Microhabitat use by wading birds in Tonga Lake, North-East Algeria

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Abstract. This study aims to determine seasonal variations in the use of microhabitats by wading birds in Lake Tonga, Algeria. Nine species from the heron and ibis families were recorded using different aquatic vegetation zones, with ten distinct microhabitats identified. The extent of these habitats changed noticeably across seasons, being largest during the breeding period and smallest in winter. Both bird species richness and abundance increased in areas with more extensive microhabitats, highlighting the strong link between habitat availability and bird communities. These findings emphasize the importance of maintaining diverse, well-preserved wetland habitats to support wading birds across seasons.

Keywords: waterbird, microhabitats, Tonga, vegetation, Algeria.

Introduction

The study of water birds makes a significant contribution to understanding ecosystems, both through fundamental research and environmental assessment (Blondel 1975). Species occupying an extensive geographical range are exposed to varied ecological conditions. To survive, their populations must adapt to the specific constraints of each habitat. 240 species of birds can be observed in or around wetlands in Algeria, among which 125 species are water birds with strong to very strong ties to these habitats. These species depend on wetlands during critical periods of their biological cycle (Bellatreche 2007).

Research on wading birds in Algeria began in the 1980s, focusing on numerous wetlands (Ledant et al. 1981, Houhamdi & Samraoui 2002, Houhamdi et al. 2008, Chettibi et al. 2019). Their presence and behavior are closely linked to the availability and quality of aquatic habitats, particularly microhabitats. Microhabitats, defined as small spatial units within larger habitats, provide essential resources such as food, nesting sites, and resting zones (Hansson et al. 2015). They are often characterized by unique environmental conditions, such as water depth and aquatic vegetation (Zwarts et al. 2009).

The wading birds, in particular, exploit a variety of microhabitats for feeding, resting, and nesting. Their ecological needs vary by species, environmental conditions, and season. Wetlands, such as Lake Tonga, offer a diversity of microhabitats and play a fundamental role in the conservation of migratory and resident waterbirds. This study aims to examine the specific characteristics of the microhabitats in Lake Tonga used by wading birds, focusing on the factors influencing their habitat selection and the implications for wetland management.

Materials and methods

<u>Study area</u>

Tonga Lake, located in northeastern Algeria within El Kala National Park (Figure 1), is a vital ecological zone characterized by its biodiversity and hydrological significance. This freshwater lake covers approximately 2,700 hectares. It is part of a Ramsar-listed wetland complex, recognized for its importance as a habitat for migratory birds, endemic species, and unique aquatic flora (Ramsar Convention 2010). The lake's seasonal water-level fluctuations, influenced by Mediterranean climatic conditions and anthropogenic factors, play a critical role in shaping its ecological dynamics (Bensouilah et al. 2016).

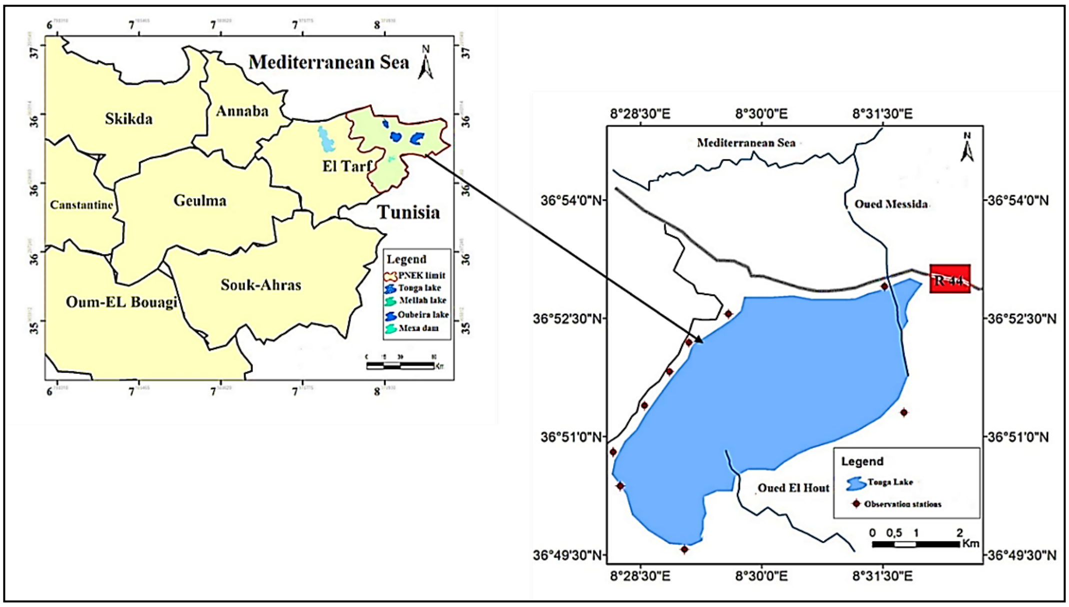

Figure 1. Location of study area.

<u>Birds survey</u>

Counts of wading birds were conducted from March 2017 to February 2018, across the life cycles of water birds (Breeding, passage, and wintering). For groups of fewer than 200 birds within 200 meters, individual counts (absolute method) were performed. For larger groups or those beyond 200 meters, the relative method was used (Blondel 1975).

<u>Identification of microhabitats</u>

We focused on identifying the main plant formations. While physiognomic and phytosociological methods are commonly used to analyze plant communities (Saifouni & Bellatreche 2014), we employed the physiognomic approach in this study. This approach was based on several ecological factors, including: (i) dominant plant species (plant formation), (ii) vegetation cover (estimated visually by number, area, and percentage), (iii) vegetation height, (iv) water depth, and (v) apparent facies within the formation (morphology, color, etc.) Such physiognomic-based assessments have been widely applied in wetland and aquatic vegetation studies (Kent 2012). In addition to field-based observations, vegetation was mapped in ArcGIS 10.2 (ESRI, Redlands, CA, USA) using multispectral imagery from Landsat 8. To characterize vegetation and quantify cover, we calculated the Normalized Difference Vegetation Index (NDVI) (Tucker 1979), a widely used normalized index for estimating relative biomass and vegetation cover (Benhizia et al. 2024). NDVI exploits the contrast between chlorophyll absorption in the red band and the high reflectance of healthy vegetation in the near-infrared (NIR) band. NDVI maps derived from LANDSAT 8 data were combined with field surveys to delineate plant formations and define microhabitat boundaries across Lake Tonga (Khallef & Zennir 2023, Benabdelkader et al. 2025).

Statistical analysis

Normality of both dependent and independent variables was tested using the Shapiro–Wilk test (Shapiro & Wilk 1965). A one-way ANOVA was then applied to determine seasonal differences in family abundance and richness, as well as in microhabitat surface area (Zar 1999). A Pearson correlation analysis was conducted to evaluate relationships among microhabitat richness, abundance, and surface area. Ecological patterns across three seasons and ten microhabitats at Lake Tonga were further explored using Factorial Correspondence Analysis (FCA) (Greenacre 2017). and results were considered statistically significant at $p < 0.05$. All statistical procedures were performed with IBM SPSS Statistics, version 23 (IBM Corp., Armonk, NY, USA).

Results

Abundance, richness, and diversity of wading birds

During our study, we identified nine species belonging to two families, Ardeidae and Threskiornithidae, using the microhabitats at Tonga Lake. The species richness of wading birds in Lake Tonga did not differ significantly across seasons (One-way ANOVA $F(2,7) = 0.92$, $p > 0.05$). The highest average richness was noted during the passage season (7.33±0.57), followed by the breeding season (6.5±2.08) and the wintering season (4±2) (Table 1).

The abundance of wading birds recorded in Lake Tonga varied significantly across seasons (One-way ANOVA $F(2,7) = 10.1$, $p < 0.005$). The highest average abundance was observed during the passage season (408± 57.41), followed by the breeding season (361.75±162.06) and the wintering season (40.33±16.86).

The Shannon-Weaver diversity index and equitability varied across seasons (Table 2). The passage season was the most diverse, with a diversity index of 1.883, followed by the wintering season (1.79). In contrast, the breeding season was the least diverse and balanced.

Identification of microhabitats

During the study period at Tonga Lake, we identified 10 microhabitats utilized by wading birds. These microhabitats were classified by the types of aquatic vegetation in the lake (Table 3).

The area of microhabitats varied significantly across seasons (One-way ANOVA, $F(2, 35) = 3.35$, $p < 0.05$). The location of microhabitats used with the highest average was recorded during the breeding season (117.9 ±101.49), followed by the passage season (116.2±133.95). The smallest microhabitat area was observed during the wintering season (24.2 ±44.30).

Table 1. Mean richness and mean abundance of wading birds across seasons at Lake Tonga.

Season	Richness			Abundance		
	Mean ± SD	%	Range (min-max)	Mean ± SD	%	Range (min-max)
Breeding	6.5±2.08	64.28	4-8	361.75±162.06	53.44	216-589
Passage	7.33±0.57	57.14	7-8	408± 57.41	41.83	347-461
Wintering	4±2	50	3-5	40.33±16.86	4.71	21-52

Table 2. Diversity indices of wading in across seasons at Tonga Lake.

	Breeding	Passage	Wintering
Species richness	8	8	5
Shannon and Weaver diversity (bit)	1.578	1.883	1.796
Equitability	0.685	0.785	0.808

Table 3. Variation in the surface area of microhabitats across seasons at Lake Tonga.

Plant formations	Types of microhabitats	Season					
		Breeding		Passage		Wintering	
		Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Hydrophytic plant formations	Water buttercup	73	3.04	0	0	0	0
	Water lily	357	15	457	20	0	0
Helophyte plant formations	Bur-reed	91	3.95	81	3. 52	0.22	0.01
	Wolgrass	217	9.43	198	8.60	0.24	0.01
	Lesser bulrush	110	4.72	110	4.72	0	0
	Reed	50	2.17	50	2.17	0	0
Training in tree and shrub plant formations	Bald Cyprée	8	0.33	8	0.33	8	0.33
	Black alder	47	2.04	47	2.04	47	2.04
	White willow	137	5.95	137	5.95	137	5.95
Other habitats	Natural lawn	89	3.86	74	3.21	50	2.17

Correlation between microhabitat area and the richness and abundance of wading birds at Lake Tonga

The analysis of seasonal variations in the surface area of aquatic vegetation formations and wading bird populations in Lake Tonga revealed a highly significant positive correlation between surface area and species richness (Pearson correlation, $r = 0.92$, $p < 0.005$) and a positive correlation between abundance and surface area (Pearson correlation, $r = 0.687$, $p < 0.05$). The percentages of microhabitat usage by wading bird species across the three seasons at Lake Tonga are illustrated in Figures 2, 3, and 4.

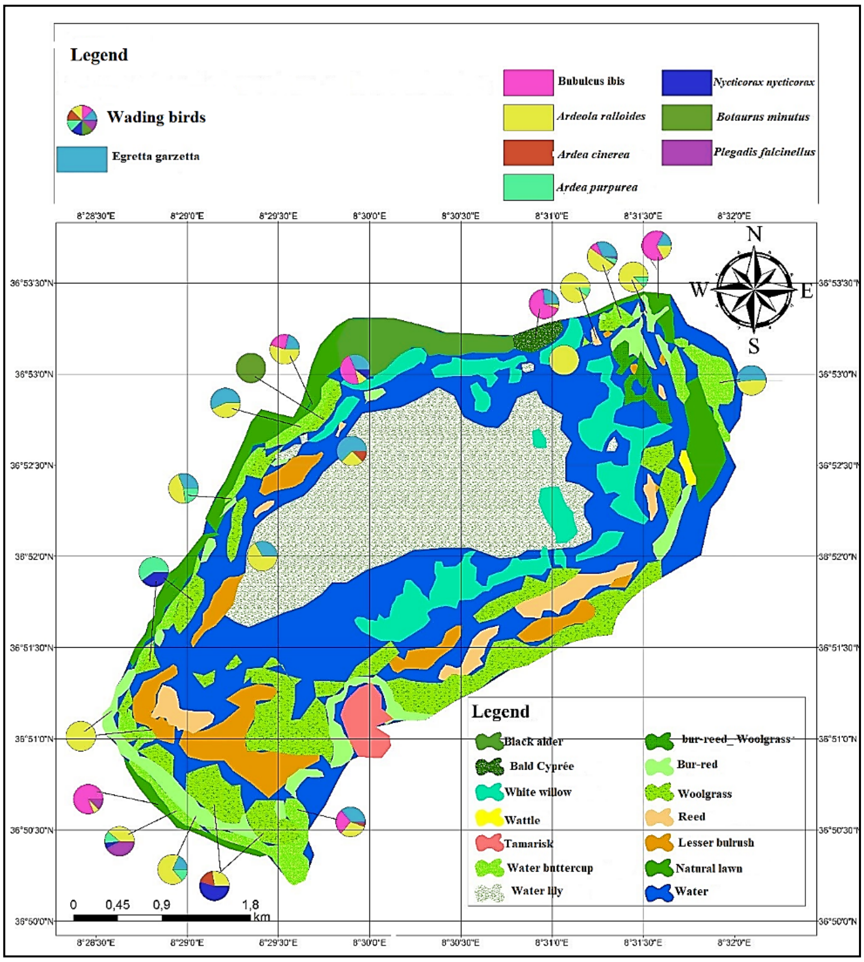

Figure 2. Map showing the distribution of wading birds across microhabitats during the breeding season at Lake Tonga.

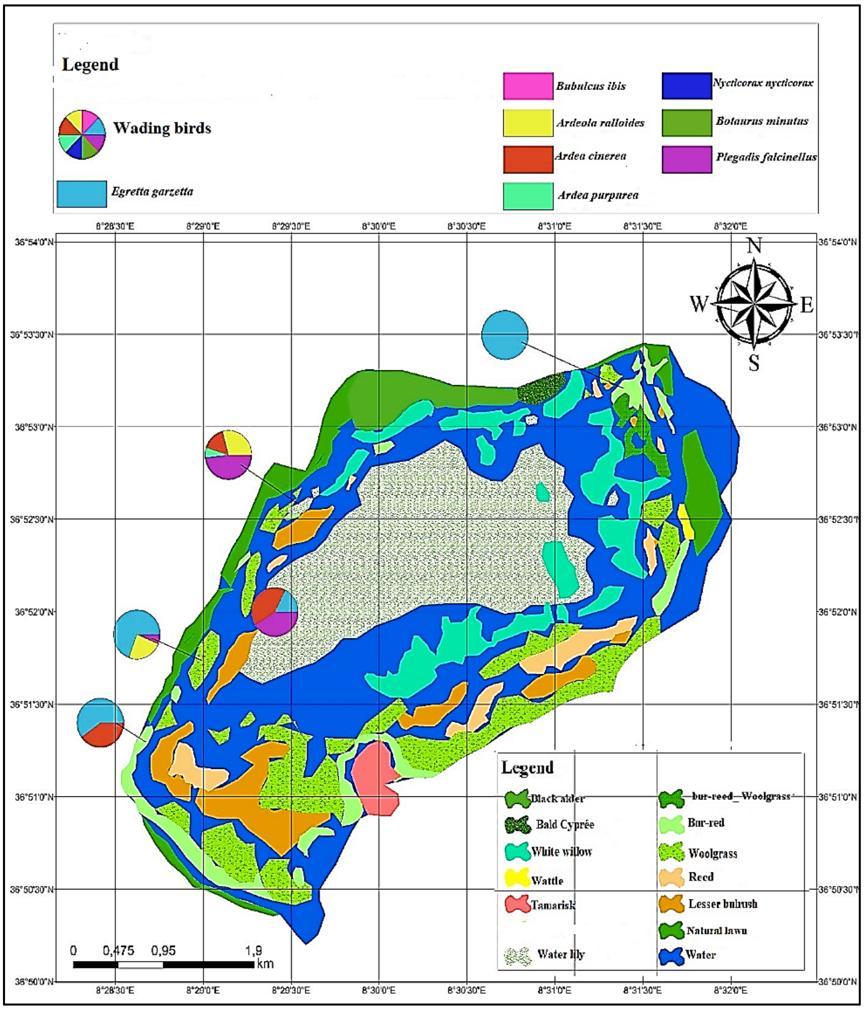

Figure 3. Map showing the distribution of wading birds across microhabitats during the passage season at Lake Tonga.

<u>Factorial Correspondence Analysis</u>

The Factorial Correspondence Analysis (FCA) of the data collected over the study period is expressed on the factorial plane (F1xF2), with an inertia rate of approximately 100% (Fig. 5). The factorial map provides information on the spatio-temporal distribution of wading birds. The graphs from the analysis clearly show that Axis 1 (F1) accounts for 94.49% of the variance, while Axis 2 (F2) accounts for 5.51%.

Axis 1 contrasts two groups, the first in the positive position corresponding to the passage season, where the most preferred microhabitat, the water lily, hosts a very high abundance of waders. The second group, on the negative side, is characterized by the microhabitats that are less used during the breeding season: Lesser bulrush, Reed, Bald Cypress, Black Alder, and White Willow. During this season, the most preferred microhabitat is the Water Buttercup.

Axis 2 highlights a single group in a positive position, representing the wintering season. In this period, the most utilized microhabitat by avian species is the Lesser Bulrush.

Discussion

In this study, the term "microhabitat" refers to specific vegetation types within the wetland that provide structural and trophic resources for bird species, such as emergent islands, emergent stands, and shrubs. Our results revealed pronounced seasonal fluctuations in the extent of these microhabitats. Such variation is consistent with patterns observed in other wetland

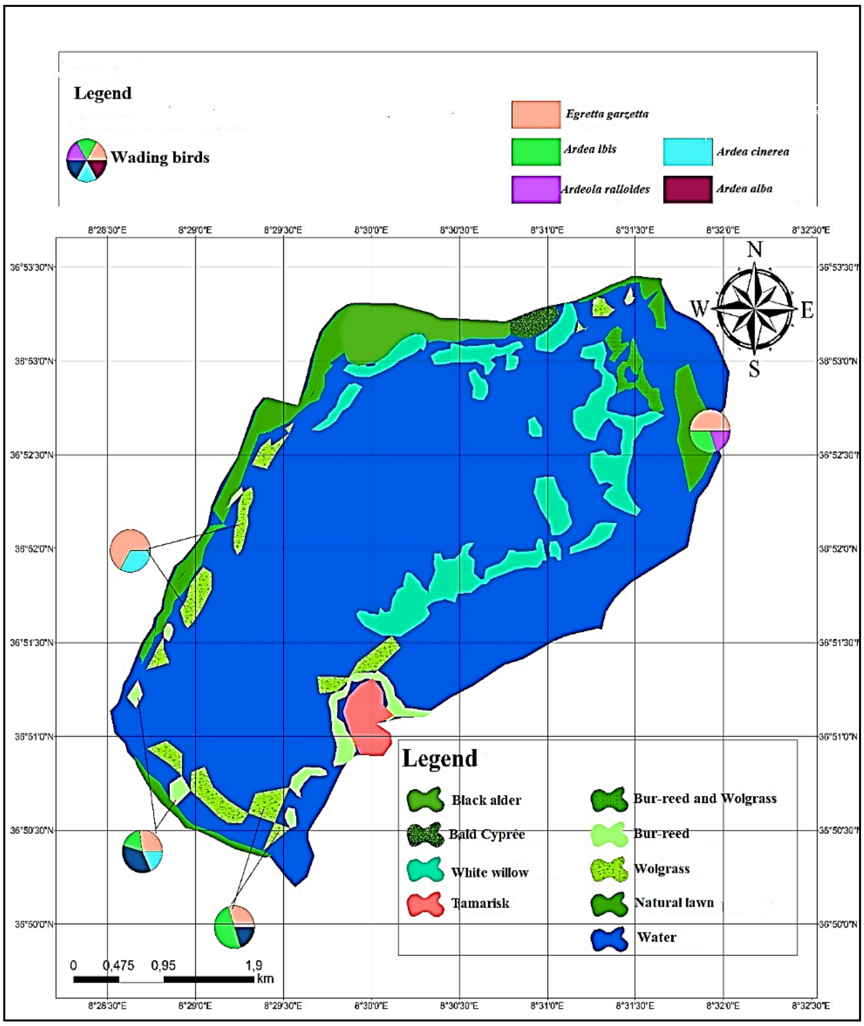

Figure 4. Map showing the distribution of wading birds across microhabitats during the wintering season at Lake Tonga.

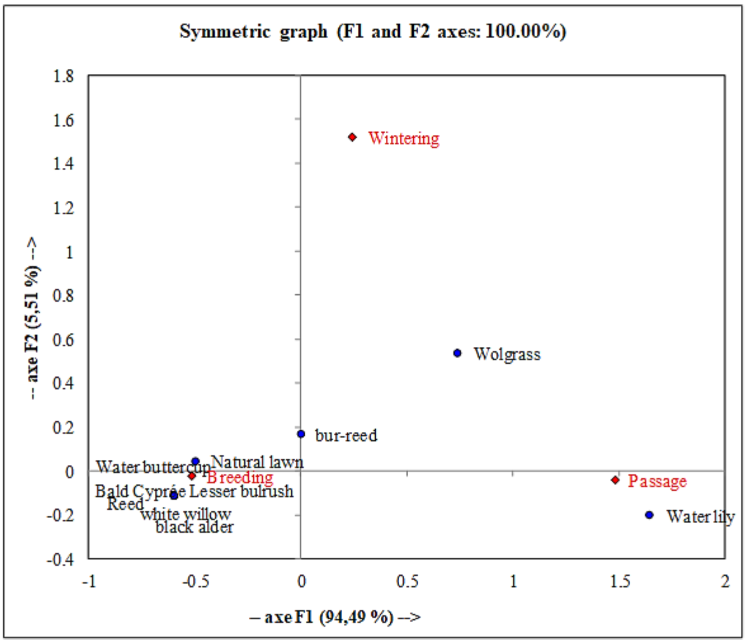

Figure 5. Factorial Correspondence Analysis (FCA) performed on three seasons and ten microhabitats at Lake Tonga.

ecosystems, where water-level dynamics and vegetation succession play a central role in determining habitat suitability for waterbirds (Colwell & Taft 2000, Ma et al. 2010).

Waterbirds, and particularly wading species, differ from many other avian groups in their reliance on aquatic habitats, making them more sensitive to changes in wetland structure and land use (Sun et al. 2023).

Morphological adaptations in waders, including beak, leg, and neck length, restrict species to particular feeding depths (Pöysä 1983, Bolduc & Afton 2004), which makes the seasonal availability of microhabitats a critical determinant of community composition. At Lake Tonga, the breeding season coincided with the largest average microhabitat areas, providing enhanced spatial opportunities for nesting and foraging. Among the available habitats, Water Buttercup was most frequently used, consistent with earlier findings that certain vegetation types serve as dual resources, providing both protective cover and abundant prey (Kushlan & Hancock 2005, Roberts & Jost 2019). These habitats are known to concentrate invertebrates, amphibians, and gastropods (Chettibi et al. 2019, Djamai et al. 2019), resources that are particularly important during the energetically demanding breeding period. The strong association between breeding activity and the availability of productive vegetation zones highlights the role of food access and shelter in shaping habitat selection by waders. Similar patterns have been reported in other wetlands, where species' breeding distribution is closely linked to temporal peaks in prey abundance and vegetation dynamics (Ucero et al. 2025). Such seasonal dependence underlines the importance of conserving diverse vegetation types within wetlands, as these habitats sustain reproductive success and ultimately influence the long-term persistence of wading bird populations.

In contrast, wintering was characterized by the smallest habitat area, likely reflecting restricted resource availability and reduced spatial use by birds, a pattern also noted elsewhere (Johnson et al. 2020).

Beyond Water Buttercup, additional vegetation types contributed to habitat partitioning. Reed beds were particularly important for large waders, offering shelter from predators and disturbance during nesting. During migration, Water Lily stands were frequently used, with their extensive coverage in central lake areas providing secure resting and foraging sites for females and chicks. Together, these patterns highlight the role of structural heterogeneity in maintaining avian diversity, as different vegetation types of support species with varying ecological requirements across seasons. Seasonal declines in vegetation cover during winter substantially reduce wader abundance by limiting foraging opportunities and decreasing the availability of invertebrate prey, which are typically concentrated in vegetated habitats (Goss-Custard et al. 2002, Ma et al. 2010). Moreover, the loss of cover increases exposure to predators and heightens competition for the remaining suitable habitats (Colwell & Taft 2000). For migratory waders, these constraints at wintering grounds can have far-reaching consequences, reducing body condition and survival and ultimately lowering reproductive success in subsequent breeding seasons (Newton 2004, Wauchope et al. 2017).

The strong positive correlations between habitat area and both species richness and bird abundance further support the principle that diverse and extensive habitats sustain higher biodiversity (Tilman et al. 2014, Maclean et al. 2008). This ecological relationship has been documented in other Mediterranean wetlands, including Doñmana National Park, where habitat heterogeneity drives wader distributions (Felipe et al. 2024), and the Camargue wetlands, where depth and vegetation structure determine species assemblages (Tourenq et al. 2001). Similar dynamics have been reported worldwide, such as in the Everglades, USA, where seasonal flooding regulates prey accessibility (Frederick & Ogden 2003), and in East African Rift Valley wetlands, where anthropogenic disturbances fragment habitats and reduce bird populations (Bennun 2000).

By situating the findings from Lake Tonga in a global context, this study highlights the broader ecological significance of microhabitat diversity in shaping wader distributions. Wetland conservation efforts must therefore prioritize maintaining vegetation heterogeneity and mitigating anthropogenic pressures to ensure the persistence of waterbird communities.

Understanding the habitat preferences of wading birds and shorebirds is crucial for wetland conservation, as these birds serve as bioindicators of ecosystem health. The presence, abundance, and diversity of species in specific microhabitats reflect the overall ecological integrity of the wetland. Protecting and restoring these microhabitats can enhance biodiversity and ecosystem resilience, ensuring that key ecological functions, such as nutrient cycling and food web stability, are maintained.

This study underscores the importance of ecological diversity and habitat availability in supporting wading bird populations at Lake Tonga. The results highlight the need to preserve wetland ecosystems to ensure their sustainability for both resident and migratory bird species. By integrating conservation efforts, sustainable management practices, and further research, we can safeguard the ecological integrity of these vital habitats for future generations.

In conclusion, the study of the microhabitats used by wading birds and shorebirds at Lake Tonga highlights the importance of ecological diversity and the specific conditions this environment provides for these species. The results show that habitat selection is influenced by multiple factors, including water depth, breeding territory, and the availability of feeding and resting areas.

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