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Research Article

Role of urban parks in supporting bat communities under accelerating urbanization

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Abstract

Rapid urbanization has intensified the need to preserve urban green spaces for maintaining biodiversity. However, limited research has investigated the impact of urban green spaces on bat communities amid accelerating urbanization. Therefore, this study assessed the role of urban parks in supporting bat communities by providing conditions that mimic their natural habitats. By using manual detectors, we recorded the activity of nine distinct bat species in three different urban parks according to size, year of establishment, and blue-green-brown area ratios in Ankara, TURKEY, from May to November 2022. Despite high levels of light, noise, and human traffic, which reduced bat activity, no significant differences were observed in bat community composition or annual biological activity among these parks. These findings underscore the critical role of urban parks as wildlife refuges in metropolises, suggesting that enhanced park management substantially improved urban biodiversity, particularly for bats. This study emphasizes the need for ongoing enhancements of urban park management strategies to better support local wildlife.

Keywords: Ankara, urban bats, echolocation, synurbization, wildlife

Introduction

Bats (*Order Chiroptera*) comprise over 1300 species and have a unique ability for powered flight. They provide vital ecological services, including pollination, pest control, and seed dispersal, contributing to ecosystem stability and health (Jones et al., 2009; Voigt & Kingston, 2016). Their presence in urban environments highlights their adaptability; however, urbanization presents significant challenges. Urban development transforms natural landscapes into built environments, often resulting in habitat loss, species homogenization, and decreased biodiversity (Baker & Harris, 2007; Ming & Du, 2021).

Urban green spaces such as parks are increasingly recognized for their critical roles in maintaining urban biodiversity, providing refuge and resources for many wildlife species, including bats, and offering essential ecosystem services, such as climate regulation and air quality improvement (Aronson et al., 2017). Urban green spaces, such as parks, may mitigate the negative effects of urbanization by providing critical resources for wildlife. However, their effectiveness depends on factors like vegetation complexity and levels of human disturbance. It was hypothesized that urban parks with greater vegetation heterogeneity and lower human disturbance would support higher bat diversity and activity levels compared to more degraded or disturbed areas. To test this hypothesis, the diversity, activity patterns, and community structure of bats were investigated in three urban parks in Ankara, Turkey. The findings provide insights into the role of urban green spaces in supporting bat populations and inform strategies for sustainable urban park management. In Turkey, rapid urbanization—particularly in cities like Ankara—has led to habitat loss and increased pressure on urban green spaces (Gün et al., 2020). While green infrastructure (e.g., parks) is critical for urban biodiversity, its role in supporting bat communities remains poorly understood. Globally, autonomous acoustic monitoring has advanced bat research, yet studies investigating bat responses to urban green spaces are scarce in rapidly developing regions like Turkey (Coşkun & Sert, 2023). This knowledge gap limits the development of effective conservation strategies for urban bat populations. Previous acoustic studies in Turkey have provided insights into bat ecology. For example, Baş and Arslan (2021) recorded six bat species in Konya Province, including *Pipistrellus pipistrellus* and *Hypsugo savii*, which are known to exhibit adaptability to human-modified environments. To address this knowledge gap, the present study aimed to document the presence, frequency, and community parameters of bat species in three major urban parks in Ankara, the capital of Turkey. By assessing how these urban green spaces support bat communities, this study emphasizes the need for effective urban park management and planning to enhance urban biodiversity and ensure the sustainability of these essential urban inhabitants.

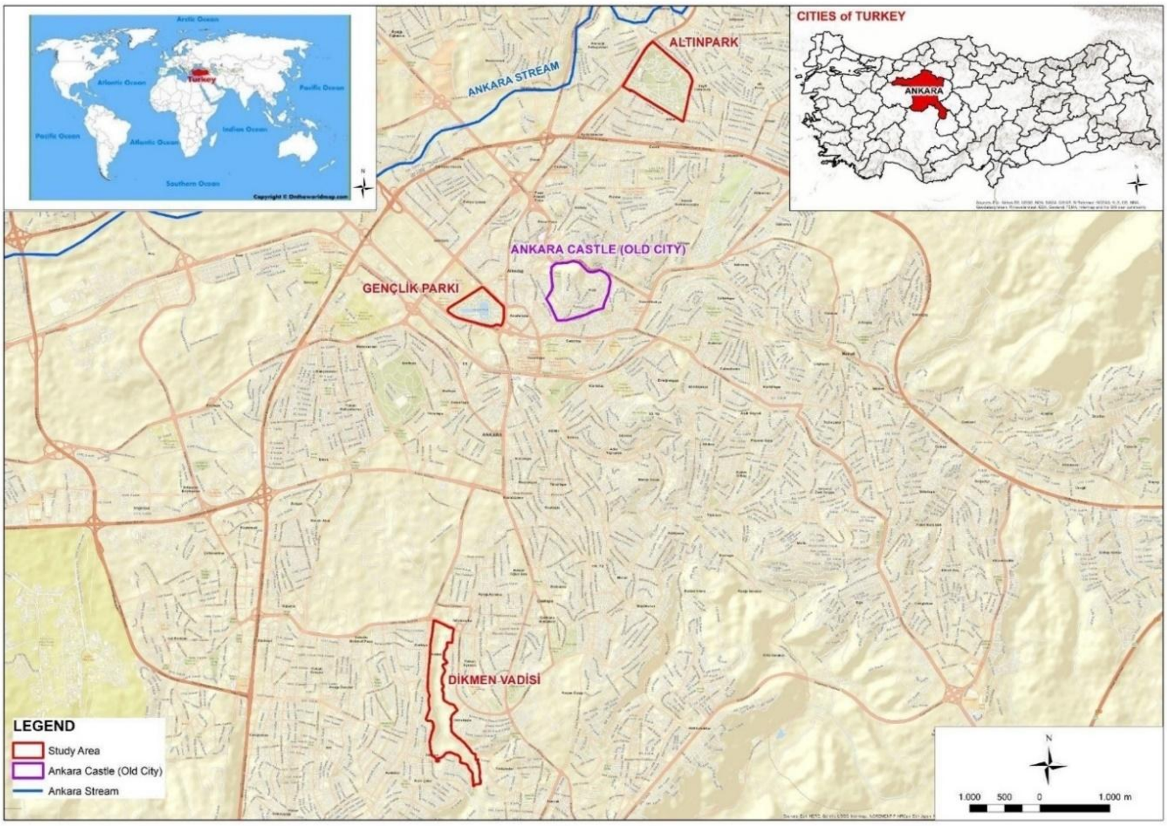
Material and methods

Ethical Considerations

This study used ultrasonic detectors to passively monitor bat species. This methodology minimizes disturbance to bats and their habitats while ensuring ethical compliance with best practices for wildlife research. No capture or handling of animals during the study period, and all methods of observation followed the American Society of Mammalogists' guidelines for research on wild mammals, as detailed in Sikes et al. (2016). This noninvasive method does not necessitate approval from the Institutional Animal Care and Use Committee.

Study Area

The study was conducted across three urban parks in Ankara: Golden Park (Altınpark), Youth Park (Gençlik Parkı), and Dikmen Valley (Dikmen Vadisi; Figure 1). These parks encompass various habitats, such as buildings, green areas, and ponds. The parks were digitally mapped using Google Earth and analyzed in ArcGIS to generate detailed area maps and calculate the area of patches (Figure 2). Details of the parks are summarized in Table 1.



(Figure 1)

Figure 1. Map of the studied parks. Upper left: Turkey in the world. Upper right: borders of Ankara in Turkey. Main map: locations of studied parks in Ankara City.

(Figure 2)

Figure 2. Habitat characteristics of (A) Youth Park (Gençlik Parkı), (B) Golden Park (Altınpark), and (C) Dikmen Valley (Dikmen Vadisi).

Table 1. Features of the studied parks

Features	**Dikmen Valley (Dikmen Vadisi)**	**Youth Park (Gençlik Parkı)**	**Golden Park (Altınpark)**
The year the park was founded	1994	1936	1977
Brief description	In 1989, an urban transformation plan was implemented in the valley, which was in a neglected state until the 90s when unplanned urbanization prevailed. This project was completed in 1994 and was the first urban transformation project implemented in the under-resourced areas of the country.	Youth Park is one of the historical parks of Ankara. It was established on 28 ha of land covered with swamps in the first years of the Turkish Republic.	This land was used as a golf course until 1977, after which it was converted into a city park through renovations.
Distance to Ankara Stream (km)	6.9 km	2.4 km	1.4 km

Distance to Ankara Castle (Old City; km)	5.1 km	1.3 km	3.3 km
Total area (ha, %)	61.96 ha, 100.00 %	27.54 ha, 100.00 %	60.69 ha, 100.00 %
Water bodies (ha, %)	2.74 ha, 4.43 %	4.42 ha, 16.04 %	3.32 ha, 5.48 %
Buildings (ha, %)	19.64 ha, 31.69 %	12.84 ha, 46.64 %	25.68 ha, 42.32 %
Green areas (ha, %)	39.58 ha, 63.88 %	10.28 ha, 37.33 %	31.68 ha, 52.21 %
Light pollution (Low, Moderate, High)	Moderate	High	High
Noise pollution (Low, Moderate, High)	Low	High	Moderate
Density of activities (Low, Moderate, High)	Low	High	Moderate
Fieldwork dates during 2022	May 11th, 2022 to November 30th, 2022	May 12th, 2022 to November 29th, 2022	May 13th, 2022 to November 28th, 2022
Transect length	6.2 km	3.5 km	4.9 km

Note: Dikmen Valley (D), Youth Park (Y), and Golden Park (G). This table summarizes key features of the three studied urban parks, including their founding year, proximity to Ankara landmarks (Ankara Stream and Ankara Castle), total area, and percentage of land use for water bodies, buildings, and green areas. Additionally, the table highlights the level of light and noise pollution, density of activities, and transect lengths for fieldwork conducted during 2022.

Data Collection

To assess bat activity in urban parks, we employed a bat detector (Echo Meter Touch 2 Pro for Android; Wildlife Acoustics, Inc., Maynard, MA, USA) to record bat echolocations from May 10 to November 30, 2022, across three representative parks in Ankara (Figure 1). The detector enabled real-time automatic recording of nighttime noises and full-spectrum recording of bat sounds, automatically separating them from other sounds to identify the species of bats. The detector captured the frequency, time interval, and species data. While ultrasonic detectors such as the Echo Meter Touch 2 Pro are effective for monitoring bat activity, their performance may be limited by low-intensity echolocation calls (e.g., faint or distant bats) and environmental factors such as background noise or distance from the target species. The Echo Meter Touch 2 Pro has a frequency range of (20–192) kHz, which generally covers most bat species, but detection accuracy may still vary depending on call strength and ambient conditions. These limitations were taken into account during data interpretation. Fieldwork involved walking along predetermined routes from 20:00 to 23:00 (local time) and standing at designated points to record bat echolocations using indirect (non-interventional) methods (Correia et al., 2013; Korner-Nievergelt et al., 2013). The bat detector was used 30 min before dusk. The researcher walked along the designated path for 3 h, pausing every 15 min to record bat calls for 10 min at each location. This was conducted once a week over 7 months.

Human disturbance, including light pollution, noise pollution, and activity density, were monitored and classified based on existing data from the Green Areas Branch Directorate of the Environmental Protection and Control Department of the Ankara Metropolitan Municipality. This helped to contextualize bat activity within various urban settings. Descriptive data on park conditions (e.g., light and noise pollution levels and activity densities) were documented meticulously and are summarized in Table 1.

Data analyses

The sound recordings from the detector were processed and recorded simultaneously using licensed analytical tools, including bcAdmin, BatIdent, and bcAnalyze (ecoObs GmbH, Nuremberg, Germany), on an Apple MacBook OSX 10.10.1 laptop. The three programs were operated sequentially. The number of files and sounds in the recordings was first determined by analyzing the collected records using bcAdmin. Based on the likelihood percentage, the BatIdent program then identified which bat species the sounds belonged to.

Finally, the identified species was confirmed using the bcAnalyze application to display the visuals of each sound individually and compare the acoustic patterns with reference literature (Ahlén, 1981; Ahlén and Baagøe, 1999; Parsons & Jones, 2000; Walters et al., 2012; Jones et al., 2013; Walters et al., 2013; Barataud et al., 2015). Species identification was based on peak, minimum, and end frequencies. Species with a confidence interval of ≥80% were considered among those identified using the BatIdent program. Files that did not belong to a bat or could not be identified by looking at their sonograms, as well as sounds to which the analysis program attributed <80% likelihood, were not included in the assessment. The accuracy of bat call identification was prioritized, with collaborative efforts made to verify and refine data accuracy.

The following bat community parameters were calculated to gauge biodiversity:

Dominance Index (Krebs, 1989)

Richness (Krebs, 1989)

Margalef's Richness Index (Margalef, 1958)

Shannon–Wiener Diversity Index (Spellerberg & Fedor, 2003)

Evenness Index (Magurran, 1988)

Sørensen's Similarity Index (Sørensen, 1948; Krebs, 1989).

For statistical analysis, one-way analysis of variance (ANOVA) was conducted to compare bat species distribution across the three parks, treating nightly observations as replicates. This analysis was performed using R software (version 4.2.3; R Foundation for Statistical Computing, Vienna, Austria) in accordance with ANOVA standards (Herberich et al., 2010).

Results

Bat species

Nine bat species were identified in three urban parks in Ankara (Table 2): *Hypsugo savii*, *Miniopterus schreibersii*, *Nyctalus noctula*, *Pipistrellus kuhlii*, *Pipistrellus nathusii*, *Pipistrellus pipistrellus*, *Pipistrellus pygmaeus*, *Tadarida teniotis*, and *Vespertilio murinus*.

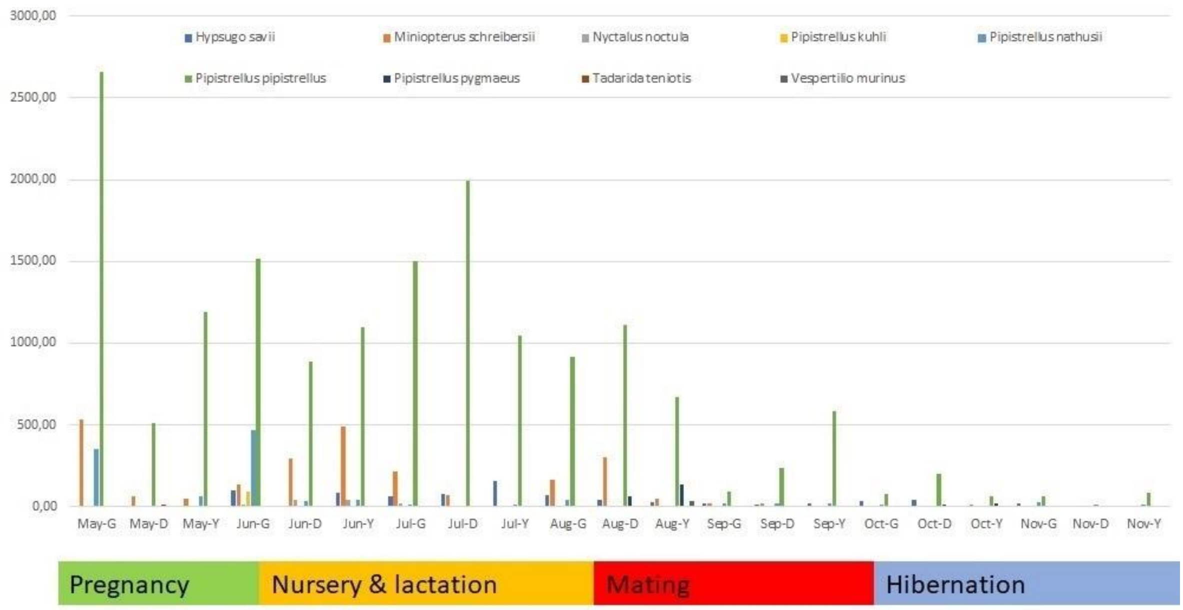
Table 2. The bat fauna list recorded in the three urban parks

Month-Park	*Hsav*	*Msch*	*Nnoc*	*Pkuh*	*Pnat*	*Ppip*	*Ppyg*	*Tten*	*Vmur*
May-G	0	43 (535.5)	0	0	31 (354.37)	229 (2660.1)	0	0	0
Jun-G	11 (99.20)	9 (135)	2 (11.7)	6 (87.67)	36 (469.62)	132 (1514.4)	0	0	0
Jul-G	10 (64.2)	16 (213.53)	2 (21.27)	0	1 (15)	139 (1498.4)	0	0	1(6.8)
Aug-G	7 (67.2)	12 (164.4)	0	0	5 (41.89)	91 (912.35)	0	0	0
Sep-G	2 (15.62)	3 (19,8)	0	0	2 (16.71)	11 (93)	0	0	0
Oct-G	5 (32.04)	0	0	0	2 (11.8)	7 (74.8)	0	0	0
Nov-G	2 (17.8)	0	0	0	3 (25.9)	8 (61.75)	0	0	0
May-D	0	6 (61.5)	0	0	0	53 (510)	0	2 (13.56)	0
Jun-D	0	21 (293.5)	4 (41.23)	0	4 (34)	79 (886.5)	0	0	0
Jul-D	9 (75.17)	6 (72.71)	0	0	0	209 (1996.3)	0	0	0
Aug-D	5 (40.9)	27 (302)	0	0	0	103 (1112.8)	8 (64.4)	0	0
Sep-D	2 (10.72)	4 (22.2)	0	0	3 (20.5)	33 (237.2)	0	0	0
Oct-D	4 (43.8)	0	0	0	0	22 (196.3)	2 (12.87)	0	0
Nov-D	0	0	0	0	0	2 (9.9)	0	0	0
May-Y	0	4 (44.76)	0	0	6 (65.61)	109 (1187.5)	0	0	0
Jun-Y	8 (85.94)	34 (488.8)	3 (38.95)	0	4 (38.15)	98 (1093.6)	0	0	0
Jul-Y	20 (153.73)	0	0	0	1 (15)	94 (1044.3)	0	0	0
Aug-Y	4 (24.05)	5 (46)	0	0	0	69 (673)	19 (136.6)	0	2 (30)
Sep-Y	3 (16.28)	0	0	0	3 (18.93)	52 (581.6)	0	0	1 (7.2)
Oct-Y	0	1 (14.15)	0	0	0	10 (64.1)	3 (18.5)	0	0
Nov-Y	0	0	0	0	1 (9.4)	10 (84.3)	0	0	0

Note: Golden Park (G), Dikmen Valley (D), Youth Park (Y), *Hypsugo savii* (Hsav), *Miniopterus schreibersii* (Msch), *Nyctalus noctula* (Nnoc), *Pipistrellus kuhlii* (Pkuh), *Pipistrellus nathusii* (Pnat), *Pipistrellus pipistrellus* (Ppip), *Pipistrellus pygmaeus* (Ppyg), *Tadarida teniotis* (Tten), and *Vespertilio murinus* (Vmur). The first numbers show the total bat voice records. The numbers in parentheses show the total activity of the bat species (seconds) in the total voice records.

Bat activity

Throughout the 7-month study period, a total of 21, 280 seconds of bat activity was recorded. Golden Park exhibited the highest activity level, accounting for 43% of total recording time, followed by Dikmen Valley at 28.9% and Youth Park at 28.1%. *Pipistrellus pipistrellus* emerged as the dominant species, accounting for 77.5% of total activity, whereas *T. teniotis* displayed the lowest activity at 0.06%. Notably, species richness peaked in Golden Park in June and July, whereas November had the lowest activity, particularly in Dikmen Valley, where only one species was recorded. The peak activity of *P. pipistrellus* occurred in May in Golden Park, accounting for 12.5% of total activity during this period (Figure 3). Activity patterns varied seasonally, with peaks during the nursery and lactation periods and minimal activity during the hibernation period.



(Figure 3)

Figure 3. Graph of bat species activity (in seconds) by months and parks due to annual biological cycles.

Community parameters

A comparative analysis of community parameters across the parks was conducted using the Dominance, Margalef's Richness, Shannon–Wiener Diversity, Evenness, and Sørensen's Similarity indices, along with Richness and average population size. Dikmen Valley demonstrated the highest dominance ratio, primarily owing to the prevalence of *P. pipistrellus*. Although species richness was consistent across the parks, Golden Park showed the highest diversity, evenness, and average population size. Sørensen's Similarity Index revealed equal similarity ratios between Golden Park and Youth Park and between Dikmen Valley and Youth Park, but the similarity ratio between Golden Park and Dikmen Valley was lower (Table 3).

Table 3. Bat community parameters for the three urban parks

Community parameter	Golden Park	Dikmen Valley	Youth Park
Dominance Index	84.54	92.92	86.17
Richness (species number)	7	7	7
Richness Index	0.89	0.93	0.94
Diversity Index	0.884	0.680	0.841
Evenness	0.454	0.349	0.432
Average population size	118	86.9	80.6
Similarity Index	**Golden Park**	**Dikmen Valley**	**Youth Park**
Golden Park	*	1.4	0.85
Dikmen Valley	1.4	*	0.85
Youth Park	0.85	0.85	*

Note: Golden Park (G), Dikmen Valley (D), Youth Park (Y). The table summarizes bat community parameters across the three urban parks, including Dominance Index, Species Richness, Richness Index, Diversity Index, Evenness, and Average Population Size. Similarity Index values were based on the presence of similar species, with higher values indicating greater similarity between parks.

Statistical analyses

Due to the non-normal distribution and variance in the data, we employed a multiple comparison test (Herberich et al., 2010). This analysis revealed that the probability values (Pr[>|t|]) were consistently >1.000, indicating no significant differences in the variables tested across the parks (Table 4).

Table 4. Multiple comparisons of the linear hypotheses

Species	Comparison	Estimate	Standard error	t value	Pr(>|t|)
Hsav	**D - G == 0**	-2.7857	2.1296	-1.3080	0.399
	Y - G == 0	0.5476	3.7918	0.1440	0.988
	Y - D == 0	3.3333	3.5978	0.9260	0.622
Msch	**D - G == 0**	-3.357	7.200	-0.466	0.887
	Y - G == 0	-5.190	8.617	-0.602	0.819
	Y - D == 0	-1.833	7.129	-0.257	0.964
Nnoc	**D - G == 0**	-0.0714	0.6667	-0.1070	0.9940
	Y - G == 0	-0.0714	0.6773	-0.1050	0.9940

	Y - D == 0	0.0000	0.7653	0.0000	1.0000
	D - G == 0	-9.8040	6.2690	-1.5640	0.2590
Pnat	**Y - G == 0**	-9.9290	6.2480	-1.5890	0.2490
	Y - D == 0	-0.1250	1.1630	-0.1070	0.9930
	D - G == 0	-11.8900	42.6800	-0.2790	0.9580
Ppip	**Y - G == 0**	-32.6400	38.8400	-0.8410	0.6790
	Y - D == 0	-20.7500	30.3800	-0.6830	0.7730
	D - G == 0	1.2500	1.0640	1.1750	0.4580
Ppyg	**Y - G == 0**	3.6670	3.4020	1.0780	0.5150
	Y - D == 0	2,4170	3.5650	0.6780	0.7630
	D - G == 0	-0.1429	0.1543	-0.9260	0.6120
Vmur	**Y - G == 0**	0.3571	0.4047	0.8820	0.6390
	Y - D == 0	0.5000	0.3742	1.3360	0.3730
	D - G == 0				
Tten	**Y - G == 0**	Inconsistent, Invalid			
	Y - D == 0				
	D - G == 0				
Pkuh	**Y - G == 0**	Inconsistent, Invalid			
	Y - D == 0				

Note: Golden Park (G), Dikmen Valley (D), Youth Park (Y), *Hypsugo savii* (Hsav), *Miniopterus schreibersii* (Msch), *Nyctalus noctula* (Nnoc), *Pipistrellus kuhlii* (Pkuh), *Pipistrellus nathusii* (Pnat), *Pipistrellus pipistrellus* (Ppip), *Pipistrellus pygmaeus* (Ppyg), *Tadarida teniotis* (Tten), and *Vespertilio murinus* (Vmur).
D-G == 0: Comparison between Dikmen Valley and Golden Park.
Y-G == 0: Comparison between Youth Park and Golden Park.
Y-D == 0: Comparison between Youth Park and Dikmen Valley.
Statistical Terms: Estimate, Standard error, t value, Pr(>|t|) (p-value <0.05 is considered statistically significant).

Discussion

Biodiversity and habitat utilization in urban parks

Our findings provide evidence that urban parks are vital habitats that support a diverse array of bat species, including those typically found in natural settings such as forests. Notably, *H. savii*, *T. teniotis*, and *V. murinus* were documented for the first time in urban settings in Turkey, suggesting an extension of their known distribution beyond traditional habitats. The high activity levels of *P. pipistrellus* and *P. kuhlii* underscore the adaptability of some bat species to urban environments, which is consistent with findings from previous studies illustrating the resilience of certain wildlife to urbanized landscapes (Geggie & Fenton, 1985; Gehrt & Chelsvig, 2003).

Impact of duman disturbance

Consistent with other studies, this study highlights the negative impacts of human disturbances, specifically light and noise pollution, on bat activity (Straka et al., 2019). Youth Park, which experienced the highest level of disturbance, had the lowest bat activity, reinforcing the sensitivity of bats to urban stressors. However, the persistence of high activity levels in some species suggests potential behavioral adaptations, which could be a focus for further studies on urban wildlife resilience and adaptation.

Community parameters and habitat suitability

The absence of significant differences in bat species distribution across the parks may reflect the uniformity of urban park management in Ankara. However, variations in species richness and community parameters, such as dominance and evenness, across different parks indicate the influence of microhabitat features and specific management practices on bat assemblages.

Each park has unique features that make it a suitable habitat for bats to thrive in different ways. In Golden Park, the presence of creek systems provides water sources and supports various vegetation that attracts insect prey and provides diverse roosting sites, which likely contribute to the diversity of bat species found in the park. In contrast, Youth Park's location offers fewer plant varieties with expansive open areas, which may serve as a suitable habitat for generalist bat species, but suggests limited roosting opportunities due to sparse vegetation. Dikmen Valley has a linear layout with scattered tree cover, which serves as travel routes for bats; nevertheless, the lack of dense canopy cover and presence of artificial lighting negatively affect bat species diversity in the area.

Synurbization and adaptation

The concept of synurbization, whereby wildlife adapts behaviorally and ecologically to urban environments, is supported by our observations of bats actively foraging and roosting in highly urbanized areas (Parker & Nilon, 2008; Hume et al., 2019). These adaptations may also include modifications to acoustic behavior, as urban bats may modify their echolocation to mitigate interference from urban noise (Starik & Götter, 2022).

Limitations of the study

This study provides valuable insights into bat communities in urban parks; however, several limitations should be acknowledged. First, the study duration of 7 months may not fully capture seasonal variations in bat activity or long-term ecological trends. Future research incorporating multi-year monitoring is recommended to address this gap. Second, the reliance on acoustic detectors, while non-invasive and effective, may introduce biases, as species with low-intensity calls or those less active during the study period could have been underrepresented. Additionally, the study was geographically confined to three urban parks in Ankara, which may limit the generalizability of the findings to other urban areas with differing environmental conditions. Finally, although key habitat features influencing bat activity were identified, the specific contributions of individual elements, such as tree species composition and water bodies, were not quantified. Addressing these limitations in future studies will enhance the understanding of urban bat ecology and inform more effective conservation strategies.

Explanation of rare or undetected species

The limited detection of certain bat species, such as *Nyctalus noctula* and *Tadarida teniotis*, or their complete absence in some parks may be attributed to both ecological and methodological factors. Ecologically, these species may have specific habitat requirements or behavioral traits that make them less suited to urban environments, particularly those with high levels of artificial lighting and noise pollution (Straka et al., 2019). For example, *T. teniotis* is known to forage in open spaces and may avoid areas with dense human activity or insufficient canopy cover, which could explain its low activity levels in Dikmen Valley and Youth Park. Methodologically, the use of acoustic detectors may introduce biases, as species with low-intensity echolocation calls or those active outside the study timeframe may have been underrepresented. Additionally, environmental factors such as background noise and distance from the detector may have affected detection accuracy. These limitations highlight the importance of combining acoustic monitoring with other methods, such as mist-netting or roost surveys, to obtain a more comprehensive understanding of bat communities in urban settings.

Conservation implications and future research

Urban parks are instrumental in the conservation of bats in cities, offering refuges that support their life cycles despite the challenges posed by urbanization. Enhancing the ecological features of these parks, such as increasing tree cover and water features, may mitigate the negative impacts of urbanization. Furthermore, integrating urban parks into broader urban planning and green infrastructure strategies will substantially benefit urban biodiversity.

Sustaining bat populations in city settings requires well-informed conservation strategies. Based on Threlfall et al. (2016), optimizing plant composition, ensuring ample understory vegetation, and preserving mature trees in city parks can benefit urban bat populations significantly. In addition, conserving water bodies such as ponds within city parks could offer feeding and drinking spots, as various bat species and their activity levels are affected by the plants in the surroundings (Ancillotto et al., 2019; Straka et al., 2020). Setting up bat boxes as man-made shelters can create living spaces when natural habitats are no longer available, helping sustain bat populations within parks (Mering & Chambers, 2014; Printz et al., 2021). For bats to thrive, light pollution should be addressed through urban planning strategies, striking a balance between conservation efforts and societal approval (Laforge et al., 2019; Pauwels et al., 2019). Bats likely prefer foraging and traveling along corridors, near parks, particularly at the edges. Such hallways could offer suitable habitat characteristics, with increased bat presence, according to Walsh and Harris (1996) and Hein et al. (2009). Future studies should aim for long-term monitoring of bat populations to better understand their ecological needs and responses to ongoing urbanization. Such data are crucial for developing targeted conservation strategies to ensure the sustainability of these vital urban ecosystems.

Conclusion

The present study aimed to survey, document, and compare bat species in three different urban parks in Ankara City (Turkey), focusing on their existence, frequency, and community features. Urban parks are indispensable sanctuaries for bat species in urban environments as they mitigate some of the adverse effects of urban development. Effective management strategies that minimize human disturbance, such as noise and light pollution, and enhance habitat diversity through green spaces and water features, are crucial for promoting urban wildlife conservation. Future research should delve more deeply into how urban planning decisions influence bat activity patterns, facilitating the formulation of refined conflict management and conservation strategies. Such efforts are vital for preserving bat populations and maintaining ecological balance within urban areas.

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