Spring 2023

Bat Activity and Insect Biomass on McConnell Airforce Base Compared to Surrounding Wichita Parks

Michaela Sielaff
Fort Hays State University, michaelasielaff541@gmail.com

Recommended Citation
Sielaff, Michaela, "Bat Activity and Insect Biomass on McConnell Airforce Base Compared to Surrounding Wichita Parks" (2023). *Master's Theses*. 3226.
DOI: 10.58809/XHZN5680
Available at: https://scholars.fhsu.edu/theses/3226

BAT ACTIVITY AND INSECT BIOMASS ON

MCCONNELL AIRFORCE BASE

COMPARED TO

SURROUNDING

WICHITA

PARKS

A Thesis Presented to the Graduate Faculty

of Fort Hays State University in

Partial Fulfillment of the Requirements for

the Degree of Master of Science

by

Michaela Sielaff

Bachelor of Science, Fort Hays State University

Date 4/21/2023 Approved ____________________
Major Professor

Approved ____________________
Graduate Dean

GRADUATE COMMITTEE APPROVAL

The graduate committee of Michaela S. Sielaff approves this thesis as meeting partial fulfillment of the requirements for the Degree of Master of Science.

Approved ______________________

Chair, Graduate Committee

Approved ______________________

Committee Member

Approved ______________________

Committee Member

Approved ______________________

Committee Member

ABSTRACT

Bats are bioindicators of the communities to which they belong, giving researchers insight into the overall health of those ecosystems. Bats are also very adaptable and are capable of tolerating urbanization. Some species, such as *Lasiurus borealis* and *Lasionycteris noctivagans* may even benefit from adjacent industrial and commercial land use, although this is not the case for all bat species. In 2021, we began acoustic and mist net surveys of bats at McConnell Air Force Base (MAFB, or “base”) in Wichita, KS. However, no bats were captured or seen during mist net surveys, although some were detected acoustically over a four-month period. We also encountered very few insects. These observations lead us to wonder if bat activity differed between MAFB and the surrounding Wichita area. During the summer of 2022, we again conducted mist net surveys, acoustic surveys, collected insect biomass at MAFB, and expanded our surveys to include nearby Wichita parks. We found a significant difference in bat activity in the Wichita parks compared to MAFB. Our most detected species was the Eastern red bat in the parks and MAFB. We also found no significant difference in insect biomass when comparing the parks and MAFB. With this study, we have gotten a closer look into the lives of bats in Wichita, Kansas.

ACKNOWLEDGMENTS

This project was funded by Fish and Wildlife Service Cooperative Agreement #F21AC00448-00. I want to thank Mike Jungen and Oliva Reed from the Fish & Wildlife Service and undergraduate students Lilly Duncan, Brett Koehn, and Tori Carpenter for aiding me in my research efforts. The Sternberg Museum for lending us transportation services and equipment. Wichita Parks & Recreation for access to the parks, specifically Amanda Alessi, who facilitated our access to the parks, and David McGuire for graciously taking us around the city of Wichita properties off the beaten path - and Google maps. The Great Plains Nature Center for allowing us to access their trails as well as participate in Moth Mania. The Fort Hays Graduate School for the Graduate Scholarly Experience Grant, and Senior Administrative Assistant Mrs. Diana Stabb for all her time, all the traveling paperwork, and purchasing processes. Finally, I would like to thank my advising committee for all their help with this project, especially my fantastic advisor Dr. Lorielei Patrick for all her time and help throughout all these years. I would also like to thank them for their friendship and advice over the years. I truly appreciate you all!

DEDICATION

This thesis is dedicated to the loving memory of Curtis Schmidt. He was an inspiration to all around him, especially me. He was a kind soul whom everyone loved to be around, full of knowledge, light, joy - and jokes. He was very loved and appreciated. This is for you, Curtis. You will be so very missed. I would also like to dedicate this thesis to my Creator, who gave me a passion for science.

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INTRODUCTION

Bioindicators can include biological processes, species, or communities that are used to assess the quality of the environment and how it changes over time. (Holt and Miller, 2010). They are vitally important to track environmental alterations and can give insight into tackling the potential issues in an environment (Russo et al, 2021). There are four main types of indicators, including ecosystem health assessment, ones that measure human effects, human interventions, and human health and well-being (Burger, 2006). These types of indicators can be used to track the current health of a species or system, as well as the effects of human activities on ecosystems and the success of management and restoration, as well as track trends over time (Burger, 2006).

Bats can be critical environmental indicators because they are sensitive to a wide range of environmental stressors and respond in predictable ways (Jones, et al., 2009). Bats are exceptional mammals for many reasons, including being the only mammal that has sustained flight, the second most diverse taxon among mammalian orders (Kasso and Balakrishnan 2013), and the only mammals besides toothed whales that echolocate. Bats are a species-rich group providing essential ecosystem services to their environments, such as consuming agricultural pests (Brooke et. al, 2022). Other services include pollination, aiding in seed dispersal, soil fertility, and nutrient distribution (Kasso et al, 2013). Bats show clear reactions to environmental changes and stressors, including responses in activity levels to insect availability. Because bats usually have only one pup a year, they are prone to rapid population declines (Russo et al, 2021). Based on the few available studies, the prospect of bats being used as bioindicators is extremely promising in measuring the health of ecosystems and has been seen as increasingly important in the overall conservation of habitats and the organisms that exist within them (Jones, et al., 2009).

There are many habitats that support bat species (Taylor, 2019), including woodlands, plains, grasslands, and deserts (Taylor (2019). Furthermore, bats can make their roosts in a variety of different structures, like trees, cracks in buildings, bridges, roof ridges, barns, and caves (Taylor 2019). Bats tend to prefer enclosed areas to avoid potential predation and to provide stable temperatures and shelter from the elements (Keeley, 1998). Bats typically prefer warmer temperatures but use several strategies to deal with the cold, including hibernation and migration (Taylor, 2019). Bats require a nearby source of open water to drink and to produce or attract insects; sufficient water is especially important for pregnant and lactating bats (Taylor, 2019).

Researchers have shown that some bat species can thrive in urbanized areas, and the effect of urbanization on bats varies at the family level (Jung et al, 2016). This work also suggested that individual species' behavioral and/or morphological traits may predict bats' adaptability to urban areas (Jung et al, 2016). Some bat species with certain species-specific traits seem to thrive in these urban environments (Duchamp and Swihart 2008). These are the bat species with high wing loadings (the bat's weight divided by the wing area), which are presumed to forage in open areas (Norberg and Rayner, 1987). These species seemed to be able to adapt to urban environments with enough tree cover (Dixon, 2012).

Bats vary in size and wing shape; this variation is strongly correlated with maneuverability, flight speed, and thus also, with the use of space (Norberg 1990). For insectivorous bats, size and wing shape correlate with the structure of their echolocation calls (Norberg 1990). Usually, bat species with long and narrow wings fly fast and use long, powerful echolocation calls suited for long-range detection of insects in the open air, while those with shorter and broader wings are maneuverable, slow flying, and use echolocation pulses appropriate for short-range detection of insects close to vegetation or close to water surfaces (Neuweiler 1989). The feeding success of aerial insect predators depends on insects' availability and distribution in the area (Racey & Swift 1985). On the species level, bats vary greatly in their preferences for foraging areas (Denzinger, 2013).

Even with some bat species varying in size and wing shape, and species-specific traits that allow them to adapt to urban environments, some studies have suggested that there is a relative decline in species richness and abundance of bats in urban areas compared to forested areas (Avila-Flores and Fenton 2015). The loss of natural habitats within the urban landscape has reduced the availability of foraging grounds for bats (Russo and Ancillotto 2014), due to the loss of vegetation, that has often been suspected as the main factor sustaining insect prey populations, such as those preyed upon by bats (Avila-Flores & Fenton, 2005). This loss of vegetation is leading to population declines in taxonomic groups of importance to bat foraging, such as moths (Conrad et al., 2006) and therefore affect bats (Avila-Flores and Fenton, 2005; Geggie and Fenton, 1985; Jung and Kalko, 2011). Still, some insectivorous bat species seem to remain in these urban environments. These bats can forage around streetlights (Jung and Kalko 2010), potentially capitalizing on the phototactic insects that are attracted to these lights (Fenton and Morris 1976). With these few studies expanding on the behavior of bat species in cities, it is essential to continue monitoring bat activity in urban areas with the increasing encroachment of urbanization into habitats (Grimm et al, 2008).

Kansas bats are all insectivores, feeding on tons of insects yearly, such as mosquitoes, moths, beetles, crickets, leafhoppers, and much more (Schmidt et al, 2021). There are 16 species of bats in Kansas, and they tend to be generalists, meaning that they are not specialized in eating one particular kind of insect, but a wide range of different insects (Schmidt et al, 2021). Generalist species tend to do better in habitats with low insect diversity, such as urban areas (Rocha et al, 2018, Theodorou, Radzevičiūtė, Lentendu, et al, 2020). If the insect populations decline, their predators will also decline. This has been observed on several continents (P van der Sluijs 2022), including Europe, with many populations of insects declining over the years (Aebischer 1991) and likely leading to declines in bat populations (Stebbings 1988). Agricultural intensification and habitat loss are listed as reasons for the decline of all six BAP (biodiversity action plan) species of the United Kingdom (Wickramasinghe et al. 2003).

While there have been studies of how urbanization affects bat communities in Europe and some in North America (Rega-Brodsky, Aronson, Piana, et al 2022), there have been fewer studies and bat surveys in Kansas. One location in Kansas where bat monitoring has taken place is McConnell Air Force Base (MAFB). Previous bat acoustic studies were undertaken by contractors in 2015, 2016 and 2019. These studies identified 4 different species of bats in 2015 (Johnson et al., 2015), 7 in 2016 (Hauer & Schwab 2017), and 13 in 2019 (Carver 2019) using the airspace over MAFB. However, these assessments only took place over a short time period, for example 4 days in July during the 2019 assessment (Carver, 2019). In 2021, MAFB contracted with researchers at Fort Hays State University to conduct longer and more thorough bat surveys to identify the species of bats present at MAFB, monitor their population dynamics, and assess their habitat use. Acoustic detectors were deployed for five months instead of five days to 12 weeks, and mist-netting was conducted to confirm the species identities of bats using the area. Although bats were detected acoustically, no bats were captured in mist nets nor observed flying in the area. In addition, very few insects were encountered by the researchers.

These observations made the researchers wonder whether bat activity and prey availability at MAFB differed from that in Wichita, more specifically, the more natural parks. This observation led to the questionI sought to address.

This research aimed to provide a comparison of overall bat activity and insect biomass on MAFB versus the urban Wichita area. We had four objectives: compare acoustic bat activity between 2021 and 2022, investigate whether there were differences in bat species and activity levels between MAFB and Wichita parks using acoustic detectors; confirm the acoustic findings by mist netting for bats to determine if there were differences in species and capture numbers between MAFB and Wichita; and investigate if there are differences in insect biomass between MAFB and Wichita using light traps.

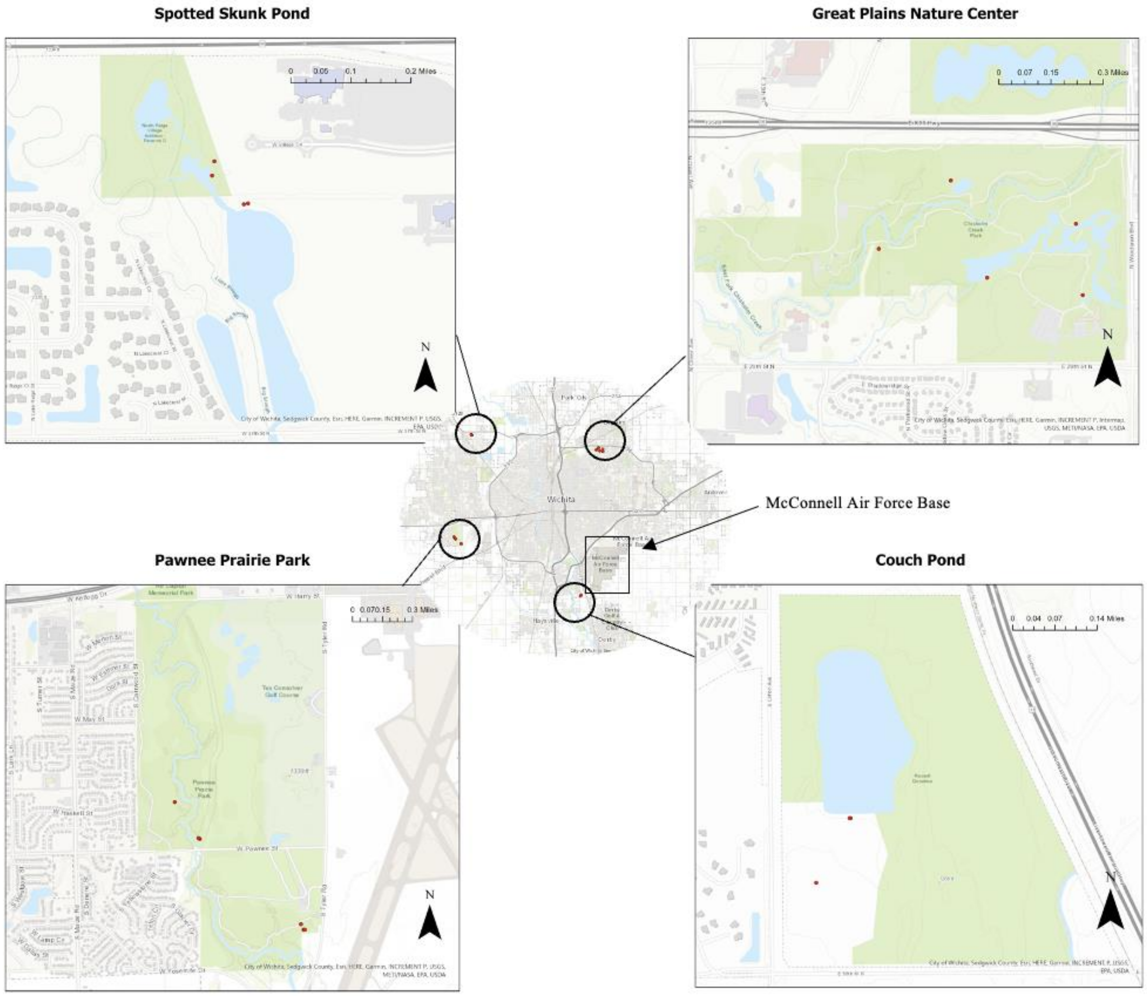
METHODS

Study Sites

Wichita is the largest city in the U.S. state of Kansas and the seat of Sedgwick County (Rydjord, 1972), with a population of 647,610 people in 2020 for the Wichita metro area (United States Census Bureau, 2020).

MAFB is located four miles southeast of the central business district of Wichita. The main base occupies 3,616 acres (INRMP McConnell Air Force Base, 2019). The base habitat is a mix of grassland and wetlands, with several locations with water and trees sufficiently large for bats to roost in. The woodlands extend along the stream from the former golf course area south to the base boundary and along the streams in the clear zone south of 47th Street (south of base). Tree and shrub species common in the wooded areas are eastern cottonwood, green ash, common hackberry, Osage orange, coralberry, smooth sumac, and poison ivy (INRMP McConnell Air Force Base, 2019).

We surveyed a total of 4 parks in the Wichita area, these parks included 2 public parks, Pawnee Prairie Park, Great Plains Nature Center, and 2 non-public land parcels owned by the City of Wichita, which we refer to as Spotted Skunk Pond and Couch Pond; we refer to these non-MAFB sites collectively as “parks”. These parks share a similar habitat to MAFB, given that they are in the same urban area. However, the parks were located on the four corners of the city of Wichita, giving us a wide range of the habitats available within the city limits (Map 1). We aimed to find similar habitats to MAFB, but also have other habitat types. Couch Pond can be described as a semi-agricultural landscape with a larger body of water and some residential buildings nearby, it is also relatively close to MAFB, to the south. Spotted Skunk Pond also had a larger body of water and residential/office buildings adjacent. Both of these parks were not improved for public access. Pawnee Prairie Park and the Great Plains Nature Center were similar to each other in that they both are open to the public and contain more wooded areas than the previously mentioned parks. These latter parks also have creeks that run through the area, minimal manicured/mowed lawns adjacent, and Pawnee Prairie is near the Eisenhower airport. They are also neighboring more manicured lawn areas and residential budlings. Landcover for MAFB and parks is discussed in more detail below.



Map 1. The park sites in Wichita are shown above, with the corners reflecting their locations respectively. The location of MAFB is also outlined in black. The red dots represent the sites where acoustic detectors were placed.

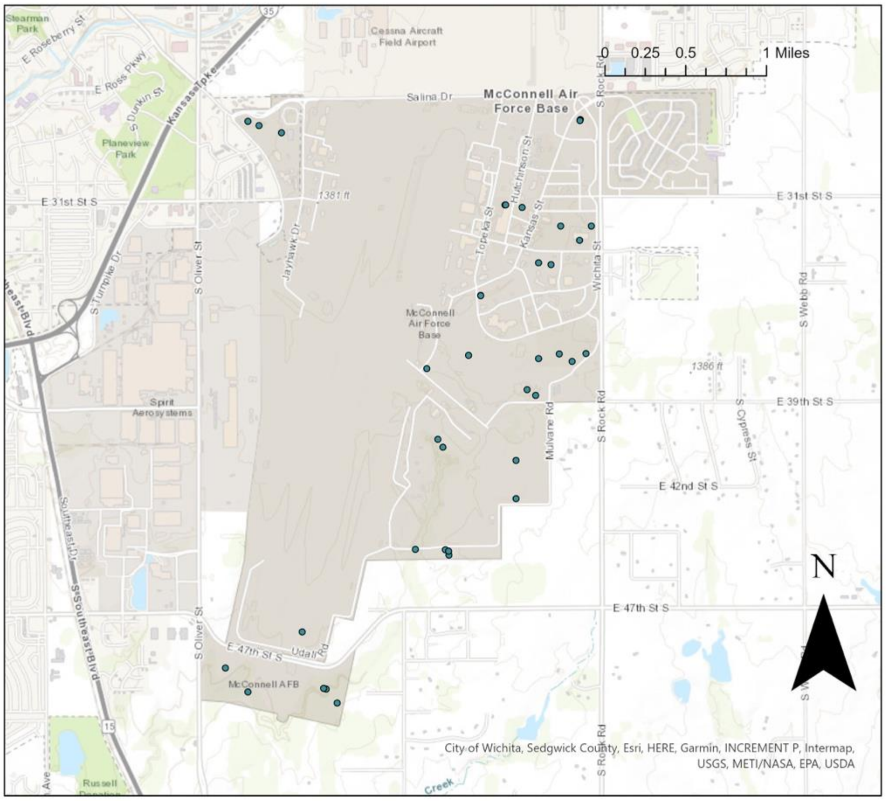
Acoustic surveys

Acoustic surveys were used to determine the overall bat activity at each study site. All acoustic surveys used Song Meters (Wildlife Acoustics, Maynard, MA). Song Meters are ruggedized, long-deployment acoustic recorders. We utilized the settings specifically for bat call recordings. *(See Appendix A for configuration settings).*

Suitable acoustic detector sites at MAFB were scouted with MAFB personnel each time because of fluctuating water levels and grass-mowing schedules. Since the study site was an urban area, there was no set distance between the detectors at each site, but the parks were large enough to place the detectors at least 400 meters away from the previous deployment site each round of deployment. The detector sites for the local parks were also scouted during daylight hours. Ideal sites were located near water where bats come to drink, at the edge of fields where bats likely forage, or near suspected roost sites, including man-made structures. We also tried to place the detectors at least 3 meters away from the tree lines to avoid clutter calls, which happens when an echolocation call bounces off surrounding objects, creating a narrow-band call unsuitable for identification in the data analysis phase. We deployed 4 bat detectors at MAFB and 3-4 at the Wichita parks. See the maps below for acoustic placement at sites and the surrounding Wichita area.

On MAFB, from June-October 2021 and April-October of 2022, we deployed 4 acoustic detectors a total of 24 times at 17 separate sites with suitable habitat for bats on base (Map 2). Systematically, we mist netted for 2 nights each month, 1 night at MAFB and 1 night in the parks. We did not have access to the surrounding parks to do surveys of base until June. When we did gain access, from June-October of 2022, we placed 3-4 detectors at 2-3 separate sites for each park a total of 19 times.

MAFB Acoustic Sites



Map 2. Acoustic detector placement sites. Sites were scouted beforehand. Each dot represents a location of deployment. Most locations had multiple deployments in the exact area/location.

Approximately every four weeks, the detectors were checked, batteries replaced if needed, SD cards removed and replaced, and in most cases, the detectors were moved to a different location within site. One of the 4 parks' detectors malfunctioned for 2 months before the problem was identified and fixed.

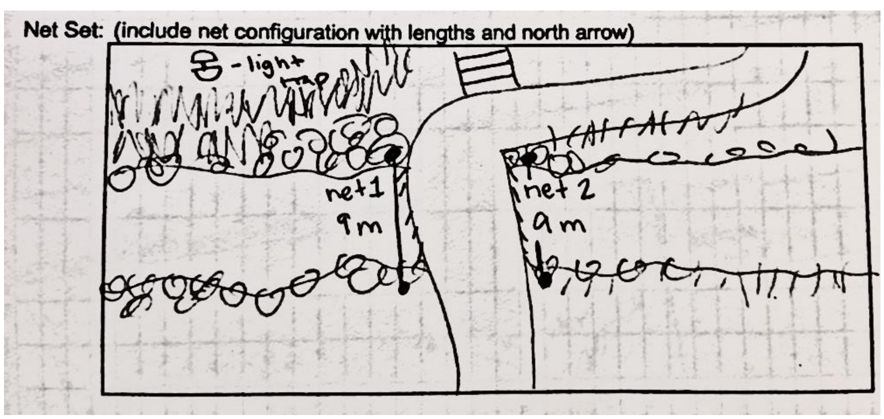
Acoustic data were analyzed using Kaleidoscope Pro (Version 5.4.9) to identify the species of bats in the area using AutoID. We took the recordings collected by the Song Meters, downloaded them into a hard drive, and organized the wav files into folders by recording dates. Then, we ran the files through the Kaleidoscope AutoID algorithm that uses classifiers to differentiate between known bat species calls. After this, we exported the data to be manually vetted. (*The entire protocol can be found in Appendix B).* In short, we removed calls with <20% AutoID confidence, accepted the AutoID calls identified with >80% confidence, and considered calls with 20-80% confidence as "ambiguous". These ambiguous calls were used in the overall activity analyses because we were confident that they were bats, but removed from species-specific analyses outlined below.

After the calls were vetted, they were exported to spreadsheets and analyzed in R (R Development Core Team 2013). The acoustic detectors start recording when a bat calls nearby; these recordings can vary from just a few echolocation pulses to over 100 pulses, depending on the distance of the bat to the microphone as well as the activity of the bat, either approaching an insect which produces more rapid pulses or searching for an insect, producing slower pulses. Each continuous recording becomes one row in the datasheet. To analyze overall bat activity between MAFB and the parks, we used the dplyr package in R to sum the number of rows for each site type per night; we call these "bat passes". Because bat detectors were not deployed until June at MAFB in 2021 in the parks in June 2022, we are only comparing data from June-October for both years. We performed t-tests in R to determine if there was a significant difference in the number of bat passes per night between 2021 and 2022 at MAFB and between the two site types (parks and MAFB) in 2022. We also graphed the number of bat passes between the site types over time.

To investigate whether there were differences in bat activity for specific species, we performed t-tests on number of bat passes for each species AutoIDed with >80% confidence.

Mist net surveys

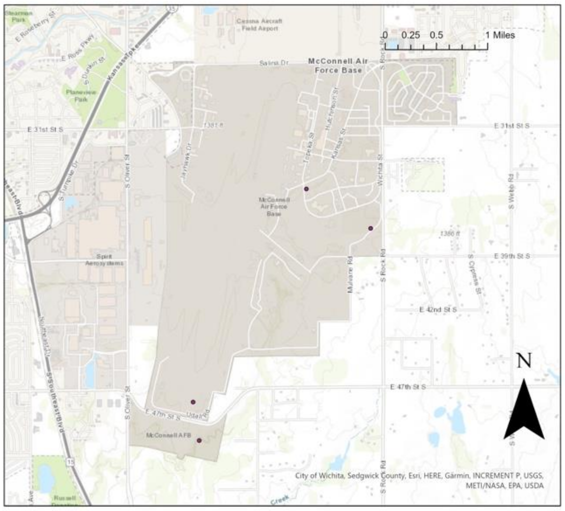
Suitable mist netting sites were scouted during each monthly visit. These sites are typically located over shallow water where trees naturally restrict bat flight paths. The number and size of mist nets deployed at each site were determined by site-specific factors, such as the water availability nearby and the net sizes available. Most mist netting occurred with single-high nets; the August and September 2022 mist netting sessions used one triple-high net, about 9 m tall, and multiple single-high nets, about 3 m tall. Net lengths varied based on the conditions at each site, but included 2.6 m, 6 m, 9 m, and occasionally used 12 m net lengths. The position(s) and the number of nets varied depending on the topographical features that provided the greatest opportunity to catch bats at any given site; Map 3 gives an example of how net-set information was recorded on the datasheets.



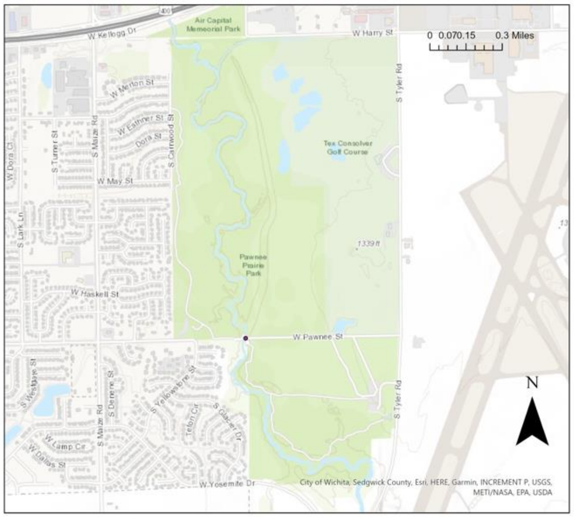
Map 3. This handwritten map shows the dimensions of a net set at Pawnee Prairie Park, near the bridge. Using 2, 9 m nets on each side.

Surveys were conducted 1-2 times per month, from May to September, which is when bats are the most active. Weather permitting, we conducted mist nets surveys at least once per month on MAFB and once per month at a park. During each survey, mist nets were open from dusk, or when the first bat was visually detected, through thirty minutes past the last bat detection of the night or four hours. Nets were checked every 10-15 minutes. Mist netting locations are shown in Map 4.

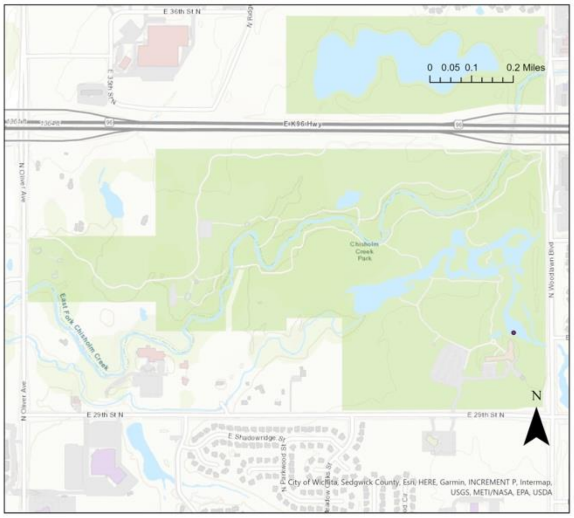
MAFB Mist Netting Sites



Pawnee Prairie Mist Netting Site



Great Plains Nature Center Mist Netting Site



Map 4. Mist netting sites for MAFB, Pawnee Prairie Park, and Great Plains Nature Center. Surveys were conducted 1-3 times per month from May to September.

Captured bats were identified, sexed, measured, wing-biopsied, and held in a cup for up to 30 minutes to collect guano. All survey efforts followed USFWS decontamination protocols regarding White-nose Syndrome as appropriate and complied with COVID-19 procedures when they were put in place. All team members were vaccinated for rabies and COVID-19.

The survey protocol was approved by the Fort Hays State University Institutional Animal Care and Use Committee study # 21-0010. Permits were issued by Kansas Department of Wildlife and Parks (SC-091-2022) and the USFWS (PER0012961).

Light traps

Light traps (Bioquip Products Inc #2851A Universal Collecting System) were deployed during each mist netting survey to capture insects in the area. The light traps were placed at a considerable distance from the mist net to avoid potential adverse effects of light around the foraging area, thus affecting sampling rates (Froidevaux, et al. 2018). The collected insects were stored in 70% ethanol.

Due to the weather, some sampling nights were shorter than others. Biomass was corrected to reflect differences in deployment time.

Insect Biomass

The biomass measurement protocol is based on a previously published protocol (Hallman et al. 2017). In order to closely replicate this protocol, we first measured the weight of the scale tray and the weight of the coffee filter separately. A coffee filter was used to prevent smaller insects from getting trapped in the sieve, thus not including them in the total biomass measurement. Each sample of insects were then poured onto the coffee filter located at the base of the angled stainless-steel sieve (10cm diameter) of 0.8 mm mesh width. The sieve was placed at 30 degrees over a plastic bowl. This angled position accelerated ethanol's first runoff and the measuring process. The drop sequence was observed and timed with a stopwatch. When the time between two drops reached 10 seconds for the first time, and the coffee filter was mostly dry, the weighing process was performed with a laboratory scale. The weight of the coffee filter and weigh boat was then subtracted from the overall measured weight.

Biomass was divided by the number of hours the light trap was deployed to account for differing lengths of deployments due to permitting issues and weather. A t-test and a Mann-Whitney U-test were performed in R to determine if there was a significant difference in corrected biomass between the parks and MAFB. A Mann-Whitney U-test was used because the data were not normally distributed.

Landcover

The study areas were variable in their land usage and cover. This is an essential factor for analysis as it may play a part in roosting/foraging activities of bats (Shapiro et al, 2020). Landcover data was accessed from the Impact Observatory, Microsoft, and Esri, and the maps were created using ArcGIS® software by Esri. To begin the analysis of landcover, data were first downloaded from the "Sentinel-2 10m land use/land cover time series of the world" layer from the Living Atlas downloader. This layer displays a global map of land use/land cover (LULC) derived from ESA Sentinel-2 imagery at 10m resolution. Each year is generated with Impact Observatory's deep learning AI land classification model, which is trained using billions of human-labeled image pixels from the National Geographic Society (Impact Observatory, Microsoft, and Esri. 2023). See Appendix C for Landcover class definitions. After the layer was downloaded, a series of polygons were created over the areas of our study. The raster data from the landcover layer was then clipped to the appropriate dimensions of the polygons. The raster data then provided the appropriate counts for each landcover type, the cell size (the dimension of the area covered on the ground and represented by a single pixel, = 9.99999872988023 units), and the linear units of the raster data (1 meter). These measurements were taken down in an Excel sheet to be analyzed. The area of each landcover type (Area of Landcover Types = Cell Size x Count) and the total area of the raster clip (Total Area = Sum of Areas of Landover Types) were calculated (Buckley, A. 2010). To calculate the percentage of land cover use, the Area of each cover type was divided by the site's total area (% Land Use = (Area of Landcover Type/ Sum of Areas of Landover Types Per Site). The measurements for the area were in meters squared. These steps were repeated for each study site.

Weather and bat activity

Suboptimal weather conditions can significantly negatively influence insectivorous bats' survival and reproductive success (Burles et al, 2009). To determine if weather influenced bat activity, we downloaded temperature, precipitation, wind, cloud cover, and moon phase data from https://www.visualcrossing.com/weather/weather-data-services, for Wichita for June 6th 2022 – October 17th 2022. We used R to calculate Spearman product-moment correlation coefficients to assess whether there was a relationship between the number of bat passes and each weather variable.

RESULTS

Comparison of bat activity at McConnell Air Force Base in 2021 versus 2022

We found that on MAFB, the overall bat activity varied significantly between years, with 2021 seeing significantly more activity (Figure 1; Welch Two Sample t-test t=4.1867, df = 276.41, p-value = 0.00003808, MAFB 2021 Mean = 30.9, MAFB 2022 mean = 18.33, 95% CI [6.659195 , 18.479159]). For more site-species-specific graphs from MAFB, see Appendix D. Bat activity June-August differed between years, but were more similar August-October (Figure 2).

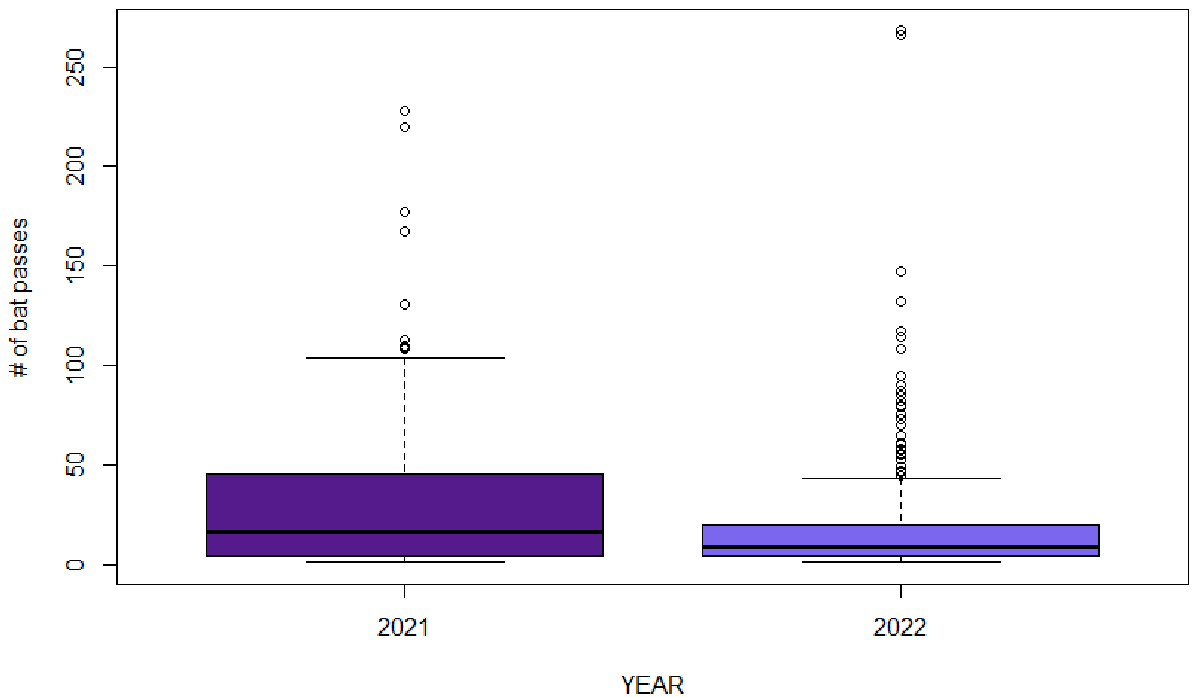


Figure 1. This boxplot shows the number of bat passes at MAFB between the 2021/2022 field seasons, with 2021 on the left and 2022 on the right. There was significantly more bat activity in 2021 (Welch Two Sample t-test t=4.1867, df = 276.41, p-value = 0.00003808, MAFB 2021 Mean = 30.9, MAFB 2022 Mean = 18.33, 95% CI [6.659195 , 18.479159]).

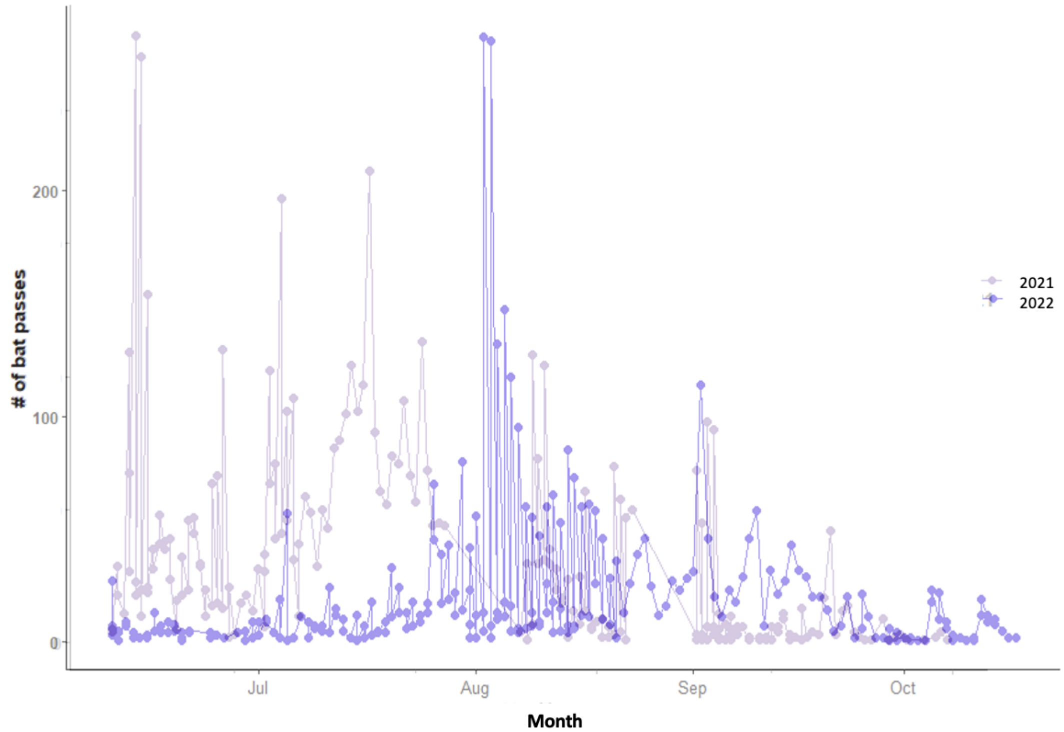


Figure 2. This graph demonstrates the overall number of bat recordings per night over time. The graphs starts on June 10 due to permit constraints and ends in October, the end of the season. The 2021 data is lighter purple, whereas the 2022 data is darker purple.

There were a total of 7 unambiguously identified species and several ambiguous species recorded at MAFB throughout the 2021/2022 season (Table 1). These species included, from most detected to least detected, Eastern red bat (LASBOR) with 886 passes; Big brown bat (EPTFUS) with 408 passes; Hoary bat (LASCIN) with 330 passes; Tri-colored bat (PERSUB) with 303 passes, Brazilian free-tailed bat (TADBRA) with 288 passes, Silver-haired bat (LASNOC) with 55 passes, and finally the Evening bat (NYCHUM) with 45 passes. Although there were more total bat passes in 2021 most of these calls came from ambiguously identified bats; Eastern red bats and Tri-colored bats were the only unambiguously identified species that were significantly different between years (Table 2). Note, a bat pass may include the *same* individual bat passing by the mic several times or potentially several *different* individual bats echolocating near the microphone during the same recording.

Table 1. The table below shows the total bat calls for each species at MAFB in 2021 and 2022. (All the "ambiguous" species are in one category.)

	MAFB 2021			MAFB 2022	
Species		**# Of Bat Passes**	**Species**		**# Of Bat Passes**
EPTFUS		249	EPTFUS		109
LASBOR		571	LASBOR		348
LASCIN		223	LASCIN		115
LASNOC		39	LASNOC		13
NYCHUM		29	NYCHUM		8
PERSUB		180	PERSUB		53
TADBRA		192	TADBRA		61
	Total:	1483		**Total:**	707
Ambiguous Species		2396	**Ambiguous Species**		753
	Grand Total:	3879		**Grand Total:**	1460

Table 2. The species-specific statistics for the 7 species detected at MAFB during 2021, and 2022 seasons, respectively. Bolded p-values indicate significant differences between years.

Species	**t**	**df**	**p-value**	**mean 2021**	**mean 2022**
EPTFUS	-1.2537	107.31	0.2127	0.127273	2.848101
LASBOR	2.9428	320.85	0.003489	10.369427	6.183432
LASCIN	0.74828	62.962	0.4571	0.673469	1.971429
LASNOC	1	11	0.3388	1.166667	1
NYCHUM	1	9	0.3434	1.3	1
PERSUB	2.0606	76.412	0.04275	4.176471	2
TADBRA	1.68	49	0.09928	3.933333	1.772727

Comparison of overall bat activity at MAFB and Wichita parks (2022)

Bat activity (number of bat passes per night) in the Wichita parks was significantly higher than at MAFB (Figure 3; Welch Two Sample t-test t = -4.9951, p-value = < 0.001, MAFB Mean = 18.8, Parks Mean = 38.3, 95% CI [-27.14146 , -11.79139]). This significant difference is in spite of the fact that only three detectors were functional in the parks during much of this time.

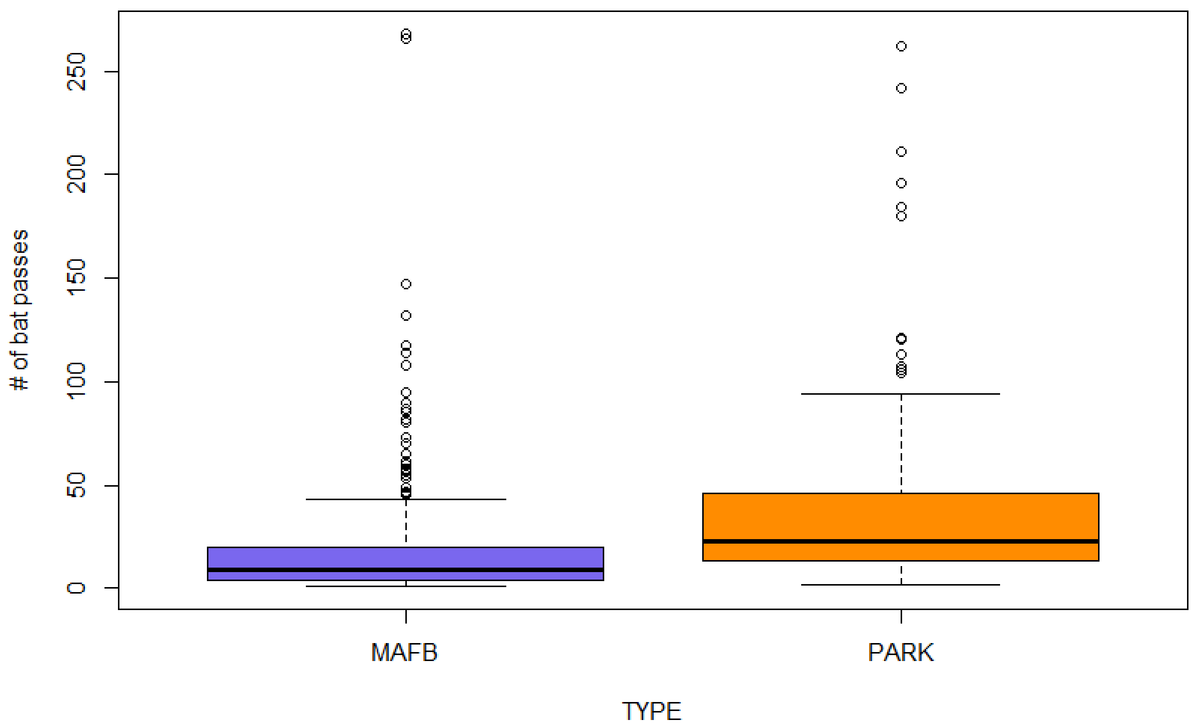


Figure 3. This boxplot displays the significance difference between the number of bat passes per night in 2022 according by site type. (Welch Two Sample t-test t = -4.9951, p-value = < 0.001, MAFB mean ± SE = 18.8, Parks mean ± SE =38.3)

Despite these potential issues, the number of bat passes per night still represents the measured overall bat activity. MAFB had more total bat passes compared to Parks (Table 3). However, Parks had a higher average number of bat passes (Figure 3).

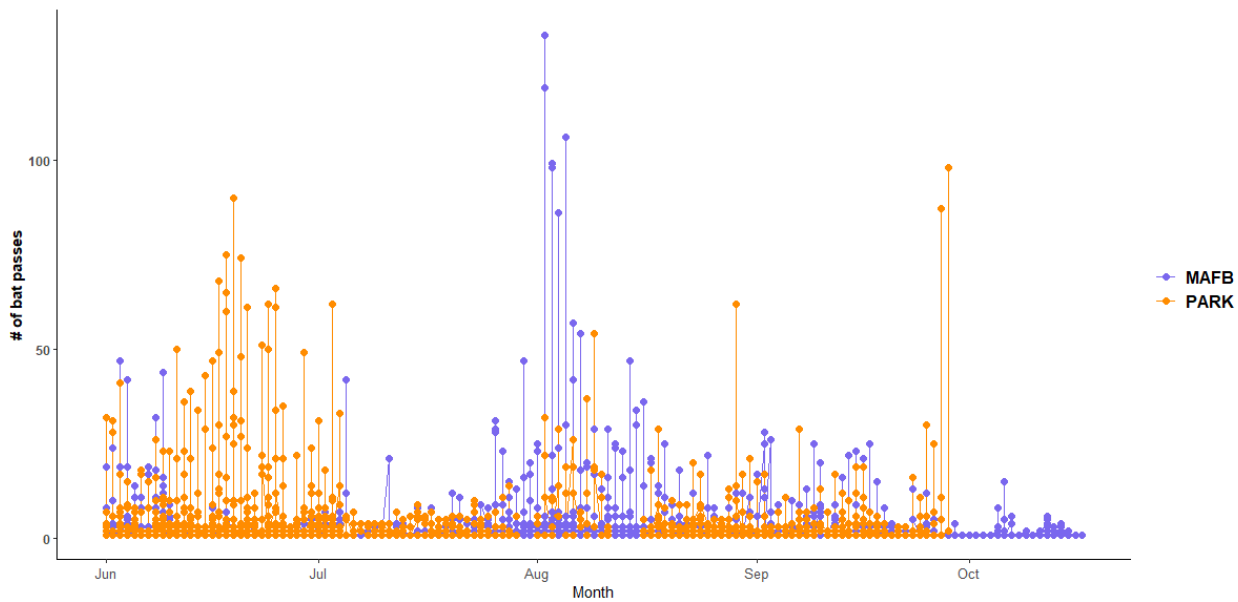


Figure 4. The graph above illustrates the number of bat passes per night by site type over the 2022 season. Each dot represents an individual night. The bat activity was variable each night. The park data is in orange and the MAFB in purple.

Bat activity was quite variable throughout the months of study (Figure 4). For example, in August on MAFB, there was a spike in bat passes, but very few bat passes July – August (Figure 4). Another example is the steady level of activity in the parks from June to July but less activity in the parks from July to August. When looking at the species level, for the unambiguous species, only Tri-colored bats were significantly different between the parks and MAFB (Table 4). Brazilian free-tailed bats were close in significance, and Eastern red bats had a p-value of almost 1, demonstrating essentially identical means between the parks and MAFB (Table 4).

Table 3. The table below shows the total bat calls for each species at MAFB vs the parks. (All the “ambiguous” species are in one category.) It is important to note that although there were apparently more calls on MAFB recorded during the 2022 season, the statistical tests looked at the average number of calls per night per type, creating a significant difference between the parks and MAFB.

	Number of Bat Passes	
Species	**Parks 2022**	**MAFB 2022**
EPTFUS	76	109
LASBOR	140	348
LASCIN	55	115
LASNOC	10	13
NYCHUM	10	8
PERSUB	78	53
TADBRA	67	61
Total:	436	707
Ambiguous Species	752	753
Grand Total:	1188	1460

Table 4. The table below describes the species-specific statistics for the 7 species detected at the parks and MAFB for the 2022 season. Please note that the LASNOC data could not be analyzed for this table because there wasn’t enough variability in the data (only one bat pass on the few nights it was recorded).

Species	t	df	p-value	mean MAFB	mean Parks
EPTFUS	1.2908	153.29	0.1987	2.422018	1.868421
LASBOR	0.0053577	574.51	0.9957	4.16954	4.165992
LASCIN	-1.4565	158.71	0.1472	2.608696	3.444444
NYCHUM	-1.964	9	0.08113	1	1.3
PERSUB	-4.0137	101.58	0.0001145	1.924528	9.75
TADBRA	-1.9588	124.94	0.05236	2.114754	2.939394

Bat activity in Wichita parks

Bat activity in the parks themselves varied with each site and each night (Figures 5-8). At Couch Pond, there is a spike in activity in August, then shortly after seems to decrease at the end of the month. PERSUB was the most detected species at this site (Figure 5). At the Great Plains Nature Center, there seemed to be no stark difference between species, but there was a slight spike in June of TADBRA and a slight spike in LASCIN in June (Figure 6). At Pawnee Prairie Park, LASBOR was the most detected species at this site, but there was a spike in PERSUB in June (Figure 7). The fewest detections were observed at Spotted Skunk Pond, where the detector had technical issues, but there were still some detections (Figure 8).

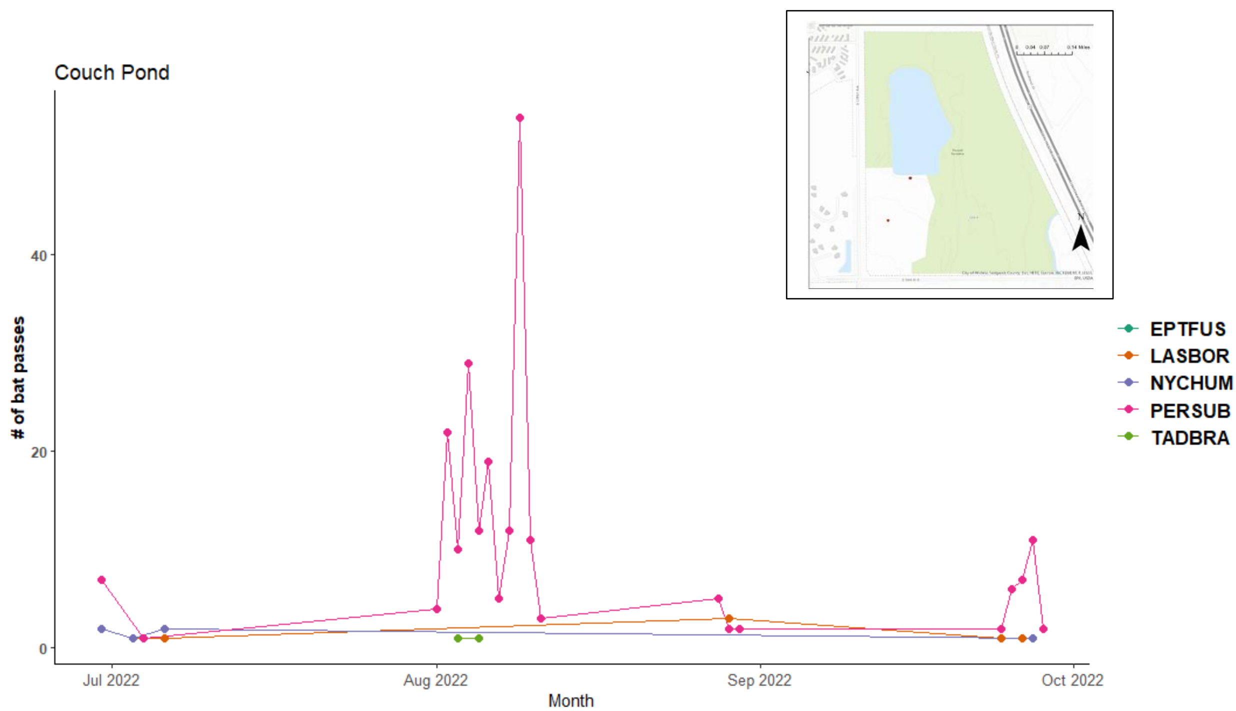


Figure 5. The graph above shows the number of bat passes per night at Couch Pond over time. The detector placements are indicated on the map to the right.

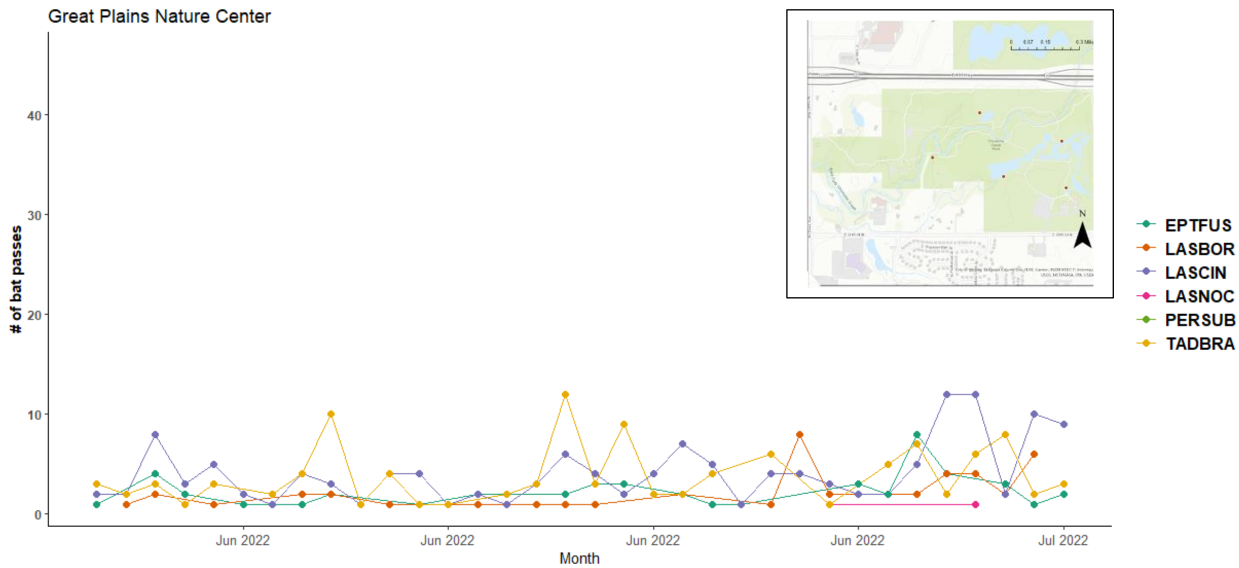


Figure 6. The graph above shows the number of bat passes per night at Great Plains Nature Center over time. The detector placements are indicated on the map to the right.

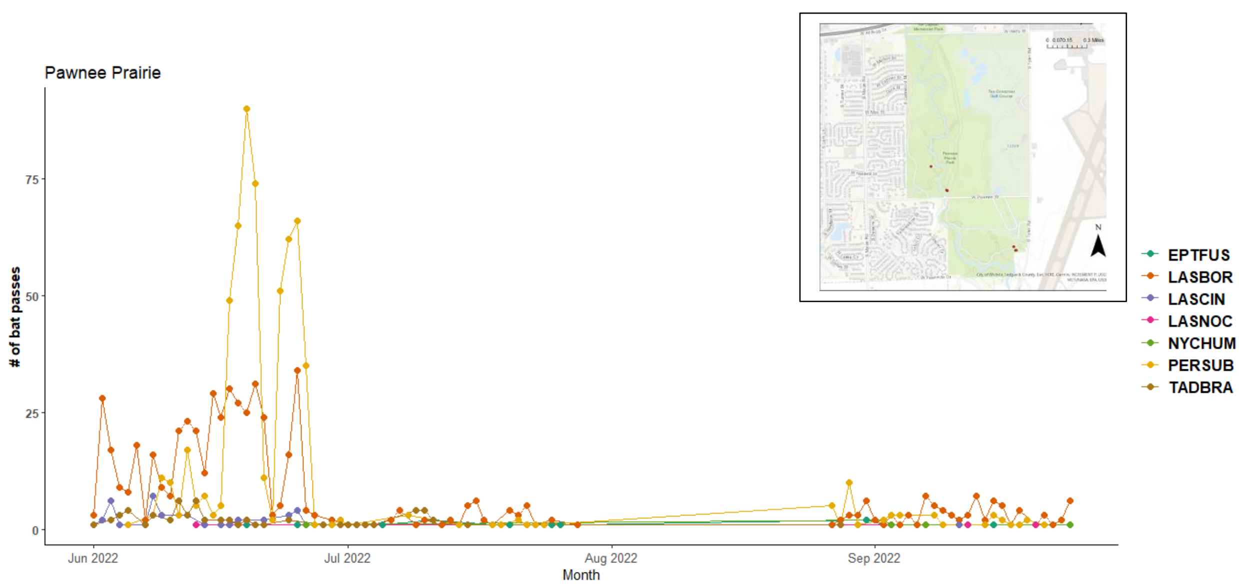


Figure 7. The graph above shows the number of bat passes per night at Pawnee Prairie Park over time. The detector placements are indicated on the map to the right.

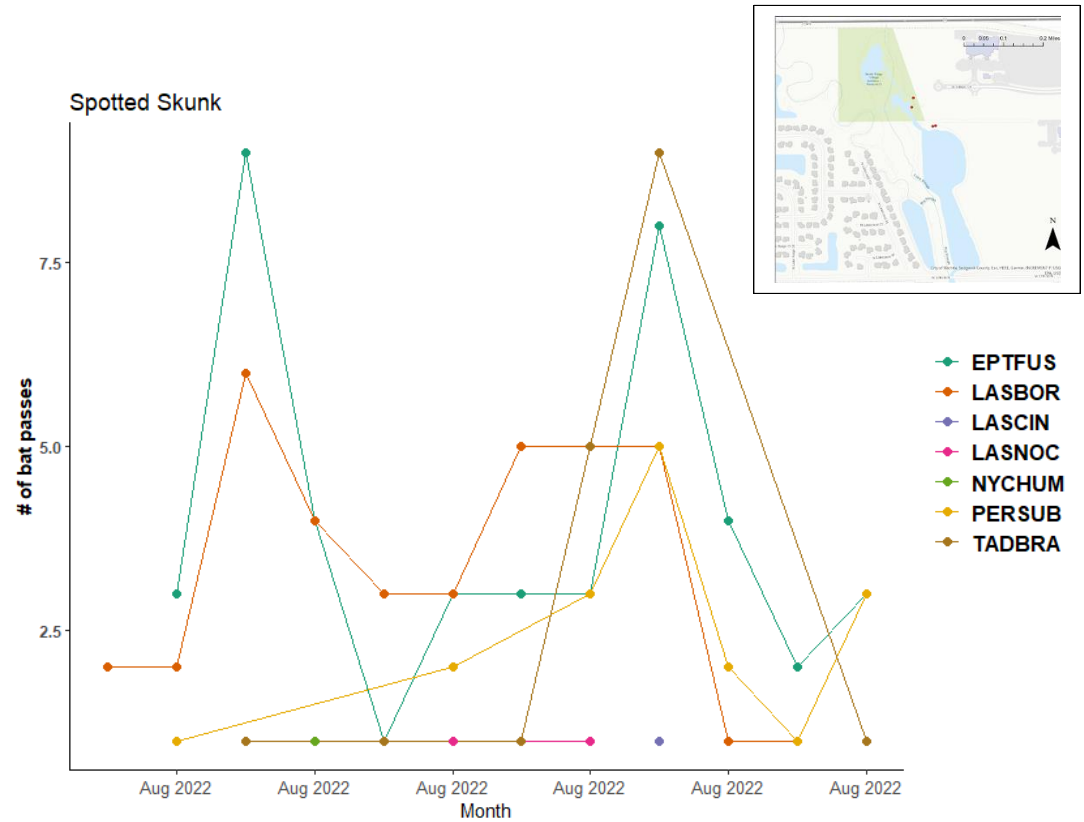


Figure 8. The graph above shows the number of bat passes per night at Spotted Skunk over time. The detector placements are indicated on the map to the right. Note that only August is shown on the x-axis due to the detector not working until it was fixed it in August. There also seems to be no apparent activity in September and October, or it was all ambiguous species calls.

Insect Biomass

We collected a total of 18 samples from the 2022 season over the span of April-September. These samples were both from the parks and MAFB combined. There was no significant difference in insect biomass between the park sites and MAFB (Welch Two Sample t-test t= 1.4697, df = 0.6063, p-value = 0.1954, MAFB Mean = 6.88, Parks Mean = 4.64; Kruskal-Wallis rank sum test, Chi-Squared = 0.83333, df = 1, p-value = 0.3613; Wilcoxon rank sum exact test W = 20, p-value = 0.4286)

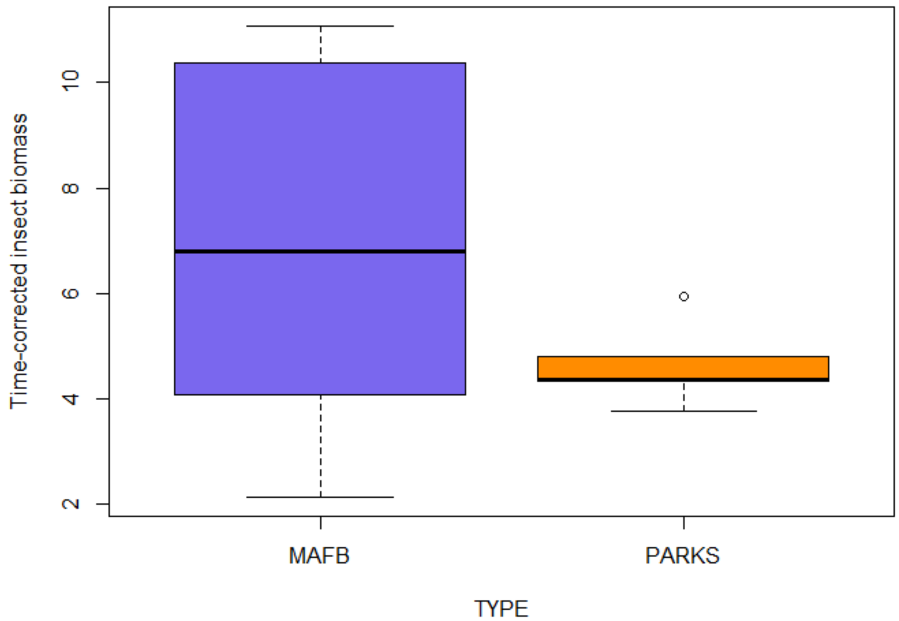


Figure 9. The figure above demonstrates the time-correlated insect biomass over time from June 2022 to September 2022.

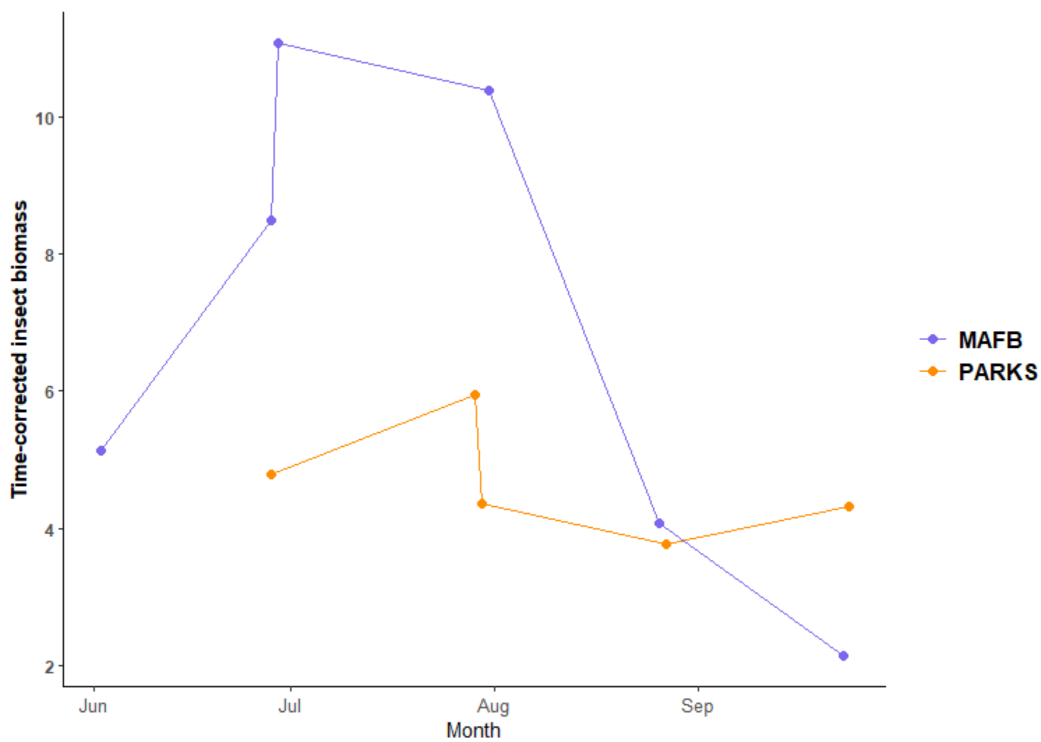


Figure 10. The figure above demonstrates the time-correlated insect biomass over time from June 2022 to September 2022.

Although the mean of the MAFB biomass was higher, it was not high enough to be considered statically significant (Figure 9). There was a lot of variation in biomass from one sampling event to the next. Some of this variation included weather (Figure 10). On two occasions, we had to cut sampling shorter due to rainfall. Thus, instead of being able to sample the regular 4 hours, it was 2.5 hours for two nights.

Predictors of bat activity

Table 5. The table below shows the correlations of weather factors, maximum temperature, minimum temperature, average precipitation, etc.

Variable	Correlation coefficient	T-value	df	p-value
Maximum Temperature	0.097	2.0757	453	0.03849
Minimum Temperature	0.1313214	2.8194	453	0.005022
Average Temperature	0.1203037	2.5793	453	0.2702
Precipitation	-0.05179444	-1.1039	453	0.2702
Wing Gust	-0.002276767	-0.048458	453	0.9614
Wind Speed	0.04016787	0.85562	453	0.3927
Cloud Cover	-0.00460282	-0.097967	453	0.922
Moon Phase	0.02320137	0.49395	453	0.6216

Of the environmental variables examined in this study, only temperature was weakly (albeit significantly) positively correlated with the number of bat passes (Table 5, Figure 11).

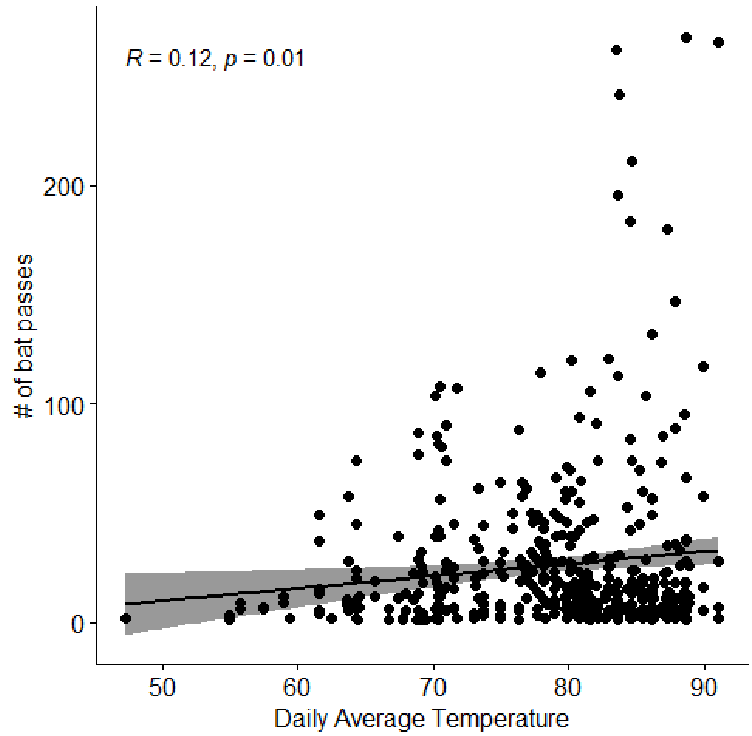


Figure 11. This figure shows the daily average temperature (°F) in Wichita, KS, for the 2022 season. The daily average temperature was the only weakly-positively correlated factor with the number of bats passes.

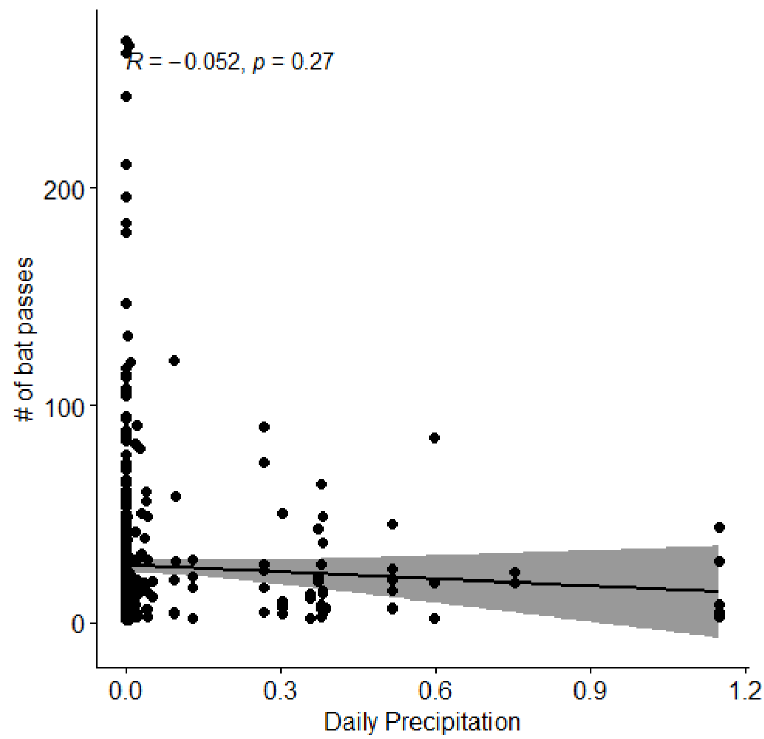
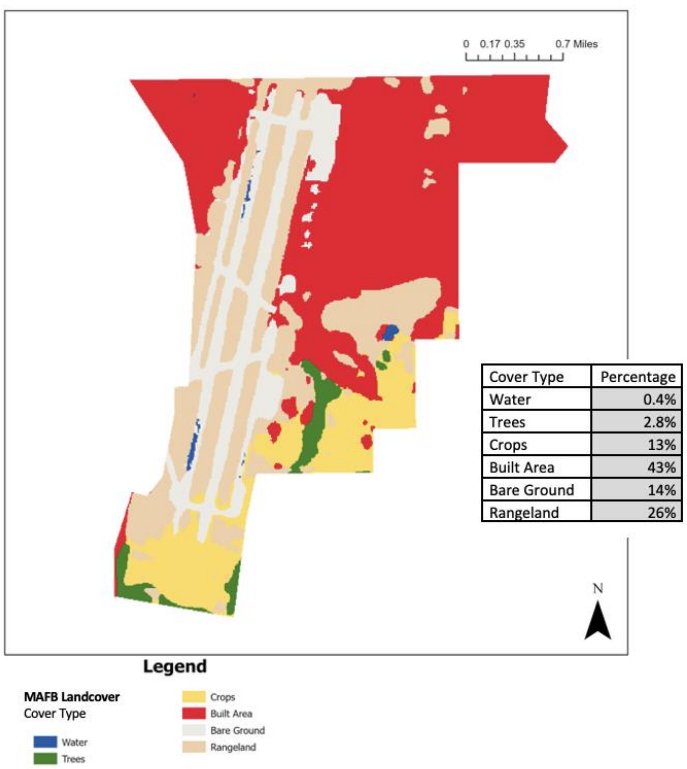


Figure 12. This figure shows the daily precipitation (cm) in Wichita, KS, for the 2022 season. There was no correlation between daily precipitation and the number of bat passes.

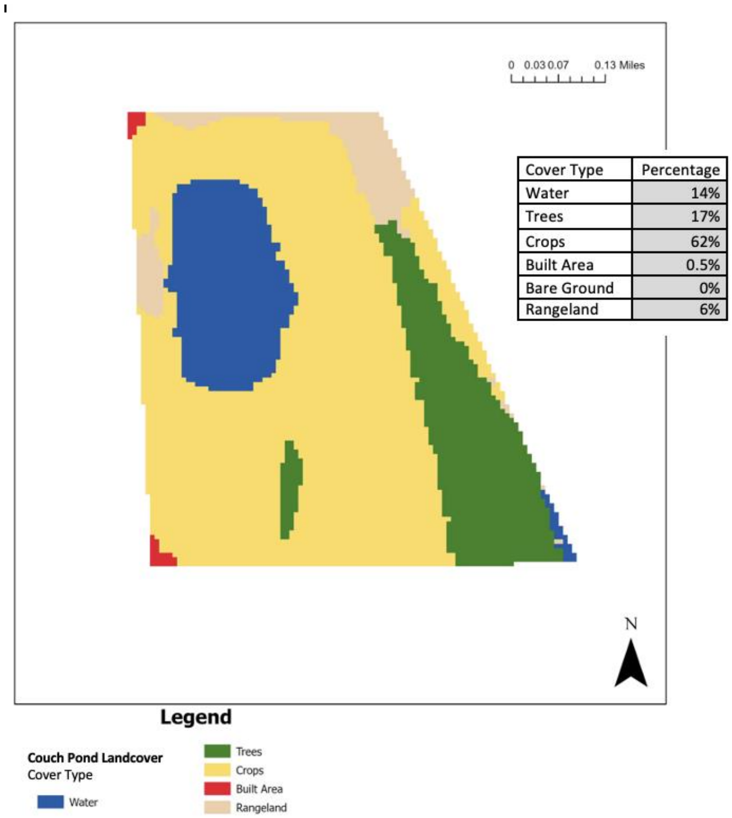
Landcover

MAFB had the least percentage of water land use of all the sites, with only 0.4%. Most of the land use of MAFB is built area with 43%, with rangeland being the next most land use with 26%. Couch Pond had the highest percentage of crops land use of all the sites, with 62%. Couch Pond had the least percentage of built area of all the sites, with 0.01%. Spotted Skunk had about 0 crop land use with only 0.01% but had a fair amount of rangeland with 31%. Pawnee Prairie had the most rangeland percentage of land use than any other site, with 68%; it also had very little bare ground land use, with only 0.07%. Finally, at the Great Plains Nature Center, it came second to the Pawnee Prairie rangeland percentage of land use with 54%. This site also had 0% of bare ground land use. For tree land use percentages, in descending order, Pawnee Prairie had the most with 25% of land use; both The Great Plains Nature Center and Spotted Skunk Pond had 22% of land use; Couch Pond had 17% of land use, and finally MAFB had 2.8% of tree land use.



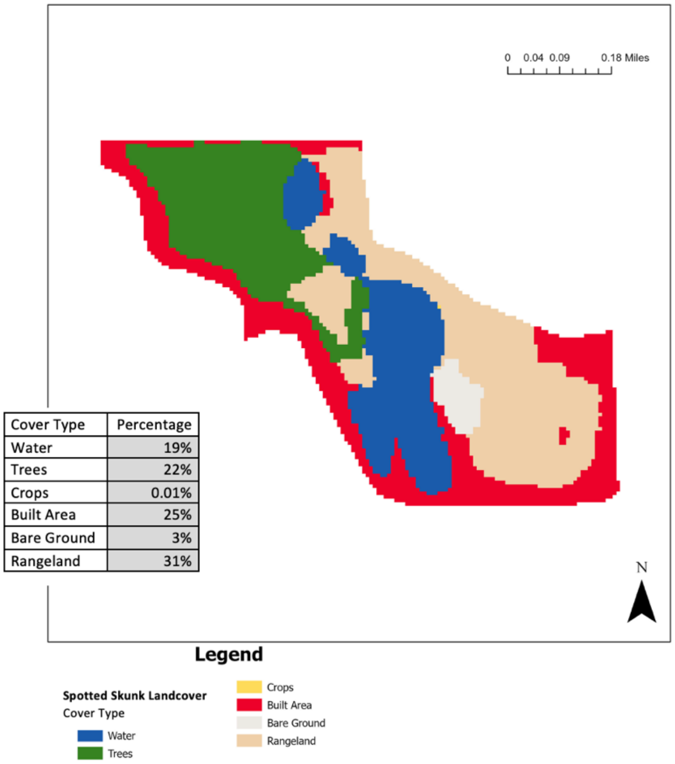
Cover Type	Percentage
Water	0.4%
Trees	2.8%
Crops	13%
Built Area	43%
Bare Ground	14%
Rangeland	26%

Map 5. The map above displays the land cover of MAFB. The percentage calculations can be seen in the table to the right. Most of the land use of MAFB is built area (43%), and the least is water (0.4%).



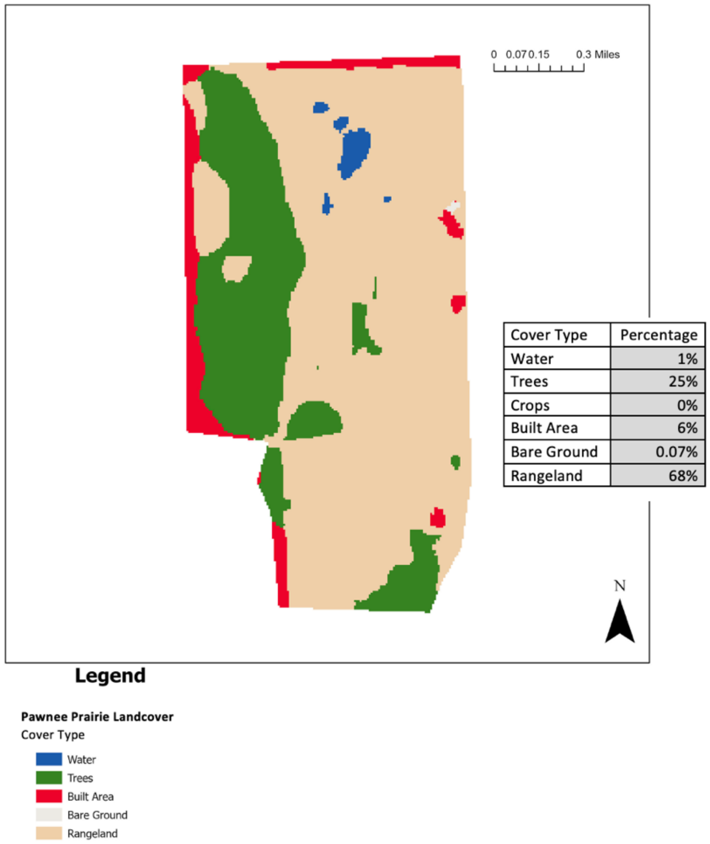
Cover Type	Percentage
Water	14%
Trees	17%
Crops	62%
Built Area	0.5%
Bare Ground	0%
Rangeland	6%

Map 6. The map above displays the land cover of Couch Pond. The percentage calculations can be seen in the table to the right. Most of the land use of Couch Pond is crops (62%), and the least is built area (0.01%).



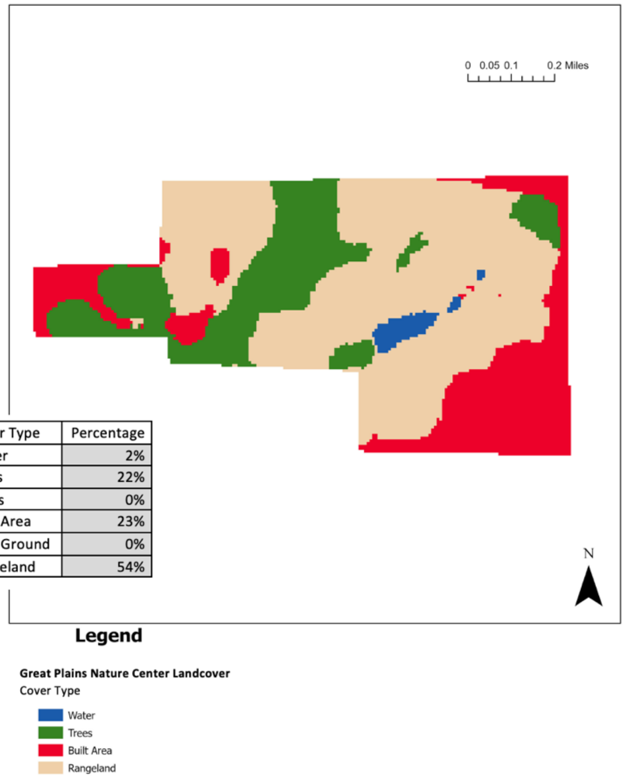
Cover Type	Percentage
Water	19%
Trees	22%
Crops	0.01%
Built Area	25%
Bare Ground	3%
Rangeland	31%

Map 7. The map above displays the land cover of Spotted Skunk. The percentage calculations can be seen in the table to the right. Most of the land use of Spotted Skunk is rangeland (31%), and the least is crops (0.01%).



Cover Type	Percentage
Water	1%
Trees	25%
Crops	0%
Built Area	6%
Bare Ground	0.07%
Rangeland	68%

Map 8. The map above displays the land cover of Pawnee Prairie. The percentage calculations can be seen in the table to the right. Most of the land use of Pawnee Prairie is rangeland (68%%), and the least is crops (0%) and bare ground (0.07%)



Cover Type	Percentage
Water	2%
Trees	22%
Crops	0%
Built Area	23%
Bare Ground	0%
Rangeland	54%

Map 9. The map above displays the land cover of the Great Plains Nature Center. The percentage calculations can be seen in the table to the right. Most of the land use of The Great Plains Nature Center is rangeland (54%), and the least is crops (0%) and bare ground (0%).

DISCUSSION

We found that bat activity on McConnell Air Force Base was significantly higher in 2021 compared to 2022. In 2022, bat activity was significantly lower at McConnell Air Force Base compared to the Wichita Parks in 2022. It is important to note that this was in spite of the fact that *even with* fewer overall detectors on the parks (4 on base, 3 on the parks on some occasions), bat activity was still greater at the parks. When working with any equipment, the possibility of malfunction or damage is always a possibility. A microphone was damaged at one of the park sites, Spotted Skunk Pond, possibly by a bird. We found the microphone unplugged from the detector at another park site, Couch Pond.

The main mission of McConnell Air Force Base is to provide global reach by conducting air refueling and airlift when and wherever it is needed; thus, there is a significant amount of air traffic in the base area. This consequently produces pollution both in the air and potentially the water. A 2007 assessment of MAFB indicated that mission-related land-use requirements resulted in pollution and hazardous waste generation (MAFB 2007a, Environmental Assessment of Installation Development and McConnell Air Force Base, Kansas, 2007). As with many Department of Defense (DoD) installations, MAFB's mission readiness capabilities result in unavoidable deleterious environmental effects. Luckily, Sikes Act requirements continue to force DoD sites to minimize negative environmental effects of their mission. Over time pollution and hazardous waste generation continue to decrease as much as possible while still achieving MAFB's military readiness. Much like airports, Air Force Bases will always produce pollution, but hopefully at the lowest level possible

The habitat of MAFB and the Wichita Parks is comparable and similar in many ways. For example, in our landcover analysis, both areas had about the same amount of built area, MAFB

=43% and Parks =54%. Both sites had adequate access to water even with MAFB with much less (MAFB=0.4% and Parks=36%), and – presumably – potential roosting site availability; however, we also suspect the parks had far less artificial light at night (ALAN) than the base, which ran its lights at all-night hours for military operations. We did not measure light intensity for this study, but through our observations, the light duration was much longer on base compared to the parks. The parks were near residential buildings, giving off some artificial light at night, but the intensity on base was far greater and more prolonged. For future studies, a light meter could measure the light intensity in the environment, as well as analyze water quality.

For our landcover analysis, it was insightful to see the different percentages of land use in the areas, especially the differences in the amount of water in the areas. For example, MAFB only had about 0.4% of water land use, while the parks totaled together 36% of water land use. Bats can forage over the water (Ingemar et al, 2009) and bats need fresh, open water for drinking (Salvarina 2016). There is also a significant amount of built area (43%) on MAFB, understandably, because it is a military installation. But the parks combined also had about the same percentage of the built area (54%). The built areas are defined as human-made structures; major road and rail networks; large homogenous resistant surfaces, including parking structures, office buildings, and residential housing (Karra, Kontgis, et al. 2021). Two parks sites that showed the most interesting results were Couch Pond, with its amount of PERSUB activity, and Pawnee Prairie Park, with its LASBOR activity, as also where we caught the only two bats of the season. Couch Pond had a majority of cropland use percentage (62%). The cropland class is defined as human-planted/plotted cereals, grasses, and crops not at tree height; examples: corn, wheat, soy, and fallow plots of structured land (Karra, Kontgis, et al. 2021). In one study of the spatial distribution of bat activity in agricultural fields in Nebraska, the researchers found that

PERSUB were acoustically detected almost exclusively at sites containing large amounts of tree cover, they were most active in forest interior and edge habitats (Fill et. al, 2016). At Couch Pond, there was a tree line to the east of the cropland habitat. The trees land use percentage of Couch Pond was 17%, not including the private land to the right of that. It is also interesting to note that the larger body of water (14% of land use) was also only 0.13 miles away from the tree line, potentially drawing PERSUB out of the tree lines and into the open cropland. At Pawnee Prairie Park, there was a significant amount of tree land use (25%) and rangeland (68%). Rangeland use is defined as open areas covered in homogenous grasses with little to no taller vegetation, for examples, natural meadows and fields with sparse to no tree cover. LASBOR are regarded as fast-flying aerial hawkers who catch flying insects on the wing (Hackett et al., 2014), often found in open spaces by vegetation and sometimes at high altitude (Norberg and Rayner 1987). This could explain why LASBOR is utilizing this habitat that is mostly rangeland and potentially roosting in the nearby trees.

Another difference in habitat to note is the water quality on and off base. A 2007 assessment of MAFB found that the base generates hazardous wastes primarily due to aircraft maintenance, vehicle maintenance, and tenant and contract activities (MAFB 2007a). While we did not test the water quality in this study, it cannot be overlooked when considering potential run-off into the water supply. Positively, addressing this situation has been getting progressively better over recent years. According to the Fish and Wildlife Service, there have been noticeable improvements in overall water quality, meaning the absence of foam, discoloration, or general smell. The base does not use as much pesticide as one would think. In fact, they only spray decorative trees intermittently to control bagworms, but otherwise, only some herbicide is used to control vegetation and invasive species in some areas. However, an area threat to these improvements is that the base is surrounded by agricultural fields, including cotton fields to the East and Southeast. Cotton farming can severely degrade soil quality. Cotton production has depleted and degraded the soil in many areas all over the world. Most cotton is grown on well-established fields, but the fields exhaustion leads to expansion into new areas and then more destruction of habitat (World Wildlife Fund, U. S. 2001). There is also cropland grown to the South of the base, such as wheat, sorghum, and corn, which also requires pesticides and herbicides to maintain (U.S. Fish and Wildlife Service, 2022).

Although we did not test the water quality for this study, researchers have tested the effect of water quality on bat activity and found that EPTFUS and LASBOR were more active in areas of with higher water quality, whereas PERSUB was less active. NYCHUM did not respond to water quality degradation (Li & Kalcounis-Rueppell, 2018). It would be interesting to test the water quality of our study sites to see if this study translates to Wichita.

There could be several other factors influencing why we observed and detected fewer bats on McConnell Air Force Base. While there has been significant and continued study on White Nose Syndrome in the U.S impacting bat species, there was not much research on bats in urban areas before the introduction of WNS in 2006 (Deeley et al 2021). Thus, a gap in knowledge exists of how bats functioned in urban cities before the emergence of WNS. Many areas did not do have comprehensive surveys of their bat populations before white-nose syndrome struck in 2006, because it was not seen as a need until it was too late. Other factors that could potentially be affecting bat populations on MAFB could be the use of pesticides on base in residential areas, accidental chemical spills relating to the mission, human activity on base, light pollution from base activity, overall noise, and much more. We observed a weak positive correlation between daily average temperature and the number of bat passes, and of the environmental variables examined in this study, Maximum Temperature, Minimum Temperature, Precipitation, Wing Gust, Wind Speed, Cloud Cover, and Moon Phase, we found no other negative or positive correlations. Insectivorous bats have been shown to be influenced by the climate they live in, being more active in warmer, low-precipitation environments (Erickson 2022). Wichita experienced very little rainfall in the 2022 season (Condos 2023), and the temperatures were varied (Visual Crossing Corporation, 2023). This could explain the activity levels and their variations and differences. In order to thoroughly investigate this, individual temperatures and precipitation would have to be taken from each site to compare and analyze for differences or similarities.

The most common species we detected was the LASBOR, or the Eastern red bat, both at MAFB and the parks. Eastern Red bats occur mostly in eastern North America, including southeast Canada. They are fast-flying bats, being equipped to catch moths at night mainly. Female red bats give birth in summer, usually to twins, and this species is considered common (Taylor 2019). Roosting habits of bats are influenced by the diversity and number of roosts available (Kunz 1982). The preferred roosting sites of both male and female Eastern Red bats tend to be of large-diameter live hardwood trees, particularly hickory and oak as day roosts (Menzel et al., 1998). The habitat of the Wichita, KS area are in the Chautauqua Hills, which are known for their thick layers of sandstone and dense vegetation of oak and timber. Eastern Red bats seem to have a strong preference for oak trees for their day roosts, which one study showing that the tree species highly influence the selection of roost sites in Eastern Red bats, with oak trees being selected for 37% (Mager & Nelson, 2001).

Many previous authors have reported that the most important factors governing bat distribution are the availability of roosts, prey, and perhaps water (Barbour & Davis, 1969; Fu et al., 1987). These habitat components can be found in urban areas where large trees are preserved. Kenneth J. Mager and Thomas A. Nelson of the Department of Biological Sciences in Eastern Illinois University conducted a study in 2001 to investigate natural roost-site selection by Eastern Red bats and the results revealed that urban trees in the strongly farmed areas of the Midwest provide important habitats for red bats (Mager & Nelson 2001). Tree shade with dense canopies and open understories provide important roosting habitat for the red bats. Wooded parks, residential areas, and riparian corridors with shade trees that have dense canopies and open understories provide suitable roosts and are valuable when they are scattered among lawns and fields, which provide foraging habitat. This could explain the large number of Eastern Red bats being detected and as well as captured in the area. Eastern Red bat captures in the state of Illinois tends to increase during mid-June and peak in August (Hoffmeister, D. 1989). In the present study, red bat activity peaked in August. This could potentially be due to the Eastern Red bats beginning to migrate south, to central Florida, western Texas, southern New Mexico, and northern Mexico, for the winter months.

An interesting species detected at Couch Pond and Pawnee Prairie Park was the Tri-colored Bat (PERSUB), despite the habitat at Couch Pond appearing less than desirable. The Tri-colored bat is one of the smallest bats in North America and it has a wide range across the eastern and central United States and portions of southern Canada, Mexico, and Central America. It is important to note, that in 2022 the Tri-colored bat has been petitioned to be listed as an endangered species, making these findings even more important (U.S. Fish & Wildlife Service, 2022). During the spring, summer, and fall, Tri-colored bats are found in forested habitats where they roost in trees, primarily among the leaves (Blaise et al, 2021). Tri-colored bats have also been observed roosting during the summer in pine needles, eastern red cedar, in artificial roosts like barns, beneath porch roofs, bridges, concrete bunkers, and rarely within caves. Tri-colored bats are opportunistic feeders, meaning they can feed on a variety of insects including ground beetles, leafhoppers, mosquitos, midges, ants and moths (Kunz 1984). Tri-colored bats also showed a preference in their consumption of caddisflies suggesting they fed predominately over water (Feldhamer, Carter, & Whitaker 2009; Jones and Manning, 1989). This is interesting because caddisflies are known to be indicators of good water quality in their respective environments. With further analysis, it will be noteworthy to see which insects are readily available at Couch Pond and if this plays a role in the supposed abundance of Tri-colored bats in the area. The Couch Pond site has a large pond area where the Tri-colored bats could drink and forage, which is ideal for these short-distance migrators.

We were surprised by the lack of significant differences in the biomass between site types. We anticipated there to be more insect biomass at the parks, given the percentage of water in the parks compared to MAFB and presumably better habitat, since many insects are attracted to the moisture to prevent them from dying up (Mellanby, K. 1934). The greater insect biomass on base could also be from the lack of bat activity, foraging, and flying over, thus leading to an increase in insects because they are not being foraged upon as much as in the parks. Another thing to note is the type of insects that may occur on and off base. For this study, we just observed the overall insect biomass. With our samples, it is possible to take insects out of the samples for future analysis to see the difference in species diversity over the areas. With this, it would be interesting to see if one insect is being selected for more than another. This could give us insight into the types of insects bats are foraging on in Wichita. Potentially the insects being selected are more accessible or even more nutritious than others.

Of the environmental variables we examined, only temperature was slightly associated with the amount of bat activity in the area. There was no association with the moon phase or cloud cover, which other studies have found (Lang et. al, 2005; Helm et. al, 2016). Another possibility that would explain the variability in bat activity in the parks and MAFB is that bats are likely to be more attracted to where the food source is abundant. Maybe bats know where the insects are hatching/living and therefore are more likely to forage in that area than others. Investigating this would mean finding where and if the insects hatch more in the parks than MAFB. In 2022, Kansas was also experiencing record-breaking drought conditions in the west of the state (Condos 2023). Wichita was not an exception in being affected by this drought, with only 77.5 cm of precipitation in the 2022 season (Condos 2023).

With this study, we did run into certain limitations. For example, we did not catch as many bats as we would have hoped to confirm our acoustic findings. We did have a bat that was collected from an airstrike on base that was identified as NYCHUM, and we did catch two LASBOR at Pawnee Prairie, but we did not catch or see any of the other bat species we detected acoustically. We also had technical difficulties with the acoustic detectors at times, such as batteries dying unexpectedly, the settings not being where they needed to be, human interference, and even wildlife interference with birds pecking at the microphone. We also had to wait until well into the season to use our triple-high nets because they were back-ordered.

This study has several future directions, one being to utilize more triple-high nets when mist-netting; we have two net sets now. The amount of mist netting effort was sufficient, but perhaps the bats were flying over our nets, and the wind speed was also very variable, causing our nets to be seen by the bats. In the future, we could also analyze both the land cover and environmental variables using multi-model inference (Patrick & Stevens, 2016). With the acoustic data we gathered for both the 2021 and 2022 seasons is it possible to analyze the amount of feeding buzzes in each recording at each site using SonoBat Software for bat call analysis. With this analysis, we can determine whether the bats are actively foraging over the areas of study or just flying over. As mentioned before, we did not measure water quality or light intensity in this study, but these are factors worth looking into. We also would like to finish identifying the species of insects in the biomass samples to determine the diversity of certain species over the areas and times.

CONCLUSION

Through this research, we have added to the overall knowledge of the bat species in urban areas, mainly urban areas in Kansas. We found there to be a more significant amount of bat activity in the parks of Wichita compared to MAFB. With the continuation of urbanization, monitoring its effects on the bat populations in the Wichita area is more important than ever. Bats possess both extrinsic and intrinsic value in their roles as pollinators, indicators, pest control, and seed dispersers, and as incredibly unique and diverse mammals. With their position as valuable bioindicators in their ecosystems, monitoring these bats can help us document and get insight into the overall health of other members of their ecosystems in urban cities. With long-term acoustic surveys, mist net surveys, and insect biomass surveys, we have gained some insight into the bat species living at or passing through MAFB and the greater Wichita area.

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APPENDICES

Appendix A. *Configuration Settings for Acoustics*

1. Insert four D Batteries into the back, to do this, open the first cover but lifting the side lever. After this is done, you have to add a little pressure to the side where the indent is in order to release the back cover, insert the batteries as directed. *(Side note: under this front cover you will find the SM4's (Song Meter 4's) unique serial number.)*
2. After the batteries are inserted, you can now switch the SM4 on. To do this, locate the switch on the right side of the SM4 and switch this to "INT". This tells the SM4 to use "internal" power in order to turn on. *(If you had an external power source, such as a generator, etc., then you would switch the SM to "EXT", but since we will be using batteries, this will be our "off" switch.)*
3. The SM4 should then turn on, and you will see the **MAIN MENU**. Under the **MAIN MENU** there will be a list of options; **QUICK START, SETTINGS, SCHEDULE,** and **UTILTIES**. To navigate these options, press down on the blue down arrow. To select the option, press the middle button that says **ENTER/MENU**.
4. Select **QUICK START.**
5. After selecting **QUICK START**, go to the first option **RECORD**. This should be set to **SUNSET->SUNRISE**.
6. Go down to the second option. This also says **RECORD**. This should be set to **-30SET->+30RISE**
7. Go down to the third option. This also says **RECORD**, this should be set to record **ALWAYS.**
8. Go back to the **MAIN MENU** using the left arrow button.
9. Scroll down to the second option, **SETTINGS**.
10. In **SETTINGS**, you will find several options such as; **AUDIO**, **DATE AND TIME, LOCATION, SUNRISE/SUNSET TYPE, DELAY START, LED INDICATOR,** and **ADVANCED**.
11. Select the first option, **AUDIO**.
12. In **AUDIO**, the settings should be set to the following for recording *BATS*:
    1. **GAIN** – 12dB
    2. **16k HIGH FILTER** set to OFF
    3. **SAMPLE RATE** – 256kHz
    4. **MIN DURATION** – 1.5ms
    5. **MAX DURATION** – none
    6. **MIN TRIGGER FREQUENCY** – 16kHz
    7. **TRIGGER LEVEL** – 12dB
    8. **TRIGGER WINDOW** – 3.0s
    9. **MAX LENGTH** 00:15s
    10. **COMPRESSION** – none
13. Exit the **AUDIO** settings and return to the **SETTINGS** menu by clicking the back arrow.
14. On the **SETTINGS** menu, scroll down to the second option, **DATE AND TIME**.

15. In **DATE AND TIME**, the settings will vary to the exact date and time (*note this is military time) of deployment. The **RISE** and **SET** time will also vary depending on the **SUNSET TYPE**.
16. To change the date and time, use the arrow keypad to place the cursor over the year, month, day, and time. Using the up and down arrows to adjust the numbers corresponding with the desired date.
17. Use the back arrow to exit back to the **SETTINGS** menu.
18. Scroll down to the **LOCATION** option.
19. In this option, the options will include **PREFIX** (the name of the SM4), **LATITUDE**, **LONGITUDE**, and **TIMEZONE UTC**.
20. The **PREFIX** setting will not change unless there is an otherwise desired naming system.
21. The **LATITUDE** and **LONGITUDE** settings will vary upon location of deployment.
    1. SMOKEY VALLEY LAT and LONG – 38.51641N, 100.58960W
    2. MCCONNELL AIR FORCE BASE – 37.62669N, 097.26760W
22. The **TIMEZONE UTC** should be set to – 5:00
23. Use the back arrow to exit back to the **SETTINGS** menu.
24. Scroll down to the **SUNRISE/SUNSET TYPE** option.
25. The **SUNRISE/SUNSET TYPE** should be set to **SOLAR CIVIL**. Putting the **RISE** time to 05:53, and the **SET** time to 21:26.
26. Use the back arrow to exit back to the **SETTINGS** menu.
27. Scroll down to the **DELAY START** option.
28. This setting is used if the date of deployment is planned in advance and upon the date entered will commence the indicated schedule times that are programmed. For now, this setting is not enabled.
29. Use the back arrow to exit back to the **SETTINGS** menu.
30. Scroll down and select the **LED INDICATOR** option.
31. Select the **MODE** to be **ALWAYS.**
32. Use the back arrow to exit back to the **SETTINGS** menu.
33. Scroll down to the last option **ADVANCED**.
34. In **ADVANCED**, the **BATTERY CUTOFF** should be set to 00.0
35. Select the second option under **ADVANCED**, the **SCHEDULE MODE.**
36. Under **SCHEDULE MODE,** set the setting to record **DAILY**
37. Use the back arrow to exit back to the **ADVANCED** menu.
38. Use the back arrow to exit back to the **SETTINGS** menu.
39. Use the back arrow to exit back to the **MAIN MENU**.
40. Scroll down to the third option, **SCHEDULE.**
41. There will be three options, **EDIT SCHEDULE**, **IMPORT**, and **EXPORT**.
42. The **IMPORT** and **EXPORT** options are available if you have a schedule saved on an SD card and simply want to upload the schedule to another SM4.
43. Select **EDIT SCHEDULE.**
44. Under this option, the settings should be as follows:
    1. **START**: set -00:30 (indicating to <u>start</u> recording 30 minutes <u>after</u> sunset)
    2. **DUTY**: always
    3. **END**: rise +00:30 (indicating to <u>stop</u> recording 30 minutes <u>before</u> sunrise)

4. The 01/01 [ADD] is a setting option to add another schedule if it differs from the first schedule. For example, one night recording 30 min, and the next night recording 15 min before or after sunrise/sunset. But for now, we will only be using one schedule.

45. Use the back arrow to exit back to the **SCHEDULE** menu.
46. Use the back arrow to exit back to the **MAIN MENU**.
47. Scroll down to the final option, **UTILITIES.**
48. Under **UTILITIES,** the options are as follows: **TIME EXPANSION MODE** (these settings will be left as is), **EXPORT DIAGNOSTICS** (this is not a setting), **SET FACTORY DEFAULT, CALIBRATE MIC, FORMAT ALL CARDS,** and **FIRMWARE UPDATE.**
49. The only options that might be used are **CALIBRATE MIC, FORMAT ALL CARDS,** and **FIRMWARE UPDATE.**
50. **CALIBRATE MIC** is used when the mics are attached to the SM4 and have been set up and are about to be deployed. This allows the mics to be calibrated to the SM4 and to make sure the mics are in correct working order without any issue.
51. **FORMAT ALL CARDS** is used to allow the SD cards to also adjust to the SM4 and to make sure there are no issues with the cards or the reader in the SM4.
52. **Finally, the FIRMWARE UPDATE** option is used when the firmware needs an update. Wildlife Acoustics assists in notifying its customers when a new firmware is available to download.
53. To update the firmware on the SM4:
    1. You must first have an account on WA website to access the download of the firmware.
    2. Navigate to the downloads tab on WA's website under 'MY ACCOUNT'.
    3. Once there, follow the prompts:
        1. Download firmware file that corresponds to the recorder model (SM4).
        2. Copy the file to the SD card.
        3. Insert SD card to Slot A (top slot) on the SM4.
        4. Go to **UTILITIES**, then to **FIRMWARE UPDATE**.
        5. The file should automatically display. Select the correct version of the firmware by pressing **ENTER.**
        6. The prompts on the SM4 should indicate whether the firmware is downloaded and installed.

<u>Tips for Success</u>

*To see the status of the SM4, by clicking the 'i' button on the front of the SM4 that says 'Status Check', this will show you the details of the SM4, such as the date, the time, the battery level, the SD card status (such as how many files have been recorded thus far), and the internal temperature of the SM4.

*This can also be used to "wake up" the SM4 if it is in sleep mode and not actively on a schedule or currently recording.

*Before you deploy the SM4, literally as you are about to leave it to run its schedule, *make sure* to push the ‘Schedule Start’ button on the bottom on the front face. This will make sure that the schedule that is programmed, will commence when it is programmed to.

*To stop the schedule and to enter the menu setting and such, press the ‘Schedule Stop’ button that is red. This will stop the schedule, so be sure to start the schedule when you are ready to deploy.

*The LED indicator will let you know when the recording is in progress. It will blink when the schedule is initiated and in progress.

*A full D-Battery produces about 6.3-6.4 V of power. This can last several weeks and the SM4 is able to use as little battery as possible to conserve this power.

*Make sure to write down the serial number on the SM4 detector on the SD card as well as the slot it is correlated with, ‘Slot A’ or ‘Slot B’.

Appendix B. *Protocol for Manually Vetting*

First, Auto ID files

Organize by Detector and by dates recorded
Then separate into data folder and AutoID folder

2. 80% of confidence, unambiguous - accept

Open id.csv
Column “S” - Match Ratio
Sort from “A to Z”
Inspect Match Ratio and Auto ID
Highlight species with above 80% match ratio. Also, highlighting the unusual species in a different color (to look at later.)

3. Manually vet unusual species that ID over 80% confidence

Highlighted unusual species in the previous step manual vetting process:

- It must be at least three seconds
- Frequency (kilohertz) of the call - check Fmin and Fmax
- The shape of the call
- The pattern across the sequence of the call
- Power Distribution within a call
- Geography of the species distribution

When in doubt - group the calls or go with a secondary ID

- ***See the Manual in GoogleDrive***

Unusual species include: MYOGRI, NYCMAC, CORTO, MYOCIL, MYOVEL, MYOSEP, ANTPAL, MYOYUM, MYOLUC

Other resources for Fmin:
https://go.gale.com/ps/i.do?p=AONE&u=googlescholar&id=GALE|A331169841&v=2.1&it=r&sid=AONE&asid=fd0c939f

4. Ambiguous species below 20-80% confidence - group together

See the species list below

Other notes:
Species Couplet Recommendation from NABat:

Table 4. Species couplet, group, and frequency class labels recommended for labelling files with recordings of species that are acoustically similar and can occur sympatrically (adapted from Loeb and others, 2015). Also included are labels for files without bat recordings (NOTBAT) and for files that contain a bat pulse, but no grouping or user-defined category applies. While this is not an exhaustive list, we recommend you try to use these labels for consistency, but document any additional user-defined categories you use and submit to the North American Bat Monitoring Program (NABat). For consistency, always place the species names making up a couplet label in alphabetical order.

Common name	Scientific name	Label
Pallid bat, Big brown bat	*Antrozous pallidus, Eptesicus fuscus*	ANPAEPFU
Big brown bat, Silver-haired bat	*Eptesicus fuscus, Lasionycteris noctivagans*	EPFULANO
Western red bat, Canyon bat	*Lasiurus blossevillii, Parastrellus hesperus*	LABLPAHE
Eastern red bat, Tri-colored bat	*Lasiurus borealis, Perimyotis subflavus*	LABOPESU
Eastern red bat, Little brown bat	*Lasiurus borealis, Myotis lucifugus*	LABOMYLU
Eastern red bat, Seminole bat	*Lasiurus borealis, Lasiurus seminolus*	LABOLASE
Silver-haired bat, Mexican free-tailed bat	*Lasiurus noctivagans, Tadarida brasiliensis*	LANOTABR
Hoary bat, Mexican free-tailed bat	*Lasiurus cinereus, Tadarida brasiliensis*	LACITABR
Long-eared or Keen's myotis, and Northern bat	*Myotis evotis, Myotis keenii, Myotis septentrionalis*	LEMY
California bat, Yuma bat	*Myotis californicus, Myotis yumanensis*	MYCAMYYU
Not a bat		NOTBAT
Bat, but no grouping or user-defined category applies		NoID
	User-defined categories	
User-defined frequency class	*Various species with pulses that have a minimum frequency of approximately 15–25 kHz.*	25k
User-defined frequency class	*Various species with pulses that have a minimum frequency in the range of 35–45 kHz.*	40k
User-defined frequency class	*Various species of Myotis with pulses that have a minimum frequency in the range of 35–40 kHz.*	40kMyo
User-defined frequency class	*Various species with pulses having a minimum frequency lower than ~30 kHz.*	LowF
User-defined frequency class	*Various species with pulses having a minimum frequency higher than ~30 kHz.*	HighF

Source: Reichert, B., and Lausen, C., Loeb, S., Weller, T., Allen, R., Britzke, E., Hohoff, T., Siemers, J., Burkholder, B., Herzog, C., and Verant, M., 2018, A guide to processing bat acoustic data for the North American Bat Monitoring Program (NABat): U.S. Geological Survey Open-File Report 2018–1068, 33 p., ISSN: 2331-1258
https://pubs.usgs.gov/of/2018/1068/ofr20181068.pdf

5. Species below 20% confidence/noise - don't analyze

Appendix C: *Landcover Class Definitions*

Class definitions

Water
Areas where water was predominantly present throughout the year; may not cover areas with sporadic or ephemeral water; contains little to no sparse vegetation, no rock outcrop nor built up features like docks; examples: rivers, ponds, lakes, oceans, flooded salt plains.

Trees
Any significant clustering of tall (~15 feet or higher) dense vegetation, typically with a closed or dense canopy; examples: wooded vegetation, clusters of dense tall vegetation within savannas, plantations, swamp or mangroves (dense/tall vegetation with ephemeral water or canopy too thick to detect water underneath).

Flooded vegetation
Areas of any type of vegetation with obvious intermixing of water throughout a majority of the year; seasonally flooded area that is a mix of grass/shrub/trees/bare ground; examples: flooded mangroves, emergent vegetation, rice paddies and other heavily irrigated and inundated agriculture.

Crops
Human planted/plotted cereals, grasses, and crops not at tree height; examples: corn, wheat, soy, fallow plots of structured land.

Built Area
Human made structures; major road and rail networks; large homogenous impervious surfaces including parking structures, office buildings and residential housing; examples: houses, dense villages / towns / cities, paved roads, asphalt.

Bare ground
Areas of rock or soil with very sparse to no vegetation for the entire year; large areas of sand and deserts with no to little vegetation; examples: exposed rock or soil, desert and sand dunes, dry salt flats/pans, dried lake beds, mines.

Snow/Ice
Large homogenous areas of permanent snow or ice, typically only in mountain areas or highest latitudes; examples: glaciers, permanent snowpack, snow fields.

Clouds
No land cover information due to persistent cloud cover.

Rangeland
Open areas covered in homogenous grasses with little to no taller vegetation; wild cereals and grasses with no obvious human plotting (i.e., not a plotted field); examples: natural meadows and fields with sparse to no tree cover, open savanna with few to no trees, parks/golf courses/lawns,

pastures. Mix of small clusters of plants or single plants dispersed on a landscape that shows exposed soil or rock; scrub-filled clearings within dense forests that are clearly not taller than trees; examples: moderate to sparse cover of bushes, shrubs and tufts of grass, savannas with very sparse grasses, trees or other plants.

Appendix D. *Site-specific species activity*

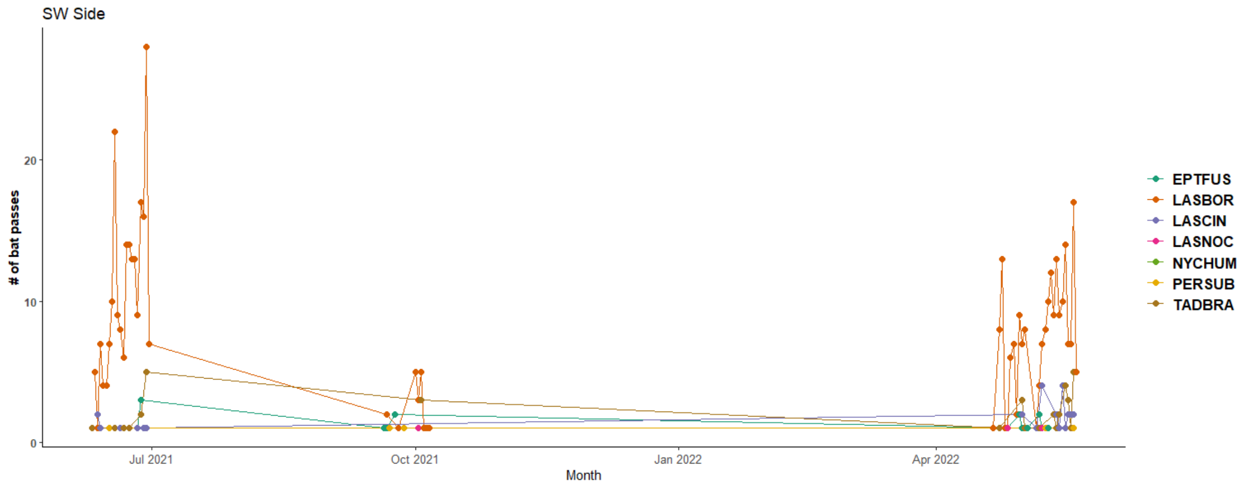

Figure 9. The graph above shows the number of bat passes at the "South West Side" site on MAFB. This site included MAFB 9, 16, 22, and 40.

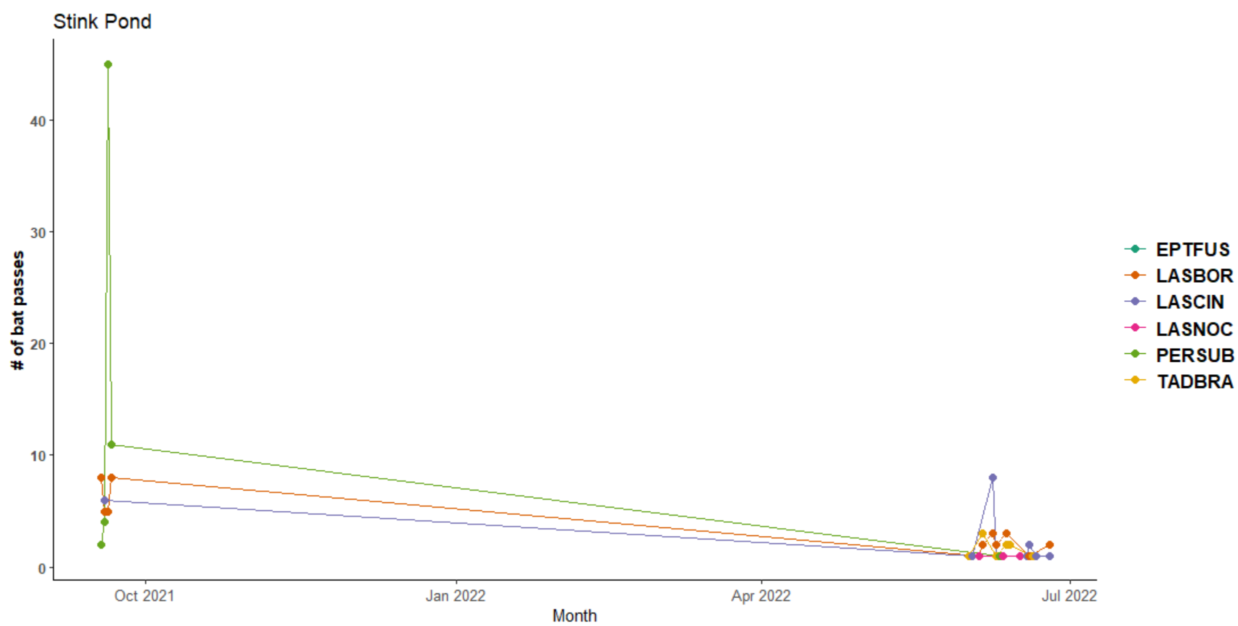

Figure 10. The graph above shows the number of bat passes at the "Stink Pond" site on MAFB. This site included MAFB 10, 19, 23, and 25.

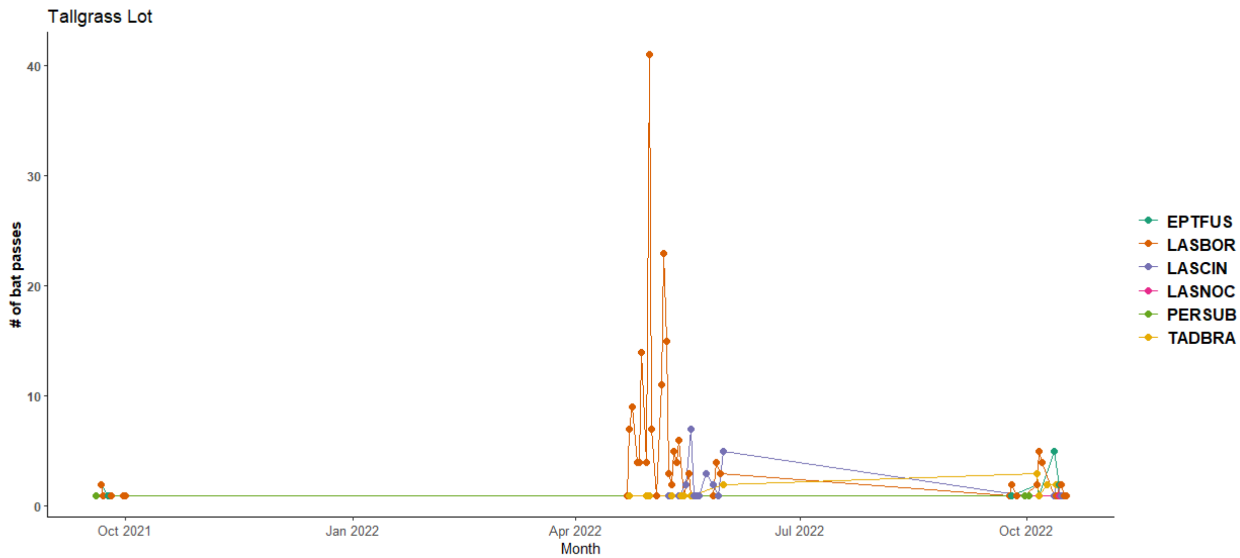

Figure 11. The graph above shows the number of bat passes at the “Tallgrass Lot” site on MAFB. This site included MAFB 18, 24, 41.

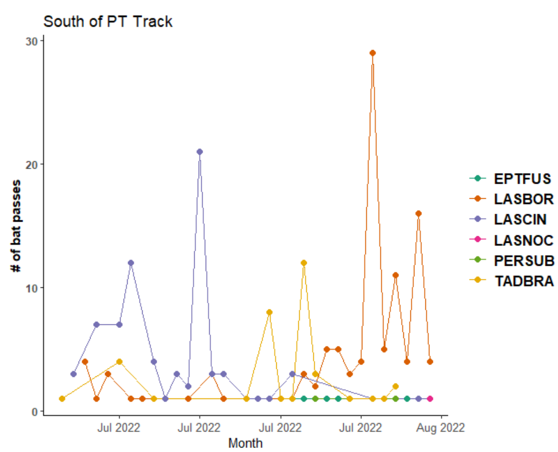

Figure 12. The graph above shows the number of bat passes at the “South of PT Track” site on MAFB. This site included MAFB 11 and 29.

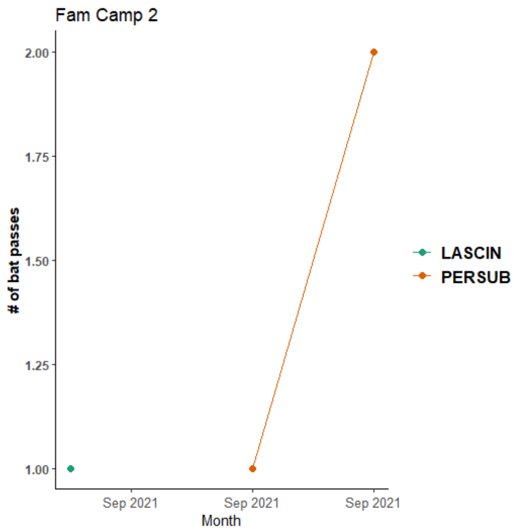

Figure 13. The graph above shows the number of bat passes at the "Family Camp 2" site on MAFB. This site included MAFB 6, 13, 20.

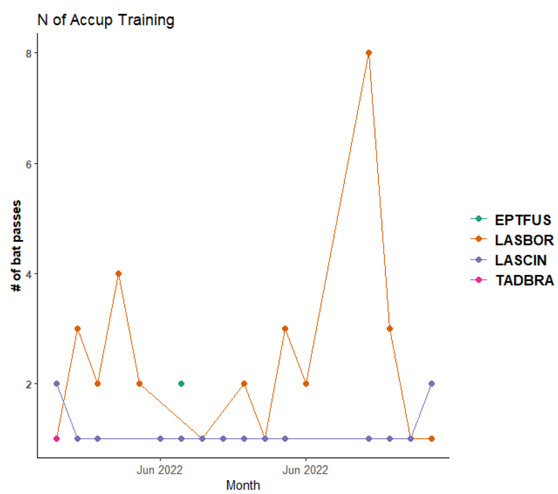

Figure 14. The graph above shows the number of bat passes at the "North of the Accup Training" site on MAFB. This site included MAFB 8 and 28.

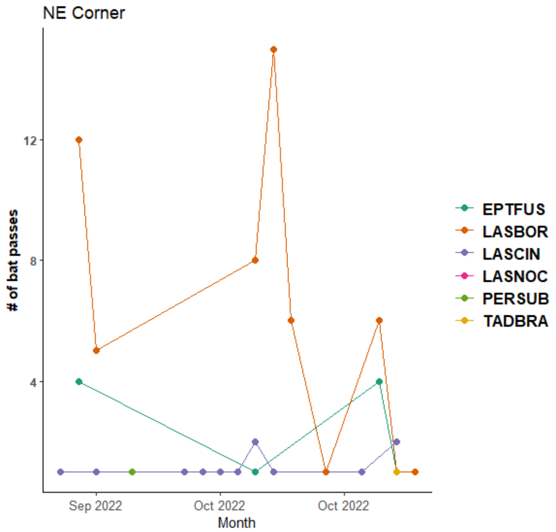

Figure 15. The graph above shows the number of bat passes at the "North East Corner" site on MAFB. This site included MAFB 33, 43, 44.

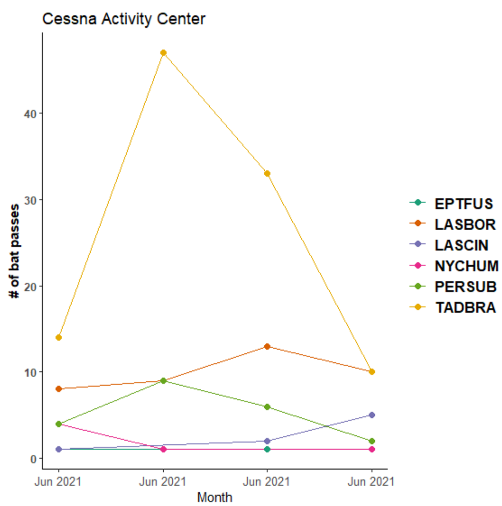

Figure 16. The graph above shows the number of bat passes near the "Cessna Activity Center" site on MAFB. This site included MAFB 1.

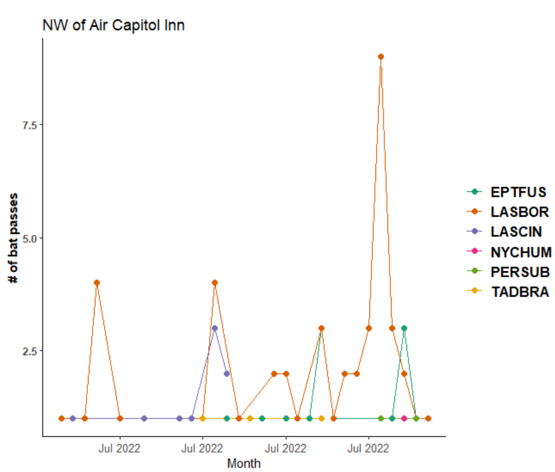

Figure 17. The graph above shows the number of bat passes at the "North West of Air Capitol Inn" site on MAFB. This site included MAFB 17 and 30.

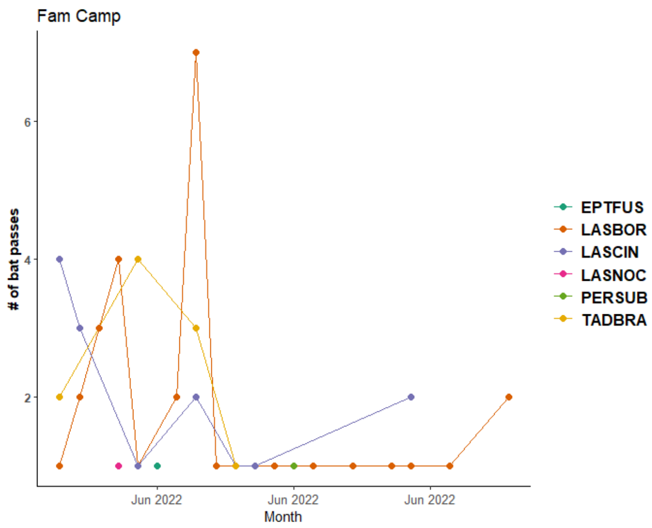

Figure 18. The graph above shows the number of bat passes at the "Family Camp" site on MAFB. This site included MAFB 12 and 31.

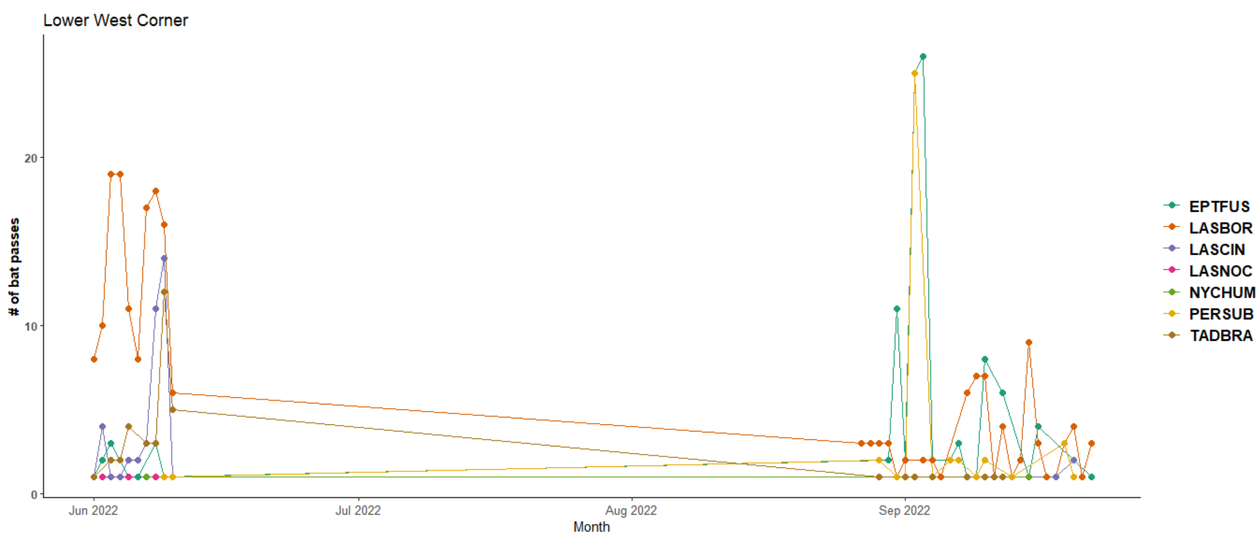

Figure 19. The graph above shows the number of bat passes at the "Lower West Corner" site on MAFB. This site included MAFB 3, 5, 27, 39.

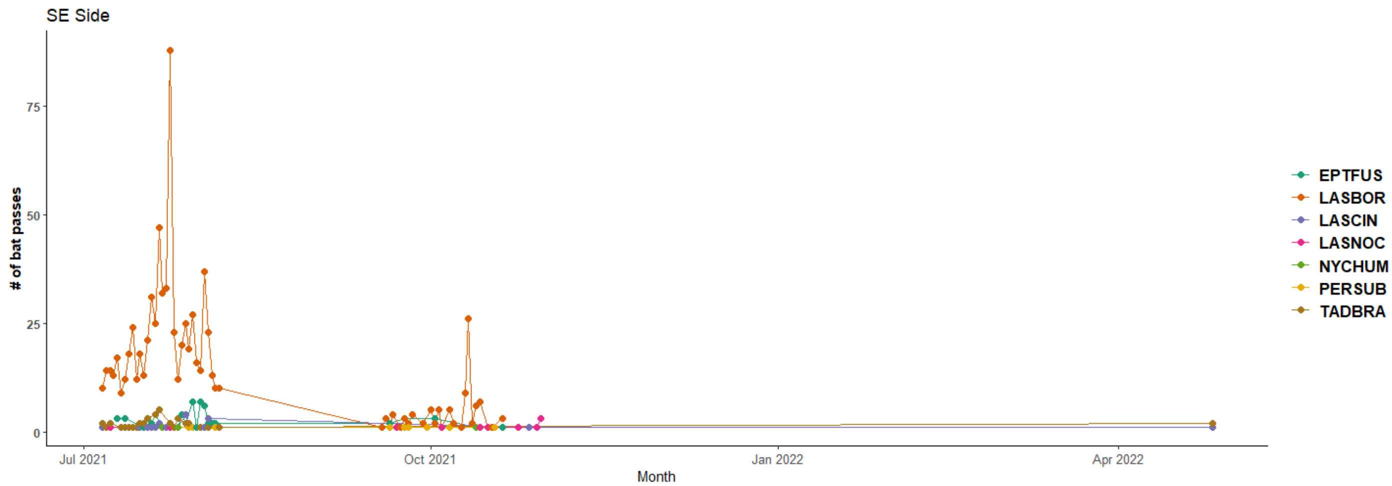

Figure 20. The graph above shows the number of bat passes at the "South East Side" site on MAFB. This site included MAFB 9, 16, 22, 40.

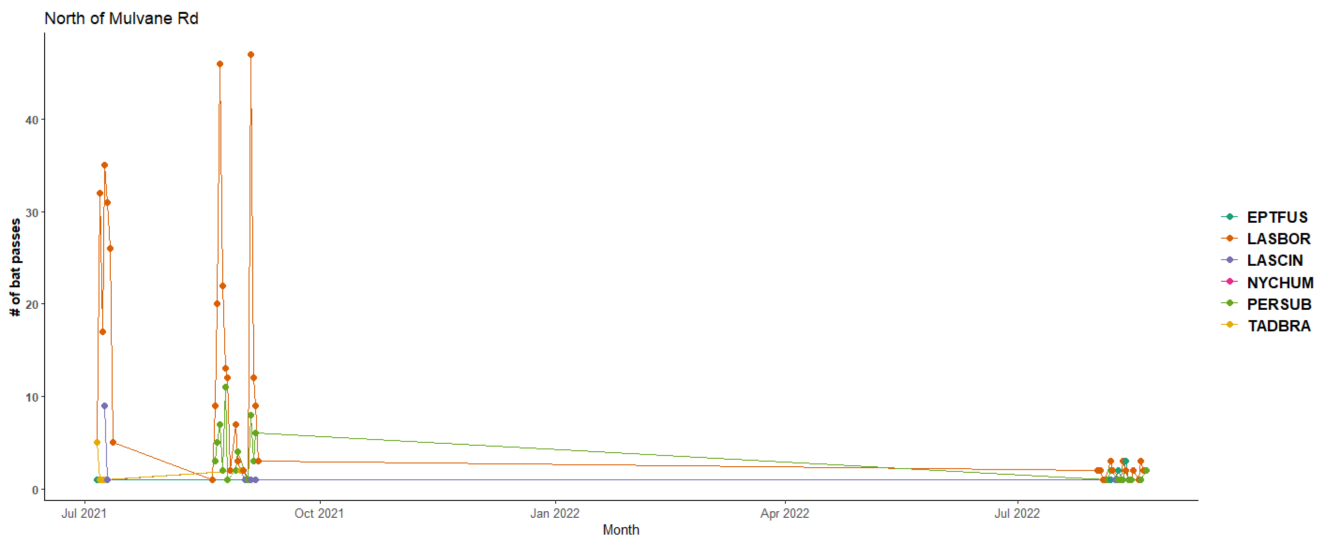

Figure 21. The graph above shows the number of bat passes at the "North of Mulvane Road" site on MAFB. This site included MAFB 7 and 35.

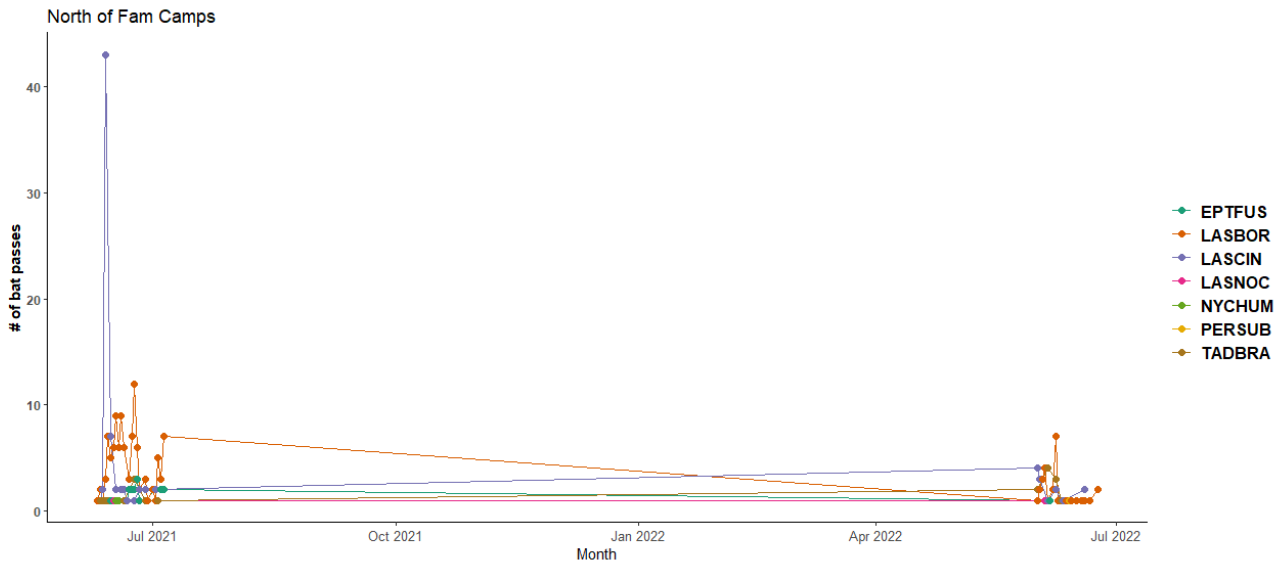

Figure 22. The graph above shows the number of bat passes at the “North of the Family Camp” site on MAFB. This site included MAFB 2 and 26.

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