A snapshot of bat activity across urban microhabitats in the Botanical Garden of the University of Vienna

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As part of the university field course 300032 UE Bat Monitoring and Methods (summer term 2025), a one-night acoustic survey was conducted in the Botanical Garden of the University of Vienna to assess bat activity across urban microhabitats. Five ecologically contrasting areas were selected to obtain insights into species occurrence, presence patterns, and spatial habitat use. Using full-spectrum detectors, a total of 7,163 validated bat passes were recorded. The resulting species assemblage was dominated by urban-adapted taxa, particularly species of the genus *Pipistrellus*. Activity levels and behavioural call types varied among sites, with the coniferous forest exhibiting the highest levels of foraging and social activity. Activity at the water pond was elevated compared to the remaining sites but substantially lower than in the coniferous forest. Although data collection was limited to a single spring night, the study highlights the potential of small-scale acoustic surveys for assessing urban biodiversity and underlines the value of university-based field courses for monitoring bat populations in urban green spaces.

Nouioua R (2026) Fledermäuse in urbanen Mikrohabitaten des Botanischen Gartens der Universität Wien.

Im Rahmen der universitären Lehrveranstaltung „300032 UE Fledermaus Erfassung und Methoden" (Sommersemester 2025) wurde eine nächtliche akustische Erhebung im Botanischen Garten der Universität Wien durchgeführt, um die Fledermausaktivität in unterschiedlichen urbanen Mikrohabitaten zu erfassen. Hierfür wurden fünf ökologisch kontrastierende Teilbereiche ausgewählt, um Einblicke in das Artenspektrum, Präsenzmuster und räumliche Habitatnutzung zu gewinnen. Mithilfe von Vollspektrumdetektoren wurden insgesamt 7.163 validierte Fledermausaktivitäten aufgezeichnet. Die resultierende Artengemeinschaft wurde von urban angepassten Taxa dominiert, insbesondere von Arten der Gattung *Pipistrellus*. Aktivitätsniveau und Art der Verhaltensrufe variierten zwischen den Standorten, wobei der Nadelwald die höchsten Werte für Fangrufe und Sozialrufe aufwies. Die Aktivität im Bereich des Teiches war im Vergleich zu den übrigen Standorten erhöht, jedoch deutlich geringer als im Nadelwald. Obwohl die Erhebung auf einen einzelnen Frühjahrsabend beschränkt war, verdeutlichen die Ergebnisse das Potenzial kleinräumiger akustischer Untersuchungen zur Bewertung urbaner Biodiversität. Gleichzeitig unterstreicht die Studie den Wert universitärer Lehrformate für die praxisnahe Erfassung und das Monitoring von Fledermäusen in städtischen Grünräumen.

Keywords: Chiroptera, acoustic monitoring, urban ecology, habitat use, bat activity.

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Introduction

Urban green spaces, such as botanical gardens, provide vital refuges for wildlife within increasingly sealed and fragmented cityscapes (Russo & Ancillotto 2015). Among the species that benefit from such habitats are bats, which fulfil key ecological functions as

insectivores. Due to their high sensitivity to habitat structure, climate variation, and anthropogenic disturbance (e.g. light pollution, urbanization), bats are regarded as valuable bioindicators (Voigt & Kingston 2016). Understanding how bats use urban green spaces is therefore essential in the context of accelerating global urbanisation and its impacts on biodiversity conservation.

One key approach to studying bat presence and activity in such environments is acoustic monitoring. Bats rely on echolocation to navigate, forage, and communicate during the night. By emitting ultrasonic calls and interpreting returning echoes, they perceive their surroundings in great detail. This natural behaviour enables researchers to detect and identify bat species in situ through bioacoustic methods (López-Baucells et al. 2019). Compared to traditional techniques such as mist-netting, acoustic monitoring is non-invasive, continuous, and particularly effective in detecting elusive or high-flying species. For these reasons, it has become a cornerstone of contemporary bat research and was chosen for this study.

The Botanical Garden of the University of Vienna, located near the city centre, comprises a mosaic of semi-natural habitat types embedded within an urban environment, including forested areas, edge zones, and sites with water availability. As one of several green spaces embedded in Vienna's urban fabric, it contributes to the city's ecological value at a time when increasing emphasis is being placed on biodiversity monitoring and species protection (Stadt Wien n.d.). While earlier projects such as *Die Tierwelt des Botanischen Gartens der Universität Wien* (Pernstich & Krenn 2004) compiled comprehensive species records across numerous taxa, from invertebrates to birds and small mammals (Hoffmann 2004), bats were only marginally considered. This student project, conducted in spring 2025, adds to existing work by using passive acoustic monitoring to document bat activity during a single night in the Botanical Garden of the University of Vienna.

The aim of this study was (1) to compile a preliminary inventory of bat species occurring in the Botanical Garden of the University of Vienna, and (2) to explore how small-scale habitat variation shapes bat activity and species-specific temporal patterns in this urban green space.

We tested the following hypotheses: (1) Bat activity and species composition differ across microhabitats within the Botanical Garden, with higher activity levels and species richness expected in structurally diverse and insect-rich areas compared to more open or anthropogenically influenced locations. (2) Temporal patterns of social and feeding activity differ between species and microhabitats, with distinct activity peaks occurring at different times and sites, reflecting variation in behavioural habitat use.

Methods

Study site and acoustic survey design

To monitor bat activity and species composition within the Botanical Garden of the University of Vienna, we deployed five stationary passive acoustic detectors (AudioMoth v1.11.1, Open Acoustic Devices), programmed to record full-spectrum echolocation calls. This non-invasive approach follows standard practice in bat research, where passive acoustic monitoring is widely used to detect species presence and activity patterns

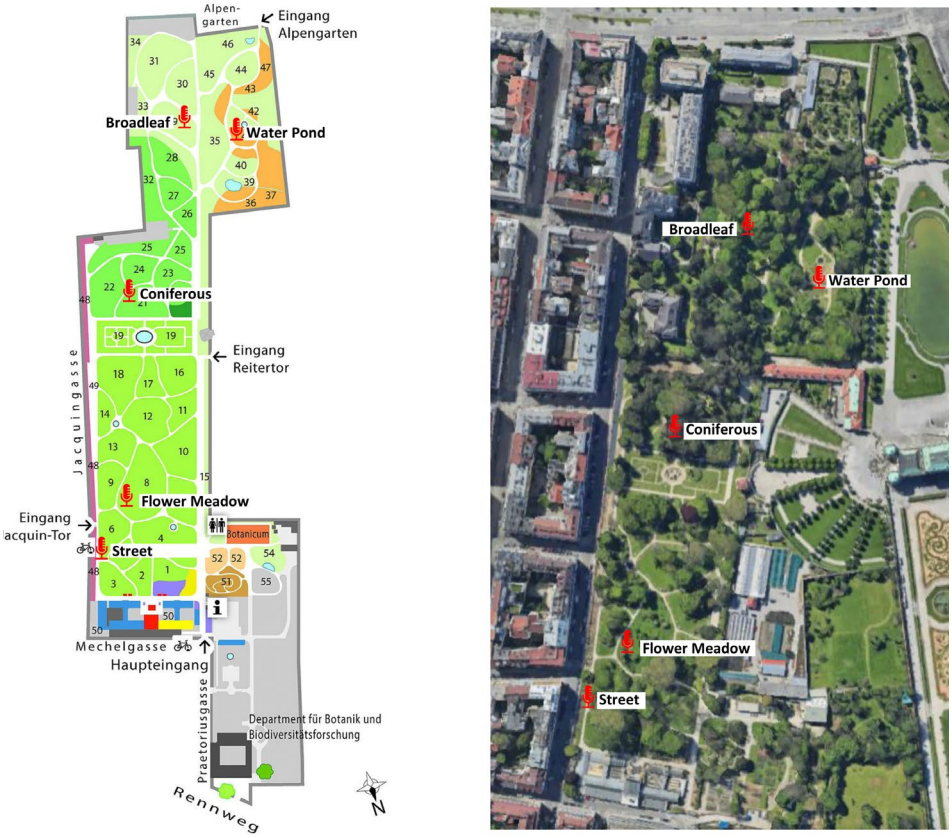


Fig. 1: Overview of the five recording locations within the Botanical Garden of the University of Vienna, as used during the acoustic bat survey on 28–29 April 2025. The left panel shows a schematic site map with habitat designations (Botanical Garden of the University of Vienna, https://botanischergarten.univie.ac.at/der-garten/gartenplan/; publicly available web content). The right panel shows an aerial and satellite image representation for spatial context (© Google Maps). All annotations by the author. Recording sites include street, flower meadow, coniferous forest, broadleaf forest, and water pond. | **Abb. 1:** Überblick über die fünf Aufnahmestandorte im Botanischen Garten der Universität Wien, die während der akustischen Fledermauserhebung am 28.–29. April 2025 verwendet wurden. Die linke Abbildung zeigt eine schematische Standortkarte mit Habitatbezeichnungen (Kartengrundlage: Botanischer Garten der Universität Wien, https://botanischergarten.univie.ac.at/der-garten/gartenplan/; öffentlich zugänglicher Webinhalt). Die rechte Abbildung zeigt eine Luft- und Satellitenbilddarstellung zur räumlichen Einordnung (© Google Maps). Sämtliche Annotationen durch die Autorin. Die Aufnahmestandorte umfassen Straße, Blumenwiese, Nadelwald, Laubwald und Teich.

(e.g. Vaughan et al. 1997; López-Baucells et al. 2019). Devices were configured for quasi-continuous operation (55 s recording / 5 s pause), with a sampling rate of 250 kHz, enabling detection of ultrasonic signals up to 125 kHz. Gain was set to *high* (level 2), optimized for quiet environments. Two units were housed in commercial IPX7-rated waterproof cases; the remaining three used custom-built enclosures.

Five passive acoustic recorders were deployed at ecologically contrasting microhabitats within the Botanical Garden (Fig. 1). These included: a street-edge site (48°11'35.6"N, 16°23'05.8"E) characterised by sealed surfaces, artificial lighting, and minimal vegetation; a flower meadow (48°11'34.7"N, 16°23'04.3"E) with herbaceous vegetation, open canopy, and presumed high insect abundance; a dense coniferous forest stand (48°11'29.0"N, 16°23'02.9"E) with low light penetration; a structurally complex broadleaf forest patch (48°11'24.3"N, 16°22'58.8"E) dominated by mixed deciduous trees; and a water pond site (48°11'24.7"N, 16°22'56.8"E) featuring a permanent still waterbody. Each device was mounted 1–1.5 m above ground and secured to nearby vegetation. All units were activated on 28 April 2025 at 19:30 CEST, 30 minutes before local sunset, and recorded continuously until 06:00 CEST the following morning.

Acoustic data processing and identification workflow

Each of the five recording stations produced a full night of recordings, resulting in a total sampling effort of 48 hours of full-spectrum audio data. Recorders were programmed to collect 55-second audio files followed by a 5-second pause, with a sampling rate of 250 kHz and no triggering filters enabled. All audio files were saved in .wav format. The recordings were subsequently processed in Kaleidoscope Pro (version 5.4.0, Wildlife Acoustics Inc., Maynard, MA, USA) using Bat Analysis Mode and the "Bats of Europe" classifier (Austria region). The AUTO-ID sensitivity was set to 0 to balance false-positive and false-negative rates. Bat passes were defined as sequences of up to 5 seconds containing at least two distinct echolocation pulses, following established standards (Fenton 1970; Barataud 2015; Dietz & Kiefer 2016). The detection algorithm filtered for pulses with a peak frequency between 9 and 120 kHz; files outside this range were automatically excluded as noise.

For each accepted file, Kaleidoscope produced an AUTO-ID species label, sonogram visualisation, and an associated metadata file, containing timestamp, species, and classifier confidence values. These outputs were then subjected to post manual validation, during which each file was inspected to verify bat pass identity, eliminate false positives, and remove non-bat sources (e.g. wind, insects, rodents). Validation was based on call structure (e.g. frequency, modulation, duration, inter-call interval) and guided by acoustic references. These call parameters are well-established identifiers in European bat echolocation research (Barataud 2015; Dietz & Kiefer 2016). All final identifications were made by the author, ensuring overall consistency. Participants from the university course *300032 UE Bat Monitoring and Methods (2025S)* conducted site-level analyses focusing on species composition, habitat-specific bat activity, feeding and social activity and temporal patterns. All statistical analyses and data visualizations were performed in R (version 4.3.1; R Core Team, 2023), using the package ggplot2.

Results

Species composition and habitat use

Across all five habitat types, a total of 7,163 validated bat passes were recorded (Tab. 1). These were assigned to ten bat species or broader groups. The most frequently detected species group was *Pipistrellus kuhlii* (Kuhl. 1817)/ *Pipistrellus nathusii (Keyserling & Blasius,*

Tab. 1: Number of validated bat passes per species and habitat type recorded across five sites in the Botanical Garden of Vienna; * taxonomic authors in the results section. | **Tab. 1:** Anzahl der validierten Fledermaus-Passagen pro Art und Habitattyp, erfasst an fünf Standorten im Botanischen Garten Wien; * taxonomische Autoren im Ergebnisteil

Species / Site	Water Pond nPass	Coniferous nPass	Broadleaf nPass	Flower Meadow nPass	Street nPass	Total nPass per species
Nyctalus noctula (Schreber, 1774)	159	8	44	127	42	380
Nyctalus leisleri (Kuhl, 1817)	62	4	19	59	11	155
Eptesicus serotinus (Schreber, 1774)	85	5	9	25	5	129
Hypsugo savii (Bonaparte, 1837)	76	19	178	103	21	397
*Pipistrellus kuhlii / Pipistrellus nathusii**	1,015	2,082	714	290	96	4,197
Pipistrellus pipistrellus (Schreber, 1874)	99	440	43	28	19	629
Pipistrellus pygmaeus (Leach, 1825)	138	861	147	34	52	1,232
Myotis daubentonii (Kuhl, 1817)		4	5			9
*Myotis mystacinus / Myotis brandtii**		1				1
Myotis sp.	5	17	12			34

1839), accounting for 4,197 passes (58.6%) of all recorded activity. This was followed by *Pipistrellus pygmaeus* (1,232 passes; 17.2%), *Pipistrellus pipistrellus* (629; 8.8%), *Hypsugo savii* (397; 5.5%) and *Nyctalus noctula* (380; 5.3%). Less frequently recorded were *Nyctalus leisleri* (155; 2.2%) and *Eptesicus serotinus* (129; 1.8%). *Myotis* taxa were rare overall, contributing less than 1% to the dataset: *Myotis daubentonii* (9 passes), *Myotis mystacinus (Kuhl, 1817)/ Myotis brandtii* (Eversmann, 1845) (1 pass), and unidentified *Myotis* sp. (34 passes) (Tab. 1).

Species composition and relative activity varied between habitat types (Tab.1). The coniferous forest exhibited the highest overall activity (3,441 passes; 48.0% of total detections), followed by the water pond (1,643; 22.9%), broadleaf forest (1,167; 16.3%), flower meadow (666; 9.3%), and street (246; 3.4%). *Pipistrellus kuhlii / P. nathusii* was dominant across all sites, with the highest activity in the coniferous forest (2,082 passes; 29.1% of total detections) and at the water pond (1,015; 14.2%). *Pipistrellus pygmaeus* followed a similar pattern, with particularly high activity in the coniferous forest (861; 12.0%). *Hypsugo savii* showed the highest activity in the flower meadow and broadleaf forest. In contrast, *Myotis* sp. detections were limited to structurally complex habitats (coniferous, broadleaf forest, and water pond) and entirely absent from the street and flower meadow.

Behavioral call types

A total of 1,318 social calls and 284 feeding buzzes were recorded across all sites (Tab. 2). Social calls occurred most frequently in the coniferous forest (941; 71.4%), followed by the water pond (200; 15.2%), broadleaf forest (133; 10.1%), street (30; 2.3%), and flower meadow (14; 1.1%). Feeding buzzes were most commonly detected in the coniferous forest (151; 53.2%), followed by the water pond (69; 24.3%), broadleaf forest (50; 17.6%), flower meadow (11; 3.9%), and street (3; 1.1%).

Temporal and habitat-specific activity patterns

Bat activity varied distinctly across the night, showing clear temporal and habitat-specific patterns (Fig. 2). The highest overall activity was recorded during the first hour after sunset (20:00 – 20:59 CEST), with the broadleaf forest, water pond, and flower meadow contributing most strongly to this early peak. It was driven by multiple species, most notably *P. kuhlii / P. nathusii*, followed by *P. pygmaeus*, *P. pipistrellus*, as well as increased activity of *H. savii* and *N. noctula*.

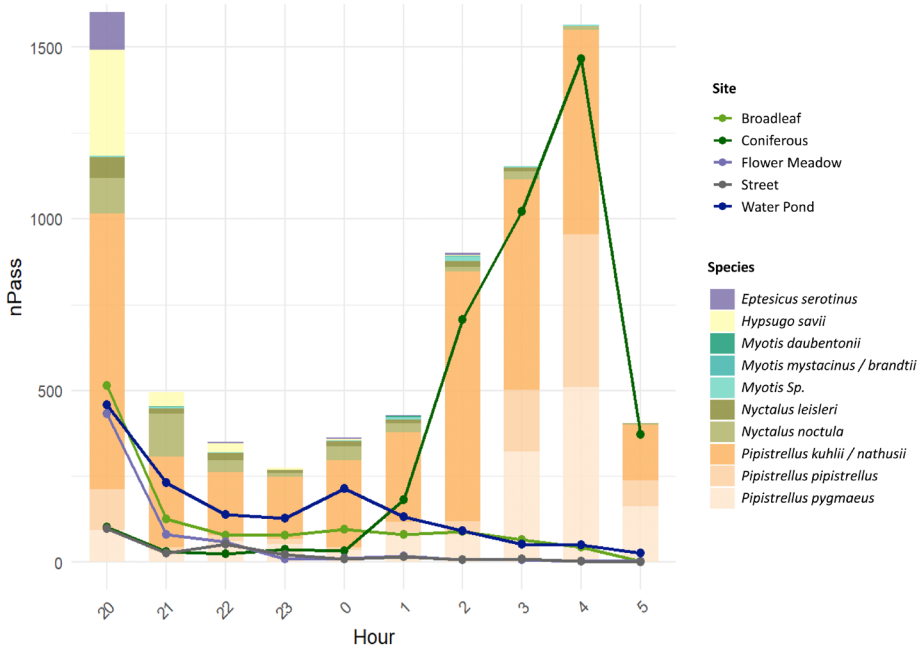


Fig. 2: Hourly bat activity by species and site during the recording night (28–29 April 2025) in the Botanical Garden of the University of Vienna, based on the validated number of bat passes (nPass). Coloured stacked bars show species-specific bat activity per hour aggregated across all recording sites, whereas coloured lines represent site-specific bat activity per hour. | **Abb. 2:** Stündliche Fledermausaktivität nach Art und Standort während der Aufzeichnungsnacht (28.–29. April 2025) im Botanischen Garten der Universität Wien, basierend auf der validierten Anzahl an Fledermausaktivitäten (nPass). Farbige, gestapelte Balken zeigen die artspezifische Fledermausaktivität pro Stunde, aggregiert über alle Aufnahmestandorte, während farbige Linien die standortspezifische Fledermausaktivität pro Stunde darstellen.

Tab. 2: Number of validated social calls and feeding buzzes per bat pass recorded across five sites in the Botanical Garden of Vienna. | **Tab. 2:** Anzahl der validierten sozialen Rufe und Fress-Summlaute (Feeding Buzzes) pro Fledermaus-Vorbeiflug, aufgezeichnet an fünf Standorten im Botanischen Garten Wien.

Behavior / Site	Water Pond	Coniferous	Broadleaf	Flower Meadow	Street	Total
Social Calls	200	941	133	14	30	1,318
Feeding buzzes	69	151	50	11	3	284

Following the initial peak, activity declined across all habitats and remained moderate during the central hours of the night (21:00 - 01:00 CEST). From around 02:00 onwards, a second increase in bat passes was observed in the coniferous forest, where activity gradually rose and approached levels similar to the initial peak by 04:00. This late-night peak was again dominated by *Pipistrellus* spp.

In contrast, activity at all other sites remained low throughout most of the night, particularly at the street-edge and flower meadow sites following the initial peak. *Myotis* spp. were rarely recorded and were confined to the water pond and forested habitats. Due to their low overall detection rate, no clear temporal pattern could be identified for this genus.

Discussion

Although our results represent a single-night snapshot, the observed bat activity shows spatial and temporal patterns that are consistent with known ecological traits and habitat preferences of the detected species. The dominance of *P. kuhlii* / *P. nathusii* across all sites likely reflects the ecological flexibility of this group and its widespread association with urban environments (Ancillotto et al. 2016). Particularly high activity levels in the coniferous forest and at the water pond may result from a combination of structural complexity, water proximity, and elevated insect abundance.

While echolocation-based classification does not allow unambiguous species-level discrimination between *P. kuhlii* and *P. nathusii*, the urban setting and the known ecological association of *P. kuhlii* with built environments suggest that a substantial proportion of detections likely correspond to *P. kuhlii* (Ancillotto et al. 2016). However, *P. nathusii* is a migratory species, and transient individuals may contribute to acoustic detections during spring migration (Hutterer et al. 2005). In addition, model-based projections indicate spatially heterogeneous but locally suitable conditions for *P. nathusii* in parts of continental Europe, such that occasional occurrences in Central European urban green spaces cannot be excluded (Lundy et al. 2010). Importantly, individual-level studies from urban and peri-urban environments in Austria have demonstrated pronounced within-species variability in space and time use for both *P. kuhlii* and *P. nathusii* (Milchram et al. 2025). Such individual flexibility provides a plausible explanation for overlapping acoustic activity patterns between these two taxa, even when their species-level ecological associations differ.

By contrast, *Pipistrellus pygmaeus* showed a similar habitat association, particularly in the coniferous site, which aligns with previous findings on fine-scale habitat partitioning among *Pipistrellus* spp. *Pipistrellus pygmaeus* typically prefers wetter and more structurally complex habitats than *P. pipistrellus*, which was recorded less frequently and more evenly across sites (Davidson-Watts et al. 2006).

Hypsugo savii and *Nyctalus noctula* were primarily active in open or edge-dominated habitats, such as the flower meadow and water pond. These spatial patterns and their pronounced early-night peaks are consistent with open-air foraging strategies and high mobility. The occasional pre-dawn activity of *N. noctula* may represent roost return flights, as documented in temperate zones (Kaňuch 2007).

Nyctalus leisleri and *Eptesicus serotinus* were recorded less frequently but showed clear site associations. *Nyctalus leisleri* occurred mainly at the flower meadow, while *E. serotinus* was more common at the water pond and flower meadow sites, both matching their known preference for open foraging areas and some tolerance of urban structures (Dietz & Kiefer 2016).

Myotis spp. were rare and confined to the more structurally complex habitats, coniferous and broadleaf forest. Their low detectability likely reflects both ecological constraints and methodological limitations, as their low-intensity, broadband calls are more difficult to capture with passive acoustic monitoring (Barataud 2015; Dietz & Kiefer 2016).

The spatial distribution of behavioural call types reinforces the interpretation that the coniferous forest served not only as a major foraging area, but also as a socially important zone. Most social calls, particularly advertisement calls, were recorded in this habitat, suggesting either proximity to roosts or territorial interactions. Habitat structure around roosts has been shown to influence calling behaviour and site fidelity (Oakeley & Jones 1998; Middleton et al. 2014). The occurrence of feeding buzzes and social calls across all sites suggests that bats actively used the entire garden, albeit likely for different functional purposes.

Temporally, bat activity followed a bimodal pattern, with a broad early peak after sunset and a second, more pronounced peak in the coniferous forest patch between 02:00 and 04:00. The first likely reflects emergence and initial foraging, while the second may correspond to resumed activity near roosts (Rydell et al. 1996). Notably, this late peak was again dominated by *Pipistrellus* spp. and coincided with an increase in social calls, particularly in the coniferous forest.

Despite bat activity being recorded at all sites, total bat passes and behavioural call types varied substantially. The coniferous forest and water pond, both located deeper within the Botanical Garden, emerged as key activity hotspots, likely due to a favourable combination of vegetation structure, humidity, and overall low disturbance levels (Russo & Ancillotto 2015; Voigt & Kingston 2016). In contrast, the street-edge site yielded the lowest activity, which may be attributed to its exposed position, minimal vegetation, and proximity to artificial lighting and traffic noise, conditions generally unfavourable for bats. The flower meadow showed a brief spike in early-night activity, followed by a sharp decline, potentially indicating transient foraging in response to short-lived insect availability.

Several limitations of this study must be acknowledged. Passive acoustic monitoring tends to favour the detection of loud, mobile and open-space foraging species, while quieter, clutter-adapted taxa such as species of the genera *Myotis* and *Plecotus* are often underrepresented due to their low-intensity echolocation calls and spatially restricted activity patterns (Barataud 2015; Dietz & Kiefer 2016). In addition, acoustic similarity among some taxa, particularly within *Pipistrellus* spp. and among *Myotis* spp., constrains species-level resolution (López-Baucells et al. 2019). Despite these constraints, the use of standardized recording protocols and thorough manual post-validation ensured a conservative and internally consistent dataset, suitable for exploratory comparisons between habitat types.

When interpreted in the context of the known bat fauna of Vienna, the species composition recorded here is highly consistent with results from recent urban and peri-urban activity-based surveys. Classical faunistic syntheses document a comparatively species-rich bat fauna for Vienna and its surroundings, including numerous forest-associated and roost-specialised taxa (Spitzenberger 1990; Spitzenberger 2001). However, these inventories primarily document species presence and roost occurrence across Vienna and its surroundings, rather than fine-scale, activity-based patterns derived from standardized acoustic surveys within small inner-city green spaces.

In contrast, more recent studies focusing explicitly on bat activity within the urban core consistently show that acoustic activity in small urban green spaces is dominated by a subset of edge and open foraging species, particularly *Pipistrellus* spp., *Hypsugo savii*, and *Nyctalus noctula* (Hüttmeir et al. 2010; Wiesinger 2017; Reiter et al. 2023).

Species such as *Vespertilio murinus*, although widespread and regularly documented in Vienna, are strongly associated with high-rise building roosts and typically forage at greater heights and over large spatial scales. Their activity is therefore less likely to be captured by stationary detectors placed within enclosed urban green spaces (Spitzenberger 1990; Hüttmeir et al. 2010; Reiter et al. 2023).

Similarly, *Plecotus* spp., including *Plecotus austriacus*, are well documented from Vienna but emit very low-intensity echolocation calls and forage close to vegetation or roost structures, resulting in highly localised activity patterns that are difficult to detect with passive acoustic monitoring alone (Spitzenberger 1990; Barataud 2015). The absence or rarity of these taxa in the present dataset therefore most likely reflects species-specific ecology, spatial scale, and survey design rather than true absence from the urban landscape. Overall, the observed assemblage aligns well with current knowledge of bat activity patterns in Vienna and supports the interpretation of the Botanical Garden as a functionally important urban foraging habitat for common and adaptable species.

Implications for urban bat conservation

This study highlights the ecological value of small yet structurally diverse green spaces in urban environments. The Botanical Garden of the University of Vienna supported a functionally rich bat assemblage, with clear spatial and temporal structuring of activity across habitat types. Key features promoting bat presence and behavioural diversity included vertical vegetation structure, water availability, and low levels of human disturbance (Russo

& Ancillotto 2015; Voigt & Kingston 2016). These findings complement earlier faunal surveys such as *Die Tierwelt des Botanischen Gartens der Universität Wien*, by documenting nocturnal and mobile species previously underrepresented (Pernstich & Krenn 2004). In light of ongoing urbanisation, conserving and enhancing such habitat features is critical to maintaining bat diversity and the ecosystem functions it supports within cities (Voigt & Kingston 2016).

Compared to earlier methods employed in the 2004 survey (e.g. visual observations, trapping, direct collection), passive acoustic monitoring offers a non-invasive and temporally resolved approach well suited to detecting elusive, mobile species like bats (Pernstich & Krenn 2004; Kiehn 2004). The data generated here add a complementary layer to the garden's biodiversity profile and illustrate the potential of standardised acoustic surveys, implemented within an educational framework, for small-scale urban bat assessments.

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