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Research Article

LIVING ON THE EDGE: NATURE PRESERVES AS AN OASIS FOR BIRDS, BATS, AND OTHER MAMMALS IN THE URBAN DESERT AND CONCRETE JUNGLE

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ABSTRACT

Increasing urbanization threatens a variety of vital vertebrate habitats, including those of birds, and both terrestrial and aerial mammals. Nature preserves near urban centers at the rural/urban interface may harbor natural areas which can help to offset loss of habitat as cities expand. Therefore, techniques which allow managers to conduct short term surveys for vertebrates are needed. I conducted non-invasive, passive camera trapping and acoustic surveys in the vicinity of the urban area of Charlotte, North Carolina across 8 sites within Mecklenburg, Cabarrus, and Union counties during summer to fall 2023 to collect data on avian and mammalian communities. Five species of bats were documented, alongside 39 birds, and 11 terrestrial mammals. Bat activity decreased consistently along the sample period whereas terrestrial mammals were consistently sampled during the same time frame, with early summer providing effective data on avian presence. Automated identification software followed by manually vetting for bats and birds was effective in documenting diversity alongside camera trapping. The results presented here provide baseline data for future monitoring to inform urban planning management strategies and future studies on the potential presence of avian and mammalian presence in nature preserves.

Keywords: Chiroptera, Acoustic Surveys, Biodiversity, Anthropogenic, Urban Ecology, Conservation.

INTRODUCTION

As cities become increasingly populated, urban growth has the potential to further reduce available habitat for a variety of wildlife, and this urban expansion threatens available urban/rural habitat. Specifically, urbanization can lead to altered bat assemblages across fragmented natural habitats, with one to two species often opportunistically dominating urban communities (Russo &Ancillotto, 2015). Impacts of urbanization are bifurcate in their effect on avian communities, by reducing species richness, while concomitantly for some species increasing abundance in some cases (Batary *et al*., 2017), likely due to a wide range of habitat/food species requirements for birds less sensitive to urban settings. Urban bird habitats can house species diversity in both residential areas with species diversity highest in protected parklands (Taylor *et al*., 2013). However, urban and rural areas can still provide the potential for forested mammal communities, mature trees with nesting cavities combined with water sources and arthropod prey for bats even though these habitats may be fragmented in an urban landscape (Lewanzik *et al*., 2022). Nature preserves may provide refugia for a number of widespread vertebrates near urban centers. Moreover, nature preserve managers and naturalists are often required to consider presence of multiple vertebrate groups for monitoring. Subsequently, methods are needed to provide baseline data from rapid, timely surveys on mammal and avian presence.

Passive surveys are emerging as a powerful method for monitoring wildlife via trail cameras (Glover-Kapler *et al*., 2019) and acoustic recording units (Darras *et al.*, 2019) with both becoming increasing affordable to researchers and preserve managers (Gibb *et al*., 2019; Webb, 2020). This emerging technology opens the door for the development of monitoring via rapid assessment of biodiversity with automated sound classification programs (Rhinehart *et al*., 2020), which can inform urban avian diversity (Rajan *et al*., 2019) alongside traditional camera

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trapping surveys for mammals. Moreover, acoustic sampling of bats has been shown to be effective for characterizing eastern United States bat communities (Nocera *et al*., 2019) as an option comparable to mist-netting for determining species presence and activity (O'Farrell & Gannon, 1999). These tools available for city wildlife managers should be assessed for their essential use to conduct rapid assessments of habitat available to urban communities.

The Piedmont region of the southeast has been surveyed to a lesser extent in comparison to coastal and mountainous areas for vertebrates, despite the potential for habitat loss due to anthropogenic factors (Kapfer & Munoz, 2012). Therefore, there exist gaps in our knowledge within the southeastern U.S. on the species presence and rapid assessment methods for natural areas outside the large urban city of Charlotte, North Carolina, for which vertebrate survey data are lacking. Herein, I report baseline information on Piedmont bat, bird, and terrestrial (non-volant) mammal presence across the rural/urban interface outside Charlotte, North Carolina within eight nature preserve/natural areas. This goals of this short term case study was to 1) assess non-invasive passive sampling for fauna avian and mammal diversity in nature preserves and 2) document patterns across the rural landscape for species across natural areas outside a large urban city. I predict diversity will be similar for species across preserves, with slight differences in vertebrate presence. I also discuss the advantages and disadvantages of using passive survey methods in urban areas to sample wildlife.

MATERIALS AND METHODS

Study Area

Survey sites (n = 8) were strategically selected proximate to the urban center of Charlotte, North Carolina (Figure 1). Sites were primarily nature preserves, county parks, and one university natural area and specific survey locations within these natural areas selected with similar habitat features (near water, open flyways along edge habitats, potential roost areas, etc.) to account for habitat impact on echolocation (Starik & Gottert, 2022) and potential for bird and mammal presence across Mecklenburg, Cabarrus, and Union counties. Sites included Union County Heritage Trail at the Union County Agricultural Center (AGCT), Wingate University Campus Lake Natural Area (WING), Rob Wallace Park (ROBW), McDowell Creek Nature Preserve (MCDW), Cane Creek Park (CANE), Stevens Creek Nature Preserve (STEV), St. Stephens Church Road Preserve (STST), and Buckeye Cove Nature Preserve (BUCK). AGCT and WING were geographically proximate, but were included due to potential for detection of bats based on previous surveys (Blackburn & Unger, 2019). Size of sites (area) ranged from 110 acres for WING to 1,132 acre MCDW. Distance of sites to urban center of Charlotte ranged from 20.1 to 48.4 km with a mean distance across all sites of 34.8 km. Dominant tree species across sites included *Acer rubrum*, *Liquidambar stryaciflua*, *Quercus phellos*, *Pinus taeda*,*Liriodendron tulipfera*, *Platanus occidentalis*, *Carya ovata*, and *Fagus grandifolia*.

Figure 1. Sites selected for this case study showing proximity to Charlotte urban center. Created on Google Earth version 10.42.0.1, 2023 Google LLC.

Field Surveys

All surveys were conducted between May and October 2023, and included 4 visits (~monthly) with sites randomly selected for sample visits to maximize deployment of sound detectors and trail cameras across the urban landscape outside Charlotte, North Carolina. Sample periods were as follows: 1= 05/31/2023- 06/07/2023, 2= 07/17/2023 – 07/24/2023, 3= 08/20/2023- 08/27/2023, and 4= 09/26/2023- 10/03/2023. Daily average temperature and maximum wind speed were calculated from weather underground (www.wunderground.com). This study occurred summer to fall to allow for rapid short term detection which corresponded to the primary breeding bird season (Wilson & Bart, 1985) and also to sample resident and migrating bats (Lehrer *et al*., 2021). For each sample period, trail cameras were deployed for 7 total trap nights, with acoustic (bird and bat) detectors deployed for 3 full days within the same sample period and location following Loeb *et al*., 2009.

Terrestrial mammals were surveyed by deploying two Bushnell E3 16 MP Trophy Trail cameras at each location secured to trees and baited with corn/sardines following Sasse et al. 2023, and Chupp *et al*., 2013. Settings for camera were as follows: Camera Mode, 1 picture captured every 1 minute upon trigger (interval), 24 hour mode, auto sensor. Avian vocalizations were surveyed using Wildlife Acoustics Song Meter Micro (www.wildlifeacoustics.com) to record bird calls in the mode of "record birds/frogs 2 hours around sunrise and 2 hours around sunset". Meters were zip-tied to trees at ~1.8 m height attached to trees with microphones strategically placed towards openings in flyways and away from nearby streams to minimize noise interference. Parameters of recording were as follows: sample rate of 24000 Hz, maximum recording length 5 minutes, gain set to 18 dB. For birds the first sample period was selected due to the large amount of recordings and likelihood to capture early summer avian species.

Acoustic bat calls for identification were recorded using Wildlife Acoustics Song Meter Mini Bat Ultrasonic Recorders. Acoustic detectors were deployed in open flyways, near water, securely attached with large cable ties to locked, anchored modified 7.1 m extension poles. Both full spectrum and zero crossing recordings were made. Settings included the following: recording format both zero-crossing and full spectrum, full spectrum sample rate of 256 kHz, minimal trigger frequency of 16 kHz, maximum recording length of 15 seconds, trigger window 3 seconds. Mode of recording was "record bats from sunset to sunrise subject to triggering following standard acoustic survey techniques (Hourigan *et al*., 2006; Reichert *et al*., 2018). Calls were chosen from two mornings and two evenings during the first full days of deployment for bats.

Species Identifications

Mammals were identified manually from trail camera images and examined for all sample periods and sites by combining images from both trail cameras deployed at each location. All identifications were taxonomically identified to species, with the exception of small rodents, which when detected, were not identified down to species. Only presence at each site and sample period was recorded, i.e. once a mammal was detected, it was noted as present for that sample period. All images captured by cameras were assessed for each location and sample period.

A subset of 96 calls were processed for the first sample period (end of May-early June) at each site to determine avian presence. Birds were identified by uploading recordings onto BirdNET for analysis, which provides a confidence score between 0 to 1 for identification when submitted online (birdNET.cornell.edu). BirdNet broke out 5 minute recordings and analyzed every 2.5 second spectrogram (~118 per 5 minute recording), and species probabilities. Identification of individual bird presence was determined by only using species probability of identification of greater than 90 to 100% in BirdNet. Additionally, I only included species as present with either more than one identification per recording or found across multiple recordings, similar to recommendations by Perez-Granados, 2023 and Sethi *et al*., 2021. Moreover, all calls were manually vetted when processing each recording and species identification, following vetting protocol by Ware *et al.*, 2023, whereby BirdNet was used for initial identification, followed by manual auditory confirmation.

Bats were identified in Kaleidoscope Pro 5.6.0c using North American Classifier and auto ID function using primarily zero crossing calls. Calls were then manually vetted using an iterative process, which included manual examination of call pulse characteristics for each species (duration of call, slope of call, min and max frequency of call, etc.; Britzke *et al*., 2011), filtering identifications which had low MLE (Britzke *et al*., 2002; USFWS, 2020), and only including calls with >- 5 pulses (Britzke & Murray, 2000). Moreover, identifications were confirmed by additional examination of full spectrum recordings during the vetting process. In cases where *Lasiurus borealis* was detected at the same site as *Lasiurus seminolus*, these calls were grouped together due to both species being acoustically similar (Andersen *et al*., 2022). As an indirect measure of overall temporal bat activity across nature preserves, the total number of calls processed as bats (both identified and with no identification), with a bat pass defined as an echolocation call with a minimal of two pulses (Seidman &Zabel, 2001) was noted. Primarily descriptive statistics are reported in this case study for both avian and mammal presence. A Chi-squared test was run for total species across eight preserves to assess if there were differences in total diversity across preserves.

RESULTS AND DISCUSSION

Overall, a total of 11 species and one group (rodent super family Muroidea) of terrestrial mammals, 39 birds (Table 1), and 5 bats (4 species and one species complex) were identified. The most commonly encountered mammals across all sites and sample periods included *Procyon lotor*, *Didelphis virginiana*, *Sciurus carolinensis*, and *Odocoileus virginiana* (Figure 2). *Urocyon cineroargenteus* was documented at both larger and smaller nature preserve areas, with peak presence increasing throughout the study and detected in 5/8 sites during the September/October sample period. Similarly, *Canis latrans* presence was highest during August. Interestingly, I also documented multiple reptiles on deployed trail cameras, including *Terrapene carolina* and *Pantherophis obsoletus,* in addition to several bird species including *Cardinalis*, *Thryothorus ludovicianus*, *Coragyps atratus*, *Ardea Herodias*, *Turdus migratorius*, and *Buteo lineatus*. Representative examples are included in Figure 3. The total number of trail camera images across all sites and sample period was 12,620.

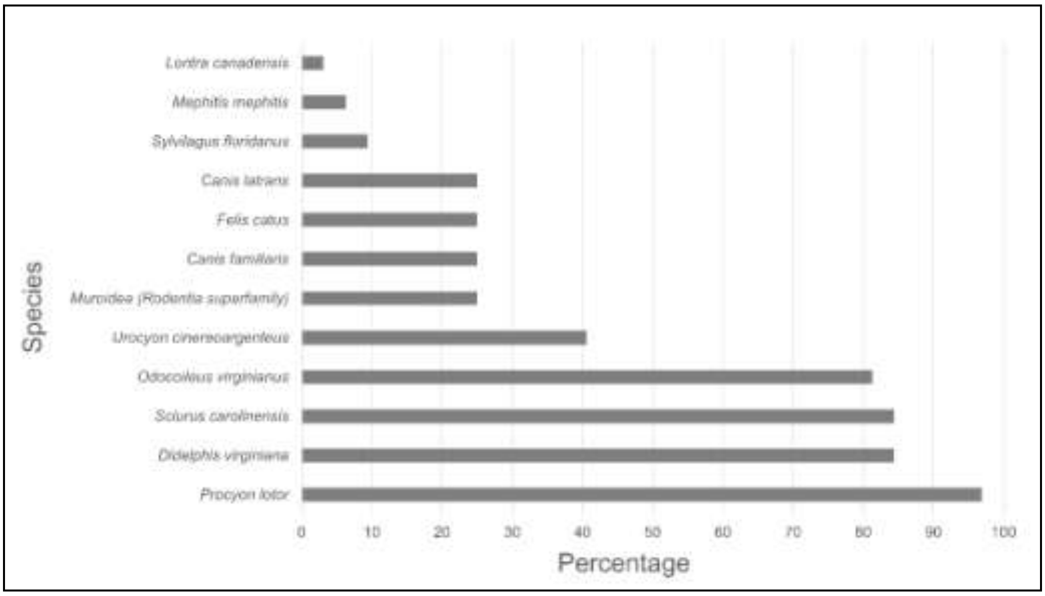

Figure 2. Terrestrial mammals species identified and relative percentages across all sample sites in this case study with trail cameras.

BirdNet followed by manual vetting was effective in determining bird presence at nature preserves for all 39 species detected, with a mean of 12 ± 3.38 S.D. birds detected per preserve, minimum = 6, maximum = 16. All birds identified were IUCN status of Least Concern, with the exception of the *Setophaga dominica* (Near Threatened), and *Chaetura pelagica* (Vulnerable). Only *Baelophus bicolor* was detected at all sites, with *Piranga rubra*, *Thryothorus ludovicianus*, and *Piranga rubra* detected at 75% of sites. Presence of birds across all nature preserves included representatives from 21 families and several orders, Passeriformes (25), Piciformes (5), Accipitriformes (2), Apodiformes (2), Charadriiformes (1), Cuculiformes (1), Galliformes (1), Pelecaniformes (1), and Strigiformes(1).

Species of bats detected in nature preserves included *Eptesicus fuscus*, *Lasiurus borealis*, *Lasiurus seminolus*, *Tadarida brasiliensis*, and *Perimyotis subflavus*. For simplicity, *L. seminolus* identified at STEC in June and July was grouped with the acoustically similar *L. borealis*, resulting in *E. fuscus* being detected at 81.3%, *L. borealis/seminolus* at 78.1 %, *T. brasiliensis* at 37.5%, and *P. subflavus* at 9.4% of survey occasions and across all sample periods and locations, respectively. *P. subflavus* was only identified from ROBW and BUCK sites. All bats identified were IUCN status of Least Concern, with the exception of *P. subflavus* (Vulnerable). The number of total passes identified as bats decreased across sample period, with 9,737 for May/June, 5,703 for July, 2,234 for August, and 687 for September/October across all sites combined. STEV, BUCK, and WING had the highest amount of total bat passes across all sample months, with 4,119, 4,117, and 3,972, respectively. Average daily temperature (°C) and maximum wind speed (km/hr) for sample period 1,2,3, and 4, were 21.6: 20.9, 26.1: 16.9, 27.5: 21.9, and 20.8: 17.9, respectively. The mean number of species detected across all three methods was 22.6 ± 3.81, and ranged from 19 to 27 species. Overall, the number of species detected across all preserves was not statistically significant, X^2 (7, N = 8) = 4.92, p = 0.67.

This study represents a novel approach for combining existing methods to set up sound/monitoring stations within nature preserves for rapid determination of avian and mammal species presence and activity patterns across nature preserves. As expected, passive sampling for between 3 days (acoustics) and 7 days (trail cameras) across summer to fall in nature preserves resulted in presence data allowing for preliminary baseline information for future monitoring natural areas surrounding a large urban center. While the majority of species identified in this study are cosmopolitan and widespread in their range, their presence is nonetheless important to document in anthropogenic areas experiencing growth. Interestingly, I detected several birds while camera trapping, notably *C. atratus*, which I likely would not have detected if relying solely on acoustics. Moreover, I did detect frog species (not reported here) on sound meters, which when taken collectively indicate that using multiple methods of acoustic and camera trapping may help to document different species across taxonomic groups.

Potential drawbacks of this study include the amount of time needed for post field collection data processing and lack of sampling multiple habitats across sites, as sample locations remained the same. However, the goal of this project was to minimize field deployment time and allow for short term comparisons across nature preserves/natural areas using passive surveys and available affordable technology. I further recommend researchers consider surveying early to capture increased bird diversity, in Spring (April – May), as surveys conducted during typical 45 day peak detection windows should include both early and late breeding periods (Harms & Dinsmore, 2014). Regarding bats, I recommend future surveys across different habitat types (i.e. deploying multiple meters per survey, etc.) as incorporating calls recorded in both open and clutter areas like forest edges can improve identification accuracy (Findlay &Barclay, 2020). Subsequently, increasing the number of trail camera deployments could potentially increase detection of mammals, especially carnivores or other rare, cryptic species. Therefore, I recommend researchers consider balancing the amount of trapping and acoustic data generated and sample methodology with overall research goals for monitoring or assessing biodiversity if there are rare target species present in urban areas.

Figure 3. Example images from camera trapping including *Urocyon cinereoargenteus*, *Terrapene carolina*, *Lontra canadansis*, *Canis latrans*, *Didelphis virginiana*, and *Coragyps atratus*.

Table 1. MortBird presence and relative percentage across all sites identified by BIRDNET and manually vetted. Note * all bird species listed as IUCN status Least Concern (LC), with the exception of *Setophaga dominica* (Near Threatened), and *Chaetura pelagica* (Vulnerable).

Percent Presence across sites	Species
100	*Baeolophus bicolor*
75	*Piranga rubra, Thryothorus ludovicianus, Coccyzus americanus*
62.5	*Myiarchus crinitus, Vireo olivaceus*
50	*Empidonax virescens, Cardinalis, Picoides pubescens*
37.5	*Setophaga pinus, Progne subis, Buteo lineatus*
25	*Toxostoma rufum, Strix varia, Ardea Herodias, Corvus brachyrhynchos, Parkesia motacilla, Passerina cyanea, Sitta carolinensis, Melanerpes carolinus, Polioptila caerulea, Archilochus colubris, Sialia sialis, Contopus virens*
12.5	*Sayornis phoebe, Setophaga dominica**, *Charadrius vociferus Protonotaria citrea, Colaptes auratus, Accipiter striatus, Piranga olivacea, Leuconotopicus villosus, Mniotilta varia, Leiothlypis peregrina, Peocile carolinensis, Chaetura pelagica**, *Dryocopus pileatus, Vireo griseus, Meleagris gallopavo*

The use of autonomous recording units can result in 79% agreement with estimates by human observers for birds (Perez-Granados & Traba, 2021). BirdNET has emerged as a powerful tool to use for the identification of birds with high precision (Bota *et al*., 2023) and is utilized by citizen scientists (Wood *et al*., 2022). While BirdNET can be utilized for single species identification (Kahl *et al*., 2021), it also allows for multiple species to be identified within one five minute recording, as I observed in this study. It is possible that some bird vocalizations were too far away or difficult for BirdNET to identify, as the percent identified correctly decreases with distance to recorder (Perez-Granados, 2023). However, all sites included nearby streams which is known to support urban avian biodiversity (Tellez-Hernandez *et al*., 2023). I did observe in some cases, the auto ID in BirdNet program misidentified summer tanagers as false species (Red whiskered bulbul, or barn owl), Northern flicker as Pileated woodpecker, and a Fowlers toad as a Barn owl. Therefore, care should be taken to manually vet avian calls as birds display multiple categories of call types, especially nocturnal vocalizing species if frogs are present at survey sites. Additionally, I noted the clearly audible sound of airplanes and vehicles at multiple preserves, noting that some anthropogenic noise is present. I also qualitatively conducted additional short recordings when visiting sites using the BirdNET smartphone application, which supported identifications in this study. Therefore, I recommend researchers conduct further studies perhaps using citizen science methods to characterize avian diversity at nature preserves using smartphones.

Other studies have noted the bat *Eptesicus fuscus* to be both ubiquitous and abundant in urban forested parks, potentially due to their ability to utilize anthropogenic structures for day-roosts (Johnson, *et al*., 2008). Indeed, the two most common bats identified in this study are known to be common and active following sunset (D'Acunto *et al*., 2018). Golf courses may provide additional habitat to bats in urban landscapes (Drake *et al*., 2023), as one of the sample locations (WING) represents an old golf course. Factors influencing occupancy of bats in urban areas include access to water, with some species known to avoid high noise areas (Lehrer *et al*., 2021). I detected *P. subflavus* at ROBW (~143 acres) and BUCK (~384 acres), both sites with forested roosting habitat, a relatively smaller sized county park and nature preserve. Future roosting surveys should be done here since up to 54% of individual *P. subflavus* are known to be residents in the areas they hibernate (Smith *et al*., 2022) and this species has experienced significant declines across its range due to white-nose syndrome (Loeb &Winters, 2022).

The deployment of acoustic detectors in this study required strategic placement across nature preserves to avoid potential theft of equipment. Future studies in urban settings should consider the potential for theft and deploy acoustic detectors in areas less likely to be removed and secure them with locks. I recommend additional monitoring of bats using acoustic detectors, as some bats are adept at being urban dwellers, generalist bats associated with water, while other species may require more forest habitat and be negatively impacted by additional anthropogenic activities (Vlaschenko *et al*., 2021). Interestingly, sites with the highest amount of bat passes (~ a proxy for bat activity), included smaller sized preserve areas with the two largest of sites having moderate number of bat passes, which may be indicative of habitat (flyway) sampled along edge habitats and not preserve size. If cost of bat detectors and auto-ID software (~ $750 + $400 U.S.), is deemed out of reach for nature preserve managers, I recommend the use of smartphone bat detectors, possibly incorporating citizen science programs, followed by manually vetting species calls using free software. I further recommend researchers survey during May/June as this is when I noted the largest number of bat passes across all sites, which corresponds with summer migratory and volancy patterns for bats.

CONCLUSION

While passive acoustic surveys are not a direct replacement for active trapping of bird and mammal communities, they can provide managers with both rapid assessments of presence and a source for continued and future monitoring. Maintaining urban nature preserve areas, parks, and greenways can benefit mammal and bird communities (Gallo *et al*., 2017; Bhakti *et al*., 2021). Likely utilization of habitat and food resources alongside predator/prey relationships may explain why some species are able to exist in anthropogenic areas along the urban and rural landscape (DeGraaf & Wentworth, 1986, Hansen *et al*., 2020), as I noted in this case study. Indeed, maintaining streams and ponds in combination with nearby forested habitats (for potential roosting, etc.), is correlated to ensuring bat presence within large cities (Ancillotto *et al*., 2019). This report adds to our body of knowledge on urban/rural avian and mammalian communities preserved within natural areas near large cities, which can be an oasis of diversity in the urban desert.

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