderate vegetation	0.38	0.359	0.166	0.703
Dense vegetation	-0.238	0.582	0.023	0.976

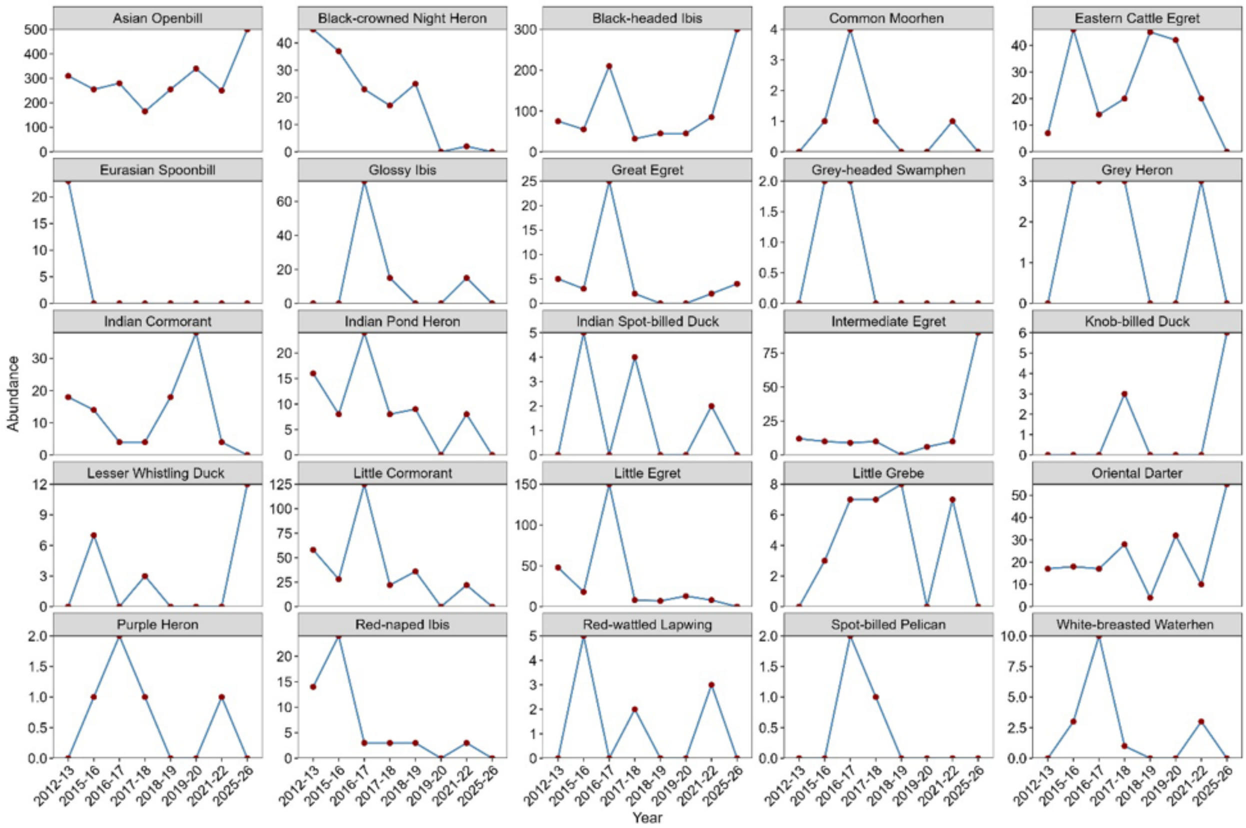

Image 4. Abundance of individual waterbird species recorded across years in Vettangudi Bird Sanctuary.

Cormorant *Microcarbo niger* did not nest in 2025–26 (Image 4).

Similarly, Asian Openbill nests were the highest, peaking at 210 in 2015–16, but declined in 2025–26. Black-headed Ibis exhibited a marked increase in nesting in 2025–26 (120 nests). Several species exhibited a complete absence of nesting in later years (after 2016–17) despite earlier occurrence. Little Egret nested from 2012–13 to 2016–17 but was absent thereafter. Black-crowned Night Heron *Nycticorax nycticorax* also declined from 28 nests (2012–13) to three nests (2017–18) and did not nest thereafter (Image 5).

Breeding waterbird community composition

The steep rank–abundance slope indicates reduced evenness, indicating strong dominance by a few species. Asian Openbill was the most abundant species, followed by Black-headed Ibis and Little Cormorant (Image

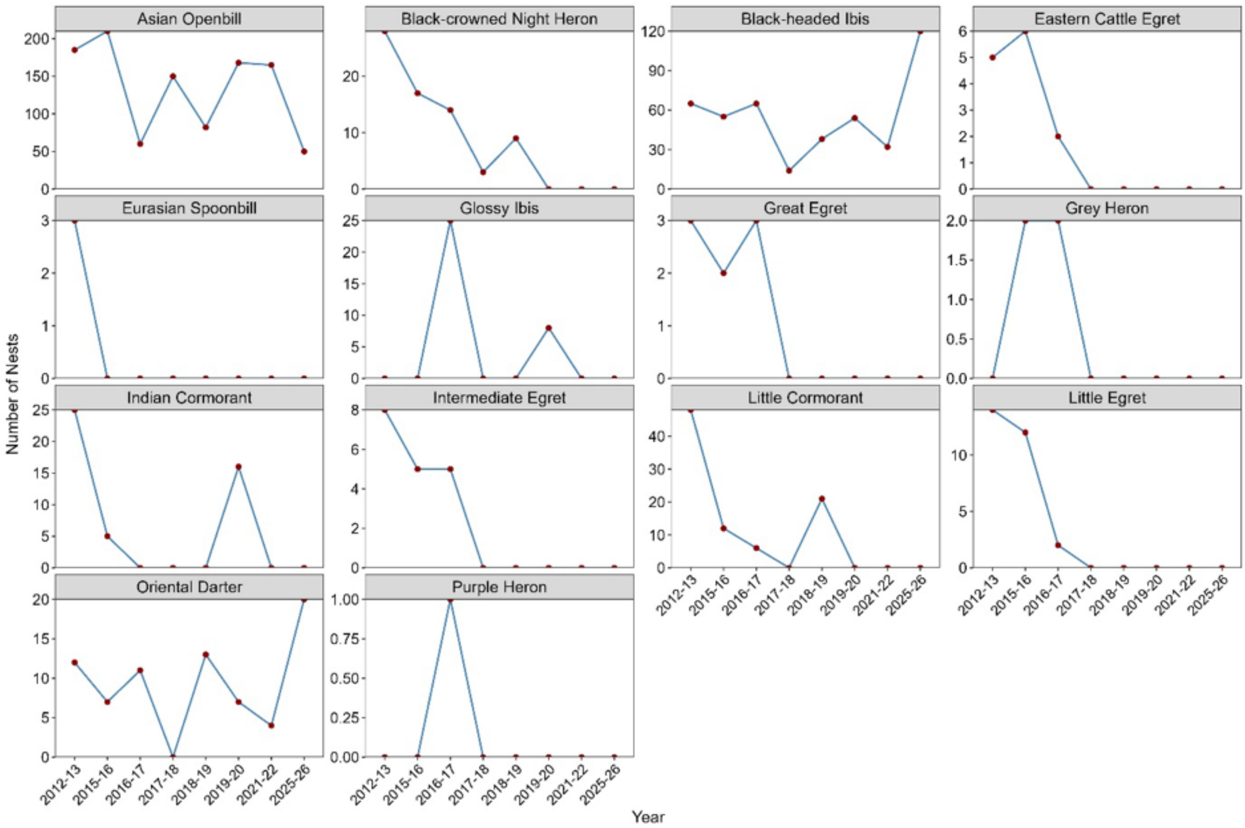

Image 5. Nest abundance of waterbird species recorded across years in Vettangudi Bird Sanctuary.

6). Bray–Curtis similarity values varied substantially among years, ranging 0.00–0.64. The highest similarity was recorded between 2017–18 and 2025–26 (0.64), followed by 2015–16 and 2025–26 (0.58). Hierarchical clustering further supported this pattern, grouping 2015–16, 2018–19, and 2021–22 together, while 2017–18 and 2025–26 formed a distinct cluster (Image 7).

Temporal trends

No significant overall temporal trend was detected in total waterbird abundance ($\tau = -0.071$, $p = 0.902$), although Sen's slope indicated a marginal decline. At the species level, significant declining trends were detected for Black-crowned Night Heron ($\tau = -0.764$, $p = 0.013$), Little Egret ($\tau = -0.618$, $p = 0.046$), and Red-naped Ibis *Pseudibis papillosa* ($\tau = -0.701$, $p = 0.032$).

Non-significant increasing trends were observed in Asian Openbill ($\tau = 0.109$, $p = 0.803$), Black-headed Ibis ($\tau = 0.182$, $p = 0.618$) and Oriental Darter *Anhinga melanogaster* ($\tau = 0.255$, $p = 0.454$) (Image 8).

Seasonal habitat characteristics and the breeding waterbirds

LULC and breeding waterbird diversity

Shannon diversity was the highest in 2016–17 (H' = 1.772) and lowest in 2017–18 (H' = 0.376) (Table 1). In the entire study period, water extent exhibited a significant negative correlation in August ($\rho = -0.74$, $p = 0.035$), and significant relationships were observed between Shannon diversity and moderate vegetation ($\rho = 0.38$, $p = 0.36$) or dense vegetation ($\rho = -0.24$, $p = 0.58$). In December, none of the LULC variables showed significant associations with diversity, including water extent ($\rho = -0.25$, $p = 0.56$), moderate vegetation ($\rho = 0.17$, $p = 0.70$), and dense vegetation ($\rho = 0.02$, $p = 0.98$), even though water extent showed a slightly negative correlation (Table 2).

LULC and nesting abundance

In the entire period of study, no significant relationship was observed between water extent and waterbird nesting abundance in either August ($\rho = -0.06$, $p = 0.88$) or December ($\rho = -0.28$, $p = 0.50$). Similarly, moderate vegetation exhibited no association with nesting abundance in August ($\rho = 0$, $p = 1.00$), although a

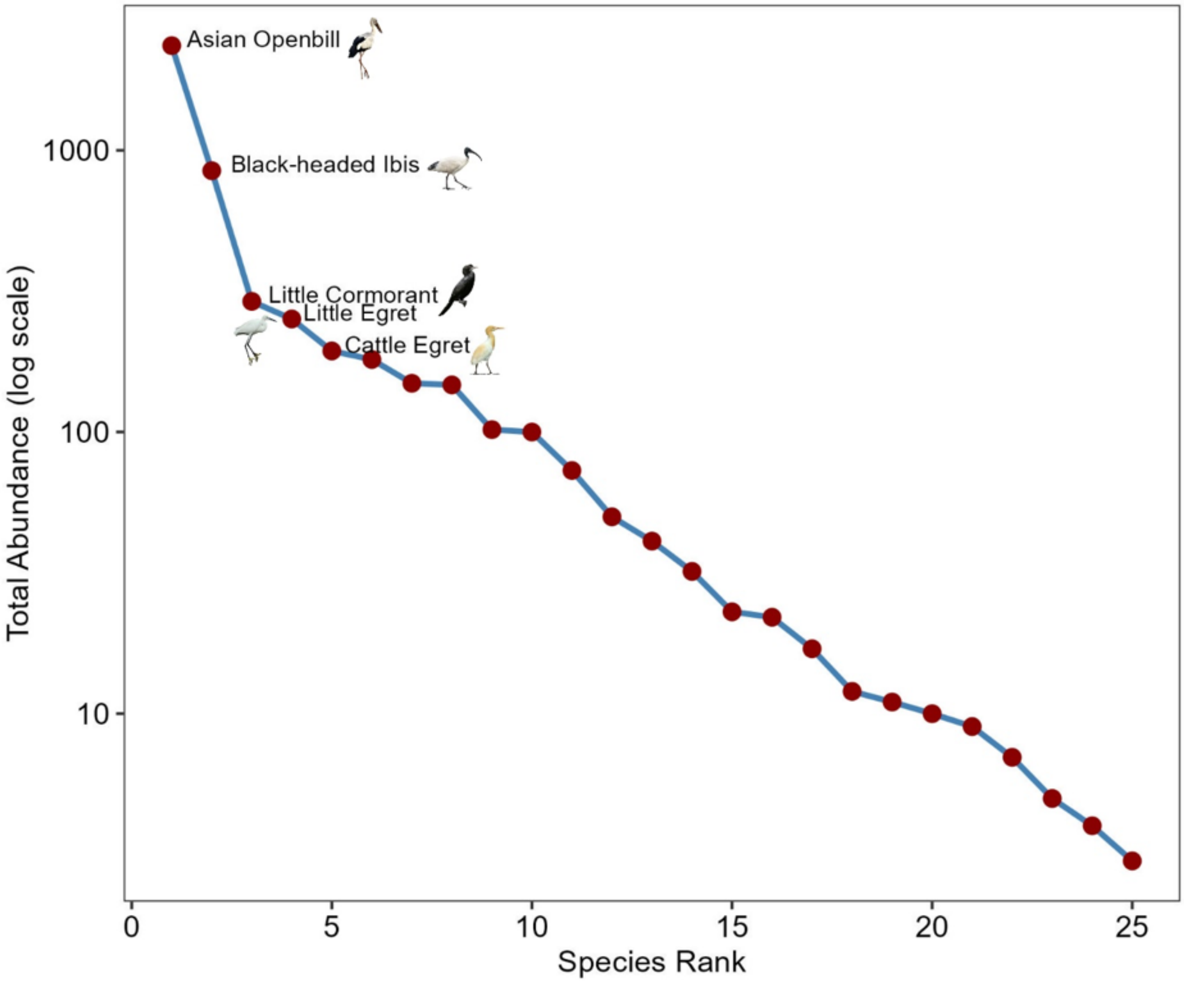

Image 6. Rank abundance curve showing the five most abundant waterbirds recorded across all years.

negative trend was observed in December (ρ = −0.60, p = 0.13). Dense vegetation showed a positive relationship with nesting abundance, with a stronger association in December (ρ = 0.52, p = 0.20) than August (ρ = 0.43, p = 0.30), with no statistical significance (Table 2).

DISCUSSION

Temporal patterns in abundance and species composition

In Vettangudi, all waterbirds showed a declining trend, except four species. Although total waterbird abundance showed considerable interannual fluctuations and no significant overall temporal trend, nesting abundance decreased from 2012–13 to 2025–26. The decline in nesting activity was accompanied by a reduction in breeding species richness, indicating that population size alone may not reflect habitat suitability for breeding waterbirds. Similar patterns have been reported from other tropical wetlands, where wetlands continue to support large numbers of foraging individuals despite experiencing reductions in nesting opportunities and breeding success (Mott et al. 2023; Wang et al. 2023).

The pronounced decline observed after 2016–17 suggests that the sanctuary underwent ecological changes affecting breeding suitability. Waterbird breeding colonies are highly sensitive to alterations in hydrological conditions, prey availability, and nesting habitat stability; hence, even relatively small changes can lead to reduced nesting effort or colony abandonment (Frank et al. 2021). The reduction in 11 nesting waterbird species during earlier years to only three species in 2025–26 indicates a possible loss of ecological resilience (Byju et al. 2025a).

Changes in assemblage composition were further reflected in the Bray-Curtis similarity analysis, which showed substantial turnover among years. The low similarity values between some breeding seasons indicate that species composition was highly dynamic

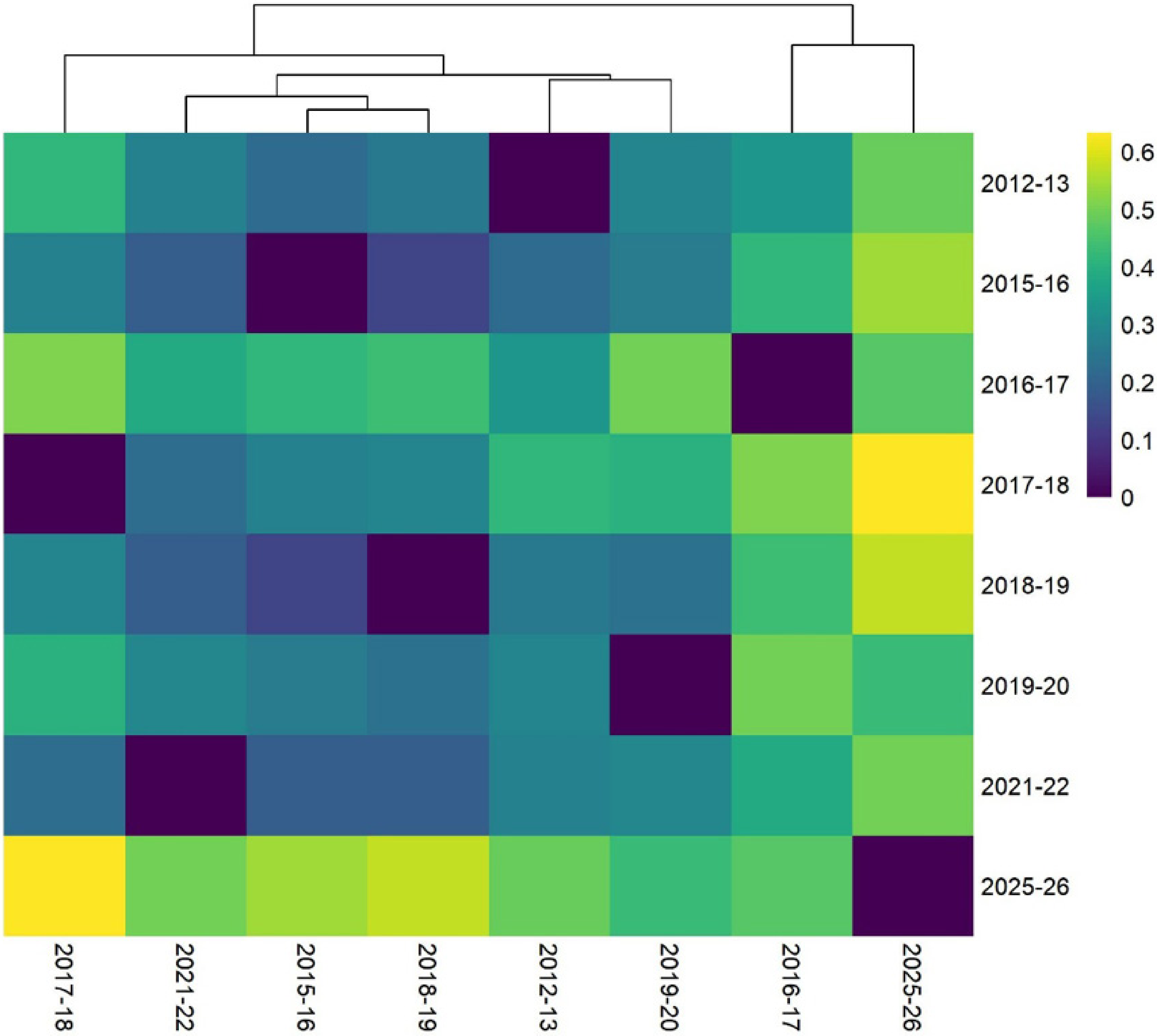

Image 7. Hierarchical cluster diagram showing the similarities in waterbird species composition among study years with Bray-Curtis values.

rather than stable through time. Such temporal turnover is often associated with fluctuations in hydrological conditions, changes in habitat structure, and shifts in resource availability that differentially affect species according to their ecological requirements (Magurran & Henderson 2010; Byju et al. 2024). The observed dominance of a few species in later years, as reflected in the steep rank–abundance curves, suggests that habitat conditions increasingly favoured a limited subset of adaptable species while becoming less suitable for others (Narwade & Ukarande 2021; Byju et al. 2023b).

Climate variability may have further contributed to these patterns. In tropical wetlands, breeding initiation is strongly influenced by rainfall, water availability, and seasonal productivity (Ramamohan & Rao 2024). Irregular rainfall and hydrological instability have been identified as major drivers of declining breeding performance in wetland birds across the Central Asian Flyway and South Asia (Mundkur et al. 2023). Consequently, the long-term changes observed in Vettangudi are likely the result of multiple interacting factors, including habitat alteration, hydrological fluctuations, and anthropogenic disturbance.

Changes in nesting tree composition/ diversity and habitat characteristics

The observed changes in colonial nesting waterbird breeding patterns appear closely linked to alterations in nesting habitat structure, reducing interspecific competition (Venkataraman et al. 2012). In Vettangudi Sanctuary, Oriental Darter, Asian Openbill and Black-headed Ibis nested on medium-sized *Acacia nilotica* and

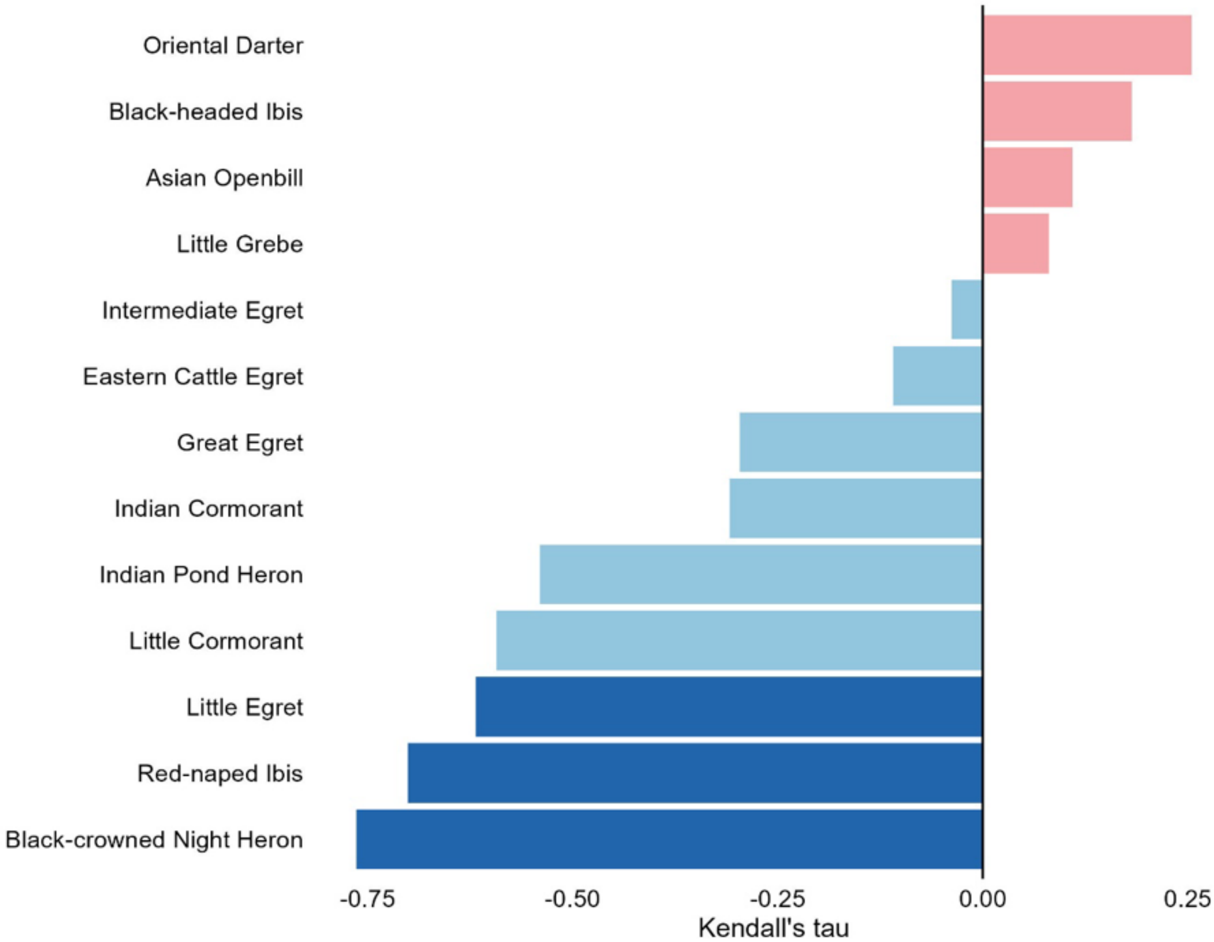

Image 8. Mann-Kendall trend analysis showing the species with positive and negative Tau values: dark blue—those with statistically significant trends | light blue and light red—no significant trend.

Neltuma juliflora trees, corroborating the findings by Frank et al. (2021), for both protection and proximity to feeding areas (Subramanya 2005). In the initial years of the study, the front layer of trees facing the waterfront had mature *Parkinsonia aculeata* trees where egrets and herons nested. In the middle years of the study period, these trees were removed for widening and deepening of the water-holding area, leading to fewer or no nesting trees for the species. Towards the later years of the study, since the newly growing young *Parkinsonia aculeata* plants are not yet suitable for nesting, the egrets and herons might have abandoned nesting in the tank for now.

The LULC analysis provides additional evidence that habitat quality may be more important than habitat extent in determining breeding responses, as clear seasonal differences were observed between August (nest initiation) and December (peak nesting) across years. Dense vegetation exhibited substantial interannual variability in August, whereas it remained comparatively more stable during December. This is reflected in relatively stronger associations between dense vegetation structure and breeding responses during December, while species diversity patterns appear more responsive to variation in water extent during the nest initiation phase. These patterns suggest that habitat conditions during the peak breeding period may exert a greater influence on nesting abundance (Ion et al. 2026).

The findings of LULC indicated that an increase in total water area alone did not correspond to improved nesting conditions, as the suitability of foraging habitats may still depend on factors such as water depth. Increased water may reduce prey availability for species that require shallow waters for foraging (Kalam & Urfi 2008). Similarly, dense vegetation did not transform into higher nesting, suggesting that the quality, structure, or vegetation heterogeneity may be more critical than their overall extent, especially with the homogenized, less diverse tree species with dominance of *Neltuma* *juliflora* (Hafner 2000; Mott et al. 2023), reducing habitat suitability for several breeding species despite maintaining overall vegetation cover.

Waterbird species-specific responses

Asian Openbill and Black-headed Ibis were the only species that showed increasing abundance and maintained substantial nesting populations in recent years. Asian Openbill, in particular, remained the dominant breeding species throughout the study and reached its highest abundance during the final breeding season. The species is known for its ecological flexibility and its ability to exploit a variety of wetland habitats and agricultural landscapes, particularly where freshwater molluscs are abundant (Choi et al. 2007). Similarly, Black-headed Ibis exhibited a marked increase in both abundance and nesting activity, suggesting that the sanctuary continues to provide suitable nesting and foraging conditions for large-bodied generalist species (Narwade & Ukarande 2021).

In contrast, several species exhibited severe declines or complete cessation of breeding. Little Egret, once among the most abundant breeding species, disappeared entirely from the nesting assemblage after 2016–17, despite continued occurrence in the surrounding landscape. Likewise, Black-crowned Night Heron declined steadily and failed to nest during the later years of the study. Red-naped Ibis also showed a significant negative trend. These declines suggest that habitat changes may have affected species differently according to their nesting preferences, foraging ecology, and tolerance to disturbance. The disappearance of several egret and heron species indicates that the sanctuary may no longer provide the structural characteristics required for nesting, even if suitable foraging habitats of agricultural fields and wetlands nearby suggest a shift in breeding site selection rather than complete local population loss (Xie et al. 2019; Byju et al. 2025b). Species-specific responses have been documented where environmental changes may selectively favour adaptable species while causing declines in habitat specialists similar to other colonial waterbird assemblages (Weseloh & Green 2018).

The increasing dominance of Asian Openbill and Black-headed Ibis therefore represents a partial recovery of waterbird populations rather than a recovery of the breeding community as a whole. This shows that only a few resilient species can adapt to changing environmental conditions, increasing their dominance (Byju et al. 2025c). Increasing dominance by a few species may indicate declining habitat heterogeneity within the wetland ecosystem (Magurran & Henderson 2010).

Management Implications

The results highlight the importance of maintaining habitat quality and structural heterogeneity rather than focusing solely on increasing water availability or vegetation cover. Conservation efforts in Vettangudi should prioritize the protection and afforestation of suitable nesting trees, particularly species historically used by egrets, herons, and ibises. Habitat restoration programmes should promote a diverse assemblage of native nesting tree species rather than reliance on a single dominant species.

Hydrological changes may represent a major concern, particularly the withdrawal of water for irrigation coinciding with the breeding period. Although measures such as strengthening bunds and desilting might have improved water availability in recent years, their timing of implementation might have disrupted the breeding season in waterbirds. Breeding waterbirds in the sanctuary are affected by a combination of hydrological changes, habitat alteration, and human disturbance due to its proximity to settlements, all of which can influence nesting success and colony stability (Byju et al. 2025d).

Asian Openbill was the first among all species to start nesting in the sanctuary in all years, particularly in the 2025–26 breeding season, despite the construction work, sand mining to increase the depth of the water column, and the related disturbances by humans and machines for a few months inside the tank.

Activities such as fuelwood collection, livestock grazing, large gatherings with noise, and sometimes firecrackers by the villagers also contribute to disturbance to birds. Establishing seasonal buffer zones around active nesting colonies and increasing community participation in sanctuary management could reduce disturbance pressures while strengthening local conservation support

CONCLUSION

This study provides one of the few long-term assessments of breeding waterbird assemblages in a tropical irrigation-tank wetland of southern India. Nesting abundance and breeding species richness declined substantially over the study period, indicating a progressive reduction in the suitability of Vettangudi Bird Sanctuary as a breeding habitat for several waterbird species.

Breeding responses appear to be influenced by a combination of habitat quality attributes, including nesting substrate availability, vegetation heterogeneity, hydrological stability, and levels of disturbance. The removal of mature nesting trees, coupled with increasing vegetation homogenization and habitat modification, likely contributed to the observed changes in species composition and nesting patterns. These results support the hypothesis that habitat quality is a more important determinant of breeding assemblage structure and nesting abundance than habitat extent alone.

The study highlights the conservation value of long-term ecological monitoring in identifying gradual changes that may not be evident from short-term surveys in Vettangudi Sanctuary. As climate variability and anthropogenic pressures continue to reshape tropical wetlands, sustaining breeding waterbird populations will require management strategies that focus not only on preserving wetland area, but also on maintaining the ecological processes and habitat complexity that underpin successful reproduction.

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