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Bird Diversity and Spatial Distribution at a High-Altitude Wetland in Eastern Anatolia: A Grid-Based Assessment of Çalı Lake (Kars, Türkiye) and Its Implications for Sustainable Wetland Management

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Abstract

High-altitude wetlands in the Caucasus Anatolia transition zone remain among the least-documented avian habitats in the Western Palearctic. Standardised avian biodiversity assessment in such systems provides essential evidence for sustainable wetland management, supporting the conservation planning and long-term ecological monitoring needed to safeguard these ecosystems under increasing anthropogenic pressure. We report on the avifauna of Çalı Lake (2237 m a.s.l.; 391 ha; Kars Province, Türkiye), a nationally designated wetland located on the Central Asian Flyway, based on five systematic survey periods conducted from March 2024 to Spring 2026 using line transects and point counts, combined with a 25 × 25 m grid-based GIS analysis encompassing 498 cells. Approximately 31 ha of the core open-water and marsh perimeter within the 391 ha designated boundary is covered; upland steppe and pasture zones beyond the active survey perimeter were excluded. A total of 154 species belonging to 18 orders and 41 families were recorded, representing approximately 30.5% of Turkey's national checklist. IUCN status assessment identified two Endangered species, *Neophron percnopterus* and *Oxyura leucocephala*, two Vulnerable, five Near Threatened, and 145 Least Concern species. Grid-level species richness averaged 1.47 ± 1.20 per cell per period; cumulative richness per grid reached 7.62 ± 2.73 across all five survey periods. Spearman rank correlation between per-grid richness (S) and abundance (N) was consistently strong across all five periods (ϱ = 0.52–0.60; all $p < 0.001$). A Friedman test indicated significant overall variation across periods ($\chi^2(4) = 127.73$, $p < 0.001$, Kendall's W = 0.064, a negligible effect size by conventional benchmarks, indicating that the statistically significant variation reflects trivially small per-cell richness differences at this block size). Bonferroni-corrected post hoc Wilcoxon tests revealed that all significant contrasts involved the 2024 Spring–Summer period or the 2026 partial Spring window, while the four fully comparable 2024 Autumn–2025 periods showed no significant differences. A Lorenz concentration curve yielded a Gini coefficient of 0.351, with the top 10% of grid cells concentrating 24.0% of all individual detections in the central and south-western lake zones. Collectively, these findings document Çalı Lake as a species-rich high-altitude wetland with significant conservation value, and establish a reproducible spatial and temporal baseline for long-term ornithological monitoring. These results demonstrate the value of standardised biodiversity assessment as a practical tool for sustainable wetland governance and align with international sustainability frameworks, including the UN Sustainable Development Goals on life on land and clean water and sanitation.

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1. Introduction

Wetlands support a disproportionately large share of global biodiversity relative to their area, yet they are disappearing faster than any other ecosystem type at a rate estimated to be three times higher than that of forests since 1970 [1]. For birds, shallow freshwater wetlands are functionally irreplaceable: the structural mosaic of open water, emergent macrophytes, shoreline ecotone, and adjacent wet grassland provides feeding, breeding, moulting, and migratory staging resources within a compact spatial footprint [2,3]. The convergence of these functions in a single landscape explains why wetland bird richness is consistently higher than that of surrounding upland habitats of equivalent area [3,4].

Turkey's geographical position at the junction of three continents makes it one of the most ornithologically significant countries in the Western Palearctic. Its inland wetlands serve as critical nodes for migratory birds travelling between Eurasian breeding grounds and sub-Saharan wintering areas. Systematic bottleneck counts at the Bosphorus alone have recorded over 100,000 soaring migrants in a single Spring season. In one such season, as many as 119,381 White Storks (*Ciconia ciconia*) were counted at this single site. These totals capture only the visible soaring-bird component of the country's migratory traffic. A much larger, less precisely quantified number of passerines and waterbirds also cross the country on a broad front each year [5,6]. Despite this strategic position, large parts of the Anatolian plateau and the Caucasus border region remain poorly inventoried, particularly at high elevation [7,8].

Çalı Lake (Kars Province; 40°26′ N, 43°10′ E; 2237 m a.s.l.; ~391 ha) lies precisely in this data-deficient zone. Designated a nationally important wetland by the Turkish Ministry of Agriculture and Forestry, the lake occupies the Eastern Anatolian plateau at the intersection of the Central Asian Flyway, a migration corridor linking breeding areas across Russia and Central Asia with wintering grounds in South Asia and sub-Saharan Africa [9]. Earlier official inventories acknowledged the site's value by listing 114 bird species and noting the presence of the globally Endangered White-headed Duck *Oxyura leucocephala*, yet no study had systematically quantified how bird assemblages are distributed spatially within the lake, whether species richness varies significantly across seasons and years, or which zones carry the highest concentrations.

The present study addressed these gaps through three objectives: (i) compile a fully annotated checklist with current IUCN conservation status for all recorded species; (ii) test using a repeated-measures framework appropriate to the resurveyed-grid design whether species richness varies across five survey periods, between seasons, and between years; and (iii) map spatial density hotspots across 498 grid cells to identify priority zones for conservation management.

2. Materials and Methods

2.1. Study Area

Çalı Lake lies on the Eastern Anatolian plateau within the administrative boundaries of Kars Central and Digor districts (Figure 1). The Kars–Digor highway bisects the lake into two hydraulically connected basins. The designated wetland covers approximately 391 ha, with an additional 481 ha buffer zone [10]. At 2237 m a.s.l., the site experiences a harsh continental climate with mean annual precipitation of approximately 500 mm; winter snow

cover typically persists from December through late February or early March, restricting surveys to the ice-free months.

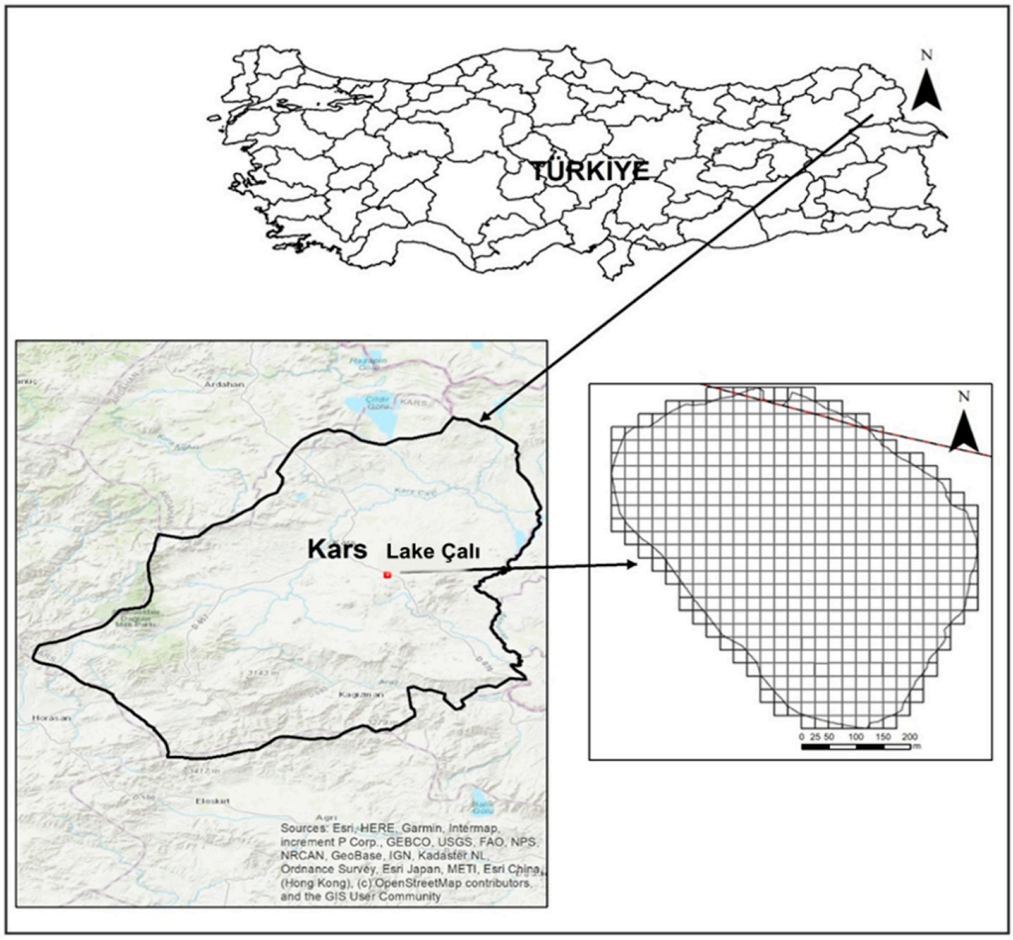


Figure 1. Location of Çalı Lake within Turkey and the 25 × 25 m survey grid applied to the study area (Kars Province, north-eastern Turkey). The inset shows the 498-cell grid overlaid on the lake boundary. Base map data © OpenStreetMap contributors, available under the Open Database License (ODbL) v1.0 (https://www.openstreetmap.org/copyright accessed on 20 June 2026); map rendering and grid overlay produced by the authors in ArcMap 10.x (ESRI, Redlands, CA, USA)

Four habitat types are recognisable within the wetland boundary (Figure 2): (1) open water, forming the hydrological core (Corine Land Cover class: water bodies); (2) inner marsh a fringe of aquatic macrophytes (predominantly Phragmites australis and Typha spp.) providing structural complexity at the land–water interface (inland marshes); (3) wet grassland and pasture; and (4) open steppe (natural grassland). The northern and north-eastern shores lie closest to the highway and the adjacent village of Borluk, creating an anthropogenic disturbance gradient that proved relevant to spatial bird distribution (see Section 3.3).

2.2. Field Surveys and Species Classification

Fieldwork was conducted from 20 March 2024 to Spring 2026 across five survey periods: Spring–Summer 2024 (March–August), Autumn 2024 (September–November), Spring–Summer 2025, Autumn 2025, and Spring 2026. Visits were spaced approximately 15 days apart within each period, conducted between 06:00–11:00 and 16:00–19:00 local time, and cancelled during rain or strong wind. Completed survey visits per period: 2024 Spring–Summer, 12 visits (six-month window, March–August); 2024 Autumn, 6 visits (September–

November); 2025 Spring–Summer, 12 visits; 2025 Autumn, 6 visits; 2026 Spring, 4 visits (partial window, March–May). The asymmetry in visit count between Spring–Summer and Autumn periods is an acknowledged potential sampling-effort confound and is addressed in the Discussion (Section 4.3). Two methods were applied simultaneously: line transects walked at a constant pace along fixed routes covering all accessible habitat types, and fixed-point counts at stations with unobstructed views over open water. Species nomenclature followed the IOC World Bird List (v12.2) [11]. Conservation status was assigned using IUCN Red List criteria [12]. (Status cutoff: 15 April 2025; no Red List category changes for the four threatened species were identified in subsequent assessments through the date of submission.) The Turkish national species list follows the Turkish Bird Records Committee [13], currently recognising 505 species [13].

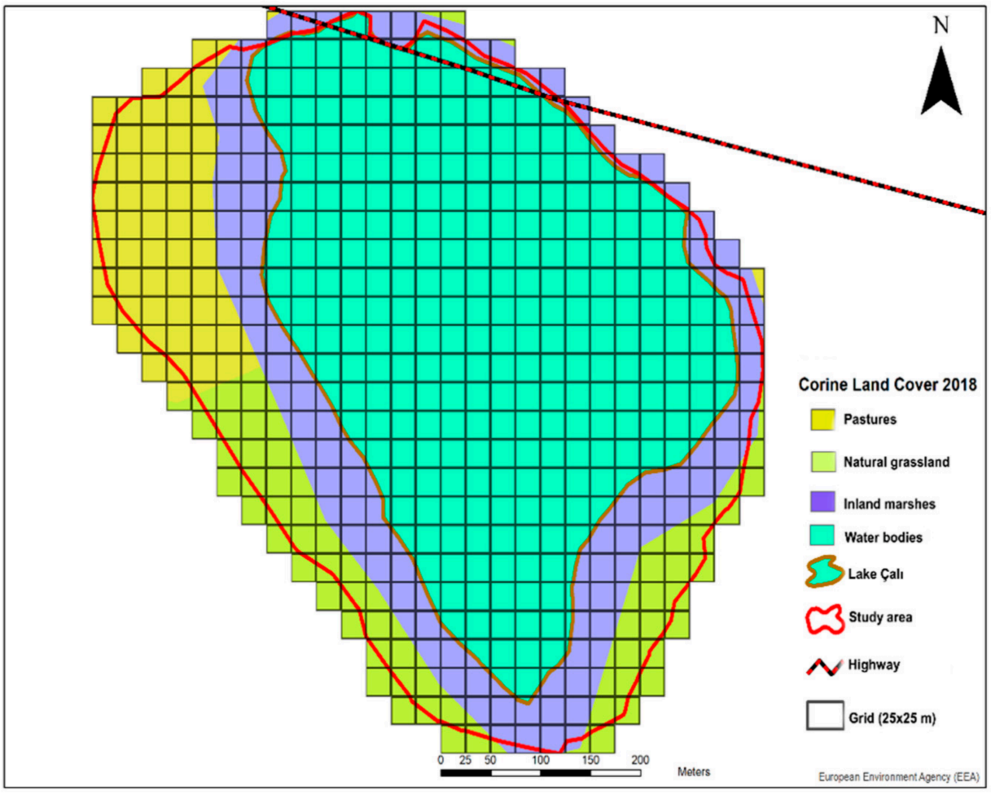


Figure 2. Habitat classification of the Çalı Lake study area based on Corine Land Cover 2018 data, overlaid with the 25 × 25 m survey grid and the Kars–Digor highway. Source: European Environment Agency (EEA). (ESRI, Redlands, CA, USA)

2.3. Grid-Based GIS Analysis and Statistics

All georeferenced detections were overlaid onto a 25 × 25 m grid using ArcMap 10.x (ESRI) (Redlands, CA, USA), producing 498 cells (total gridded area ≈ 31 ha, representing the core open-water and marsh perimeter within the 391 ha designated wetland boundary; upland steppe and pasture cells outside the active survey zone were excluded from the grid). For each cell and each period, species richness (*S*) and individual count (*N*) were extracted. Because the same 498 grid cells were resurveyed in every period, the design is inherently repeated-measures (each cell = one block observed five times). Using independent-samples tests (e.g., Kruskal–Wallis or Mann–Whitney) would inflate the effective sample size and violate the independence assumption. Accordingly, (a) a Friedman test with Kendall's W assessed overall variation across five periods; (b) Bonferroni-corrected paired Wilcoxon signed-rank tests served as post hoc comparisons (10 pairs); (c) paired Wilcoxon tests with rank-biserial correlation r assessed seasonal and inter-annual differences; and (d) Spear-

man ϱ quantified the per-grid S–N relationship. A Lorenz concentration curve and Gini coefficient described spatial heterogeneity of abundance. Detection assignment to cells followed a nearest-centroid rule: each georeferenced point was attributed to the 25 × 25 m cell whose centroid was closest to the recorded GPS coordinate. For line-transect detections, the observer's on-transect GPS location at detection was used. We acknowledge that at this resolution, flocks may register across adjacent cells, introducing positive spatial autocorrelation between neighbouring cells; this limitation is discussed in the context of the Spearman S–N interpretation (Section 4.3). All analyses were performed in Python 3.11 (SciPy 1.11; NumPy 1.25); $\alpha = 0.05$ throughout.

3. Results

3.1. Species Composition and Conservation Status

Over the full study period, 154 species belonging to 18 orders and 41 families were recorded, representing approximately 30.5% of Turkey's national checklist [13]. Passeriformes was the dominant order in every survey period. Among waterbird orders, Charadriiformes, Anseriformes, and Gruiformes made the greatest contribution in terms of individual counts. Of the 154 species, 145 (94.2%) were classified as Least Concern (LC), five (3.2%) as Near Threatened (NT), two (1.3%) as Vulnerable (VU)—Common Pochard *Aythya ferina* and Turtle Dove *Streptopelia turtur*—and two (1.3%) as Endangered (EN)—Egyptian Vulture *Neophron percnopterus* and White-headed Duck *Oxyura leucocephala*. The distribution of species across IUCN categories is illustrated in Figure 3.

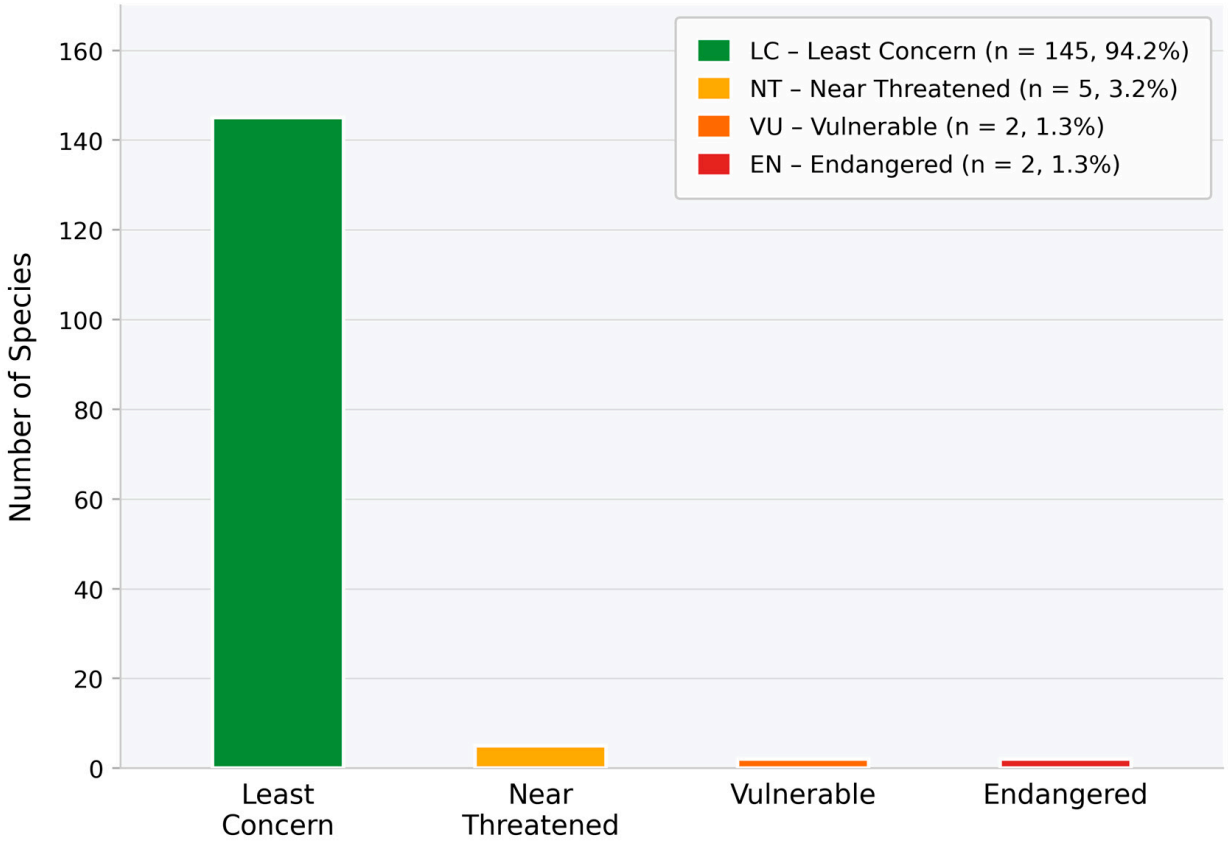


Figure 3. IUCN conservation status of 154 bird species recorded at Çalı Lake (2024–2026). LC = Least Concern; NT = Near Threatened; VU = Vulnerable; En = Endangered.

3.2. Grid-Level Richness, Abundance, and Temporal Patterns

Mean species richness per grid cell ranged from 1.18 ± 1.08 (2026 Spring) to 1.99 ± 1.10 (2024 Spring–Summer); cumulative richness per grid reached 7.62 ± 2.73 (median = 8; range = 2–17) across all periods combined. Grid occupancy the proportion of cells recording ≥1 bird was consistently between 77.7% and 79.3% across three of the four fully sampled periods, falling to 70.3% in the 2026 Spring window. Notably, the 2024 Spring–Summer period showed 100.0% occupancy (all 498 cells occupied), a clear outlier consistent with its longer six-month duration; this is acknowledged as a potential effort confound in Section 4.3. Total individual counts per period ranged from 3815 (2026 Spring) to 6774 (2024 Spring–Summer), with all period-level summaries presented in Table 1 and Figure 4.

Table 1. Per-period descriptive statistics from grid-level surveys at Çalı Lake (n = 498 grid cells).

Survey Period	Mean S (±SD)	Max S	Occupancy (%)	Total *N*	Mean N/Occupied Cell
2024 Spring–Summer	1.99 ± 1.10	7	100.0	6774	13.6
2024 Autumn	1.48 ± 1.20	6	77.7	5969	15.4
2025 Spring–Summer	1.48 ± 1.22	9	77.7	6189	16.0
2025 Autumn	1.49 ± 1.17	5	79.3	6101	15.4
2026 Spring *	1.18 ± 1.08	6	70.3	3815	10.9

S = species richness per grid cell; N = individual count per grid cell; Occupancy = percentage of 498 cells recording ≥1 individual; Mean N/occupied cell = mean count restricted to occupied cells only. * Partial survey window.

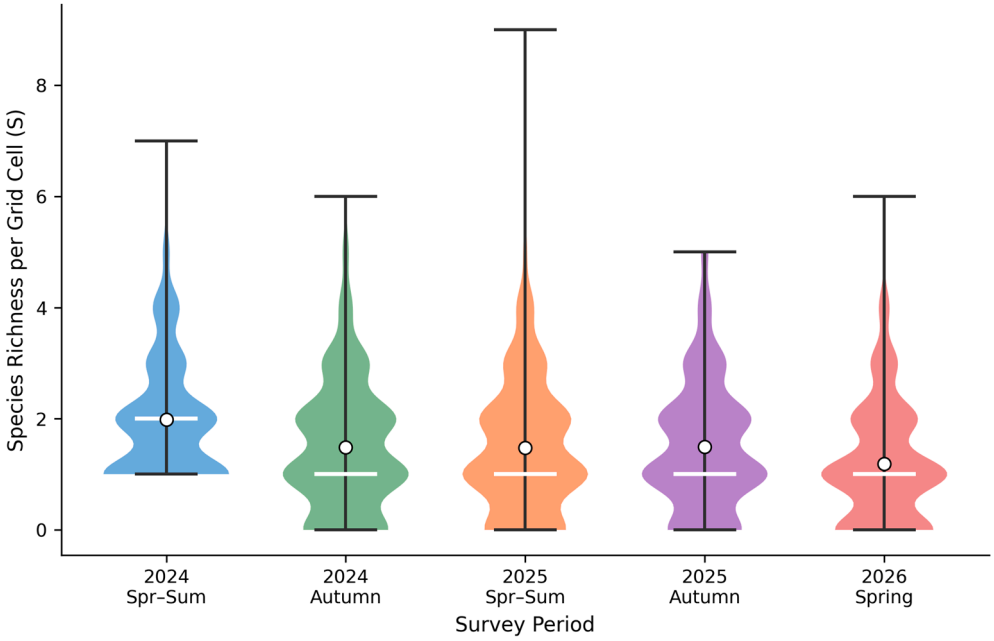


Figure 4. Distribution of grid-level species richness (S) across five survey periods (n = 498 grid cells per period). Violin width reflects the kernel density estimate; white circles = means; horizontal white lines = medians. Friedman test: $\chi^2(4) = 127.73$, $p < 0.001$, Kendall's W = 0.064.

Spearman rank correlation between S and N was positive and statistically significant across all five periods (⌋ϱ = 0.52–0.60; all $p < 0.001$; Table 2; Figure 5), with the combined dataset yielding $\varrho = 0.585$ (n = 2017 cell–period observations). This consistent positive association indicates that grid cells with large individual concentrations simultaneously support a greater variety of species, pointing to resource-rich hotspot zones that attract multiple ecological guilds.

Table 2. Spearman rank correlations between grid-level species richness (S) and abundance (N), restricted to occupied cells (S > 0).

Survey Period	Spearman ϱ	*p*-Value	n	Strength
2024 Spring–Summer	0.557	<0.001	498	Moderate–strong
2024 Autumn	0.573	<0.001	387	Moderate–strong
2025 Spring–Summer	0.523	<0.001	387	Moderate–strong
2025 Autumn	0.602	<0.001	395	Strong
2026 Spring *	0.555	<0.001	350	Moderate–strong
All periods combined	0.585	<0.001	2017	Strong

Strength classification follows conventional benchmarks [14]: ϱ 0.50–0.69 = moderate–strong; ≥0.70 = strong. * Partial survey window.

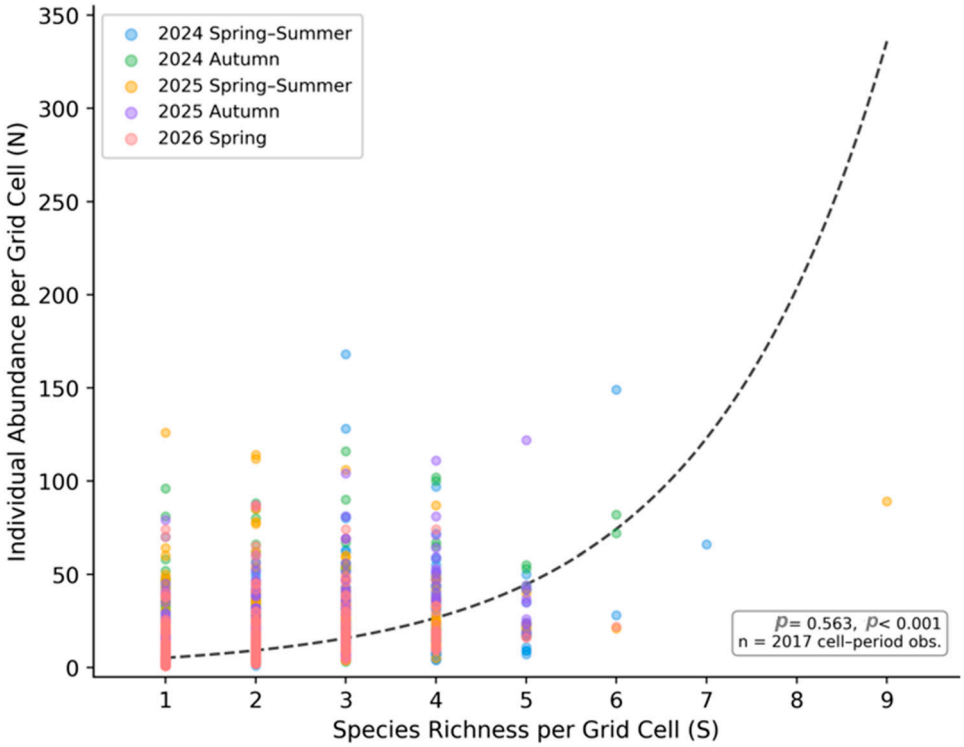


Figure 5. Spearman rank correlation between grid-level species richness (*S*) and individual abundance (*N*), pooled across all five survey periods (occupied cells only; *n* = 2017 cell–period observations). The dashed line represents a log-linear trend fitted to the pooled data.

The Friedman test revealed a statistically significant difference in per-grid richness across the five periods ($\chi^2(4) = 127.73$, $p < 0.001$; Kendall's W = 0.064; Figure 4). Post hoc Bonferroni-corrected paired Wilcoxon tests (10 comparisons; Figure 6) showed that all significant contrasts involved the 2024 Spring–Summer period (the highest-count window, mean *S* = 1.99) or the 2026 Spring partial window (mean S = 1.18) versus the other periods. Comparisons among the three genuinely stable periods (2024 Autumn, 2025 Spring–Summer, and 2025 Autumn) were uniformly non-significant (all p_adj = 1.00). The 2026 Spring partial window constituted a second outlier: its comparisons with each of the three stable periods were statistically significant (p_adj = 0.0002–0.0006), most likely reflecting reduced sampling effort (four visits) rather than a genuine shift in community composition. Paired Wilcoxon tests confirmed no meaningful seasonal effect within 2025 ($p = 0.981$, r = −0.001) and no inter-annual change in Autumn counts (2024 vs. 2025: $p = 0.907$, r = −0.007), with negligible rank-biserial effect sizes in all comparisons ($|r| < 0.02$).

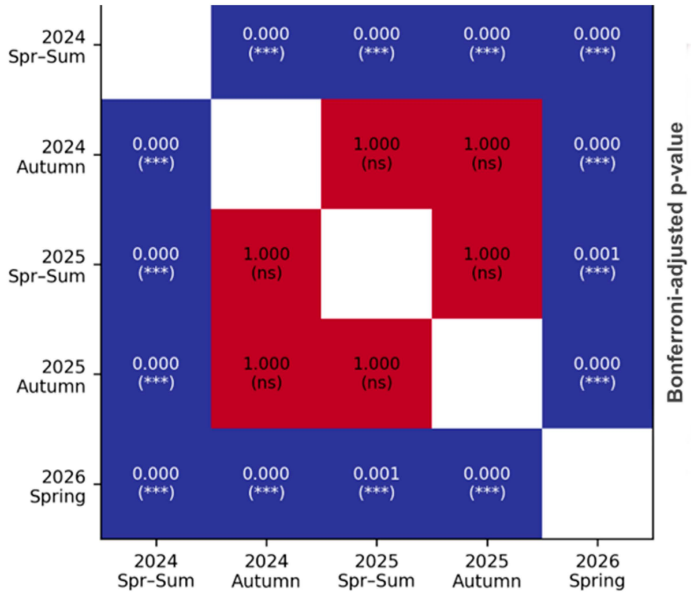


Figure 6. Bonferroni-corrected post hoc pairwise comparisons between survey periods (paired Wilcoxon signed-rank test, 10 comparisons). Dark red = p_adj < 0.001 (***); pale blue = non-significant (ns). 24SS = 2024 Spring–Summer; 24A = 2024 Autumn; 25SS = 2025 Spring–Summer; 25A = 2025 Autumn; 26Sp = 2026 Spring.

3.3. Spatial Concentration of Bird Abundance

The Gini coefficient for cumulative per-grid individual counts was 0.351, indicating moderate spatial inequality in bird use of the lake's grid cells (Figure 7). The top 10% of grid cells (n = 50) concentrated 24.0% of all individual detections across the study period. These hotspot cells were consistently located in the central, western, and south-western zones areas characterised by open water, inner marsh, and the shoreline ecotone while the northern and north-eastern sectors, proximate to the Kars–Digor highway and Borluk village, showed persistently lower densities. Gini values of 0.20–0.40 indicate moderate spatial concentration [15].

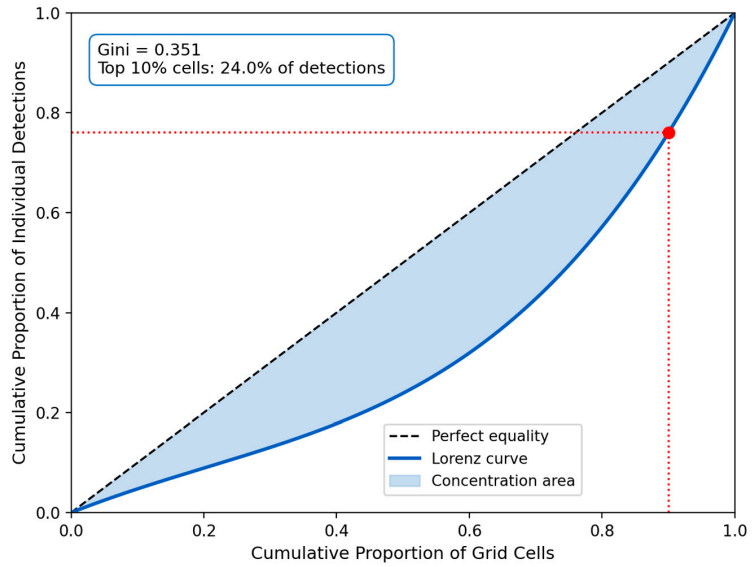


Figure 7. Lorenz concentration curve for cumulative per-grid individual detections (n = 498 grid cells, all five periods combined). The diagonal dashed line represents perfect equality. The shaded area quantifies the degree of spatial concentration. The red dotted lines mark the contribution of the top 10% of grid cells; the Gini coefficient is shown in the inset box.

Figure 8 provides a complementary summary of both species richness and total abundance across survey periods, illustrating the combined temporal pattern.

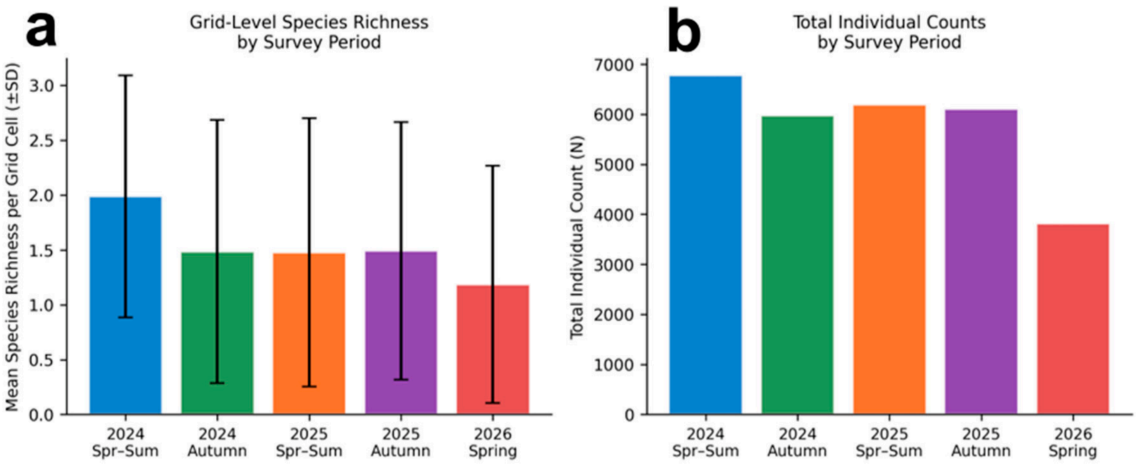


Figure 8. Descriptive summary of grid-level survey data (n = 498 cells) across five survey periods. (**a**) Mean species richness per grid cell (±SD). (**b**) Total individual counts. Colours correspond to survey periods as in Figure 4.

4. Discussion

4.1. Species Richness, Taxonomic Composition, and Regional Context

Recording 154 species at a 391 ha high-altitude lake over two complete field seasons yielded a substantial result. High-altitude wetlands in Turkey and across the broader Middle East are rarely documented in detail; those that have been surveyed typically yield between 67 and 74 species [16–19], placing Çalı Lake well above the regional mean for its elevation class. Globally, systematic inventories of high-altitude freshwater wetlands above 2000 m a.s.l. typically document between 50 and 130 species (e.g., Tibetan Plateau lakes: 80–120 species; alpine Central Asian wetlands: 55–95 species; Andean puna systems: 60–110 species), confirming that 154 species at Çalı Lake is a high value even within a global elevation-class context [4,20]. The richness documented here approaches that reported for lowland lakes receiving considerably greater research effort, such as Küçükçekmece Lake near Istanbul (171 species) [21] or Bulanık Plain in Muş (172 species) [22].

Three factors likely converge to explain this elevated richness. First, the site's position on the Central Asian Flyway channels diverse migratory assemblages through the Kars plateau each Spring and Autumn [9]. The importance of stopover availability along this flyway has been demonstrated by multiple studies showing that sites offering safe resting and foraging opportunities attract species far beyond what local breeding habitat would predict [23]. Second, the habitat mosaic of open water, inner marsh, grassland, and steppe within a compact footprint supports multiple ecological guilds simultaneously [4]. Third, the relatively low anthropogenic pressure across the western and central sectors preserves habitat quality for disturbance-sensitive species.

The dominance of Passeriformes across all survey periods reflects the surrounding open steppe landscape, consistent with other high-plateau wetlands in Anatolia [7,24]. The robust representation of Charadriiformes, Anseriformes, and Gruiformes underscores the lake's function as a waterbird staging site. Detection of Common Crane *Grus grus* across multiple periods confirms the role of the Kars plateau as a migration corridor for this species [25].

4.2. Conservation Significance of Threatened Species

The presence of two globally Endangered species is the most significant conservation finding of this study. The White-headed Duck *Oxyura leucocephala* has a global population estimated at fewer than 10,000 individuals, declining due to hybridisation pressure from the introduced Ruddy Duck *Oxyura jamaicensis*, hunting, and wetland degradation [12,26]. The eastern Turkish population using high-altitude steppe lakes in the Kars–Erzurum corridor is considered one of the species' most important strongholds [27]. Confirmed presence at Çalı Lake in each survey year strongly suggests that the site provides important staging habitat of international significance; whether the species breeds at the site requires confirmation through dedicated nest-finding surveys, as noted in the Conclusions.

The Egyptian Vulture *Neophron percnopterus* is a long-distance migrant that has undergone severe declines driven by poisoning, electrocution on power lines, and persecution in wintering areas [28,29]. European populations migrate through Turkey and the Middle East each Spring and Autumn; the Caucasus border region is a recognised bottleneck [30]. Regular records at Çalı Lake reinforce the strategic conservation importance of the Kars plateau for this species and argue for its inclusion in targeted monitoring programmes for migratory raptors.

The two Vulnerable species add further conservation weight. Common Pochard *Aythya ferina* has experienced a 30–49% global population decline due to eutrophication and degradation of freshwater habitats [31]. Turtle Dove *Streptopelia turtur* has declined by more than 75% in Europe over the past three decades, primarily from overhunting along migration routes and changes in arable land management [32].

4.3. Temporal Stability and Its Ecological Interpretation

The absence of significant variation among the comparable 2024 Autumn through 2025 Autumn periods is ecologically informative. Paired Wilcoxon tests produced negligible rank-biserial effect sizes ($|r| < 0.02$) for all seasonal and inter-annual contrasts among these windows, meaning that any difference in median richness was far smaller than one species per grid cell. This stability stands in contrast to patterns reported from lowland Turkish lakes, where seasonal fluctuations in water level and vegetation produce pronounced changes in bird community composition [3,33].

High-altitude lakes may show greater temporal stability for two complementary reasons. First, the compressed growing season and limited seasonal amplitude in water level reduce habitat variability between Spring and Autumn compared with lowland systems. Second, many species using Çalı Lake are migratory generalists present during transit and not closely tied to specific microhabitat states; such species contribute to consistent assemblage-level richness regardless of season [20]. The pattern observed for 2024 Spring–Summer with mean S = 1.99 versus 1.47–1.49 in subsequent periods most likely reflects the inclusion of early-season breeding residents in addition to the migrant component captured in later windows, rather than a true community shift. The stability confirmed for the 2024 Autumn through 2025 Autumn comparison windows of the three periods of comparable survey duration (six visits each) means that the spatial patterns described here represent a genuine ecological baseline against which future surveys can detect change. This inference explicitly excludes the 2024 Spring–Summer period (12 visits, 100% occupancy) and the 2026 Spring window (4 visits), both of which carry unresolved effort confounds.

4.4. Spatial Heterogeneity and Management Implications

The Gini coefficient of 0.351 quantifies moderate inequality in spatial bird use across the lake's grid cells. This value falls in the range commonly described as 'moderate concentration' in the ecological literature [15], indicating that bird detections were neither

uniformly distributed nor confined to a handful of extreme outlier cells. The Lorenz curve shows that the top 10% of grid cells held 24.0% of all individual detections a concentration ratio qualitatively similar to waterbird use of spatially heterogeneous Chinese lakes [34] and shorebird distribution along European estuaries [35].

The spatial identity of the hotspot zones consistently the central, western, and south-western sectors points to an interaction between habitat quality and disturbance. These sectors contain the greatest extent of open water and inner marsh, the primary foraging and resting habitats for waterbirds [4], and are also the most distant from the highway and Borluk village. The role of traffic noise and visual disturbance in reducing bird density near road infrastructure is well established across wetland habitats [36,37]. Crucially, the density gradient between the southern hotspot zones and the northern low-density sector likely reflects behavioural avoidance rather than a fundamental difference in habitat suitability; the northern sector's Corine habitat classes are not structurally different from the southern sectors at the grid-cell scale. This implies that targeted disturbance-reduction measures along the northern shoreline seasonal speed restrictions or buffer vegetation planting could expand the effective habitat area available to sensitive species without requiring physical habitat modification. We note that this disturbance gradient is a post hoc spatial association; no distance-to-road covariate was included in the formal analysis. Future work should model bird density as an explicit function of distance from the highway to establish causation rather than pattern.

5. Conclusions

Çalı Lake supports 154 bird species, including two globally Endangered and two Vulnerable taxa, with a spatially structured, temporally stable assemblage across five survey periods spanning two full-field seasons. The grid-based monitoring framework and GIS maps established here provide a reproducible spatial baseline that did not previously exist for this site. Grid-level richness showed no significant variation across the comparable 2024 Autumn through 2025 Autumn periods, confirming ecological stability under current land-use conditions. Spatial analysis identified consistent density hotspots in the central and south-western lake zones, attributable to a combination of high habitat quality and low anthropogenic disturbance relative to the northern highway corridor.

In scientific terms, this study makes three distinct contributions: (1) it establishes the first grid-based, multi-period quantitative avifaunal inventory at a high-altitude Anatolian wetland, creating a reproducible spatial baseline for decadal change-detection; (2) it demonstrates via repeated-measures statistics that grid-level richness is stable across comparable survey windows, validating the site as a reliable long-term monitoring reference; and (3) it delineates spatially defined density hotspots that can serve as sentinel zones for early detection of habitat degradation. We recommend (i) formal designation of Çalı Lake as a priority monitoring node within the Central Asian Flyway network; (ii) targeted disturbance-reduction measures along the northern shoreline; (iii) annual repeat surveys using the 498-cell grid protocol; and (iv) dedicated breeding surveys for the White-headed Duck and Egyptian Vulture, for which the present data provide distributional records but not breeding confirmation.

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Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Gardner, R.C.; Finlayson, M. *Global Wetland Outlook: State of the World's Wetlands and Their Services to People 2018*; Secretariat of the Ramsar Convention: Gland, Switzerland, 2018.
2. Haig, S.M.; Mehlman, D.W.; Oring, L.W. Avian movements and wetland connectivity in landscape conservation. *Conserv. Biol.* **1998**, *12*, 749–758. [CrossRef]
3. Ma, Z.; Cai, Y.; Li, B.; Chen, J. Managing wetland habitats for waterbirds: An international perspective. *Wetlands* **2010**, *30*, 15–27. [CrossRef]
4. Murkin, H.R.; Murkin, E.J.; Ball, J.P. Avian habitat selection and prairie wetland dynamics: A 10-year experiment. *Ecol. Appl.* **1997**, *7*, 1144–1159. [CrossRef]
5. Üner, Ö.; Boyla, K.A.; Bacak, E.; Birel, E.; Çelikoba, İ.; Dalyan, C.; Tabur, E.; Yardım, Ü. Spring migration of soaring birds over the Bosphorus, Turkey, in 2006. *Sandgrouse* **2010**, *32*, 20–33.
6. Arslangündoğdu, Z.; Dalyan, C.; Bacak, E.; Yardım, Ü.; Gezgin, C.; Beşkardeş, V. Spring migration of the White Stork, Ciconia ciconia, and the Black Stork, Ciconia nigra, over the Bosphorus. *Zool. Middle East* **2011**, *53*, 7–13. [CrossRef]
7. Özkoç, Ö.Ü. Kars ilinde üreyen ve geçit yapan kuş türleri. *Turk. J. For.* **2020**, *21*, 153–161. [CrossRef]
8. Per, E.; Uzuner, H. The first assessment on post graduate theses in ornithology in Turkey. *J. High. Educ. Sci.* **2020**, *10*, 242–252. [CrossRef]
9. Boere, G.C.; Stroud, D.A. The flyway concept: What it is and what it isn't. In *Waterbirds Around the World*; Boere, G.C., Galbraith, C.A., Stroud, D.A., Eds.; The Stationery Office: Edinburgh, UK, 2006; pp. 40–47.
10. Ministry of Agriculture and Forestry. *Wetland Inventory: Çalı Lake*; 13th Regional Directorate: Kars, Turkey, 2024. Available online: https://kars.tarimorman.gov.tr/Sayfalar/EN/Anasayfa.aspx (accessed on 20 June 2026).
11. Gill, F.; Donsker, D.; Rasmussen, P. IOC World Bird List (v12.2). 2022. Available online: https://www.worldbirdnames.org/ioc-lists/crossref/ (accessed on 16 June 2026).
12. BirdLife International. IUCN Red List for Birds. 2025. Available online: https://www.birdlife.org (accessed on 15 April 2025).
13. Turkish Bird Records Committee (TBRC). Turkey Bird Species List. 2026. Available online: https://www.kustr.org (accessed on 1 March 2026).
14. Evans, J.D. *Straightforward Statistics for the Behavioral Sciences*; Brooks/Cole: Pacific Grove, CA, USA, 1996.
15. Tokeshi, M. Species abundance patterns and community structure. *Adv. Ecol. Res.* **1993**, *24*, 111–186. [CrossRef]
16. Alanmış, R. Batmış (Cil) Gölü (Bitlis) Kuş Faunası. Master's Thesis, Bitlis Eren University, Bitlis, Turkey, 2025.
17. Yuca, H. Erzurum Palandöken (Çat) Baraj Gölü Ornitofaunası. Master's Thesis, Atatürk University, Erzurum, Turkey, 2026.
18. Ercasip, M. Turna (Keşiş) Gölü Ornitofaunası Üzerine bir Araştırma. Master's Thesis, Van Yüzüncü Yıl University, Van, Turkey, 2024.
19. Gökşen, H.İ. Nemrut Kalderası Tabiat Anıtı'nın Kuş Faunası. Master's Thesis, Bitlis Eren University, Bitlis, Turkey, 2022.
20. Newton, I. *The Migration Ecology of Birds*; Academic Press: London, UK, 2008.
21. Albağ, N. İstanbul Küçükçekmece Gölü'nün Ornitofaunası. Master's Thesis, Istanbul University, Istanbul, Turkey, 2019.
22. Cenger, D. Bulanık Ovası (Muş) Ornitofaunası Üzerine bir Araştırma. Master's Thesis, Van Yüzüncü Yıl University, Van Turkey, 2018.
23. Schmaljohann, H.; Eikenaar, C.; Sapir, N. Understanding the ecological and evolutionary function of stopover in migrating birds. *Biol. Rev.* **2022**, *97*, 1231–1252. [CrossRef] [PubMed]
24. Çelik, E.; Durmuş, A. Determining the seasonal ornithological potential of the Dönemeç (Engil) delta and generate the digital maps using geographical information systems (GIS). *J. Inst. Sci. Technol.* **2017**, *7*, 73–78. [CrossRef]

25. Alonso, J.C.; Alonso, J.A.; Bautista, L.M. Carrying capacity of staging areas and facultative migration extension in common cranes. *J. Appl. Ecol.* **1994**, *31*, 212–222. [CrossRef] [PubMed]
26. Hughes, B. (Ed.) *International Single Species Action Plan for the Conservation of the White-Headed Duck Oxyura leucocephala*; CMS Technical Series No. 13; AEWA Technical Series No. 8; CMS and AEWA Secretariats: Bonn, Germany, 2006.
27. Kear, J.; Hulme, M. *Ducks, Geese and Swans*; Oxford University Press: Oxford, UK, 2003.
28. Oppel, S.; Dobrev, V.; Arkumarev, V.; Saravia, V.; Bounas, A.; Kret, E.; Velevski, M.; Stoychev, S.; Nikolov, S.C. High juvenile mortality during migration in a declining population of a long-distance migratory raptor. *Ibis* **2015**, *157*, 545–557. [CrossRef]
29. Velevski, M.; Nikolov, S.C.; Hallmann, B.; Dobrev, V.; Sidiropoulos, L.; Saravia, V.; Tsiakiris, R.; Arkumarev, V.; Galanaki, A.; Kominos, T.; et al. Population decline and range contraction of the Egyptian Vulture Neophron percnopterus in the Balkan Peninsula. *Bird Conserv. Int.* **2015**, *25*, 440–450. [CrossRef]
30. Botha, A.J.; Andevski, J.; Bowden, C.G.R.; Gudka, M.; Safford, R.J.; Tavares, J.; Williams, N.P. *Multi-Species Action Plan to Conserve African-Eurasian Vultures (Vulture MsAP). CMS Technical Series No. 35*; Raptors MOU Technical Publication No. 5; Convention on the Conservation of Migratory Species of Wild Animals (CMS): Bonn, Germany, 2017; 164pp.
31. Brides, K.; Hall, C.; Hearn, R.; Musgrove, A.J.; Wotton, S.R. Changes in sex ratio, age ratio and abundance of Common Pochard Aythya ferina in Europe. *Bird Conserv. Int.* **2017**, *27*, 455–470. Available online: https://edepot.wur.nl/429426 (accessed on 16 June 2026).
32. Browne, S.J.; Aebischer, N.J. Temporal changes in the breeding ecology of European Turtle Doves Streptopelia turtur in Britain, and implications for conservation. *Ibis* **2004**, *146*, 125–137. [CrossRef]
33. Özgencil, İ.K.; Beklioğlu, M.; Özkan, K.; Tavşanoğlu, Ç.; Fattorini, N. Changes in functional composition and diversity of waterbirds: The roles of water level and submerged macrophytes. *Freshw. Biol.* **2020**, *65*, 1845–1857. [CrossRef]
34. Zhang, S.Q.; Zhang, P.Y.; Zou, Y.; Li, D.M.; Li, F.; Deng, Z.M.; Zeng, J.; Wang, S.Z.; Wu, T.; Song, Y.C.; et al. Waterbird diversity patterns under varied hydrological regimes in Dongting Lake and surrounding lakes. *Ecol. Evol.* **2025**, *15*, e72396. [CrossRef] [PubMed]
35. Goss-Custard, J.D.; Stillman, R.A.; West, A.D.; Caldow, R.W.G.; McGrorty, S. Carrying capacity in overwintering migratory birds. *Biol. Conserv.* **2006**, *131*, 376–393. [CrossRef]
36. Reijnen, R.; Foppen, R. Impact of road traffic on breeding bird populations. In *the Ecology of Transportation*; Davenport, J., Davenport, J.L., Eds.; Springer: Dordrecht, the Netherlands, 2006; pp. 255–274.
37. Wan, Y.; Tang, L.; Hou, X.; Lin, H.; Cai, X.; Huang, Z.; He, Y. The role of wetland vegetation and water connectivity in shaping waterbird populations under human disturbance. *Ecol. Indic.* **2025**, *178*, 114014. [CrossRef]

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