WILDLIFE BIOLOGY

Research Article

Nocturnal neighbors: exploring residents' perceptions of urban wildlife related to animal traits identified by camera traps and literature

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Wildlife Biology
2026: e01522
doi: 10.1002/wlb3.01522

Subject Editor: Christian A. Hagen
Editor-in-Chief:
Christian A. Hagen
Accepted 19 January 2026

Wildlife in urban areas is often a source of conflict, yet relatively few efforts have been directed toward fostering coexistence in these human-dominated landscapes. While previous research has focused on socio-demographic factors influencing perceptions of wildlife, the role of specific animal traits in shaping acceptance remains underexplored. This study, conducted in the city of Freiburg, Germany, analysed survey respondents' acceptance of wild mammals in their neighborhood (n = 779), considering animal traits derived from literature (diet and size) and field data (nocturnal activity and urban habitat preference) collected through camera traps (n = 24). Our results highlight nocturnal activity as the strongest predictor of 'wildlife acceptance'. More nocturnal species such as badgers *Meles meles*, foxes *Vulpes vulpes*, rats *Rattus* spp., wild boars *Sus scrofa*, and martens *Martes* spp., were generally less accepted than more diurnal species such as rabbits *Oryctolagus cuniculus* and squirrels *Sciurus vulgaris*, as well as crepuscular species such as roe deer *Capreolus capreolus*, hares *Lepus europaeus*, and hedgehogs *Erinaceus europaeus*. These findings suggest that the reduced visibility of nocturnal animals and associated misconceptions – such as fear of darkness – might contribute to their lower acceptance. This pattern indicates a need to address how the invisibility and perceived threat of nocturnal wildlife can exacerbate human–wildlife conflicts. Urban planners and educators can draw from this study to prioritize nature education and awareness campaigns focusing on nocturnal species. Proactively addressing misperceptions and emphasizing the ecological roles of nocturnal animals can help mitigate negative stereotypes and promote coexistence in urban environments.

Keywords: camera trap study, human–wildlife coexistence, human–wildlife interactions, urban wildlife, wildlife perception

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Introduction

Wild mammals are increasingly found across various urban greenspaces such as cemeteries, urban forests, and city parks (Gallo et al. 2017). These species, referred to as 'urban wildlife' (Adams 2005, McCleery 2010), exhibit notable adaptability, modifying their behaviors to navigate city life (Ditchkoff et al. 2006, Lowry et al. 2013, Ritzel and Gallo 2020). Following Fischer et al. (2015), urban wildlife can be categorized into urban avoiders (rarely found in cities), urban utilizers (occasional users of urban resources, sometimes breeding in developed areas), and urban dwellers (populations that either split between natural and urban spaces or are fully dependent on cities). Generally, species that become urban dwellers share traits like 1) activity patterns adjusted to human presence, 2) dietary flexibility, and 3) smaller body size (Adams et al. 2005, Adams 2009, Decker et al. 2012). While many urban-adapted species shift their activity to nighttime to avoid human disturbances, such as cars and dog-walkers (Gaynor et al. 2018, Gallo et al. 2022, Procko et al. 2023), others have adjusted to diurnal activity to take advantage of human presence, such as being fed (Meyer et al. 2005, Ziege et al. 2016, Devarajan et al. 2025). Omnivorous mammals and those that eat anthropogenic food sources are especially successful in urban areas (Bateman and Fleming 2012, Murray et al. 2015, Newsome et al. 2015). Regarding size, there is a tendency for small to medium mammals to settle in urban areas, as the high imperviousness of cities does not offer the habitat features needed by large mammals such as wolves *Canis lupus* (Behr et al. 2017). However, even while not settling, such larger animals as wild boar *Sus scrofa* are present in cities (Basak et al. 2022, Moesch et al. 2024a) and roam in the urban adjacent woodlands (Stillfried et al. 2017).

While urban wildlife offers potential ecosystem services (e.g. vermin control) and social benefits (e.g. human–nature reconnection), it can also generate conflicts from damage to public and private property to a threat to citizens' and pets' safety (Soulsbury and White 2015, Basak et al. 2022). To improve coexistence of humans and wildlife in urban areas, reducing conflicts is essential (Urbanik and Johnston 2017, Hunold and Mazuchowski 2020). Here, effective urban wildlife management depends on understanding public attitudes towards wild mammals that become urban dwellers, as management decisions are often guided by public perception (Manfredo et al. 2003, Davies et al. 2004). For instance, 'charismatic' species often spread more successfully due to reduced human opposition (Jarić et al. 2020). Perceptions reveal a continuum between liked and disliked animals (Rupprecht 2017, Baker et al. 2020, Perry et al. 2020, Grundei et al. 2024), and understanding the acceptance of their presence (Behr et al. 2017, Kimmig et al. 2020, Straka et al. 2022) is crucial to reducing conflict and strengthening human–nature relationships. Studies of wildlife perception often focus on socio-demographic variables as explanatory factors (Basak et al. 2022, Moesch et al. 2024b). For example, Kellert (1996) identified age as a significant influence on wildlife perception, Bjerke and Østdahl (2004) and Moesch (2024b) highlighted gender, Rupprecht (2017) emphasized education levels, Kimmig et al. (2020) explored urban versus rural living, and Murray et al. (2023) examined the impact of being parents of young children. However, there is a gap in exploring the ecological traits of wildlife that influence acceptance in residential settings. So far, place-specific animal traits affecting wildlife perception were rarely tested but rather discussed – mostly connected to size, predatory tendencies, aesthetics (including texture, e.g. fluffy, sleek), or assumed intelligence (Kellert 1989, Woods 2000, Callahan et al. 2021). For example, carnivorous animals are often viewed negatively due to perceived danger (Lescureux and Linnell 2010, Franchini et al. 2021, Newsom et al. 2025). Similarly, regarding size, larger animals are often seen as threat to life (Prokop et al. 2021) and are preferred to be far away from urban areas (Ngo et al. 2022). Animals living mostly in highly impervious urban areas are often seen as pests or nuisances rather than welcomed sights, or even not considered as wildlife, e.g. pigeons *Columba* spp. (Alshehri et al. 2023) or rats *Rattus* spp. (Byers et al. 2019, Lee et al. 2024). Linked to activity, humans know and like the animals they encounter (Sweet et al. 2023, Moesch et al. 2024b). Often traits can be seen as influencing cultural narratives of wildlife (Kalof et al. 2016). While for birds, studies suggest that traits explain perceptions (Andrade et al. 2022, Randler et al. 2023) but, so far, no study has examined how wild mammals in urban environments are perceived in relation to their traits.

Recent literature reviews call for interdisciplinary studies to bridge the divide between human dimensions research and wildlife ecology (Soulsbury and White 2015, Lischka et al. 2018, Moesch et al. 2024c). To address the current gap in investigating wildlife perception linked to animal traits, we combine data from the same study region: 1) a web-based survey among citizens on perceptions of wildlife and 2) camera trap data on urban wild mammals' activity patterns and habitat preferences. Along with dietary focus and size identified from the literature, we built a model to assess which of four animal traits identified a priori (activity, urban habitat preference, diet, and size) are most important for the acceptance of the animal's presence in the immediate neighborhood (henceforth referred to as 'acceptance').

In line with common assumptions and prior research – such as the perception of carnivores and larger species as threatening (Franchini et al. 2021, Prokop et al. 2021), the view of species in highly urbanised areas as nuisances (Alshehri et al. 2023, Lee et al. 2024), and the greater familiarity and likability of diurnal species (Sweet et al. 2023, Moesch et al. 2024b) – wildlife acceptance in urban areas appears to be influenced by traits like body size, diet, activity patterns, and habitat use. We formulate four hypotheses (H1–H4), proposing that wildlife species in urban environments are less accepted due to specific traits:

- H1: a species' activity pattern influences its acceptance, predicting that wild mammals with a more nocturnal activity pattern are less accepted

- H2: a species' habitat preference influences its acceptance, predicting wild mammals occurring in urban areas with higher imperviousness rates are less accepted
- H3: a species' diet influences its acceptance, predicting wild mammals with a more carnivorous diet are less accepted
- H4: a species' body size influences its acceptance, predicting wild mammals with larger body sizes to be less accepted

Material and methods

Study area

The study was conducted in Freiburg, Germany (7°59′56″N, 7°50′31″E), a city spanning approximately 153 km^2 (Statista 2022) with a population of approximately 240 000 residents (Statista 2024). Located in the southwest of Germany, Freiburg lies within the federal state of Baden-Württemberg and borders the Black Forest, a region with diverse wildlife (MLR 2022). Freiburg is often highlighted as an ecologically friendly and green city (Affolderbach et al. 2018), e.g. through the design of the sustainable urban district Vauban (Coates 2013).

Focal species

For the study, we concentrated on ten wild mammals (Table 1) that are common in residential areas in Germany (Ineichen et al. 2012), are among the most familiar to German citizens (Sweet et al. 2023), and that interest residents and decision-makers the most (Peerenboom et al. 2020, Moesch et al. 2024a, 2024b). These ten mammals (Table 1) are European badger *Meles meles*, roe deer *Capreolus capreolus*, red fox *Vulpes vulpes*, European hare *Lepus europaeus*, European hedgehog *Erinaceus europaeus*, marten *Martes* spp., European rabbit *Oryctolagus cuniculus*, rat *Rattus* spp., Eurasian red squirrel *Sciurus vulgaris*, and wild boar (*Sus scrofa*. Henceforth, these ten mammals will be referred to by their common names (Table 1), e.g. 'squirrel' instead of 'Eurasian red squirrel'. As definitions of wildlife vary (Tian et al. 2023), for this study we considered all focal species as 'wild species' or 'wildlife', following the definition by the Convention on Biological Diversity (CBD) that '[W]ild species are populations of species that have not been domesticated and can survive independently of human intervention' (CBD 2022,), with '[w]ildlife include[ing] wild species of both flora and fauna. The terms wildlife and wild species are interchangeable.' (CBD 2020, p. 4). Although rats are sometimes regarded primarily as pests rather than as urban wildlife (Feng and Himsworth 2014), we consider them, along with the other nine wild mammal species in our study, to be 'urban wildlife'. This aligns with ecological research in which rats are explicitly studied as urban wildlife (Baker and Harris 2007, Parsons et al. 2017) and are examined alongside other wild mammal species in perception-focused contexts (Sweet et al. 2024).

Table 1. Focused mammals. Red List status for Germany retrieved from Meinig et al. (2020), update on hedgehogs (Rote Liste Zentrum 2024).

Symbol	Species	Scientific name	Common name	Red List status
	European badger	*Meles meles*	badger	Not Threatened
	Roe deer	*Capreolus capreolus*	roe deer	Not Threatened
	Red fox	*Vulpes vulpes*	fox	Not Threatened
	European hare	*Lepus europaeus*	hare	Threatened
	European hedgehog	*Erinaceus europaeus*	hedgehog	Near Threatened
	Stone marten Pine marten	*Martes foina* *Martes martes*	marten	Not Threatened Near Threatened
	European rabbit	*Oryctolagus cuniculus*	rabbit	Not Threatened
	Brown rat Black rat	*Rattus norvegicus* *Rattus rattus*	rat	Not assessed
	Eurasian red squirrel	*Sciurus vulgaris*	squirrel	Not Threatened
	Wild boar	*Sus scrofa*	wild boar	Not Threatened

Data collection

In our study, we applied three complementary approaches to collect and combine data: 1) an online survey capturing people's perceptions of our ten focal species; 2) camera-trap data collected across the study area to quantify species' activity patterns and urban habitat preferences; and 3) a literature review compiling information on diet and body size (weight) for the focal species.

Online survey

We developed a web-based survey to engage participants across Freiburg, utilizing the online platform SoSci Survey (www.soscisurvey.de). The survey was available exclusively in German for 77 consecutive days, from 12 January to 30 March 2023. The survey link was shared through university networks and various social media platforms, such as Instagram, Nebenan.de, Twitter, and Facebook, with a particular emphasis on Freiburg-based groups (e.g. Netzwerk Freiburg). Additionally, 1500 printed flyers containing QR codes were distributed to mailboxes within a 500 m radius of the camera trap sites, ensuring at least 50 flyers per location. The remaining flyers were posted as posters in prominent public areas, such as lampposts at street intersections, tram stations, and on bulletin boards at supermarkets and cafes throughout Freiburg.

The questionnaire (Supporting information) consisted of 15 questions plus a comment field at the end, organised into three sections: 1) Participants' residential area (three questions, such as '*Where do you live in Freiburg? – Please select your nearest public transport stop*'), 2) Preferences for wild mammals in residential areas, 3) Encounters and liking of wild mammals in residential areas (four questions, such as '*Have you seen this wild mammal?*' and '*How much do you enjoy seeing the mentioned animals in your neighborhood?*'), 4) Socio-demographic background (eight questions). The questions were a mix of open-ended, multiple-choice, and single-answer formats. The question '*How much do you enjoy seeing the mentioned animals in your neighborhood?*' – as base of the acceptance index – was asked for each of the ten mammals (Table 1) using a visual analogs scale (VAS; Gore and Kahler 2015) to capture nuanced responses from 'very much' (100) to 'not very much' (0), with 100 possible intermediate steps, depending on how the slider was adjusted (Gay et al. 2015, Gore and Kahler 2015).

Camera trap data

In total, 24 motion-triggered cameras (Bushnell 16MP Trophy Cam HD Essential E3 Trail Camera) were placed within and around the city of Freiburg with one camera per location (Fig. 1; see the Supporting information for specific location IDs). Cameras were set to photo mode only (no video), capturing three images per trigger with a 30-s interval, and the sensor sensitivity was set to normal. We followed the design protocol established by the Urban Wildlife Information Network (UWIN, www.urbanwildlifeinfo.org/), based at Lincoln Park Zoo in Chicago, USA – a project that has since evolved into a multi-city collaboration and monitoring initiative primarily across the United States (Magle et al. 2019). To identify appropriate camera trap sites, we employed a stratified random sampling approach (Kays et al. 2020). Using the ArcMap platform, we created a 1.5 × 1.5 m fishnet grid covering the entire area within the municipal boundaries of Freiburg. For each grid cell, we extracted data on impervious surface cover (i.e. the proportion of built-up or sealed land), based on the Copernicus Land Monitoring data set Imperviousness Density 2018 (European Environment Agency 2020), to represent the urbanization gradient. We then reviewed each grid cell to identify suitable locations for camera placement, focusing on green spaces of different types and sizes. Our goal was to achieve spatial representation along the urban gradient – categorized as high (> 50% developed), medium (30–50%), and low (< 30%) levels of urbanization – while maintaining a minimum distance of 1 km between sites. However, due to the prevalence of restricted and privately owned areas, resulting from diverse landownership, it was not possible to include all sites of interest. As a result, only locations that received permission from the respective private or public authorities were finally selected for camera trap installation. Cameras were installed in all public and private locations by researchers involved in the wildlife camera trap study in Freiburg. When staff changed, we followed a detailed protocol and held a formal handover meeting to ensure consistency in placement, such as using exactly the same tree and maintaining the same photographing direction. The camera traps were installed at a height of approx. 0.4 m and securely fastened around tree trunks in urban greenspaces. Those comprised urban parks, including cemeteries, campus areas, and botanical gardens (n = 6), as well as in woodlands on the urban fringe (n = 7), private gardens (n = 5), and roadside green strips between streets (n = 6).

For our analysis, we used camera trap images of the three years 2022, 2023, and 2024. Camera traps were set up at the same location four times a year for each season. We aimed at collecting four weeks of camera trap data in January for winter, April for spring, July for summer, and October for autumn (see details in the Supporting information). We only used locations in our analysis with at least each season (spring, summer, fall, winter) once across the three years, resulting in a minimum of four sampling periods and a maximum of 12 periods possible. Most locations were camera-trapped for all 12 possible periods (n = 12), while four locations had data for 11 periods, one location for nine periods, four locations for seven periods, and one location for five periods. Across seasons and years on average, a camera was in the field for 30.71 days, with a range from 10.0 to 55.0 days (Supporting information). This variation in the deployment period and the number of field days was due to issues with camera functionality and challenges related to personnel availability for collection and maintenance.

Data collection through camera traps was conducted in accordance with the General Data Protection Regulation (GDPR) and local data protection laws to ensure the privacy and rights of individuals were safeguarded. Camera traps were

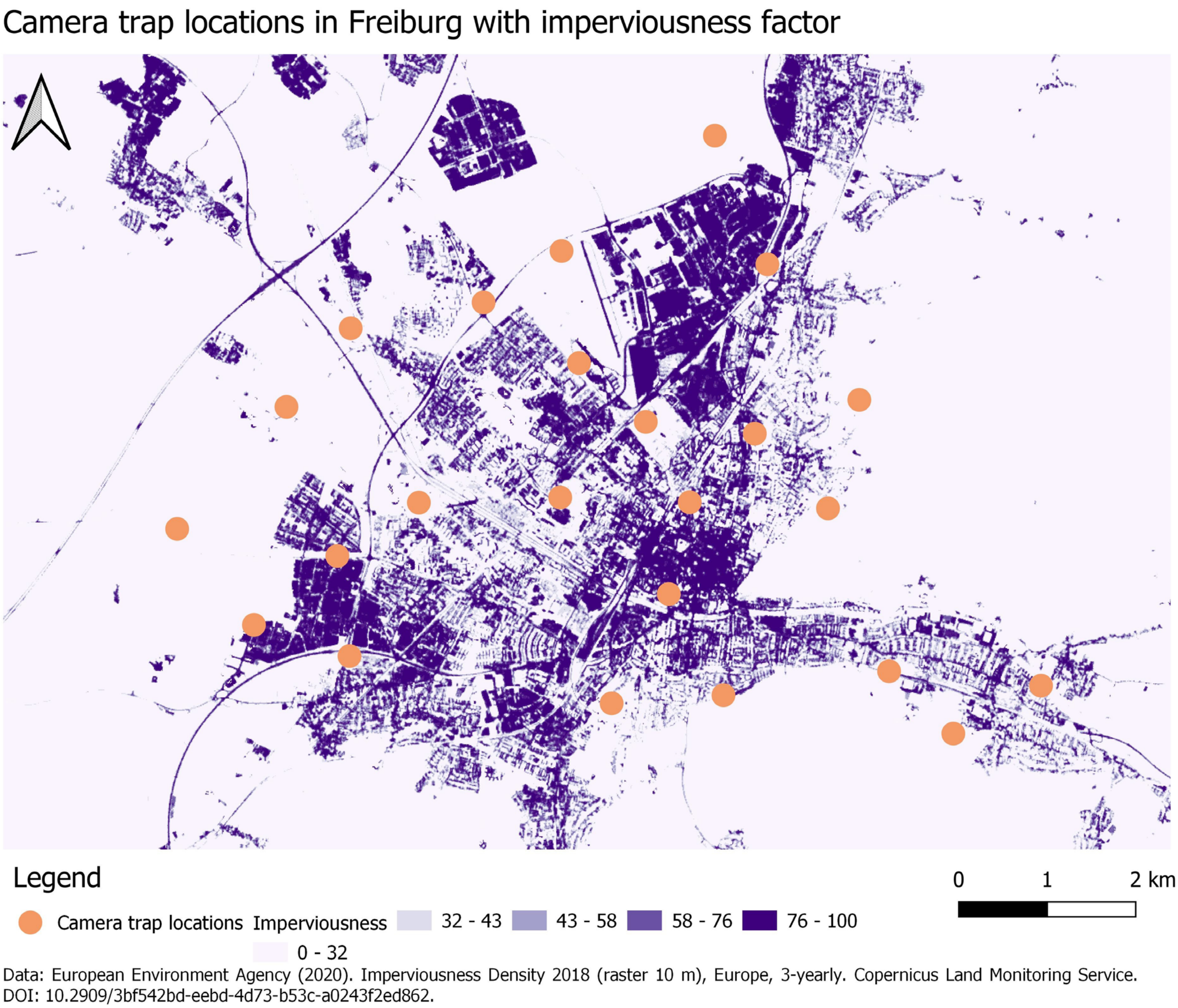

Figure 1. Camera trap locations (n = 24) in Freiburg, Germany, overlaid on the imperviousness factor from the European Environment Agency's (2020) Copernicus Land Monitoring service.

strategically placed to minimize the likelihood of capturing identifiable images of people, focusing exclusively on wildlife monitoring for scientific research purposes. Signs containing information about data protection (Supporting information), including contact information for the department responsible and data protection officer, were placed in close proximity to the camera traps. The responsible entity adhered to GDPR Article 6, Section 1, and Landesdatenschutzgesetz Baden-Württemberg (§ 13 LDSG BW) for data processing. Additionally, all recorded images were stored securely and retained only for the minimum necessary duration – either until securely transferred to a protected storage system or deleted within 3 months if no further action was warranted. Individuals retained the right to access information regarding their data, request correction, and, when applicable, deletion of personal data. Complaints or concerns could be directed to the university's data protection officer or the State Commissioner for Data Protection in Baden-Württemberg.

Using 'TimeLapse' (https://timelapse.ucalgary.ca/), a freely available program for marking wildlife species in camera trap images (Greenberg et al. 2019, Leorna and Brinkman 2022), we classified each photograph into one of the following categories: 1) the listed ten wild mammal species (Table 1, Fig. 2), 2) other wild mammals, such as raccoons *Procyon lotor*, 3) humans (including cars, bikes), 4) bird species, such as the green woodpecker *Picus viridis*, 5) domestic pets, like dogs *Canis lupus familiaris* and cats *Felis catus*, or 6) 'empty'. For 'empty', we followed Herrera et al. (2022), who classified images with no discernible animals or humans as 'empty'. Given the morphological similarities in size, shape, and phenotype between European pine martens *Martes martes* and stone martens *M. foina;* Vercillo et al. 2003) and the difficulty in distinguishing them in the camera trap photos (Schwegmann and Storch 2024), we grouped them together. Similarly, the resolution of the camera trap images made it challenging to distinguish between rats, mice,

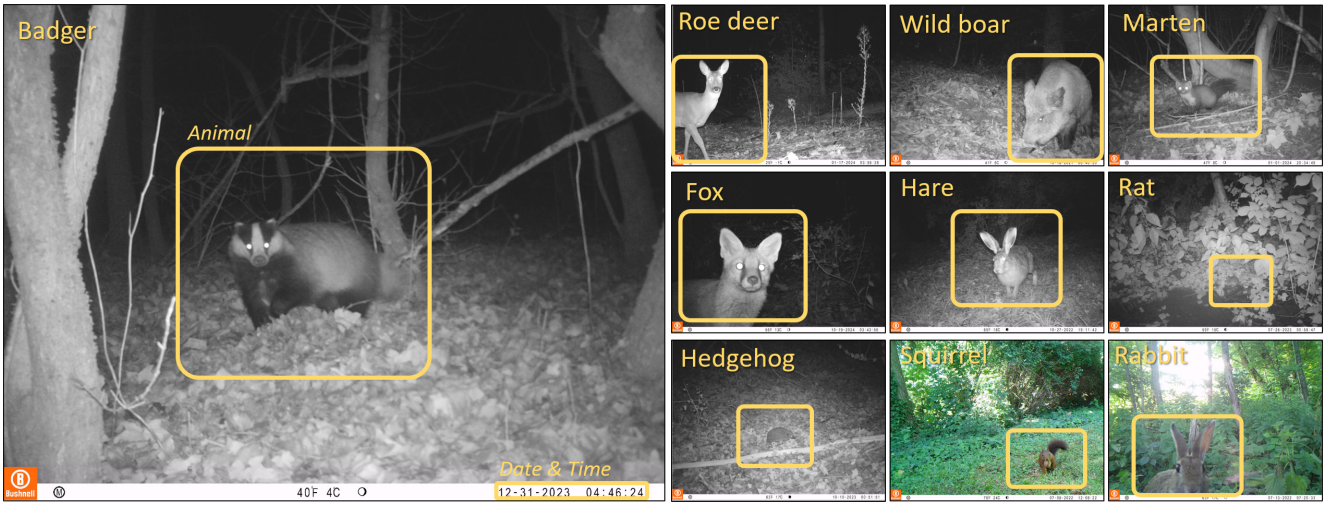

Figure 2. Identification of wildlife captured on camera with date, and time information included. Species names were manually marked using template labels. The figure features a large photo of an animal marked as a badger (yellow box) as the primary example, along with example camera trap pictures identified as roe deer, wild boar, marten, fox, hare, rat, hedgehog, squirrel, and rabbit.

shrews, and voles. For the purposes of this study, we grouped them together as 'rats' as these species often coexist sympatrically (Vadell et al. 2014, Weerakoon et al. 2014, Hancke and Suárez 2022). Two people involved in the project independently examined each image, identifying animals to the species level whenever possible. If species identification was not feasible, animals were categorized to the most specific taxonomic level allowed by the images. Following the example of other camera trap studies (Tourani et al. 2020, Loonam et al. 2021, Fennell et al. 2022), we used a 5-min interval between records of the same species; hence, an 'event' was defined as a detection of an animal species if it had not been recorded in the previous 5 min at the same site.

Literature review

We conducted a systematic review of the existing peer-reviewed literature on the diets of our ten focal mammal species. The review included articles published in English in international academic journals up to and including 30 June 2025. Following the PRISMA protocol (Moher et al. 2015), we searched the Scopus database (www.scopus.com). Search strings combined the term 'diet' with each species' common and scientific name using an OR operator (e.g. diet AND 'wild boar' OR '*Sus scrofa*'), targeting occurrences in the article title (see the Supporting information for full search strings). After removing duplicates, we removed unfitting articles based on two main criteria: 1) the study had to be conducted in Europe, and 2) the diet of the wild-living animal itself had to be the focus. Hence, we excluded studies conducted outside of Europe (e.g. on the diet on invasive foxes in Australia) and if the species appeared only as prey in another species' diet, as farmed animals raised for meat, or as pets or domestic animals. Last, we also added further publications known to contain relevant dietary information but not captured in the Scopus search. From the selected studies, we extracted dietary data for each species and, when available, we recorded quantitative estimates of diet composition. The included papers (Supporting information) were screened for information on what food the species consumed as well as values of biomass consumption (BC), showing the percentage of different food sources derived from the studied individuals' feces or stomachs. For body size, data were taken from the inventory book on urban wild animals by Ineichen et al. (2012), which covers species from Germany, Austria, and Switzerland.

Statistical analysis

Model selection

To test the acceptance of each species in relation to the selected traits, we fit a linear mixed-effects regression (LMER) using the *lmer* function from the 'lme4' R package (www.r-project.org, Bates et al. 2014). The use of an LMER is particularly suited, as it combines fixed effects with random effects, effectively estimating the contributions of both. The model is fitted using restricted maximum likelihood (REML), with significance assessed via t-tests using Satterthwaite's method (Bates et al. 2014). In this model, acceptance was the response variable, and we included four predictors ('Activity' as a temporal trait, 'Urban habitat preference' as a habitat selection trait, 'Diet' as a foraging trait, and 'Size' as morphological trait) with animal species as well as survey participants as a random factor. We tested predictor variables for multicollinearity with the variance inflation factor (VIF, Thompson et al. 2017), using the R package 'car' (Fox and Weisberg 2019). Following Akinwande et al. (2015), variables with a VIF factor < 5 can be included in the same models. For statistical significance tests, a threshold p-value of 0.05 was used.

Predictor variables

While the predictor variables for activity and urban habitat preference were derived from the camera trap data, covariates for diet and size were taken from the literature. For each species, an index was prepared to quantify their dietary composition and size, to provide a standardized basis for comparison across the ten focal species.

Regarding activity, since species' diel and nocturnal patterns are highly flexible in response to anthropogenic changes (Devarajan et al. 2025), we collected location-specific activity for the studied species. Using the *activityDensity* function from the 'overlap' R package (www.r-project.org, Meredith and Ridout 2018), we applied kernel density estimation to visualize single-species activity patterns (Ridout and Linkie 2009). To characterize the temporal activity patterns of our ten focal mammal species, we calculated probability distributions with the 'camTrap' R package (www.r-project.org, Niedballa et al. 2016). Additionally, we used the 'suncalc' R package (www.r-project.org, Thieurmel and Elmarhraoui 2023) to determine location-specific sunrise and sunset times, allowing us to categorize events into daytime and nighttime. Inspired by Herrera et al. (2022) and Gallo et al. (2022), we calculated the weighted mean as the mean proportion of nocturnal activity for each species, correcting for camera-trapping effort based on the number of days each camera was deployed in the field.

Regarding the urban habitat preference, we calculated the average imperviousness (e.g. roads, buildings, and other non-permeable surfaces) for each camera location. The imperviousness dataset, covering Europe at a 10-m resolution for the years 2017–2019, was obtained from the European Environment Agency (2020), as part of the Copernicus Land Monitoring Service. We performed spatial analyses using the R packages 'sf' (www.r-project.org, Pebesma and Bivand 2023) and 'terra' (Hijmans 2024). Camera locations and imperviousness data were provided as point and polygon shapefiles, respectively, and transformed into a common coordinate reference system for compatibility. Following other urban wildlife camera trap studies (McTigue and DeGregorio 2023, Prock et al. 2023, Oladimeji et al. 2024), a 500 mm radius buffer was created around each camera location to define the area of interest. These buffers were intersected with the imperviousness polygons, and the mean imperviousness values within each buffer were calculated. To ensure accurate analysis, rasterization of the imperviousness polygons was performed with a resolution of 10 m, facilitating efficient data extraction within buffers. For each species, a detection was calculated by dividing the number of recorded events per site by the total number of days the camera was active at the site. Using this detection and the corresponding imperviousness values per site, a weighted mean for imperviousness as the 'urban habitat preference' was calculated. This method ensures that sites with higher sampling effort did not have a greater influence on the final mean imperviousness, providing a more accurate representation of habitat preference. A higher detection (higher proportion of events of total days site was sampled) at sites with higher percentage of imperviousness indicated a stronger preference for urban environments. Imperviousness was summarized for each species as the weighted mean value (corrected for the trapping effort per site), with the standard deviation, illustrating urban habitat preferences across the spectrum of imperviousness in urban habitats (Fig. 1).

Regarding diet, we calculated the plant-based share of the diet for each species based on information from the literature included in our review (Supporting information). Each species was then assigned a 'diet value' ranging from 100% (entirely herbivorous) to 0% (entirely carnivorous). This approach was chosen because a simplified categorization into herbivores, omnivores, or carnivores (Brooker 2008) would have placed most of our focal urban mammal species into the omnivore category, given the widespread occurrence of omnivorous feeding strategies among urban wildlife (Chatelain and Szulkin 2020, Weiss et al. 2023). A continuous measure of herbivory allowed us to better capture dietary nuances and species-specific variation across the ten mammals studied.

Regarding body size, we used the weight of animals (in kilograms) as the size value from Ineichen et al. (2012). When a weight range was given, we selected the highest value to represent a fully grown individual.

Results

Online survey

Out of 916 survey participants, 779 completed all questions to the final page and were included in the analysis. Regarding the socio-demographic background (Supporting information) most survey participants were female (67%), while males accounted for 33%. The age distribution was balanced, with the largest proportion aged 18–30 years (33%), followed by 31–40 years (23%), 41–50 years (16%), 51–60 years (15%), and those aged 60 and above (13%). Most respondents held an academic degree (63%). A minority (19%) reported having children under the age of 18. Regarding garden access, 40% of participants had no access, 31% shared a garden, and 29% had access to private gardens. Additionally, the majority (61%) reported owning a car; while regarding pets, the minority (37%) indicated owning a pet. Most participants indicated their nearest bus stop in the city centre (Supporting information).

Acceptance of wild mammals in the immediate neighborhood

Wild mammal acceptance (Fig. 3) was measured on a VAS (0–100), with a median below 50 indicating lower acceptance.

Red squirrels ranked highest in acceptance (Fig. 3), with a score median of 98, followed by hedgehogs (98), hares (96), rabbits (91), and roe deer (91). Foxes (72) and badgers (71) were also generally accepted, though their medians fell into the lower two-thirds of the scale. Conversely, martens (42), wild boars (29), and rats (6) were the least accepted species, with score medians below 50. The acceptance of wild mammals, as illustrated by the mean scores (Supporting information), reveals a consistent pattern. Regarding encounters, the most frequently encountered mammal by survey participants (Supporting information), was the squirrel, observed by 689

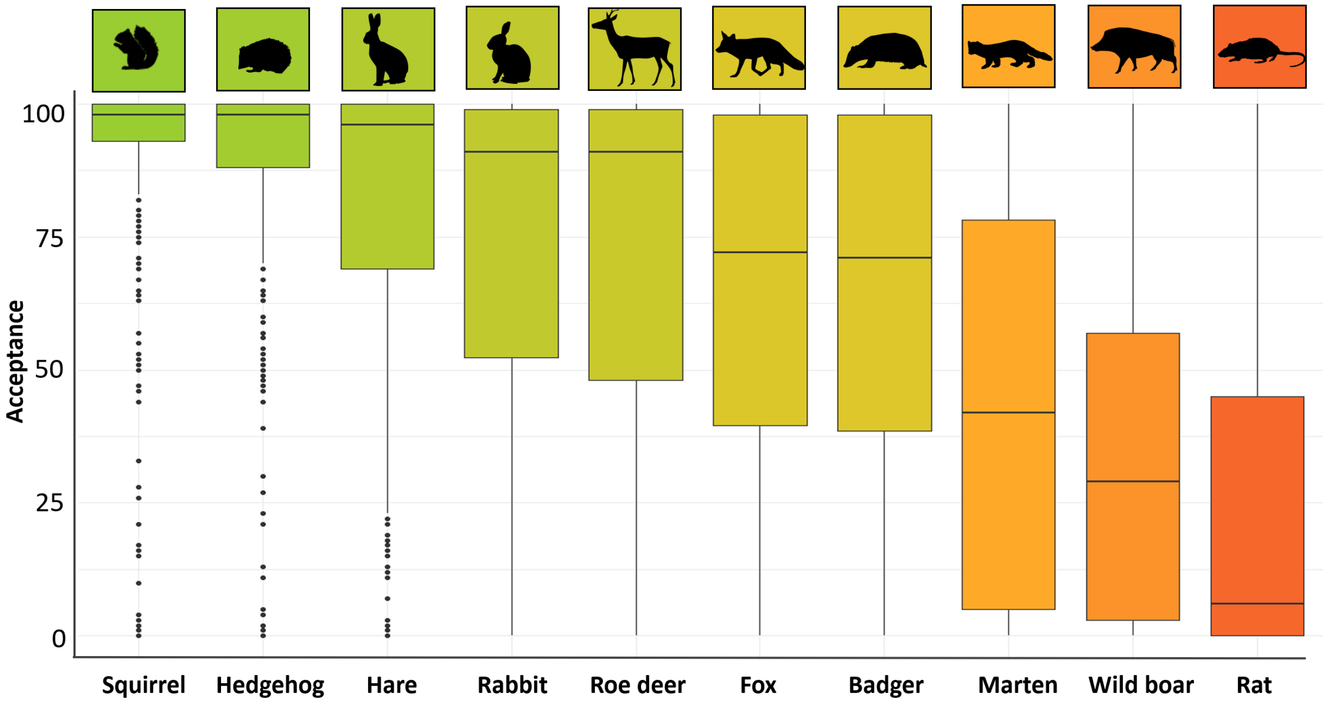

Figure 3. Acceptance of urban wild mammals in immediate neighborhoods based on survey responses. Boxplot displaying the acceptance of ten wild mammal species around the median as rated by survey participants (n = 779) using a visual analogue scale (VAS), ranging from 0 (strong agreement with enjoying the species' presence) to 100 (strong disagreement). Species are ordered from most to least accepted, with color shading reflecting the median acceptance score: green ('highly accepted'), transitioning through yellow, to red ('least accepted'). Animal silhouettes are sourced from phylopic.org.

participants (88.4%), followed by the hedgehog (n = 536, 68.8%). Approximately one-half of the participants reported encountering martens (n = 392, 50.3%) and rats (n = 361, 46.3%). Around one-third of participants indicated having seen foxes (n = 248, 31.8%), hares (n = 246, 31.6%), roe deer (n = 244, 31.3%), and rabbits (n = 225, 28.9%). Fewer than one-quarter of participants reported encounters with badgers (n = 115, 14.8%), and the least frequently observed species were boars (n = 65, 8.3%).

Mammal traits derived from camera traps

The ten mammals showed a different presence across the camera trap locations (Supporting information). Martens were observed at the highest number of locations (n = 23), followed closely by squirrels (n = 22), foxes (n = 21), and rats (n = 20). Badgers (n = 16), hedgehogs (n = 13), and hare (n = 12) were detected at over one-half of the locations. In contrast, roe deer (n = 9), wild boars (n = 7), and rabbits (n = 5) were recorded at the fewest locations. Regarding the number of events, rats were noted as having the most (n = 1487; Supporting information), followed by foxes (n = 1136), squirrels (n = 919), hares (n = 812), marten (n = 717), roe deer (n = 711), rabbits (n = 556), and badgers (n = 297). The lowest number of events was recorded for hedgehogs (n = 190) and wild boars (n = 59).

Urban habitat preference (Spatial)

On average, camera trap locations were situated in areas with an imperviousness of 29.63%. The highest imperviousness value was observed at Location 23 (a university building's garden in the city centre) with 74.43%, while the lowest was recorded at Location 13, located next to a forest road near the lake Opfinger See, with 1.72% (Supporting information).

Regarding urban habitat preference (Fig. 4), hedgehogs showed the highest urban habitat preference for areas with a high imperviousness (mean = 45.55%, SD = 23.27), similar to rats (mean = 43.65%, SD = 20.58). Likewise, martens (mean = 37.23%, SD = 23.13), squirrels (mean = 33.57%, SD = 13.37), hares (mean = 31.15%, SD = 14.46), rabbits (mean = 22.78%, SD = 2.43), and foxes (mean = 22.54%, SD = 13.64) also showed a preference for urban habitats with an imperviousness above 20%. Wild boars, badgers, and roe deer showed an urban habitat preference for lower imperviousness values, at 0.95% (SD = 2.94), 7.91% (SD = 7.29), and 9.81% (SD = 3.72), respectively.

Activity patterns (Temporal)

The ten investigated mammals showcased different activity patters (Fig. 5A). Wild boar, badger, fox, marten, and rat showed activity peaks between midnight and the early morning hours with minimal activity during daytime. These species exhibit highly consistent nocturnal behavior, peaking shortly after the evening hours (mostly sunset) and declining around the morning hours (mostly sunrise). In contrast, squirrel and rabbit displayed strong diurnal activity patterns, with activity peaks during daylight hours. Squirrels showed one peak around noon, while rabbits showed three, one peak

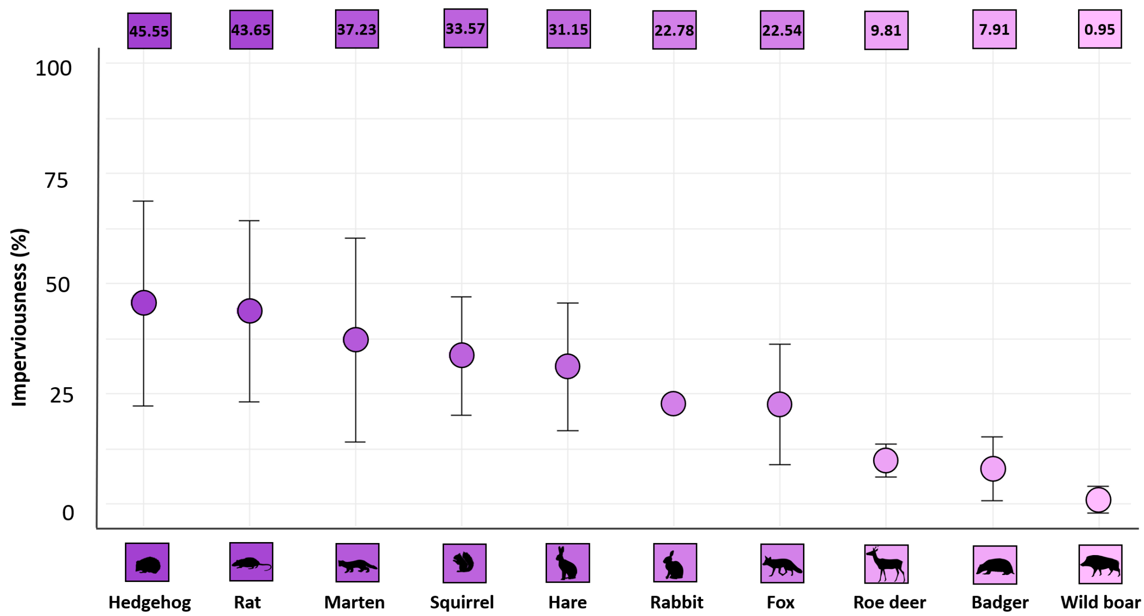

Figure 4. Urban habitat preferences derived from habitats used by the ten focal mammal species, based on average imperviousness from camera trap locations (n = 24). The plot shows the average imperviousness values for habitats, where the ten mammal species were more likely to be detected, calculated based on the detection of occurrences at sites with varying imperviousness. Mean imperviousness values are displayed at the top of each box. Darker violet shades indicate higher imperviousness, while lighter violet shades represent lower imperviousness. Whiskers represent the standard deviation of imperviousness values for each species.

in the morning, one in the afternoon, and one in the evening. Hedgehogs exhibited an activity pattern with two peaks, one around midnight and another around sunrise. Roe deer and hare exhibited bimodal activity peaks, concentrated around the early morning hours and early evening hours (mostly dawn and dusk), suggesting crepuscular behavior. Their activity patterns bridged both daytime and nighttime hours but remained distinct from the exclusively nocturnal or diurnal clusters. We calculated the nighttime activity proportions (Fig. 5B) for each of the ten mammals.

Wild boar exhibited the highest proportion of nighttime activity (95.9%) (Fig. 5B), followed closely by badger (93.0%), fox (86.7%), marten (83.8%), and rat (73.8%). Hedgehog (53.3%) and hare (48.6%) exhibited a nearly even distribution of daytime versus nighttime activity. In contrast, the remaining species demonstrated a greater tendency for daytime activity. Notably, roe deer (29.5%) showed moderate nighttime activity proportions, while rabbit (5.2%) and squirrel (0.1%) had the lowest levels of nocturnal activity.

Mammal traits derived from literature

Body size

Regarding body size (Table 2), body mass (weight) was derived from Ineichen et al. (2012), using the maximum values of the reported ranges, with wild boar (100.0 kg) and roe deer (30.0 kg) as the largest species, followed by medium-sized species such as badger (20.0 kg), fox (10.0 kg), hare (6.5 kg), and marten and rabbit (both 2.5 kg). The smallest species were hedgehogs (1.7 kg), rats (0.5 kg), and squirrels (0.4 kg).

Diet

Following the literature search for dietary information, we initially retrieved the highest number of papers for foxes (n = 65; Supporting information), followed by rats (49), wild boar and roe deer (both 35), badger (26), rabbit (23), marten (21), and a relatively low number for hare (13), squirrel (6), and hedgehog (3). After excluding studies that did not meet our inclusion criteria and incorporating additional relevant publications from known sources, we retained the highest number of papers for roe deer and foxes (both n = 28; Supporting information), followed by marten (18), wild boar and badger (both 16), rabbit and hare (both 9), and rat (7) with a limited number for squirrel and hedgehog (both 2). The papers included (Supporting information) were screened for information on biomass consumption (BC), showing the percentage of different food sources.

Of our ten focal species, three consistently showed a completely herbivorous diet across the identified studies: hare (Reichlin et al. 2006, Sangiuliano et al. 2016), rabbit (Marques and Mathias 2001, Martins et al. 2002), and roe deer (Cornelis et al. 1999, Sangiuliano et al. 2016) and all assigned a diet value of 100 (Table 2). Squirrels (diet value = 90, Table 2) showed a BC based mostly on plant-based food (Shuttleworth 2000, Wist et al. 2022). However, they are not completely herbivorous as they occasionally consume insects' grubs, bones, and birds' eggs (Shuttleworth 2000), but if given the option to choose between plant-based food (e.g. seeds, nuts) and animal-based food (insects), the latter is less favored (Wist et al. 2022). Wild boars (diet value = 90, Table 2) are generalist omnivores with a predominantly plant-based diet of roots, bulbs, seeds, nuts (Massei et al. 1996,

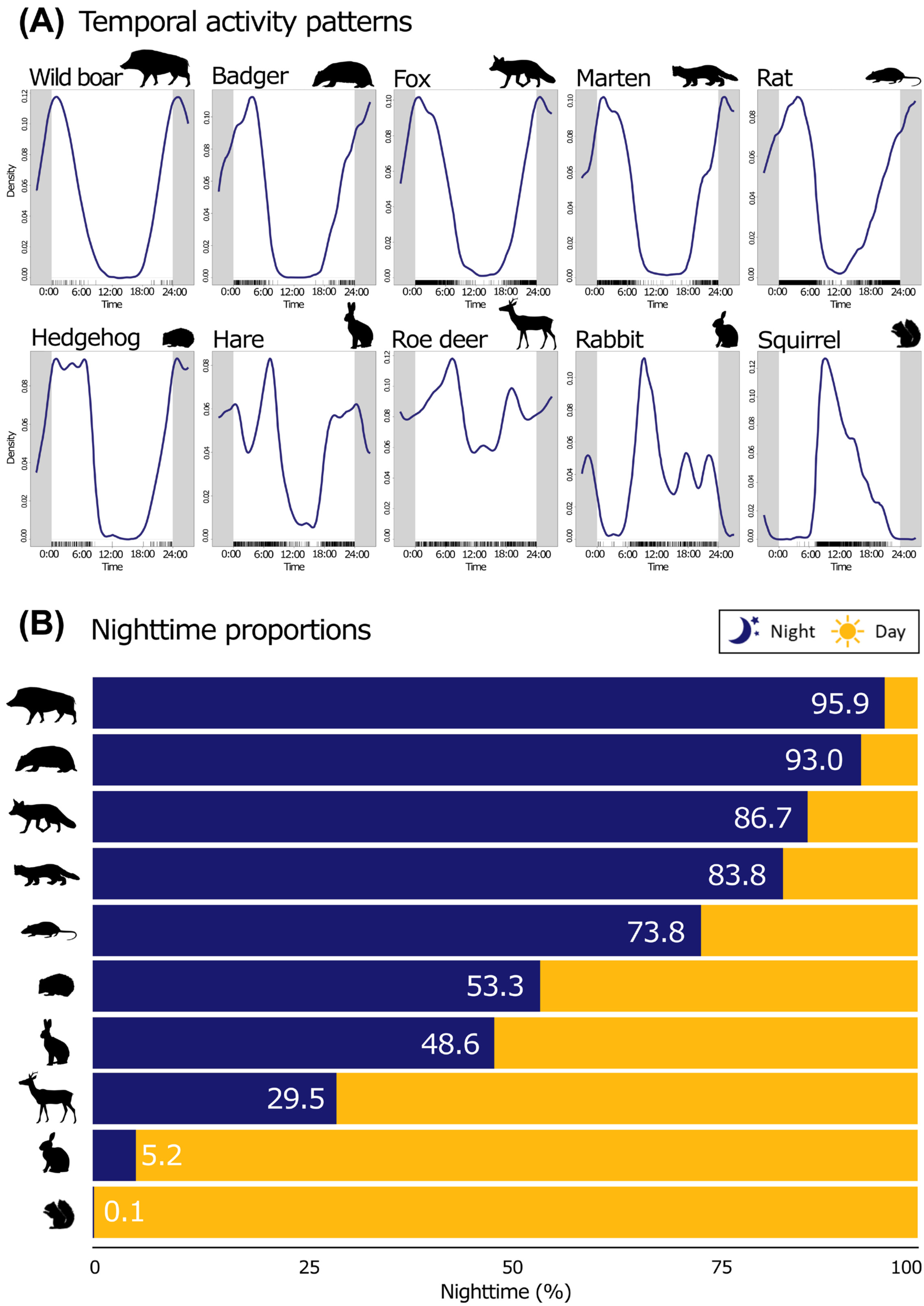

Figure 5. Temporal activity of ten urban wildlife species derived from camera traps (n=24). (A) 24-hour activity patterns of ten mammal species based on density estimates derived from observational records. Each plot represents the relative activity distribution over a 24-hour period, with the x-axis indicating time (hours) and the y-axis showing activity density. Gray areas indicate time periods that appear twice in the circular 24-h plots due to kernel density estimation over a cyclical timeline. (B) Nighttime proportions of the activity of ten wild mammals (sorted by highest to least nighttime proportions).

Table 2. Diets of ten focal mammal species derived from scientific literature. The species are characterized by their varied dietary habits, including herbivorous, omnivorous, and carnivorous preferences.

Species	Diet: The value for diet represents the percentage of herbivorous food intake from 0% to 100%	Body size: The value for size represents the min.–max. range for body mass (weight) for fully grown mammals in kg
Badger	20	15.0–20.0
Fox	10	4.0–10.0
Hare	100	3.0–6.5
Hedgehog	20	0.8–1.7
Marten	50	0.8–2.5
Rabbit	100	1.5–2.5
Rat	80	0.2–0.5
Roe deer	100	15.0–30.0
Squirrel	90	0.2–0.4
Wild boar	90	60.0–100.0

Stillfried et al. 2017), and acorns, especially in autumn and winter (Russo et al. 2017, Mikulka et al. 2018), but also animal-based food, e.g. earthworms (Russo et al. 2017), insects, and slugs (Mysterud et al. 2024) and opportunistic scavenging (Carpio et al. 2023). Generally, studies show BCs of 90% plant matter (Massei et al. 1996, Schley and Roper 2003). Badgers (diet value = 20, Table 2) feed on fruits, insects, small mammals, birds, and amphibians (Madsen et al. 2002, Zabala and Zuberogoitia 2003). Annual percentages of animal-based food in their BC range from approximately 50% (Roper and Lüps 1995, Hipólito et al. 2016), to approximately 60% (Roper and Mickevicius 1995, Goszczyński et al. 2000) to 90% (Lanszki 2004). Several studies highlight strong seasonal variation in animal-based percentage in their BC from as low as 10% in summer (Zabala et al. 2002) to 75% in spring (Zabala et al. 2002, Mysłajek et al. 2013) as well as a maximum of 90% in winter (Lanszki 2004). Martens (diet value = 50, Table 2) exhibit a highly flexible diet (Genovesi et al. 1996), with several studies reporting an equal split between animal- and plant-based food sources in their BCs for both stone marten (Bakaloudis et al. 2012, Hisano et al. 2016, Granata et al. 2022) and pine marten (Lombardini et al. 2015, Granata et al. 2022). A few other studies report more uneven dietary compositions, such as a 40:60 animal:plant ratio (Twining et al. 2019) or even 20:80 (Grabham et al. 2019) and some link such variations to seasons, as plant-based food intake can range from 20% in spring to 60% in autumn (Czernik et al. 2016), and gender differences with females consuming a higher proportion of plant matter than males (62% versus 46%; Zalewski 2007). Rats (diet value = 80; Table 2) show high adaptability in the selection of food (Pisanu et al. 2011, Pomeda-Gutiérrez et al. 2021), but with a strong preference for plants with BCs of 80% (Clapperton 2006, Guiry and Buckley 2018) to 92% (Nascimento et al. 2019). Hedgehogs (diet value = 20; Table 2), mostly depend on an animal-based diet (Gimmel et al. 2021) primarily consisting of insects such as ants, beetles, and flies, as well as earthworms, caterpillars, spiders, and slugs, with only a minimal intake of plant-based foods like seeds and nuts (Rautio et al. 2016). Last, foxes (diet value = 10; Table 2) are understood as a generalist predator (Scholz et al. 2020), mostly consuming small rodents (Pagh et al. 2015). Most studies highlight a plant-based BC around 10% (Cavallini and Volpi 1995, Contesse et al. 2004, Baltrūnaitė 2006, Helldin and Danielsson 2007), with fewer studies showing lower values of approximately 5% (Kidawa and Kowalczyk 2011, Lanszki et al. 2018), or higher at approximately 20% (Cavallini and Volpi 1996, Drygala and Zoller 2013, Lanszki et al. 2018, Petrov and Pancheva 2024).

Statistical analysis

An LMER (Fig. 6) was fitted to assess the effects of dietary habits, activity time, urban habitat preference, and size on the acceptance of animals, incorporating random intercepts for both individual species and survey participants. VIF values for all predictors were well below the threshold of 5, indicating no significant multicollinearity: diet (1.912), activity (2.17), urban habitat preference (3.07), and size (4.02). This suggests that the predictors included in the model do not suffer from excessive collinearity, allowing for independent interpretation of their effects. The REML criterion at convergence was 76005.1, indicating a good model fit. Scaled residuals ranged from −3.64 to 4.02, with the median residual close to zero (0.004), suggesting no significant outliers. Variability in the dependent variable, acceptance, was observed between the random factors: individual species (variance = 93.17, standard deviation = 9.65) and survey participant variance (859.8, standard deviation = 29.32), suggesting that other factors not captured by the model may influence acceptance. The intercept estimate was 90.66 (standard error = 18.59, t value = 5.055), which was significant ($p = 0.004$), indicating a significant baseline effect on acceptance across the sample. Among the predictors, only activity was strongly associated with acceptance (estimate = −0.47, $p = 0.02$), where wild mammals with higher nocturnal activity were accepted less. Urban habitat preference (estimate = −0.09, $p = 0.80$), diet (estimate = −0.31, $p = 0.06$), and size (estimate = 0.08, $p = 0.76$) were not strongly associated with acceptance.

Discussion

Following our four hypotheses, we found that certain wildlife traits indeed influenced human perceptions of wildlife.

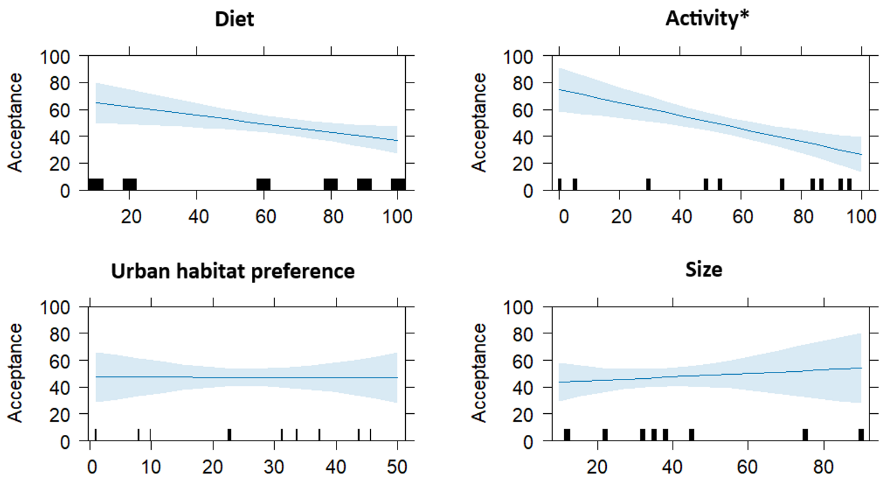

Figure 6. Relationships between the four predictor variables and the acceptance of urban mammals. Each plot includes a fitted regression line (solid blue line) with a 95% confidence interval (shaded area). * = significance effect.

We discovered that wild mammals with a higher nocturnal activity were generally less accepted (H1). In particular, more nocturnal species (badgers, foxes, rats, wild boar, and martens) were less accepted than more diurnal (rabbits and squirrels) and crepuscular species (roe deer, hares, and hedgehogs). The likelihood of wild mammals inhabiting highly urbanised habitats was not strongly correlated with their acceptance (H2). We found no evidence that wild mammals with a more carnivorous diet were less accepted (H3). Similarly, we found no support for the hypothesis that larger wild mammals were less accepted (H4).

Night and darkness: activity patterns and wildlife acceptance

The activity patterns of wildlife emerged as the most significant trait predicting their acceptance. Animals that are more active during the night (badgers, foxes, rats, wild boar, and martens) tended to be less accepted by citizens. In contrast, species that are active during the day, such as rabbits and squirrels, as well as those active during dusk and dawn (hare, roe deer, hedgehog) were generally preferred. The most liked species, squirrels and hedgehogs, however, displayed contrasting activity patterns: while squirrels were almost entirely diurnal, hedgehogs exhibited an even split between day and night. The high acceptance of hedgehogs may be attributed to their greater visibility, their recognition as a flagship species in urban conservation initiatives (DeWiSt. 2024), and their general perception as 'cute' (Ribeiro et al. 2023, Moesch et al. 2024b). Additionally, their status as threatened species (Table 1; Taucher et al. 2020, Boakes et al. 2024, Gazzard et al. 2025), particularly due to nighttime use of automated lawn mowers (Rasmussen et al. 2021, 2023), may have contributed to their high acceptance. The low acceptance of more nocturnal species might be linked to an inherent fear of humans of darkness and the night (Sommer 2016, Yilmaz 2016, Caferra et al. 2021, McGlashan et al. 2021). This fear may influence perceptions of wildlife, particularly species associated with nighttime activity. Further, nocturnal animals possess traits that allow them to thrive in the dark, especially their efficient visual senses (Banks et al. 2015), while humans struggle in the dark and are dependent on artificial light (Boyce 2019). This creates an imbalance: nocturnal animals can see us, but we cannot see them. This mismatch often means that people primarily experience the consequences of these nocturnal mammals' actions, e.g. such as damaged cars from martens (Herr et al. 2009, Basak et al. 2022), predation of companion pets by foxes (Kimmig et al. 2020), or gardens dug up by wild boars (Davidson et al. 2022) – without ever encountering the animals themselves. As a result, these species remain out of sight and out of mind, and their damage can feel sudden and unexpected, fostering more negative associations. However, while these species do in some cases bring damage to humans (Moesch et al. 2024a, 2024b), often they are present without bringing the associated damage, e.g. not every car visited by martens is damaged (Herr et al. 2009). In contrast, animals active during the day, such as roe deer and rabbits, also cause conflicts as gardens might also be damaged by roe deer (Dandy et al. 2011, Moesch et al. 2024a) and rabbits (Virchow et al. 2003). However, these issues may be perceived differently because people rather expect to encounter these animals during daylight. The visibility of these species fosters a sense of presence, making their behavior feel less surprising and potentially prompting more proactive management, such as installing fences to protect gardens from damage by roe deer (Vercauteren et al. 2006, Manning 2021) or rabbits (Virchow et al. 2003). In contrast to mammals, birds, which are predominantly diurnal (Mukhin and Helm 2009, Williams 2004), are widely liked (Clergeau et al. 2001, Cox and Gaston 2015), are promoted as flagship species (Garnett et al. 2018, Wang et al. 2023), and abundantly studied in urban areas (Magle et al. 2012, Collins et al. 2021). Randler et al. (2023) even conclude that bird visibility might be a predictor of the perception of birds by humans. Often this leads to distinct avian management and conflict-avoidance procedures in urban areas (Traut and Hostetler 2003, Threlfall et al. 2016), an approach that might be more difficult for urban wild mammals. The predominantly nocturnal activity patterns of wild mammals reduce human–wildlife interactions, and consequently, these species might be underrepresented in management and conflict-avoidance frameworks. Building on the idea that traits might influence negative views of wild mammals (Kalof et al. 2016) and that positive human–wildlife relationships are linked to positive interactions (Buijs and Jacobs 2021, Moesch et al. 2024b), it is crucial to emphasize the need for more effective representation of nocturnal mammals to promote better management strategies and coexistence plans for these species. Promoting citizen science projects at night (Kimmig et al. 2025) could help to raise more awareness for habitat creation and conflict-avoidance measures for relatively invisible nocturnal species.

Habitat preference, diet, and size do not matter in wildlife acceptance

The urban habitat preference of a mammal did not tie to a perception of this animal. Specifically, hedgehogs, the second most liked wild animal, and rats, the least liked, both preferred highly impervious urban habitats (Fig. 4). This finding is consistent with previous research showing that hedgehogs frequently occur in densely urbanised areas, particularly in garden-dominated landscapes (Gazzard et al. 2022), and that rats are widely recognised as species that are strongly associated with urban environments (Feng and Himsworth 2014, Lee et al. 2024). However, the limited importance of urban habitat preference in wildlife perception may stem from the growing evidence that, by now, many wild animals live among humans in cities (Ineichen et al. 2012, Louvrier et al. 2022). The sighting of a fox or a roe deer might not be perceived as out of place any more, especially since most urban mammals have adapted their behavior to manage city life (Gaynor et al. 2018, Gallo et al. 2022, Procko et al. 2023), which is true for our set of mammals as well (Fig. 5).

Urban mammals might live among people without people noticing their presence and hence not forming a perception based on where they roam in urban settings. Further, the spectrum of urban habitat preference was quite broad for most mammals, as indicated by the high standard deviations (Fig. 4). Many of the focused mammals adapt well to highly impervious areas, selecting habitats in residential gardens while also thriving in urban woodlands. Roe deer, wild boar, and rabbits showed a narrower range, being detected in fewer camera trap locations (Supporting information) with lower standard deviations for habitat preference (Fig. 4). While roe deer and wild boar primarily inhabited urban woodland areas at the city edge (Supporting information) and can be seen as urban avoiders (Fischer et al. 2015), rabbits were predominantly only in one location, Dietenbach Park (Supporting information). As wild animals are constantly adapting to human-influenced landscape changes (Adams 2009, Decker et al. 2012), this may vary between cities and even countries, requiring further investigations.

The diet of a mammal was not strongly linked to how it was perceived. We initially hypothesized that carnivorous animals would be associated with the predation of pet or farm animals and perceived danger (Lescureux and Linnell 2010, Franchini et al. 2021). A global review by Newsom et al. (2025) suggests that perceptions of carnivores, often believed to be more negative, are shaped more by personal beliefs and socio-economic factors than by biological traits. Our model, although not statistically significant, suggested the opposite (Fig. 5). This could be because species with low acceptance such as boars and rats (Fig. 3) have a high intake of plant-based food (Table 2), while the highly accepted hedgehogs are more carnivorous (Fig. 3, Table 2). A perception of hedgehogs as non-carnivores may persist, underlined by flyers offering help to care for injured hedgehogs, which often highlight that plant-based foods like nuts and berries are the wrong choice for hedgehogs (Neumeier 2022). Similarly, squirrels are not strictly herbivores (Table 2), which may contribute to a similar persistence of their classification as non-carnivores. This pattern is further supported by the notion of 'surprising' findings in other studies, revealing that squirrels consume other mammals, nestling birds, and birds' eggs (Kachamakova et al. 2022, Smith et al. 2024).

Wildlife size did not seem to have a significant impact on their acceptance. Notably, the largest (wild boar) and the smallest species (rats) were the two least accepted. Equally, smaller animals such as hedgehogs and squirrels were among the most accepted, similar to the second-largest species, roe deer. While larger wildlife may indeed be perceived as a threat, such as the potential for wild boar to attack (Manipady et al. 2006, Gunduz et al. 2007, Mayer et al. 2023), size may not be the only trait influencing their acceptance. Similar to larger animals, smaller animals may also evoke fear, particularly regarding the spread of illnesses, such as foxes and tapeworms (Gloor et al. 2001, König 2008, König and Romig 2010) or rats and diseases in general (Desvars-Larrive et al. 2019, Strand and Lundkvist 2019). Additionally, the high acceptance of roe deer, despite their size, may reflect the so-called 'Bambi Syndrome' (Lutts 1992), derived from Walt Disney's motion picture, Bambi, describing overly sentimental and romanticized views of wildlife, often disconnected from the realities of their potential negative impacts.

From traits to tensions: how conflicts with wildlife influence acceptance

Wildlife in urban areas can cause significant conflicts (Messmer 2009, Peerenboom et al. 2020). These range from damage to human belongings (Basak et al. 2022, Moesch et al. 2024a) to the transmission of illnesses to humans and their pets (Ramadhan 2024, Moesch et al. 2024b) to injuries and fear of wildlife (König 2008, Perry et al. 2020). Wildlife's potential to bring conflicts is inherently linked to their traits (e.g. bigger animals can cause more damage; carnivorous animals can prey on pets) and is an important factor influencing wildlife perception (Teixeira et al. 2021, Araneda et al. 2022). This relationship is borne out by our observed high acceptance of squirrels and hedgehogs, which are smaller in size and not connected to many conflicts in urban areas (Peerenboom et al. 2020, Basak et al. 2022, Moesch et al. 2024a). But not all wildlife species elicit conflict in the same way, e.g. rats illustrate that conflict is not only determined by traits, as even neutral encounters can trigger strong negative reactions due to cultural and sanitary associations (Strand and Lundkvist 2019, Lee et al. 2024) whereas similar encounters with other species like roe deer might evoke neutral or positive responses (Basak et al. 2022, Moesch et al. 2024b). As legal definitions of what constitutes 'wildlife' can shape public perceptions (Tian et al. 2023), the common classification of rats as pests (Byers et al. 2019, Lee et al. 2024) may reinforce negative interpretations and viewing of their presence as a conflict itself. However, quantifying the potential conflicts between wildlife and humans is challenging. For example, martens may damage vehicles by chewing through wires (Herr et al. 2009), while roe deer can pose a risk to cars in the event of collisions (Kämmerle et al. 2017). Despite differences in their size, activity patterns, diets, and urban habitat preferences, both species can ultimately cause damage to vehicles. It is not only roe deer and martens, as potentially any animal can be involved in a car accident (Pakula et. 2023). But how can we put a value to the animals and their potential conflict? One approach is the potential for conflict index (PCI), which measures stakeholder support for management actions (Vaske et al. 2010, Vaske 2018). Smaller PCI values indicate high agreement, while larger values reflect greater disagreement. Future studies could construct PCIs for urban wild mammals by creating targeted surveys as well as integrating public reports to authorities (Pop et al. 2023) or citizen science observations (StadtWildTiere, Geiger et al. 2024).

To foster wildlife acceptance, it becomes crucial to make wildlife more visible to urban residents. Citizen science projects (Geiger et al. 2024, Kimmig et al. 2025) or garden camera-trapping (Fardell et al. 2022, Louvrier et al. 2022) can help reveal the presence or absence of these species and demonstrate that their cohabitation with humans is often unproblematic. Ultimately, increasing public awareness of these rather elusive 'nocturnal neighbors' may help dispel misconceptions and build more positive attitudes, paving the way for better human–wildlife coexistence in residential environments.

Limitations

Our study encountered a range of limitations related to both the survey methodology and the animal traits derived from camera trap data and extracted from literature.

Regarding the survey, our sample showed a higher representation of females (67%), individuals with academic degrees (63%), and younger participants (33% between 18 and 30 years; Supporting information), which could limit the generalizability of the findings. While such bias is possible, it is not unique to our study, as similar patterns have been observed in surveys on wild animals (Herzog 2007, Hohm et al. 2024).

Urban Wildlife Information NetworkRegarding the wildlife traits, activity and urban habitat preference, derived from the camera trap data, we identify three shortcomings. First, our deployment of a relatively low number of 24 camera traps across the study area, including variations of times the cameras were out in the field (Supporting information), may have led to biased conclusions and substantially reduced the statistical power to detect spatial or temporal patterns. With a limited number of sites, the variance within and between sites cannot be adequately captured, increasing uncertainty in model estimates and lowering the probability of detecting effects. This limitation is particularly relevant in urban environments, where fine-scale heterogeneity constrains sampling coverage, a pattern also observed in other urban camera-trap studies with limited site availability (Mori et al. 2025). This is especially relevant because mammals may inhabit more densely sealed urban areas, whereas most of our cameras were placed in less built-up regions (Supporting information). This setup is challenging to avoid due to legal restrictions on camera placement in city centres – where capturing humans raises privacy concerns – and practical limitations, such as rapid battery depletion caused by frequent activations. While camera trapping is increasingly used to monitor wildlife in human-dominated landscapes (Lovell et al. 2022, Procko et al. 2023, Lu et al. 2024) and especially urban areas (Magle et al. 2019), privacy concerns in Germany constrain its application (Sharma et al. 2020). Urban camera trap studies in Europe are still emerging (Blount et al. 2021) and are limited to a few large-scale cities like Berlin (Louvrier et al. 2022), Zurich (Hegglin et al. 2004, Geiger et al. 2018), and London (Beasley et al. 2023) with generally low numbers of sites (Mori et al. 2025). Consequently, European research often relies on documenting wildlife encounters (Capon et al. 2021). Avoidance of this limitation is possible using privacy-friendly technologies, e.g. to citizen science (Green et al. 2020, Geiger et al. 2024), or by expanding European city-scale research, following the Urban Wildlife Information Network example (Magle et al. 2019). Second, we did not account for the potential displacement of species by other animals (Scott et al. 2023), e.g. the presence of pets, which has been found to influence wild animals (Herrera et al. 2022, Drenske et al. 2024), as well as the displacement by roads (Riley et al. 2014, Kent et al. 2021). Future studies could address this by directly measuring wildlife responses to pet activity (e.g. presence/absence of cats or dogs), traffic intensity, or proximity to roads to quantify their effects on species distributions. Last, we focused on general activity patterns (nocturnal versus diurnal) without considering seasonal variation. Seasonal activity could affect perceptions by altering species' visibility. For example, hedgehogs could be more noticeable in autumn before hibernation, while rabbits could be more visible in spring when raising young. Future research could examine both diurnal/nocturnal and seasonal activity to better understand their impact on species acceptance.

Regarding wildlife traits, diet, and size, derived from the literature, there remains a lack of specific literature tailored to urban areas and our study region specifically. Regarding diets, there is a general lack of diet research for urban mammals (Moesch et al. 2024c), and urban counterparts of species might forage differently than the average diet found in the literature. While our literature review provided an overview of the biomass consumption of the ten studied mammals, future research is needed to explore the diets of urban mammals, as their food selection in cities may differ from that in less urbanised areas, as well as between climatic zones. A simplistic distinction between plant-based and animal-based foods (Table 2) may even become less relevant in urban environments where artificial food sources, such as supplementary feeding (Shuttleworth 2000) or the availability of human food waste (Contesse et al. 2004, Stillfried et al. 2017) are available. To tailor diets of urban mammals (something that cannot be derived from camera trap images) future perception studies could derive these from scats (Larson et al. 2015, Murray et al. 2015) or stomachs (Contesse et al. 2004, Stillfried et al. 2017). Similarly, sizes taken from the literature might vary between urban and rural areas, as found for certain species in comparison studies (Meillère et al. 2015, Beliniak et al. 2022) as well as between sexes, e.g. female wild boars are generally lighter than males (Brogi et al. 2021).

Last, the alignment of survey and camera trap data posed a significant challenge, particularly due to data privacy concerns that prevented us from directly requesting participants' specific locations. As an alternative, we inquired whether respondents lived near a camera or bus stop, which resulted in a concentration of responses in central Freiburg, where only a few cameras were situated (Supporting information). Linking surveys to specific locations such as parks through QR-code-based participant recruitment may improve spatial alignment with camera trap data.

Acknowledgements – We thank our students Sarina Beiter, Nathalie Groß, Titus Mußhof, Marius Huber, and Nadine Erath for their support in the field, including assisting with camera trap deployment, retrieval, and data classification. We thank Lukas Scholz, Friederike Zenth, and Joao Manuel Cordeiro Pereira for their advice on analysis and model selection. We like to thank the Urban Wildlife Information Network from Lincoln Park Zoo, Chicago, USA, especially Seth Magle, Mason Fidino, and Kim Riviera, for providing all the equipment to support the start of the camera trapping project in Freiburg. We would also like to thank FVA Freiburg, especially Judith Ehrlacher and Janina Diehl, for their collaboration in the wildlife camera trap project in Freiburg, as well as the city office of Freiburg and the data protection office at the University of Freiburg. Open Access funding enabled and organized by Projekt DEAL.
Funding – This study was financially supported by the Deutsche Bundesstiftung Umwelt (DBU) through a doctoral scholarship awarded to SSM (Promotionsstipendium 20020/652-33/0). Camera traps were provided by the Urban Wildlife Information Network from Lincoln Park Zoo, Chicago, USA.
Conflict of interest – The authors declare no conflict of interest.

Author contributions

Simon S. Moesch: Conceptualization (lead); Data curation (equal); Formal analysis (lead); Methodology (lead); Visualization (lead); Writing – original draft (lead); Writing – review and editing (lead). **Marufa Sultana**: Data curation (equal); Funding acquisition (lead); Methodology (supporting); Writing – review and editing (supporting). **Geva Peerenboom**: Data curation (equal); Writing – review and editing (supporting). **Ilse Storch**: Funding acquisition (supporting); Methodology (supporting); Supervision (lead); Writing – review and editing (supporting).

Transparent peer review

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/wlb3.01522.

Data availability statement

Data are available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.73n5tb3bz (Moesch et al. 2026).

Supporting information

The Supporting information associated with this article is available with the online version.

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