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Acoustic Surveys of Bats at Northern Great Plains Parks and Preliminary Results from 2014-16

Natural Resource Report NPS/NGPN/NRR—2018/1588

ON THE COVER
Photograph of Acoustic Monitoring Equipment at Dusk
Photograph by NPS /DAN LICHT

Acoustic Surveys of Bats at Northern Great Plains Parks and Preliminary Results from 2014-16

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Executive Summary

From 2014-16, the Northern Great Plains Inventory & Monitoring Network (Network)—in collaboration with the Midwest Regional Biologist—used acoustic methods to monitor bat populations at 12 Network parks. Six parks were monitored using the nascent North American Bat Monitoring Program (NABat) framework. Six other parks did not meet *a priori* criteria for inclusion in NABat so they were monitored using similar methods, but a non-systematic sampling frame.

Fifty-five NABat stations were established along with 62 non-NABat stations. Stations were typically monitored for 4-7 nights each year using equipment that records the echolocation calls of bats. Fourteen mobile survey routes (24-47 km, 14-28 miles) were also established, one for each NABat sampling cell. Two night-time surveys were conducted per route each year. The recordings were analyzed using specialized software that uses probabilistic statistics to classify the species that made the call. A total of 1,573 nights and 847,321 bat recordings were analyzed from the stationary points. A total of 70 driving surveys were conducted, collecting another 2,439 recordings of bats.

A review of the software output indicates that 14 bat species are present in the Network (Figure ES-1). There were substantial differences in bat communities between parks, an apparent consequence of the variety of habitats in the Network and the vast size of the region as both "eastern" species and "western" species were detected. The northern long-eared myotis is the only federally-listed species in the Network. It was confirmed in several parks, but was not common in any parks.

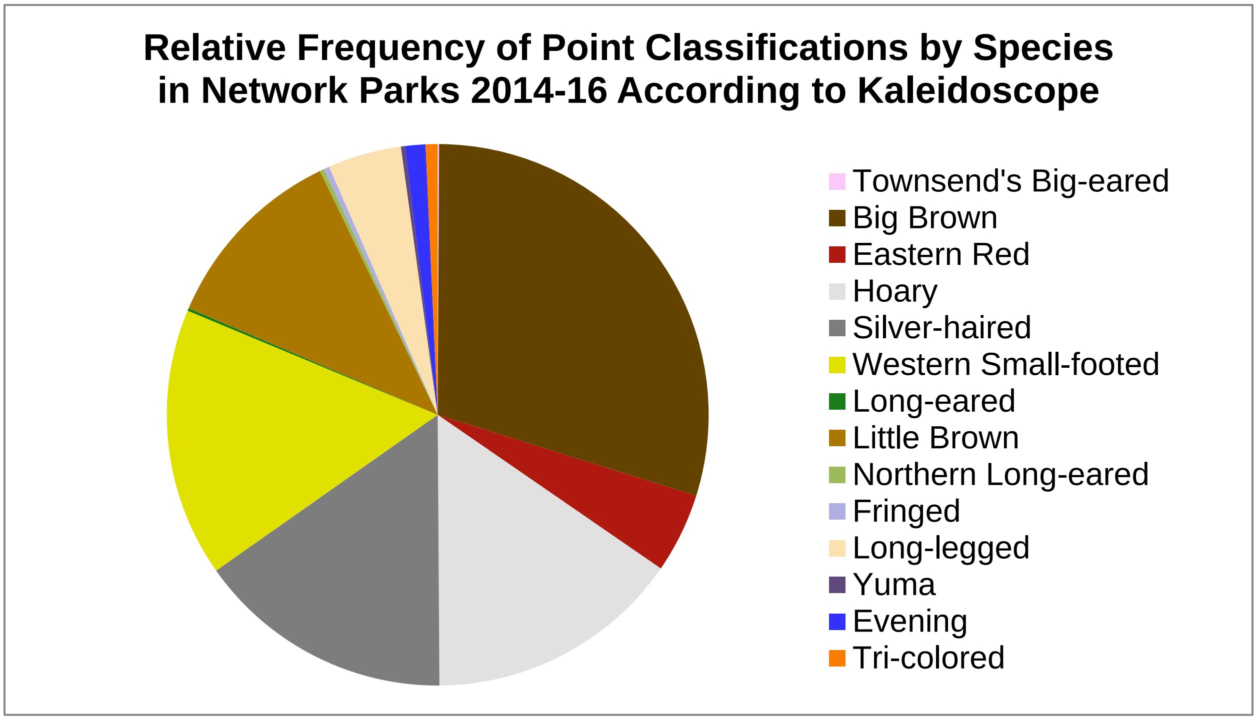

Figure ES-1. Relative frequency of all classifications from point stations across the Network (weighted by park sample size) from 2014-16 according to Kaleidoscope.

A primary purpose of the project is to monitor changes in bat abundance over time. Across the 29 NABat stationary points with usable data from all three years the average number of nightly bat detections at a station was 746 in 2014, 617 in 2015, and 865 in 2016 (unweighted by the length of the deployments; see Figure ES-2 for average number of nightly bat detections at each NABat station). At the eight mobile routes surveyed in all years the average number of detections per route was 41 in 2014, 34 in 2015, and 33 in 2016. In neither case were the Network-wide between-year differences statistically significant. However, there were some substantial differences between years at some stations and some parks. For example, at the Missouri NRR there was a large drop in the rate of detections from 2014 to 2015, but detections rebounded in 2016, highlighting the importance of monitoring for several years before assessing long-term trends in bat populations.

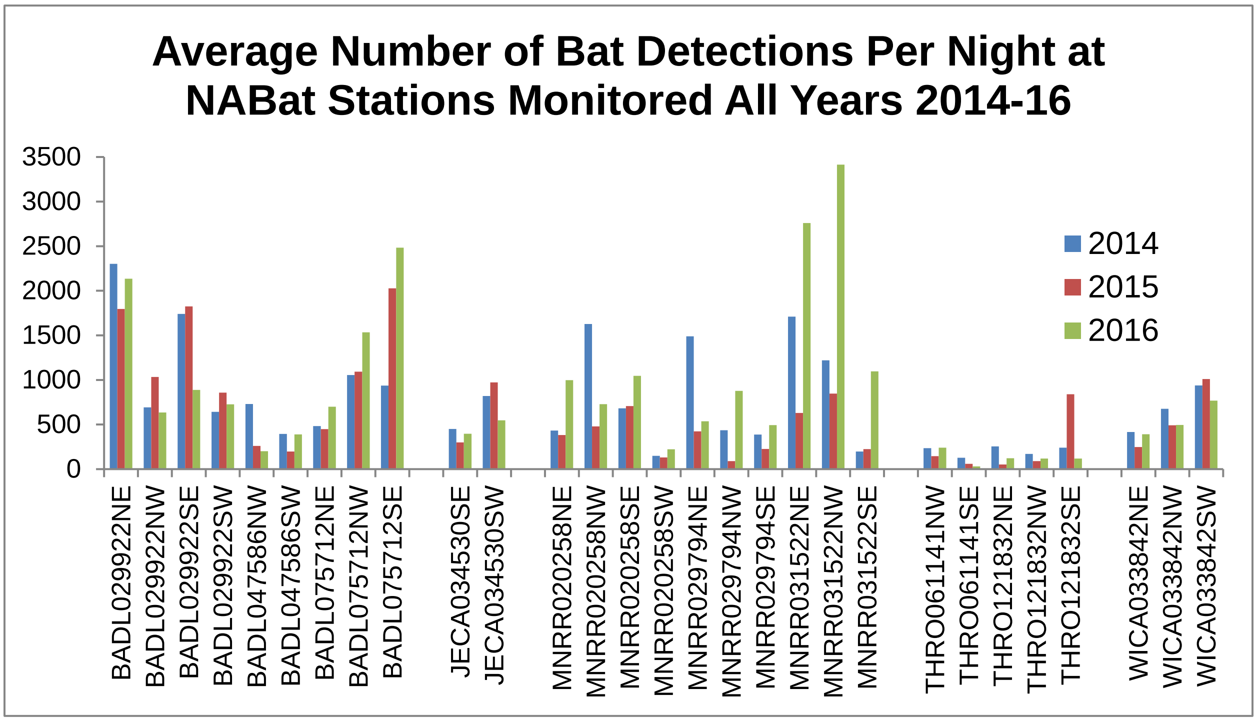

Figure ES-2. Average number of bats detected per night at NABat stations monitored all years 2014-16 according to Kaleidoscope.

Park managers can take actions to conserve bats. The highest rates of detections were typically from stations near water. In forested areas decadent trees and other woody material should be protected, specifically, trees with exfoliating bark and cavities as these provide roosting habitat for many bat species. Fort Laramie successfully established a bat house as mitigation for keeping bats out of historic structures. Education programs are important in garnering support for bat conservation.

In late 2015 the Network established an agreement with the University of Wyoming to monitor bats at the six NABat parks from 2016-20. The Midwest Regional Biologist will assist the monitoring and will attempt to monitor the non-NABat parks as well. Hopefully, bat monitoring will become a permanent component of the Network monitoring program.

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Maps throughout this report were created using ArcGIS® software by Esri[1].

[1] Mention of product names in this report does not constitute endorsement.

Introduction

The conservation of bats is a high priority within the conservation community and the National Park Service (NPS). North American bat populations appear to be in decline (Ingersoll et al. 2013), probably due to a myriad of reasons including habitat loss, pesticides, exotic species, and wind energy development (Arnett et al. 2008, Hayes 2013). However, a new and perhaps more serious threat is the recent occurrence white-nosed syndrome (WNS), an epizootic disease caused by the fungus *Pseudogymnoascus destructans* (formerly Gymnoascus destructans: Turner et al. 2011, Langwig et al. 2012). The fungus appears to have arrived in North America from Europe. New York State, the disease has spread through eastern North America and has been detected as far west as eastern Nebraska. An isolated occurrence has also been reported from the Washington State. The disease is believed to have killed about seven millions bats as of 2015 and resulted in a 90% or greater regional decline of some species. The northern long-eared bat has been listed as a threatened species under the federal Endangered Species Act (ESA) and other bat species have been petitioned for listing under the ESA.

Due the imperiled status of bats, the Washington Office (WASO) of the NPS has made funds (known as WNS funds) available to parks for protecting bat habitat, educating the public about WNS and the ecological value of bats, and inventorying and monitoring bat populations. In fiscal year (FY) 2014 the Northern Great Plains Inventory & Monitoring Program (I&M Program: see Fancy and Bennetts 2012), on behalf of the Northern Great Plains Network (Network) of parks (**Figure 1**) applied for and received $25,000 to conduct bat inventories and monitoring using acoustic monitoring methods (for information on acoustic methods see Brigham et al. 2004, Loeb et al. 2015). The Network used the FY14 funds to acquire acoustic bat recorders and associated equipment and supplies. In addition, Jewel Cave bought and donated bat recorders to the Network as they could not expend all of their FY14 funds on in-house projects. Wind Cave also loaned recorders to the Network for the 2014 field season. The NPS Midwest Regional Office (MWRO) Wildlife Biologist designed a Network-wide monitoring program and conducted monitoring at five parks in the summer of 2014. The monitoring followed the draft North American Bat (NABat) monitoring protocol (subsequently finalized in 2015: see Loeb et al. 2015). Late in FY14 the Network received an additional $35,000 from Cuyahoga Valley National Park as that park could not expend all of their FY14 funds. Those funds were used to acquire additional bat recorders and other equipment and supplies. By the end of FY15 the Network had an inventory of 34 recorders for stationary point monitoring and two recorders for mobile surveys.

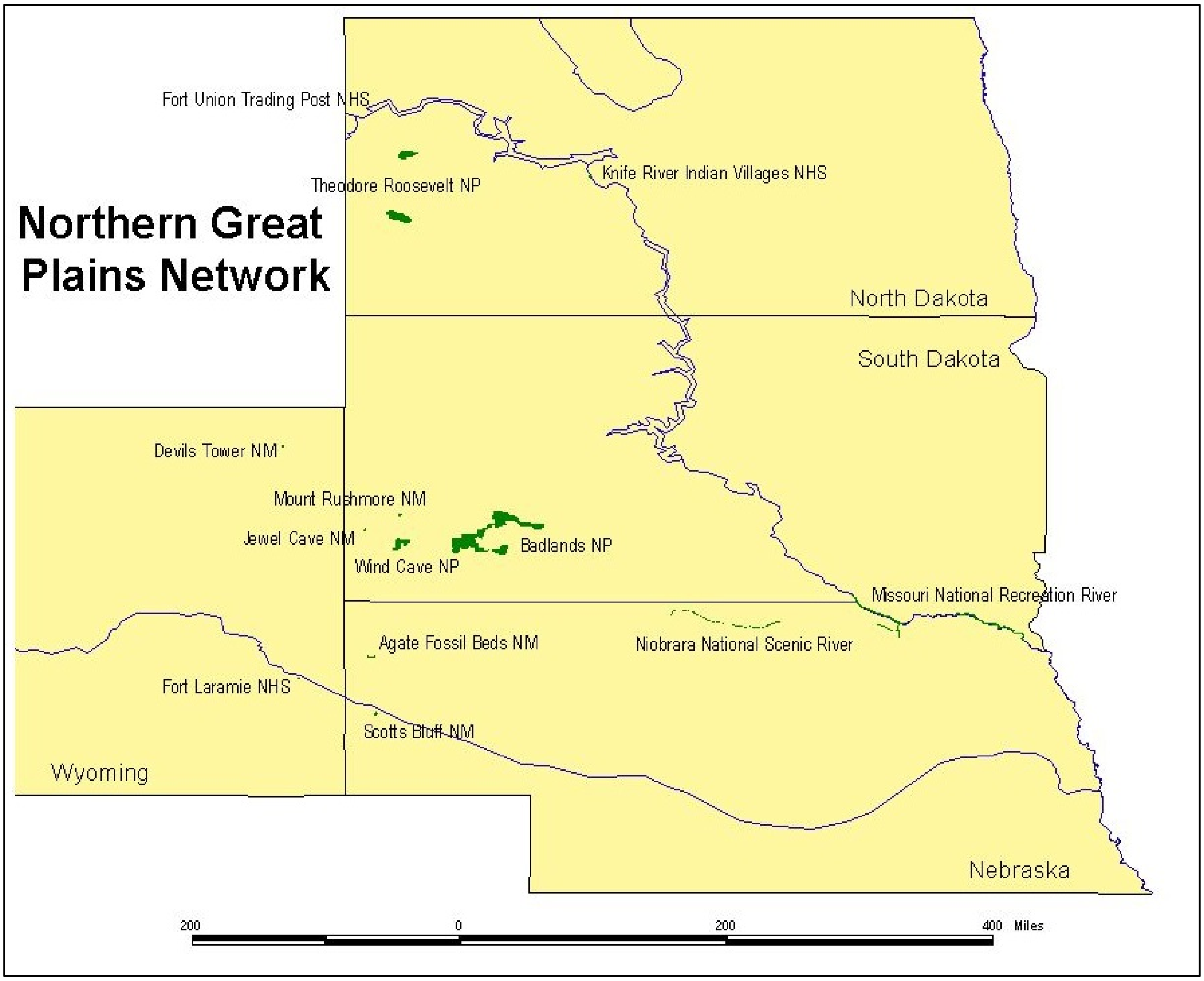

Figure 1. Map of National Park Service units in the Northern Great Plains Network.

In FY15, the Network received $140,100 from WASO for continuing and expanding bat inventories and monitoring at Northern Great Plains parks. In addition to purchasing more ancillary equipment and supplies, the Network hired a biological technician to assist with the 2015 field work. The technician and the MWRO Wildlife Biologist conducted bat monitoring at twelve Network parks that summer, using the NABat framework when appropriate and a non-NABat design where it was not. Late in FY15, the Network transferred $169,772 to the Wyoming Natural Diversity Database (WYNDD), a research unit of the University of Wyoming, to conduct acoustic monitoring at NABat cells from 2016-2020. The funds were comprised of the balance of the FY15 funds received from WASO ($115,901), an additional $38,871 from the Network I&M Program, and $15,000 transferred from Buffalo National River as that park could not expend all of their FY15 WNS funds. In 2016, a technician from the WYNDD deployed recorders and conducted mobile surveys at six Network parks. The MWRO Wildlife Biologist deployed units at the other parks. An additional $25,000 in WNS funds were received from WASO.

This report has two objectives: 1) to summarize and present the results from the 2014-16 monitoring and 2) to document the methods used. The results are presented with an understanding that species identification using acoustic methods is probabilistic. Bat calls can be difficult to distinguish, by both automated computer software and by manual review (Brigham et al. 2004, Corcoran 2007, Jennings et al. 2008, Britzke et al. 2013). As a result, exact numbers are rarely given, especially at the species level. Rather, species-level information is reported graphically. However, species identification of acoustic calls continues to be refined. Future software will likely be more accurate in terms of species classification and hence, the 2014-16 data presented here could be reanalyzed and re-reported. In other words, the information reported here should be viewed as preliminary and is subject to refinement and revision.

Methods

Bats were surveyed using acoustic monitoring methods (see Brigham et al. 2004, Loeb et al. 2015). Acoustic monitoring consists of using equipment that detects and records the ultra-sonic calls that bats emit for echolocation. The recordings can be analyzed manually by people looking at a spectrogram of the call sequence (**Figure 2**) or auto-analyzed by software using sophisticated algorithms. By comparing call characteristics (e.g., lowest frequency of a call) to a library of calls made by known bat species a probabilistic identification can be made. Although the method has limitations (e.g., some species have similar calls), it is widely used for bat monitoring and is one of the foundations for the nascent continent-wide NABat monitoring program (Loeb et al. 2015).

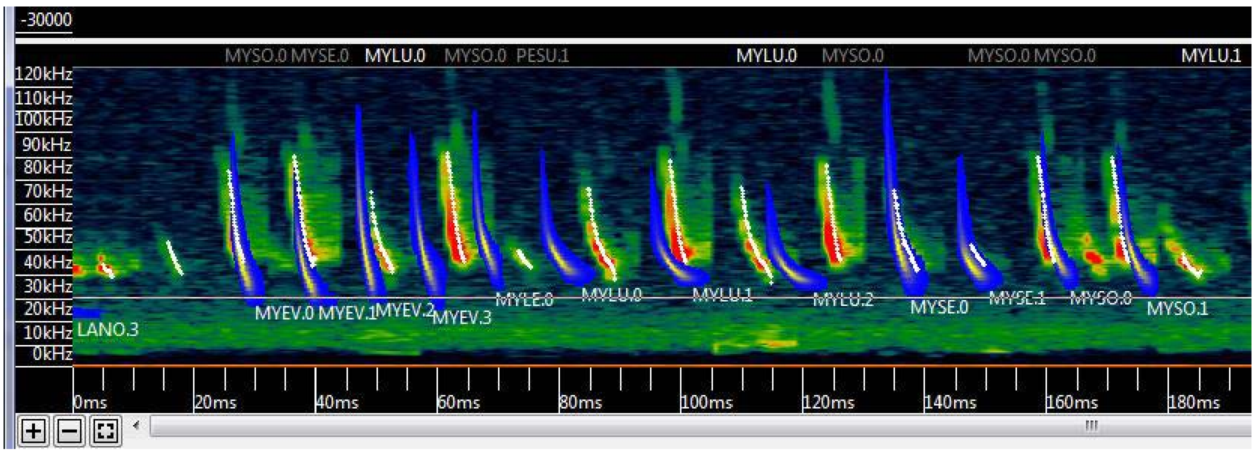

Figure 2. Spectrogram of a bat call. The red/yellow pulses are the recorded bat call. The blue pulses are from a call known to be made by a little brown bat (MYLU).

Equipment

Over 2014-15 the Network acquired 34 Wildlife Acoustics SM3Bat bat recorders (**Figure 3**). The units were used for conducting the stationary point surveys. The recorders were connected to Wildlife Acoustics SM3-U1 ultrasonic microphones by 3-m long Wildlife Acoustic cables. The waterproof recorders were situated on or near the ground with the microphone placed about 2.5 m above the ground at the end of a tripod-supported pole (**Figure 4**). Although the microphones were omni-directional, they were consistently affixed to the pole so they were horizontal (to minimize damage from rain) and pointing north (starting in 2015). Although some investigators enclose microphones in weatherproofing (see Loeb et al. 2015) the Network did not do that in 2014 due to time limitations; to maintain consistency over time weatherproofing was not used in subsequent years either. Configuration settings were constant between all stationary deployments except for the filename prefix, latitude and longitude, date, time, and coordinated universal time (UTC) settings which were customized for each site. Other configuration settings e.g., the decibel and frequency level that triggered recordings, were consistent with the recommendations in NABat (Loeb et al. 2015). The recorders were configured using the Wildlife Acoustics SM3 Configurator software. The SM3Bat configuration settings used in 2014-16 are listed in **Table 1**.

Figure 3. A Wildlife Acoustics SM3Bat recorder and SM3-U1 microphone used for monitoring bats at stationary points. Note the battery compartment on the left side and the memory card and antenna ports on the right side. (NPS)

Figure 4. A stationary point monitoring deployment (BADL075712SW). The detector is on the ground. (NPS /DAN LICHT)

Table 1. Configuration settings for bat recorders used in this study.

Configuration Parameter	SM3Bat (Point Surveys)	EM3+ (Road Surveys)
Filename Prefix	PPPPXXXXXXQQ[1]	PPPPXXXXXXRD[1]
High Pass Filter	16 kHz	–
Gain	12.0 dB	–
Sample Rate	256 kHz	256 kHz
Recording Format	WAV	WAV
Channels	Channel 0 only[2]	na
Frequency Minimum	16 kHz	12 kHz
Frequency Maximum	192 kHz	–
Duration Minimum	1.5 ms	–
Duration Maximum	50. ms	–
Trigger Level	12 dB	18 dB
Trigger Window	2.0 s	–
Trigger Maximum	5.0 s	–
Turn On	15 minutes before solar sunset	–
Turn Off	15 minutes after solar sunrise	–
Voltage Cutoff	0.0 (i.e., disabled)	–
Firmware	1.2.5 in 2014 1.2.7 in most of 2015	1.1.1 in 2014 1.2.7 in 2015

[1] PPPP = park alpha code, XXXXXX = NABat GRTS ID number, QQ = quadrant (e.g., SE) or RD if road survey

[2] In 2014 some units most units were programmed in “Auto” to automatically detect active channel.

Each NABat cell had a mobile survey route associated with it. For conducting road surveys Wildlife Acoustic EM3+ recorders were used in combination with a Wildlife Acoustics SMX-UT microphone. The EM3+ recorders used the default settings except for customizing the filename prefix for the route (**Table 1**). In contrast to the omni-directional microphone system used at the stationary points, the mobile microphones were directional. This was done by attaching a Wildlife Acoustics horn to the microphone. The horn theoretically minimized road and vehicle noise. The microphone/horn assembly was embedded in a foam-lined container and the assembly placed on the roof of a vehicle pointing skyward (**Figure 5** and **Figure 6**). A Wildlife Acoustics GPS unit with a magnetic back was also placed on the roof of the vehicle and attached by cable to the EM3+ recorders inside the vehicle, thereby recording spatial coordinates every time a recording was made (this would also provide evidence that the route was followed properly, assuming recordings were regularly made). In 2015-16 the mobile surveys were further improved by mounting a Garmin nuvi66 LM navigation system inside the vehicle. The device had the transect route pre-programmed into memory, thereby greatly reducing the complexity and safety risks of driving the often poorly-marked roads at night while also monitoring the bat recording equipment. The primary vehicle used for the surveys was a Ford Escape, although a Ford Explorer and a Chevrolet HRR were used in a few instances.

Figure 5. Vehicle used for mobile surveys. Note the microphone on the roof of the vehicle. (NPS /DAN LICHT)

Figure 6. Equipment used in mobile surveys. (NPS/ DAN LICHT)

The Network also acquired two Wildlife Acoustics Echo Meter Touch bat detector modules. These devices attach to the "lighting" port of Apple iPhones, iPads, and iPods. With the proper software the devices allow observers to detect, identify, and see a spectrogram of a bat's echolocation call in real time. The devices were tested in the field. Although they have limitations for field work (e.g., they are omnidirectional so not suitable for mobile surveys), they have enormous capability for education and outreach programs. The Network used the system for interpretive programs at Agate Fossil Beds NM and Fort Laramie NHS in 2016 and hopes to make more use in future years.

NABat Monitoring

In early FY14 the Network chose to use the nascent NABat monitoring protocol to the extent possible. NABat recommends collecting acoustic data using a combination of stationary points and mobile road surveys. The stationary points can efficiently survey long deployments and are effective at monitoring species diversity and distribution across the landscape. Conversely, the road surveys are more effective at monitoring abundance as they are less prone to multiple flyovers by the same bat under the assumption that a flying bat cannot keep pace with the vehicle.

The NABat monitoring program developed an ordered grid of 10x10 km (100 km^2) cells that overlaid North America (Loeb et al. 2015). The Network drew in order from the master sample a subset of cells in which all four quadrants of the cell were at least partially located within a Network park's administrative boundary (**Figure 7**). The South Unit of Badlands National Park was excluded from the draw due to the uncertain management future for that unit. The Missouri National Recreation River and the Niobrara National Scenic River were included in the draw even though relatively little public land exists within the park administrative boundaries; it was determined that the parks should be able to work with landowners and partners within the boundaries to conduct the surveys. The selection criteria resulted in 15 cells being drawn; they came from 6 of the 13 parks in the Network (**Table 2**). As expected, the cells came from larger parks with the exception of a cell that included Jewel Cave National Monument. NABat cell #098188 landed within the Badlands Wilderness in the North Unit of the park. There are no roads within the cell and access to the cell is difficult so that cell was not monitored in 2014-16. Fourteen cells happened to be the same number of cells the Network could logistically monitor in a summer so the order of the cells had no bearing on inclusion.

Stationary Points

The NABat protocol recommends conducting acoustic monitoring at a minimum of four stationary points within a cell, preferably from a station in each of four quadrants. Within the quadrants the location of the survey stations is discretionary, with the NABat guidance recommending establishing monitoring stations at sites with a high likelihood of bat activity (e.g., near surface water); yet the protocol also recommends surveying a variety of habitat types if a diversity of bat species is anticipated. The protocol discourages placing recorders in areas with high clutter (e.g., dense forest) as those sites tend to record poor-quality calls that make species identification difficult. Stationary points were established using that guidance (e.g., **Figure 7**). Stationary points were established in a variety of habitats including open prairie, canyons, badlands topography, woody draws, and forest edge; with an emphasis on locating sites close to surface water (**Figure 4**) and woody edge as those sites tend to have higher rates of bat activity (Morris et al. 2010, Jantzen and Fenton 2013). NABat recommendations call for deploying recorders for a minimum of four consecutive nights. In 2014 units were generally deployed for four consecutive nights; however, in 2015-16 units were typically deployed for seven consecutive nights as that was found to be more logistically effective (i.e., it avoided the need to work on weekends). Furthermore, longer deployments are less prone to data variability due to factors such as poor weather conditions (e.g., windy nights that might decrease bat activity). The units were programmed to wake from sleep mode (i.e., began monitoring) 15 minutes before sundown and continued monitoring until 15 minutes after sunrise. The NABat protocol assumes an always-revisit design where the sites are monitored every year, so the Network attempted to re-survey sites at the same time every year. More information on the deployments can be found in Appendix II and in supplemental documents (Licht 2017).

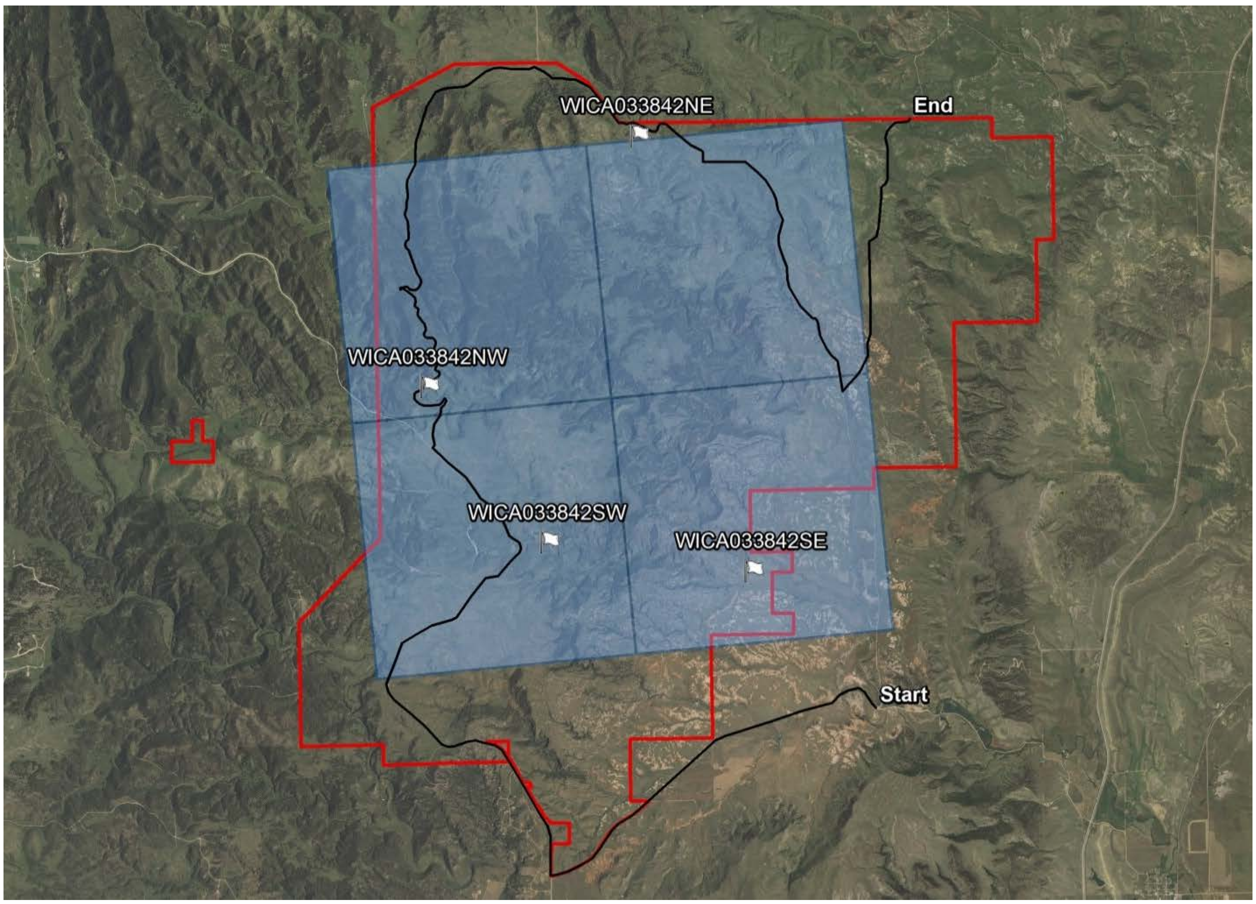

Figure 7. NABat cell #033842 at Wind Cave NP. The four blue-shaded squares are the four quadrants of the cell. The flags are the locations of stationary points. The black line is the associated mobile survey route. The red line is the park boundary.

Table 2. NABat monitoring cells drawn for bat surveys.

Park	NABat Cell #	Cell Descriptive Name	State Cell is Located In
Missouri NRR	020258	Ponca State Park	NE/SD
Missouri NRR	029794	Lower Niobrara River	NE
Badlands NP	029922	Cedar Pass	SD
Missouri NRR	031522	Burbank, SD	NE/SD
Wind Cave NP	033842	Wind Cave NP	SD
Jewel Cave NM	034530	Jewel Cave NM	SD
Badlands NP	047586	Sage Creek Road	SD
Missouri NRR	060194	Vermillion Bridge	NE/SD
Theodore Roosevelt NP	061141	South Unit: East of Little Missouri River	ND
Badlands NP	075712	Conata Basin Road	SD
Niobrara NSR	080286	Fort Niobrara NWR	NE
Niobrara NSR	097012	Rocky Ford	NE
Badlands NP	098188	Badlands Wilderness (not surveyed)	SD
Missouri NRR	105833	Niobrara State Park	NE/SD
Theodore Roosevelt NP	121832	South Unit: West of Little Missouri River	ND

Mobile Transects

The NABat protocol also recommends conducting mobile road surveys (**Figure 5**, **Figure 6**, and **Figure 7**). The document that was finalized in June of 2015 (Loeb et al. 2015) recommended that road surveys be 25-48 km (16-30 miles) long and primarily within the cell, start 45 minutes after sunset with the vehicle traveling at 32 km/h (20 mph), and be conducted on at least two nights. However, all 14 of the routes established in Network extended outside of the NABat cells for at least a portion of their length due to the limited road network within most of the cells and barriers such as rivers constraining route options. However, because the mobile surveys recorded spatial coordinates (i.e., GPS) along with the recordings the collected data could be parsed to include only recordings from within the cell boundaries should that be desired for analyses. The 2014-16 Network road surveys differed slightly from the published June 2015 NABat protocol in that the surveys started 30 minutes after sunset (versus 45 minutes after sunset). When this project started in the spring of 2014 the draft protocol stated that routes should start 30 minutes after sunset. Although this was revised in June of 2015, it was deemed more important to be consistent in methodology between 2014 and 2015-16 than it was to be consistent with the new NABat protocol. As recommended in the NABat guidance, surveys were not conducted on nights with rain, high winds, or other unsuitable weather.

Non-NABat Monitoring

Seven of the 13 parks in the Network did not meet the Network's *a priori* criteria for using the NABat sampling frame, i.e., that a portion of all four quadrants of a cell be within the park boundary. The parks were Agate Fossil Beds NM, Devils Tower NM, Fort Laramie NHS, Fort Union Trading Post NHS, Knife River Indian Villages NHS, Mount Rushmore NMEM, and Scotts Bluff NM. In addition, the North Unit of Theodore Roosevelt NP did not meet the criteria. However, acoustic monitoring was still needed at the units to better understand the status of bats and to make informed management decisions, with the exception of Devils Tower NM which was conducting its own acoustic monitoring program. Therefore, stationary point monitoring was conducted at the units; however, the location of the points was not established per the NABat sampling frame (i.e., placing a point in each of four quadrants within a cell) or other probabilistic design, but rather, stationary points were established based solely on the desire to survey various habitats within the parks and/or to survey areas of high management interest. Although the points were not established per the NABat sampling frame, the stationary points could be revisited in future years and temporal trend analysis conducted, thereby supplementing the NABat landscape-level analysis (Loeb et al. 2015).

The same hardware, deployment methods, and software configurations were used at the non-NABat stations as was used at the NABat points. Similarly, the units were typically deployed for seven nights. At most of the non-NABat parks 4-5 stations were established. A notable exception was Agate Fossil Beds NM which had 43 stations. The deployment strategy at that park was designed to collect detailed habitat use as part of a short-term study. The detailed results from that effort will be published in a separate report. Similar efforts could be conducted at other parks in the future. In a few cases a NABat sampling point was discontinued or a recorder was not placed in the correct spot. In these cases the station was renamed or given a name using the non-NABat nomenclature, e.g., THRO05, MNRR01.

Data Collection, Storage, and Analysis

Metadata was collected for all stationary point monitoring and mobile surveys. The metadata collected included the bat detector model and serial numbers, site coordinates, dates and times of the deployments, memory cards and batteries used, and field technicians deploying the equipment, among other metadata recommended by NABat (Loeb et al. 2015). Weather data was not collected at the time of the surveys, but rather, was collected later from the nearest weather station. When units were deployed and retrieved pictures were taken of the recorder LCD display, the microphone serial number, and the deployment site and habitat (**Figure 8**). The photo of the LCD display showed the date, time, unit serial number, firmware, and status of the four memory cards. Yellow notepaper next to the display showed the station ID and covered up the blinking status light on the units. The pictures were taken with the camera's GPS enabled. This routine use of pictures with embedded metadata was an effective tool for accurate record-keeping and for resolving metadata discrepancies.

Figure 8. Montage of four pictures routinely taken at stationary point deployment and retrievals. (NPS/ DAN LICHT)

Metadata for stationary points and road surveys was stored in an Excel file developed as part of this program. Although the WASO office of the NPS was in the process of designing an Access database for storage of bat acoustic monitoring data the database was still in development and had limitations and problems, therefore it was not used. The metadata collected 2014-16 could be migrated to that database at a later date if desired. The bat recordings (i.e., "wav" files) were stored on Network I&M Program servers that were routinely backed up to redundant off-site storage systems (Brumm 2009).

Prior to analyzing the data for this report I conducted a rigorous review of the data for quality and conformity. For example, in some cases recorders were not functioning when retrieved. It was possible the units shut down during the night which could bias some analyses such as hourly activity patterns. By reviewing field notes and inspecting patterns in the data I could often reasonably conclude if that had happened. In such cases I censored that entire nights data (the censored data was placed in zipped folders so it was not processed by the software, but could be later retrieved if there was a need: I did the same with mobile surveys that were incomplete due to weather or other factors). Although this censoring of data slightly reduced the number of recordings at some sites I viewed the lost as negligible and it resulted in cleaner unbiased analyses. Another potential problem that was caught in the quality review (with the aid of photos taken at deployments) was the timing of the recordings was sometimes off by an hour. This was a consequence of the Network encompassing two time zones. In these cases a batch rename program was used to automatically correct the time code in the file names. Although the erroneous settings could have resulted in the units not being operational for a brief period when bats were flying the likelihood was viewed as negligible as the large buffer in the wake-up and shut-down settings on the recorder should have still caught most early-evening and late-morning bat activity. To provide a greater buffer against this potential problem the units could in the future be configured to start 30 minutes or greater before sunset and 30 minutes or greater after sunrise.

NABat recommends that at least two methods be used to analyze calls for purposes of identifying the species that made the recording (Loeb et al. 2015). Although the NABat document is somewhat ambiguous it appears to suggest that two software packages would suffice for satisfying the recommendation. Some bat experts recommend a manual review of species classifications made by software programs; however, I opted not to that because of: 1) the massive number of recordings collected 2014-16, and 2) there is some evidence that human classifications are no more accurate than objective software classifications, including classifications by biologists with many years of experience (Jennings et al. 2008). However, if increased confidence is desired for determining the presence of rare species, or is needed for particular statistical analyses (such as the use of occupancy models), then manual review might be warranted. NABat further recommends that when a study is relying largely on auto-identification software, and there is a discrepancy in species identification, that both suggested species be considered possible. For this report I routinely couched the discussion and conclusions in that way.

The results reported here rely almost entirely on automated processing and species classifications using Wildlife Acoustics Kaleidoscope Pro version 4.1.0a software with the 4.1.0 Bats of North America classifier package, and to a lesser extent, Sonobat 4.1.0. The software packages Bat Call Identification (BCID) and Echoclass were also evaluated, but not used for the analyses reported here due to the classifier packages not adequately covering species assemblages found across the Network.

A critical step in effective use of automated classification programs is to select the proper species to be considered in the discriminatory analysis (Licht 2016). There are at least 13 species documented in the Northern Great Plains (**Table 3**); however, not all species are likely to be in all states or all parks. Wildlife Acoustics Kaleidoscope allows the user to individually select which species to include in an analysis. Sonobat restricts the user to pre-defined regional packages. For Sonobat the Midwest-North classifier package was used for the Missouri NRR, Niobrara NSR, and Knife River Indian Villages NHS. Agate Fossil Beds NM, Fort Laramie NHS, and Scotts Bluff NM were all processed using the Wyoming–East classifier package. Badlands NP, Jewel Cave NM, Mount Rushmore NMEM, and Wind Cave NP were all processed using the South Dakota–Black Hills package. Fort Union Trading Post NHS and Theodore Roosevelt NP were processed using the Montana–Plains package. In some cases I processed the data using a second regional Sonobat package (e.g., to evaluate for the presence of tri-colored bats in the Black Hills which are not included in the Sonobat Black Hills classifier package).

Table 3. Bat species of the Northern Great Plains.

Common Name	Scientific Name	4-Digit Code	Distribution in Network	General Habitat	Daytime Roosts	Winter Habitat	WNS Mortalities	Turbine Mortalities	Status[1]
Townsend's Big-eared Bat	*Corynorhinus townsendii*	COTO	Western SD. WY	–	–	Caves	None Known	–	Vulnerable
Big Brown Bat	*Eptesicus fuscus*	EPFU	All	Includes urban areas	Trees and buildings	Caves	Low	–	Secure
Eastern Red Bat	*Lasiurus borealis*	LABO	All except WY	–	Tree branches	Migrates	–	High	Apparently Secure
Hoary Bat	*Lasiurus cinereus*	LACI	All	–	Tree branches	Migrates	–	High	Apparently Secure
Silver-haired Bat	*Lasionycteris noctivagans*	LANO	All	Forage over water	Tree holes/ under bark	Migrates	Low	High	Apparently Secure
Western Small-footed Myotis	*Myotis ciliolabrum*	MYCI	All except eastern ND	Badlands and forests	Caves and crevices	–	–	–	Apparently Secure
Long-eared Myotis	*Myotis evotis*	MYEV	Western Dakotas	Primarily forests	Various	–	–	–	Apparently Secure
Little Brown Bat	*Myotis lucifugus*	MYLU	All except central NE	Forage over water	Trees and buildings	Caves	High	Some	Vulnerable
Northern long-eared Myotis	*Myotis septentrionalis*	MYSE	All except SE WY	Forage in forests	Trees	Caves	High	Low	Critically Imperiled[2]
Fringed Myotis	*Myotis thysanodes*	MYTH	Western SD and NE	Various	Caves and buildings	Migrate	–	–	Apparently Secure
Long-legged Myotis	*Myotis volans*	MYVO	Western SD and NE	Primarily Forests	Trees	–	–	–	Apparently Secure
Evening Bat	*Nycticeius humeralis*	NYHU	Eastern SD and NE	–	Trees	Migrates	–	–	Secure
Tri-colored Bat	*Perimyotis subflavus*	PESU	Unknown	–	Trees	Caves	High	Some	Vulnerable

[1] Source is NatureServe.org, accessed 10-30-2015

[2] Listed as Threatened under federal ESA

I used the NPS NPSpecies database as a first filter to determine what species might be present in a park. I then used the USGS National Gap Analysis Program species viewer. Specifically, I queried the database for a list of bats within the county the park is in. However, the range maps in the Gap database often rely on older data. Furthermore, until the advent of acoustic monitoring bats were under-sampled in terms of species distributions. As a result, I also considered other sources such as the range maps in Harvey et al. (2011). I also considered other sources, for example, I included the evening bat for the Missouri NRR based on other publications (Jones and Vaughan 1959, Higgins et al. 2000, Lane et al. 2003, Serbousek and Geluso 2009). For those species for which the data was unconvincing regarding presence or absence I tended to be inclusive. The initial species lists used for each park are shown in **Table 4**; however, in some cases I expanded the list of species considered (see individual park chapters).

NABat will rely heavily on occupancy models to analyze changes in bat populations over time (Loeb et al. 2015). Occupancy models are well suited to landscape-level analyses assuming there are a large number of optimally distributed monitoring stations with sufficient revisits. However, the method also depends heavily on definitive species identification, a challenging issue with acoustic surveys of bats (Clement et al. 2014). As a result of these requirements, I did not use occupancy modeling to analyze the 2014-16 data. Rather, I limit the species-specific analyses and reporting to general statements and graphical information. In the future the dataset might be more conducive to precise quantitative reporting and statistical analyses of trends of individual species, such as when software identification improves or a manual vetting of the dataset is conducted. I only present precise quantitative information and statistical tests when reporting total bat detections as they are less prone to software errors. I did not model co-variates that could affect differences between years, such as weather, moon phase, or seasonality (for example, bats appear to be less active on rainy nights (Erickson and West 2002) thereby biasing results downward during such periods). As the dataset becomes larger more robust multi-variate analyses could and should be conducted.

Both software packages provide a probabilistic analysis of whether the species truly is present in the form of a maximum likelihood estimate. The analysis takes into account the number of recordings classified to the species and the similarity of the species' calls to other species included in the analysis. The software developers recommend using the value from a single night's recordings. In determining whether a species is truly present at the park I reviewed the output for each species for each night. If the night-by-night analysis indicated the species was present, even for a single night, I generally reported it as present or probably present for the park. However, for reporting purposes I present the maximum likelihood estimate for the entire year for a park (reporting individual nights for each species would be unwieldy). Kaleidoscope reports the value in the form of a P-value so for reporting purposes (i.e., the tables in this report) I inverted the value to be comparable to the probability of presence outputted by Sonobat. In other words, in the table in this report a 1 indicates the species is present and a 0 indicates it is not.

Table 4. Species included in initial auto-classification for each park and source. Letters correspond to source: G= Gap Analysis, H=Harvey et al. (2011), N=NPSpecies, O=Other.

Park	T. Big-eared	Big Brown	Eastern Red	Hoary	Silver-haired	W. Small-footed	Long-eared	Little Brown	N. Long-eared	Fringed	Long-legged	Evening	Tri-colored
Agate Fossil Beds NM	G	G,H,N	G,H,N	G,H	G,H,N	G,H,N	H,N	G,H,N	H,N	G,H	G,H	–	G
Badlands NP	G,H,N	G,H,N	G,H	G,H,N	G,H,N	G,H,N	–	G,H,N	H,N	G,H,N	H,N	–	G
Fort Laramie NHS	G,H,N	G,H,N	G	G,H,N	G,H,N	G,H,N	H	G,H,N	G	G,H	G,H	–	G
Fort Union Trading Post NHS	–	G,H,N	G,H	G,H	G,H	G,H,N	G,H	G,H,N	G,H	–	G,H,N	–	–
Jewel Cave NM	G,H,N	G,H,N	G,H	G,H,N	G,H,N	G,H,N	H,O	G,H,N	G,H,N	G,H,N	G,H,N	–	G
Knife River Indian Villages NHS	–	G,H,N	G,H	G,H,N	G,H,N	N,O	–	G,H,N	G,H,N	–	O	–	–
Missouri NRR	–	G,H,N	G,H,N	G,H,N	G,H,N	G,H	–	G,H,N	G,H,N	–	–	G,N	G,H,N
Mount Rushmore NMEM	G,H	G,H,N	G,H	G,H	G,H,N	G,H,N	H,N	G,H,N	G,H,N	G,H,N	G,H,N	–	G
Niobrara NSR	G	G,H,N	G,H,N	G,H,N	G,H	G,H,N	O	G	H,N	G	O	–	G
Scotts Bluff NM	O	G,H,N	G,H	G,H	G,H,N	G,H,N	–	G,H,N	N	G,H,N	G,H	–	G
Theodore Roosevelt NP	G	G,H,N	G,H	G,H,N	G,H,N	G,H,N	G,H,N	G,H,N	G,H,N	G	G,H,N	–	–
Wind Cave NP	G,H,N	G,H,N	G,H,N	G,H,N	G,H,N	G,H,N	H,N	G,H,N	G,H,N	G,H,N	G,H,N	–	G

Results

This section provides results of the acoustic monitoring in the Northern Great Plains Network, 2014-16. The results for the bat community as a whole are generally given quantitatively whereas the results for species-specific information are generally qualitative and graphical. That is deliberate. As auto-identification software for bats improves in terms of accuracy the data from 2014-16 might be reprocessed and re-analyzed, resulting in slightly different rates of species classifications. Furthermore, different software packages produce different results; and determining which software is most accurate is not possible at this time. Even within a software package the results could differ depending on the configuration settings of the software and, most prominently, what species comprised the classifier package used for discriminating the calls. The first section summarizes the results for all parks. The sections after that give park-specific information. Some of the park-specific information is repetitive between sections; that's because the park chapters are designed to serve as stand-alone reports.

All Parks

The following results summarize all of the data collected in 2014-16 across all parks. It is important to realize that this study was not designed or intended to compare or contrast populations between parks, but rather to track populations over time. The results should be viewed with that caveat in mind. Nevertheless, some Network-wide between-park comparisons are informative. Furthermore, the cumulative dataset across parks provides for more robust landscape-level reporting and analyses.

Accuracy

I tested the two auto-ID software packages against a library of known calls that I collected from various sources. I used only species that were included in the Sonobat Black Hills classifier package. I configured Kaleidoscope to discriminate only for those species as well. However, it is important to note that some of the 155 calls of Black Hills species that I used might have been used to train the software packages and therefore the results could be biased. Nevertheless, the test sheds light on the strengths and weaknesses of the two packages. Both software packages were conservative and did not make a classification for all 155 recordings; specifically, Kaleidoscope classified 82 recordings and Sonobat classified 89 using the default settings for both packages. Had I tweaked the settings I likely could have increased the rate of classifications, although one assumes, false positives as well. For some species the software was in agreement and very accurate, such as for the hoary bat (**Figure 9**). That is not surprising as that species has a low-frequency call that is relatively diagnostic. Conversely, there was wide disagreement in regards to some other species. For example, Kaleidoscope classified many more western small-footed myotis and was closer to the actual number than was Sonobat. However, Sonobat was much closer to the actual number of bats for both the big brown and silver-haired bats. Licht (2016) conducted a similar side-by-side comparison of Kaleidoscope and Sonobat, as well as BCID and Echoclass in his analysis of acoustic recordings from Tallgrass Prairie National Preserve in Kansas.

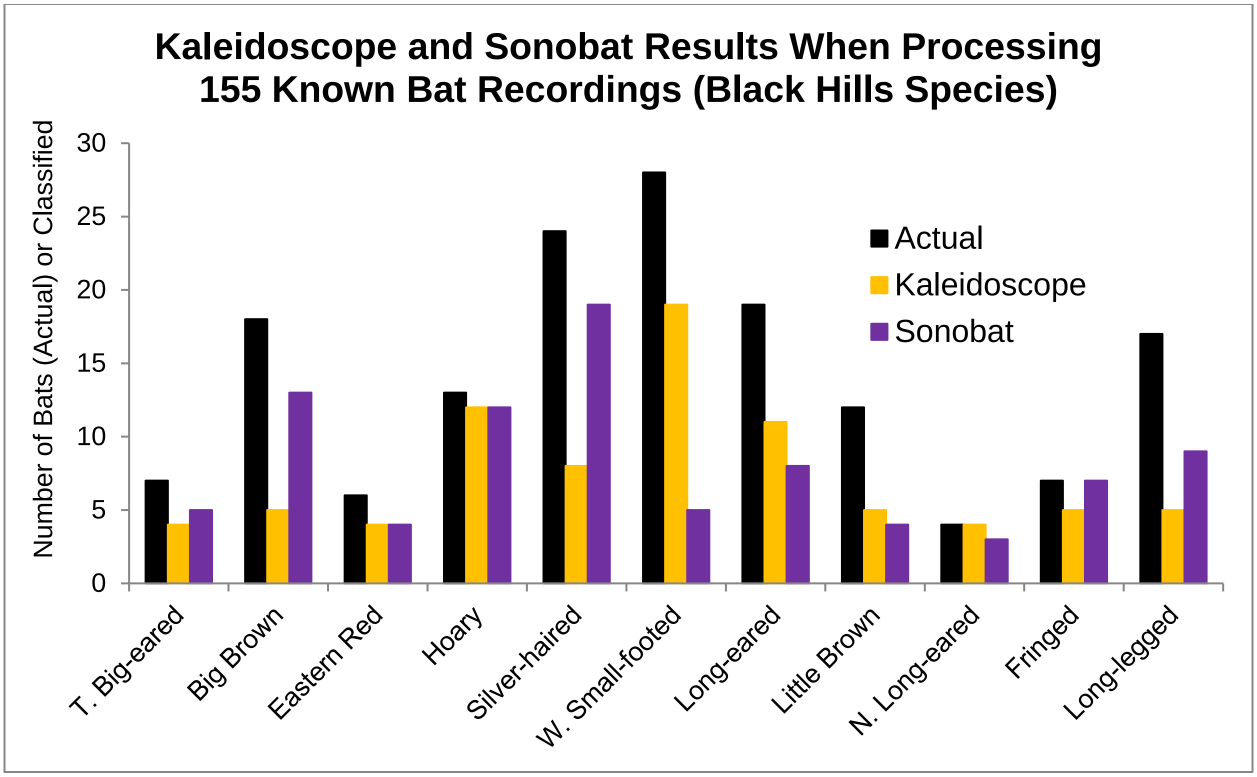

Figure 9. Accuracy of auto-ID software compared to library of known calls.

Both software packages produce a statistical value of the likelihood of the species being present based on the analyzed recordings. The formula considers the number of classifications in the dataset and the similarity of the classified call to other species. The output is generally best used when analyzing a single nights worth of data (i.e., smaller data sets), according to the developers of the software. Using my testing catalog, Kaleidoscope was more likely to predict that the species was present than was Sonobat (**Table 5**). However, caution should be used when extrapolating the test to real world conditions. For example, my testing catalog included only species that the software was configured to look for; had I included additional species the software might have resulted in more false positives.

Table 5. Likelihood estimators from Kaleidoscope and Sonobat when processing 155 known calls of Black Hills species.

Software	T. Big-eared	Big Brown	Eastern Red	Hoary	Silver-haired	W. Small-footed	Long-eared	Little Brown	N. Long-eared	Fringed	Long-legged
Kaleido-scope	1.00	0.89	1.00	1.00	0.93	1.00	1.00	0.80	0.99	1.00	0.99
Sonobat	0.28	0.86	0.20	1.00	0.97	0.64	0.96	0.53	0.12	0.97	0.89

Bat Recordings and Detections

Across the Network, 55 NABat stationary points were established (**Table 6**), or 4 points per each of the 14 NABat cells with the exception NABat cell #105833 in the Missouri NRR which had only 3 points. The NE quadrant of that cell is comprised almost entirely of private land and a suitable deployment location could not be found. Another 62 stationary points were established; these sites are collectively referred to as non-NABat stations (**Table 6**). (This total does not include 3 stations established at Adams Homestead and Nature Preserve; see the Missouri NRR section.) Of these 62 stations, three were originally established as NABat sites (MNRR01-03) but were subsequently replaced by new locations. All of the other non-NABat sites were established with no regard to the NABat sampling frame.

From 2014-16 a total of 947,875 recordings were made from the 12 parks included in the study, including both NABat and non-NABat stationary points and mobile surveys. The recordings were all made between May 27 and September 9 (**Figure 10**). Of the 935,933 recordings from stationary points, about 1% was censored from further analysis and 8% of the remaining recordings were noise files (**Table 6**). The censored recordings included corrupted files that could not be read by the software, recordings from incomplete survey nights, and other data unsuitable for the analyses in this report. Although some of the censored recordings could have value for some uses, such as determining species presence, I considered that unlikely due to the small number of such recordings. I therefore decided to censor them as their value was outweighed by the problems they caused in analysis (e.g., determining nightly detection rates). (The censored recordings have been archived on Network servers and are available for other uses.) The recordings containing only noise might have been triggered by anthropogenic sounds, insects, vegetation, or other sources. Noise files comprised 12% and 26% of the stationary recordings at Missouri NRR and Niobrara NSR, respectively, yet were 8% or less at all other parks (**Table 6**). The reason for the relatively high rate of noise files at the two parks is not known. Of the 847,521 stationary point recordings with bat detections, about 31% were not classified to the species level by the Kaleidoscope auto-identification software.

The average number of bat detections per night per stationary point across the Network for 2014-16 was 539 (**Table 6**). There were substantial differences between parks; however, some of that can be explained by study design. Generally speaking, stationary points were established at sites that appeared to have a high potential for bat activity. However, NABat stations were confined to the quadrant boundaries, some of which might not include prime bat activity areas (e.g., wetlands). Furthermore, some stations were deliberately established in habitats that had less potential for bat activity, but there was management interest in confirming bat use at the site. Especially noteworthy is Agate Fossil Beds NM where a large number of stationary points were deployed across the landscape, including in prairie areas away from surface water, to better understand habitat use by bats in the park and in Northern Great Plains grassland ecosystems. Probably as a result of that approach that park had the lowest average rate of bat detections (191 per night). Conversely, Badlands had a high average rate of detections (1,121 per night) perhaps because several units were deployed next to stock ponds and other water bodies. That difference could also be due to the small surface area of the water resources at Badlands (i.e., stock ponds), which congregated and retained foraging bats whereas at Agate Fossil Beds the available surface water (i.e., the Niobrara River) is long and linear and hence the foraging bats would be more dispersed. The park with the highest average nightly detection rate was Fort Laramie NHS, which averaged 1,503. The high rate was inflated by the unit next to the bat house (FOLA02) which averaged 4,029 bat detections per night. But even other stations in the park recorded relatively high rates. The high rate of bat activity park-wide night be due to the bat house. Consider that Scotts Bluff NM, located about 80 km (50 miles) downstream on the North Platte River, and with similar riparian habitats, averaged only 328 detections per night. Likewise, Fort Union Trading Post NHS and Knife River Indian Villages NHS had substantial riparian habitats, but did not record the high rates of bat activity that Fort Laramie NHS did.

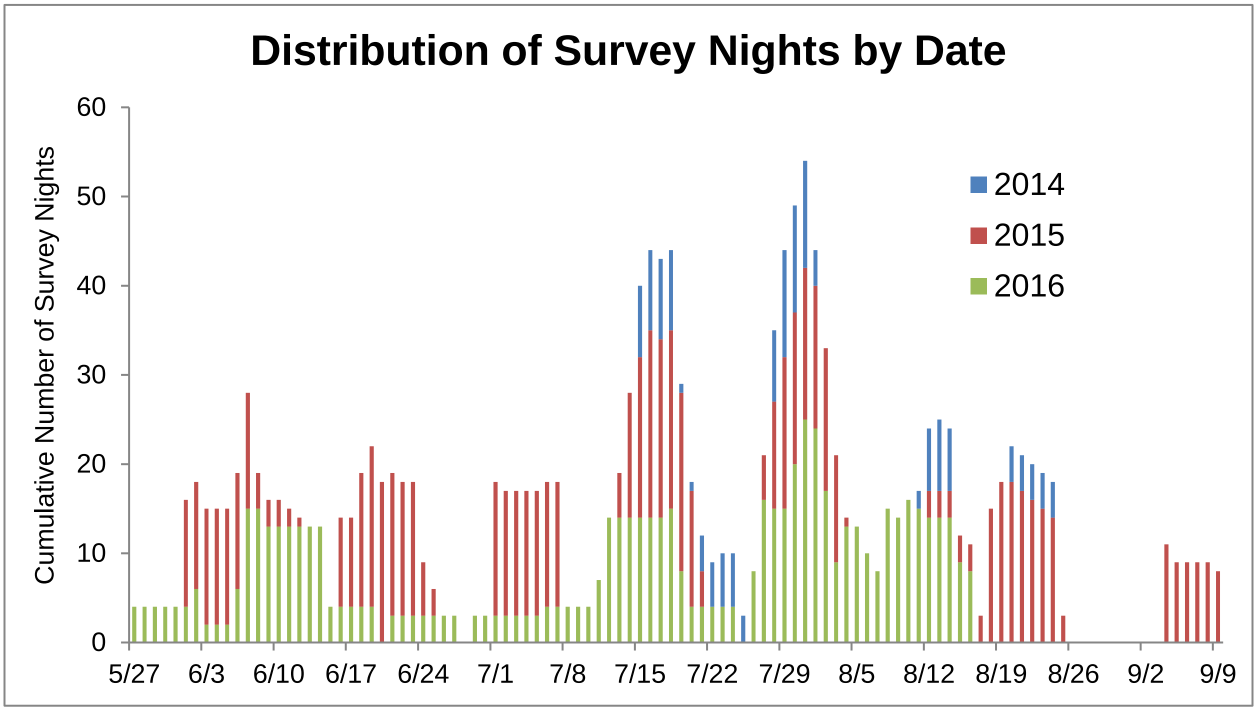

Figure 10. Distribution of stationary point survey nights by date.

Of the 11,942 recordings collected in the mobile surveys, 7% were censored and of the remaining 78% were noise files (**Table 7**). The censored files were removed because the route was not completed due to inclement weather or the route was not followed properly. The high rate of noise files is almost certainly due to the ultrasonic noise from moving vehicles. The noise associated with road surveys can also make species identification difficult; of the 2,439 recordings of bats, about 41% could not be classified by Kaleidoscope to the species level. The highest rate of bat detections in the mobile surveys was from the Missouri NRR; the lowest rate was from Theodore Roosevelt NP. However, the routes do not necessarily represent all habitats within the park. Furthermore, within a park there was often substantial variability between routes and years. See the park-specific chapters for more information.

Table 6. Summary table of stationary point recordings for all parks 2014-16 from Kaleidoscope.

Park	NABat Stations	Non-NABat Stations	Total Recordings	Percent Censored Recordings	Complete Survey Nights (After Censor)	Percent Noise Files (After Censor)	Recordings of Bats (After Censor)	Percent Unclassified To Species	Average Bat Detections Per Survey Night
Agate Fossil Beds NM	**0**	**43**	**58,012**	**2%**	**280**	6%	53,370	31%	191
Badlands NP	12	0	240,742	0%	204	5%	228,748	34%	1,121
Fort Laramie NHS	0	12	163,424	6%	95	7%	142,807	41%	1,503
Fort Union Trading Post NHS	0	4	39,494	0%	48	3%	38,439	25%	801
Jewel Cave NM	4	0	26,858	2%	60	4%	25,478	28%	425
Knife River Indian Villages NHS	0	4	14,992	0%	49	3%	14,558	37%	297
Missouri NRR[1]	19	3	186,806	0%	286	12%	164,136	23%	574
Mount Rushmore NMEM	0	10	35,758	1%	134	6%	33,711	29%	250
Niobrara NSR	8	0	56,104	2%	103	26%	40,377	24%	392
Scotts Bluff NM	0	5	28,106	1%	80	6%	26,241	23%	328
Theodore Roosevelt NP	8	6	51,142	0%	173	8%	46,883	27%	271
Wind Cave NP	4	0	34,495	0%	61	5%	32,773	30%	537
Total	**55**	**62**	**935,933**	**1%**	**1,573**	**8%**[2]	**847,521**	**31%**[2]	**539**[2]

[1] Does not include 3 stations and 16,354 recordings from Adams Homestead & Nature Reserve State Park

[2] Weighted by sample size

Table 7. Summary table of mobile surveys recordings for all parks 2014-16.

Park	Number of NABat Routes	Total Recordings	Percent Censored Recordings	Cumulative Complete Survey Nights 2014-16	Percent Noise Files	Number of Recordings of Bats	Percent of Bat Recordings Not Classified to Species	Average Bat Detections Per Mobile Survey	Average Bat Detections Per km
Agate Fossil Beds NM	–	–	–	–	–	–	–	–	–
Badlands NP[1]	3	3,001	5%	18	75%	707	45%	39.3	1.11
Fort Laramie NHS	–	–	–	–	–	–	–	–	–
Fort Union Trading Post NHS	–	–	–	–	–	–	–	–	–
Jewel Cave NM[2]	1	434	0%	4	61%	169	37%	42.3	1.12
Knife River Indian Villages NHS	–	–	–	–	–	–	–	–	–
Missouri NRR[1,3]	5	4,605	14%	22	79%	828	35%	37.6	1.26
Mount Rushmore NMEM	–	–	–	–	–	–	–	–	–
Niobrara NSR	2	1,449	0%	8	89%	166	51%	20.8	0.67
Scotts Bluff NM	–	–	–	–	–	–	–	–	–
Theodore Roosevelt NP	2	1,818	0%	12	86%	244	61%	10.2	0.55
Wind Cave NP	1	635	0%	6	50%	320	32%	53.3	1.13
Total	**14**	**11,942**	**7%**[4]	**70**	**78%**[4]	**2,439**	**41%**[4]	**34.8**[4]	**1.05**[4]

[1] Some surveys not completed due to rain.

[2] No surveys in 2014 due to road construction.

[3] 2015 Ponca State Park (MNRR020258RD) surveys censored because the surveys deviated from established route.

[4] Weighted by sample size.

Species Presence and Relative Frequency of Classifications

According to the Kaleidoscope software, the most commonly classified species across the Network was the big brown bat followed by the hoary, silver-haired, and little brown bats and the western small-footed myotis (**Figure 11**). Sonobat also classified the highest frequency of recordings to the big brown bat; but at a much higher rate than did Kaleidoscope (**Figure 12**). The hoary and little brown bats were also frequently classified by Sonobat. The two software packages showed substantial disparity in the relative frequency of western small-footed myotis, with Kaleidoscope classifying many more recordings to that species. The reason for that disparity is apparently due to the algorithms used in the software. In my side-by-side comparison of the software against a catalog of known calls from Black Hills bat species Sonobat substantially under-reported western small-footed myotis (earlier in this section). However, Sonobat was closer to the actual number of big brown bat calls than was Kaleidoscope. For another comparison see Licht (2016).

Some of the other Network-wide disparities between the results in **Figure 11** and **Figure 12** can likely be attributed to the design of the software, with Kaleidoscope allowing users to customize the list of species to filter for and Sonobat requiring users to use a fixed regional list. This became problematic in places like the Black Hills. The tri-colored bat has recently been documented from that area and some other western states (Geluso et al. 2005), yet Sonobat does not include the species in the Black Hills classifier package. As a result, the analysis in **Figure 12** likely under-reports the frequency of that species in the Network. Although I could have used a different classifier package for the Black Hills parks, specifically the Sonobat South Dakota-Eastern package which includes the tri-colored bat, that package also introduces species into the equation (e.g., evening bats) that are not known from the Black Hills. I address this problem in the park-specific sections of this report. Fortunately, the two software packages were often in agreement at the park level (see the park-specific sections).

The relative frequency of classifications might or might not be correlated with relative abundance in the Network. For example, repeated flyovers by an individual bat could lead to a false conclusion of abundance. Similarly, some species are known to be soft callers and are therefore more likely to be detected by acoustic methods (e.g., Townsend's big-eared bat). Likewise, some species might spend more time flying. Station deployments could also result in bias as some species forage over surface water (e.g., little brown bat) whereas others forage more in forests (e.g., northern long-eared bat). The deployment of a station next to the bat house at Fort Laramie likely biased the relative frequency of little brown bat detections at that park. And the large number of deployments at Badlands NP likely increased the relative frequency of western small-footed myotis in the results; however, badlands habitat is relatively isolated in the Great Plains. Nevertheless, **Figure 11** and **Figure 12** are likely reasonable approximations of bat diversity in the Network and the Northern Great Plains.

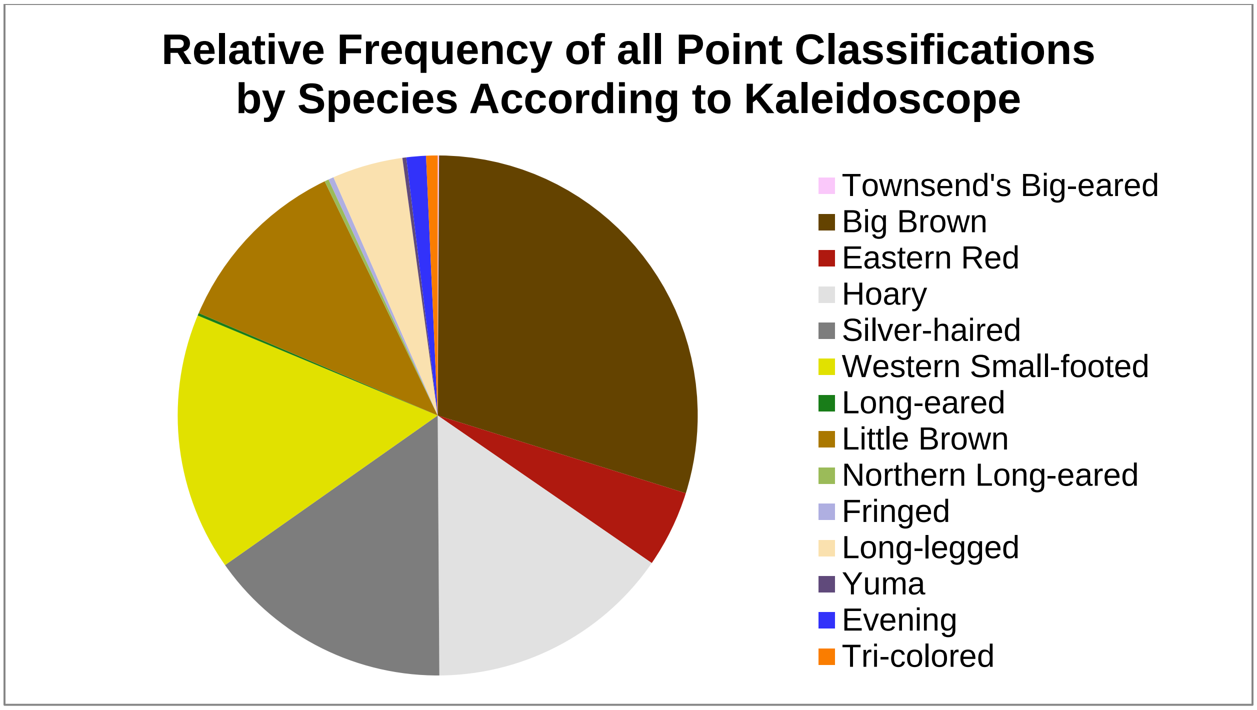

Figure 11. Relative frequency of classifications by species in Network according to Kaleidoscope. Data from stationary points only.

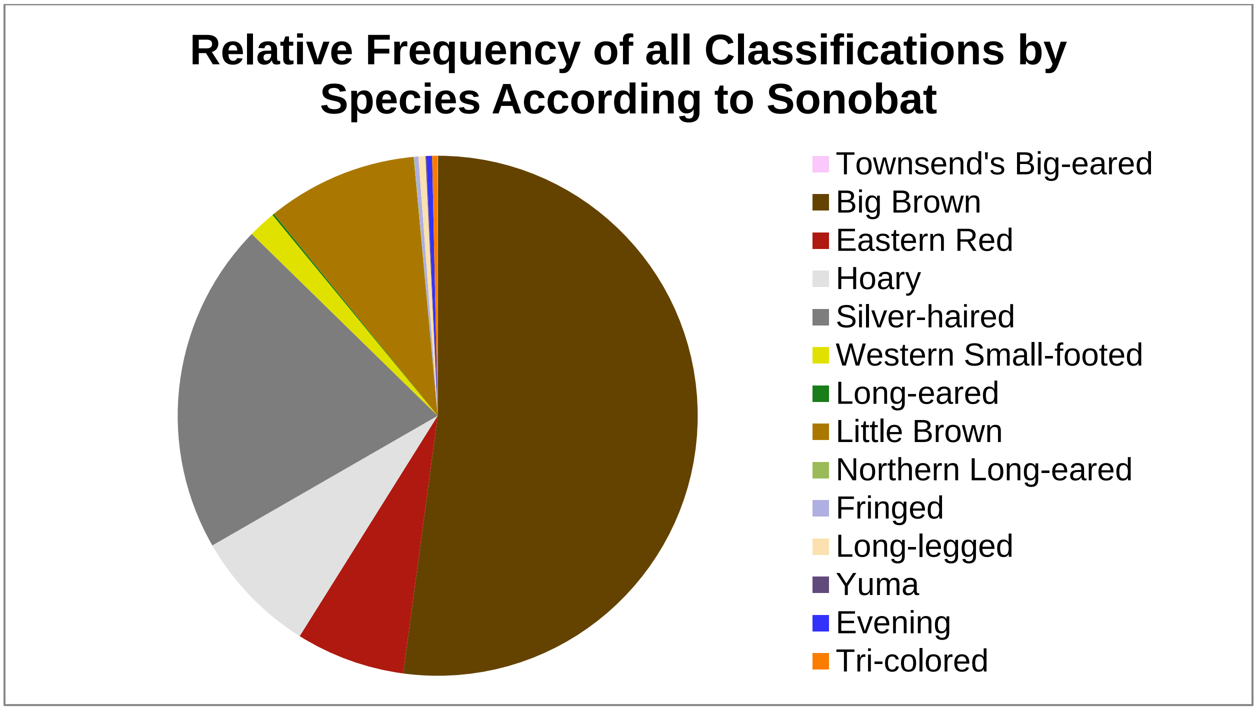

Figure 12. Relative frequency of classifications by species in Network according to Sonobat. Data from stationary points only. For some parks multiple regional classifiers were used to cover all species believed present in park.

Changes from 2014 to 2016.

The primary purpose of this project is to monitor changes in bat populations over time. An effective way to do that is to revisit sites about the same time each year. Data was collected at 29 stationary points in all three years 2014-16. The sites averaged 746 detections per night in 2014, 617 detections per night in 2015, and 865 per night in 2016 according to Kaleidoscope. However, there was much variability between and within sites (**Figure 13**). The exact reason for the large variability between years at some sites is unknown, but not unexpected.

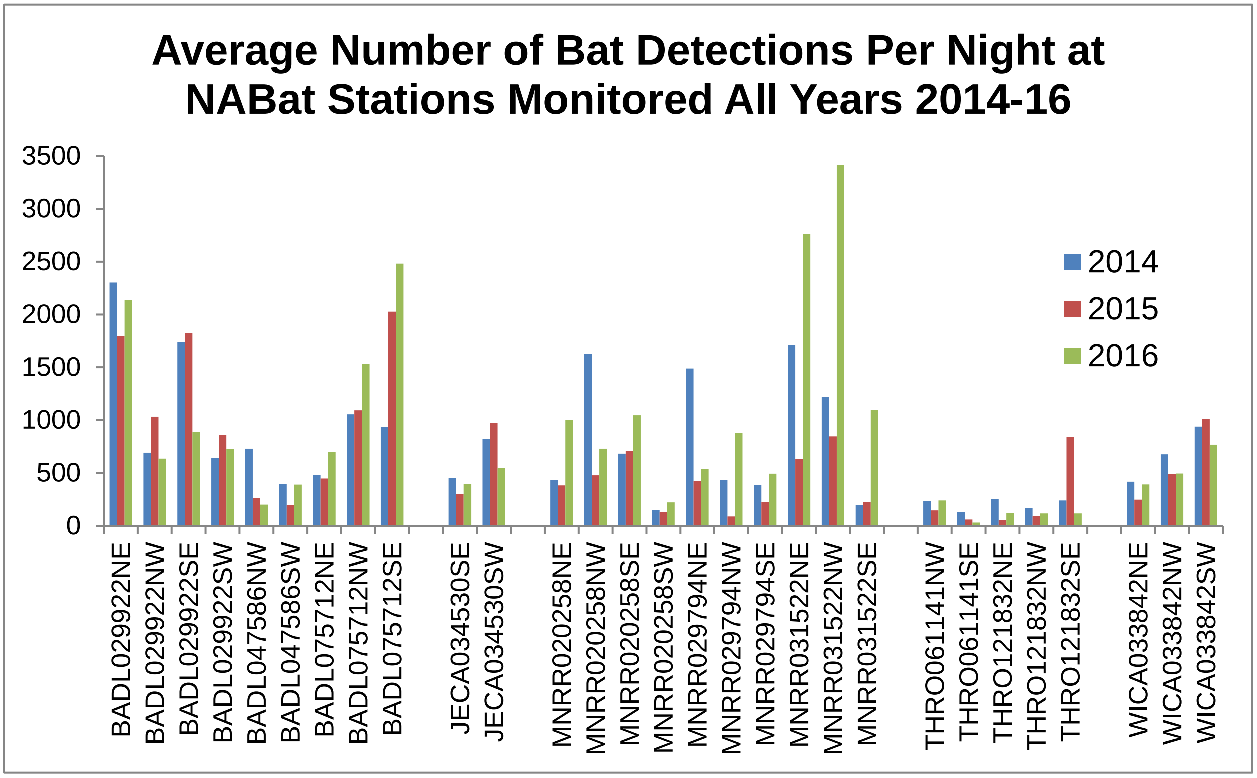

Figure 13. Average number of detections per night for stationary points surveyed both in 2014 and 2015.

Unlike stationary points, mobile surveys are less prone to repeat flyovers by the same bat because the survey vehicle is theoretically travelling faster than bats can fly. As a result, the method might have greater effectiveness at tracking year-to-year changes in abundance. Fourteen mobile routes were survey in 2014-16, although three of the Missouri NRR and both of the Niobrara NSR sites were surveyed only in 2015-16 (**Figure 14**). Furthermore, about 4.8 km (3 miles) of the Ponca State Park route (MNRR020258RD) was not surveyed in 2015. Excluding those six routes, the routes survey in all three years averaged 41 bats per night in 2014, 34 bats per night in 2015, and 33 per night in 2016 according to Kaleidoscope. **Figure 14** shows that at some routes the year-to-year differences were negligible whereas at other routes they were substantial. The reason for the dramatic changes between years is not known; however, it could be due in part to the timing of the surveys as some between-years replicates varied by almost a month and some surveys were conducted in mid to late August (see park-specific results and Appendix 1), a period that could include migrating bats and/or volant juveniles. Most notable are the 2014 mobile surveys at Theodore Roosevelt NP that occurred in mid-August whereas in 2015 and 2016 the surveys occurred in July. Future work should strive for synchrony in survey dates and completion of surveys by the end of July.

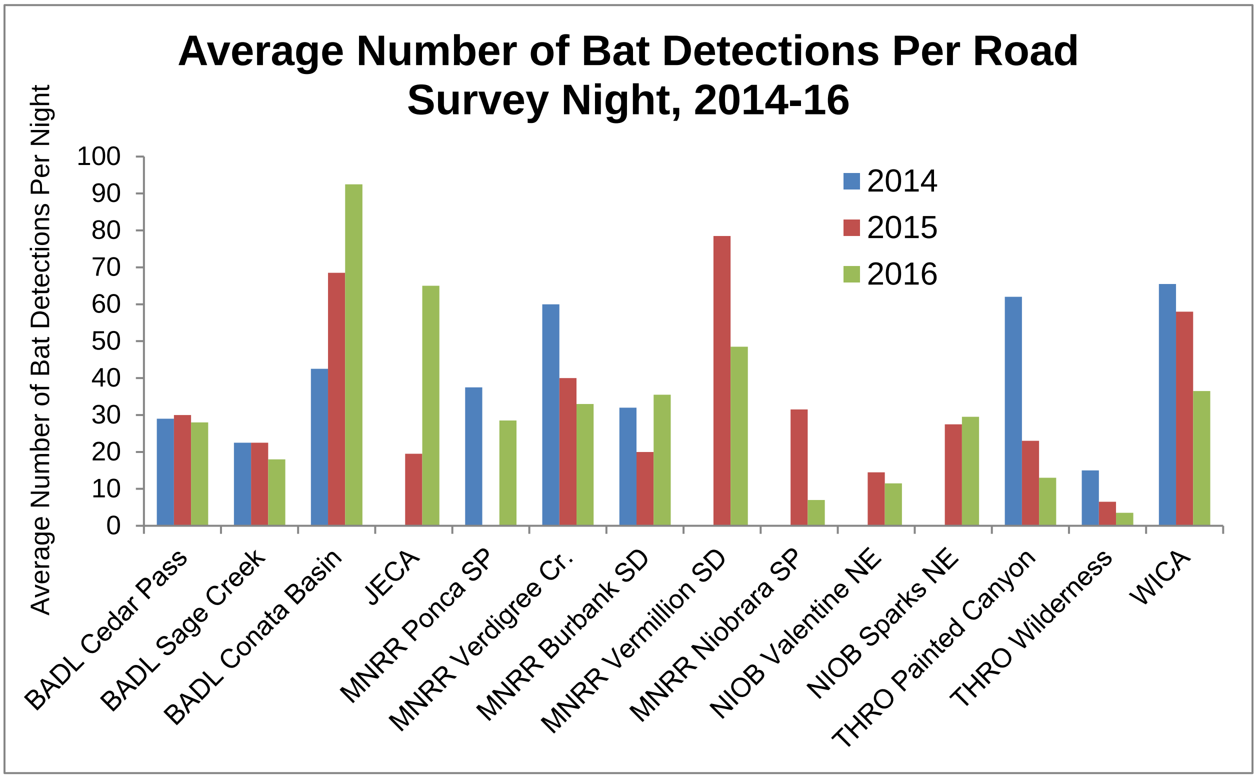

Figure 14. Average number of detections per survey for mobile routes surveyed 2014-16. The absence of a bar indicates the site was not successfully monitored in that year.

Statistical Variability

Highly variable data can mask trends and require increased sampling effort to achieve statistical significance. Knowledge of statistical variability is important for power analysis and designing a monitoring program. Therefore, I evaluated the 2014-16 data for statistical variability.

There were 247 stationary point deployments from 2014-16 (including three at Adams Homestead and Nature Preserve State Park). The average number of nights (with usable data) per deployment was 6.5 with a standard deviation of 2.0. (In 2014 deployments were typically planned for four nights; in 2015-16 they were typically planned for seven nights.) Across all 247 deployments, the average nightly rate of bat detections per station was 564.7 un-weighted by length of deployment. The lowest number of detections in a night was one at Missouri NRR (MNRR029794NE) in 2016. Interestingly, the site averaged 707.5 in the four previous nights and 372.5 in the two subsequent nights. Although it's tempting to think the low count was an equipment malfunction other nearby stations showed a similar pattern suggesting that weather influenced the count. The most bat detections in a single night were 4,392 at a large stock pond at Badlands (BADL047586NE). The lowest average rate of nightly detections over a deployment was 5.6 at a prairie site at Agate Fossil Beds NM (AGFO07) and the highest was 4,207.3 at the bat house at Fort Laramie NHS (FOLA02).

A coefficient of variation is a statistical measure that standardizes the spread or variability around a mean. The average coefficient of variation for all stationary deployments was 53% of the mean.

In 2014 most deployments were scheduled for four nights based in part on the NABat guidance (Loeb et al. 2015). In 2015-16 that was extended to seven nights in part because it was logistically efficient (e.g., we could deploy units on a Tuesday and retrieve the following Tuesday versus having to work on weekends) and in part because it was felt that longer deployments would better negate short-term influence caused by weather. It seems reasonable to conclude that longer deployments are less biased by short-term weather affects. For example, **Figure 15** shows the change in nightly detections over a 7-day monitoring session at Wind Cave. All four stations showed a dramatic reduction in bat activity on night four, but then a huge increase on the fifth night. The synchrony between stations rules out equipment affects, the presence of predators, and other station-specific factors. Weather seems the most reasonable cause in the difference between nights. Shorter deployments would have been strongly biased by the night-to-night differences in activity.

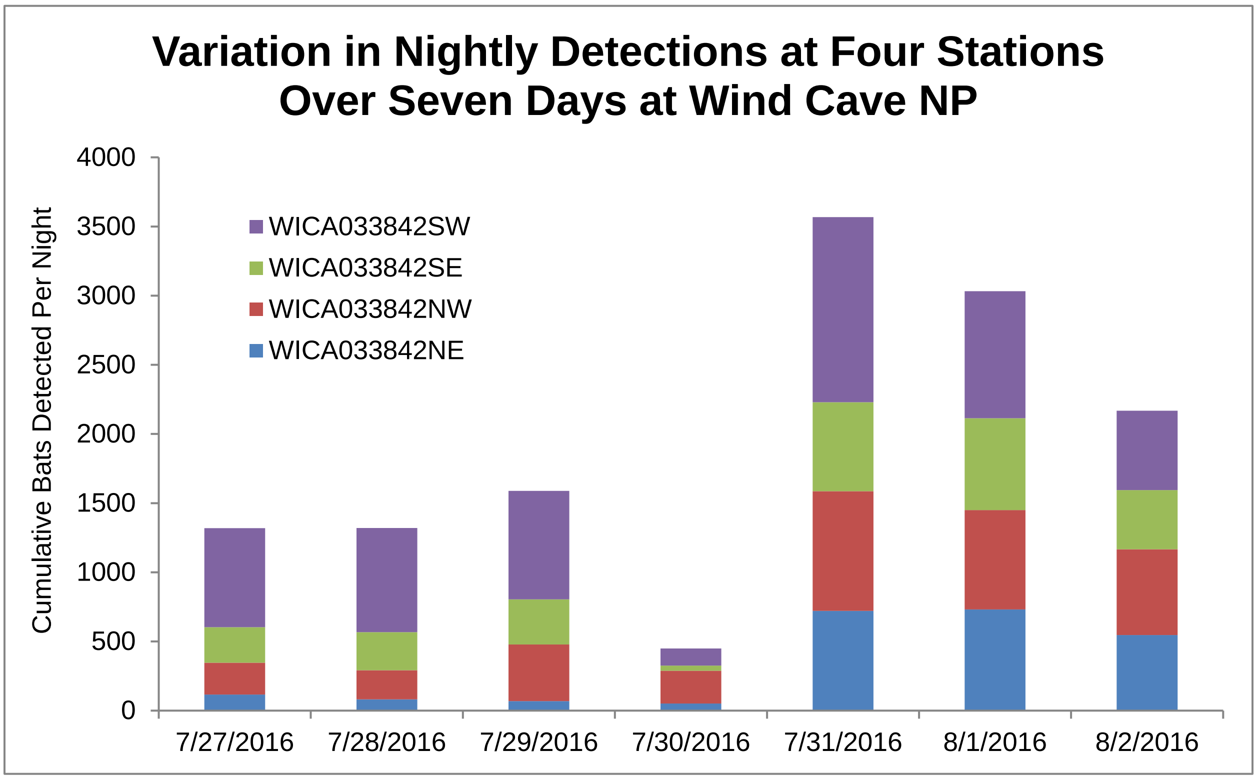

Figure 15. Nightly bat detections at four stations over seven days at Wind Cave NP in 2016.

From 2014-16 there were 34 mobile survey replicates, i.e., a route was run twice in a calendar year (this excludes the Ponca State Park route at the Missouri NRR that was not followed correctly in 2015). The fewest bats recorded in a night were 2 at the Theodore Roosevelt NP route west of the park's South Unit (THRO121832RD); the most was 115 at the Missouri NRR Vermillion Bridge route (MNRR060194RD). The fewest average number of bats over two replicates was 3.5 at the same Theodore Roosevelt route; the most was 92.5 at the Badlands Conata Basin route (BADL075712RD).

The average time between the first and second surveys was 4.1 days, with 17 of the 34 second surveys being on consecutive days. The average coefficient of variation was 25% of the mean for the two replicates. The correlation between the number of days between replicates and the coefficient of variation for the route/year was very weak (**Figure 16**), suggesting that it is not critical for replicates to be conducted on consecutive days. If fact, a few days between surveys could reduce the bias caused by short-term weather fronts.

The comparatively higher coefficient of variation at the stationary points (53%) than at the mobile surveys (25%) can reasonably be attributed to the potential for repeat flyovers of stationary points by individual bats. In contrast, mobile surveys are less prone to repeated flyovers by individual bats due to the speed of the vehicle.

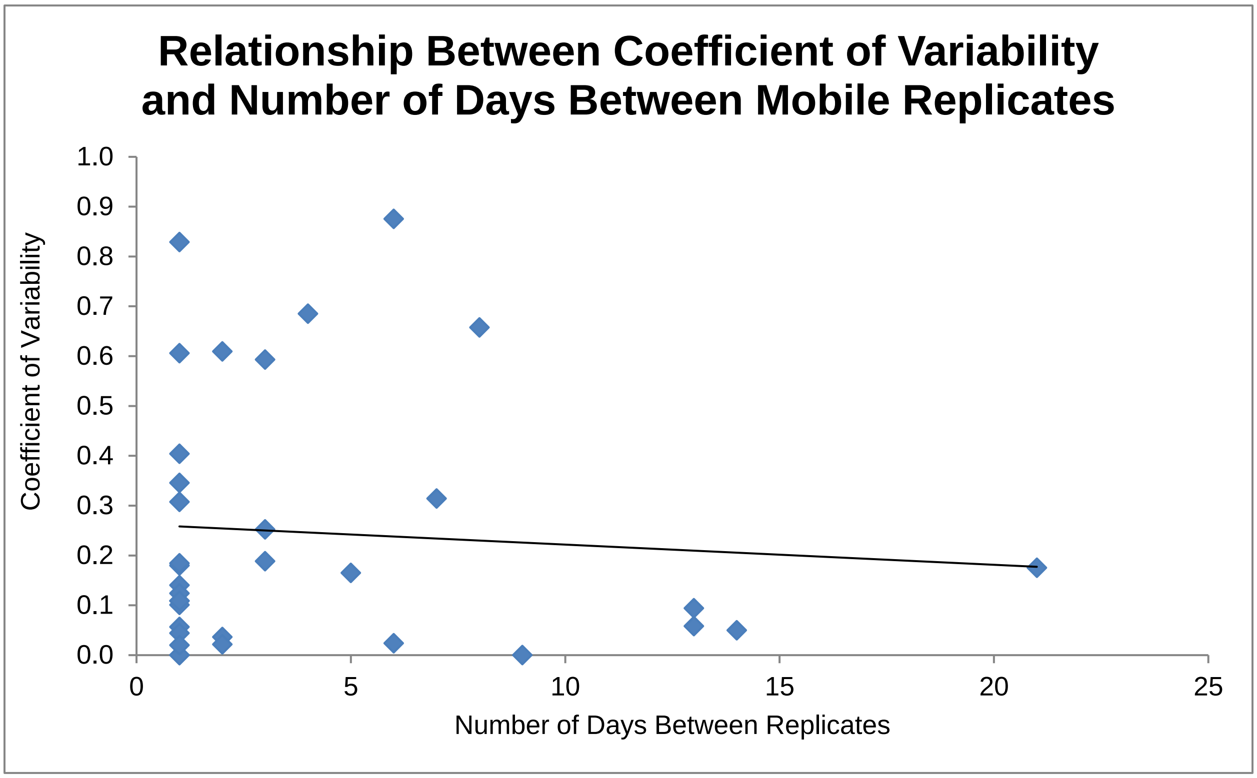

Figure 16. Relationship between coefficient of variability and number of days between mobile replicates.

Equipment Reliability

The Network acquired 34 Wildlife Acoustics SM3Bat units in FY14. Four of the units were loaned to Tallgrass Prairie National Preserve in 2014 and again in 2015 for bat monitoring. Three units were loaned to Devils Tower National Monument in 2015 for sound monitoring. The remaining 27 units were used by the Network. All were deployed in the field for varying lengths.

After two field seasons five of the units malfunctioned. One of the units loaned to Devils Tower appears to have a defective memory card slot as the recorder says *Error* where it should be displaying the size of the inserted memory cards. One of the malfunctioning units has a LCD display that is unreadable as the lines of text are corrupted. One unit repeatedly runs through diagnostic tests. The last two units will not power up: Wildlife Acoustics technical support was contacted regarding a reset process, but that failed to fix the problem. The units will be sent to Wildlife Acoustics for inspection and, if reasonable, repair. In the winter of 2015-16 Wildlife Acoustics came out with a SM4Bat model. The unit is smaller and lighter than the SM3Bat; however, the Network will continue to use the SM3Bat units for consistency between years.

The SM3Bat recorders were deployed with either 64GB Transcend class 10 cards or, more commonly, 32GB Kingston class 4 cards. The 64GB cards were less reliable with 11 of 14 deployments ending prematurely due to card failures when using firmware 1.2.5 in the recorders. In contrast none of the 126 deployments using the 32GB cards ended prematurely due to card failures. However, the 64GB cards did not experience any failures when the SM3Bat units were upgraded to firmware 1.2.7 in the summer of 2015. In 2016 only 32GB cards were used as they were more reliable and had sufficient capacity for the deployments.

No other equipment problems were experienced. All microphones appeared to be working properly; however, they should be tested prior to future field seasons and if they do not meet the manufacturer's sensitivity thresholds, discarded.

Battery Tests

The Network had a large supply of Duracell Procell D-size alkaline batteries from a previous wildlife study. They were the primary power supply used for operating the SM3Bat recorders. The Network also acquired a supply of rechargeable PowerEx 11,000 mAh NiMH batteries. The alkaline batteries were tested for longevity in the summer of 2014. The tests used the same settings as field units and bat activity at the test site was comparable to field sites in the Network. The alkaline batteries operated the units for about ten days with very little variability between recorders. Field deployments were consistent with those results as alkaline batteries tested after 4-7 day deployments showed about 40-60% of power left. The rechargeable batteries were not tested.

Agate Fossil Beds NM

Agate Fossil Beds NM encompasses 1,237 ha (3,058 ac) in western Nebraska (**Figure 1**). Habitat in the park consists of archetypal Northern Great Plains mixed-grass prairie with the only natural trees being a small grove of old cottonwoods in the floodplain of the Niobrara River. Other trees have been planted around the headquarters and staff housing (**Figure 17**). The Niobrara River passes through the park and is a significant natural resource; however, within the park the river is stream-like, generally being only a few meters across and less than a meter deep. The associated floodplain and moist-soil area is relatively broad. Substantial flooding occurred in the summer of 2015 creating large areas of standing water.

Figure 17. Habitat at Agate Fossil Beds NM. (NPS/ DAN LICHT)

The park did not meet the *a priori* criteria for inclusion in the NABat survey effort, i.e., that at least a portion all four quadrants of a 10x10 km NABat cell lie within the park. As a result, recorders were deployed at the park based on habitat features of interest to management and the author (**Figure 18**). Whereas most other Network parks had 4-12 monitoring stations, 43 stations were established at Agate Fossil Beds (however, the naming convention goes from AGFO01 to AGFO44 as no site #28 was established). The purpose of the expanded monitoring was to empirically describe the summer habitat use by bats at the park, as the park is typical of the once vast Great Plains grassland ecosystem. Detailed analysis of habitat use by bats at the park will be analyzed at a later date and published elsewhere. This report will provide only a cursory summary of the results.

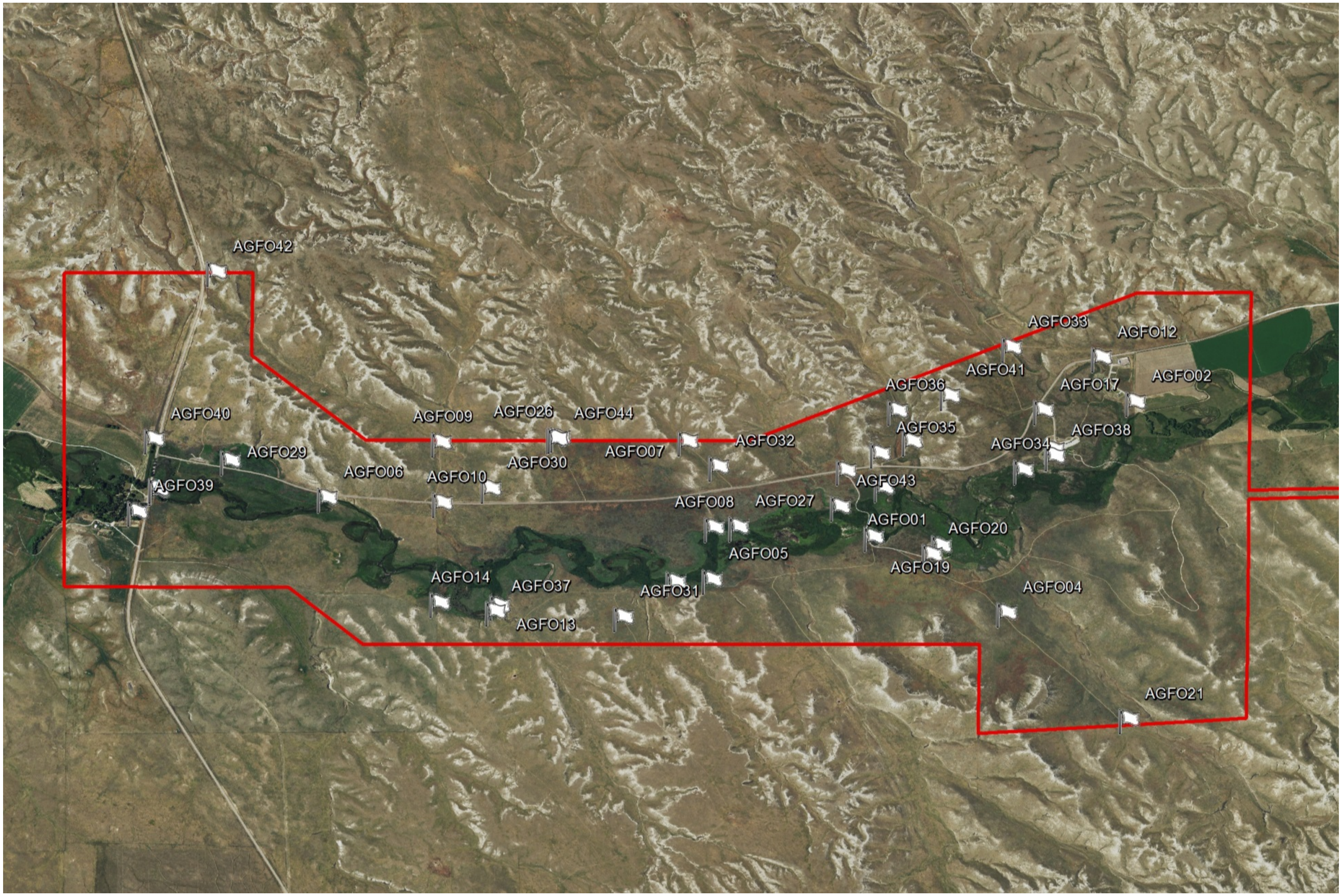

Figure 18. Location of stationary points monitored at Agate Fossil Beds NM in 2015-16.

Monitoring sessions were initiated on June 1 and September 4, 2015, and on June 7 and August 8, 2016. The sessions were intended to last 7 days; however, some units malfunctioned before the planned retrieval date and some units could not be retrieved as scheduled due to flooding. Usable data was not collected from station AGFO14 and AGFO21 due to corrupted memory cards. Stations AGFO30 and AGFO 32 stopped early in the first night for unknown reasons. In addition, at stations AGFO08, AGFO09, and AGFO44 the tripod/pole/microphone systems were laying on the ground when retrieved. The first two deployments likely fell over on June 2, 2015 due to a windstorm. The units were up-righted on June 3. An analysis of the data found nothing unusual so the data was not censored. In six of the deployment sessions the last night of data was censored as an examination of the data and the non-working status of the unit when retrieved suggested the unit had shut down during the night. The relatively higher rate of malfunctions at Agate Fossil Beds NM compared to other parks was probably due to the use of 64GB memory cards and rechargeable nickel-metal hydride (NiMH) batteries. Due to the poor performance their use was mostly discontinued.

A total of 56,601 recordings were made from the 280 complete survey nights. (Another 1,409 recordings were censored because the night was incomplete or the files unreadable.) Of the 56,601 recordings, 6% were identified as noise by Kaleidoscope. The percentage of noise files was > 20% at stations AGFO19, AGFO22, AGFO40, and AGFO43: there's no obvious reason for the high rate. Of the 53,370 bat recordings, Kaleidoscope did not identify 31% to species level.

The bat community at Agate Fossil Beds NM was poorly studied prior to the 2014-16 acoustic monitoring. The NPS NPSpecies database reported one species present at the park and six others probably present (**Table 8**). However, NPSpecies does not appear to consider six nights of acoustic surveys conducted at the park 2003-04 (Schmidt et al. 2004); that study reported seven species as present. This study suggests the presence of at least eight species, two of which were not included in the NPSpecies list for the park (**Table 8**). The auto-ID software reported with statistical confidence that the little brown bat was present, even though some authors list the park as outside the current range for the species (Benedict 2004). However, Schmidt et al. (2004) also reported that species as present at the park. Recent reports have expanded the known westward distribution of the tri-colored bat (Geluso et al. 2005). Kaleidoscope found statistical evidence the species was present in the park. The Sonobat Wyoming-East package did not include a filter for that species; however, when I ran the data through the Sonobat South Dakota-Eastern package the software said the species was likely present in 2015. Similarly, recent studies have confirmed that the evening bat ranges further west than originally thought (Serbousek and Geluso 2009). Both Kaleidoscope and the Sonobat South Dakota-Eastern package found probabilistic evidence of presence, although I'm less willing to conclude it's definitively present based on the acoustic data in part because the specie's call is similar to the eastern red bat. As a result, I conclude it's probably present. Whereas NPSpecies indicated that the northern long-eared bat was probably present in the park, this study found no convincing evidence that it is currently present. Schmidt et al. (2004) reported it as being present in both 2003 and 2004 based on acoustic surveys. The species has suffered a dramatic decline in abundance in recent years (U.S. Fish and Wildlife Service 2016) so it's not unreasonable to conclude it was once present in the park, but is now absent or very infrequent. Similarly, Schmidt et al. (2004) reported the (western) long-eared bat as being present; however, this study found no evidence of that species.

Table 8. Species presence at Agate Fossil Beds NM.

Species	NPSpecies Status[1]	Kaleidoscope		Sonobat[2]		Conclusion
		2015	2016	2015	2016	
T. Big-eared Bat	–	0	0	0	0.58	Unconfirmed
Big Brown Bat	Probably Present	1	1	1	1	Present
Eastern Red Bat	Probably Present	1	1	1	1	Present
Hoary Bat	–	1	1	1	1	Present
Silver-haired Bat	Probably Present	1	0	1	1	Present
W. Small-footed Myotis	Present	1	1	1	1	Present
Long-eared Myotis	Probably Present	0	0	0	0	Not in Park
Little Brown Bat	Probably Present	1	1	1	1	Present
N. Long-eared Bat	Probably Present	0	0.01	0	0	Unconfirmed
Fringed Myotis	–	0	0	0	0	Not in Park
Long-legged Myotis	–	1	1	0.85	0.20	Present
Evening Bat	–	1	1	1	0.54	Probably Present
Tri-colored Bat	–	1	0.38	1	0.74	Present

[1] NPSpecies accessed 9-30-2015.

[2] Used Wyoming–Eastern classifier package for all species except for evening and tri-colored bats that used South Dakota-Eastern package.

Kaleidoscope classified about 1/3rd of the bat recordings as hoary bats (**Figure 19**). Conversely, Sonobat assigned most of its classifications to the silver-haired bat, the big brown bat, and then the hoary bat (**Figure 20**), demonstrating the lack of agreement that is often found between the software (Licht 2016).

According to Kaleidoscope the average number of bat detections per night per station was 191. This is lower than at many other parks; however, this can be explained in part by the study objectives. Many units were deployed in open prairie where bat activity was expected to be low, thereby bringing down the park average. The highest rate of detections occurred at stations deployed near trees and surface water (**Figure 21**). This is not surprising as trees provide roosting sites and surface water is often associated with prime night-time foraging. The highest detection rate for any site was AGFO37, which averaged 915 detections per night: that site was located in a natural grove of old cottonwood trees. Bat activity was slightly above average at the two headquarters deployments (about 200 bats per night). The reason for the high rate of bat activity near the headquarters is not known. There are no large roosting trees in the vicinity and the park does not keep an outdoor light on that would attract insects and foraging bats. However, the concrete parking lot might be retaining heat that attracts nocturnal insects and foraging bats. Or bats might be using the buildings for short-term night-time roosting (they are not known to daytime roost at the structures). The recorder deployed in 2015 along the north boundary close to a privately-owned fabricated stock tank had 222 bats per night whereas in 2016 the tank was dry and a nearby unit recorded only 22 bats per night. Bats were probably using the tank for drinking in 2015. Substantially fewer bat detections occurred at stations placed in prairie areas, regardless of whether or not they were near the blacktop road (**Figure 21**). More detailed analysis of habitat use will be conducted outside of this report.

This study substantially increased the list of bat species known to be using park. The study also provided useful information on habitat use by bats. The old cottonwood trees along the Niobrara River, as well as the planted trees at the park housing, provide critical roosting habitat for bats. Without the trees it is almost certain that there would be much less bat activity at the park. A subset of deployment sites, with emphasis on sites near trees and surface water, should be revisited in future years to monitor changes in bat activity over time.

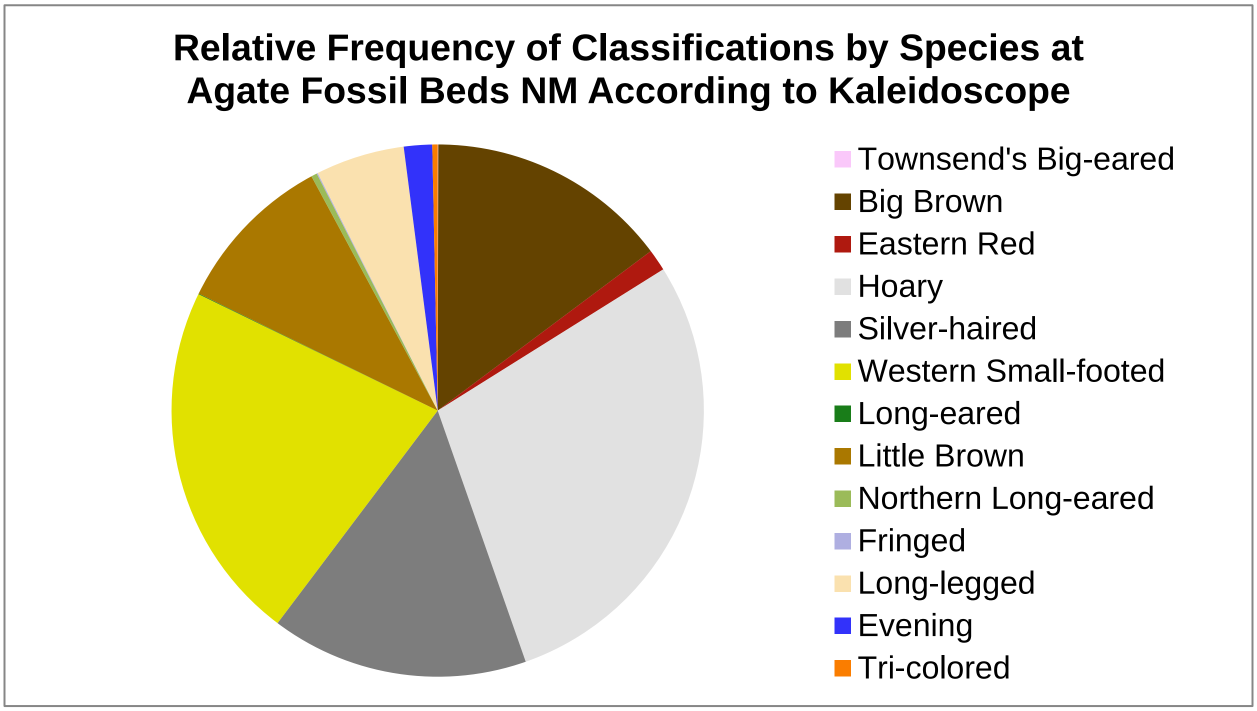

Figure 19. Relative frequency of classifications by species at Agate Fossil Beds NM according to Kaleidoscope.

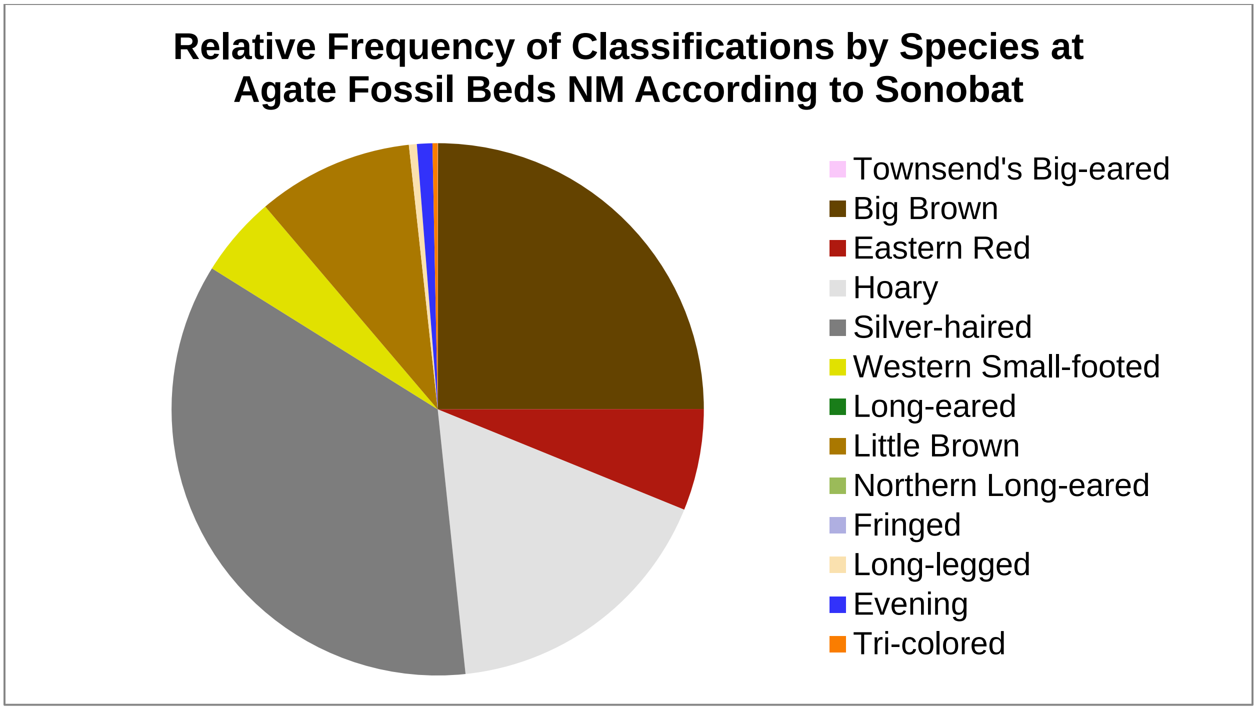

Figure 20. Relative frequency of classifications by species at Agate Fossil Beds NM according to Sonobat. Results from Wyoming-East classifier package except for evening and tri-colored bats which came from the South Dakota-Eastern package.

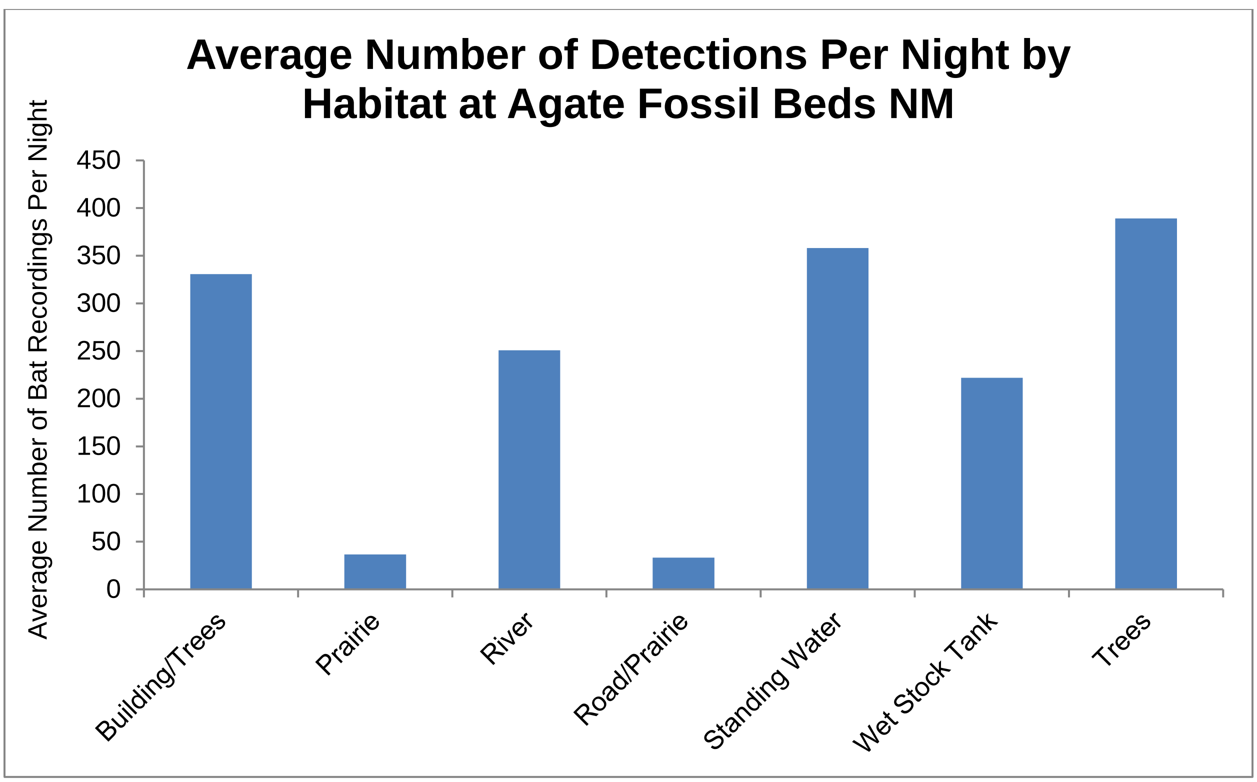

Figure 21. Average number of detections per night by habitat at Agate Fossil Beds NM.

Badlands NP

Badlands NP encompasses 98,239 ha (242,756 ac) in southwestern South Dakota. The park is comprised of a North Unit, a South Unit, and a discontiguous Palmer Unit. The South and Palmer Units comprised about half of the park. Those units lie within the Pine Ridge Indian Reservation and have been proposed for tribal management. Yet there remains much uncertainty as to whether such transfer will occur and who will ultimately have management jurisdiction. As a result, bat monitoring was not conducted in those units. The North Unit consists of rugged badlands topography interspersed with mixed-grass prairies. Natural surface water is scarce and is mostly found in the sediment-laden Sage Creek drainage. However, to support the bison herd several large anthropogenic stock ponds have been maintained. Woody vegetation is scarce and consists primarily of wooded ash draws, juniper stands within the badlands topography, and a few cottonwoods. The highly eroded badlands likely provide roosting habitat for some bat species.

Four NABat cells had at least a portion of all four quadrants within the boundaries of the North Unit and were therefore considered for monitoring using the NABat protocol. However, one of the cells was entirely within designated wilderness and there were no roads within the cell. Furthermore, the quadrants were all a significant distance from roads and had poor access. As a result, that cell (NABat #098188) was not monitored in 2014-16. Due to the limited road network much of the mobile routes in the three monitored cells extended outside the NABat cell boundary.

Stationary monitoring was conducted in each year 2014-16. In four cases the recorders were not operating when retrieved and in three cases the tripod/microphone assemblies had been tipped over, probably by bison in two of the cases and by wind or park horses in the other. These data were censored where appropriate, i.e., if the unit appeared to stop working mid-way through a night that night's data was not used. The censoring resulted in no data for two of the 2016 deployment sessions (BADL047586NE and BADL047586SE). Station BADL075712SW was determined subsequent to the 2014 field season to be outside the NABat cell; a replacement site was searched for in 2015 but not found, hence monitoring resumed at the station in 2016.

Two mobile surveys were at each cell each year. However, the GPS unit failed to record spatial data on two of the mobile surveys. Three of the surveys were conducted after August 15; hence the counts might have been confounded by migrants and volant young.

A total of 240,738 recordings were made at Badlands in 2014-16 (excluding censored records). Of those, 5% were rejected by Kaleidoscope as noise files. This was a low rate of noise files, perhaps a consequence of the absence of trees and anthropogenic ultrasonic noises. Of the point recordings identified as being made by bats, 34% could not be identified to the species level by Kaleidoscope. An additional 2,840 recordings were collected in the completed mobile surveys, of which 75% were noise files. Of the remaining 707 recordings identified as bats, 45% could not be identified by Kaleidoscope to the species level.

Prior to this study there were nine species reported to be present at Badlands NP according to NPSpecies (**Table 9**). Kaleidoscope and Sonobat agreed on the presence of seven species, including the eastern red bat, a species not listed as being present by NPSpecies. However, both software packages indicated the presence of a species not confirmed by the other package; specifically, Kaleidoscope indicated the long-legged myotis was present and Sonobat indicated the fringed myotis was present. NPSpecies reported the threatened northern long-eared bat as being present; however, that determination was likely based on a 1999 mist netting capture by Tigner (1999). Based on the 2014-16 acoustic data there was insufficient evidence to say with statistical confidence that the threatened northern long-eared bat was still present in the park. Furthermore, a 2005 acoustic survey and manual vetting by Tigner (2006) also failed to report the species. Likewise, the 2014-16 acoustic recordings did not confirm the presence of the Townsend's big-eared bat at statistically significant levels; however 1999 mist netting (Tigner 1999) and an acoustic survey in 2005 (Tigner 2006) indicated the species was present. Jones and Genoways (1967) reported a 1928 record of a long-eared bat being found in the Badlands region of South Dakota; however, current range maps suggest the park is outside that specie's range (**Table 4**). Hence, I did not include it in the Kaleidoscope processing; however, it was included by default in the Sonobat South Dakota-Black Hills package. The software did not find statistically significant evidence of the specie's presence. The tri-colored bat has recently been reported further west in the Great Plains region than originally thought (Geluso et al. 2005); Kaleidoscope reported the species being present at Badlands with a high degree of certainty. The species was not included in the Sonobat South Dakota-Black Hills package; however it is included in the South Dakota-Eastern package. When I ran the 2014-16 data through that package Sonobat reported a 0.74 likelihood of species presence in all three years (however, were the species included in the Black Hills package the likelihood estimate would likely be different because then the species would be "discriminating" against a different suite of bats).

Table 9. Species presence at Badlands NP.

Species	NPSpecies Status[1]	Kaleidoscope			Sonobat[2]			Conclusion
		2014	2015	2016	2014	2015	2016	
T. Big-eared Bat	Present	0	0	0	0.77	.77	0.77	Unconfirmed
Big Brown Bat	Present	1	1	1	1	1	1	Present
Eastern Red Bat	–	1	1	1	1	1	1	Present
Hoary Bat	Present	1	1	1	1	1	1	Present
Silver-haired Bat	Present	0	1	1	1	1	1	Present
W. Small-footed Myotis	Present	1	1	1	1	1	1	Present
Long-eared	–	–	–	–	0.56	0.75	0.56	Unconfirmed
Little Brown Bat	Present	1	1	1	1	1	1	Present
N. Long-eared Bat	Present	0	0	0	0.55	0.18	0.37	Unconfirmed
Fringed Myotis	Present	0	0	0.28	1	1	1	Present
Long-legged Myotis	Present	1	1	1	0.60	0.99	0.61	Present
Tri-colored Bat	–	1	1	1	–	–	–	Present

[1] NPSpecies accessed 9-30-2015.

2 South Dakota - Black Hills classifier package.

Kaleidoscope assigned most of the recordings from the stationary points to the western small-footed myotis (**Figure 22**). Badlands was the only park in the Network where that species comprised a plurality of the classifications. This is not surprising as the species is generally associated with arid treeless environments with rugged topography. However, Sonobat assigned most of the recordings to the big brown bat followed by the silver-haired bat and then the western small-footed myotis (**Figure 23**). This disparity highlights the different ways the software classify a call and the challenges in using acoustic data for species-specific analyses.

The relative frequency of detections generally varied between stationary points in predictable ways. For example, at the Sage Creek Road cell (NABat #047586) the two stations in the eastern quadrants had relatively high rates of bat activity (**Figure 24**); both stations were next to stock ponds. In contrast, the stations in the two western quadrants had comparatively less activity. Those stations were near Sage Creek, but apparently that sediment-laden water source doesn't provide suitable drinking water and/or the forage base for bats compared to the stock ponds.

In contrast to the Sage Creek Road cell, where most of the classified recordings were assigned to the big brown bat, the Conata Basin cell (NABat #075712) had a relatively higher frequency of calls classified by Kaleidoscope as western small-footed myotis (**Figure 25**). The difference is not surprising as the Conata Basin cell included a greater amount of rugged badlands topography, a likely roosting habitat for the species. Within the cell the stationary point with the most activity was the site located in the SW quadrant. The site was next to a large wetland. Although the site was determined to be outside the cell prior to the 2015 field season, and therefore not monitored in that year, monitoring at the site resumed in 2016 as no suitable replacement was found. The stationary point in the SE quadrant was next to a dry stock pond; however, there was a grove of decadent cottonwoods next to it that likely provided quality roosting habitat. It's possible that in wet years back activity at the site could increase substantially.

The Cedar Pass cell (NABat #029922) cell is noteworthy because the stationary point in the NE quadrant (**Figure 26**) was one of the more active stations in the Network. The station was next to a small stock pond within a prairie landscape. Similarly, the station in the SE quadrant also had a high rate of bat activity; that site was next to the park's sewage ponds. Sewage ponds are known to have high rates of bat activity (Stahlschmidt et al. 2012). That station also had more red bat detections than other stations in the park. This is plausible as the site is near the visitor center and administrative buildings where large deciduous trees are relatively common. The two stations in the western quadrants were within arid badlands topography and had relatively few detections. They were a substantial distance from surface water and large trees.

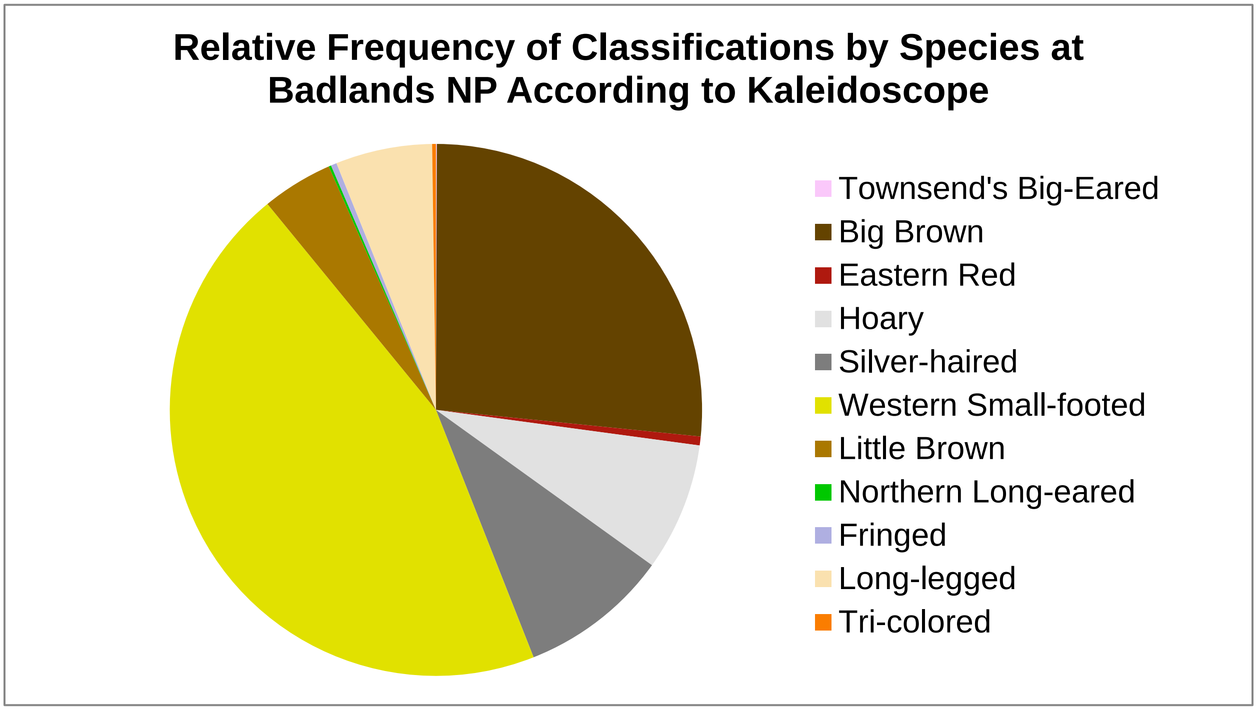

Figure 22. Relative frequency of classifications by species at Badlands NP according to Kaleidoscope.

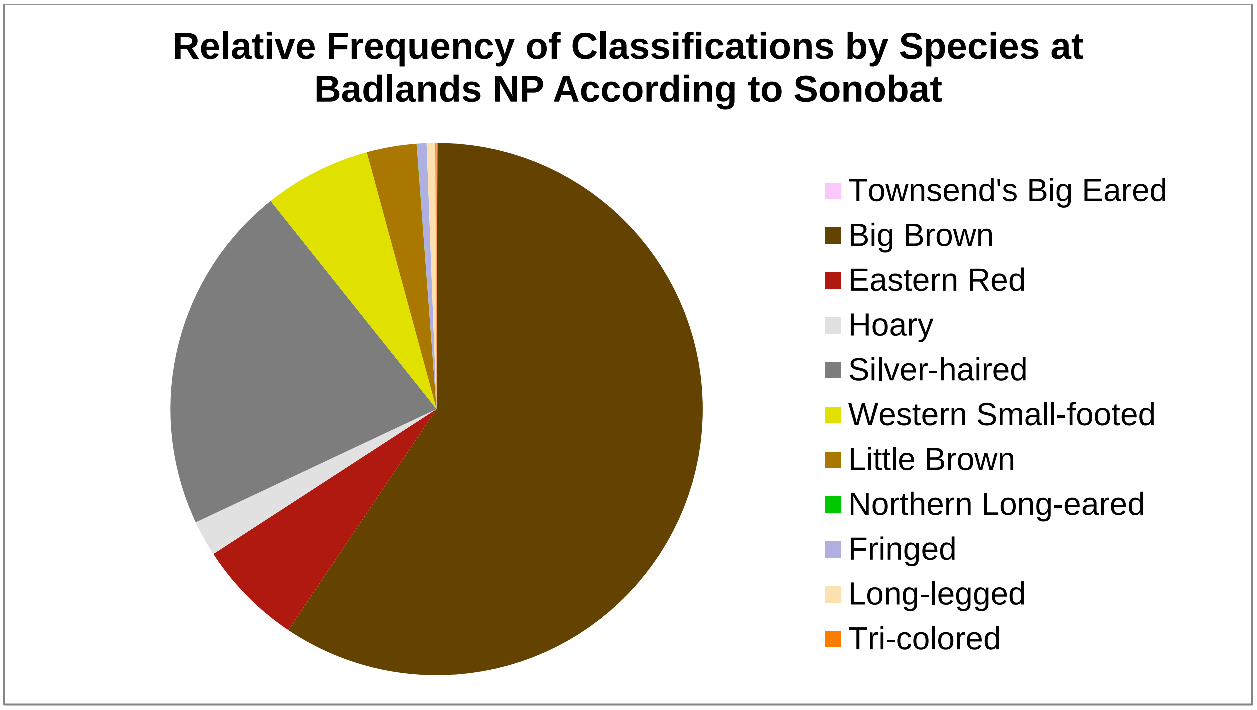

Figure 23. Relative frequency of classifications by species at Badlands NP according to Sonobat. Results from South Dakota-Black Hills classifier package except for tri-colored bat which came from South Dakota-Eastern package.

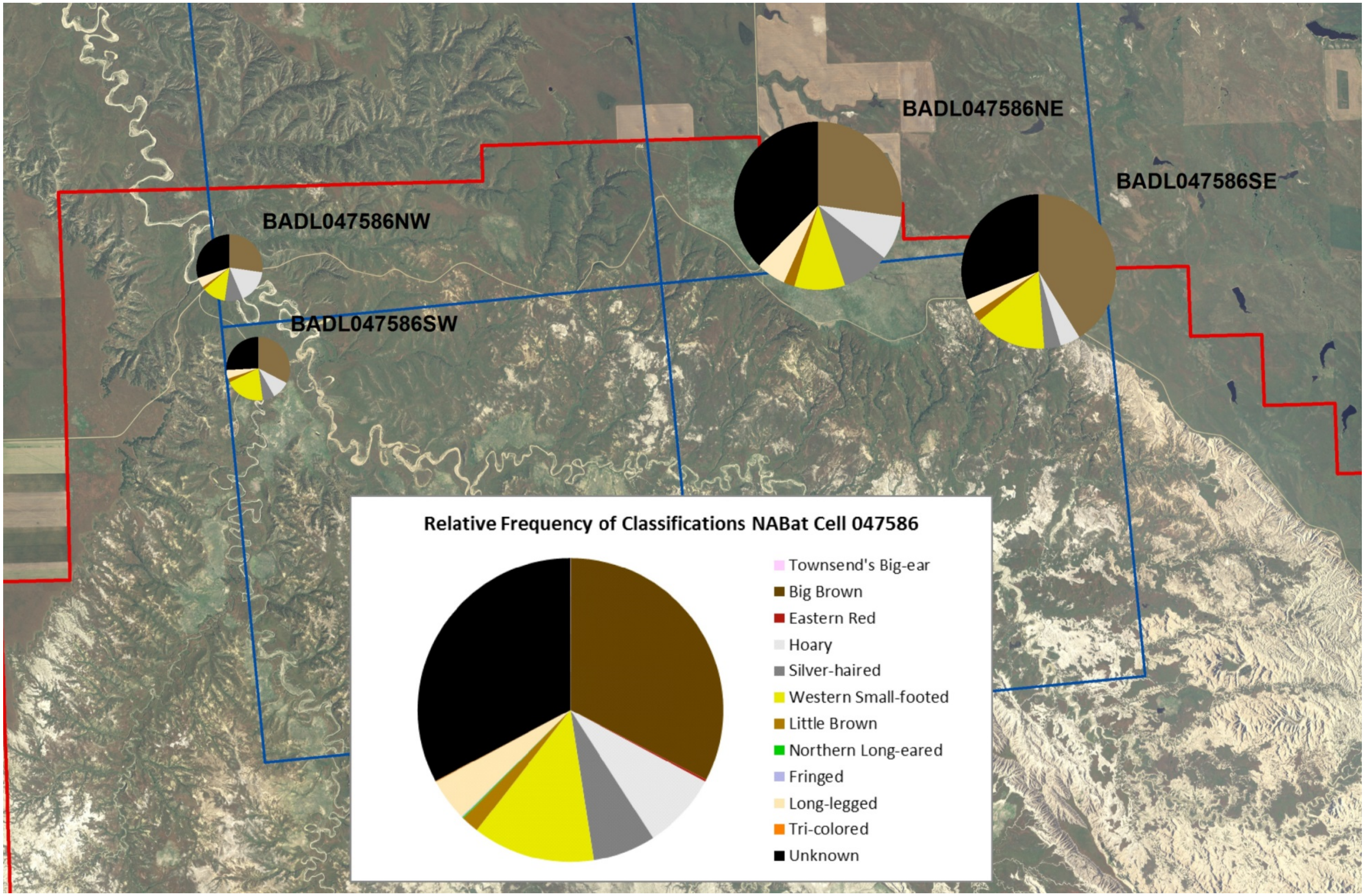

Figure 24. Relative frequency of classifications by species at the Badlands NP Sage Creek Road cell (NABat #047586). Size of circles is correlated with the rate of nightly detections. Blue lines are the NABat cell quadrants and red lines are the park boundary.

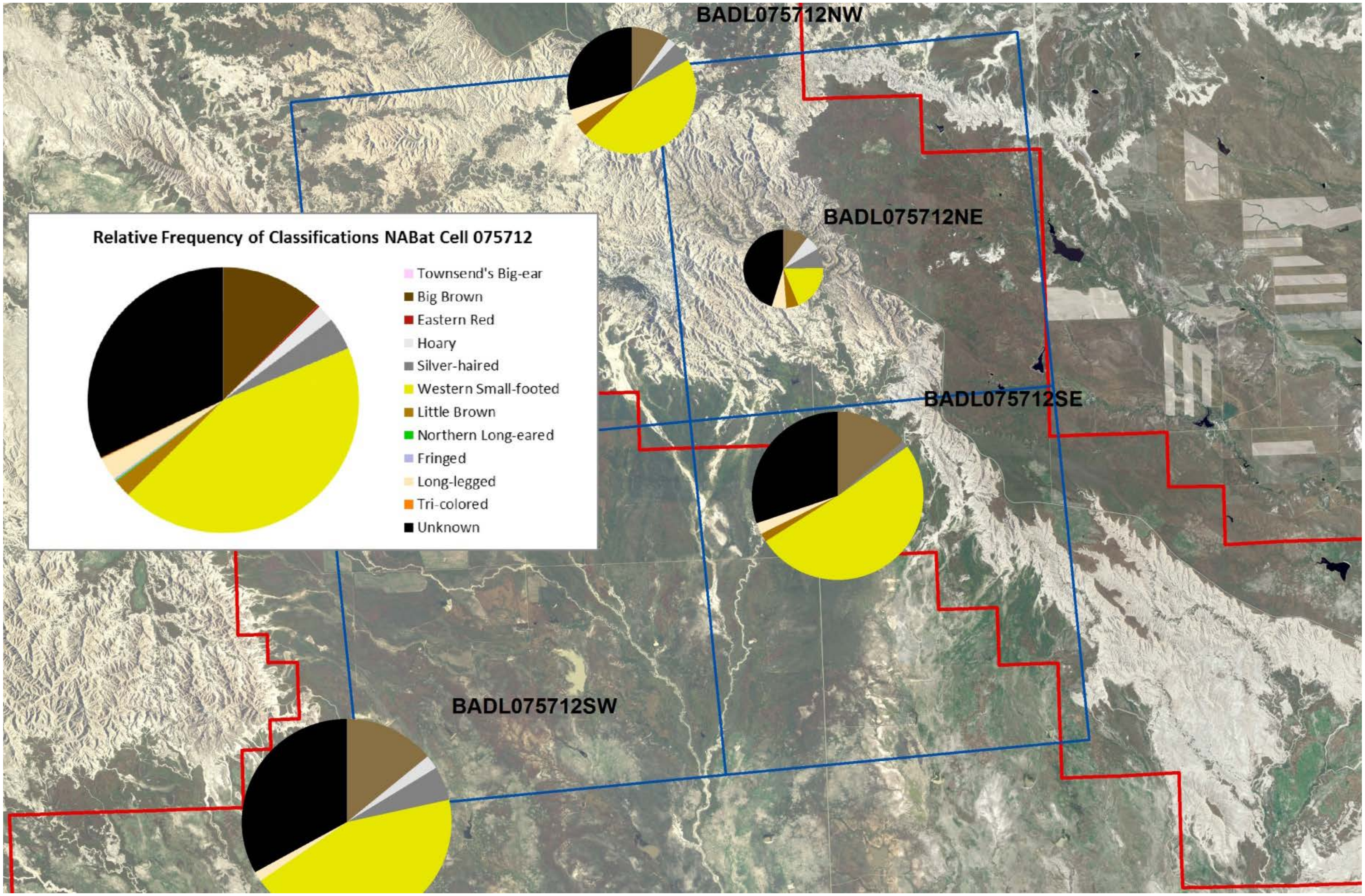

Figure 25. Relative frequency of classifications by species at the Badlands NP Conata Basin cell (NABat #075712). Size of circles is correlated with the rate of nightly detections. Blue lines are the NABat cell quadrants and red lines are the park boundary.

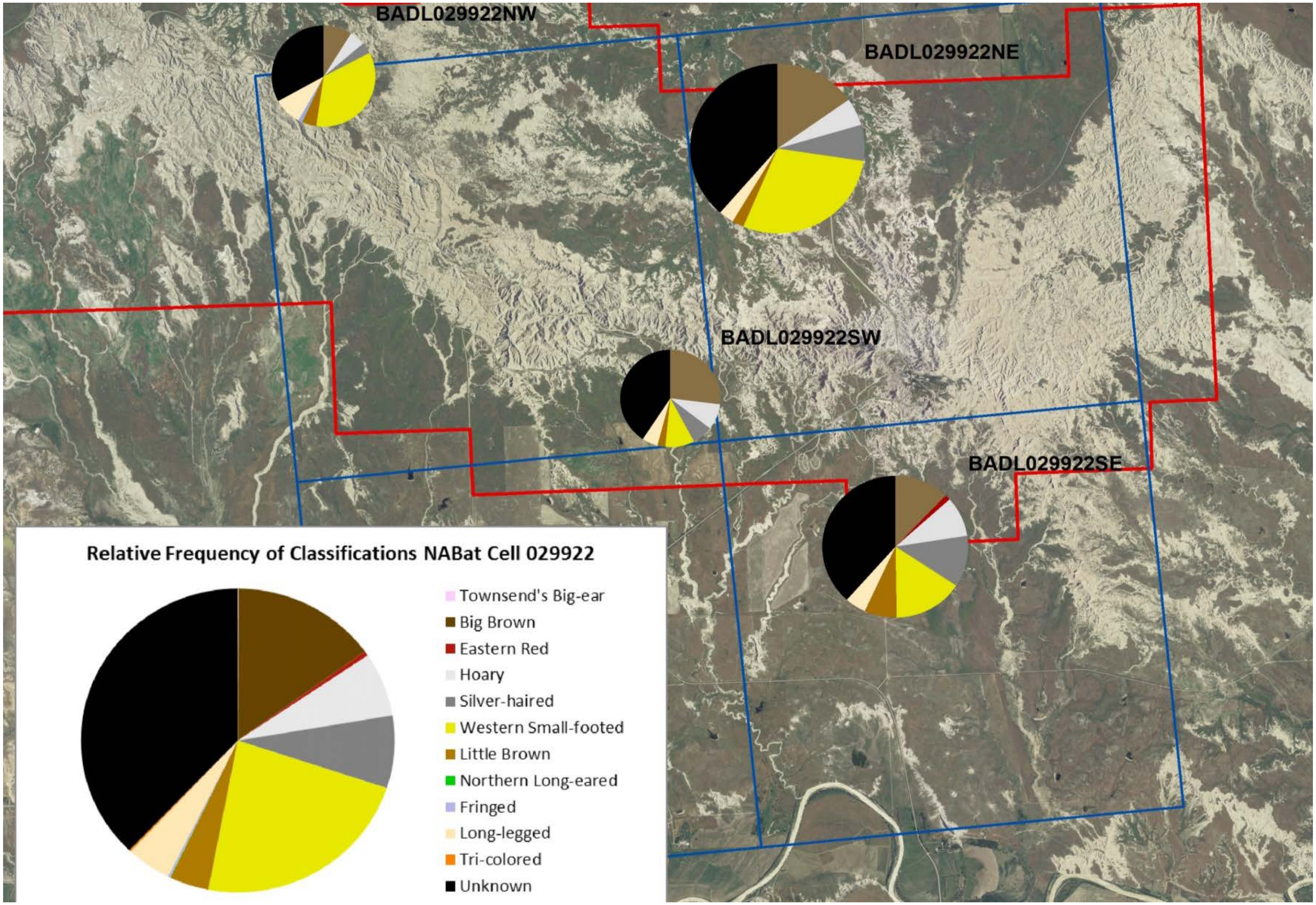

Figure 26. Relative frequency of classifications by species at the Badlands NP Cedar Pass cell (NABat #029922). Size of circles is correlated with the rate of nightly detections. Blue lines are the NABat cell quadrants and red lines are the park boundary.

The 9 stationary points monitored in all three years 2014-16 averaged 987 detections per night in 2014 compared to 1,052 in 2015 and 1,064 in 2016 (unweighted by the number of nights in the deployment session). Although the total numbers indicate a slight increase in activity each year there was no consistent year-to-year pattern across the stations (**Figure 27**) nor were the between-year differences statistically significant ($P>0.05$). The stations were deployed across a variety of habitats and as one would expect, differences between sites were statistically significant ($P<0.05$).

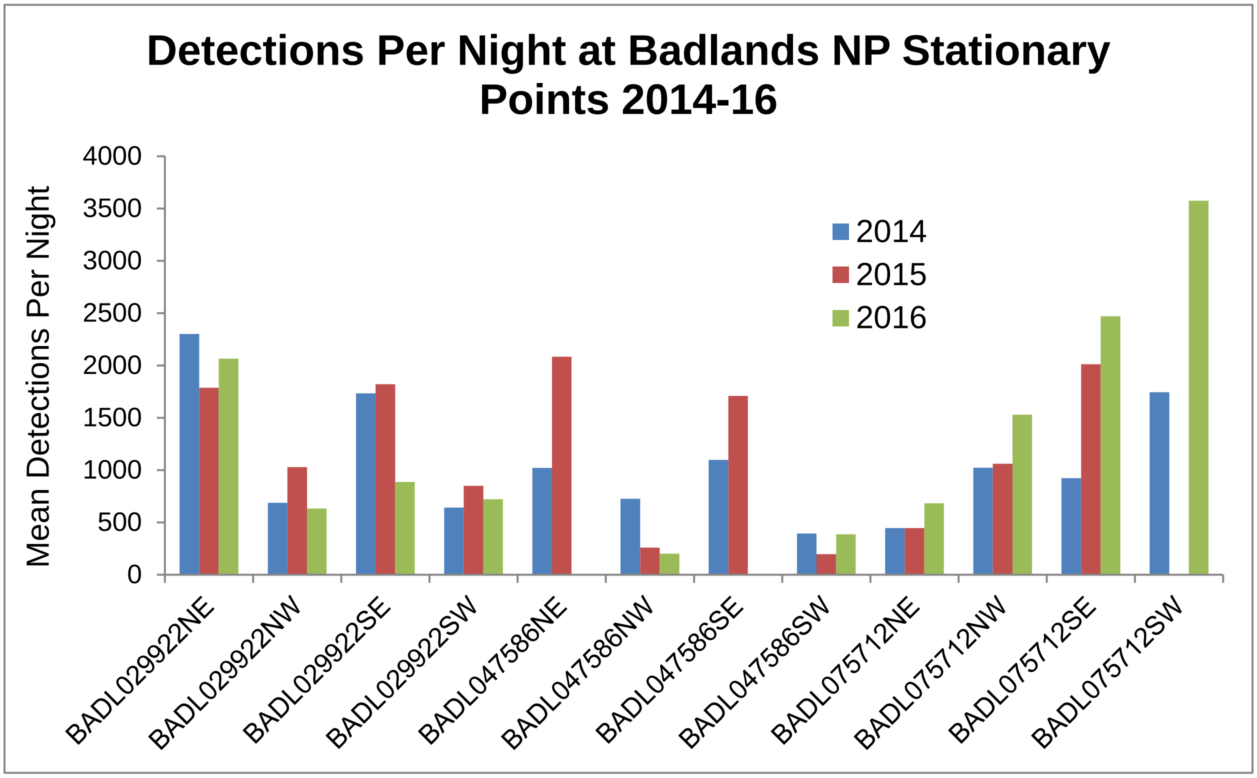

Figure 27. Detections per night at Badlands NP stationary points 2014-16. The absence of a bar indicates the site was not successfully monitored in that year.

The three mobile survey routes were run twice each year 2014-16. A common theme was that road sections near water and badlands topography had more detections than did road sections in flat prairie. For example, the Cedar Pass route (NABat #029922) had a high rate of detections when it passed through Badlands topography compared to when it passed through open prairie north of the park (**Figure 28**). The Sage Creek route (NABat #047586) had very little activity except for when it passed a large wetland near a 90 degree turn in the road about 6.5 road km (4 miles) west of the park's west boundary (**Figure 29**).

The most active of the three routes was associated with the Conata Basin cell (NABat #075712: **Figure 30**). That route had a high rate of detections in all years and throughout the route. The east half of the route traversed the edge of a badlands wall and the west half went through private ranches that had several stock points. An interesting phenomenon of the route was that the author of this report frequently observed bats foraging in the light shine of vehicle headlights, especially in the section above the badlands wall. The bats were often flying just a few meters above the blacktopped Highway 240 (i.e., the main park road). It's possible that the warm road surface attracted insects which in turn attracted foraging bats. The observed bats were very small and moth-like in flight, characteristic of the western small-footed myotis, a conclusion consistent with the data. The bats might have day-roosted in the nearby badlands topography. In some of these observations the skyward-pointing roof-mounted directional microphone failed to detect the low-flying bats and hence, the road surveys might have under-recorded the numbers of bats present, and specifically, the number of western small-footed myotis. This phenomenon warrants further investigation both in terms of bats not being detected and the blacktop road being used by bats for foraging.

The three routes averaged 58 bats per night in 2014 versus 68 in 2015 and 73 in 2016. Although suggesting an increase there were no consistent between-year patterns (**Figure 31**) and the between-year differences were not statistically significant ($P>0.05$); however, the differences between routes was statistically significant ($P<0.05$).

In summary, there doesn't appear to be any between-year difference in bat abundance at Badlands NP, suggesting that the overall population is not currently being impacted by white-nosed syndrome. However, the threatened northern long-eared bat was captured with mist-nets in 1999 (Tigner 1999), yet this study failed to confirm with statistical confidence that the species was still present in the park. Yet absence of proof is not proof of absence and the park should manage resources as if the bat is present. Badlands appears to have a bat community somewhat different than many other parks in the Network, probably a consequence of its unique physiographic environment. For example, the western small-footed myotis, a species often associated with arid environments, appears to be relatively common in the park. Not surprisingly, bat activity was much higher near surface water than at other areas within the park, specifically, at sites near anthropogenic surface water. However, the anthropogenic water sources might also have higher recorded rates of activity because they are point attractants whereas the creeks and streams are linear and therefore might result in more dispersed bat foraging. The park maintains several of the anthropogenic wetlands for bison; their value to bats also needs to be considered in management. The stock ponds and sewage pond are likely especially important for lactating females (Adams and Hayes 2008) and might have a substantial influence on bat reproduction in the park.

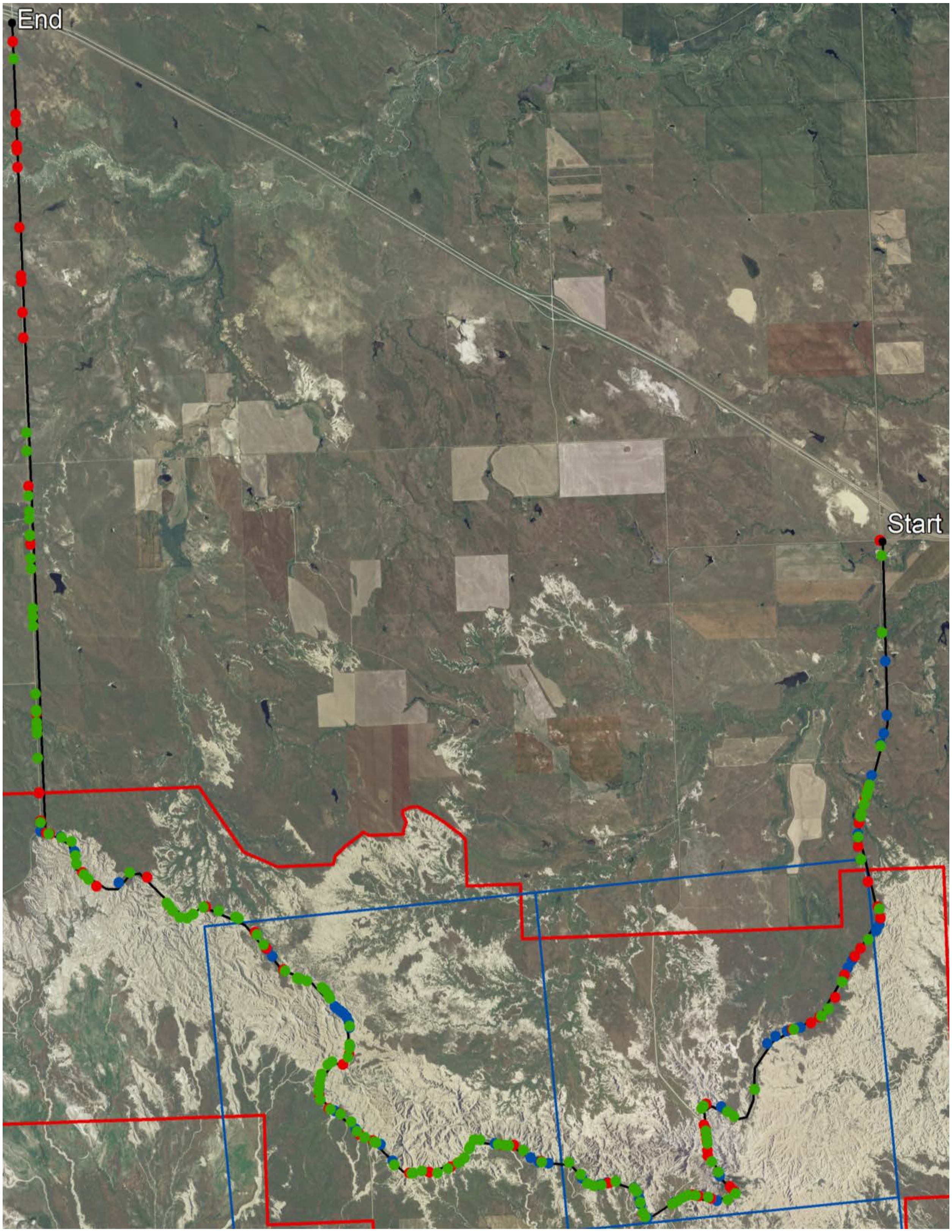

Figure 28. Detections from Badlands NP Cedar Pass (NABat cell #029922) mobile surveys 2014-16. First replicates only. Blue circles from 2014, red from 2015, and green from 2016. Blue square is the NABat cell and red line is the park boundary.

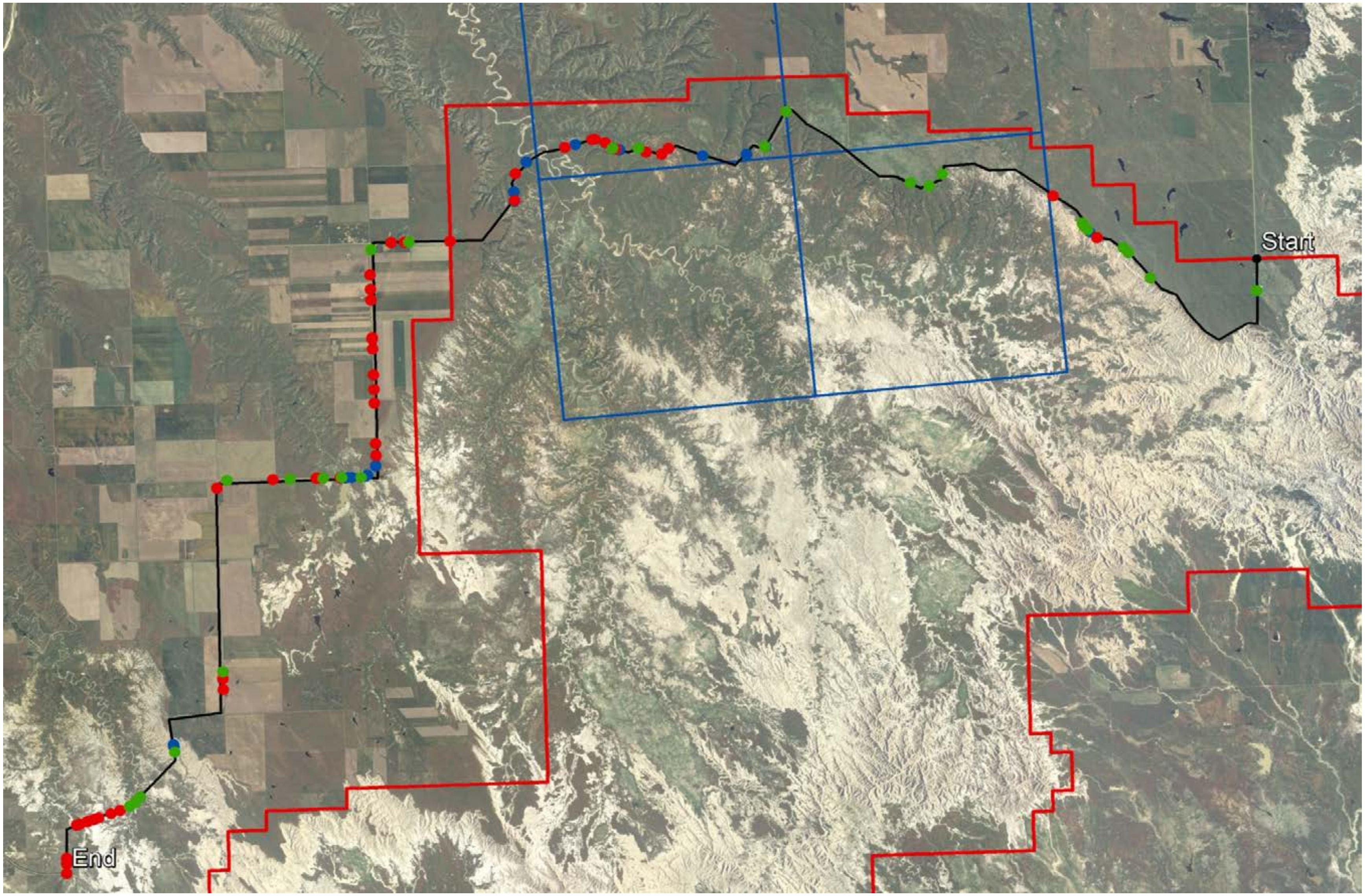

Figure 29. Detections from Badlands NP Sage Creek Road (NABat cell #047586) mobile surveys 2014-16. First replicates only. Blue circles from 2014, red from 2015, and green from 2016. Blue square is the NABat cell and red line is the park boundary.

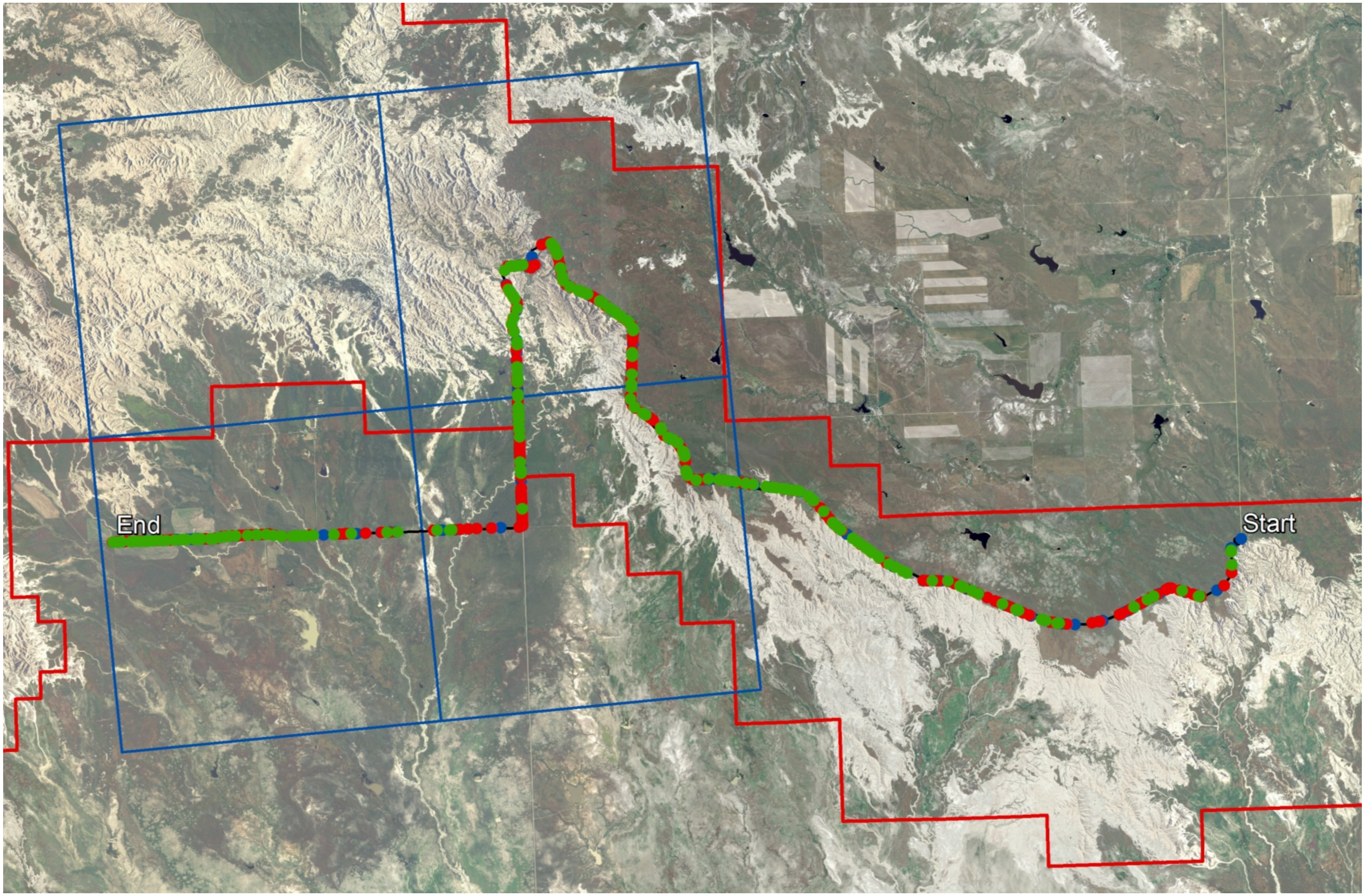

Figure 30. Detections from Badlands NP Conata Basin Road (NABat cell #075712) mobile surveys 2014-16. First replicates only. Blue circles from 2014, red from 2015, and green from 2016. Blue square is the NABat cell and red line is the park boundary.

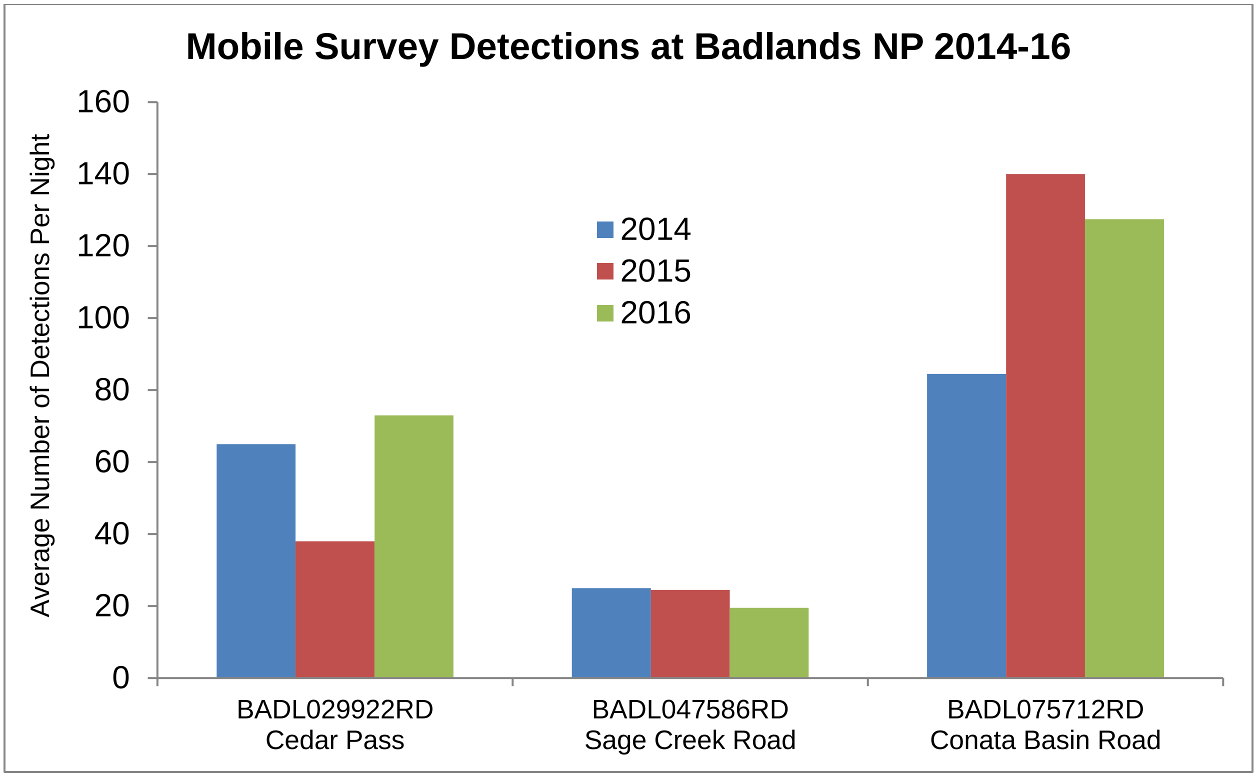

Figure 31. Average number of detections per mobile survey route at Badlands NP 2014-16.

Devils Tower NM

Devils Tower NM is a 545-ha (1,347-ac) park in the extreme northern Black Hills region in Wyoming (also known as the Bear Lodge Mountains). The park is part of the Northern Great Plains Inventory & Monitoring Network. The park did not meet the Network's *a priori* criteria for inclusion in the NABat sampling effort, i.e., that at least a portion of all four quadrants of a NABat cell lie within the park boundaries. Like the other small Network parks, it was considered for non-NABat monitoring; however, the park had a very active bat acoustic monitoring program in 2014-16 using its own equipment. A decision was made not to include that park as part of this study.

Although not a part of this monitoring project, the preliminary results from a bat study at Devils Tower are worth mentioning. The study, being conducted in collaboration with the University of Wyoming, uses radio-telemetry to identify habitat use by northern long-eared bats (Abernethy et al. 2017). The monitored bats have been found to use a wide variety of material for roosting including downed woody debris (**Figure 32**). The results are important because forest clearing and thinning is routinely done in Network parks for purposes of fuel load reduction. However, such actions could be reducing bat roosting habitat, and perhaps, bat abundance and diversity. Jewel Cave started a similar study in 2017 to better understand bat habitat use at that park.

Figure 32. Researcher locating a radio-transmittered roosting bat under loose bark. (NPS)

Fort Laramie NHS

Fort Laramie NHS, located in southeastern Wyoming, is a 337-ha (833-ac) park that conserves and interprets historic Fort Laramie. Significant natural resources include the North Platte and Laramie Rivers which converge in the park, and the associated riparian forests. Much of the remainder of the park is comprised of open grasslands and the fort grounds. A notable feature in regards to bats is a large bat house the park constructed in an effort to entice and keep bats out of historic buildings. The bat house is occupied and is viewed as successful although bats still roost in some of the historic buildings.

Fort Laramie did not meet the criteria for NABat monitoring, i.e., the park did not encompass at least a portion of all four quadrants of a NABat cell. Therefore, monitoring stations were established without regard to a sampling frame; rather, the stations were selected based on likely importance to bats and interest to management. In 2015 six stations were established; three in riparian forests, one at the bat house, one in the fort grounds, and one along a canal that borders the park. These stations are well suited for long-term park-wide monitoring of bat abundance. In 2016 six more stations were established. Five of these were associated with historic buildings at the fort grounds and the other was at the bat house. In all six of the latter deployments a directional horn was affixed to the microphone and the assembly pointed at the structure of interest (**Figure 33**). The intent of the latter deployments was to see if bats were exiting the buildings, the species using the buildings, a sense of how many, and their hourly use of the structures. These deployments were not intended for long-term monitoring of overall park abundance, but rather, because the data was of interest to management.

Figure 33. A microphone assembly with a directional horn pointed at a historic building at Fort Laramie NHS.

Six bat detectors were deployed on June 17, 2015 and retrieved on June 25 (stations FOLA01 to FOLA06). However, all of the units experienced memory card errors and some shut down prematurely. These were the first units deployed with 64GB Transcend Class 10 cards. Subsequent testing found poor compatibility between those cards and SM3Bat firmware version 1.2.5 (subsequent upgrading to version 1.2.7 generally resolved the problem). Fortunately, the units were revisited during the daylight hours of June 18 and restarted if needed. When the memory cards were inserted into a computer they would not read properly, but much of the data was salvaged using data recovery software. Yet when the data was subsequently analyzed there were irregularities for the first night hence all data was censored from the first night of each deployment. This resulted in the censoring of 4,815 recordings, but there were enough complete nights of recordings to conduct the needed analyses for the park. The censored data is archived in zip files and is available for re-evaluation and use.

On July 30, 2016 the six sites were revisited; the units were retrieved on August 7. On August 9, 2016 three of the units were reconfigured with directional horns and aimed at historic structures suspected of having bats (stations FOLA07 to FOLA09). Four days later, on August 13, park staff retrieved the three units and moved them to other historic buildings (stations FOLA10 to FOLA12). The deployments ended on August 17.

After censoring for incomplete nights, 154,009 recordings were made over 95 nights, 2015-16. Noise files comprised 7% of all recordings, leaving 142,807 recordings of bats. For some unknown reason, 40% of the recordings from site FOLA04 in 2016 were noise files; the next highest rate of noise files from a deployment was only 6%. Furthermore, in 2015 noise files comprised only 2% of the recordings at that same site. Of all the recordings with bats, Kaleidoscope did not identify a species in 41% of the recordings.

After censoring the anomalous 2016 FOLA04 deployment, a t-test was conducted comparing the rate of noise files between deployments with just a microphone and deployments with a microphone/horn assembly; the difference was not statistically significant ($P>0.05$). Interestingly, the deployments with a microphone/horn assembly had a significantly higher rate of recordings where the bat species were not classified by Kaleidoscope, i.e., unidentified recordings ($P<0.05$). This result was possibly due to the microphone/horn assemblies being deployed at locations where multiple bats were recorded at the same time, i.e., emerging concurrently from the buildings. In such cases where there is high bat traffic bats can alter their calls (e.g., increase pulse rate or slope) making identification difficult. Or the recordings could have had a high rate of echoes as the calls bounced of nearby buildings. All of those factors would have complicated the software analysis and possibly resulted in the software not assigning the call to a species.

Prior to this study there were four species reported to be present at Fort Laramie NHS and two other species reported as probably present (**Table 10**). I concluded six species were present and two were probably present. Sonobat documented the probable presence of six species using a likelihood estimator; however, two species reported by Kaleidoscope, the long-legged myotis and the tri-colored bat were not part of the Sonobat Wyoming-Eastern package so I used the Sonobat South Dakota-Eastern package for those species. The Sonobat Wyoming-Eastern package did include the pallid bat (*Antrozous pallidus*), the spotted bat (*Euderma maculatum*), the California myotis (*Myotis californicus*), and the Yuma myotis (*Myotis yumanensis*), species which are generally not reported as being in the vicinity of the park (Abernethy et al. 2015). Sonobat reported their likelihood of presence as 0.45, 0.00, 0.74, and 1, respectively, based on the 2015-16 data. The value of 1 for the Yuma myotis occurred in both years, and even on multiple deployments (Sonobat recommends using the likelihood estimators for shorter durations than generally reported here). Therefore, the 2015-16 Fort Laramie data was run through Kaleidoscope again but with the Yuma myotis filter enabled. Kaleidoscope also indicated the species was present both years based on the likelihood estimator. Kaleidoscope assigned 1,391 recordings to the species and Sonobat assigned 156 (using the consensus count output). In spite of that there was reluctance to conclude the species is present in the park based on published range maps including recent mist-netting and modeling in Wyoming by Abernethy et al. (2015). Furthermore, the Yuma myotis has a similar call to the little brown bat and could be confused for that species. This is especially likely in large concentrations of little brown bats where some individual bats might alter (i.e., raise) the frequency of their calls to distinguish their signals from other little brown bats in the vicinity. The altered call could sound like a Yuma myotis. This would be a very real possibility around the buildings and the bat house where large numbers of little brown bats roosted.

Table 10. Species presence at Fort Laramie NHS.

		Kaleidoscope		Sonobat[2]		
Species	**NPSpecies Status[1]**	**2015**	**2016**	**2015**	**2016**	**Conclusion**
T. Big-eared Bat	Present	0	0	0	0.38	Unconfirmed
Big Brown Bat	Present	1	1	1	1	Present
Eastern Red Bat	–	1	1	1	1	Present
Hoary Bat	Probably Present	1	1	1	1	Present
Silver-haired Bat	Present	1	1	1	1	Present
W. Small-footed Myotis	Probably Present	0	1	0.74	0.17	Probably Present
Long-eared Myotis	–	0	0	0.75	0.75	Unconfirmed
Little Brown Bat	Present	1	1	1	1	Present
N. Long-eared Bat	–	0	0	0.37	0.74	Not in Park
Fringed Myotis	–	0	0	0	0	Not in Park
Long-legged Myotis	–	1	1	–	–	Present
Yuma Myotis	–	1	1	1	1	Unconfirmed
Tri-colored Bat	–	1	1	0	0.77	Probably Present

[1] NPSpecies accessed 9-30-2015.

[2] Output from Eastern Wyoming classifier package except for northern long-eared and tri-colored bats from South Dakota-Eastern package.

Both Kaleidoscope (**Figure 34**) and Sonobat (**Figure 35**) assigned about half of the classifications at the park to the little brown bat (using data from all 12 sites and both years), by far the highest relative frequency for that species in the Network. The big brown bat—another species known to use buildings—comprised about a quarter of the classifications according to both software packages.

Little brown bats were the most commonly classified species at the park, comprising about half of the classifications (**Figure 36**, **Figure 37**). This result is consistent with 2003 mist-netting by Schmidt et al. (2004) whereby almost all the captures were from that species. The apparent high abundance of little brown bats is likely due in part to the park's bat house (**Figure 38**). Little brown bats regularly use bat houses and they were by far the most classified species at the house (**Figure 36**). However, in the mid-August 2016 deployment at site FOLA07 the long-legged and western small-footed myotis were also frequently reported (**Figure 37**). The western small-footed myotis is known to use buildings; the long-legged myotis less so. All three of the species belong to the myotis genus and their calls could be confused by the software. Hence, it's possible that some of the calls attributed to the latter two species were actually little brown bats. Or it's possible there was a real seasonal shift in the diversity of species using the bat house. The recorder at FOLA07 was deployed on August 9, 2016 whereas station FOLA02 was deployed on June 18, 2015 and July 30, 2016. Season-long monitoring of the house would shed more light on this potential change.

The relative frequency of bat classifications at the twelve stations was both interesting and expected. For example, sites near the riparian areas showed more species diversity than locations at the fort grounds or the bat house. Forested riparian zones provide roosting and foraging habitat for a wide variety of bats. Specifically, both leaf roosting bats (e.g., eastern red, hoary) and bark roosting bats (little brown, big brown) use riparian forests. Conversely, at the fort grounds there was less diversity. Big brown bats appear to be the primary species using the Old Guardhouse (FOLA08) for roosting whereas at the Burt House (FOLA09) and the Captain's Quarters (FOLA12) the little brown bat appeared to be the primary roosting species. The author gave an evening bat presentation to the public in August 2016 and confirmed that almost all of the bats at the Old Guardhouse were big brown bats.

The highest rate of nightly bat activity at the park was recorded at the station near the bat house (FOLA02). That station averaged 5,026 detections per night in 2015 and 3,851 in 2016. Excluding the deployments with the directional microphones (sites FOLA07-12), the next highest rate of activity was at the station in the fort grounds (FOLA06) which averaged 1,959 detections per night over the two years. The three riparian sites (FOLA01, FOLA03, and FOLA04) averaged 1,258 detections per night (unweighted by the number of nights per site). The station at the canal (FOLA05) averaged only 335 detections per night over the two years.

Six stations were monitored in both years. In 2015 the six averaged 1,656 bats per night (unweighted by the number of nights per deployment). In 2016 the six stations averaged 1,925 bats per night. The difference between years was not statistically significant ($P>0.05$) and the direction of change was not consistent among sites (**Figure 39**).

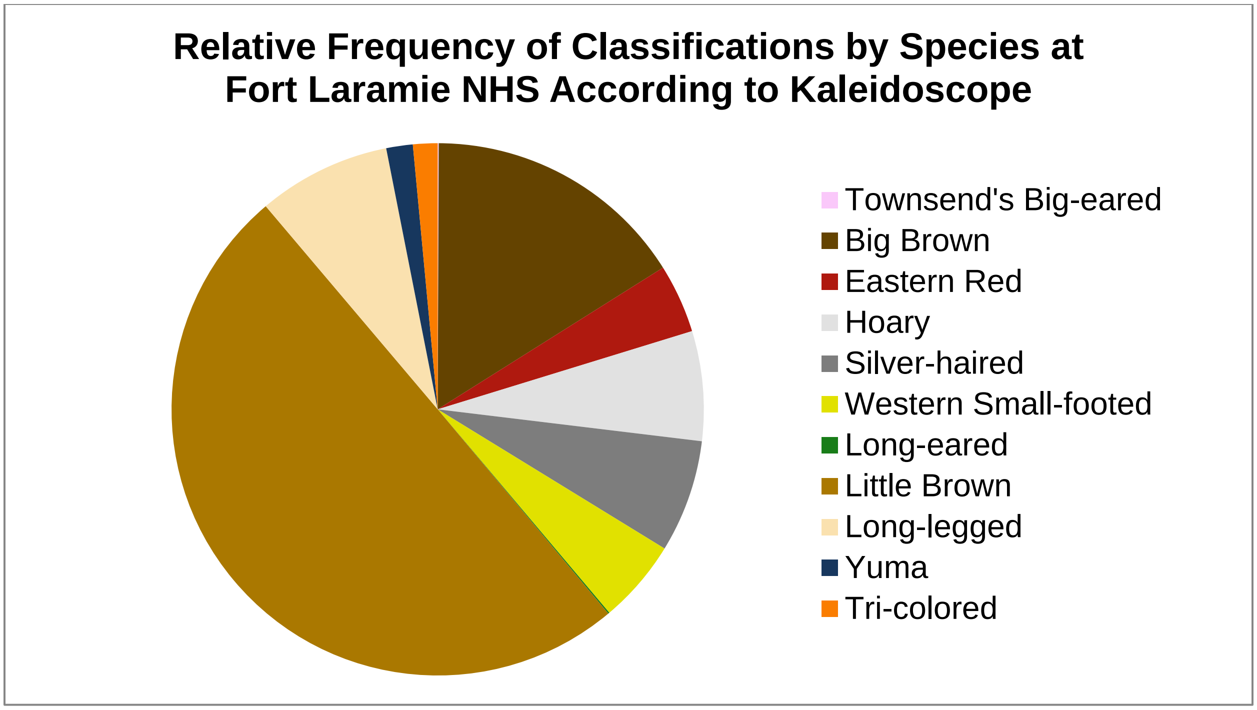

Figure 34. Relative frequency of classifications by species at Fort Laramie NHS according to Kaleidoscope.

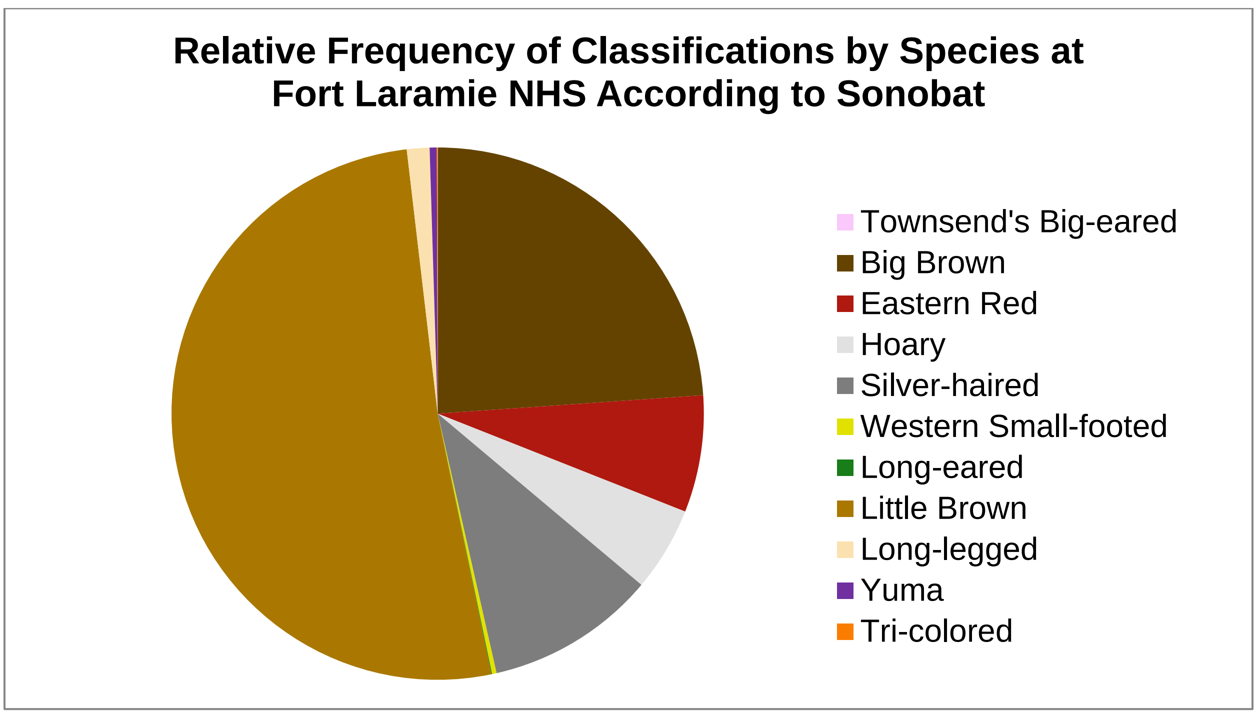

Figure 35. Relative frequency of classifications by species at Fort Laramie NHS according to Sonobat. Results from Wyoming-Eastern classifier package except for tri-colored bat which came from South Dakota-Eastern package.

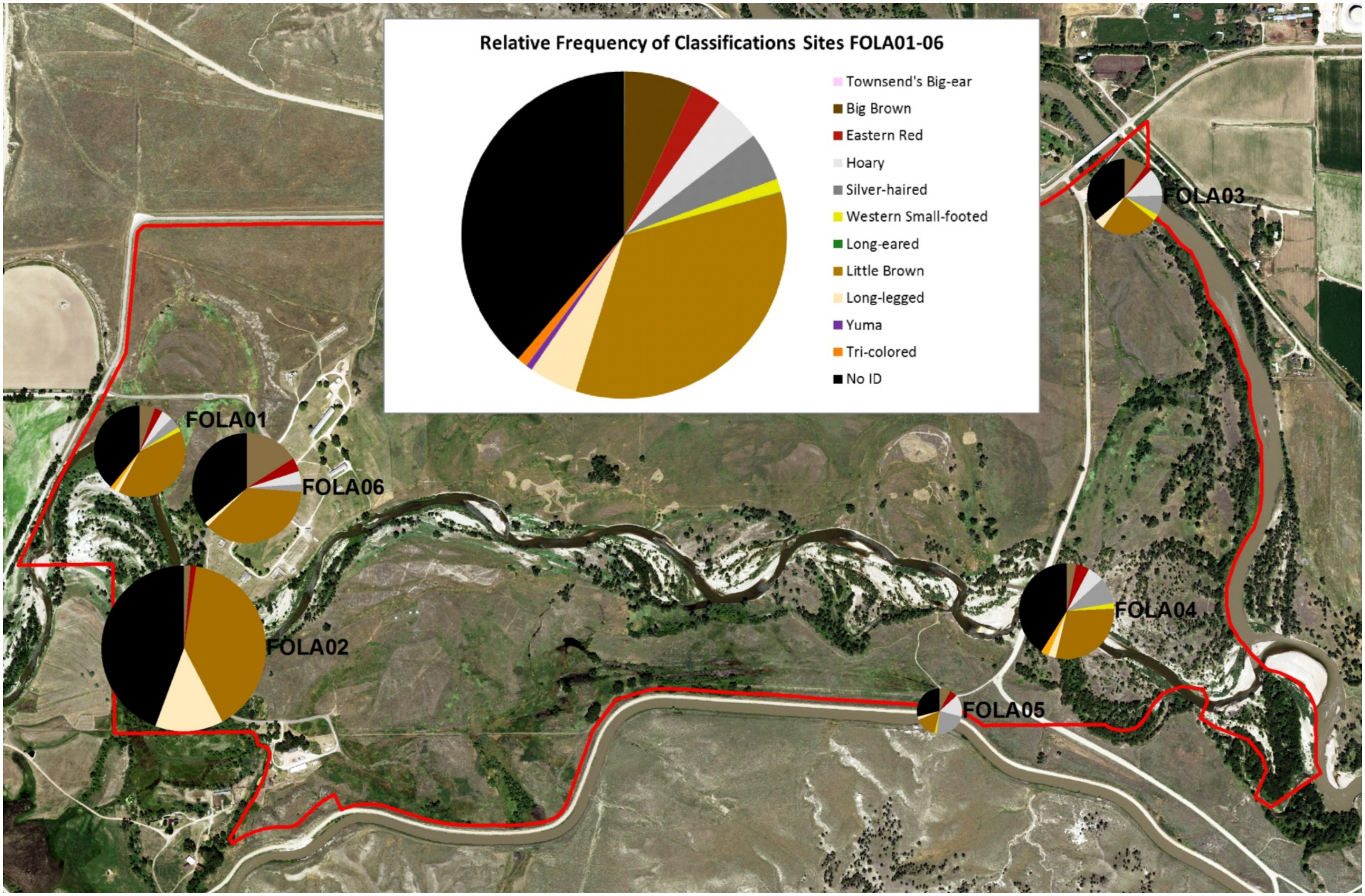

Figure 36. Relative frequency of bat classifications by species at Fort Laramie NHS 2015-16. Size of circles correlates to the rate of nightly detections.

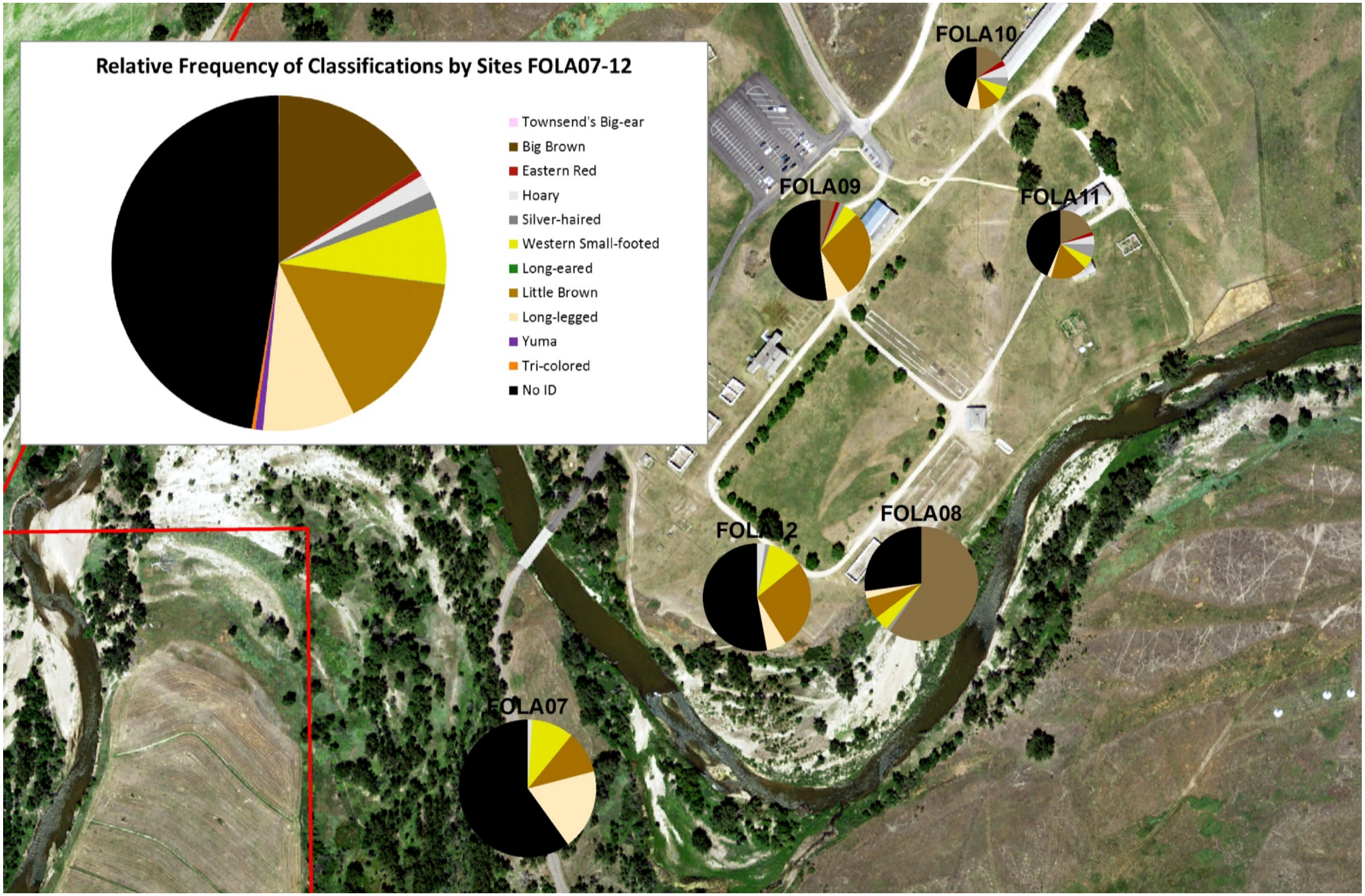

Figure 37. Relative frequency of bat classifications by species at Fort Laramie NHS fort grounds 2016. Size of circles correlates to the rate of nightly detections.

Figure 38. Bat house at Fort Laramie NHS. (NPS)

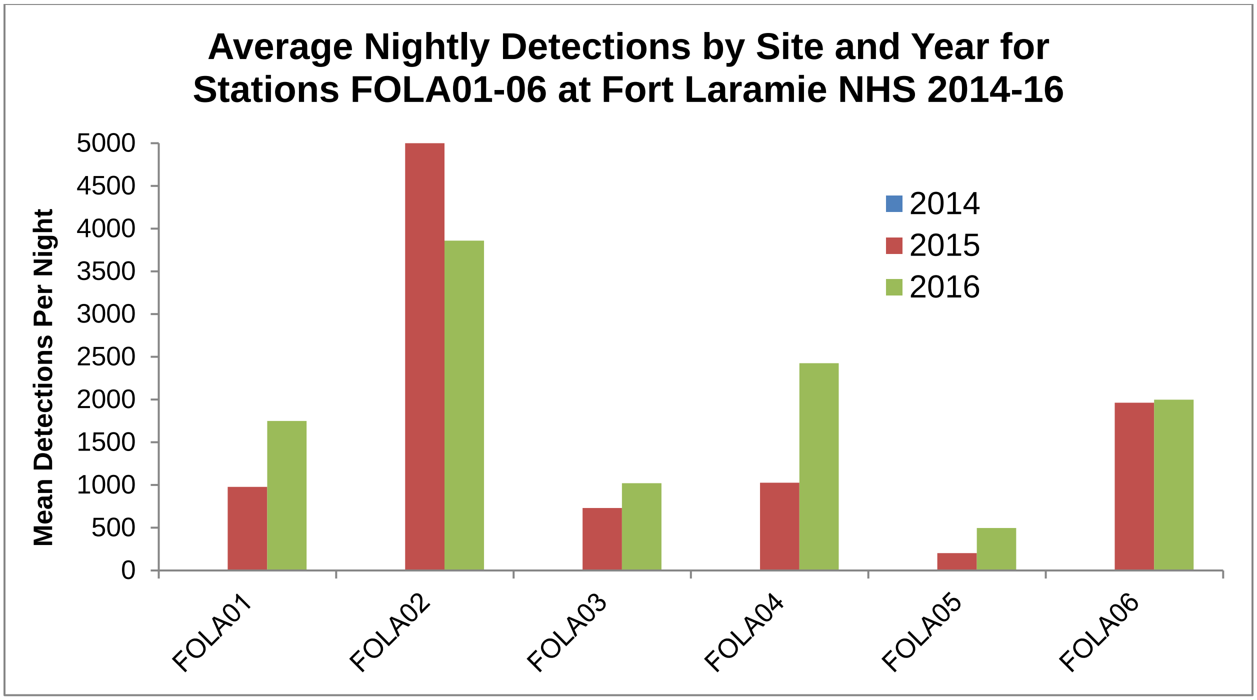

Figure 39. Bat detections per night at Fort Laramie NHS 2015-16. Absence of a bar means the site was not monitored that year.

Bat activity often peaks shortly after sunset, with a lesser peak just before sunrise (Hayes 1997, Licht 2016). The three bat detectors placed in the riparian areas did not show a strong or consistent temporal pattern (**Figure 40**), perhaps because the sites were used both for foraging and roosting. The canal site, which would have had value only for foraging or drinking, showed a strong peak shortly after sunset and then little activity the rest of the night.

Conversely, several of the bat detectors stationed near the historic buildings and the two detectors placed near the bat house showed a strong peak of activity just before daylight (**Figure 41**). It's likely that bats were swarming near the structures prior to roosting for the day, whereas at evening emergence (the beginning of the night) the bats would quickly depart to go out to drink and forage. However, the differing patterns between the natural areas and the structures could also be due to different temporal patterns of the various species. Preliminary analysis of some of the other 2014-16 acoustic data collected throughout the Network indicates that little brown bats commonly have a peak of activity just before sunrise regardless of habitat. Interestingly, the Cavalry Barracks (FOLA10) and Visitor Center (FOLA11) did not show dramatic pre-sunrise peaks, suggesting bats are not roosting near those structures.

In summary, Fort Laramie NHS appears to have a healthy bat population. In spite of some equipment malfunctions in 2015, this study documented the presence of several species not currently listed in the NPSpecies database. The bat house appears to be very effective in terms of conserving a healthy population of little brown bats. Big brown bats are still using several of the historic structures, especially the Old Guardhouse. The riparian forests also provide roosting habitat for those as well as other species, plus they probably provide high quality foraging areas.

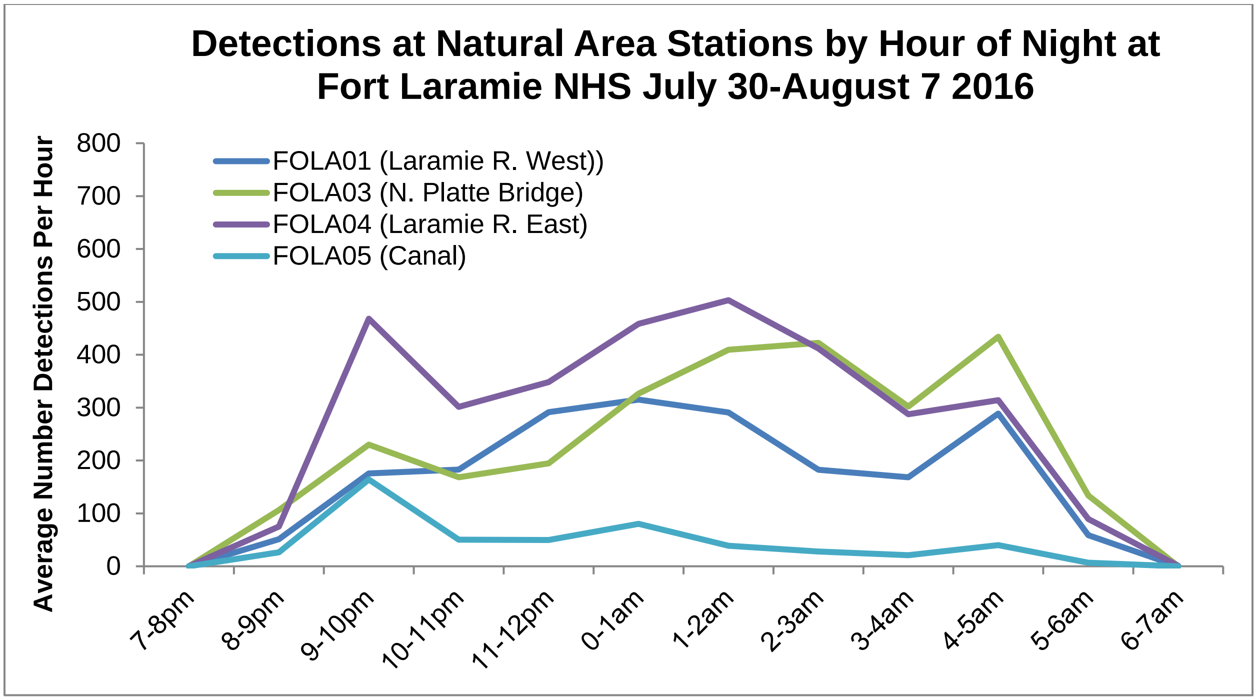

Figure 40. Detections at natural area stations at Fort Laramie NHS by hour of night July 30-August 7 2016.

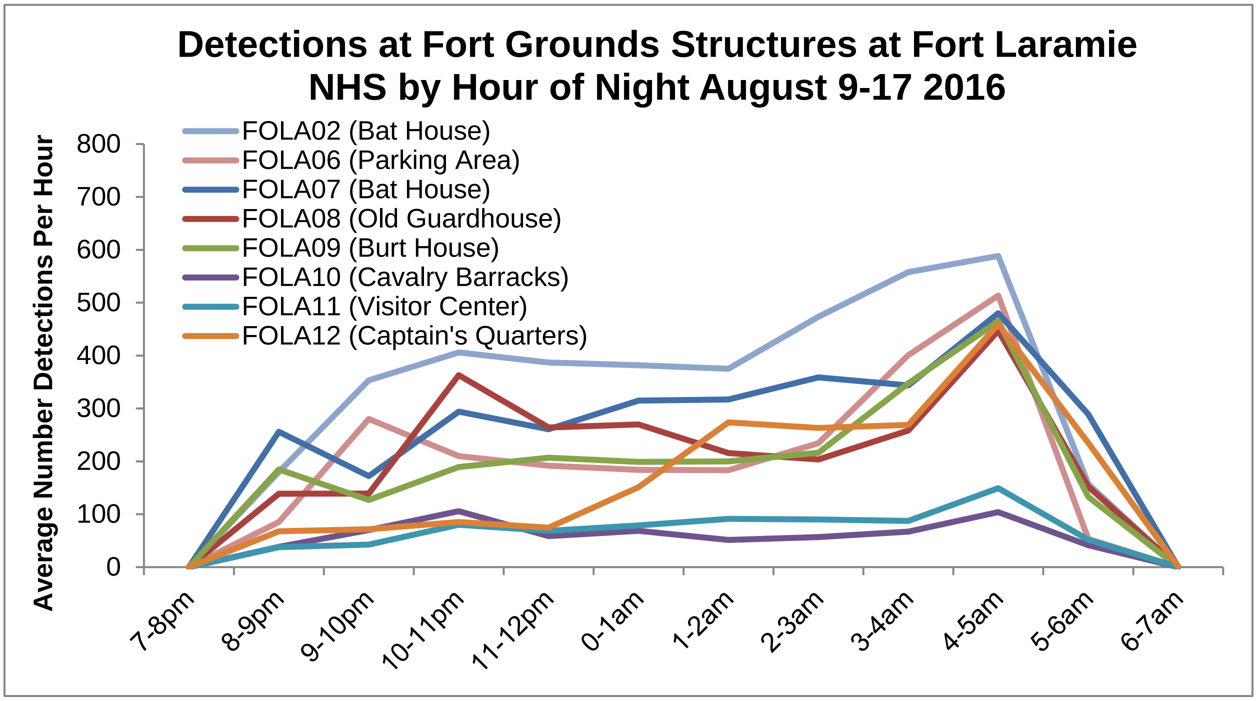

Figure 41. Detections at Fort Laramie NHS stations at fort grounds structures by hour of night August 9-17 2016.

Fort Union Trading Post NHS

Fort Union Trading Post NHS is a 170-ha (419-ac) park straddling the North Dakota/Montana border. The park conserves a historic fur-trading post. A significant natural resource is the Missouri River and associated floodplain forest (outside the park much of the floodplain has been converted to cropland). The upland areas within the park are comprised mostly of restored prairie.

Fort Union Trading Post did not meet the criteria for NABat monitoring, i.e., that at least a portion of all quadrants of a NABat cell be within the park. Therefore, four stations were established based on features of interest to management; three above the floodplain and one in the floodplain (**Figure 42**).

On July 16, 2015 four bat detectors were deployed at the park. The units were retrieved on July 21. Units were deployed at the same sites on July 12, 2016 and retrieved on July 19. A total of 39,494 recordings were made, of which 3% were noise files. Of the remaining 38,439 recordings, 25% could not be identified to species by the Kaleidoscope software.

Prior to this study two species were listed as present at the park and two other as probably present (**Table 11**). The list appears to come from 2003 field work by Schmidt et al. (2004). Jones and Genoways (1966) reported 5 species from western North Dakota in the mid-1960s. They did not include the northern long-eared myotis in their list. Swenson and Shanks (1979) reported on five species taken in northeastern Montana in the late 1970s including the northern long-eared myotis. They also reported a Townsend's big-eared bat; however, that species is not included in current range maps and was not considered in the Kaleidoscope auto-classification. The Sonobat Montana-Plains package did include the species, but the software did not classify a single call to the species. This study indicates that six species are present at the park. Recordings were also classified as coming from three other species, including the threatened northern long-eared bat (**Table 11**); however, the data was insufficient to say with statistical confidence that the species were in the park as there were only a few recordings and the species (all part of the myotis clan) have calls similar to other species.

The most commonly classified species at the park were the big brown and silver-haired bats, which together comprised well over 3/4ths of the detections according to both Kaleidoscope (**Figure 43**) and Sonobat (**Figure 44**). These two species can be difficult to distinguish so the true relative abundance might differ somewhat from what is reported here; however, the two software packages were generally consistent in their relative frequency. The next most frequently classified bats were the little brown and hoary bats.

Species composition varied between sites in a logical way (**Figure 42**). For example, big brown bats were classified at a greater rate near the fort structure. Bats are known to be roosting at the structure and big brown bats commonly make use of buildings. The little brown bat was relatively more common near the maintenance area; it too commonly roosts in structures and could be roosting in some of the nearby buildings. Conversely, the eastern red and silver-haired bats were reported more near the remote park lot. The lot is bordered by several large cottonwood trees that likely provide ideal roosting habitat for the species. The two species, along with the hoary bat, are sometimes referred to as leaf roosting bats as they typically spend days hidden among the leaves of tall trees.

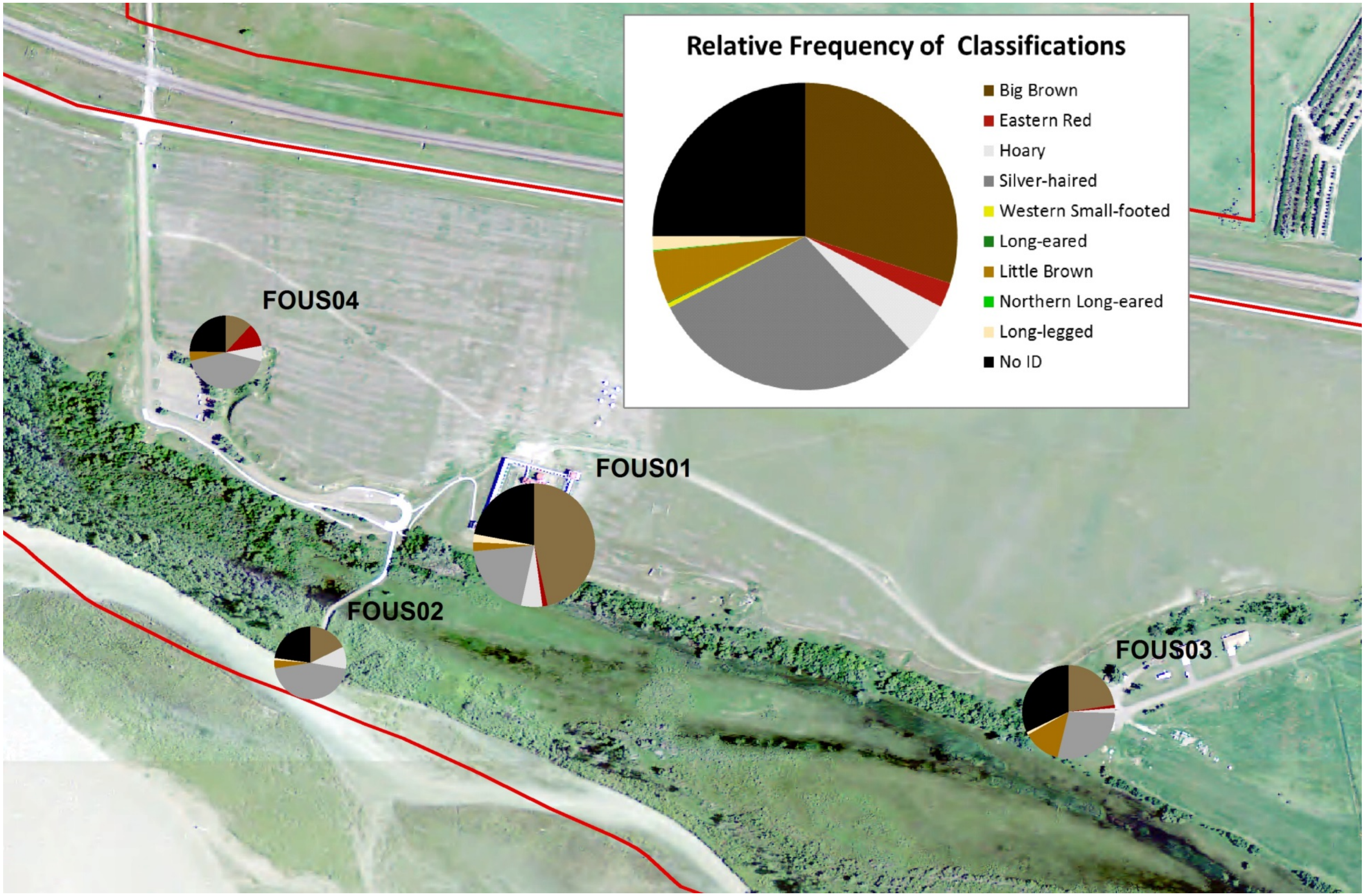

Figure 42. Relative frequency of classifications by species and site at Fort Union Trading Post NHS 2015-16. Size of circles is correlated with the rate of nightly detections.

Table 11. Species presence at Fort Union Trading Post NHS.

Species	NPSpecies Status[1]	Kaleidoscope		Sonobat[2]		Conclusion
		2015	2016	2015	2016	
Big Brown Bat	Present	1	1	1	1	Present
Eastern Red Bat	–	1	1	0.73	0.98	Present
Hoary Bat	–	1	1	1	1	Present
Silver-haired Bat	–	1	1	1	1	Present
W. Small-footed Myotis	Probably Present	0	0	0.18	0.55	Probably Present
Long-eared Myotis	–	0	0	0.89	0.81	Probably Present
Little Brown Bat	Present	1	1	1	1	Present
N. Long-eared Bat	–	0	0	0	0.18	Unconfirmed
Long-legged Myotis	Probably Present	1	1	0.99	0.92	Present

[1] NPSpecies accessed 9-30-2015.

[2] Using Montana-Plains classifier package.

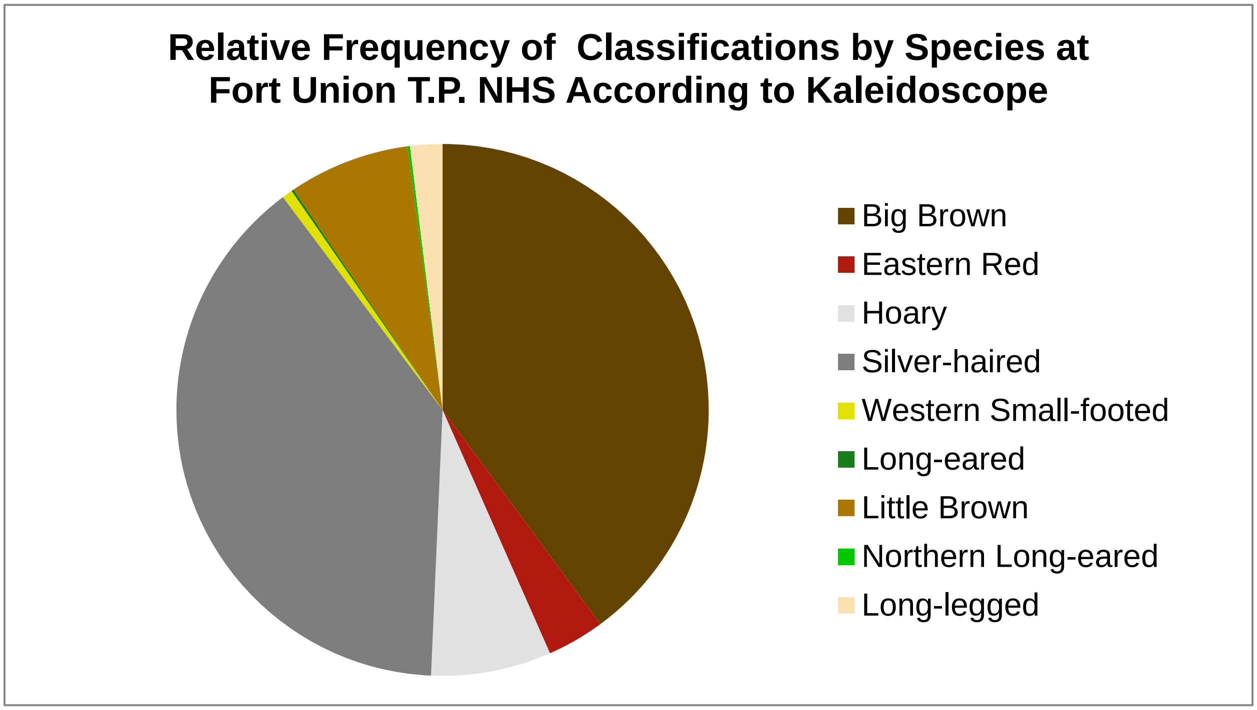

Figure 43. Relative frequency of classifications by species at Fort Union Trading Post NHS according to Kaleidoscope.

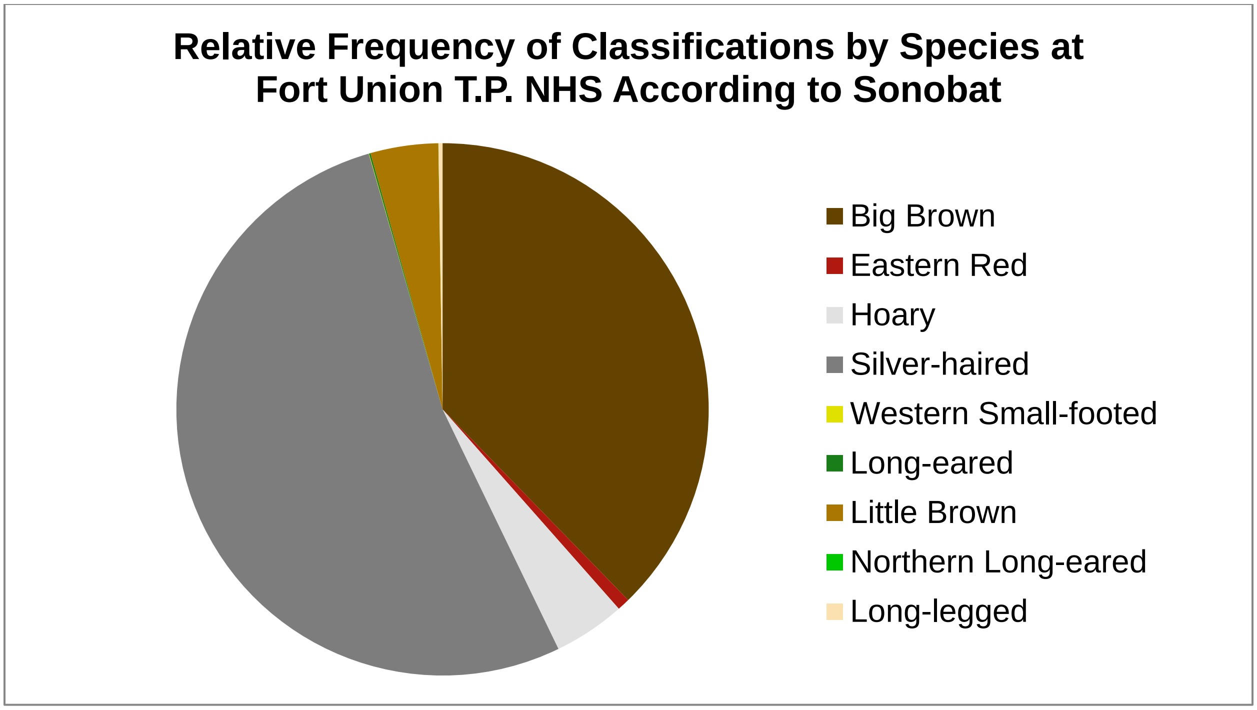

Figure 44. Relative frequency of classifications by species at Fort Union Trading Post NHS according to Sonobat. Results from Montana-Plains classifier package.

The highest rate of nightly detections 2015-16 was site FOUS01, located at the southeast corner of the historic fort (**Figure 42**, **Figure 45**). The station averaged 1,347 detections per night. The station near the cottonwood trees by the remote parking lot (FOUS04) averaged 827 detections per night whereas the remaining two sites averaged just over 500 detections per night. There was no significant change in the rate of nightly detections between years (**Figure 45**).

In summary, this study documented several new species for the park. Bat activity at the park was moderate compared to other parks in the Network. The absence of large old trees with loose bark and cavities might be limiting bat abundance. Although the northern long-eared myotis was not confirmed as being present in this study, it could still occur in the park periodically. The species was captured in 2016 near Culbertson, Montana, about 30 miles up the Missouri River from the park (February 8, 2017 letter from Jodi Bush of the Fish and Wildlife Service to a general audience). Two of the captured individuals were reproductive females. The northern long-eared bat, like several other bat species, is strongly tied to forests (Henderson and Broders 2008) so maintaining the forested Missouri River floodplain is critical. Swystun et al. (2007) found that cottonwood stands 60 years or older had higher bat activity then younger cottonwood stands. The establishment of a large bat house, such as the one at Fort Laramie, could mitigate for the clearing of much of the floodplain forests in the vicinity of the park and could help to restore bat populations, specifically, big brown and little brown bats.

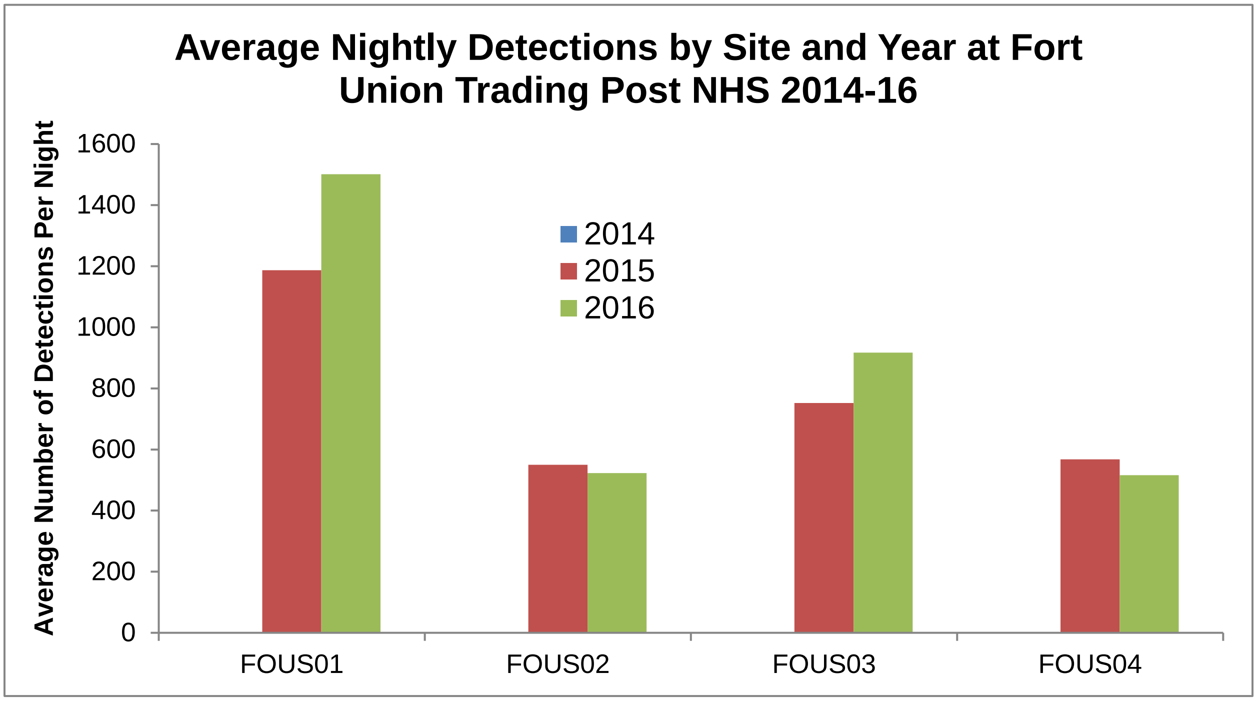

Figure 45. Average nightly detections by site and year at Fort Union Trading Post NHS. Absence of a bar means the site was not monitored that year.

Jewel Cave NM

Jewel Cave NM is 515-ha (1,274-ac) park located in the Black Hills of western South Dakota. The park was established to protect the namesake cave. The complex cave network stretches for many miles, including extending outside the park boundary. The primary visitor entrance to the cave is via sealed doors; that portion of the cave has no regular bat activity. However, a small entrance to the cave was enlarged by people in the early 1900s; that portion of the cave is now used as a bat hibernaculum. The habitat in the park is generally open ponderosa pine forest mixed with grassland meadows. A large wildfire in the year 2000 created open areas with snags. Surface water is rare in the vicinity of the park; a notable exception is the park's sewage pond. Partly as a result of the cave hibernaculum the bat community at the park is comparatively well studied (Jones and Genoways 1967, Turner and Jones 1968, Turner and Davis 1970, Martin and Hawks 1972, Mattson 1994, Choate and Anderson 1997, Cryan et al. 2001, Schmidt 2003, Tigner and Stukel 2003).

The park applied for and received NPS "WNS funds" in 2014 and 2015. Some of the 2014 funds were used to purchase SM3Bat detectors that were subsequently donated to the Network and used in this study. The park purchased several units for its own use and has been conducting acoustic monitoring, including placing detectors at the entrance to the hibernaculum. This report does not discuss those activities. In the summer of 2017 the park, in collaboration with the University of Wyoming, will start a bat study using radio-transmitters and subcutaneous tags.

In spite of the small size of the park, a portion of all four quadrants of a NABat cell #034530 was within the park boundary. Therefore, the Network monitored bats at the park using the NABat monitoring framework, i.e., deploying a monitor within each of four quadrants and conducting a mobile survey. Much of the mobile survey is outside of the park boundary and traverses private or U.S. Forest Service lands.

The stationary point in the NE quadrant and the road surveys were not conducted in 2014 due to road construction. The other three recorders were deployed for four days in 2014 and all four units were deployed for seven days in 2015. In 2016 the monitored intended for the NW quadrant was misplaced; the deployment was subsequently named site JECO01. From 2014-16 a total of 26,406 recordings were made from the stationary points, of which 4% were noise files. Of the 25,478 bat recordings, 28% could not be identified to species by Kaleidoscope. In the 2015-16 road surveys 434 recordings were made of which 61% were noise. Of the 169 recordings with bats, 37% could not be identified to species by Kaleidoscope.

Prior to this study there were nine species reported to be present at Jewel Cave NM according to the NPSpecies database (**Table 12**). This study identified 10 species as being present. Species added to the park list were the eastern red bat and the tri-colored bat, both of which are on the western edge of their range at Jewel Cave. The tri-colored bat has only recently been documented in the Black Hills (Geluso et al. 2005). However, this study did not confirm the presence of the northern long-eared bat, a species that is present according to the NPSpecies database. Although acoustic recordings were classified by the software as being from that species, the sample size was too small and the bat's call too similar to other bats to say with statistical confidence that it is present in the park.

Table 12. Species presence at Jewel Cave NM.

Species	NPSpecies Status[1]	Kaleidoscope			Sonobat[2]			Conclusion
		2014	2015	2016	2014	2015	2016	
T. Big-eared Bat	Present	1	1	1	0.77	0.77	0.58	Present
Big Brown Bat	Present	1	1	1	1	1	1	Present
Eastern Red Bat	–	1	1	1	0.98	1	1	Present
Hoary Bat	Present	1	1	1	1	1	1	Present
Silver-haired Bat	Present	1	1	1	1	1	1	Present
W. Small-footed Myotis	Present	1	1	1	0.67	1	1	Present
Long-eared	–	0	0	0	0.30	0.75	0	Unconfirmed
Little Brown Bat	Present	1	1	1	1	1	1	Present
N. Long-eared Bat	Present	0.90	0	0.78	0.37	0.37	0.18	Probably Present
Fringed Myotis	Present	1	1	1	1	1	1	Present
Long-legged Myotis	Present	1	1	1	1	1	0.87	Present
Tri-colored Bat	–	0.23	1	1	0	1	0.99	Present

[1] NPSpecies accessed 9-30-2015.

[2] Output from South Dakota - Black Hills classifier package except for tri-colored bat which came from South Dakota-Eastern package.

Compared to many other parks, Jewel Cave appears to have a very even or diverse bat community (**Figure 46**, **Figure 47**). The most commonly classified species were big brown, hoary, and silver-haired bats. Interestingly, the long-legged myotis, a former candidate for listing and species of conservation concern, comprised only a small proportion of the bat recordings. That species was historically reported as one of the most species in the Black Hills (Turner 1974, Cryan 1997). Similarly, Choate and Anderson (1997) reported that northern long-eared bats comprised 17% of the bats captured in their study; yet they were essentially absent in the classifications in this study. The difference in bat diversity between stations (**Figure 48**) was minor compared to some other Network parks. The little brown bat is known to forage over water; that species was proportionately more common near the sewage ponds. Conversely, the western small-footed myotis, an arid land species, was classified relatively more frequently in the dry Lithograph Canyon site.

The highest rate of species detections per night occurred at the sewage pond which average 746 detections per night, 2014-16. The other three sites had less bat activity; none were affiliated with standing water.

A road survey was not conducted in 2014 due to construction on Highway 16. The 2015 road survey showed a rather uniform distribution of bats across the landscape (**Figure 49**). The survey generally traversed open pine forests and grassland areas. It did not pass any areas with surface water.

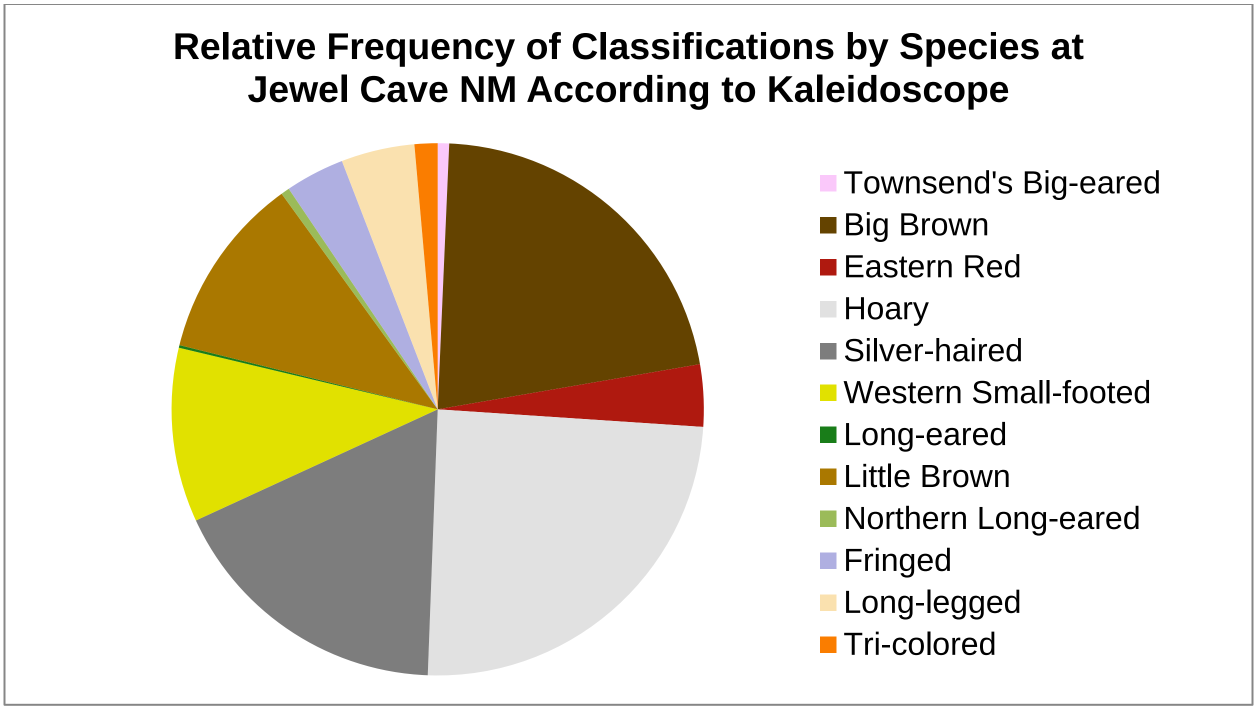

Figure 46. Relative frequency of classifications by species at Jewel Cave NM according to Kaleidoscope.

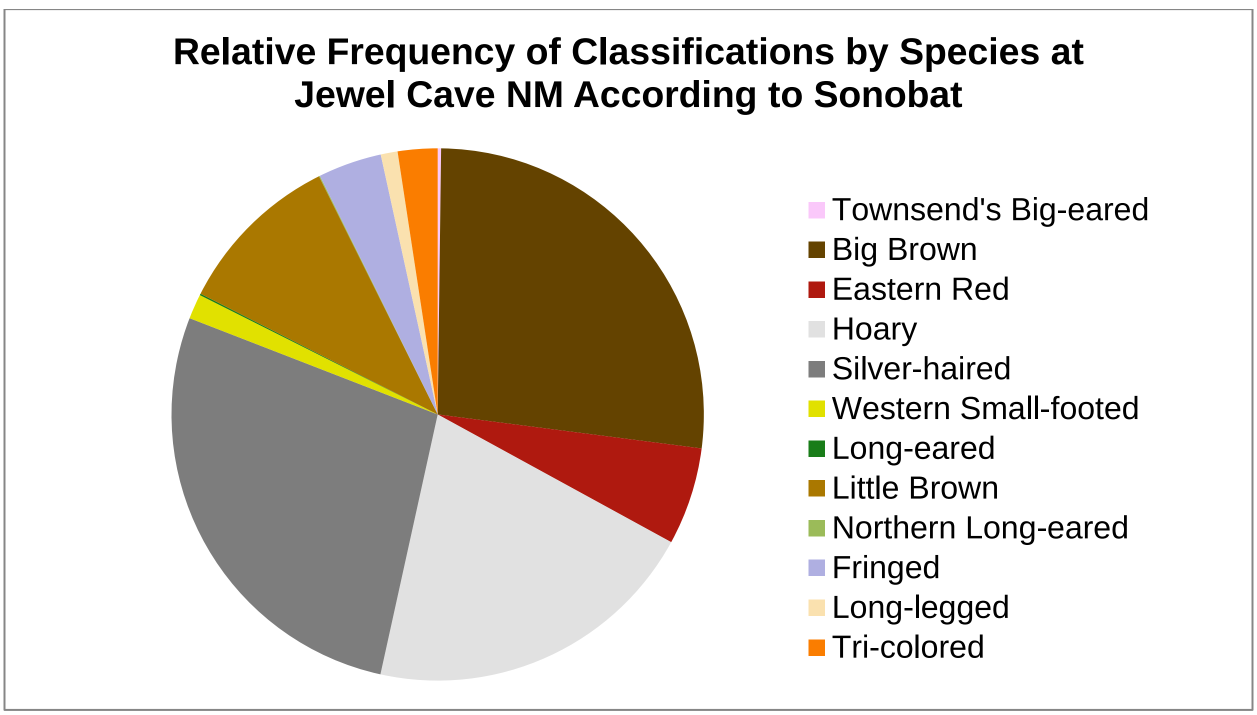

Figure 47. Relative frequency of classifications by species at Jewel Cave NM according to Sonobat. Results from South Dakota-Black Hills classifier package except for tri-colored bat which came from South Dakota-Eastern package.

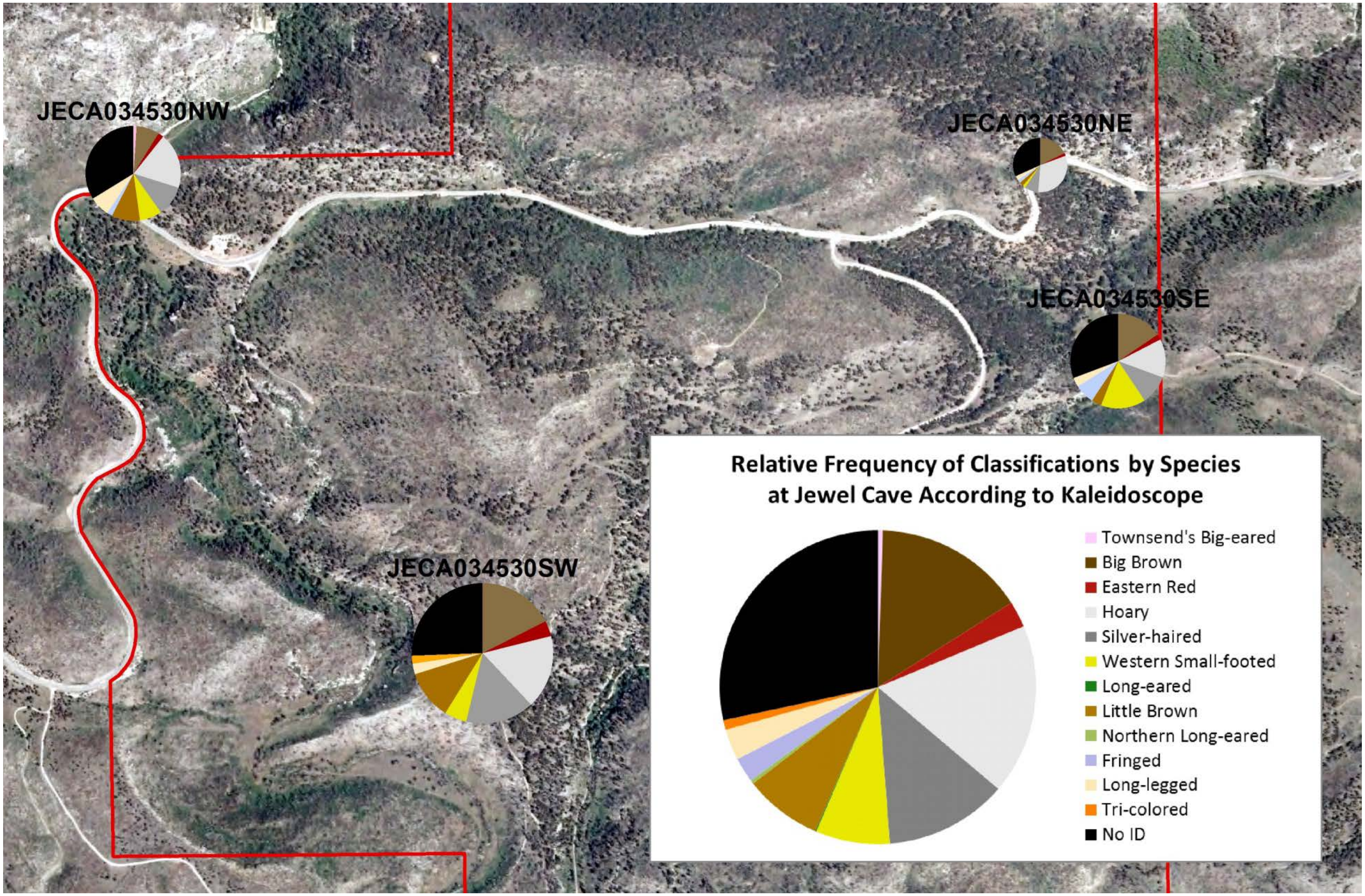

Figure 48. Relative frequency of classifications by species at Jewel Cave 2014-16. Size of circles is correlated with rate of nightly activity.

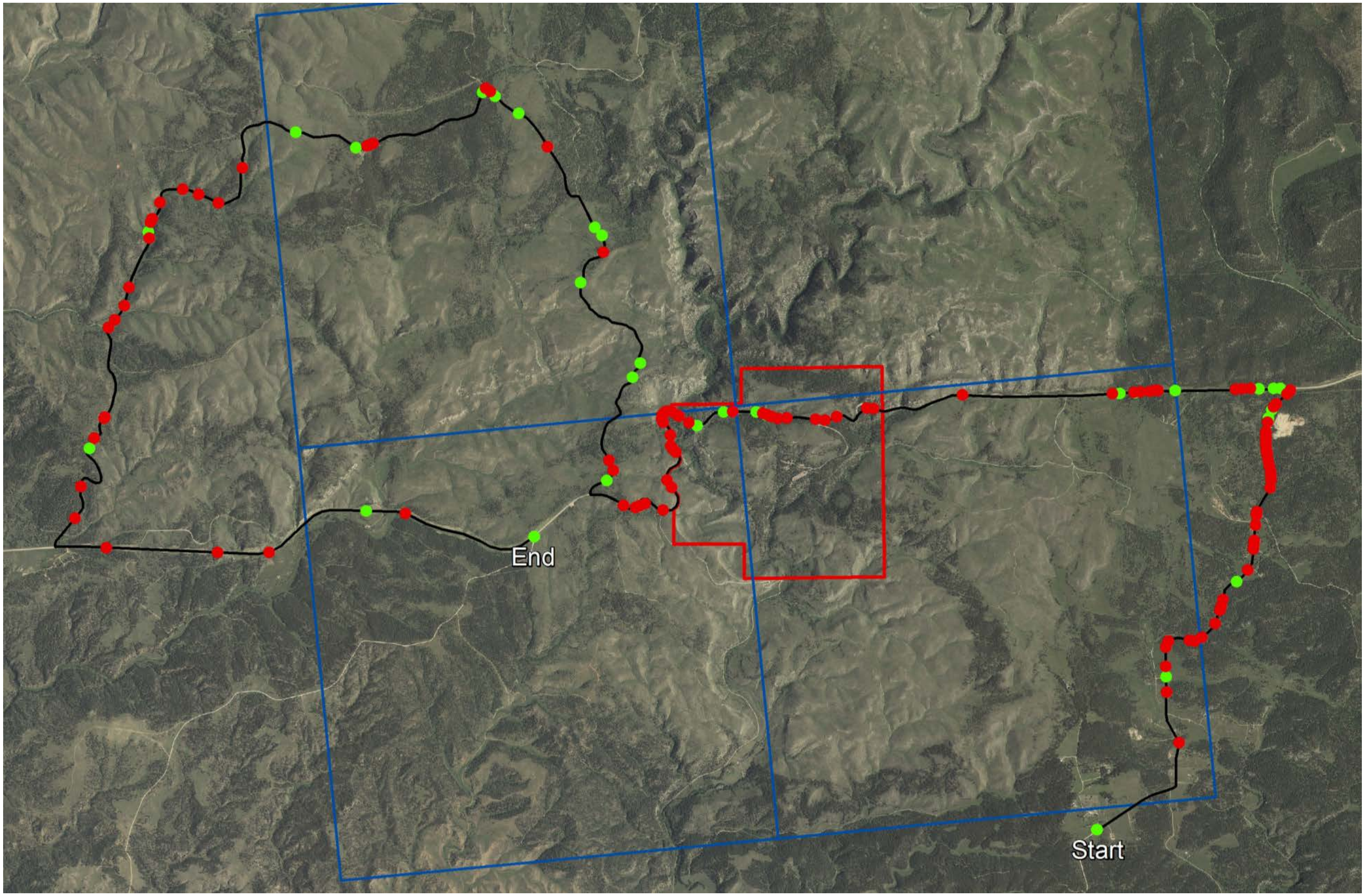

Figure 49. Detections from Jewel Cave NM (NABat cell #034530) mobile surveys 2015-16. First replicates only. Red circles from 2015 and green from 2016. Blue square is the NABat cell and red line is the park boundary.

The primary goal of this project is to monitor changes in bat abundance over time. A graph of species detections by stationary point does not show a park-wide trend in bat activity between years (**Figure 50**). The 2015 road surveys averaged 20 bat detections per night compared to 65 detections per night in 2016. Although dramatic, it does not differ from some of the year-to-year changes recorded from some of the other road surveys in the Network. Interesting, the first and second replicates in 2015 and 2016 counted 19 and 20 bats and 66 and 64 bats, respectively.

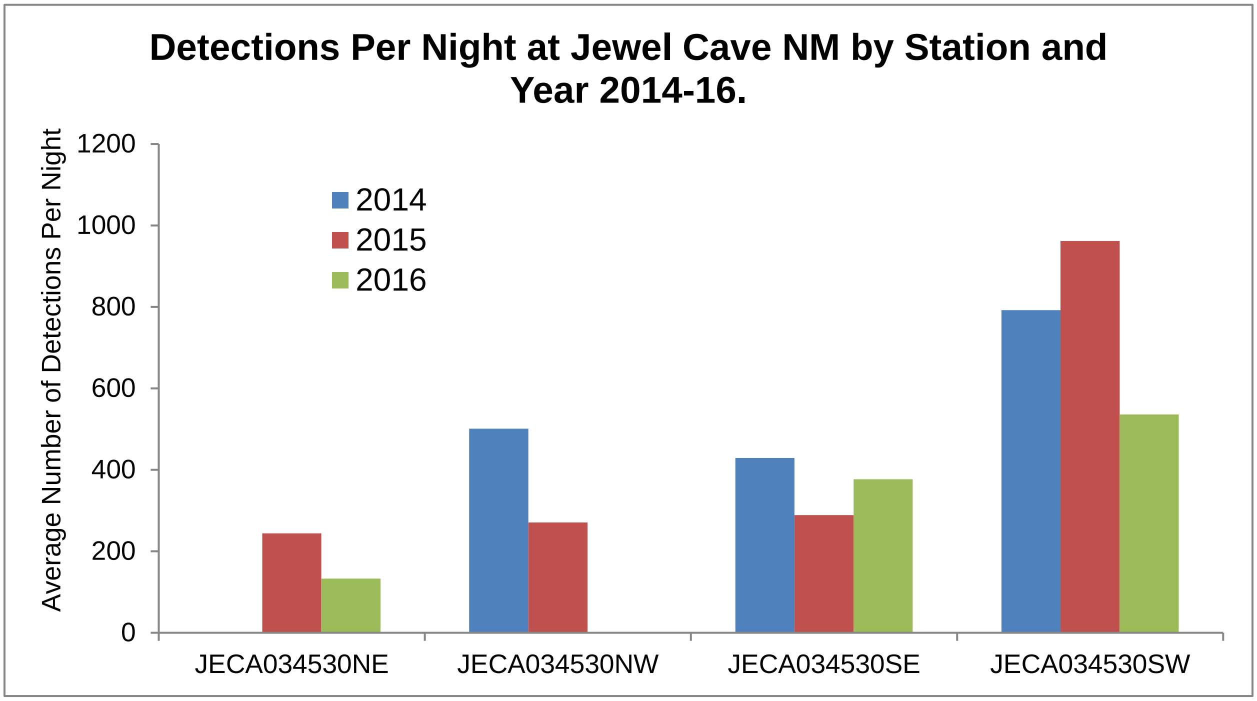

Figure 50. Detections per night at Jewel Cave NM stationary points 2014-16. The NE station was not surveyed in 2014 due to highway construction. The NW station was misplaced in 2016.

Jewel Cave continues to play a critical role in bat conservation in the Black Hills and the Northern Great Plains. The results presented here show a diverse and apparently healthy bat community. The reader should also contact the park as they are conducting a variety of monitoring projects. Roosting habitat could decline in the future as snags from the 2000 Jasper fire fall over. Such snags are important for roosting bats, including maternity colonies (Mattson et al. 1996). The anthropogenic sewage ponds probably play a critical role in bat reproduction in the area as lactating females make regular use of surface water (Adams and Hayes 2008). Studies have found that during lactation little brown bat females have home ranges of only 17 ha with a core area of 6 ha (Henry et al. 2002) and that the species shows reduced survival and recruitment in dry years (Frick et al. 2010), a phenomenon that could be mitigated by permanent surface water.

Knife River Indian Villages NHS

Knife River Indian Villages is a 707-ha (1,749-ac) park immediately north of Stanton, North Dakota. The site was established to protect and interpret the remains of an historic Mandan village. The park includes the lower reach of the Knife River and a small portion of the west bank of the Missouri River. The associated riparian areas are dominated by cottonwood forests. The uplands include native and restored prairies. Much of the surrounding landscape is cropland (**Figure 51**).

Knife River Indian Villages did not meet the *a priori* criteria for NABat monitoring, i.e., that at least a portion of all four quadrants of a NABat cell lie within the park boundary. Therefore, stations were established based on features of interest to management. Four stations were established: one in the visitor center/administrative area, one along a reach of the Knife River bordered by small trees, one along a reach of the Knife River bordered by large trees, and one in upland woodland.

In 2015 detectors were deployed on July 15 and retrieved on July 22. In 2016 units were deployed on July 12 and retrieved on July 18. Unit KNRI03 malfunctioned in 2016 and no data was collected. A total of 14,992 recordings were made, of which 3% were noise files. Of the remaining 14,558 recordings, 37% were not identified to species by the software. Not surprisingly, site KNRI04, which was located within a dense woodland, had a higher rate of files that were not be identified to species (58%). This can occur because of the forest clutter disrupting call quality.

Prior to this study there were two species reported to be present at Knife River Indian Villages NHS and four other species reported as probably present (**Table 13**). The list appears to have been generated in part from 2003 field surveys by Schmidt et al. (2004). The park is east of some range maps for the long-legged and the western small-footed myotis; however, some sources indicate the species occupy the forested Missouri River corridor (e.g., https://gf.nd.gov/wildlife/id/bats) so I included them in the auto-classification. This study indicates that at least six species are present. There was insufficient evidence to indicate the threatened northern long-eared bat was present; however, it is possible the species occasionally occurs in the park.

The silver-haired bat comprised one half or more of the classifications (**Figure 52**, **Figure 53**). The big brown, hoary, and little brown bats each comprised about $1/8^{th}$ of the classifications.

Across all stations and all nights the average nightly rate of bat detections was 297 according to Kaleidoscope. The highest rate of bat detections (478 per night) was in the woodland near the north end of the park (**Figure 51**). The trees in this area likely provide quality roosting habitat. The next highest rate of bat detections (296 per night) occurred in the riparian forest just north of the town of Stanton. The visitor center/administrative had the next highest rate of activity (250 detections per night). Bats could be foraging at the site on insects attracted by outdoor lighting or warm surfaces such as the parking lots. They might also be using structures for night-time roosting. The lowest rate of activity was along an upper reach of the Knife River (165 detections per night); the habitat where the recorder was stationed consisted of smaller trees and shrubs compared to other forested sites.

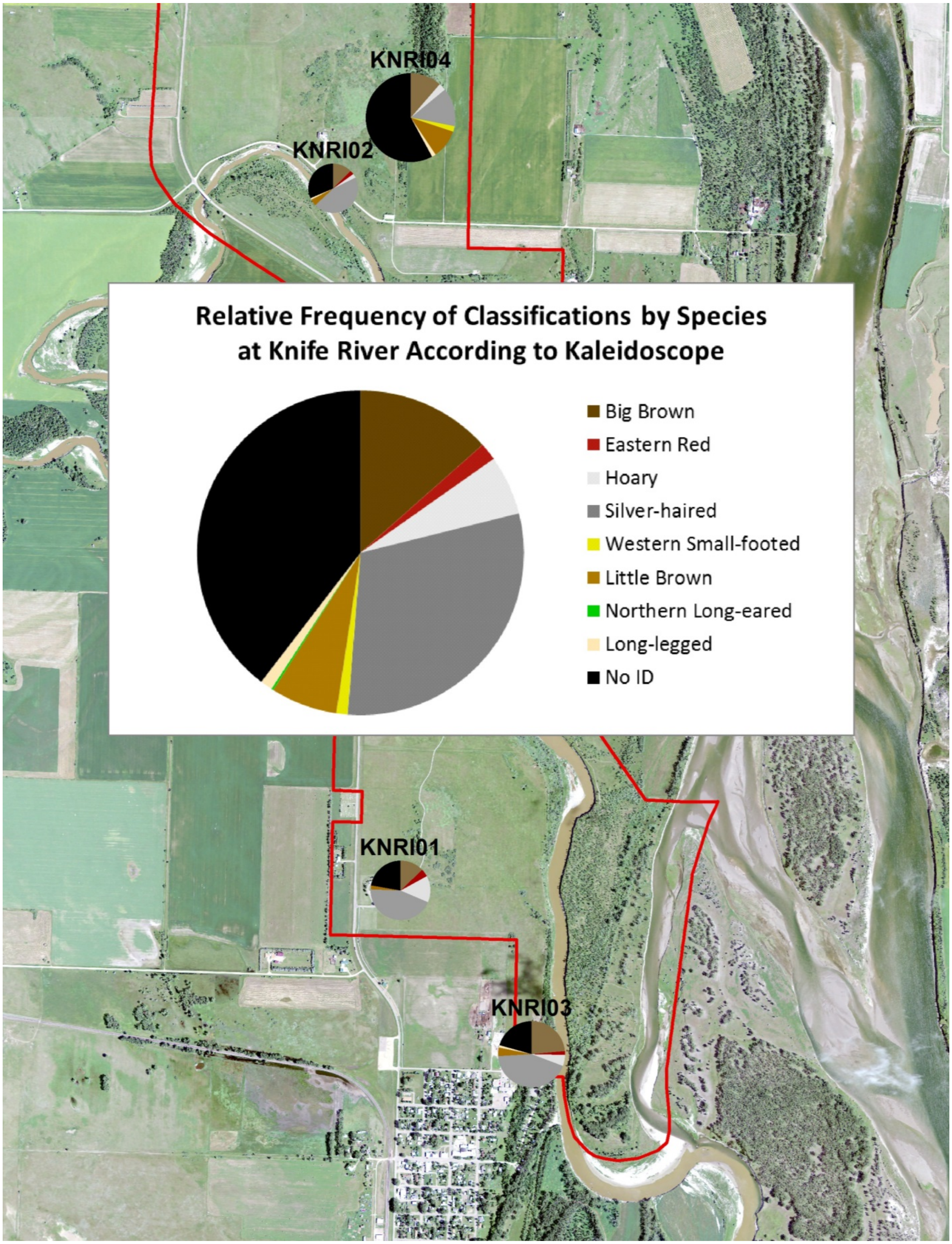

Figure 51. Relative frequency of classifications by species at Knife River Indian Villages NHS 2015-16. Size of circles is correlated with the rate of nightly activity.

Table 13. Species presence at Knife River Indian Villages NHS.

Species	NPSpecies Status[1]	Kaleidoscope		Sonobat[2]		Conclusion
		2015	2016	2015	2016	
Big Brown Bat	Probably Present	1	1	1	1	Present
Eastern Red Bat	–	1	1	1	0.38	Present
Hoary Bat	Present	1	1	1	1	Present
Silver-haired Bat	Probably Present	1	1	1	1	Present
W. Small-footed Myotis	Probably Present	0.89	1	0.55	0	Probably Present
Little Brown Bat	Present	1	1	1	1	Present
N. Long-eared Bat	Probably Present	0.80	0	0.18	0	Unconfirmed
Long-legged Myotis	–	1	1	1	1	Present

[1] NPSpecies accessed 9-30-2015.

[2] Using Montana-Plains classifier package.

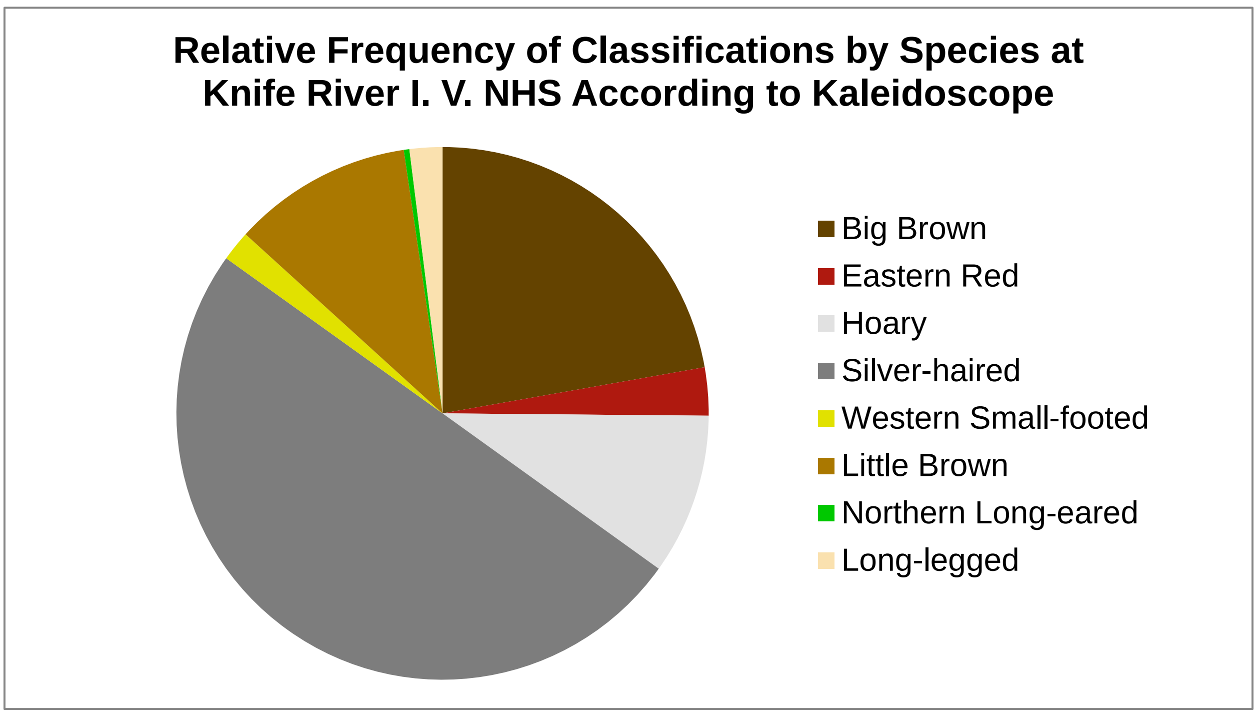

Figure 52. Relative frequency of classifications by species at Knife River Indian Villages NHS according to Kaleidoscope.

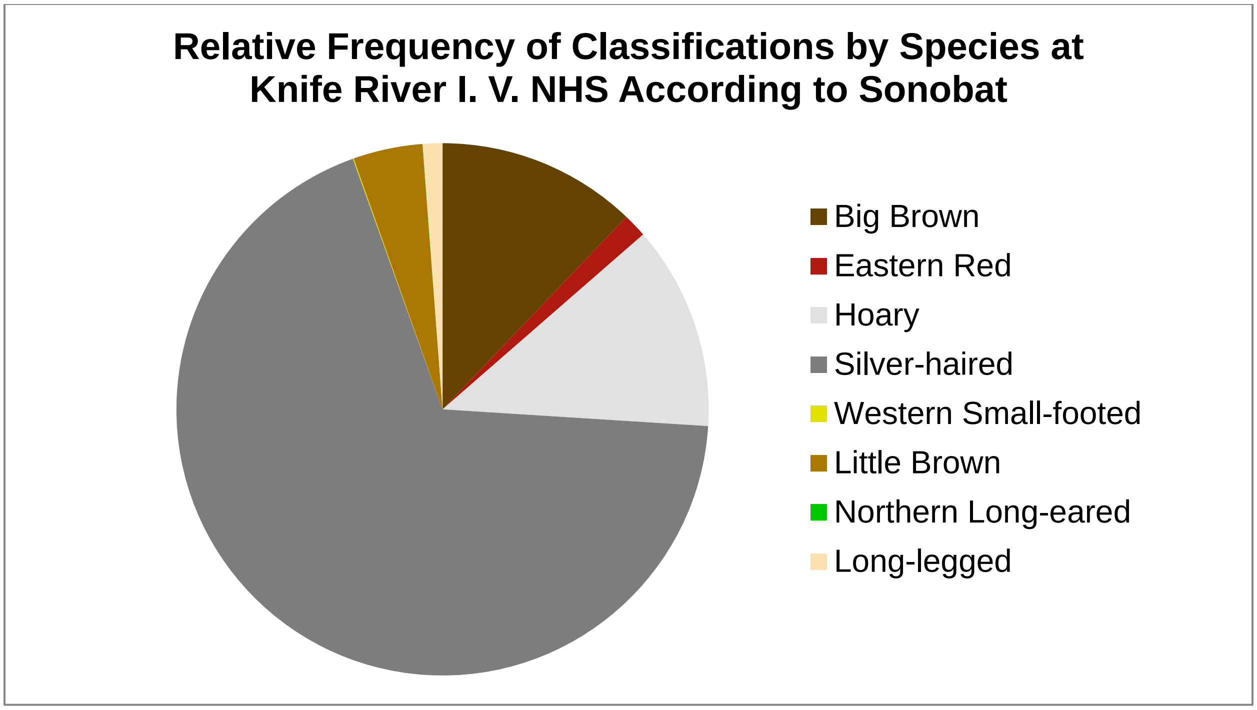

Figure 53. Relative frequency of classifications by species at Knife River Indian Villages NHS according to Sonobat. Results from Montana-Plains classifier package.

Compared to some other parks, there was little variability between the monitoring stations in terms of species diversity. Little brown bats were classified relatively more at the woodland site and hoary and silver-haired bats were more frequently classified at the other more sites all of which were more open.

There was no noticeable difference in the average nightly detection rates between 2015 and 2016 (**Figure 54**). Bat activity by hour of night generally showed peaks just after sunset and just before sunrise (**Figure 55**). (Sunset during that period was about 9:35pm and sunrise about 6:10am.) However, the site near the visitor center/administrative area only showed a peak just after sunset. This suggests bats were foraging at the site, but probably not day roosting. Conversely, site KNRI04, which was located in the woodland, showed a strong peak just before daybreak, probably due to bats swarming before roosting in a tree.

Although Knife River Indian Villages is used by bats, and appears to provide quality habitat, average nightly use was less than at some other apparently similar parks. For example, the recorder in the forested riparian area just north of the town of Stanton averaged 296 detections per night; in contrast, three recorders in the forested riparian area at Fort Laramie NHS averaged 943 bat detections per night. A plausible reason for the difference is that the latter park established a bat house. Establishment of a bat house at Knife River Indian Villages NHS could be justified as mitigation for the loss of old growth riparian habitat along the Missouri River. Such a structure might greatly increase bat activity in the park, especially for the little brown bat. To conserve the threatened northern long-eared bat the park should protect, and if possible, expand the forested areas in the park as the species is strongly associated with forests (Henderson and Broders 2008). Cottonwood stands 60 years or older have been found to provide better Missouri River habitat for bats than younger stands (Swystun et al. 2007) and therefore should be protected. Schmidt et al. (2004) recommended that the park avoid summer burns to protect bats.

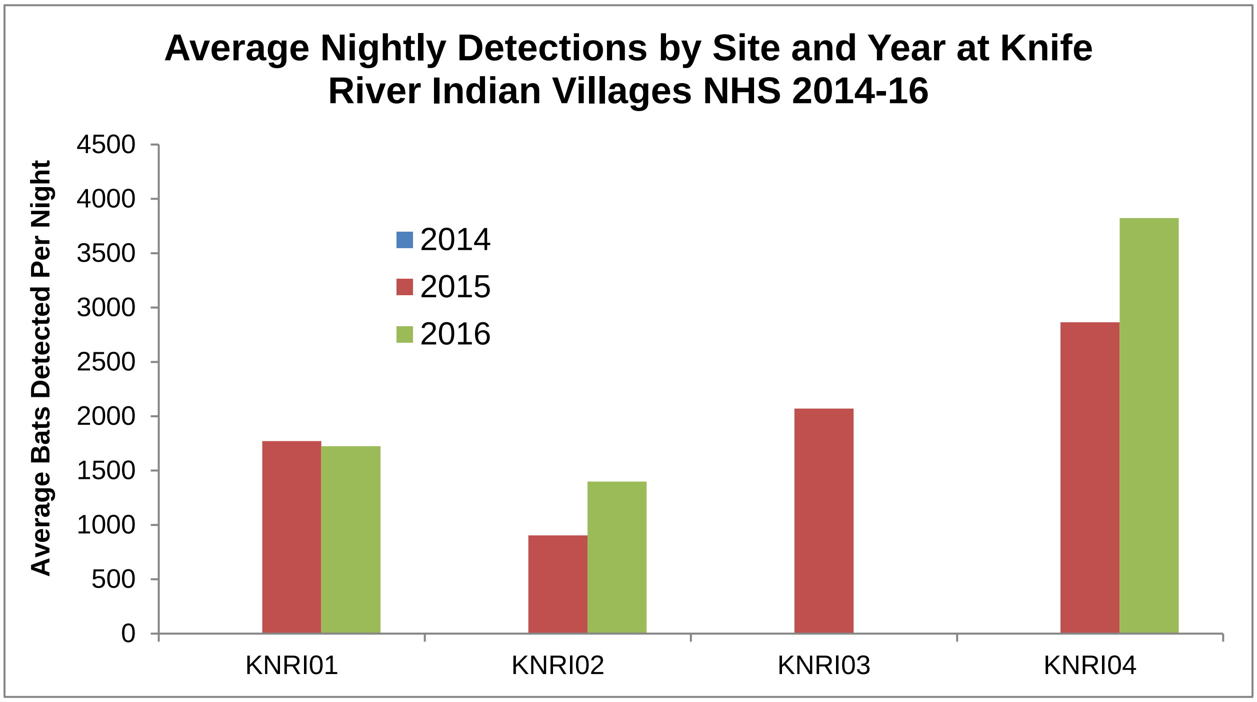

Figure 54. Average nightly detections by site and year at Knife River Indian Villages NHS 2015-16. Absence of a bar means the site was not monitored that year. Station KNRI03 malfunctioned in 2016.

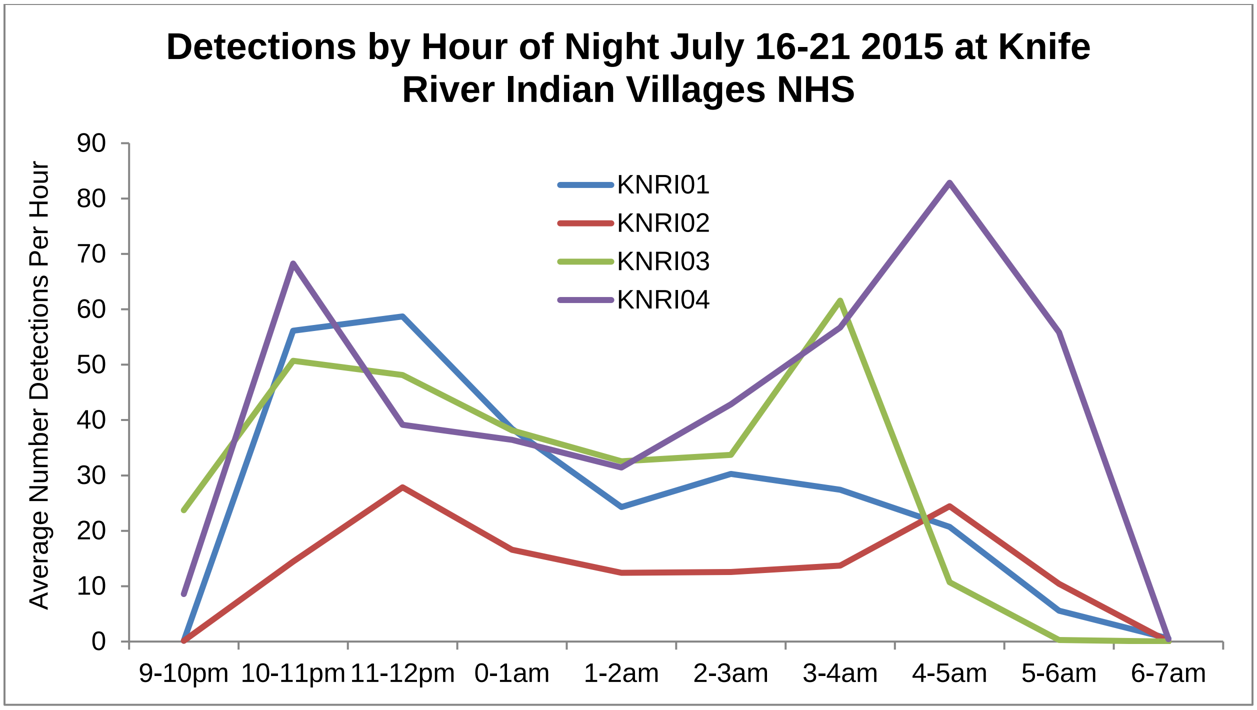

Figure 55. Detections by hour of night July 16-21 2015 at Knife River Indian Villages NHS.

Missouri NRR

The Missouri NRR encompasses 27,973 ha (69,124 ac) within its administrative boundary (land and water); however, only 124 ha (308 ac) are federal acres managed by the NPS. Other public land exists within the park's administrative boundary in the form of state parks and federal lands administered by other agencies such as the Army Corp of Engineers and the U.S. Fish and Wildlife Service. The Missouri River and associated riparian zone is the primary natural feature and resource within the park. Uplands consist of wooded bluffs, some small prairie remnants, and substantial amounts of cropland and pasture. Stock ponds are present in many of the agricultural lands.

Five NABat GRTS cells had all four quadrants at least partially within the park's administrative boundary, therefore, bat monitoring at the park used the NABat sampling frame and protocol. Three of the cells were clustered south of Vermillion, SD (the "Lower Reach", 59-Mile District), and two were clustered upriver near Niobrara, NE (the "Upper Reach", 39-Mile District). In 2014 only three of the cells were monitored due to the late arrival of equipment. In 2015 all five cells were monitored; however, a suitable location could not be found for deployment of a recorder in the NE quadrant of NABat cell #105833. In 2015 the station in the SW quadrant of NABat cell #029794 was relocated to a publicly owned State of Nebraska wildlife area.

In 2014 monitoring was initiated on July 28 and 29 with deployments scheduled for four days. However, station MNRR020258SE was relocated after the second night (with the original site renamed MNRR01). Station MNRR029794SW was subsequently be relocated in 2015 to a State of Nebraska Wildlife Management Area with the former site renamed MNRR02. In 2015 monitoring was initiated at two cells on July 1 and three cells on August 18. Deployments were scheduled for seven days in 2015; however, station MNRR060194NW stopped after one night. At the request of Adams Homestead and Nature Preserve State Park, three units were deployed at that site on August 19, 2015. The results are not included here, but are discussed later in a subsection. In 2016 deployments occurred throughout the summer. At cell MNRR105833 only two units were deployed and one of those did not function for a complete night. In 2016 the site at the Nebraska Wildlife Management Area was relocated again with the deployment in 2015 renamed MNRR03.

Using Kaleidoscope, there were 186,250 recordings from the 22 stationary points 2014-16; this includes the three sites that were discontinued (i.e., relocated). Of those recordings, 12% were noise files. This rate is substantially higher than at many other parks. The reason is unknown; however, it could be due to a higher rate of deployments near trees. Of the 164,136 bat recordings collected from stationary points, 23% could not be classified to species. Paradoxically, that rate is lower than most other parks in the Network.

A road survey route was established for each of the five cells. The intent was to conduct two surveys per route each summer. However, in 2014 only three cells were surveyed due to time limitations. In 2015 route MNRR020258RD was not followed properly so that data was censored. In two other cases only a single replicate was done in a year due to inclement weather. From 2014-16, 22 mobile surveys were conducted at the park. Excluding the censored data, there were 3,939 recordings from mobile surveys, of which 79% were noise files. Of the 828 bat recordings, 35% were not classified to the species level.

Prior to this study there were seven species reported to be present, and one species as probably present, at the Missouri NRR according to the NPSpecies database (**Table 14**). That list is generally consistent with what was found by Swier (2006) and Lane et al. (2003).

The Missouri NRR stretches from the edge of the eastern forest biome out into the western grassland biome. The park is also on the periphery of the range of several bat species that could be present only in a portion of the park. The NABat cells where the monitoring was conducted were clustered into an eastern group and a western group. As a result, for purposes of analyses I divided the park into upper (i.e., western; 39-Mile District) and an eastern (i.e., lower; 59-Mile District) reaches.

This study indicates that at least eight species are present within the park boundaries. The eight are present in both the lower reach (**Table 14**) and the upper reach (**Table 15**). Although **Table 14** and **Table 15** suggest some uncertainty about the presence of some species (e.g., tri-colored bat), an analysis of deployment-specific output (a more appropriate use of the statistical estimators) indicates the species were present, at least at some deployments.

The park is the easternmost park within the Northern Great Plains I&M Network. It is the only park in the Network where the evening bat was documented. The auto-identification software confirmed the presence of the northern long-eared bat, a threatened species. The Indiana bat is an endangered bat found from New England to the Midwest, with some range maps extending the range into central Iowa and southeastern Nebraska. Because the bat is of elevated conservation concern I used Kaleidoscope to conduct a separate auto-classification of the lower reach data that included the Indiana bat filter: there was insufficient evidence to conclude that the species was present within the park. The range of the western small-footed bat is generally considered to be west of the park; however, a few sources show it could extend eastward in the park (e.g., Higgins et al. 2000). Therefore, I ran the data from the upper reach stations through Kaleidoscope including the filter for that species; there was insufficient evidence to indicate it was present.

Table 14. Species presence in the 59-Mile District of the Missouri NRR.

Species	NPSpecies Status[1]	Kaleidoscope			Sonobat[2]			Conclusion
		2014	2015	2016	2014	2015	2016	
Big Brown Bat	Present	1	1	1	1	1	1	Present
Eastern Red Bat	Present	1	1	1	1	1	1	Present
Hoary Bat	Present	1	1	1	0.98	1	1	Present
Silver-haired Bat	Present	0	0	0	0.52	0.99	0.19	Present
Little Brown Bat	Present	0	1	0	0.73	0.26	0.12	Present
N. Long-eared Bat	Present	1	1	1	0.99	0.95	0.90	Present
Evening Bat	Prob. Present	0.47	1	1	0.74	0.99	1	Present
Tri-colored Bat	Present	0	1	0.08	0.74	0.73	0.74	Present

[1] NPSpecies accessed 9-30-2015.

[2] South Dakota - Eastern classifier package.

Table 15. Species presence in the 39-Mile District of the Missouri NRR.

Species	NPSpecies Status[1]	Kaleidoscope			Sonobat[2]			Conclusion
		2014	2015	2016	2014	2015	2016	
Big Brown Bat	Present	1	1	1	1	1	1	Present
Eastern Red Bat	Present	1	1	1	1	1	1	Present
Hoary Bat	Present	1	1	1	1	1	1	Present
Silver-haired Bat	Present	0	0	0.99	0.97	1	1	Present
Little Brown Bat	Present	1	1	0	0.50	0.55	0	Present
N. Long-eared Bat	Present	1	1	1	0.09	0.93	0.94	Present
Evening Bat	Prob. Present	1	1	1	0.88	0.97	1	Present
Tri-colored Bat	Present	0.14	0	0	0.74	0.18	0.55	Probably Present

[1] NPSpecies accessed 9-30-2015.

[2] South Dakota - Black Hills classifier package.

The most commonly reported species across the park was the big brown bat. This was true for both reaches and both software packages (**Figure 56** thru **Figure 59**). Although the two software packages showed some disparity in terms of relative species abundance, they were somewhat consistent in the reported differences between the lower and upper reaches of the Missouri. Both packages indicated a relatively greater proportion of eastern red and evening bat classifications in the upper reach of the Missouri. However, those results should be viewed cautiously as the deployment stations were not designed to compare regional differences and hence the results could simply be a reflection of the micro-habitats the units were deployed at.

The eastern red bat comprised a greater portion of the classifications at Missouri NRR than any other park, a not surprising result as this species is strongly associated with deciduous trees and its range is eastern North America. Conversely, the little brown bat was only a small portion of the species classified at the park. Some range maps show the species being absent from the southern Great Plains, including central Nebraska (Benedict 2004, Harvey et al. 2011).

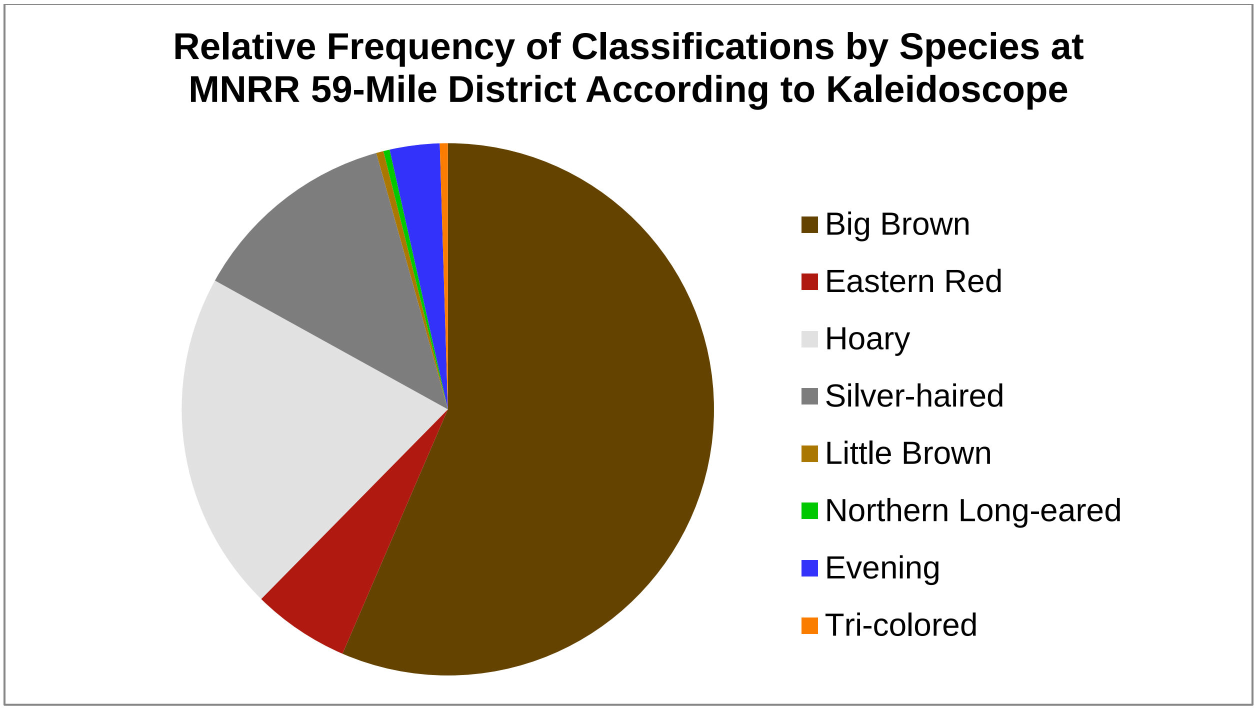

Figure 56. Relative frequency of classifications by species in the 59-Mile District of the Missouri NRR according to Kaleidoscope.

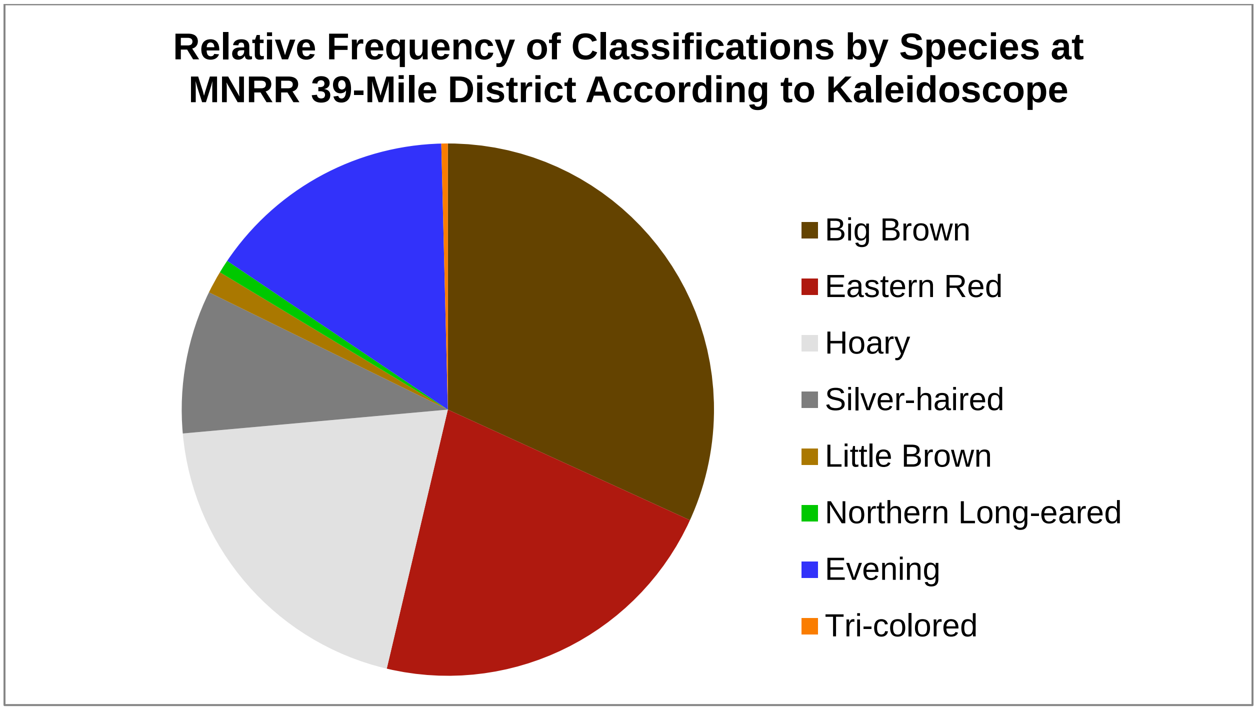

Figure 57. Relative frequency of classifications by species in the 39-Mile District of the Missouri NRR according to Kaleidoscope.

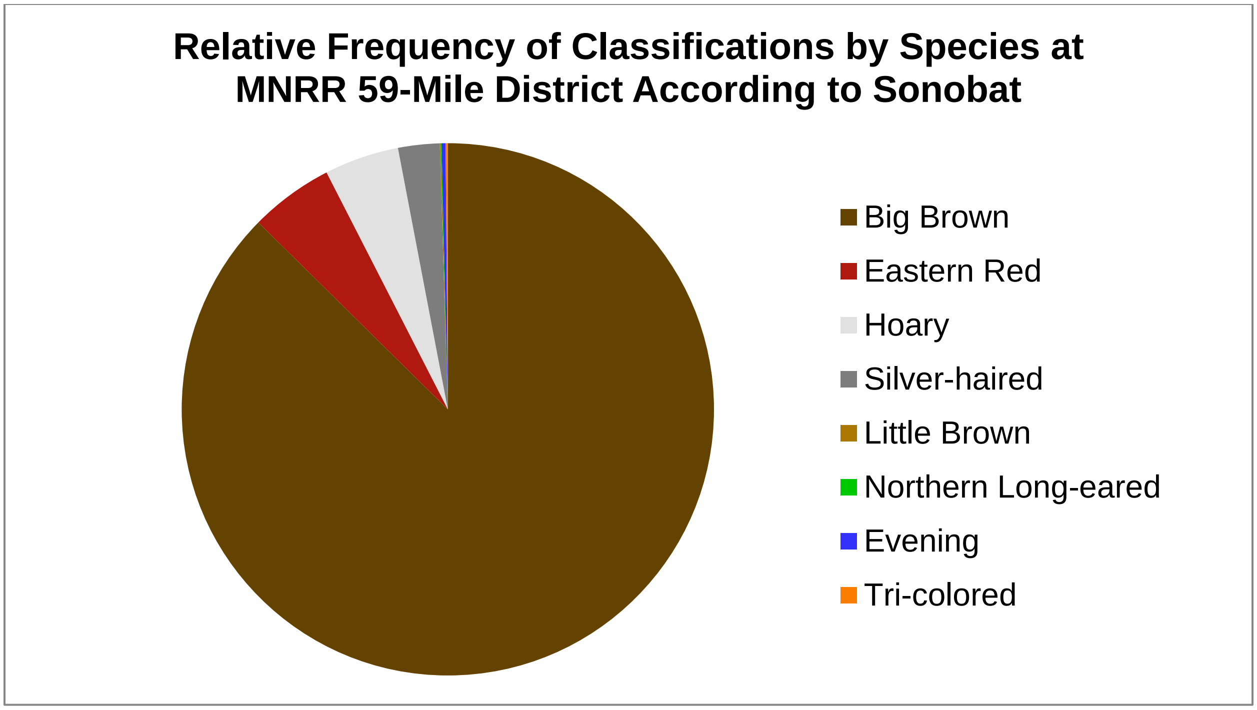

Figure 58. Relative frequency of classifications by species in the 59-Mile District of the Missouri NRR according to Sonobat. Results from Midwest classifier package.

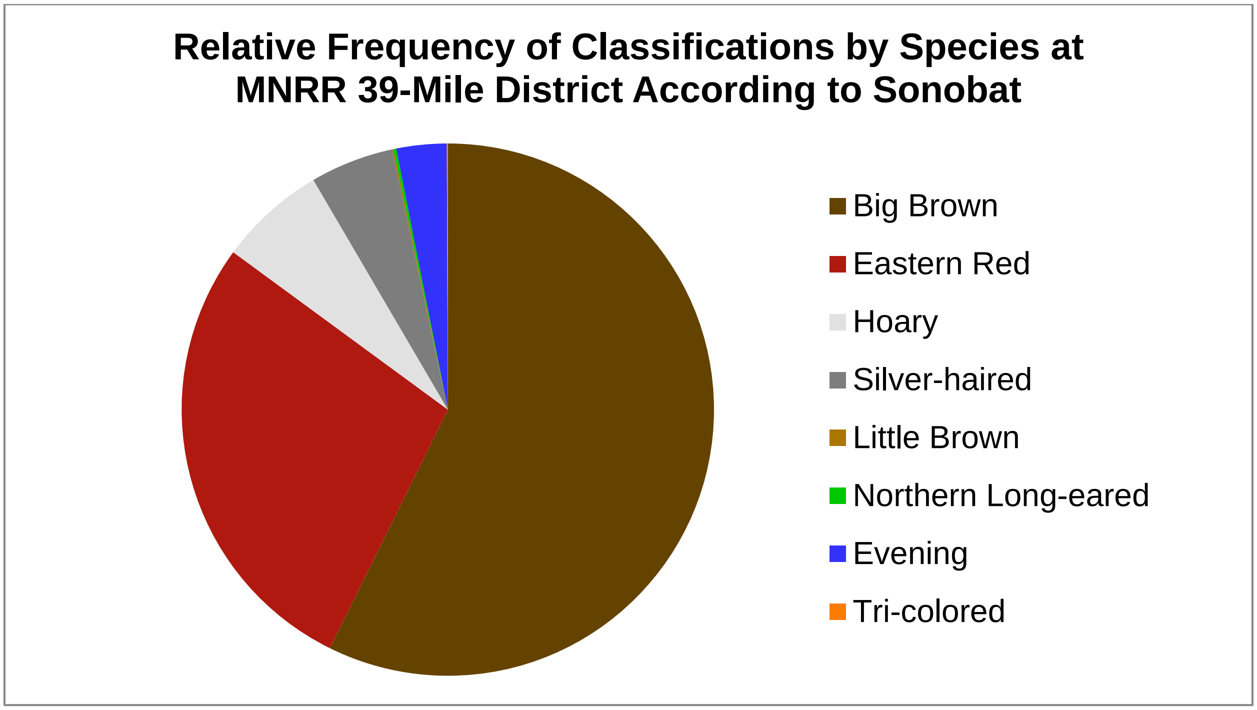

Figure 59. Relative frequency of classifications by species in the 39-Mile District of the Missouri NRR according to Sonobat. Results from Midwest classifier package.

Five NABat cells had at least a portion of each quadrant within the park administrative boundary and were therefore used for monitoring. However, the park boundary is long and linear as it follows the Missouri River and larger tributaries (**Figure 60** thru **Figure 64**), hence, large portions of cells were outside the narrow park administrative boundary. Furthermore, the federal government owns very little property in the region, even within the park boundary. As a result, almost all stations were deployed on non-federal properties.

NABat cell #105833 encompassed Niobrara State Park and the confluence of the Niobrara and Missouri Rivers as well as the town of Niobrara, NE (**Figure 60**). With the exception of the state park, much of the land was privately owned. Three monitoring stations were established, but no suitable location could be found in the NE quadrant. Efforts should be made in the future to find a suitable site. The units in the SE and SW quadrants were both within the state park and associated with water. Both showed moderately-high rates of bat activity. In contrast, the station in the NW quadrant was in a road right-of-way in a cultivated landscape; it showed some of the lowest bat activity of any station in the Network.

NABat cell #029794 encompassed the Lower Niobrara River and Verdigree Creek (**Figure 61**). In 2014 the station in the SW quadrant was deployed on private land. In 2015 it was moved to the Bohemia Prairie Wildlife Management Area (WMA); however, the new site was in a grassland/juniper habitat that had little bat activity so in 2016 it was moved to two wetlands within the WMA. The station in the NE quadrant was along the bank of the Niobrara River. The station in the NW quadrant was located on Ponca Tribal property near some large cottonwood trees; it was noteworthy because of the high percentage of red bat classifications.

South of Vermillion, South Dakota was NABat cell #060194 (**Figure 62**). The site included the Mulberry Bend Overlook, a small tract of federal property under the jurisdiction of the park. Two stations were placed at the site, barely over 275 m (300 yd) apart. Station MNRR060194SE, although considered the SE station, was actually just inside the NE quadrant, nevertheless, this slight deviation from protocol was made because of the desire to monitor the NPS property. Station MNRR060194NW was on land managed by the Army Corp of Engineers.

NABat cell #031522 included substantial cropland, especially on the South Dakota side of the Missouri River (**Figure 63**). In spite of that, a station next to Burbank Lake in the NE quadrant and a station next to the Missouri River in the NW quadrant had some of the highest bat activity in the Network (> 1,600 bats per night). Big brown bats, and to a lesser extent, hoary and silver-haired bats comprised almost all of the classifications within the cell.

NABat cell #020258 included Ponca State Park and was the eastern-most cell in the Network (**Figure 64**). The SE station was next to a pond within the park administrative/visitor area. The NW station was within a discontiguous unit of the park. The site was on the bank of the Missouri River next to a forested area; it showed high rates of bat activity. The NE station was on a State of Nebraska Elk Point Bend Wildlife Management Area. The eastern red bat was common at the site than many other sites in the Network.

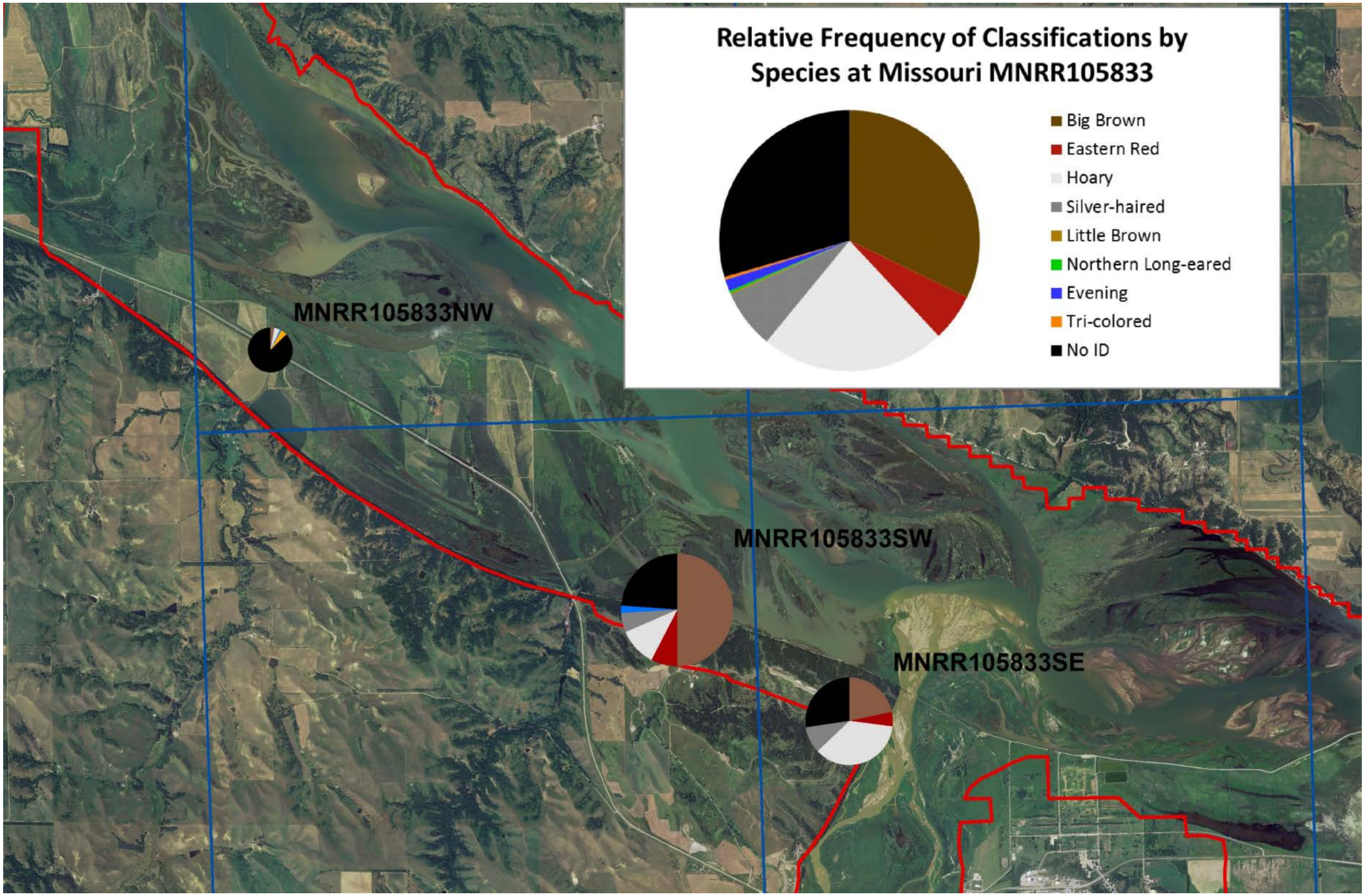

Figure 60. Relative frequency of classifications by species at Missouri Niobrara State Park cell (#105833). Size of circles is correlated with rate of nightly activity. Blue lines are the four quadrants of the NABat cell and red lines are the park boundary.

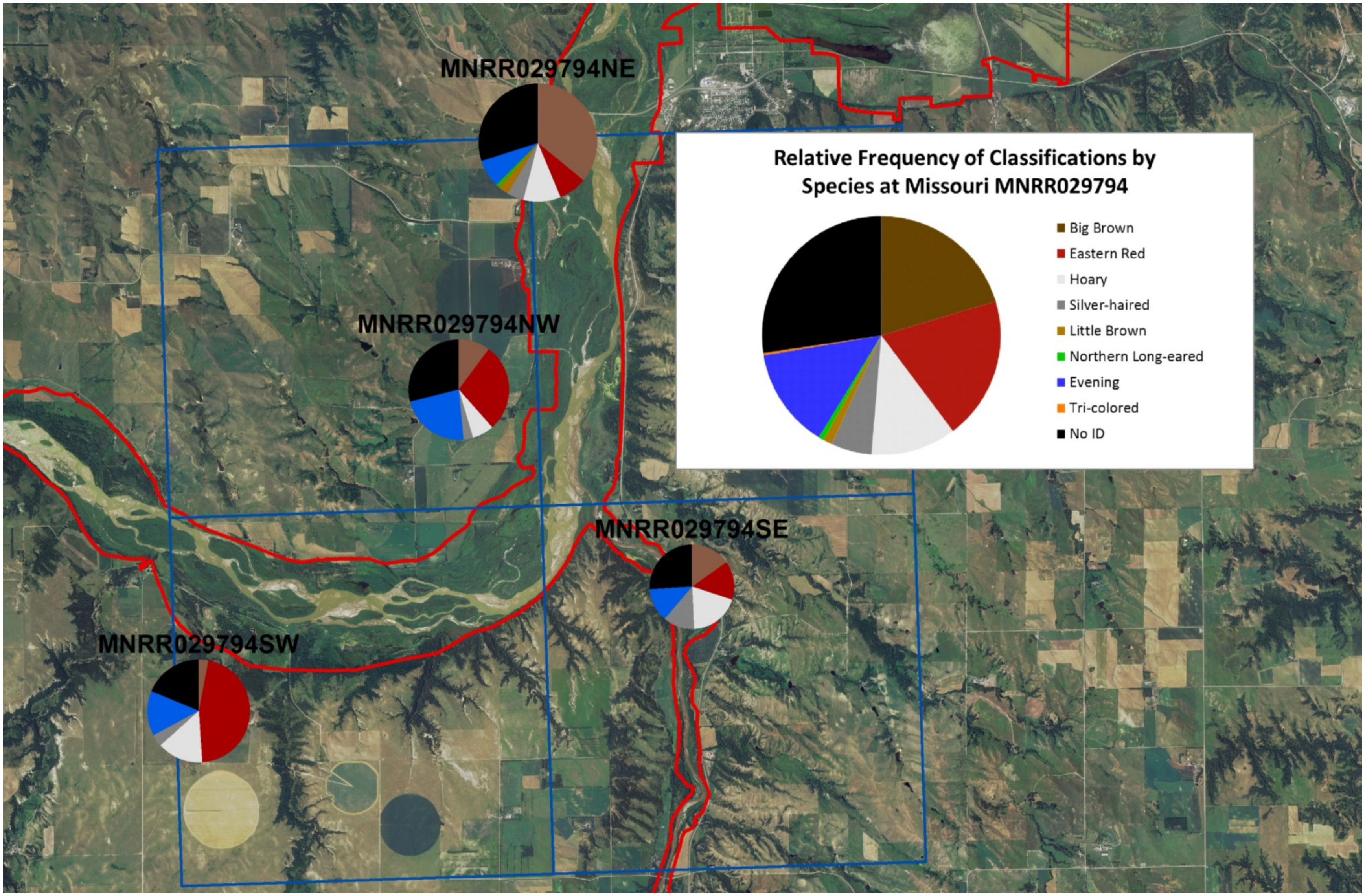

Figure 61. Relative frequency of classifications by species at Missouri Niobrara River cell (#029794). Size of circles is correlated with rate of nightly activity. Blue lines are the four quadrants of the NABat cell and red lines are the park boundary.

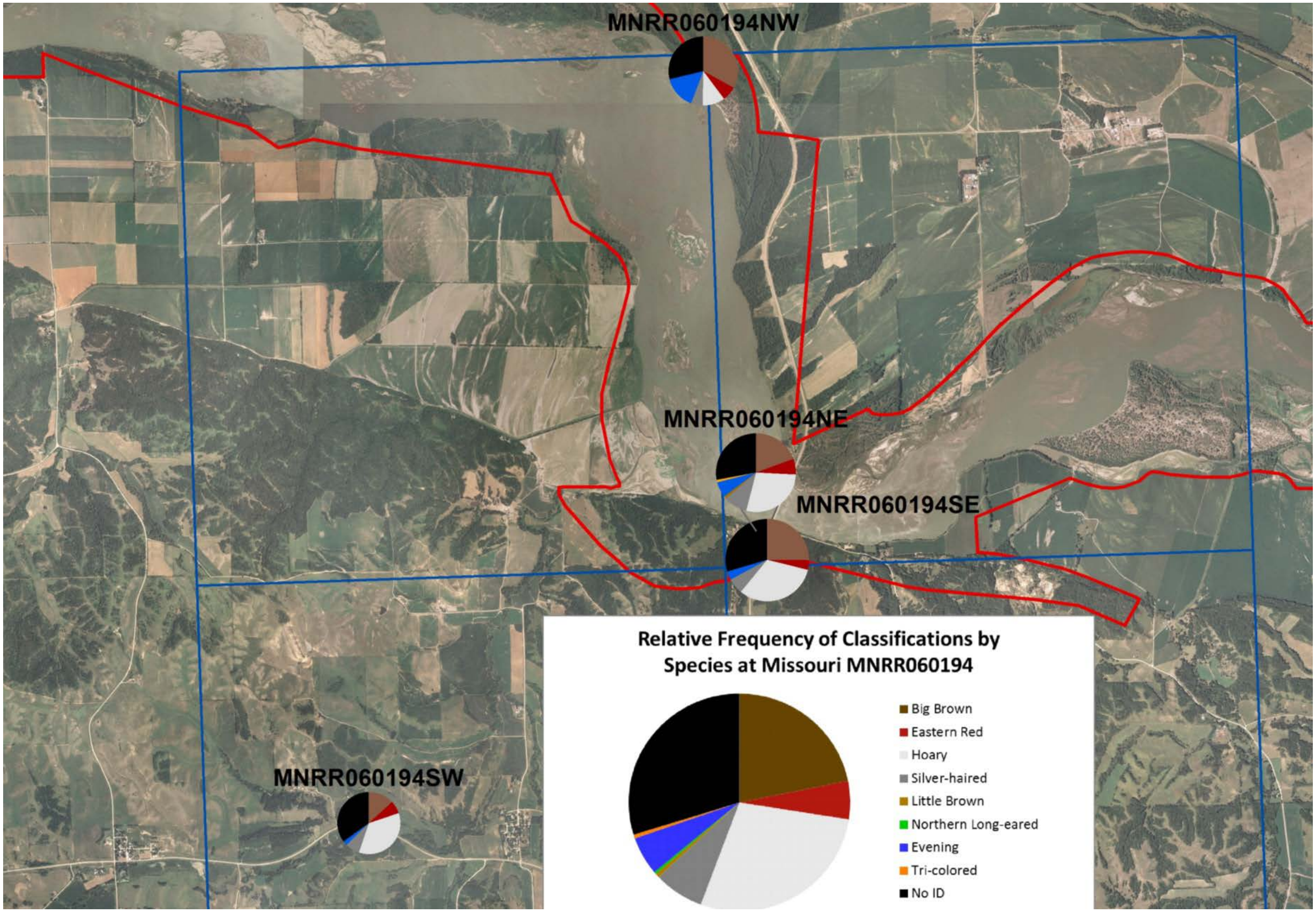

Figure 62. Relative frequency of classifications by species at Missouri Vermillion Bridge cell (#060194). Size of circles is correlated with rate of nightly activity. Blue lines are the four quadrants of the NABat cell and red lines are the park boundary.

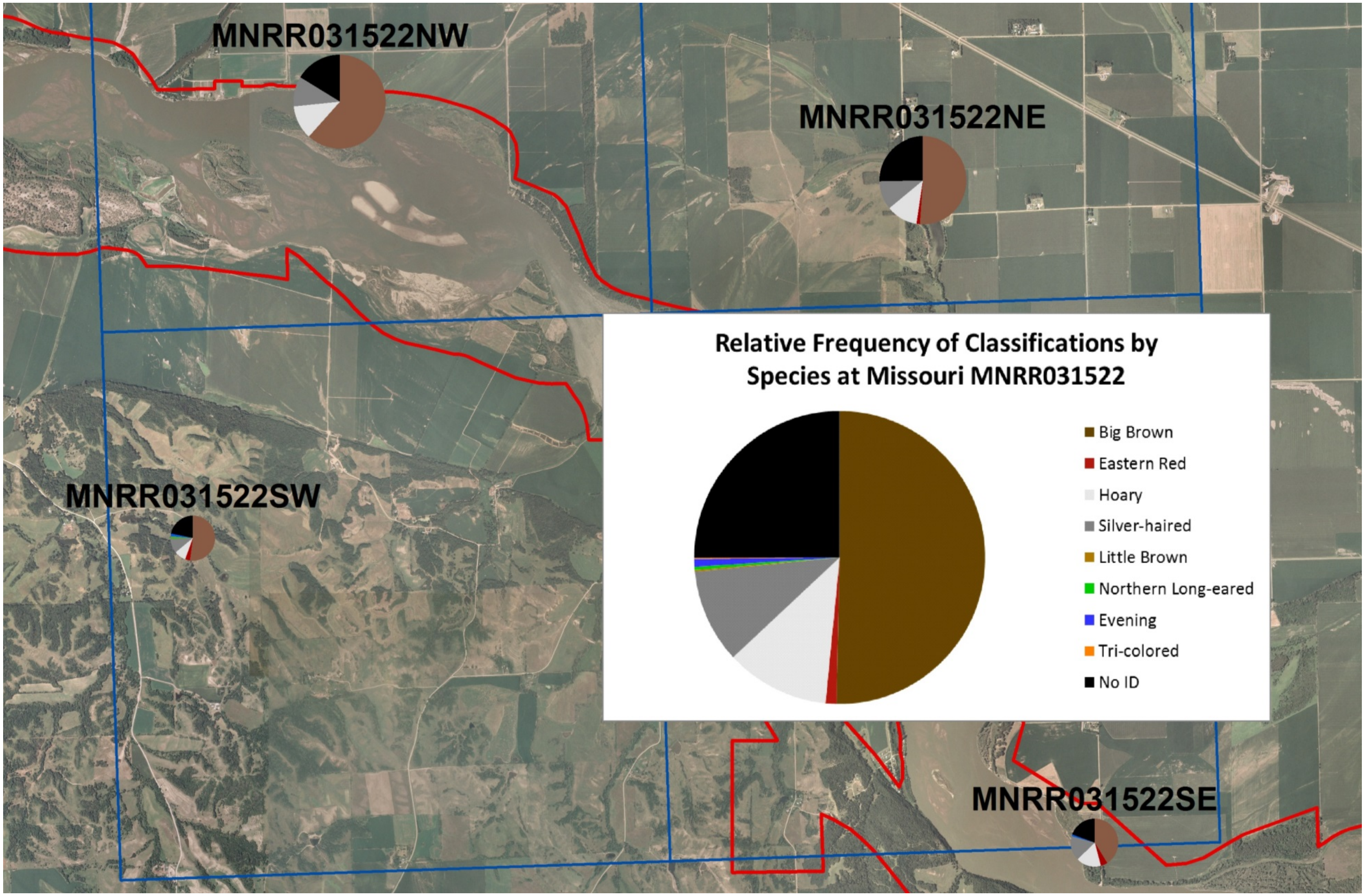

Figure 63. Relative frequency of classifications by species at Missouri Burbank SD cell (#031522). Size of circles is correlated to rate of nightly activity. Blue lines are the four quadrants of the NABat cell and red lines are the park boundary.

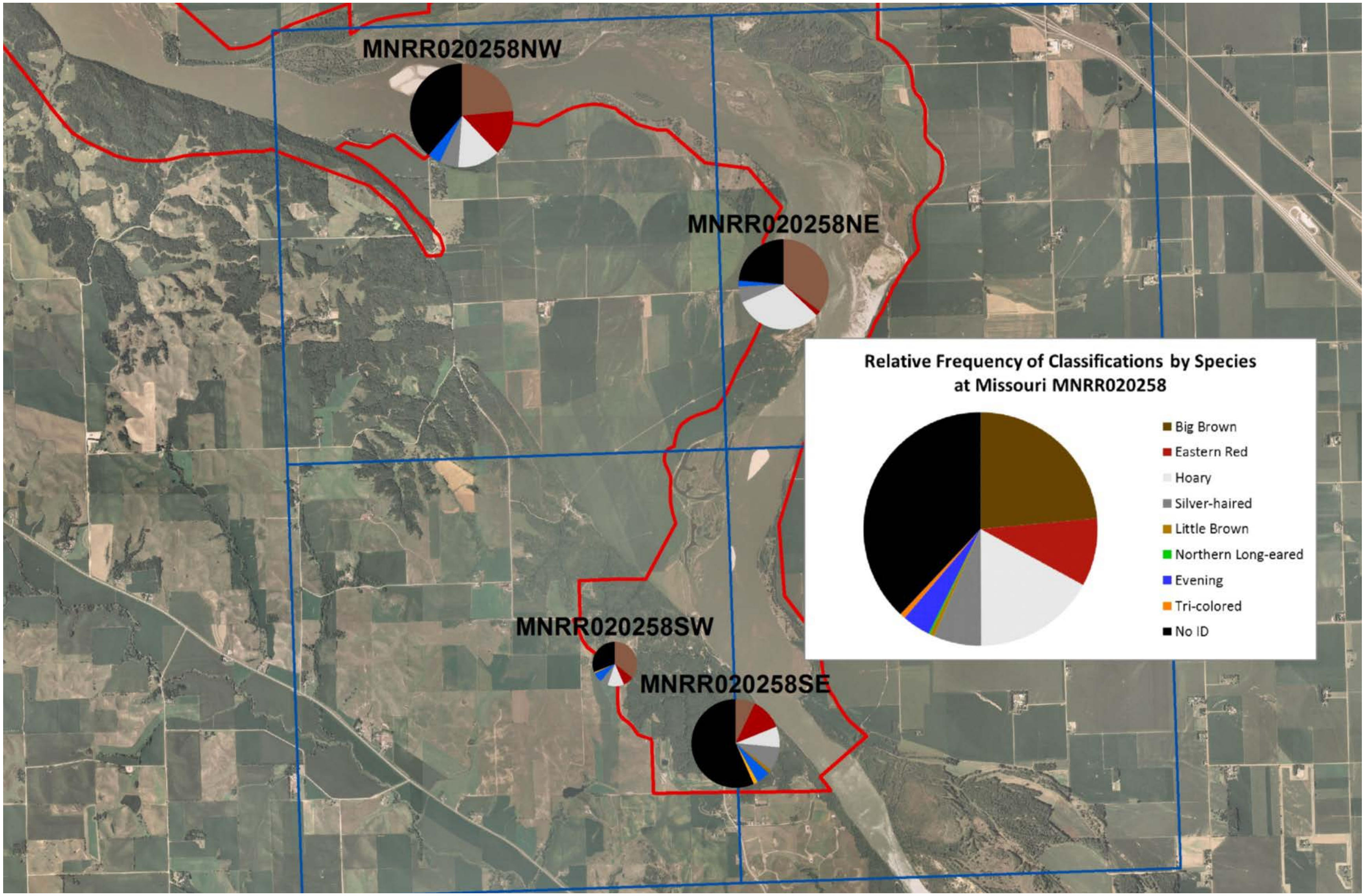

Figure 64. Relative frequency of classifications by species at Missouri Ponca State Park cell (#020258). Size of circles is correlated to rate of nightly activity. Blue lines are the four quadrants of the NABat cell and red lines are the park boundary.

Across all stationary points for all years the average number of detections per night at the Missouri NRR was 574. There were substantial inter-year differences within some stations (**Figure 65**). The results demonstrate the risks in interpreting long-term trends from short-term changes. For example, of the 10 stations monitored in all three years 2014-16, eight showed a decline from 2014 to 2015, yet from 2015 to 2016 all 10 showed an increase. More specifically, those 10 stations averaged 833 bats per night in 2014, 414 per night in 2015, and 1,217 per night in 2016 (unweighted).

Ideally, mobile routes would be located entirely within NABat cells. However, that was problematic at the Missouri NRR because rivers bisected several cells and bridges were not suitably located. Furthermore, roads were limited. As a result, considerable portions of the routes were outside the NABat cells. However, spatial coordinates were collected with the recordings allowing flexibility in analysis (e.g., researchers could use only detections within the cell if desired).

Mobile survey route MNRR105833RD (Niobrara State Park) was established and first ran in 2015 (**Figure 66**). Much of the route went through cropland. Few detections were made compared to other road surveys in the Network. Nevertheless, the route should be revisited in future years.

Mobile survey route MNRR029794RD (Niobrara River) was run all three years (**Figure 67**); however, the second replicate in 2015 was cancelled due to weather. Bat detections were substantially greater than in NABat cell #105833 (immediately to the north). This is likely due to the greater amount of woody vegetation along the route and the higher percentage of the route in close vicinity to water. The portions of the route that went through open cropland had less bat activity.

Mobile survey route MNRR060194RD (Vermillion Bridge) was established and first ran in 2015 (**Figure 68**). The first survey had almost constant bat detections and could have been a malfunction. Hence, I used the second replicate that year in **Figure 68**. However, the second survey does not appear to have ended at Chestnut Street in the town of Vermillion as three bats were detected after that junction (essentially in town). Future surveys should take steps to end at Chestnut Street.

Much of mobile survey route MNRR031522RD (Burbank SD) was outside of the NABat cell (**Figure 69**). This was necessary because the Missouri River prevented a barrier to efficiently covering the cell. The tail end of the route passes through NABat cell #060194. The NABat program will have to decide how to analyze this data when conducting landscape-level analyses. The fact that GPS data is collected along with each detection allows researchers to parse the mobile survey data to meet their needs. Detections were generally evenly spread throughout the prairie/woodland habitats, but greatly increased when the route concluded by the Missouri River.

Mobile survey route MNRR020258RD (Ponca State Park) was run all three years. However, in 2015 a wrong turn was made so those replicates were censored (but are archived should they be needed). As a result, **Figure 70** shows data only from the first replicates in 2014 and 2016. As was the case for most of the road surveys, bat detections were much less over cropland areas.

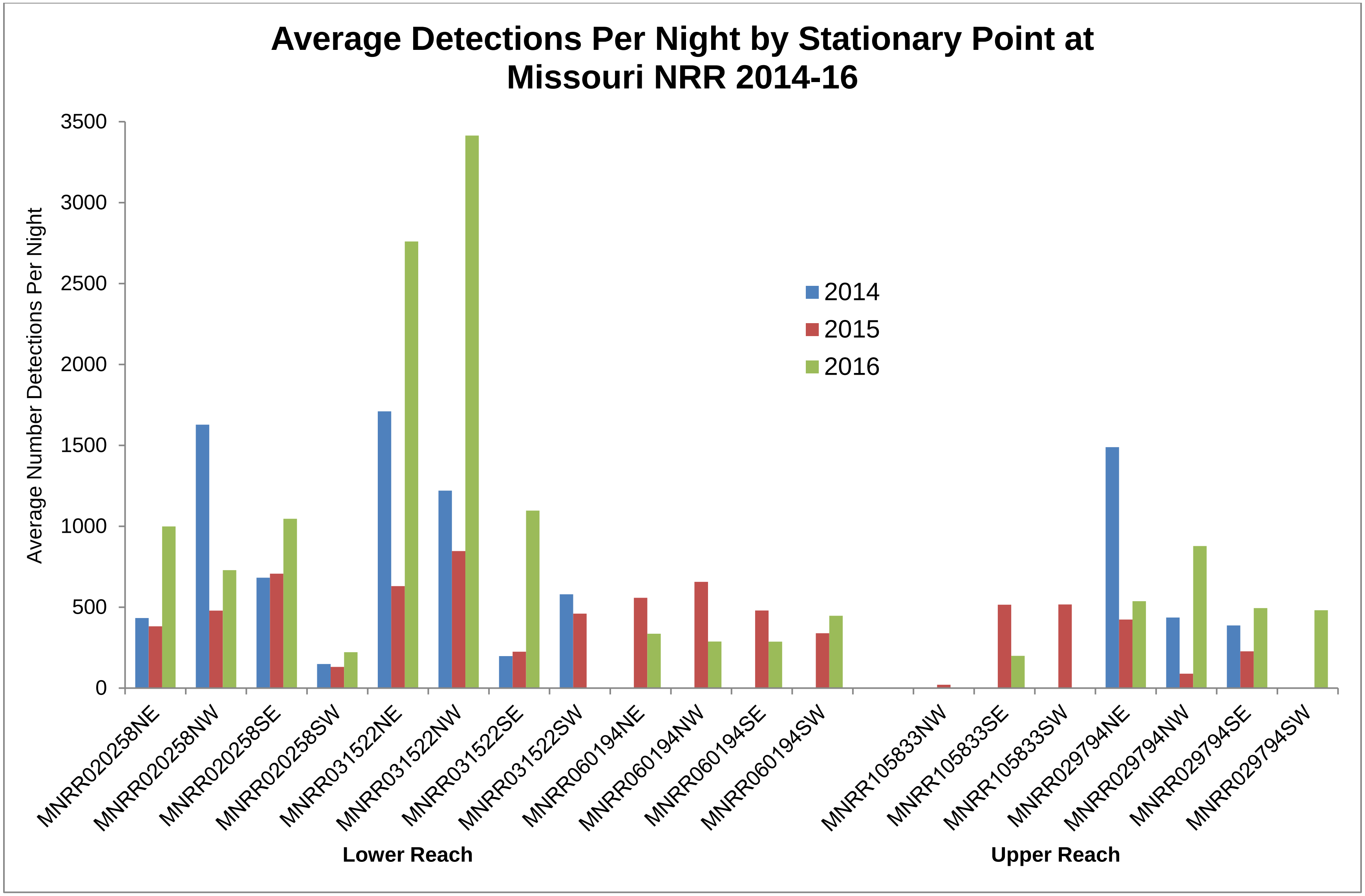

Figure 65. Average number of detections per night at stationary points at Missouri NRR 2014-16. The absence of a bar indicates the site was not successfully monitored in that year.

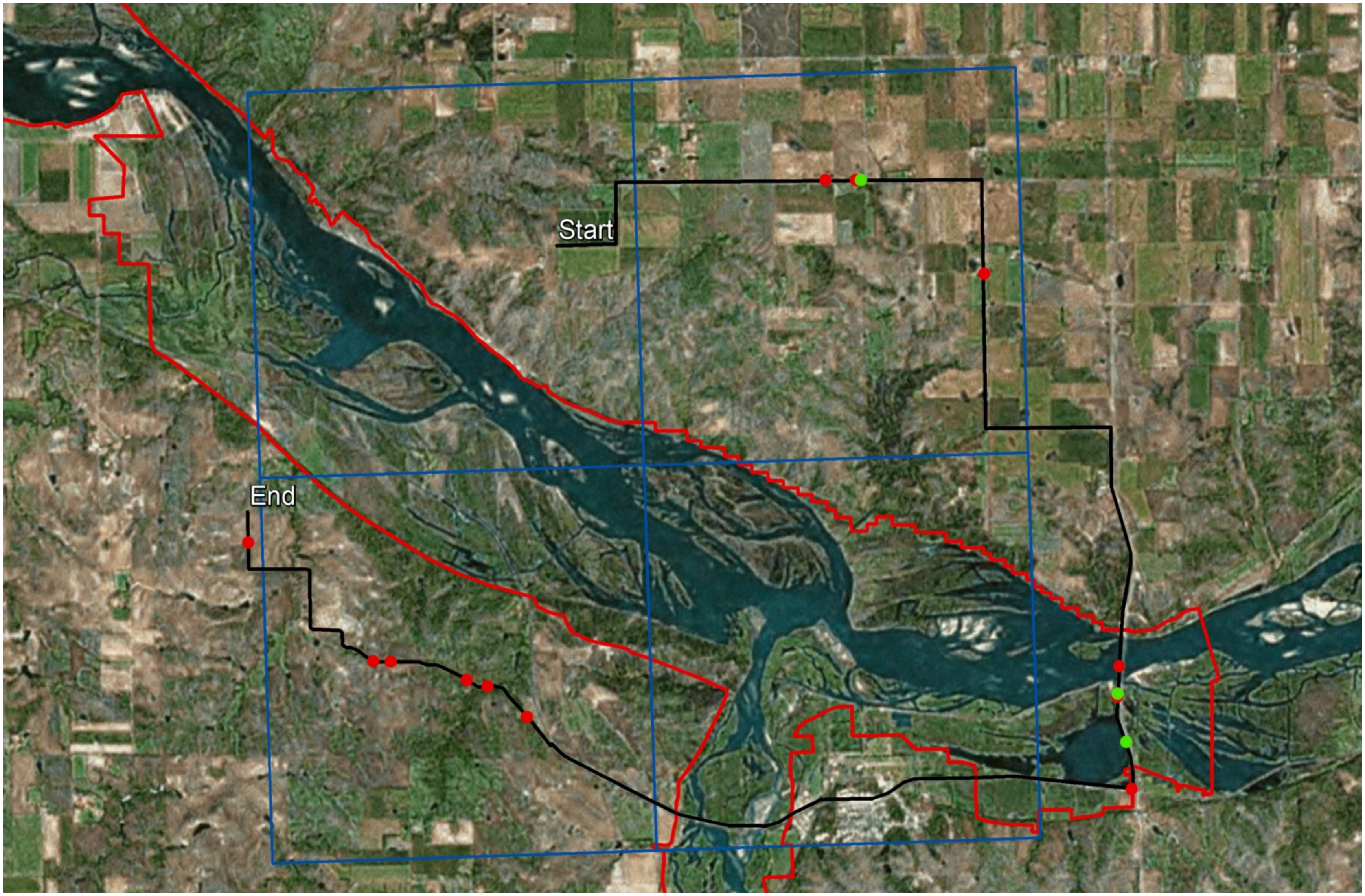

Figure 66. Detections from Missouri NRR Niobrara State Park (NABat cell #105833) mobile surveys 2015-16. First replicates only. Red circles are from 2015 and green from 2016. Blue square is the NABat cell and red line is the park boundary.

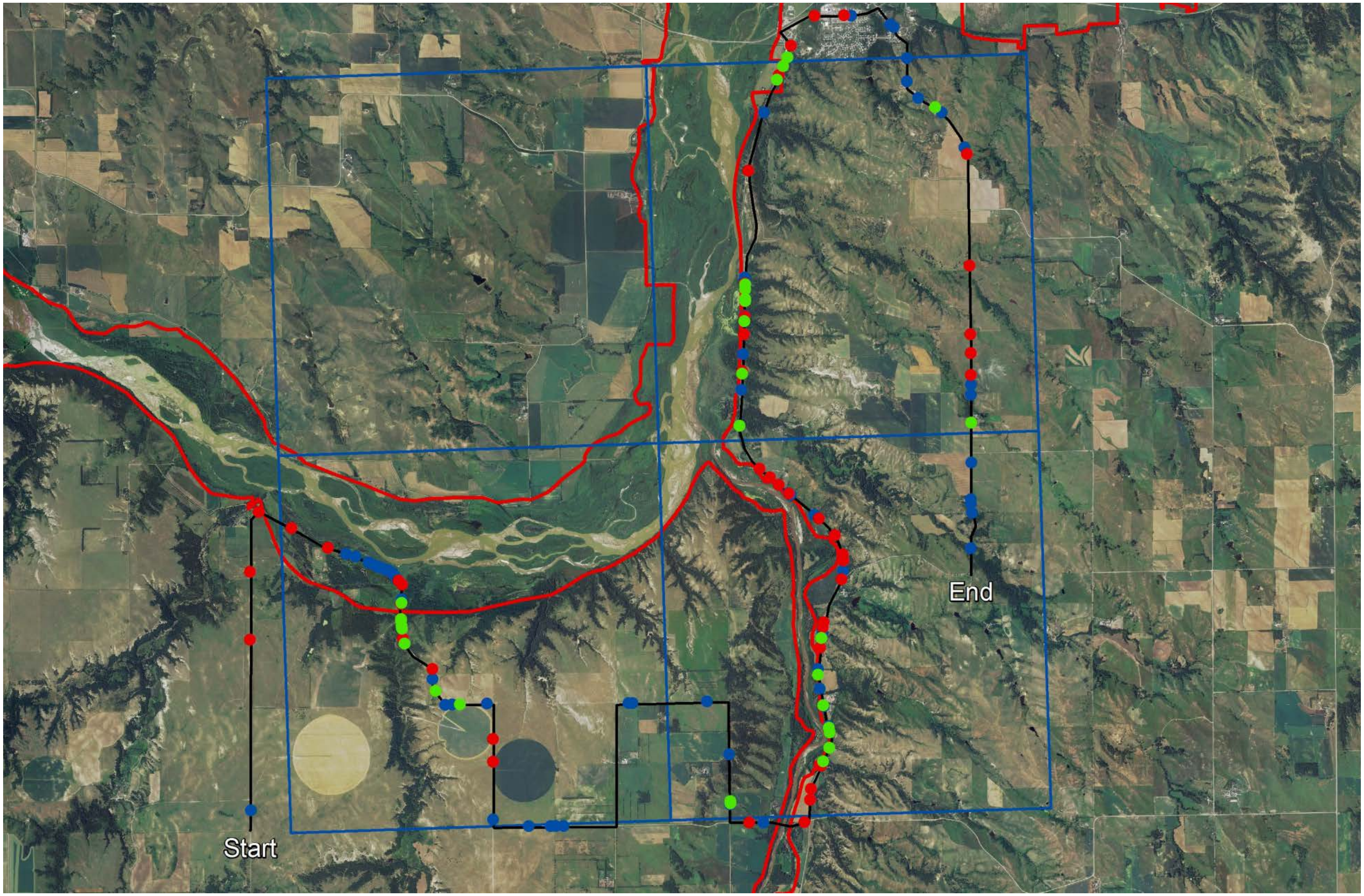

Figure 67. Detections from Missouri NRR Niobrara River (NABat cell #029794) mobile surveys 2014-16. First replicates only. Blue circles are from 2014, red from 2015, and green from 2016. Blue square is the NABat cell and red line is the park boundary.

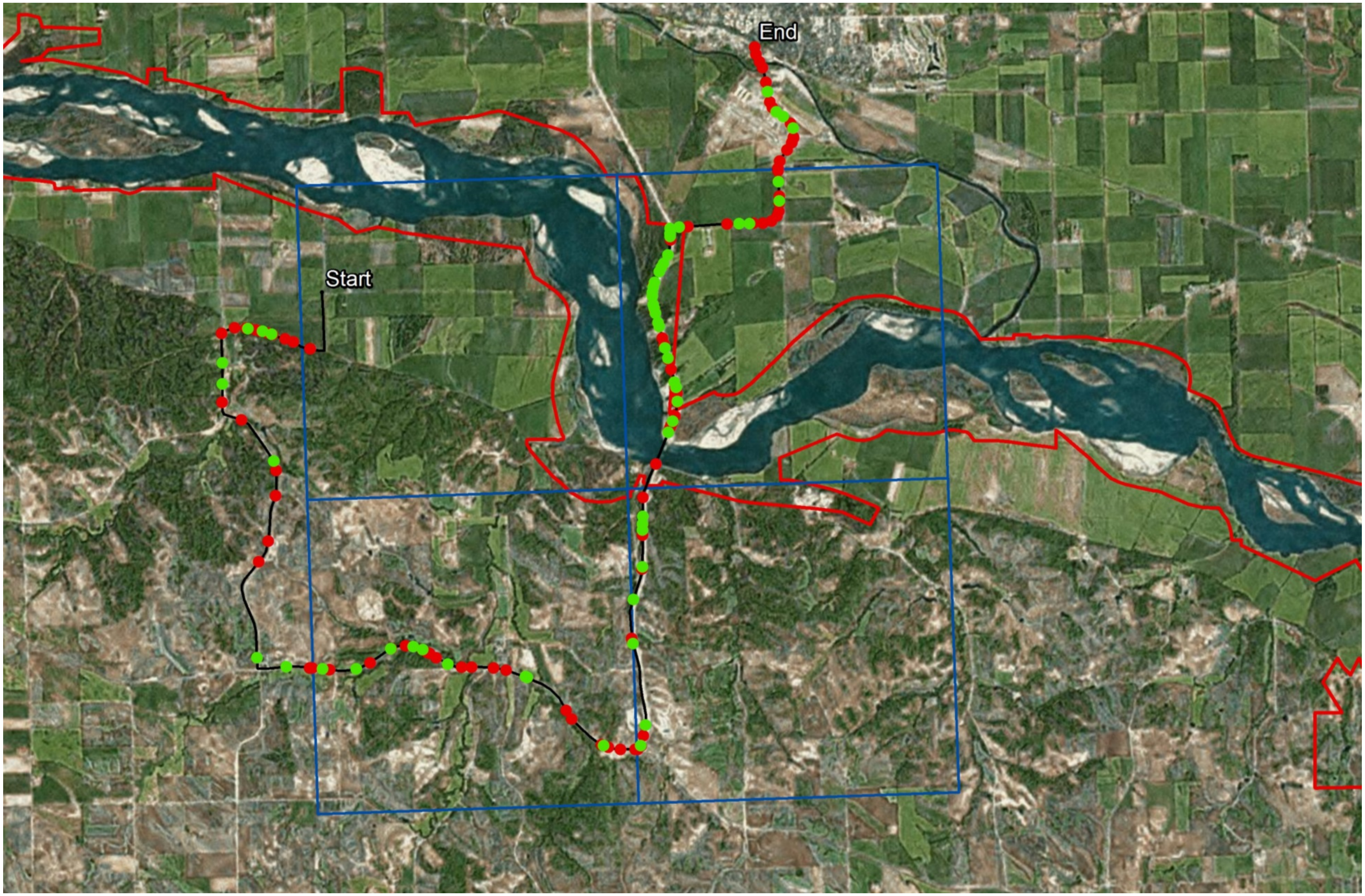

Figure 68. Detections from Missouri NRR Vermillion Bridge (NABat cell #060194) mobile surveys 2015-16. First replicates only. Red circles are from 2015 and green from 2016. Blue square is the NABat cell and red line is the park boundary.

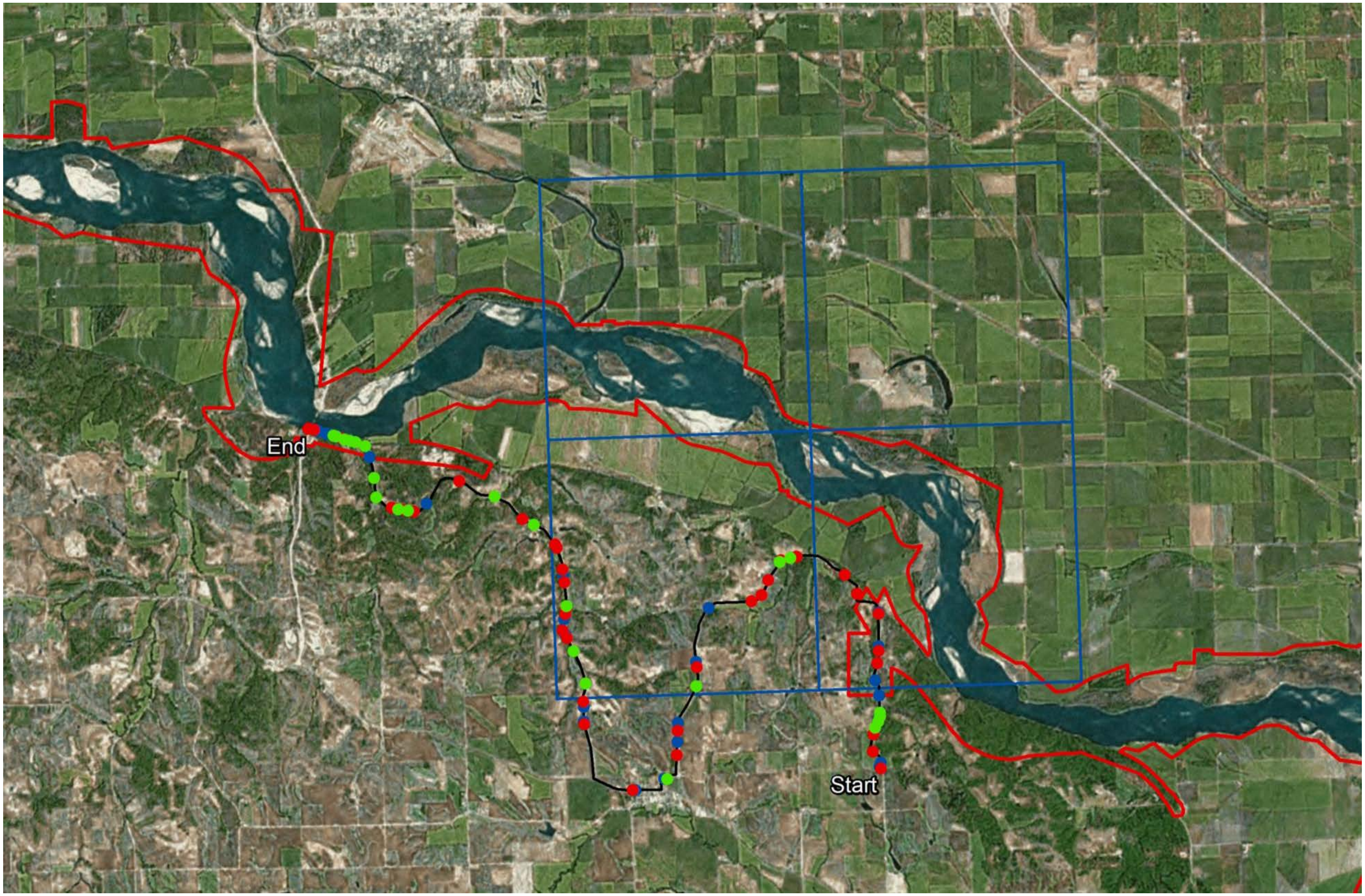

Figure 69. Detections from Missouri NRR Burbank Lake (NABat cell #031522) mobile surveys 2014-16. First replicates only. Blue circles are from 2014, red from 2015, and green from 2016. Blue square is NABat cell and red line is the park boundary.

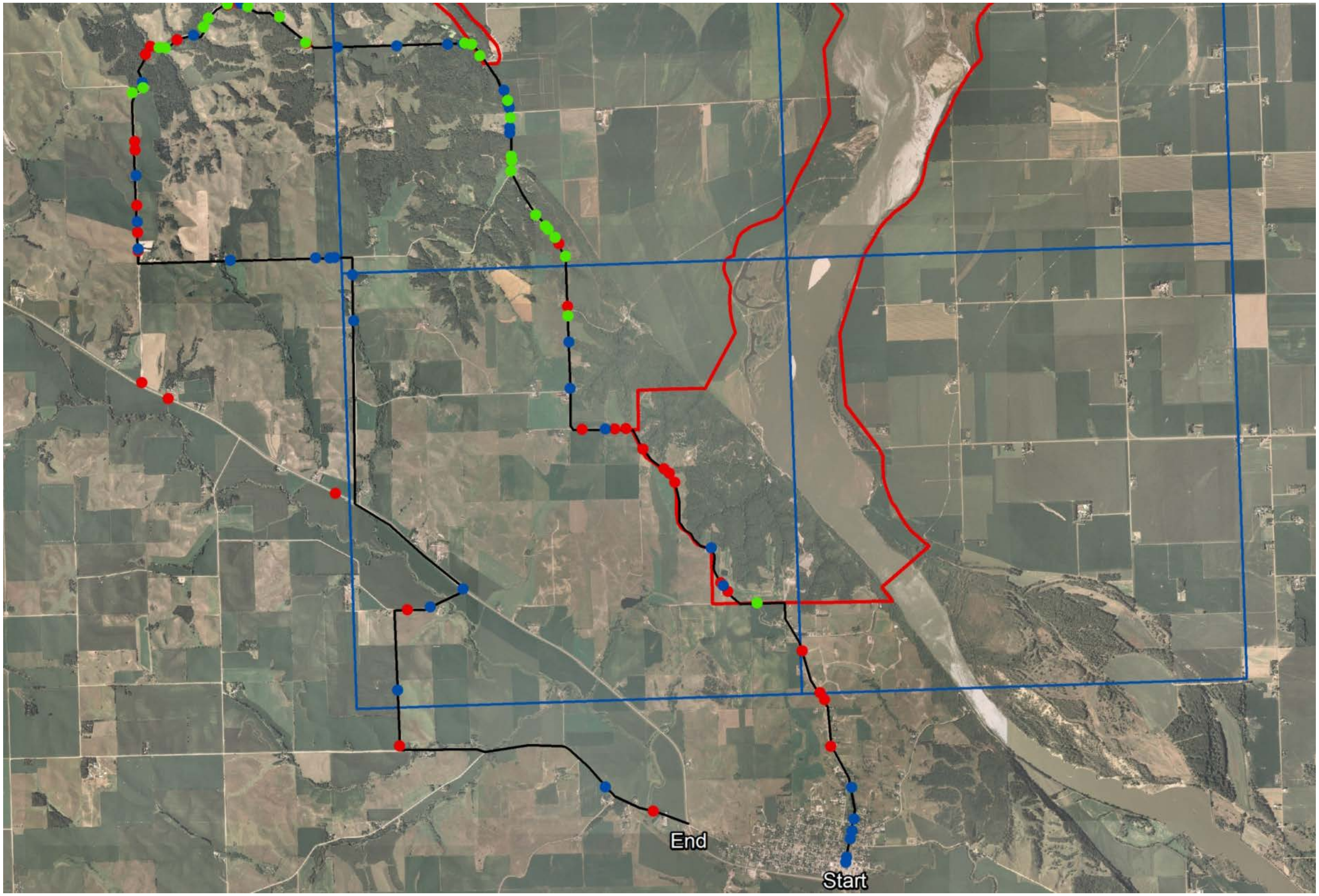

Figure 70. Detections from Missouri NRR Ponca State Park (NABat cell #020258) mobile surveys 2014-16. Blue circles are from 2014, red from 2015, and green from 2016 (the 2015 data was censored for purposes of analysis due to the route not being followed). First replicates only. Blue square is the NABat cell and red line is the park boundary.

Mobile surveys were conducted at the five NABat cells 2014-16. However, due to time limitations two routes were not run in 2014. In 2015 the two replicates at NABat cell #020258 deviated from the established route (**Figure 70**: the deviation was about 4.8 km [3 miles] in length; the GPS coordinates of the bat detections could be used to censor data from that stretch of the route for all three years for trend analysis; however for the analysis presented here I chose to simply exclude the 2015 data). Excluding those surveys, each route was run twice in a year with the exception of MNRR029794RD; that route was only surveyed once in 2015 due to inclement weather.

The mobile surveys at the park averaged 1.26 detections per km, the highest rate in the Network. A graph of the data suggests there could be a decline in bat abundance at the park (**Figure 71**); however, the sample size is small. The mobile surveys seem to somewhat track the data from the stationary monitoring points (**Figure 65**).

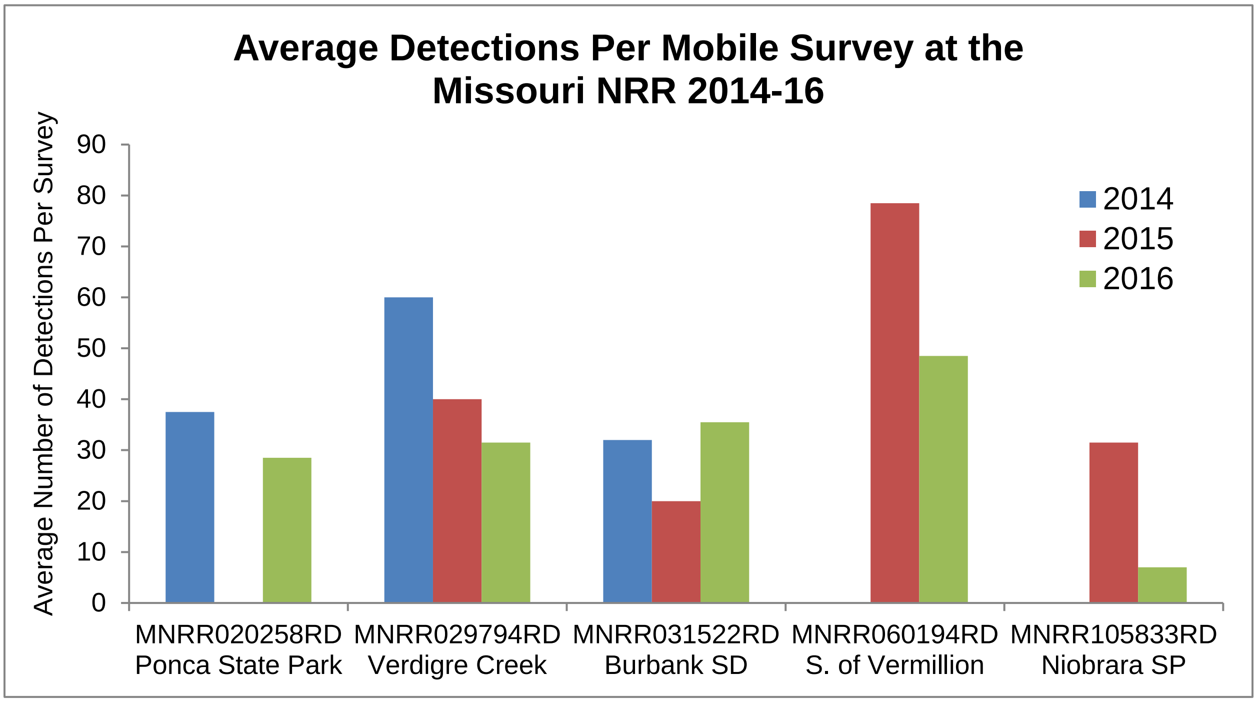

Figure 71. Average number of detections from mobile surveys at Missouri NRR 2014-16. The absence of a bar indicates the site was not successfully monitored in that year.

Bat monitoring should remain a high priority at the Missouri NRR. The park is near the western edge of the known range of the white-nosed syndrome fungus. Special attention should be given to the little brown, tri-colored, and northern long-eared bats as they are especially vulnerable to white-nose syndrome. The latter is listed as a threatened species under the Endangered Species Act and the other two have been recommended for listing. Lemen et al. (2016) found evidence of northern long-eared bats (as well as tri-colored bats) over-wintering in deep cracks in limestone outcrops at Ponca State Park. The little brown bat population at the park is considered by some as being within the range of an eastern subpopulation whereas all other parks in the Network are within the range of a western subspecies (Vonhof et al. 2015).

Although bat monitoring at the park is complicated by the lack of federal ownership and large rivers (which are a barrier to mobile surveys), there are benefits to the situation. For example, many of the stationary points are on lands owned by state agencies, a tribe, and other partners. Collaborating with these entities can lead to better bat conservation. The partners might be receptive to the installation of bat houses and other conservation actions that could benefit bats. Restoration of old-growth riparian forests would benefit bats, especially the threatened northern long-eared bat. Cottonwood trees 60 years and older appear to provide the best habitat for bats based on a study in the vicinity of the Missouri NRR (Swystun et al. 2007). Therefore, such forests should be restored and protected.

Adams Homestead and Nature Preserve

To meet its conservation mission, the Missouri NRR partners with other entities including state agencies. The results of NPS monitoring on the Ponca and Niobrara state parks, as well as other state and partner lands within or near the Missouri NRR boundary, were described earlier in this section. In addition to those efforts, in 2015 the Network was approached by personnel from the Adams Homestead and Nature Preserve, managed by the State of South Dakota. They asked if the Network would conduct an acoustic bat inventory on their property. Although the site was outside of the established NABat cells and approximately 13km (8 miles) from the Missouri NRR administrative boundary, three bat recorders were deployed at the site. The results are presented here. The Network will maintain the acoustic recordings.

Three units were deployed from August 19-25, 2015. A total of 16,354 recordings were made from the 21 survey nights. Of the recordings 10% were noise files, leaving 14,734 recordings of bats. Kaleidoscope did not classify a species to 35% of the bat recordings.

Kaleidoscope concluded statistically that the big brown, eastern red, silver-haired, little brown, northern long-eared, evening, and tri-colored bats were all present within the park during the recording period. Sonobat listed the big brown, eastern red, northern long-eared, and tri-colored bats all having a likelihood of presence > 0.90 and the others above 0.50.

Big brown bats comprised over 3/4ths of the classifications by Kaleidoscope (**Figure 72**) and almost all of the classifications by Sonobat (**Figure 73**). Two of the monitoring stations showed relatively more diversity, with silver-haired and hoary bats being the next most common species, but big brown bats still the most commonly classified species (**Figure 74**). Sites MNRR04 and MNRR06 averaged about 900 bat detections per night whereas site MNRR05 averaged just over 300 detections per night.

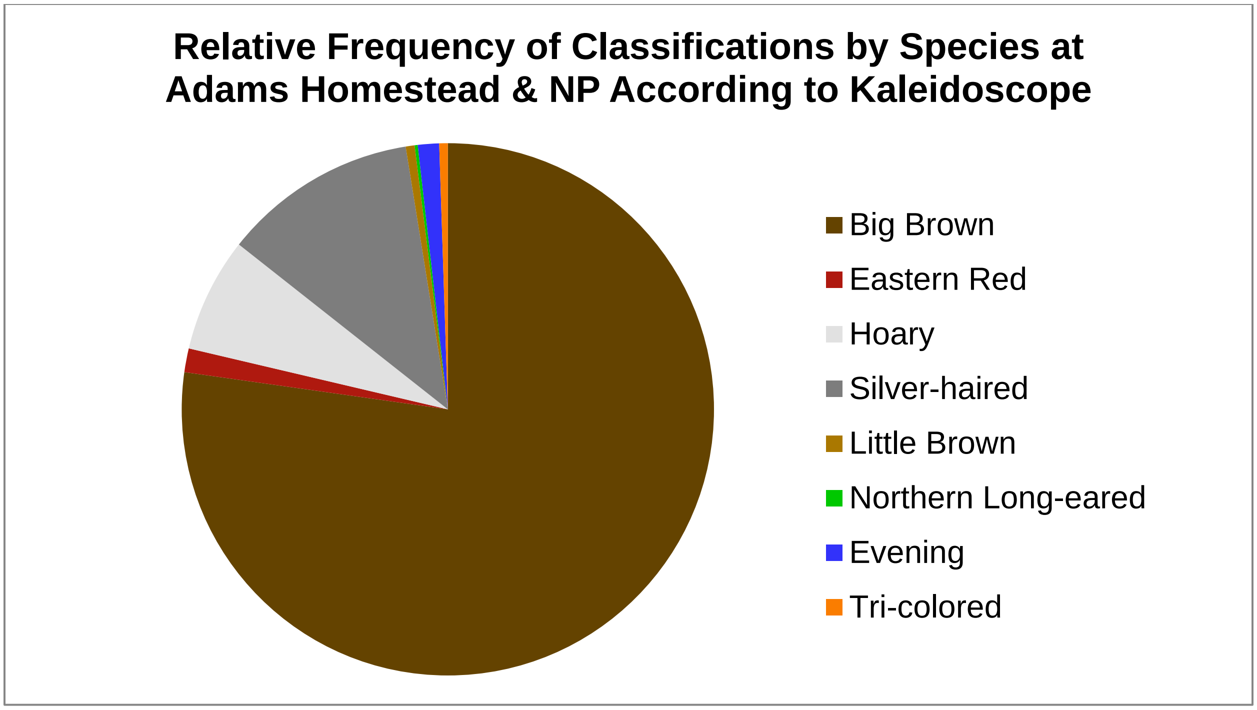

Figure 72. Relative frequency of classifications at Adams Homestead and Nature Preserve according to Kaleidoscope.

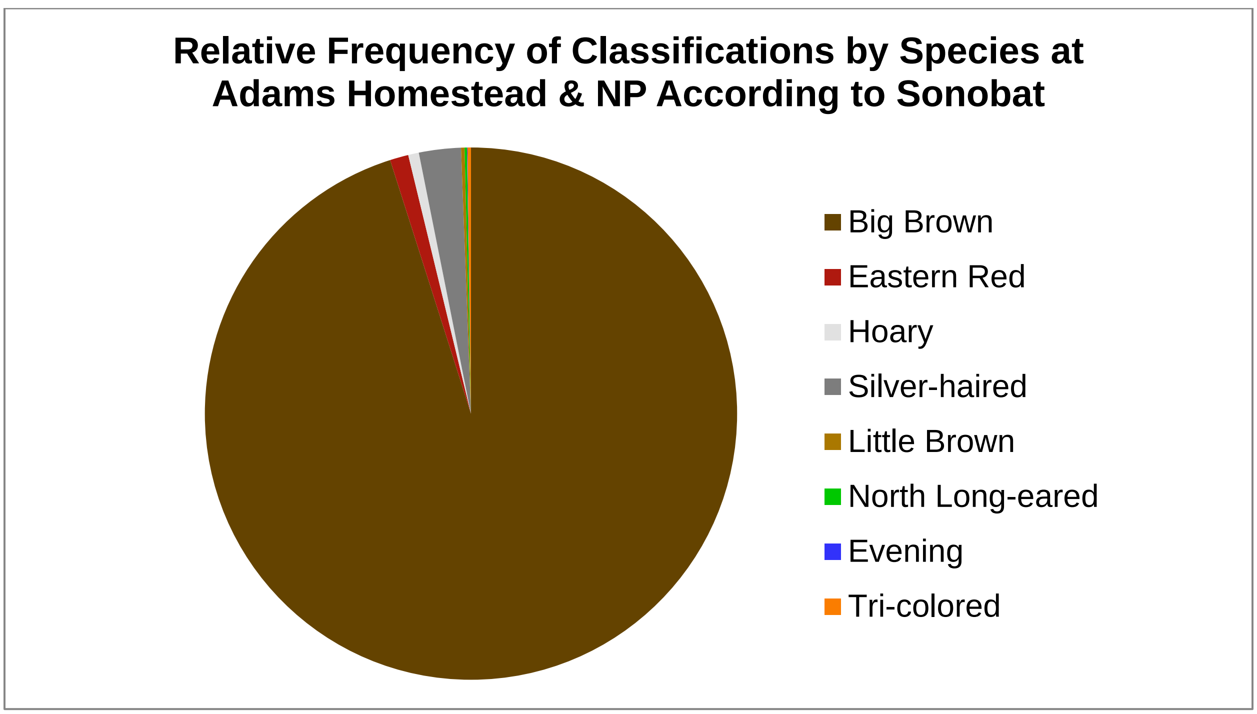

Figure 73. Relative frequency of classifications at Adams Homestead and Nature Preserve according to Sonobat. Results from Midwest classifier package.

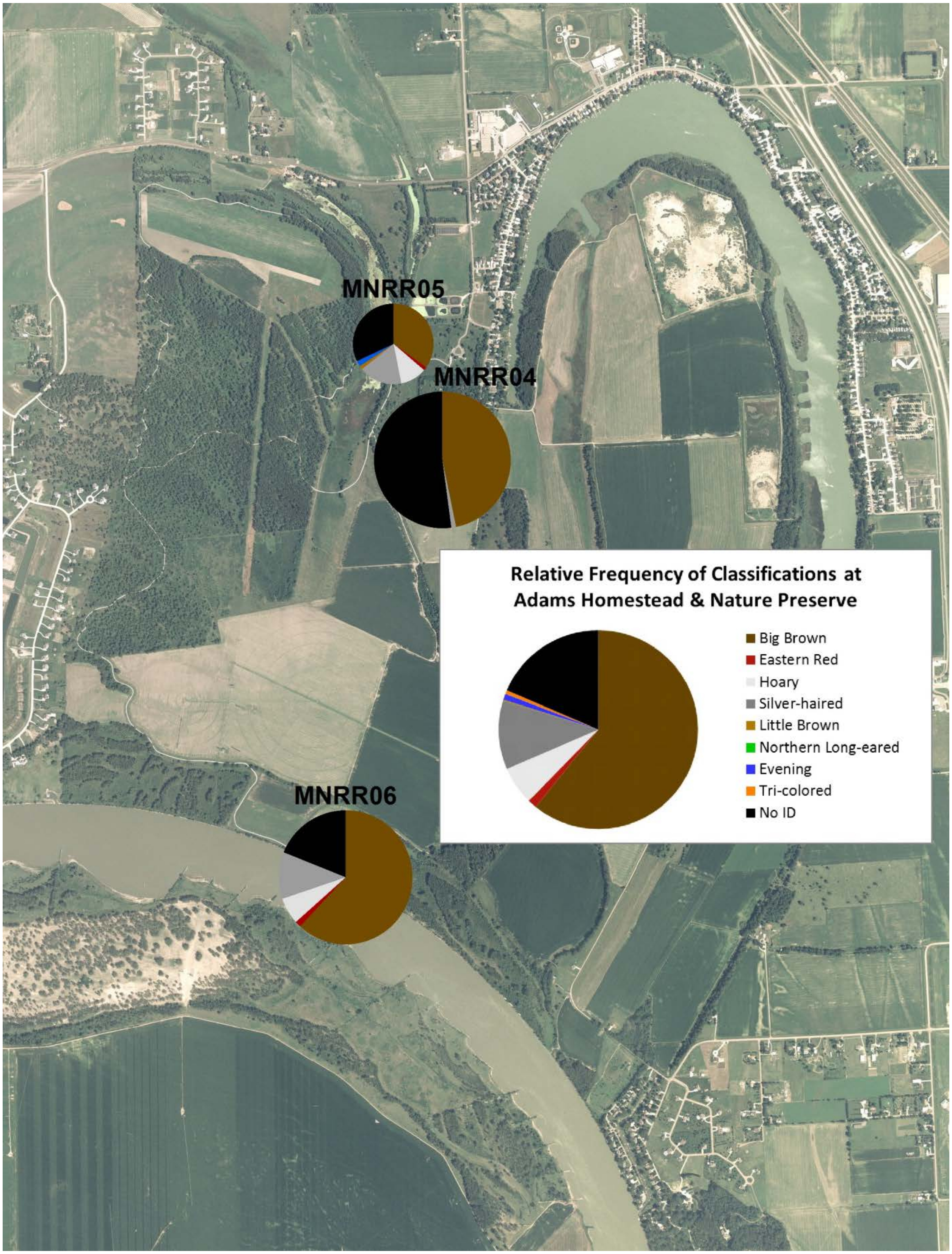

Figure 74. Relative frequency of classifications at Adams Homestead and Nature Preserve 2015. Size of circles correlates to rate of nightly detections.

Mount Rushmore NMEM

Mount Rushmore NMEM is a 517-ha (1,278-ac) park located in the Black Hills of South Dakota. The park was established to protect the granite outcropping carved with the faces of four presidents. Much of the park's forest has old growth ponderosa pine characteristics (Symstad and Bynum 2007). However, the integrity and aesthetics of the old-growth have been comprised in recent years by fire-prevention activities, perhaps with impacts to flying squirrels and other small mammals (Licht et al. 2013). Surface water is essentially absent from the park, consisting primarily of a small portion of Grizzly Creek that runs through the southeast corner of the park. A beaver pond once existed in Starling Basin, and was of great importance to bats (Schmidt et al. 2004), but the pond has succeeded to a marshy clearing. Granite outcroppings might provide small crevices that could be used by some species of bats for roosting. The visitor center/administrative complex provides a clearing within the otherwise forested park and an area of light that could attract night-time insects and foraging bats.

Mount Rushmore NMEM did not meet the *a priori* criteria for NABat monitoring. Therefore, stations were established based primarily on features of interest to management. On June 16, 2015, ten SM3Bat detectors were placed at the park and retrieved on June 24. Two of the units did not operate for the entire session. In 2016 units were deployed at the sites on July 26-27 and retrieved on August 2-3. Two of the units stop prematurely. At station MORU07 the entire microphone assembly was on the ground; I analyzed the data and subsequently censored all data from that deployment. Station MORU01 recorded about 50 bats per night the first two nights, no bats for the next three nights, and about 200 bats per night the last two nights. It is unclear if this was a temporary shutdown or there was indeed no bat activity those nights. Some of the other stations also showed less bat activity in the nights that no bats were detected at MORU01. Although suspicious, I decided not to censor those nights from the analyses. Excluding censored data, a total of 35,531 recordings were made over 134 survey nights 2015-16, of which 6% were noise files. Of the remaining 33,511 recordings of bats, 29% were not identified to species level by Kaleidoscope.

Prior to this study six species were reported to be present at the park and two as probably present (**Table 16**): the park list appears to be based in part on 2004 field surveys conducted at the park by Schmidt et al. (2004). This study indicates that eight species are present and two more are probably present. Although the long-eared bat and the northern long-eared bat were classified in a very small number of recordings, the classification rates were small enough and the calls ambiguous enough that neither software package concluded with statistical confidence that the species were present. The northern long-eared bat is especially noteworthy because it is listed as a threatened species. In 2004 that species comprised six of 32 bat captures in the Starling Gulch area in the park (Schmidt et al. 2004) and was one of the more common species in the Black Hills (Tigner and Stukel 2003). The tri-colored bat was not listed by NPSpecies as being present in the park. The results from Kaleidoscope were inconclusive. The species is not part of the Sonobat South Dakota-Black Hills package so I ran the data through the South Dakota-Eastern package and there was insufficient evidence to conclude its presence. The species has recently been confirmed in the Black Hills including in nearby Hill City (Geluso et al. 2005) so it could be in the park.

Table 16. Species presence at Mount Rushmore NMEM.

Species	NPSpecies Status[1]	Kaleidoscope		Sonobat[2]		Conclusion
		2015	2016	2015	2016	
Townsend's Big-eared	–	0.93	0.04	0.19	0	Probably Present
Big Brown Bat	Present	1	1	1	1	Present
Eastern Red Bat	–	1	1	1	1	Present
Hoary Bat	–	1	1	1	1	Present
Silver-haired Bat	Present	1	1	1	1	Present
W. Small-footed Myotis	Present	1	1	0.98	1	Present
Long-eared	Probably Present	0	0	0.56	0.38	Unconfirmed
Little Brown Bat	Present	1	1	1	1	Present
N. Long-eared Bat	Present	0	0	0.18	0.18	Unconfirmed
Fringed	Probably Present	0.70	0	1	1	Present
Long-legged Myotis	Present	1	1	1	0.87	Present
Tri-colored	–	0.95	0	0.11	0.18	Probably Present

[1] NPSpecies accessed 9-30-2015.

[2] Using South Dakota-Black Hills classifier package.

The silver-haired and hoary bats each comprised about 1/4th of the classifications made by Kaleidoscope (**Figure 75**) and Sonobat (**Figure 76**). Other commonly classified species at the park were the big brown, eastern red, and little brown bats. The agreement between the two software packages was much higher than at many other parks in the Network. A notable difference is that Kaleidoscope classified a relatively higher percentage of the recordings to the western small-footed myotis, a difference that was consistent in my testing of a catalog of known bat calls and in analyzing the 2014-16 data from other parks.

There was variability in species diversity between monitoring stations (**Figure 77**), which can generally be explained by the ecology of the various species. For example, the hoary bat was classified at a comparatively high rate in the open area around the parking garages and the viewing terrace (MORU04 and MORU05). That species is an open country flyer and forager (Lee and Gary 2004). In contrast, the smaller and more maneuverable little brown bat comprised a larger portion of the classifications in forested areas (MORU07).

The highest rate of activity was recorded by the old beaver pond in the Starling Basin (MORU07: 615 detections per night). The diverse site provides excellent bat habitat. The next highest rate of nightly bat activity was in a small clearing between the park garages (site MORU04: 608 detections per night). A plausible explanation is that the lights, warm surfaces, and other anthropogenic structures attracted insects which attracted foraging bats. However, a high rate of bat activity does not necessarily equate to a high rate of bat abundance as a single or small number of bats could be flying repeatedly over the detectors. The lowest rates of detections were generally in the homogenous even-aged ponderosa pine stands. Across all stations for all nights the average number of detections at Mount Rushmore was 250, a rate somewhat lower than other parks in the Network.

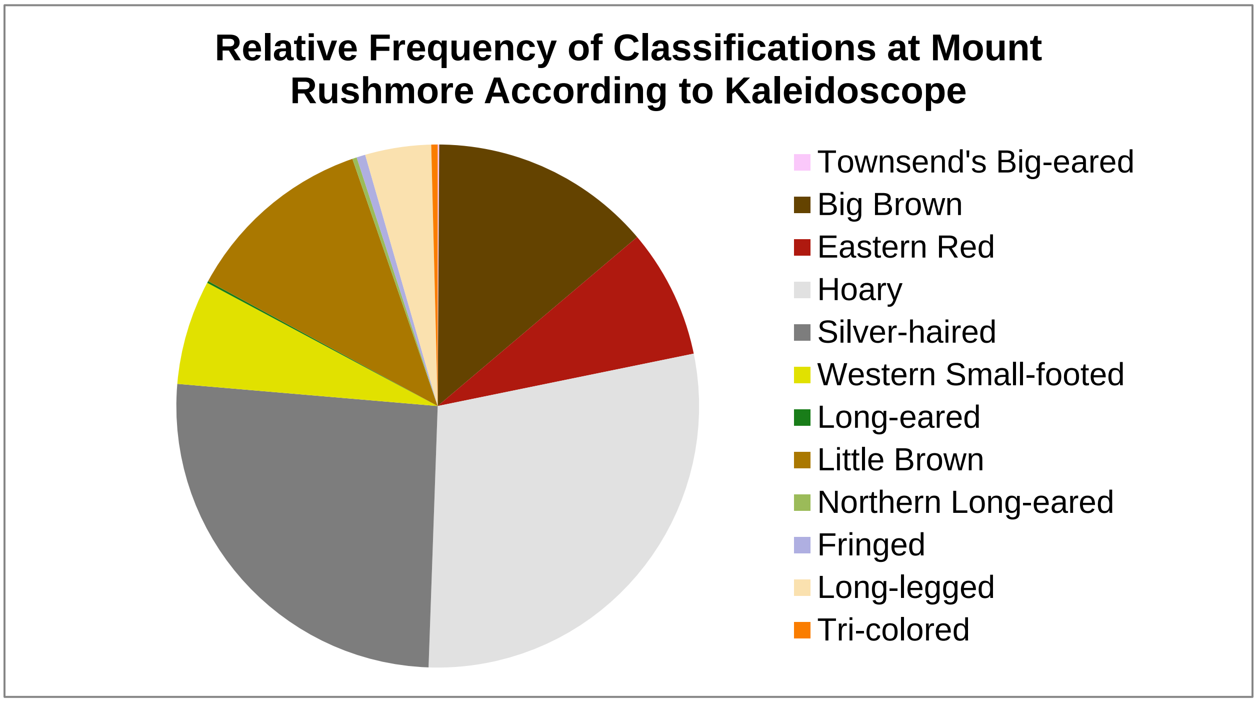

Figure 75. Relative frequency of classifications by species at Mount Rushmore NMEM according to Kaleidoscope.

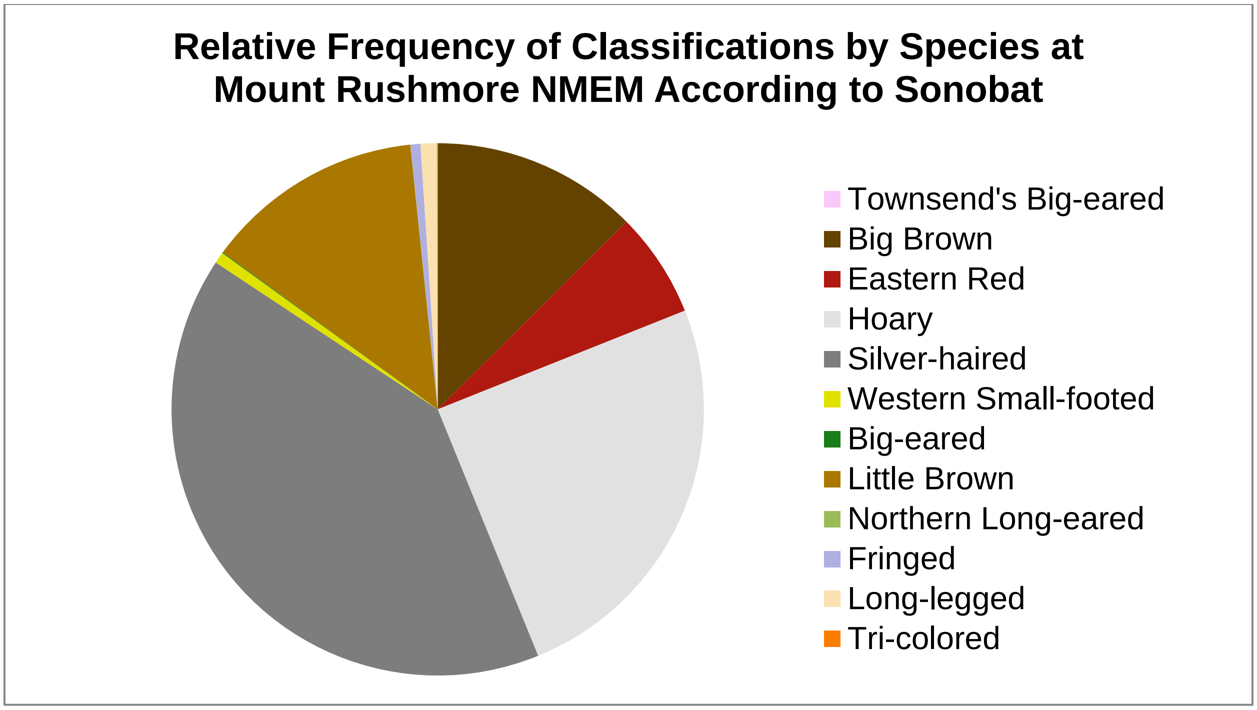

Figure 76. Relative frequency of classifications by species at Mount Rushmore NMEM according to Sonobat. Results from South Dakota-Black Hills classifier package except for tri-colored bat which came from South Dakota-Eastern package.

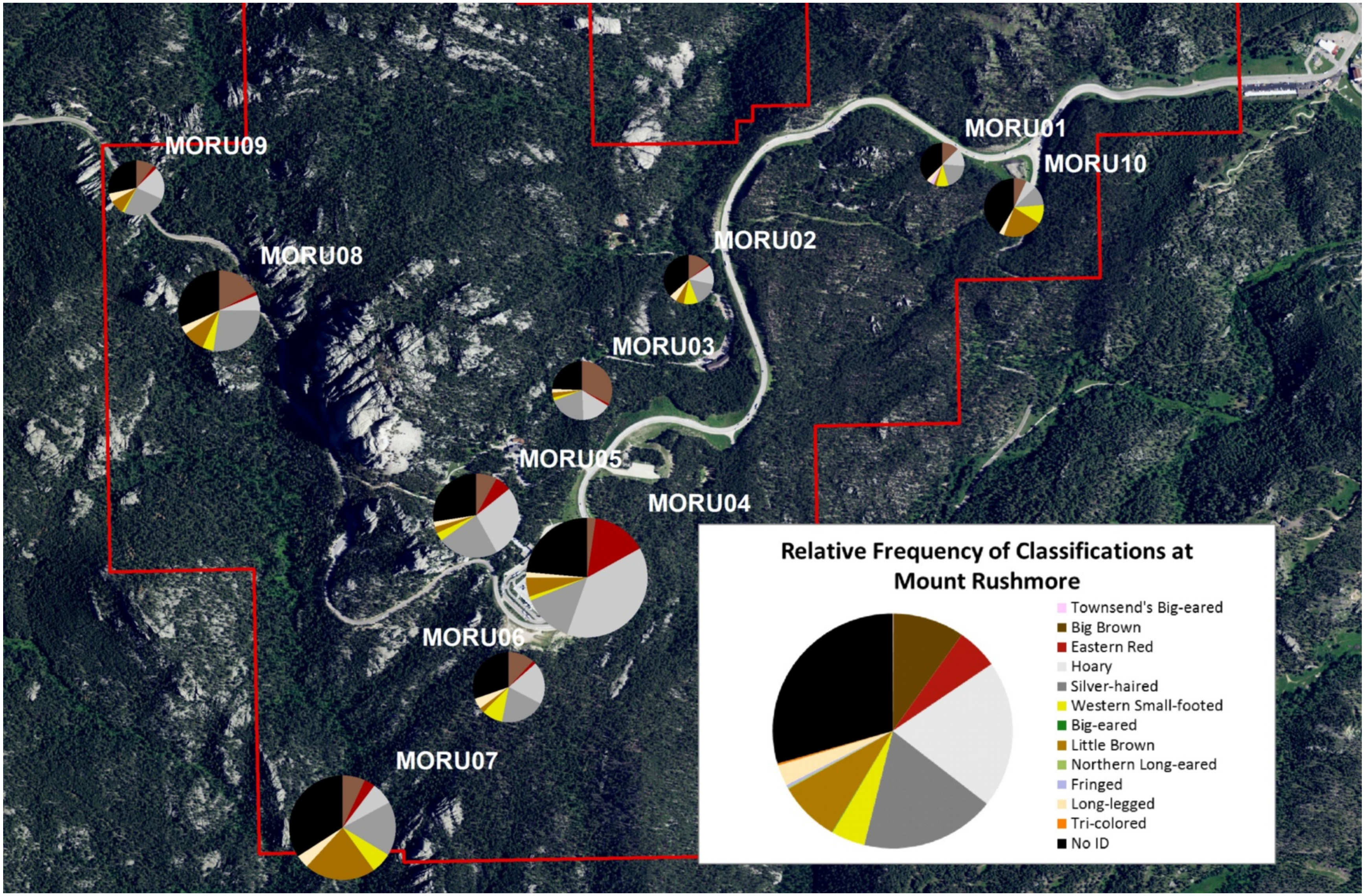

Figure 77. Relative frequency of classifications by species at Mount Rushmore NMEM 2015-16. Size of circles correlates to rate of nightly bat activity.

The primary intent of this study is to track changes over time. There was no consistent pattern in bat detections between years at Mount Rushmore (**Figure 78**).

The pattern of night-time bat detections by hour showed some interesting trends at Mount Rushmore (**Figure 79**). The eight forested stations showed the bimodal peak pattern typical at most stations in other parks in the Network. The post-sundown peak was especially strong at site MORU07 in the Starling Basin. This peak of activity shortly after sundown suggests that is a roosting area for many bats. The site does contain several large decadent snags that could provide quality daytime roosting habitat. Conversely, the two sites located in the visitor complex (MORU04 and MORU05) do not show a peak of activity until later in the night. This pattern was especially strong at the site between the park garages (MORU04), and was unlike anything else in the Network. A plausible explanation is that bats are only using the area for foraging and that much of that foraging occurs after the human activity has subsided.

In 2003 the northern long-eared bat comprised 6 of the 32 bat captures at the park (Schmidt et al. 2004). The 2015-16 acoustic surveys failed to confirm with statistical significance that it was even present in the park. Although the software did not confirm its presence at a statistically significant level, it is reasonable for management to proceed as if the species was present. The species is of high conservation concern at the park because of its threatened status, its habitat needs, and proposed trail developments at the park. The species is most commonly found in forests (Brooks 2009), and often forages along forest ridges, but will also forage over forest creeks with a closed or mostly closed canopy (Henderson and Broders 2008) as well as other small forest openings (Owen et al. 2003).

Mount Rushmore's old growth forests have the potential to provide critical roosting habitat for bats. Species such as the silver-haired bat and long-legged myotis use Black Hills forests with high densities of snags (Mattson 1994, Cryan 1997). The threatened northern long-eared bat also uses snags as well as down woody debris (see **Figure 32** in the Devils Tower Results section and **Figure 102 in the Discussion** section). Forest thinning and fuel load reduction can impair bat habitat if dead woody material is not left *in situ*. Schmidt et al. (2004) recommended conserving the open pool of water in the Starling Gulch stating it was a critical resource for bats; however, beavers abandoned the site and the pools are now gone. Agency policies (National Park Service 2006) would generally discourage artificial restoration.

Mount Rushmore NMEM also has great potential to aid bat conservation through outreach and education. The park receives millions of visitors annually and it conducts evening interpretive programs. Bats are very active in the area where the programs are conducted. Rangers could inform the public about the ecological benefits of bats and their dire conservation status. Such information could be enhanced by tools such as iPad/Echo Meter touch systems that detect and graphically display and broadcast bat echolocation activity in real time.

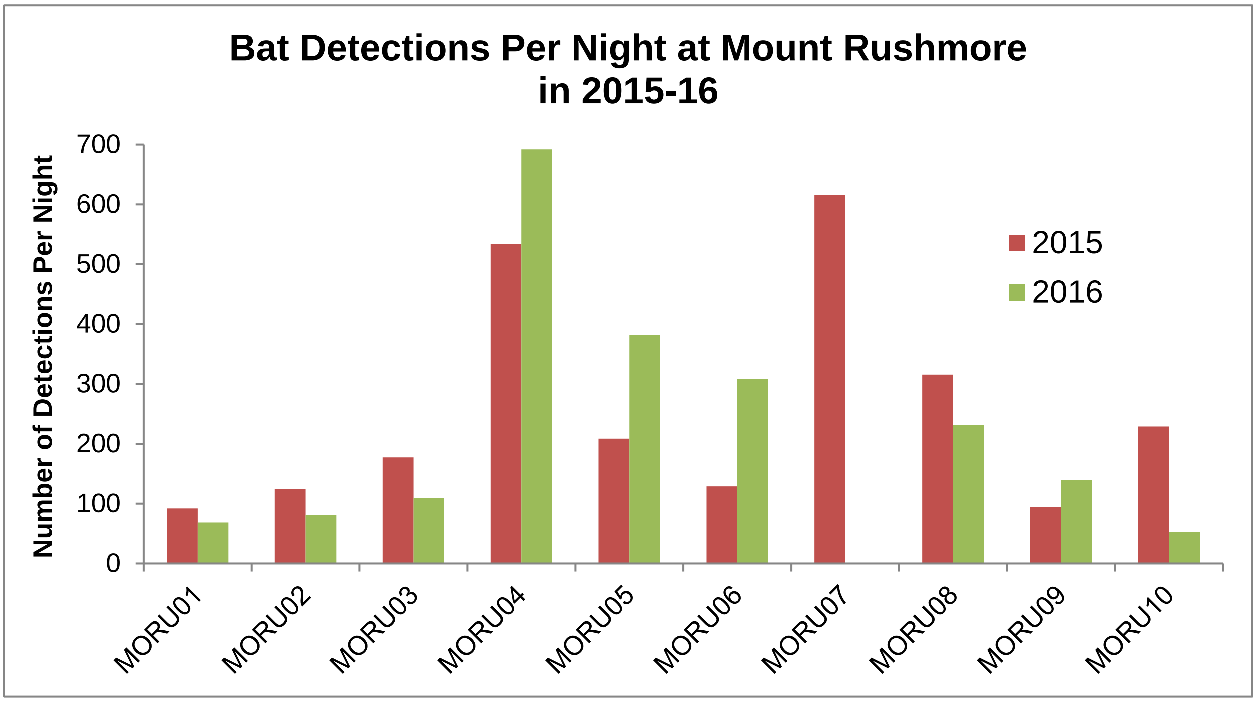

Figure 78. Detections per night at Mount Rushmore NMEM in 2015-16. The absence of a bar indicates the site was not successfully monitored in that year.

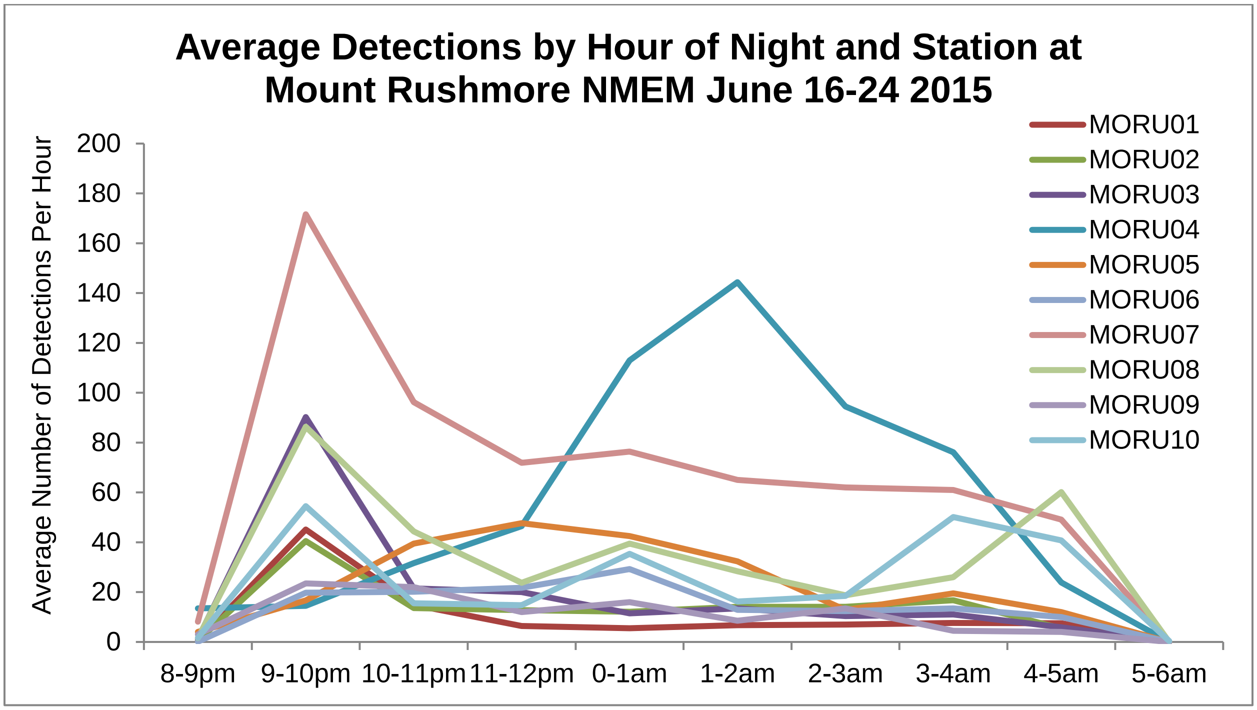

Figure 79. Detections by hour of night and station from June 16-24 2015 at Mount Rushmore NMEM.

Niobrara NSR

The Niobrara NSR administrative boundary encompasses 11,776 ha (29,101 ac); however, the NPS owns only 75 ha (186 ac) within the boundary. Most of the land within the boundary is owned by private entities, The Nature Conservancy, and the U.S. Fish and Wildlife Service. Habitat within the park is diverse consisting of the Niobrara River, riparian forests, and bluffs and upland areas comprised of forest and grasslands. The forests are of several types including western coniferous forests and patches of northern boreal and eastern deciduous forests.

Two NABat cells had all four quadrants at least partially within the park's administrative boundary, therefore, bat monitoring at the park used the NABat sampling frame and protocol. NABat cell #080286 was located just east of Valentine, NE and was comprised primarily of the Fort Niobrara National Wildlife Refuge (NWR) managed by the U.S. Fish and Wildlife Service. NABat cell #097012 was located further downstream near a rapid known as Rocky Ford. The cell was comprised mostly of private land; thankfully, the landowners allowed deployments on their properties.

In 2015 units were deployed on July 27-28 and retrieved on August 3. However, the four units in NABat #080286 all stopped prematurely, apparently due to failure of the rechargeable batteries (which were problematic and unreliable at other parks as well). When NPS personnel retrieved the units on August 3 the LCD displays were non-responsive. An analysis of the data revealed that two of the units had no recordings after the morning of August 2 and the other had no recordings after the morning of July 31. The remaining unit was retrieved by refuge personnel on August 3. That unit was found lying on the ground and in two pieces near where it was deployed. It most likely had been knocked over by elk (pers. comm., Kathy McPeak, U.S. Fish and Wildlife Service). The unit had been deployed next to a stock tank so there was a high likelihood of animal disturbance. After analyzing the data I decided to not censor the deployment as the number of detections seemed reasonable for the site and there was no substantial drop in detections over the deployment so it's plausible that the disturbance happened after battery failure. In 2016 recorders were deployed at NIOB080286 on June 29 and at NIOB097012 on July 6; in both cases the units were retrieved approximately seven days later. However, unit NIOB080286SE was again found on the ground, apparently again knocked over by animals. In this case there were very few records (and many fewer than in 2015) so I opted to censor the entire deployment.

Excluding the censored recordings, a total of 54,890 recordings were collected from the eight stationary points at the park over 103 survey nights. Of those, 26% were noise files. This rate is substantially higher than at other parks. Of the 40,377 bat detections collected from stationary points, 24% could not be identified to the species level.

In 2015 mobile surveys were conducted July 27-28 at NIOB080286 and August 3-4 at NIOB097012. In 2016 they were conducted July 4-5 at NIOB080286 and July 7 and 13 at NIOB097012. Of the 1,447 mobile recordings, 89% were noise files. Of the 166 recordings with bats, 51% could not be classified to the species level. The reason for the high rates of noise in both the stationary point and the mobile surveys at Niobrara NSR is unknown.

Niobrara NSR is on an ecotone between several biomes and at the periphery of several reported ranges for bats. This made analysis of acoustic data challenging as it was unclear as to what species to include in the software processing. Prior to this study there were four species reported to be present at the Niobrara NSR and one species reported to be probably present (**Table 17**). Based on the acoustic data and the software analysis I concluded that six species are present and two more are probably present. I listed three other species as unconfirmed.

The acoustic data was not compelling for the presence of the little brown bat. That species was originally thought to be absent from much of central Nebraska (see Harvey et al. 2011) although recent work has expanded its range (Benedict 2004, Geluso et al. 2013). A small number of records were classified to the species; however, the recordings might have been made by other similar sounding bats. The software found some evidence of species that are associated with northwestern Nebraska and the Black Hills, i.e., the long-eared and long-legged myotis (Freeman et al. 1997); I view it as unlikely these species are in the park, but not impossible, so I listed the species as unconfirmed. The auto-classification software found some evidence for the presence of northern long-eared myotis, so I concluded the specie was probably present. Freeman et al. (1997) reported a Brazilian free-tailed bat (*Tadarida brasiliensis*) from Kaya Paha County; however, they also reported fewer than 10 records from Nebraska; hence, I did not include it in the analyses.

Table 17. Species presence at Niobrara NSR.

		Kaleidoscope		Sonobat[2]		
Species	**NPSpecies Status[1]**	**2015**	**2016**	**2015**	**2016**	**Conclusion**
Townsend's Big-eared	–	0	0	0	0	Not in Park
Big Brown Bat	Present	1	1	1	1	Present
Eastern Red Bat	Present	1	1	1	1	Present
Hoary Bat	Probably Present	1	1	1	1	Present
Silver-haired Bat	–	1	1	1	1	Present
W. Small-footed Myotis	Present	1	1	1	0.93	Present
Long-eared	–	1	0	0.19	0.16	Unconfirmed
Little Brown Bat	–	0	0	0.55	0.02	Unconfirmed
N. Long-eared Bat	Present	1	0.17	0	0.24	Probably Present
Fringed	–	0	0	0	0	Not in Park
Long-legged Myotis	–	1	1	0.18	0.55	Unconfirmed
Evening	–	0.96	1	0.73	0.18	Probably Present
Tri-colored	–	1	1	1	1	Present

[1] NPSpecies accessed 9-30-2015.

[2] Using South Dakota-Black Hills classifier package except for evening and tri-colored bats where the value came from the South Dakota-Eastern package.

Big brown, silver-haired, and hoary bats made up most of the classifications in 2015-16 according to both Kaleidoscope (**Figure 80**) and Sonobat (**Figure 81**). Kaleidoscope classified substantially more classifications to the evening bat as well as some of the other less-frequent species than did Sonobat.

Most stations showed an increase in nightly detections in 2016 over 2015 (**Figure 82**). This same pattern was observed at the Missouri NRR. However, as discussed in that section, numbers were also up in 2014 at that park so the low rates of activity in 2015 could have been due to weather. The number of detections and the relative frequency of species classifications did vary by stationary point. For example, at the Fort Niobrara NWR cell (NABat #080286) there were a relatively large number of detections of the tri-colored bat at the station in the SW quadrant, near the refuge headquarters (**Figure 83**). The reason for this is not known. At the Sparks, Nebraska cell (NABat #097012) big brown bats made up a larger frequency of the classifications (**Figure 84**).

Two road surveys were conducted for each of the two routes in each of the two years. At the Fort Niobrara NWR cell (NABat #080286) bat detections were rather uniform (**Figure 85**). At the Sparks cell (NABat #097012) there was a more clumped distribution as detections were more prevalent along the river and wooded canyons than in areas going through cropland (**Figure 86**). In 2015 the NIOB080286 route averaged 14.5 bats per night whereas in 2016 it averaged 11.5. In 2015 the NIOB097012 route averaged 27.5 bats per night whereas in 2016 it averaged 29.5

Compared to other parks, the stationary points and road surveys at Niobrara NSR had fewer bat detections. This could be due to the fact that only two points were near standing water. Several stations were near the Niobrara River, but that fast moving stream might not provide the forage base that wetlands do. In spite of this, bat conservation should be a high priority at the park.

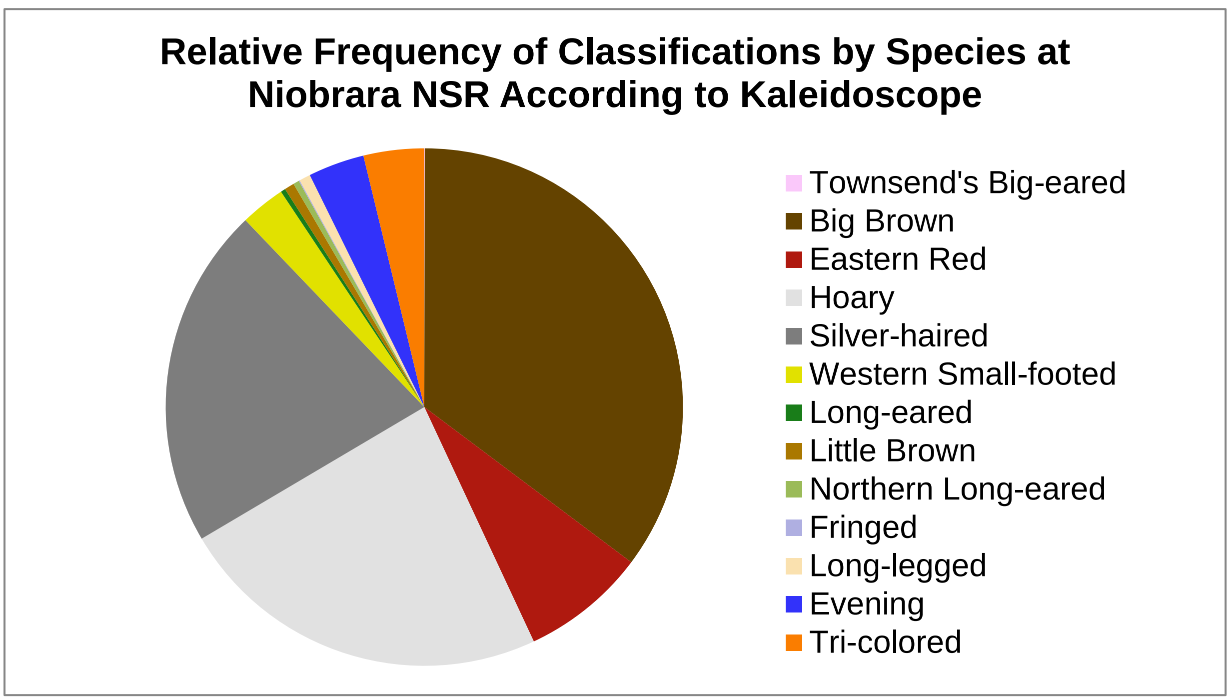

Figure 80. Relative frequency of classifications by species at Niobrara NSR according to Kaleidoscope.

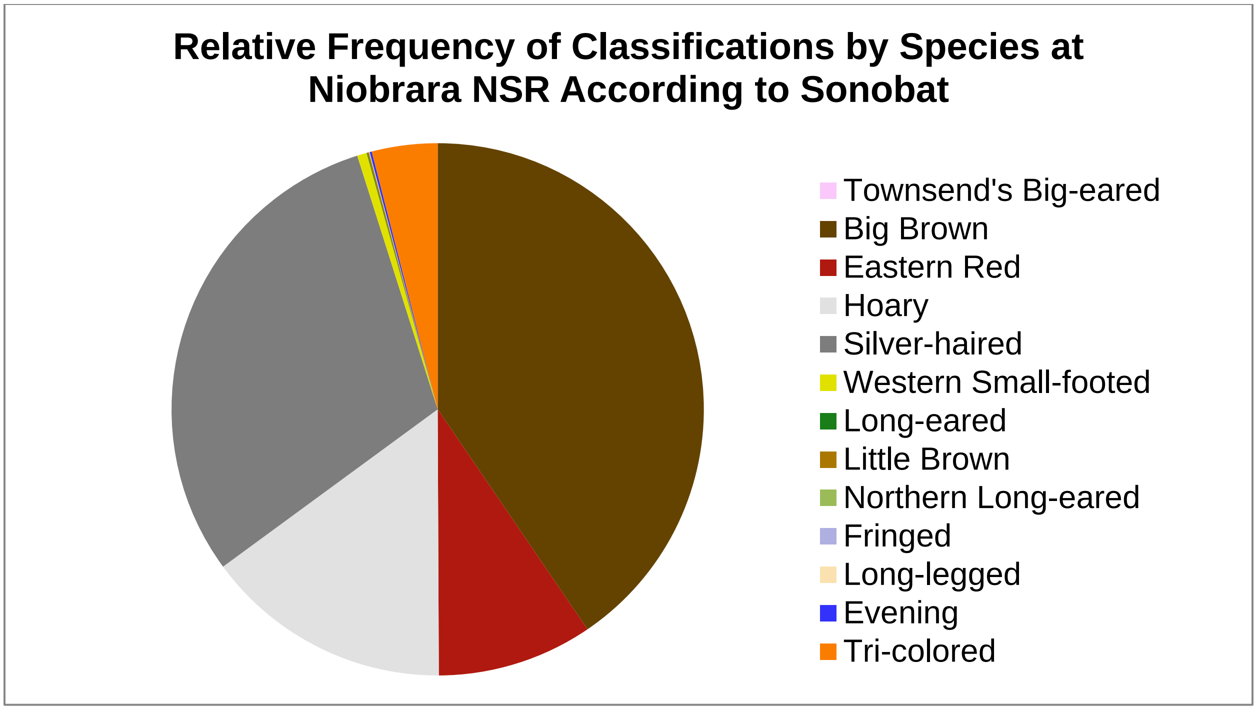

Figure 81. Relative frequency of classifications by species at Niobrara NSR according to Sonobat. Results from South Dakota-Black Hills classifier package except for evening and tri-colored bat which came from South Dakota-Eastern package.

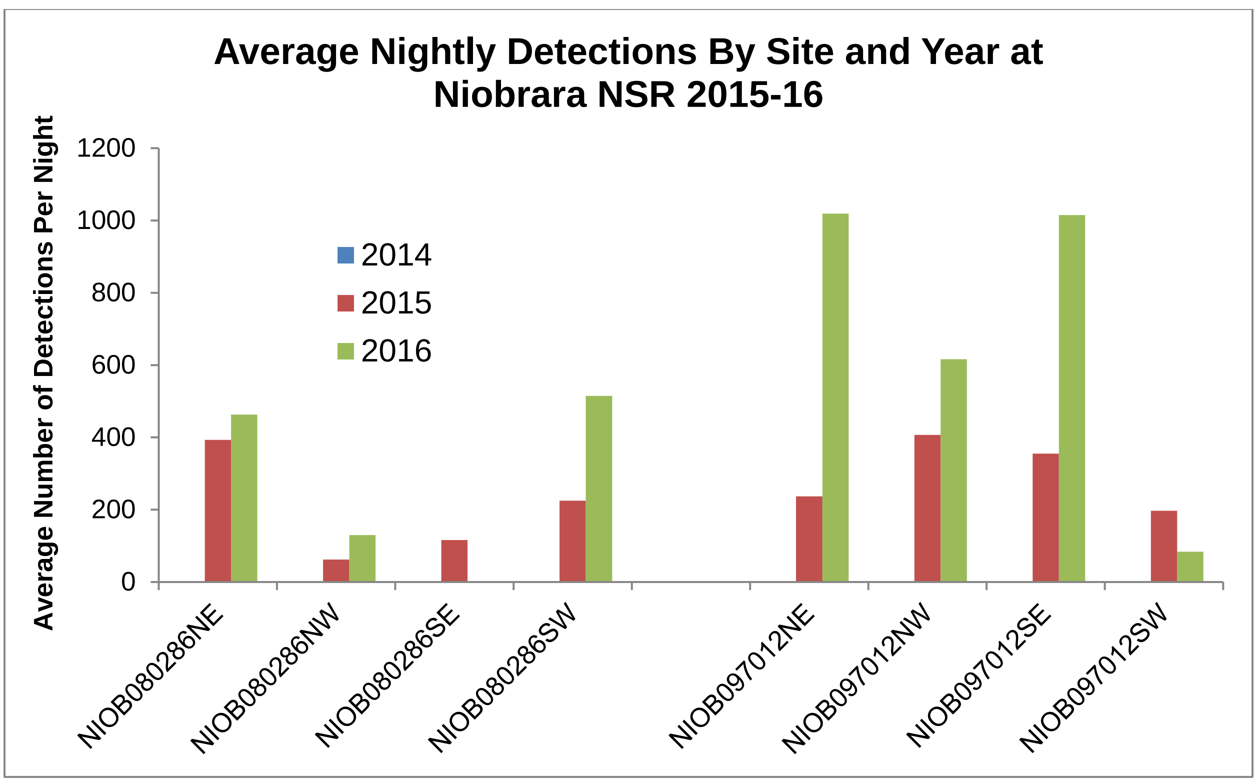

Figure 82. Average number of detections per night at Niobrara NSR 2015-16. The absence of a bar indicates the site was not monitored in that year.

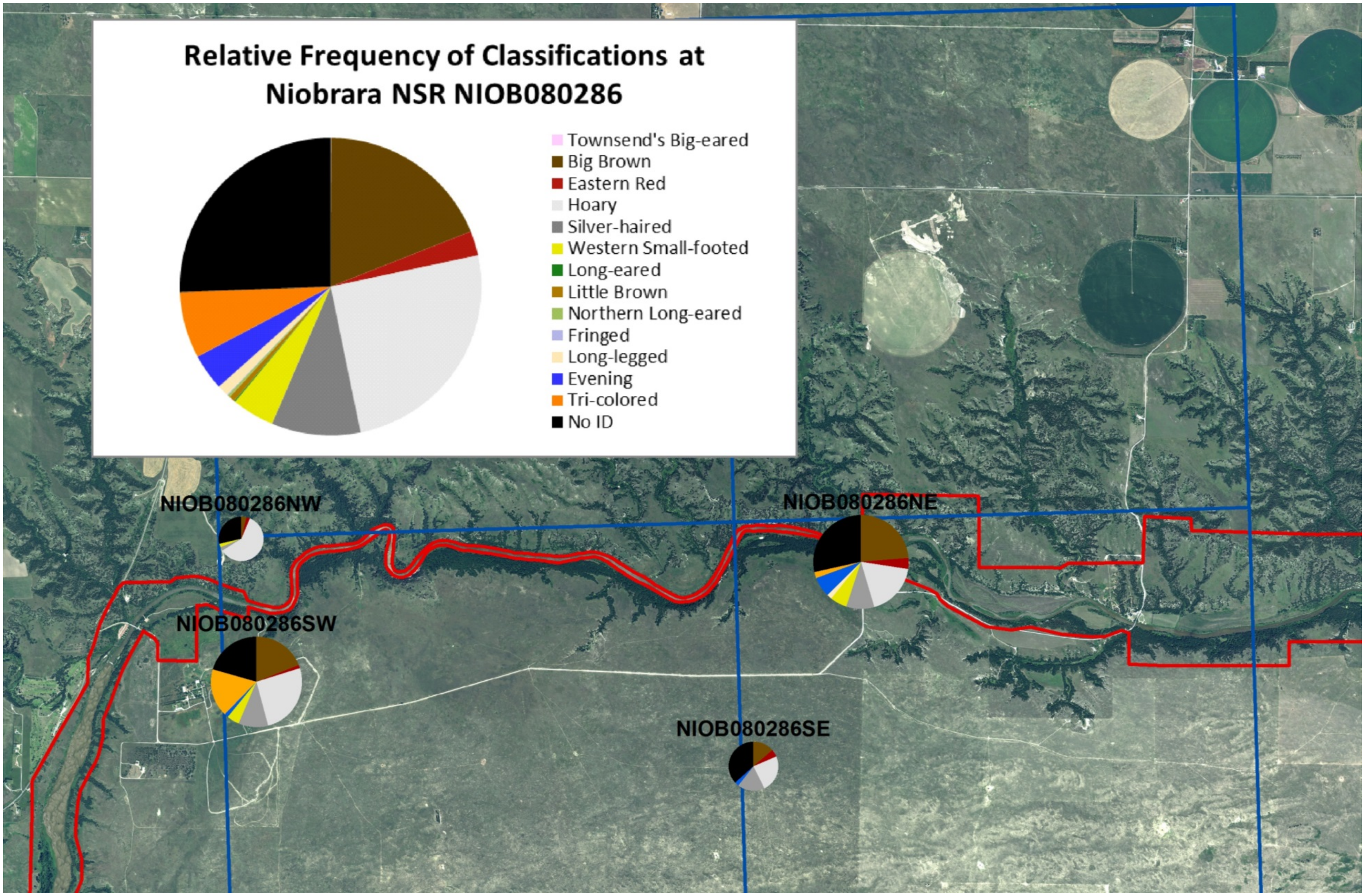

Figure 83. Relative frequency of classifications by species at Niobrara NABat cell #080286. Size of circles correlates to rate of nightly bat activity.

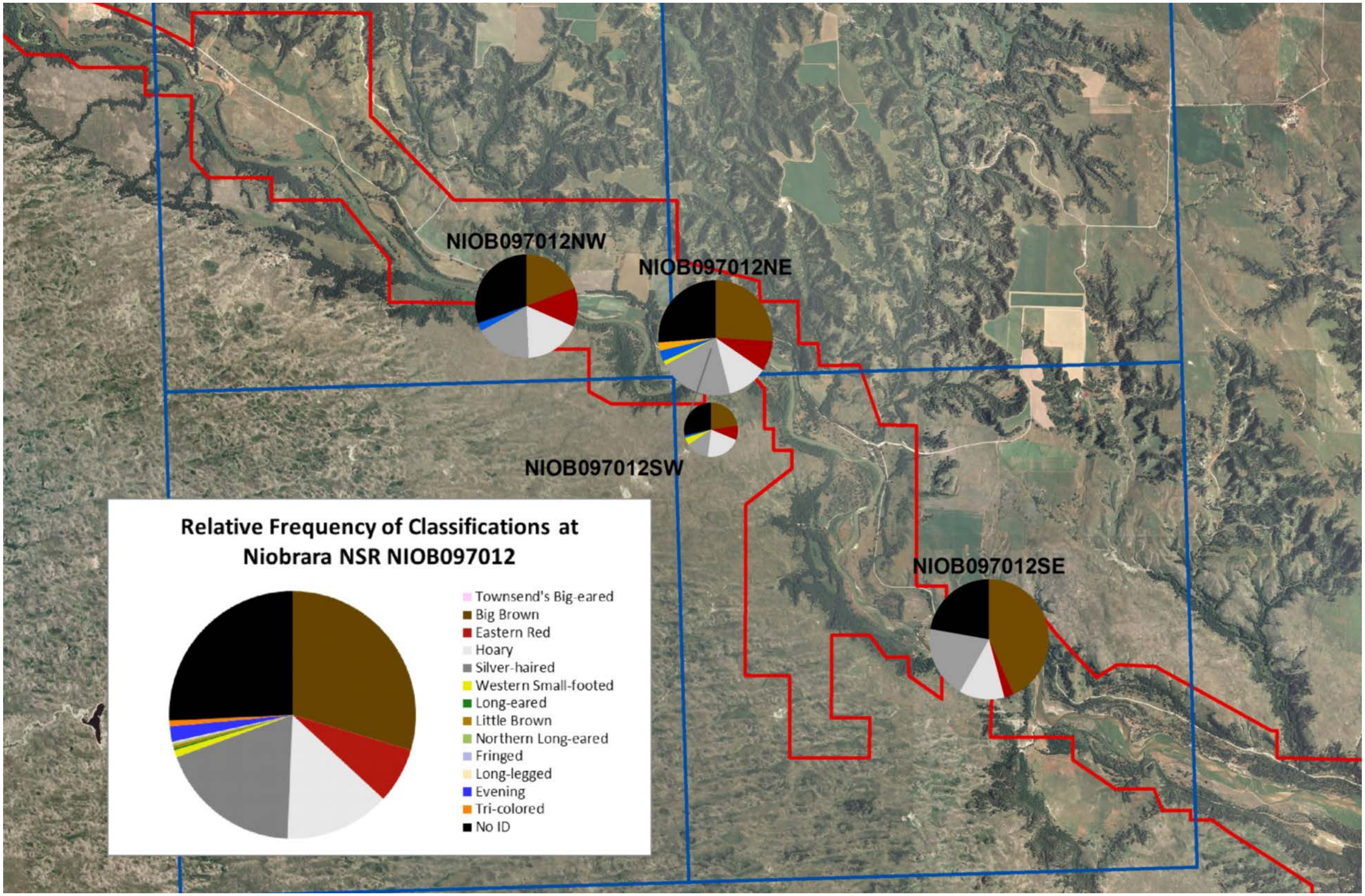

Figure 84. Relative frequency of classifications by species at Niobrara NSR NABat cell #097012. Size of circles correlates to rate of nightly activity.

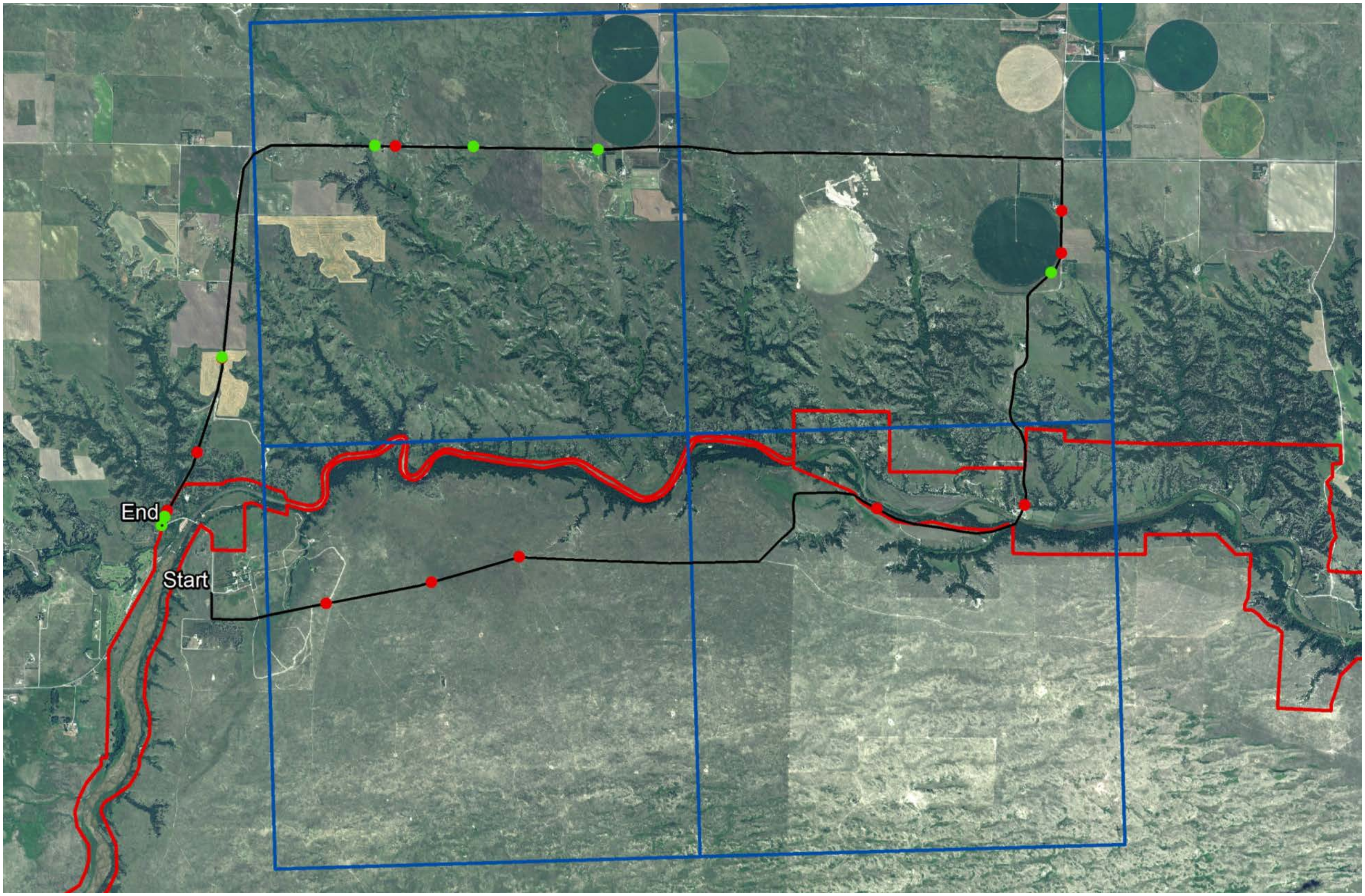

Figure 85. Detections from Niobrara NSR NABat cell #080286 mobile surveys 2015-16. First replicate only. Red circles are from 2015 and green from 2016. Blue square is the NABat cell and red line is the park boundary.

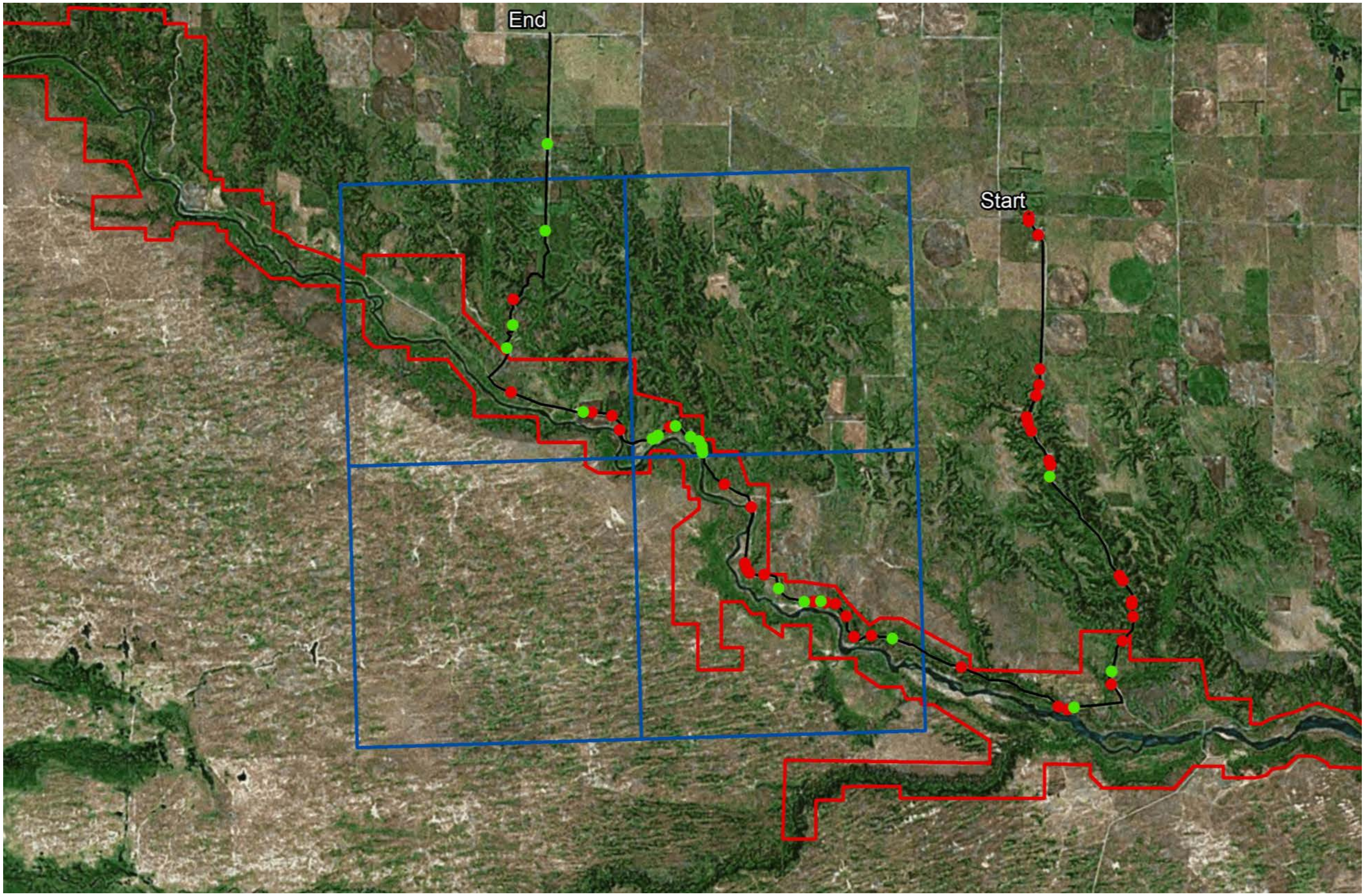

Figure 86. Detections from Niobrara NSR Sparks (NABat cell #097012) mobile surveys 2015-16. First replicate only. Red circles are from 2015 and green from 2016. Blue square is the NABat cell and red line is the park boundary.

Scotts Bluff NM

Scotts Bluff NM is a 1,216-ha (3,005-ac) park in southwestern Nebraska. The park abuts the town of Gering, Nebraska, and is immediately south of Scottsbluff, Nebraska. It is the most urban of all parks in the Network. The park protects the namesake bluff as well as badlands, prairie, summit ponderosa pine/Rocky Mountain juniper forest, and riparian habitats. Water resources consist of the North Platte River and an anthropogenic canal.

Scotts Bluff did not meet the criteria for NABat monitoring, i.e., that at least a portion of all four quadrants of a NABat cell lie within the park. Therefore, stations were established based on features of interest to management. Five stations were established in 2015 and a sixth in 2016. Five units were deployed on June 19, 2015. The units were retrieved on June 25; however, SCBL01 and SCBL05 malfunctioned. Due to the malfunctions a second deployment session was initiated on July 29; that session concluded on August 3-4. In that session unit SCBL04 malfunctioned. The malfunctions appeared to be due to rechargeable NiMH batteries. In 2016 five units were deployed on July 31; heavy rains prevented access to station SCBL02. The units were retrieved on August 7-8. Unit SCBL05 malfunctioned. A total of 27,843 recordings came from 80 survey nights, of which 6% were classified as noise. Of the remaining 26,241 recordings, 23% were not identified to species.

Prior to this study there were two species reported to be present at the Scotts Bluff NM and four reported to be probably present (**Table 18**). This study identified seven species as present. This study found strong statistical evidence of the little brown and evening bats, although the park is outside of the currently reported range for the species (Freeman et al. 1997, Benedict 2004, Harvey et al. 2011): I concluded the species were probably present. Kaleidoscope suggested the northern long-eared bat was present at the 2016 deployment at SCBL04, but other than that the evidence was poor.

Scotts Bluff NM, along with Fort Laramie NHS, is one of the two most southwestern parks in the Network. The park could conceivably have western species not found elsewhere in the Network. Hence I expanded the species list for Kaleidoscope and re-ran the data (Sonobat already included several western species in the Wyoming-Eastern classifier package). Kaleidoscope did not find statistical evidence of the presence of the California myotis, the pallid bat, or the long-eared myotis even though some recordings were classified to each of the species. Sonobat reached a similar conclusion for the three species, although it gave a higher likelihood of presence for the California myotis. Interestingly, Kaleidoscope concluded the spotted bat was present based on a single classification (station SCBL02); that species has a diagnostically low-frequency call and it appears that Kaleidoscope gave that heavy weight in its determination. However, Sonobat failed to classify any calls to the species so I view it unlikely that it occurs in the park.

Table 18. Species presence at Scotts Bluff NM.

Species	NPSpecies Status[1]	Kaleidoscope		Sonobat[2]		Conclusion
		2015	2016	2015	2016	
Townsend's Big-eared	–	0	0	0	0	Not in Park
Big Brown Bat	Present	1	1	1	1	Present
Eastern Red Bat	–	1	1	1	1	Present
Hoary Bat	–	1	1	1	1	Present
Silver-haired Bat	Probably Present	1	1	1	1	Present
W. Small-footed Myotis	Present	1	1	1	1	Present
Little Brown Bat	Probably Present	1	0	1	0.65	Probably Present
N. Long-eared Bat	Probably Present	0	0.94	0	0	Probably Present
Fringed	Probably Present	0	0	0	0	Not in Park
Long-legged Myotis	–	1	1	0.74	0.03	Present
Evening	–	1	1	1	0.96	Probably Present
Tri-colored	–	0	0.64	0.74	0.18	Present

[1] NPSpecies accessed 9-30-2015.

[2] Results from South Dakota-Black Hills classifier package except for evening and tri-colored bat which came from South Dakota-Eastern package.

The silver-haired bat, hoary bat, and big brown bats were the most frequently classified species by both Kaleidoscope (**Figure 87**) and Sonobat (**Figure 88**). The silver-haired bat was until recently thought to only migrate through Nebraska; however, recent studies have found evidence of reproduction (Geluso et al. 2004). The western small-footed myotis and the eastern red bat were also frequently classified: the park is near the western extent of the eastern red bat range, but the large cottonwoods along the North Platte River likely provide good roosting habitat. Conversely, there were comparatively few recordings classified as little brown bats. Interestingly, about 80 km (50 miles) upstream at the North Platte River at Fort Laramie NHS that species was one of the most frequently classified species. Both Scotts Bluff and Fort Laramie contain forested North Platte River riparian habitat. The disparity between the sites could be due to the anthropogenic bat house constructed at Fort Laramie.

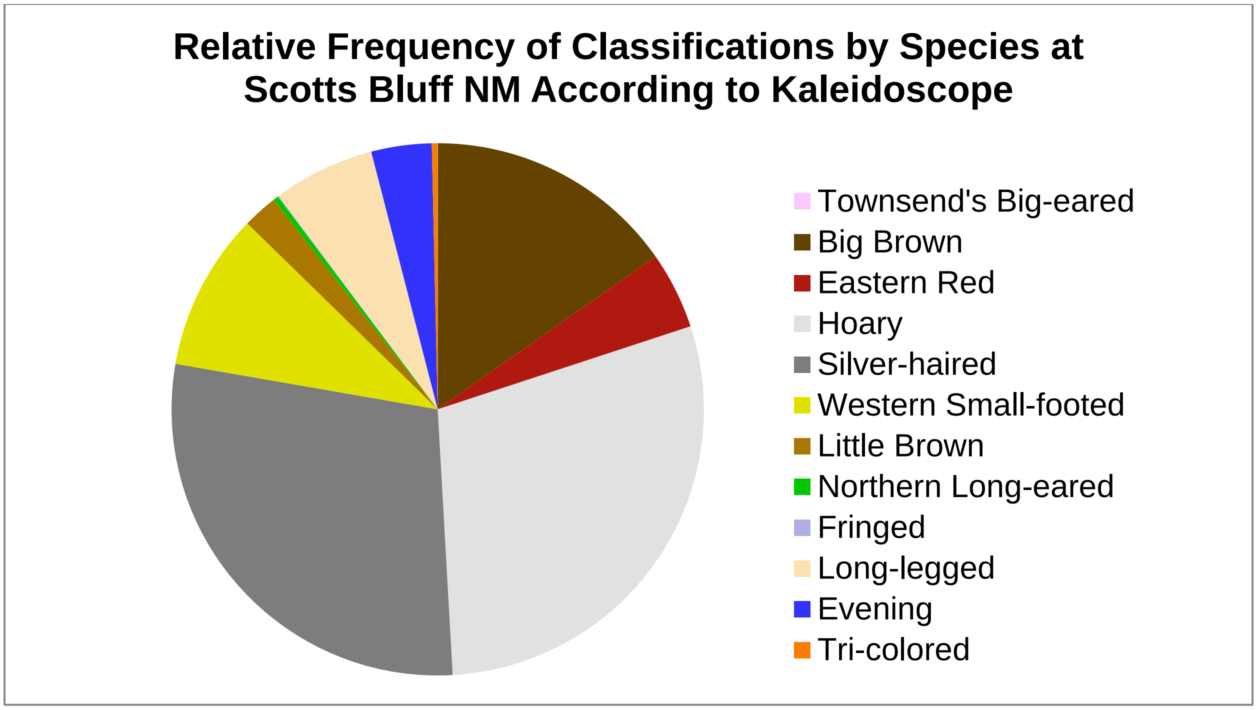

Figure 87. Relative frequency of classifications by species at Scotts Bluff NM according to Kaleidoscope.

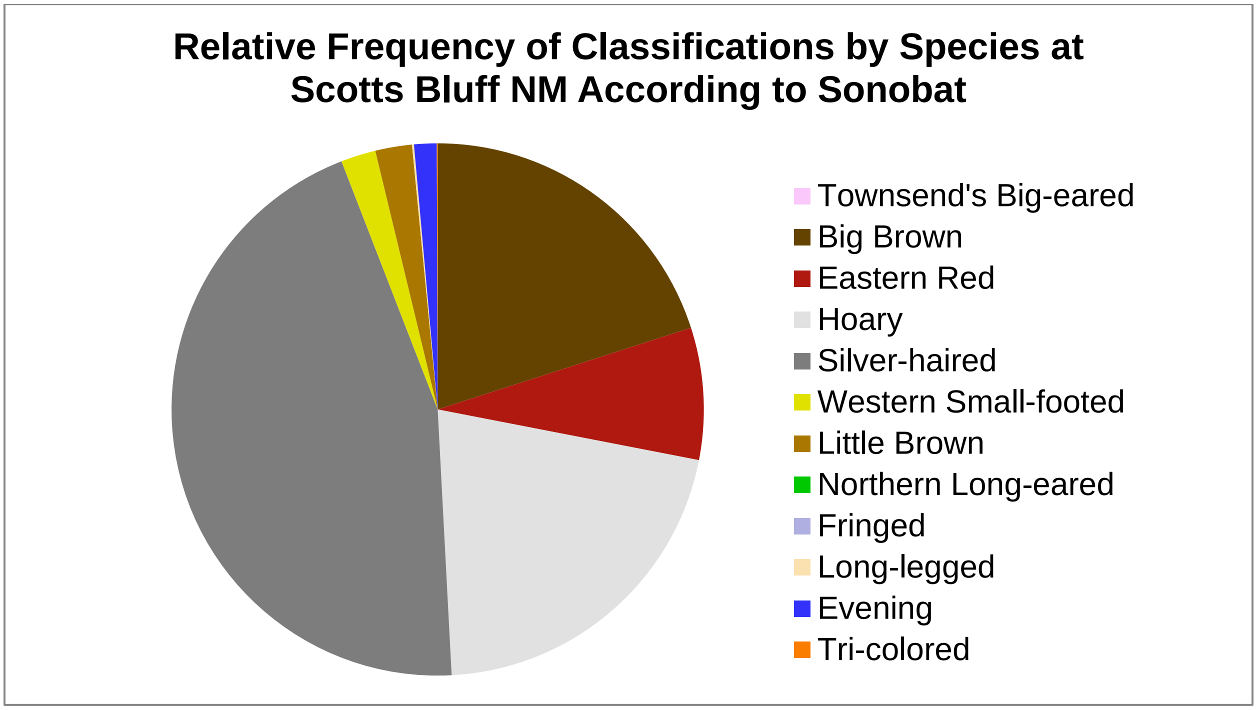

Figure 88. Relative frequency of classifications by species at Scotts Bluff NM according to Sonobat. Results from South Dakota-Black Hills classifier package except for evening and tri-colored bat which came from South Dakota-Eastern package.

Species classifications varied by habitat in somewhat predictable ways. For example, the tree-roosting eastern red bat was classified relatively more frequently in the forested North Platte River riparian zone (sites SCBL03 and SCBL04) whereas the cliff roosting western small-footed myotis was more frequently classified in the bluffs leading to the top of Scottsbluff (SCBL05; **Figure 89**). Across all stations for all nights the park averaged 328 nightly detections per station. The two stations in the North Platte River riparian forests detected more bats per night (x = 434; unweighted by number of nights) than did the four stations in the badlands/prairie habitats (x = 240). The riparian zone provides excellent habitat for bats as it includes old trees suitable for roosting and surface water for foraging and drinking.

Two units collected data in late July/early August 2015 and again in 2016 about that same time period. Site SCBL01 averaged 173 bats per night in 2015 and 355 bats per night in 2016. Station SCBL03 averaged 483 bats per night in 2015 and 312 bats per night in 2016.

This study concluded that evening bats are probably present based on the automated software analysis of the park data. Although the park is generally thought to be west of the species range, Serbousek and Geluso (2009) found it to be the most common bat captured in their study area along the Republican River in extreme southwestern Nebraska. Mist-netting should be conducted for a definitive identification of presence.

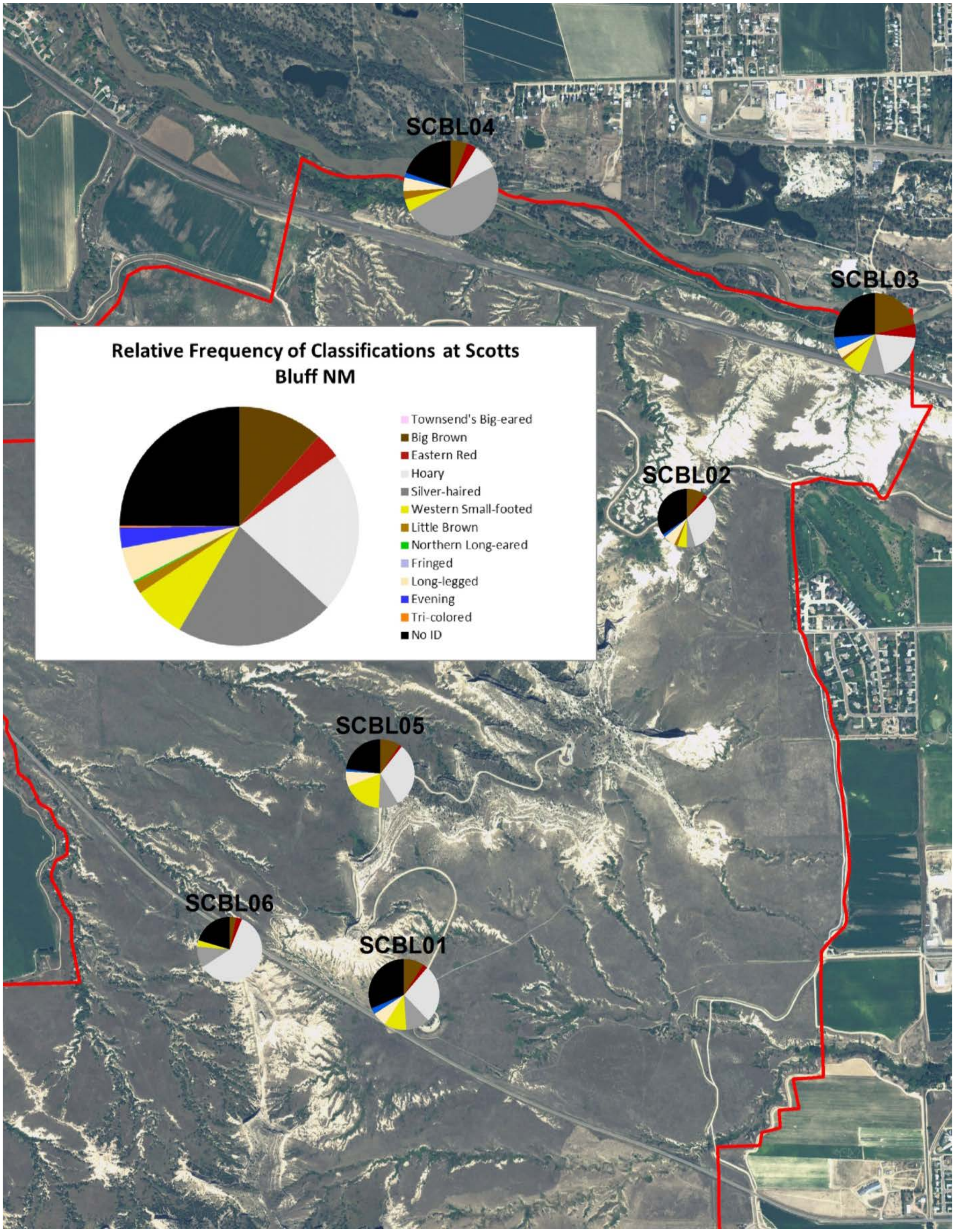

Figure 89. Relative frequency of classifications by species at Scotts Bluff NM in 2015-16. Size of circles correlates to rate of nightly activity.

Theodore Roosevelt NP

Theodore Roosevelt NP is comprised of 28,508 ha (70,447 ac), split about evenly between a South Unit and a North Unit. There is also a small Elkhorn Unit. Habitat within the park primarily consists of a mosaic of rugged badlands topography interspersed with flatter prairie habitats. The Little Missouri River traverses both the South and North Units and is a significant natural resource. The river is undammed and has a relatively natural hydrograph and riparian cottonwood forest. Woody vegetation consists of dense stands of juniper in the badlands topography, draws of green ash and other small trees and shrubs, and the cottonwood stands in the Little Missouri River riparian zone. The eroded badlands topography probably provides daytime roosting for some bat species and might even serve as an over-winter hibernaculum.

Two NABat cells had at least a portion of all four quadrants within the park boundary. Both were in the South Unit. Therefore, that unit was monitored using the NABat protocol and framework, i.e., eight stationary points and two mobile transects. The North Unit also has substantial natural resources and was deemed worthy of monitoring. That unit was monitored using a non-NABat approach, i.e., the same equipment, hardware configurations, and number of deployment days, but the five stationary points (THRO01-04, THRO06) were not located so as to have a point in each quadrant of a NABat cell and no mobile surveys were conducted in the unit.

In 2014 units were deployed at the eight NABat stations on August 11-13. Units were retrieved on August 14. Unit THRO121832NE stopped recording after one night. In 2015 units were deployed July 13-14 at the eight NABat sites and four non-NABat sites (THRO01-04) in the North Unit. However THRO061141SW was misplaced; the deployment was subsequently renamed THRO05. Unit THRO121832SW malfunctioned and no data was collected. The units were retrieved on July 19-20. In 2016 units were deployed at the four NABat stations on July 11 and the four other stations on July 18. Units were deployed at four non-NABat stations in the North Unit on July 13 (the exact location of THRO02 could not be determined so no deployment was made). All of the deployments lasted about a week. Unit THRO061141NE was knocked over and did not collect any data (it’s unclear if it was by animal, wind, or vandalized).

A total of 51,075 recordings were made from the 14 stations over 173 complete survey nights in 2014-16. Of those, 8% were determined by Kaleidoscope to be noise files and therefore discarded from analysis. Of the remaining 46,883 recordings, 27% were not identified by the software to the species level. Interestingly, noise files comprised 27% of the recordings in 2014 and only 5% in 2015-16; the reason for the poorer data collection in 2014 is unknown.

A total of 1,818 recordings were collected during the eight mobile surveys (2 routes each run twice in each of the three years). Of those, 86% were noise files. Of the 244 bat recordings from mobile surveys, 61% were not identified to the species level by Kaleidoscope.

Prior to this study, NPSpecies reported one bat species as being present at the Theodore Roosevelt and seven species as probably present (**Table 19**). This study indicates that ten species are present. There was insufficient evidence to say that the threatened northern long-eared bat is present: although some recordings were classified as coming from that species the sample size was small and the recordings could have come from other similar sounding myotis bats. The park is within the range of the northern long-eared myotis according to some authors (Harvey et al. 2011) and it is reasonable to conclude the species is present in the park, although perhaps at low densities and only seasonally. Conversely, the park is outside of the known range for tri-colored bats (Harvey et al. 2011, Barnhart and Gilliam 2017) and it is reasonable to conclude that species is not present in the park; however, recent work has been documenting the species further west into the Great Plains than originally thought (Geluso et al. 2005).

Table 19. Species presence at Theodore Roosevelt NP.

Species	NPSpecies Status[1]	Kaleidoscope			Sonobat[2]			Conclusion
		2014	2015	2016	2014	2015	2016	
T. Big-eared	–	1	0.29	1	0	0.38	0.77	Present
Big Brown Bat	Prob. Present	1	1	1	1	1	1	Present
Eastern Red Bat	–	1	1	1	1	1	1	Present
Hoary Bat	Prob. Present	1	1	1	1	1	1	Present
Silver-haired Bat	Prob. Present	1	0.94	1	1	1	1	Present
W. Small-footed	Prob. Present	1	1	1	0.72	1	1	Present
Long-eared	Prob. Present	1	1	1	0.55	1	1	Present
Little Brown Bat	Present	1	1	1	1	1	1	Present
N. Long-eared Bat	Prob. Present	0	0	0	0	0	0	Unconfirmed
Fringed	–	1	0	1	0.64	0.87	0.21	Present
Long-legged	Prob. Present	1	1	1	0.98	0.99	0.38	Present

[1] NPSpecies accessed 9-30-2015.

[2] Montana - Plains classifier package.

Big brown bats were the most frequently classified species by both Kaleidoscope (**Figure 90**) and Sonobat (**Figure 91**). Both software packages also reported a high rate of silver-haired bat classifications. Kaleidoscope classified a higher relative rate of hoary bats and western small-footed myotis than did Sonobat.

The relative frequency of species classifications varied by station (**Figure 92**), generally in predictable ways. For example, in the South Unit the big brown bat comprised about 3/4th of the classifications at the station in the Little Missouri River floodplain, a site dominated by old cottonwood trees. Conversely, the western small-footed and the long-legged myotis, species associated with arid habitats, were relatively more frequently classified in upland sites comprised of badlands topography. The North Unit generally showed a more diverse bat community. The big brown bat was again frequently classified, but at about the same rate as the hoary and silver-haired bats and the western small-footed myotis (**Figure 93**). The long-eared bat had its highest relative rate of classification within the Network at unit THRO04, located in an arid badlands draw.

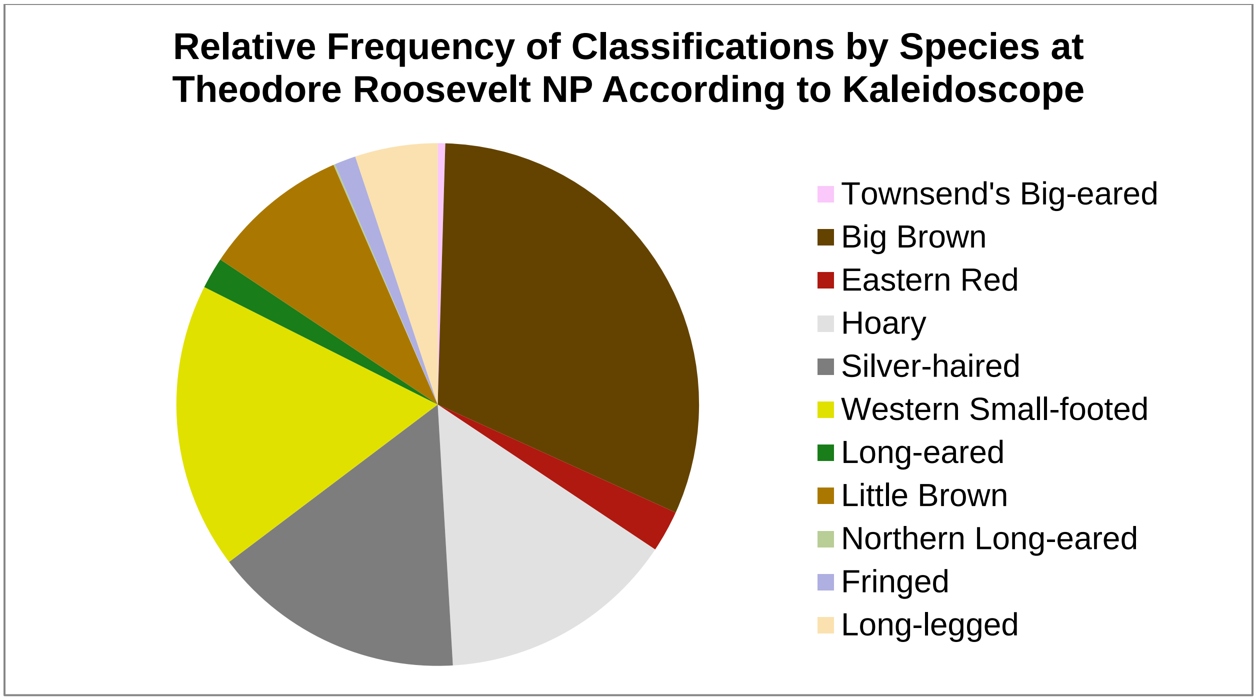

Figure 90. Relative frequency of classifications by species at Theodore Roosevelt NP according to Kaleidoscope.

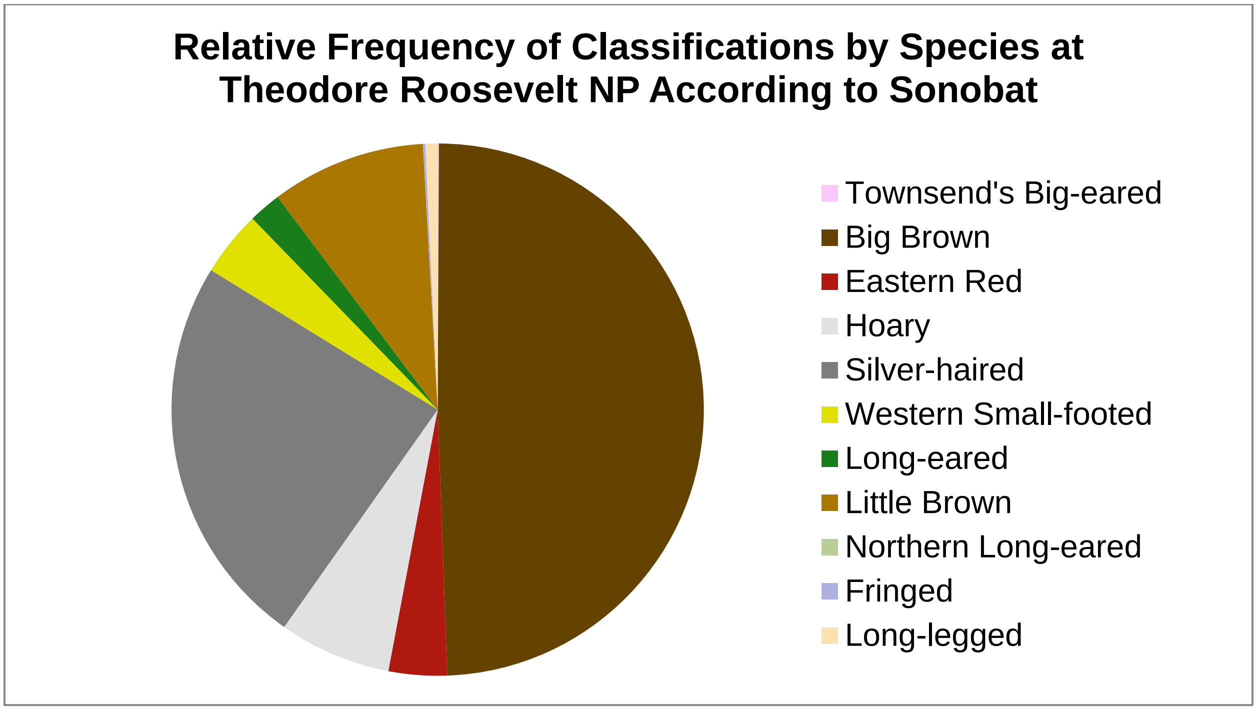

Figure 91. Relative frequency of classifications by species at Theodore Roosevelt NP according to Sonobat. Results from Montana-Plains classifier package.

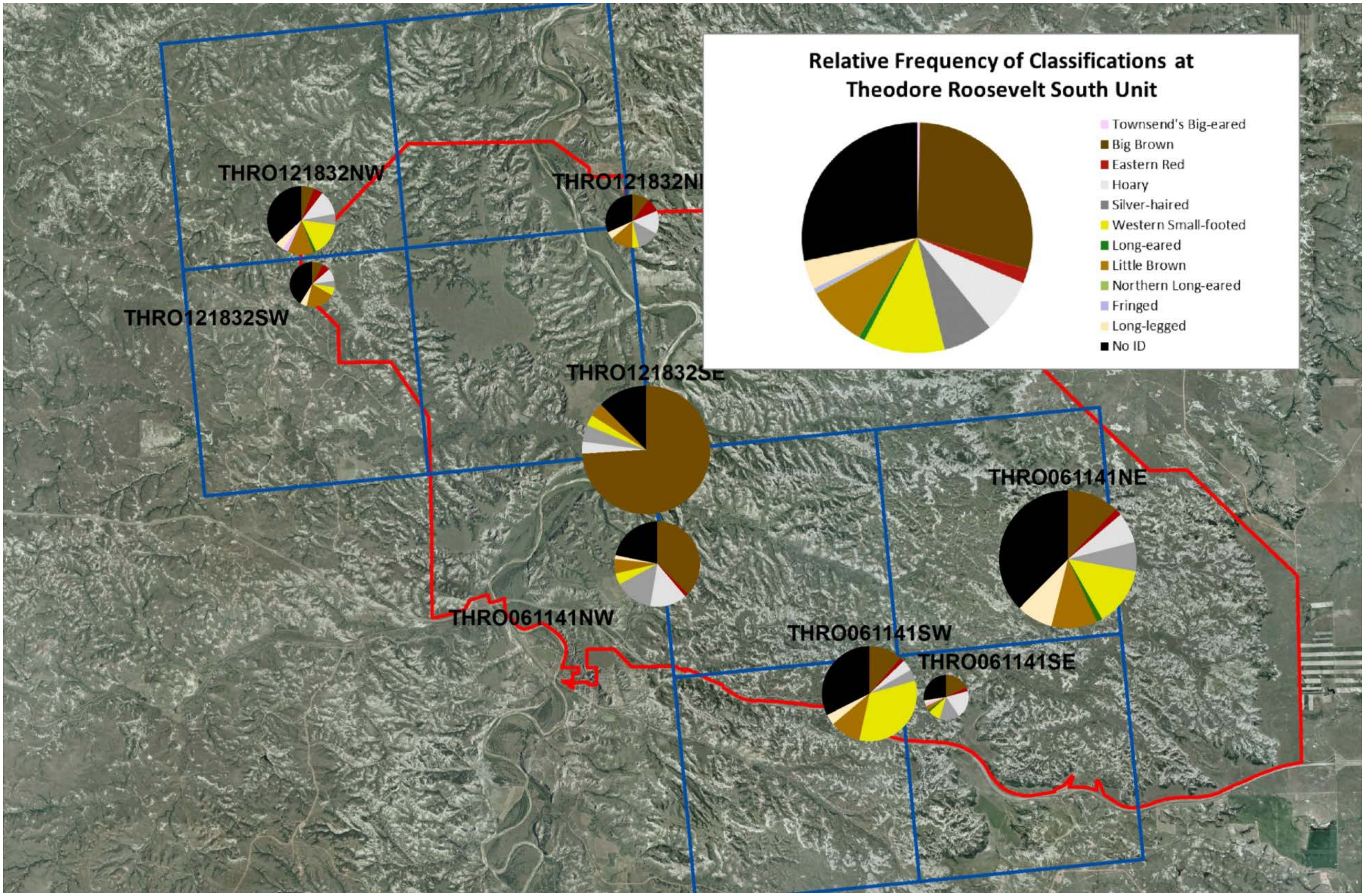

Figure 92. Relative frequency of classifications by species at Theodore Roosevelt NP South Unit. Size of circles correlates to rate of nightly activity. The red line is the boundary of the South Unit and the blue lines are the quadrants of the two NABat cells.

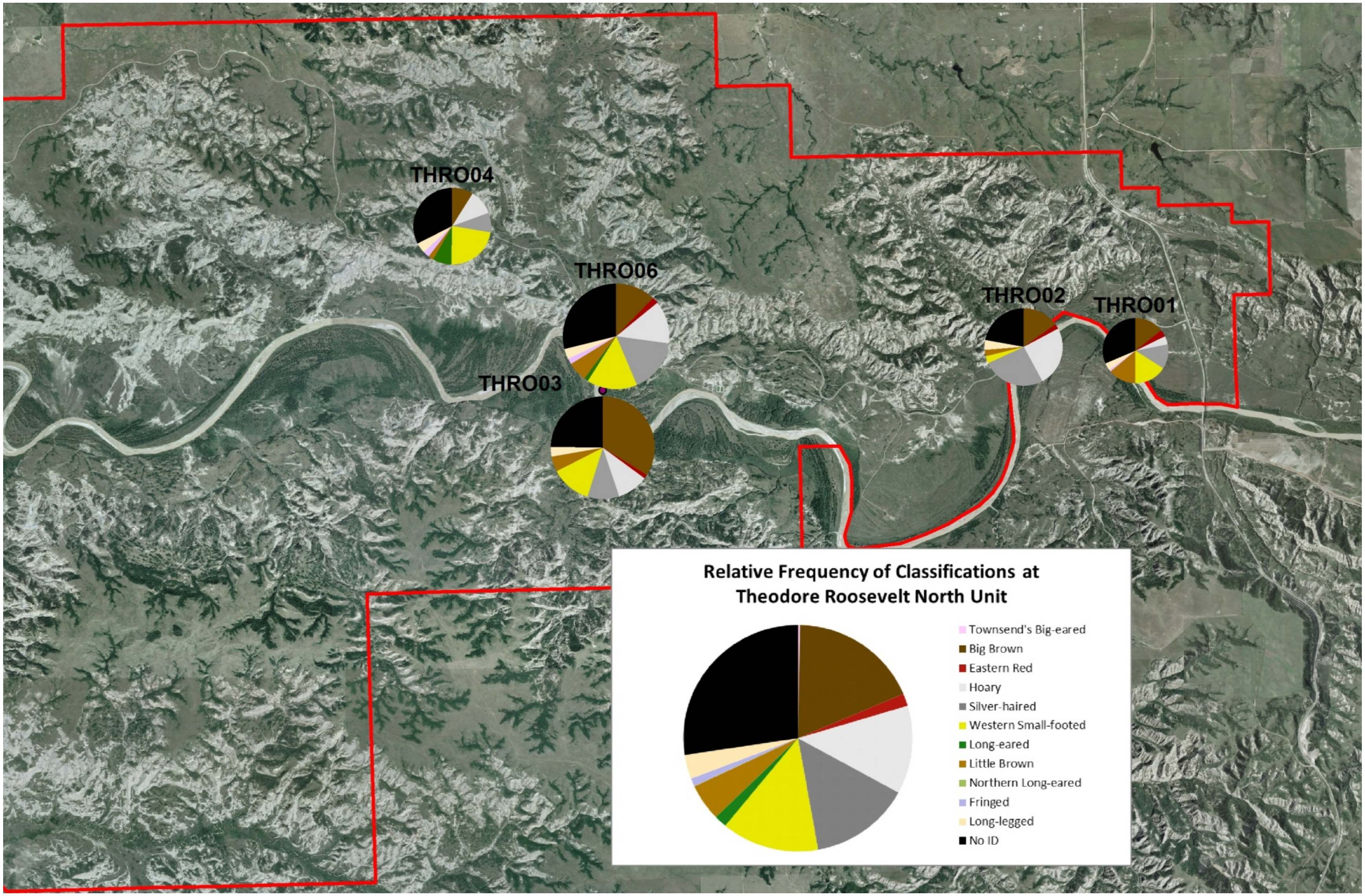

Figure 93. Relative frequency of classifications by species at Theodore Roosevelt NP North Unit. Size of circles correlates with rate of nightly activity. The red line is the North Unit boundary.

The highest rate of nightly classifications across all three years was at site THRO06 in the North Unit which was located along a beaver pond with inundated trees and snags. The site was monitored only in 2016: it averaged 702 bat detections per night in that deployment. The site with the second highest average rate of activity 2014-16 was next to the Little Missouri River in the North Unit and adjacent to the campground (THRO03). Interestingly, the unit next to the sewage ponds in the North Unit had only moderate activity (THRO01). Sites away from water, trees, and badlands topography had some of the lowest nightly rates in the Network (e.g., THRO121832SW and THRO061141SE). Sites THRO061141NE and THRO121832SE had very high rates of activity for deployments in 2014 and 2015, respectively, but much lower in the other years (**Figure 94**).

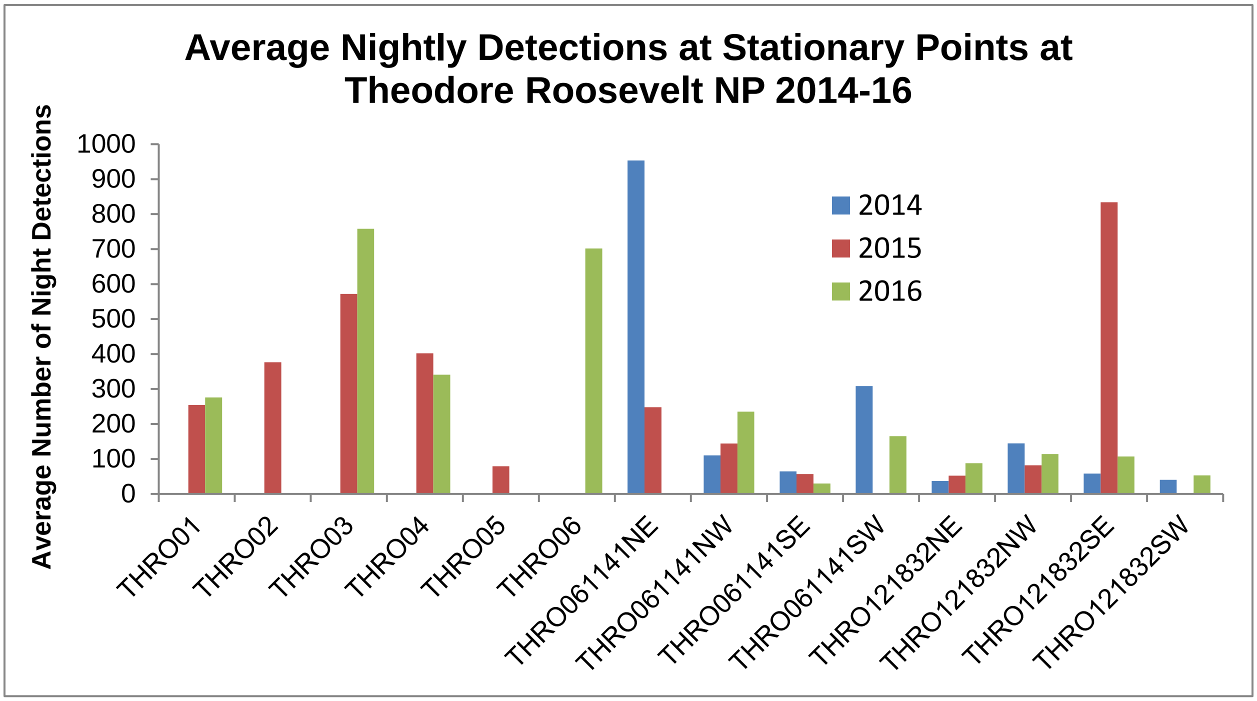

Figure 94. Average nightly detections at Theodore Roosevelt NP 2014-16. The absence of a bar indicates the site was not monitored in that year.

Based on the point data there was no obvious trend in the rate of bat activity over time (**Figure 94**). There were substantial year-to-year differences, most notably at THRO061141NE and THRO121832SE (**Figure 94**). The former was on a bluff overlooking a drainage with ephemeral pools of water. It had several times more nightly detections in 2014 than in 2015. Unfortunately, the deployment malfunctioned in 2016. Site THRO121183SE was located in a riparian grassland between the Little Missouri River and some old decadent cottonwood trees. The reason for the dramatic spike in nightly activity in 2015 is unknown. All of the other sites showed modest year-to-year changes.

In contrast to the point monitoring, the mobile surveys did show a consistent decline from 2014 to 2016 in the number of bats detected (**Figure 95**). The reason for the discrepancy between the two methods is unknown. The higher rate of detections in the 2014 road surveys than in 2015-16 might have been due to the mid-August surveys in 2014 hence the inclusion of migrants and flying juveniles in the count. Conversely, the 2015 and 2016 surveys were conducted in mid-July.

The mobile survey route for NABat cell #061141 followed the South Unit park loop road. Bats were generally detected at a consistent rate throughout the route (**Figure 96**) suggesting uniform use of habitat within the park. However, the road rarely approached the river where bat activity might be greater. The road route for NABat cell #121823 was entirely west of the park. Whereas the route within the park averaged 0.72 detections per km the route west of the park only averaged 0.29 detections per km. This disparity could be due to the relative lack of woody vegetation west of the park, although other causes cannot be ruled out. Some energy development has been occurring in the area west of the park; the impact of that on bats is not well known and warrants further research.

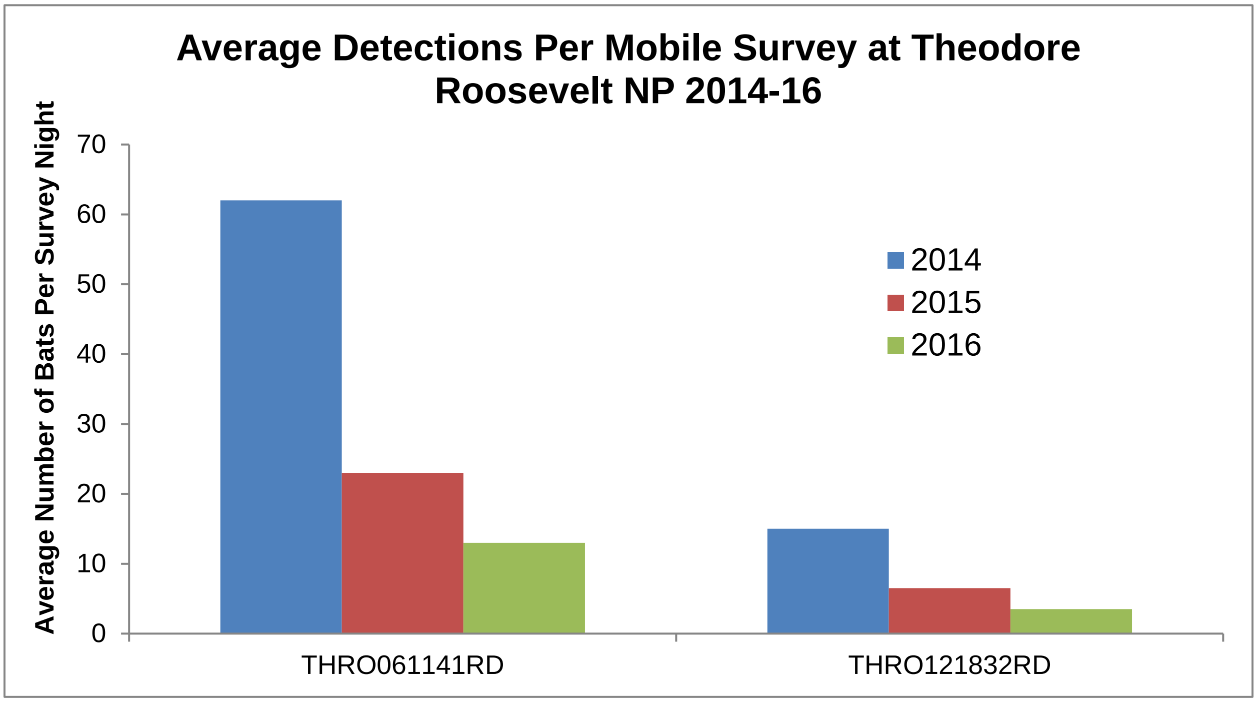

Figure 95. Average number of detections per mobile survey at Theodore Roosevelt NP 2014-16.

The park should continue to monitor bat activity. Season or year-long monitoring should be done if possible to determine migration peaks in the vicinity of the park as they might have influenced the 2014-16 results. The work of Barnhart and Gilliam (2017) should be expanded to determine the degree to which the park provides over-winter hibernacula. Mist-netting can provide definitive proof of the presence of the northern long-eared bat; this study did not find compelling evidence that it is present in the park.

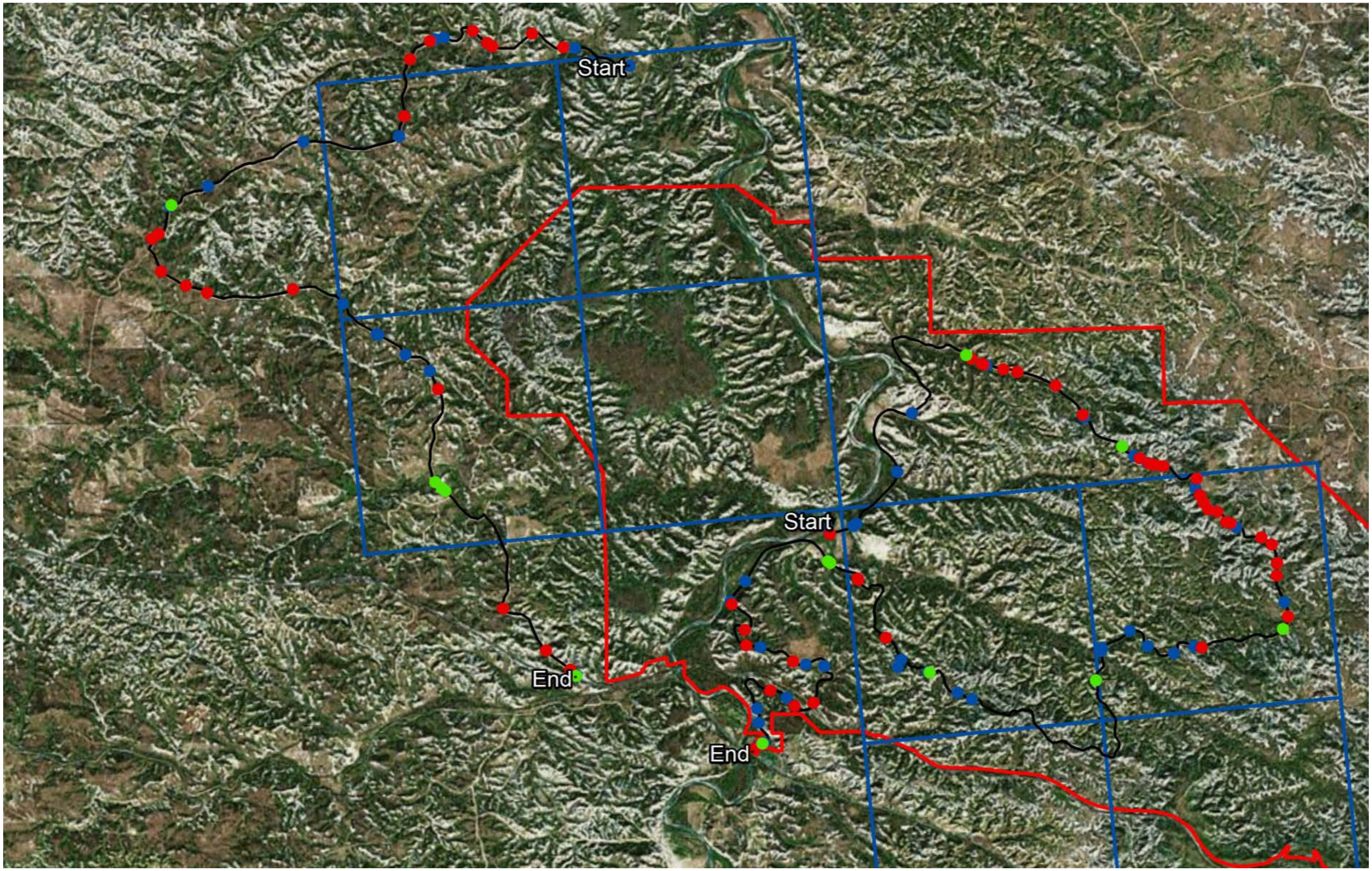

Figure 96. Bat detections from Theodore Roosevelt NP East River and West River (NABat cells #061141 and #121832) mobile surveys 2014-16. First replicates only. Blue circles are from 2014, red from 2015, and green from 2016. Blue squares are the NABat cells and red line is park (South Unit) boundary.

Wind Cave NP

Wind Cave NP is a 13,728-ha (33,924-ac) park located in the southern Black Hills in western South Dakota. The park was initially established to protect the namesake cave, but was expanded several times in part to conserve large animals such as bison and elk. Entrances to the namesake cave are sealed, however, bat activity is infrequently observed within the cave system (Dan Roddy, pers. comm.) and near the cave entrance (Turner and Davis 1970). However, the cave does not appear to be a hibernaculum for large numbers of bats. Other small caves exist throughout the park, but none are known to serve as hibernacula or roosting sites for large numbers of bats. Uplands within the park are a mixture of grasslands and ponderosa pine forests with some deciduous trees in moist-soil areas. Rocky fractured limestone cliffs are common and certainly provide roosting habitat for bats. Natural surface water primarily consists three perennial streams measuring only a few meters in width. Sewage ponds are present near the administrative area. Seasonal ponds sometimes form in in wet years.

The park received WNS funding in 2014-16 and used the funds to conduct acoustic surveys and mist-net surveys in those years. The results from the park's in-house bat studies are not presented here.

A single NABat cell (#033842) had at least a portion of all four quadrants within the park boundary, so the Network monitored bats at the park using the NABat sampling frame and protocol. A stationary point was established in a prairie setting along Highland Creek near the bison coral (NE quadrant), at a site on newly acquired property near an old homestead overlooking a dry canyon (SE quadrant), near the park sewage ponds (SW quadrant), and on a bluff near a historic bridge spanning Beaver Creek Canyon (NW quadrant). It was subsequently determined that the stationary point in the NE quadrant is just outside of the NABat cell; however, the station was retained.

Stationary point and mobile surveys were initiated on July 21, July 14, and July 27, of 2014-16, respectively. Deployments were for four nights in 2014 and seven nights in 2015-16. In 2014 the microphone pole at the stationary point in the NE quadrant was knocked to the ground during the deployment period, probably by a bison: data indicates it was knocked over after the first night so the remaining nights were censored. In 2015 the stationary point in the SE quadrant was not surveyed due to wet conditions preventing access.

A total of 34,340 recordings were made from the 61 survey nights at the four stations 2014-16, of which 5% were noise files. Of the 32,773 bat recordings from stationary points, Kaleidoscope did not classify a species in 30% of the recordings.

Of the 635 recordings made on mobile surveys, 50% were noise files, leaving 320 recordings of bats in six survey nights. Of those, 32% were not identified to species by Kaleidoscope.

Prior to this study there were ten species reported to be present at Wind Cave and one species reported to be probably present according to NPSpecies (**Table 20**). This study indicates that ten species are still present; however, this acoustic study could not confirm the presence of the northern long-eared bat at a statistically significant level, a species that was listed as present in the NPSpecies database. That species was captured in August 2004 at the park (Schmidt et al. 2004). The bat was also captured in mist-netting that was concurrent with the years of this study (Dan Roddy, pers. comm.). Therefore, I concluded it was present, making 11 confirmed species (**Table 20**). This acoustic study found evidence that the tri-colored bat was present at the park; a species not listed as being present in the NPSpecies database. Geluso et al. (2005) reported the tri-colored bat being present in the Black Hills based on captures at mines in the vicinity of Hill City, South Dakota. Two individuals were captured in Wind Cave during the period when this study was being conducted, further confirming its presence (Dan Roddy, pers. comm.).

Table 20. Species presence at Wind Cave NP.

Species	NPSpecies Status[1]	Kaleidoscope			Sonobat[2]			Conclusion
		2014	2015	2016	2014	2015	2016	
T. Big-eared	Present	1	0.92	0	0.38	0	0.38	Present
Big Brown Bat	Present	1	1	1	1	1	1	Present
Eastern Red Bat	Present	1	1	1	0.47	0.99	1	Present
Hoary Bat	Present	1	1	1	1	1	1	Present
Silver-haired Bat	Present	1	1	1	1	1	1	Present
W. Small-footed	Present	0.94	1	1	0.48	1	0.22	Present
Long-eared	Prob. Present	0	0	0	0	0.19	0	Unconfirmed
Little Brown Bat	Present	1	1	1	1	1	1	Present
N. Long-eared Bat	Present	0	0	0	0	0.18	0	Unconfirmed
Fringed	Present	0	0	0	1	1	1	Present
Long-legged	Present	1	1	1	0.75	0.94	0.10	Present
Tri-colored	–	0.61	0.99	1	0.18	0	0	Present

[1] NPSpecies accessed 9-30-2015.

[2] Results from South Dakota-Black Hills classifier package except for tri-colored bat which came from South Dakota-Eastern package.

Kaleidoscope (**Figure 97**) and Sonobat (**Figure 98**) were in high agreement regarding the relative frequency of bat species classifications compared to the results from several other parks in the Network. Both found the silver-haired bat to be the most frequently classified species followed by the big brown, hoary, and little brown bats. This study found the long-legged myotis to be a comparatively small component of the bat community; that species has historically been cited as one of the most common species in the Black Hills (Jones and Genoways 1967, Turner 1974, Schmidt 2003).

Compared to some other parks in the Network, there was not much noticeable difference in the relative frequency of classifications between sites (**Figure 99**). The three most common species, the big brown, hoary, and silver-haired bats, consistently comprised about 5/8ths of the classifications regardless of the site. The little brown bat did show a slight increase in relative classifications at the park's sewage pond in the southwest quadrant, a not surprising as that species often forages over water.

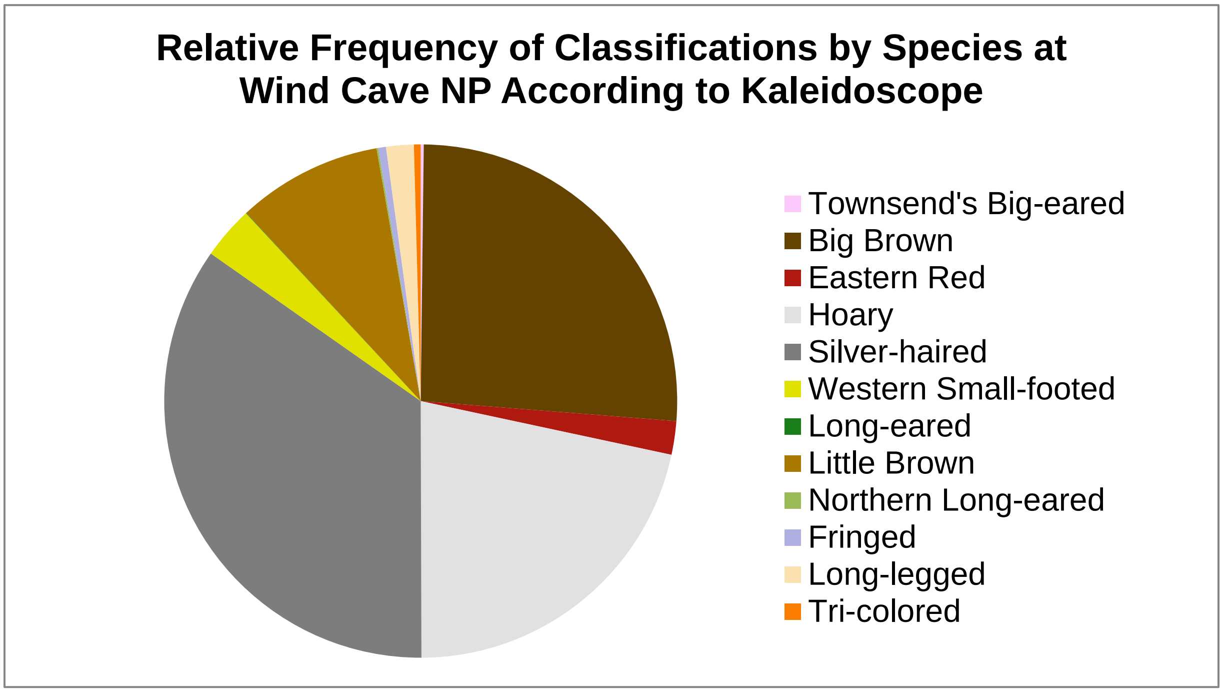

Figure 97. Relative frequency of classifications by species at Wind Cave NP according to Kaleidoscope.

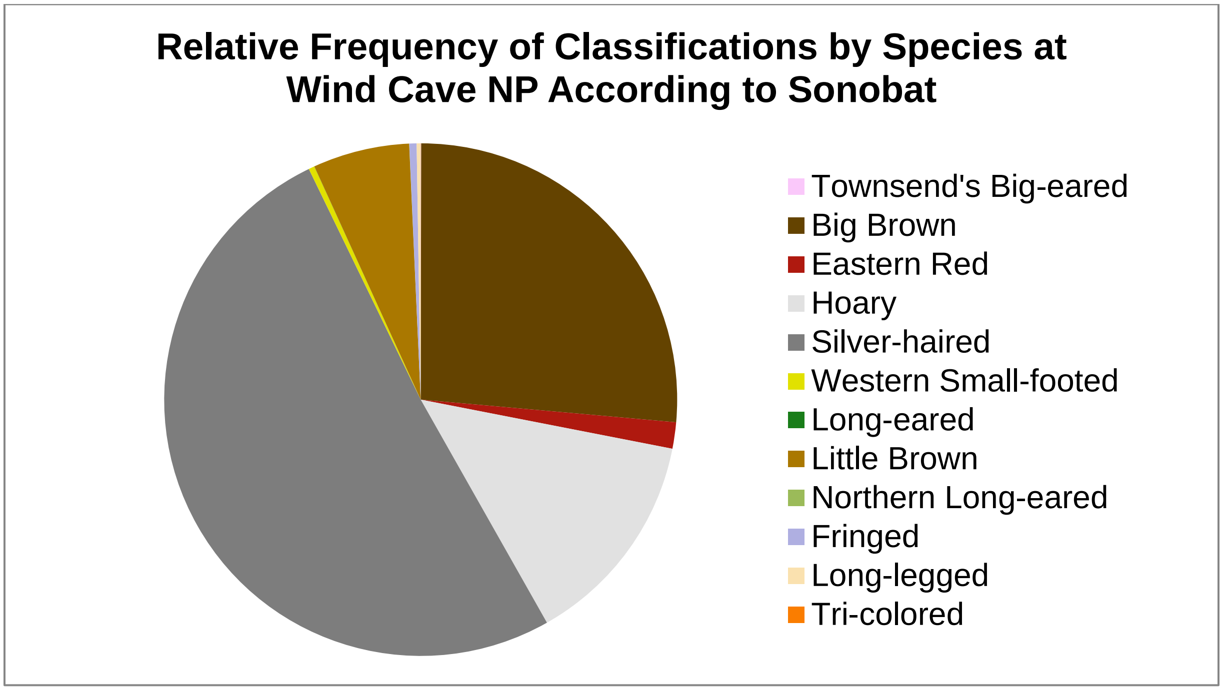

Figure 98. Relative frequency of classifications by species at Wind Cave NP according to Sonobat. Results from South Dakota-Black Hills classifier package except for tri-colored bat which came from South Dakota-Eastern package.

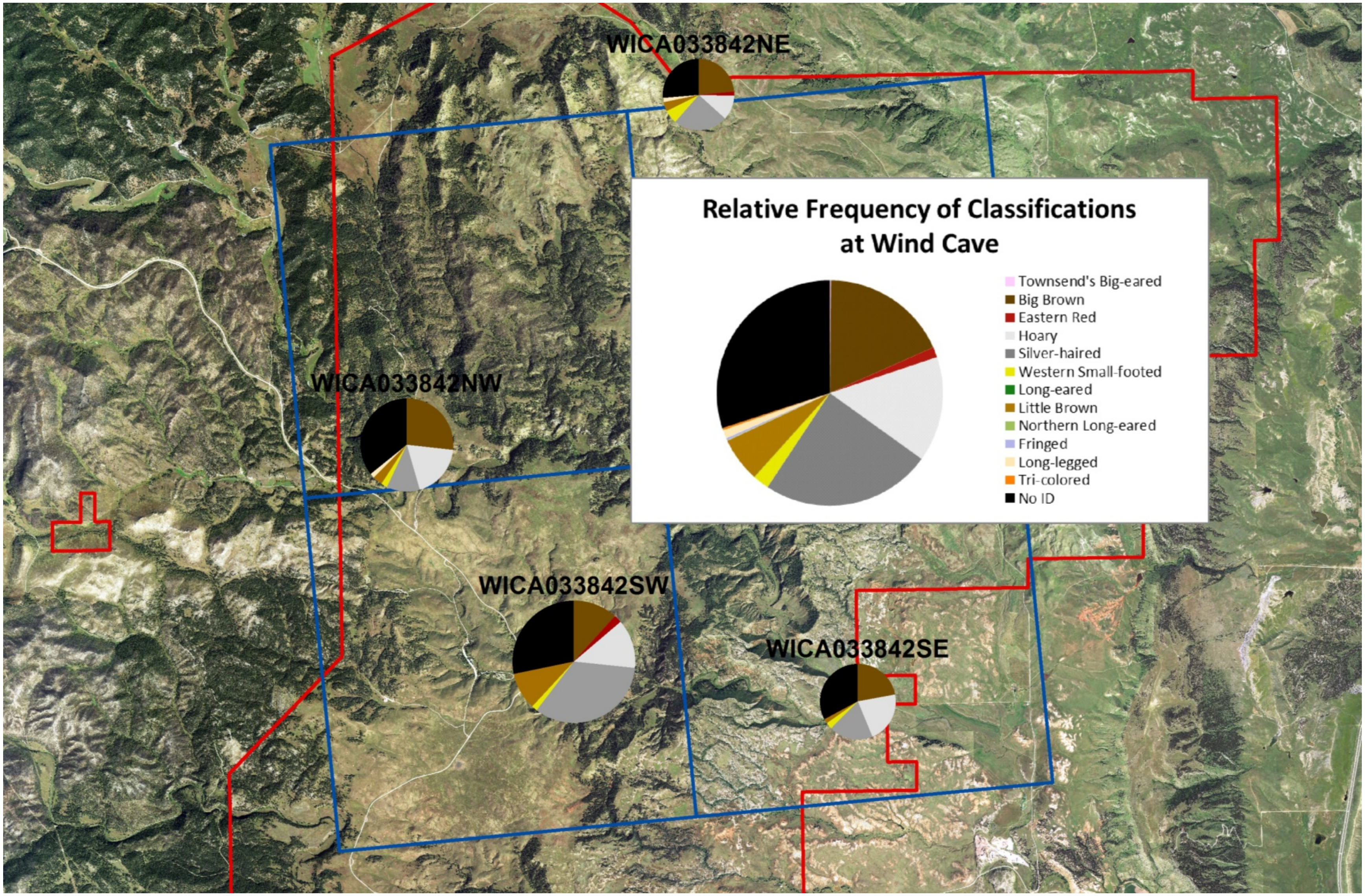

Figure 99. Relative frequency of classifications by species at Wind Cave NP 2014-16. Size of circles correlates to rate of nightly bat activity. Red lines are the park boundary and blue lines are quadrants of NABat cell #033842.

The stationary point in the SW quadrant of the NABat cell had the most bat activity (**Figure 99**, **Figure 100**), averaging 878 detections per night. The point was next to the park's sewage pond, which comprises the largest body of permanent surface water in the park. The point in the NW quadrant was located on a bluff over Beaver Creek Canyon and near a historic bridge on Highway 87; it averaged 506 detections per night. The station in the SE quadrant was on a bluff over a dry canyon and near an old ranch house; it averaged 336 detections per night in 2014 (it was not monitored in 2015). The least activity was at the point in the NE quadrant that was in an open prairie area along Highland Creek; it averaged 297 detections per survey night. There was no noticeable trend in abundance over time across the park (**Figure 100**); however, the station in the southeast quadrant did show a dramatic increase in 2016 compared to 2014 (it was not monitored in 2015 due to wet conditions and a lack of access).

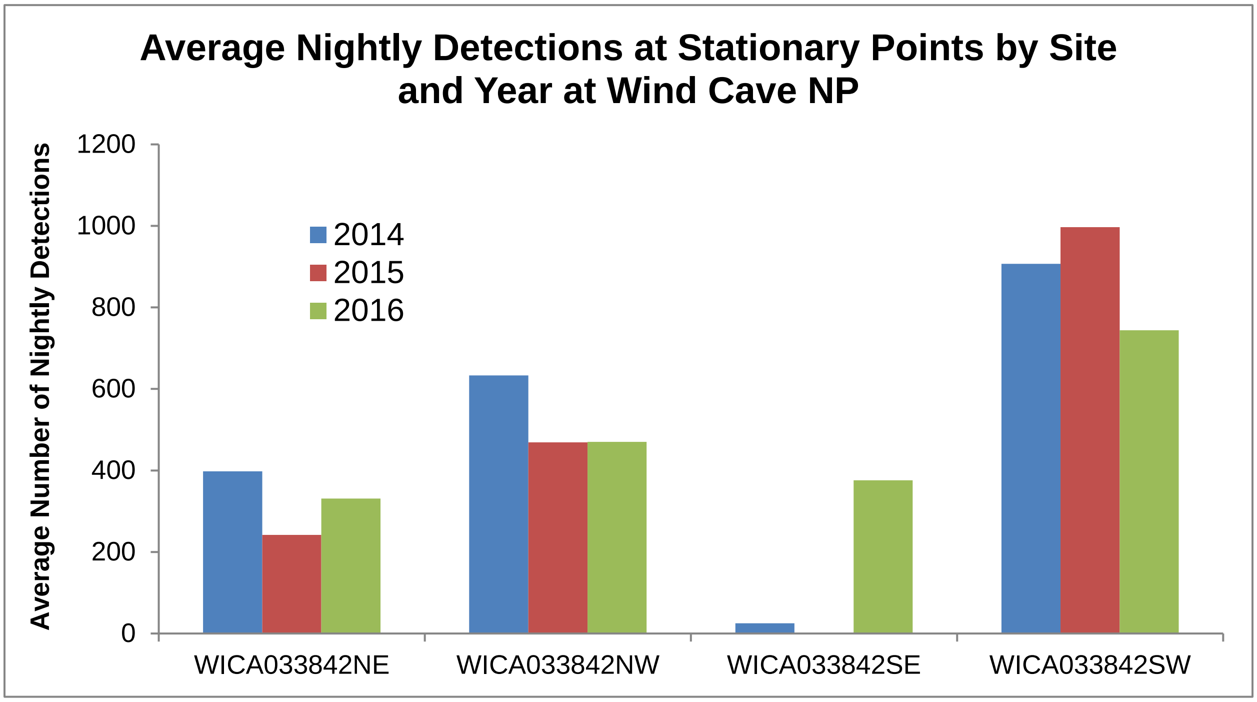

Figure 100. Average number of detections per night by site and year at Wind Cave NP 2014-16. The absence of a bar indicates the site was not monitored in that year.

The mobile surveys detected the most bat activity on a portion of Highway 87 that went through the forested Reeves Gulch area (**Figure 101**). This area is comprised of relatively large ponderosa pines and deciduous trees. There were generally fewer bat detections in open prairie areas.

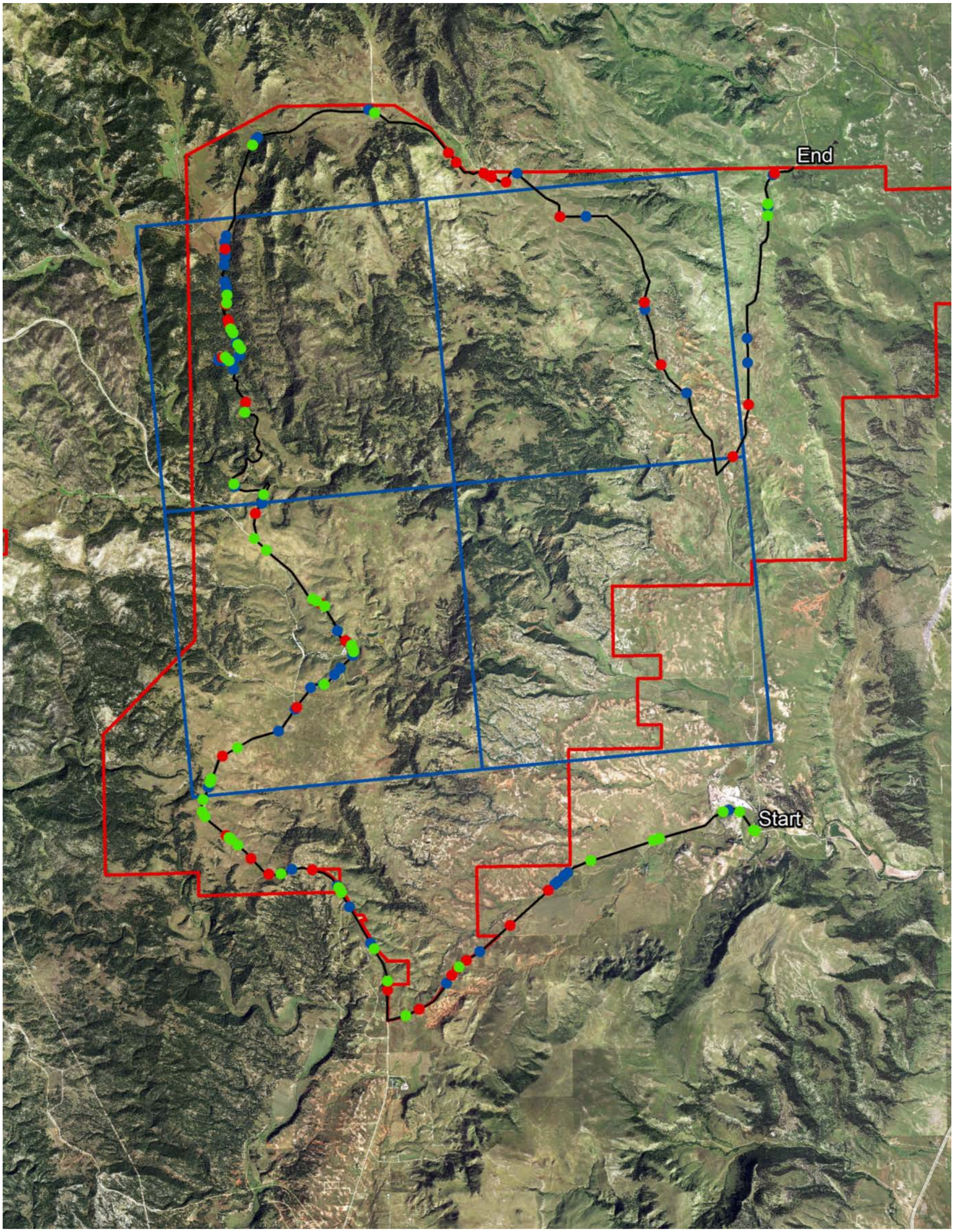

Figure 101. Detections from Wind Cave NP (NABat cell #033842) mobile surveys 2014-16. First replicates only. Blue circles are from 2014, red from 2015, and green from 2016. Blue square is the NABat cell and red line is the park boundary.

The mobile surveys corroborated the point surveys in that they too showed no apparent difference in bat activity at the park from 2014 to 2016. The two replicates each year averaged 66, 58, and 37 bats per night in 2014-16, respectively. The average rate of bat detections was 1.3 per km traveled, one of the higher rates in the Network.

The Wind Cave bat community appears to be abundant, diverse, and stable. Continue monitoring should be conducted at the stationary points and mobile route used in 2014-16. The anthropogenic sewage ponds appear to have high value to bats in the park, a fact that should be considered in park planning and management. Surface water is especially critical to lactating females (Adams and Hayes 2008) so the sewage ponds might be playing an important role in bat reproduction in the park. Wind Cave is at the lower elevations of the Black Hills so it might be more important to female bats than it is to males, which prefer higher elevations (Cryan et al. 2000). Some species such as the little brown bat can show reduced survival and recruitment in dry years (Frick et al. 2010), a decline that could be mitigated by permanent water sources such as the sewage ponds. Conversely, anthropogenic forest thinning and removal of woody debris could harm and reduce bat use at the park and should be avoided if bat conservation is a high priority. Forest crown fires could provide additional short-term habitat for bats by providing loose bark that bats roost under.

Discussion

Bats are critical for ecosystem services and have substantial economic value (Kunz et al. 2011). For example, bat guano at the base of roost trees can increase nutrient levels several fold and lead to increased plant diversity and abundance (Duchamp et al. 2010). And according to a study by Boyles et al. (2011), bats in the Northern Great Plains have an economic value of over $50 million annually per county as a result of insect control. Hence, a healthy bat community is important. Monitoring bats can determine the status of a bat community and detect changes over time. This study reports on three years of bat monitoring in the Northern Great Plains using acoustic methods.

Results from acoustic studies—especially species-specific results—should be interpreted cautiously as species misidentification is problematic (Britzke et al. 2013). Different automated identification software can produce different results (Lemen et al. 2015, Licht 2016). Similarly, different manual reviewers can also come to differing conclusions (Fritsch and Bruckner 2014). Misclassification is especially problematic between closely related species such as the various myotis (Britzke et al. 2013). And environmental conditions such as habitat clutter can compromise species identification. For example, the little brown bat and northern long-eared myotis can produce different calls flying through clutter than when they are out in the open (Broders et al. 2004, Wund 2006). Rather than assume absolute precision in species-specific results, readers should view the species-level results presented here as an approximation using the best available software at the time of the analyses. In contrast, results of total bat detections can be viewed with more confidence. But even then, readers should keep in mind that acoustic surveys collect a measure of bat activity, i.e., flyovers, which might not be directly correlated with abundance. In spite of these caveats and limitations, the results from acoustic monitoring in 2014-16 have produced some interesting and useful information.

Conclusions

- Most bat activity in the Northern Great Plains Network was attributed to the big brown bat, followed by the silver-haired, hoary, Western small-footed, and little brown bats. Fourteen species were documented to varying degrees in Network parks, although some species are found only in the eastern portion (e.g., evening bat) and some in the western portion (e.g., long-eared and Yuma myotis).

- The threatened northern long-eared bat was very rare, if present at all, in the 12 Network parks in this study. Conversely, at the beginning of the 21st Century the species was reported from several parks based on limited mist-netting and acoustic surveys (Tigner 1999, Schmidt et al. 2004). As recently as 2011, Harvey et al. (2011) wrote that the northern long-eared bat was one of the most common species where it is found. It appears that the species has suffered a dramatic decline in the Northern Great Plains prior to this study being implemented.

- The range of the tri-colored bat appears to extend further west than originally thought. For example, the species range map in Harvey et al. (2011) shows it barely reaching the Dakotas. The results here suggest that it extends to the western Dakotas. In 2014 two tri-colored bats were captured at Wind Cave, further confirming its presence. Other researchers have also suspected a larger range for the species than once thought (Geluso et al. 2005).

- Bat abundance in the North Great Plains does not appear to have changed from 2014 to 2016. However, there have been noticeable year-to-year changes at some parks. For example, at the Missouri NRR there was a noticeable drop in detections from 2014 to 2015, but in 2016 numbers rebounded to 2014 levels.

- The coefficient of variation for the nightly counts from the stationary deployments is about 53%. The coefficient of variation for the mobile survey replicates is about 25%. The values, along with other patterns observed in the 2014-16 data, are evidence of the challenges to detect trends over time at statistically significant levels.

Management Implications

The goal of this study was to monitor bat abundance in the parks due to concerns that bat populations might decline as a result of white-nosed syndrome, energy development, and other threats outside of the control of the parks. However, some of the results from this project can aid and guide management actions within control of the parks.

- Water. The highest bat activity in the Network was regularly associated with surface water, and more specifically, standing water. In most cases the standing water was human-made, such as sewage ponds and impoundments for bison. Managers can benefit bats by conserving these water resources and creating more surface water. However, the creation and conservation of anthropogenic water needs to be reconciled with agency policies.

- Bat Houses. Fort Laramie NHS had the highest park-wide rate of bat activity as measured by detections. This might be due to the bat house at the park. That structure was built as mitigation to keep bats out of the historic buildings at the fort. Bat houses could greatly increase bat abundance in all parks. However, the establishment of bat houses would also need to be reconciled with policies.

- Forest Management. Forest management projects have occurred at several parks in the Network and will likely continue to occur, especially at parks in the Black Hills. These projects often alter habitat such as the removal of woody debris for purposes of fuel load reduction. However, woody debris often provides suitable roosting habitat for bats. For example, a study conducted at Devils Tower NM found bats roosting in down woody material only a few feet above the ground (**Figure 102**). Network parks could best conserve bats by not removing such material.

- Compliance. The only bat species found in the Northern Great Plains that is currently listed under the Endangered Species Act is the northern long-eared bat. However, several other species such as the little brown bat and the long-legged myotis have been considered for listing. Projects that go through environmental compliance, such as the National

Environmental Policy Act (NEPA), should strongly consider the impacts and potential benefits to all bat species.

- Education and Outreach. All of the parks in the Network can play a major role in educating the public about the ecological value of bats, the factors threating bat populations (e.g., WNS), and actions people can take to conserve bats (e.g., building bat houses and protecting large snags). For example, Jewel Cave and Wind Cave get hundreds of thousands of visitors annually to tour the caves. All of these visitors could be informed about bats as part of the tours. Jewel Cave has made bats a prominent feature in their visitor center. Non-cave parks can also educate the public about bats. For example, Mount Rushmore has an evening program during which time bats are often observed flying overhead and Badlands conducts night sky programs. Fort Laramie has created special events regarding bats; the author participated in an evening program in the summer of 2016. Presentations about bats could be enhanced by using Wildlife Acoustics EchoMeter Touch modules for real-time detection and display of bat calls. The results from this study could be used in outreach efforts.

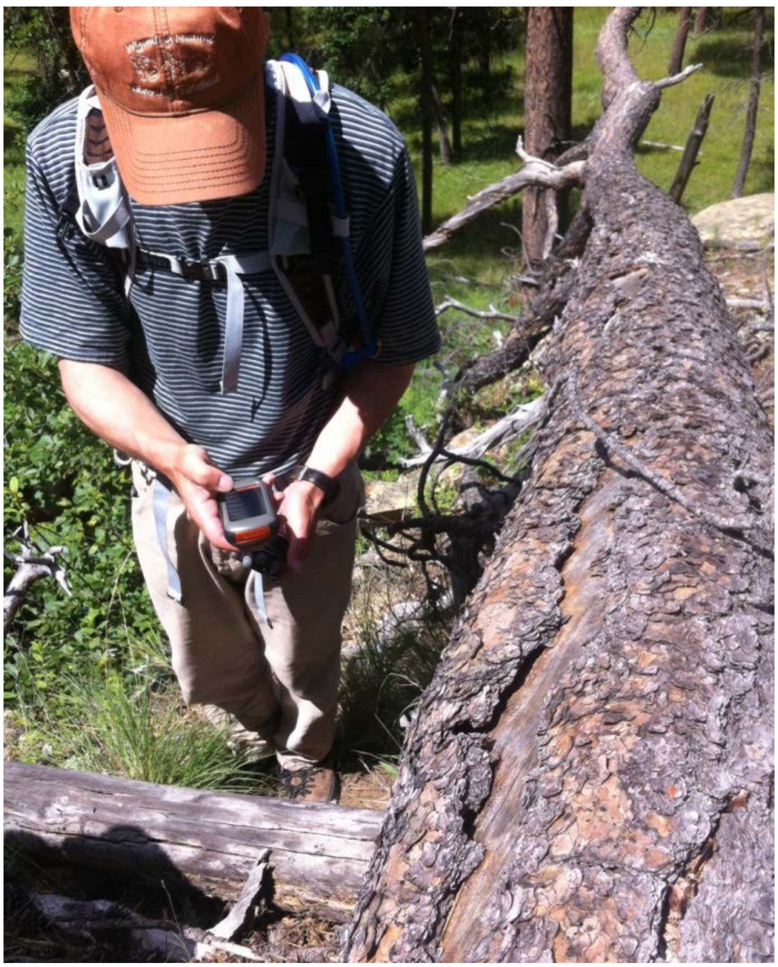

Figure 102. Fallen tree used by roosting bats in the Black Hills. (NPS)

Moving Forward

The following bullets should be considered by people continuing the Network bat monitoring program and/or wishing to conduct additional studies.

- Subsequent to their deployment, stationary points BADL075712SW and WICA033842NE were found to be just outside their respective NABat cell boundaries. My recommendation is to continue monitoring the stations as the continuity of data collection from the same location is more important than relocating the station within the cell boundary.

- The mobile surveys conducted in 2014-16 started 30 minutes after sunset. This was consistent with the draft NABat protocol in the spring of 2014; however, the final protocol published in June 2015 (Loeb et al. 2015) calls for starting mobile surveys 45 minutes after sunset. My recommendation is to continue starting the mobile surveys at 30 minutes after sunset as the continuity of data collection is more important than revising the monitoring to be consistent with the published protocol.

- More information is needed on the timing of seasonal changes in bat activity in the Northern Great Plains, specifically, the timing of the first flights of young-of-the-year bats and the timing of the spring and fall migrations. It's possible that the mid-August and September surveys were biased by volant juveniles and migrating animals. For example, Geluso et al. (2013) found evidence that Eastern red and hoary bats migrate through Nebraska in late July/early August. Future surveys should be conducted in June and July (and perhaps late May), yet preferably within a week or two of when the 2014-16 surveys were conducted.

- The NABat mobile survey protocol calls for the use of rooftop-mounted directional microphones pointed skyward. However, at Badlands NP bats were observed in the headlights of the survey vehicle flying low over the road surface: some of these bats were not detected by the rooftop directional microphone (but were detected by an omni-directional EchoMeter touch system that was running concurrently). It appears that the bats were feeding just above the road surface, perhaps because the blacktop was still warm and attracted insects. This phenomenon may be unique to Badlands and of little consequence to NABat temporal analyses; nevertheless, it could result in misleading results should spatial comparisons be made. Research should be conducted on this apparent phenomenon and potential bias.

- More analyses can be conducted on the 2014-16 dataset. For example, the rate of bat detections could be correlated to weather, moon phase, habitat, and season. As software programs improve in species classification the analyses conducted here could be re-run, perhaps slightly improving the accuracy of the results and allowing for species-specific analyses.

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Appendix I. Metadata for Stationary Points and Mobile Surveys

The Network used a combination of stationary points and mobile surveys to monitor bats 2014-16. The stationary points could further be categorized into NABat stations and non-NABat stations.

The NABat program developed a bat monitoring sampling design for all of North America. The design consisted of a grid of 10x10 km cells overlain on the continent. The Northern Great Plains Inventory & Monitoring Network selected cells in which all four quadrants of the cell were at least partially located within a park administrative boundary. Cells from the South Unit of Badlands National Park were excluded due to the uncertain management future for that unit. Fifteen cells met the criteria; however, one cell was in the Badlands Wilderness and was excluded from monitoring in 2014-16. The cell could be included in future monitoring; however, it is logistically difficult to access and there are no roads within the cell. The goal was to place a stationary monitoring point in each of the four quadrants within the cells. Recorders would be deployed for a minimum of four, and preferably seven, days during the summer months, i.e., before the emergent of volant juveniles and arrival of migrants. Sites would be revisited in future years. A listing of the stationary points, the NABat cells, and deployment periods for 2014-16 is in **Table 21**. Detailed maps and photos of each station can be found in Licht (2017).

Six other parks in the Network did not meet the criteria for the NABat framework, i.e., a station in each quadrant of a 10x10 km cell. These parks were small in acreage. Stationary points were established in these parks using other objectives and criteria, typically, areas of interest to management. The number of points per park ranged from four to 43. Other than the spatial arrangement, deployments and recording was comparable to the NABat stationary points. A listing of the stationary points and the deployment periods for 2014-16 is in **Table 22**. Detailed maps and photos of each station can be found in Licht (2017).

The NABat protocol calls for the use of mobile surveys in combination with stationary points. A mobile survey route was established for each of the 14 NABat cells monitored 2014-16. NABat calls for the routes to be 25-48 km (16-30 miles) long with little backtracking; however, that was logistically impossible in the cells within the parks. Some of the cells contained only a single road and in some cells the road network was constrained by rivers and other barriers. As a result, large portions of each route went outside the cell boundary. However, because spatial data was collected for each recording the data could be parsed to use only records from within the NABat cell if that is desired for analysis. Each NABat mobile route was intended to be run twice in a summer; however, surveys were not to be run in inclement weather and as a result not all routes were surveyed twice in a summer. The routes can be seen in the maps in this report, in Licht (2017), or received in GIS format from the Network. A list of the mobile routes and the survey dates 2014-16 can be found in **Table 23**.

Table 21. NABat stationary points metadata and deployment dates 2014-15.

Station ID	Station Descriptive Name	NABat GRTS ID	NABat Descriptive Cell Name	Latitude	Longitude	2014 Deploy-ment Date	2015 Deploy-ment Date	2016 Deploy-ment Date
BADL029922NE	Old Park Road Stock Pond	029922	Cedar Pass	43.777992	-101.952849	7/15/2014	7/1/2015	5/27/2016
BADL029922NW	Scattered Cottonwoods	029922	Cedar Pass	43.787712	-102.019096	7/15/2014	7/1/2015	5/27/2016
BADL029922SE	Sewage Lagoon	029922	Cedar Pass	43.900238	-102.410149	7/15/2014	7/1/2015	5/27/2016
BADL029922SW	Saddle Pass Creekbed	029922	Cedar Pass	43.751022	-101.969948	7/15/2014	7/1/2015	5/27/2016
BADL047586NE	Big Roberts Wetland	047586	Sage Creek Road	43.915089	-102.330368	7/15/2014	7/1/2015	6/2/2016
BADL047586NW	Sage Creek Bridge	047586	Sage Creek Road	43.910648	-102.413773	7/15/2014	7/1/2015	6/2/2016
BADL047586SE	Pond East End Roberts	047586	Sage Creek Road	43.907616	-102.299492	7/15/2014	7/1/2015	6/3/2016
BADL047586SW	Sage Creek Campground	047586	Sage Creek Road	43.900238	-102.410149	7/15/2014	7/1/2015	6/2/2016
BADL075712NE	Junction Conata Basin Road	075712	Conata Basin Rd	43.8428535	-102.2031326	8/20/2014	8/12/2015	8/4/2016
BADL075712NW	Ancient Hunters Overlook	075712	Conata Basin Rd	43.8659096	-102.2279816	8/20/2014	8/12/2015	8/4/2016
BADL075712SE	Dry Stock Pond	075712	Conata Basin Rd	43.8140488	-102.1951675	8/20/2014	8/12/2015	8/4/2016
BADL075712SW	National Grassland Wetland	075712	Conata Basin Rd	43.775	-102.2808333	8/20/2014	–	8/4/2016
JECA034530NE	Highway Shoulder	034530	Jewel Cave	43.738099	-103.819823	–	7/28/2015	7/26/2016
JECA034530NW	Hells Canyon	034530	Jewel Cave	43.73767	-103.845003	7/22/2014	7/28/2015	–
JECA034530SE	Lithograph Canyon	034530	Jewel Cave	43.733763	-103.817510	7/22/2014	7/28/2015	7/26/2016
JECA034530SW	Sewage Lagoon	034530	Jewel Cave	43.727908	-103.835656	7/22/2014	7/29/2015	7/26/2016
MNRR020258NE	Elk Point WMA	020258	Ponca State Park	42.64170833	-96.70274444	7/28/2014	8/18/2015	6/16/2016
MNRR020258NW	Boat Ramp	020258	Ponca State Park	42.65991944	-96.7469177	7/28/2014	8/18/2015	6/16/2016
MNRR020258SE	Park Wetland & Buildings	020258	Ponca State Park	42.59454	-96.711205	7/30/2014	8/18/2015	6/16/2016
MNRR020258SW	Watertower	020258	Ponca State Park	42.60305833	-96.72771389	7/28/2014	8/18/2015	6/16/2016

Station ID	Station Descriptive Name	NABat GRTS ID	NABat Descriptive Cell Name	Latitude	Longitude	2014 Deploy-ment Date	2015 Deploy-ment Date	2016 Deploy-ment Date
MNRR029794NE	Mormon Monument	029794	Lower Niobrara River	42.744045	-98.062874	7/29/2014	8/18/2015	6/13/2016
MNRR029794NW	Ponca Headquarters	029794	Lower Niobrara River	42.714199	-98.076385	7/29/2014	8/18/2015	6/13/2016
MNRR029794SE	Hay Field	029794	Lower Niobrara River	42.689915	-98.038261	7/29/2014	8/18/2015	6/13/2016
MNRR029794SW	Bohemia WMA	029794	Lower Niobrara River	42.682381	-98.1238556	–	8/18/2015	6/16/2016
MNRR031522NE	Burbank Lake	031522	Burbank, SD	42.723888	-96.804375	7/28/2014	8/18/2015	6/21/2016
MNRR031522NW	Missouri River Bank	031522	Burbank, SD	42.73153333	-96.8693	7/28/2014	8/18/2015	6/21/2016
MNRR031522SE	State WMA Beach Access	031522	Burbank, SD	42.66947222	-96.7872	7/28/2014	8/18/2015	6/21/2016
MNRR031522SW	Private Ranch	031522	Burbank, SD	42.696208	-96.886935	7/28/2014	8/18/2015	–
MNRR060194NE	Mulberry Point North	060194	Vermillion Bridge	42.7160187	-96.9543991	–	7/1/2015	8/8/2016
MNRR060194NW	DOD Land by River	060194	Vermillion Bridge	42.7559586	-96.9589386	–	7/1/2015	8/8/2016
MNRR060194SE	Mulberry Point South	060194	Vermillion Bridge	42.7133141	-96.9530868	–	7/1/2015	8/8/2016
MNRR060194SW	Road Ditch	060194	Vermillion Bridge	42.6913556	-97.0000076	–	7/1/2015	8/8/2016
MNRR105833NW	Road in Cropland	105833	Niobrara State Park	42.7952576	-98.1189575	–	7/1/2015	8/9/2016
MNRR105833SE	Niobrara SP Pond	105833	Niobrara State Park	42.7641716	-98.0549316	–	7/1/2015	8/9/2016
MNRR105833SW	Niobrara SP River	105833	Niobrara State Park	42.773632	-98.0739136	–	7/1/2015	–
NIOB080286NE	Bluff Over Niobrara River	080286	Fort Niobrara NWR	42.9070396	-100.3956299	–	7/27/2015	6/29/2016
NIOB080286NW	Rolling Hills	080286	Fort Niobrara NWR	42.8732948	-100.5496368	–	7/27/2015	6/29/2016
NIOB080286SE	Stock Tank	080286	Fort Niobrara NWR	42.8887443	-100.4078827	–	7/27/2015	6/29/2016
NIOB080286SW	Headquarters Ponds	080286	Fort Niobrara NWR	42.8953896	-100.4676361	–	7/27/2015	6/29/2016
NIOB097012NE	Rocky Ford Rapids	097012	Rocky Ford	42.8315582	-100.1547394	–	7/28/2015	7/6/2016
NIOB097012NW	Niobrara River Upstream	097012	Rocky Ford	42.8351517	-100.1771545	–	7/28/2015	7/6/2016

Station ID	Station Descriptive Name	NABat GRTS ID	NABat Descriptive Cell Name	Latitude	Longitude	2014 Deploy-ment Date	2015 Deploy-ment Date	2016 Deploy-ment Date
NIOB097012SE	Niobrara River Middle	097012	Rocky Ford	42.8062286	-100.1206283	–	7/28/2015	7/6/2016
NIOB097012SW	Niobrara River Downstream	097012	Rocky Ford	42.8281174	-100.1598892	–	7/28/2015	7/6/2016
THRO061141NE	Talkington Canyon	061141	E. of Missouri R.	46.9380379	-103.3821487	8/12/2014	7/13/2015	7/11/2016
THRO061141NW	Peaceful Valley Corral	061141	E. of Missouri R.	46.9576073	-103.501091	8/12/2014	7/13/2015	7/11/2016
THRO061141SE	Open Prairie Next to PD Town	061141	E. of Missouri R.	46.911125	-103.427032	7/13/2015	8/11/2015	7/11/2016
THRO061141SW	Dry Stream	061141	E. of Missouri R.	46.912037	-103.4406889	8/12/2014	–	7/11/2016
THRO121832NE	Remote Horse Corral	121832	W. of Missouri R.	47.006977	-103.507011	8/13/2014	7/14/2015	7/18/2016
THRO121832NW	West Fence Boundary	121832	W. of Missouri R.	46.9989281	-103.6037216	7/14/2014	8/12/2015	7/18/2016
THRO121832SE	Lone Tree in Floodplain	121832	W. of Missouri R.	46.96138	-103.50425	8/13/2014	7/13/2015	7/18/2016
THRO121832SW	Open Prairie	121832	W. of Missouri R.	46.9955597	-103.6005783	8/12/2014	7/14/2015	7/18/2016
WICA033842NE	Bison Corrals	033842	Wind Cave	43.62743333	-103.4370583	7/21/2014	7/14/2015	7/27/2016
WICA033842NW	Highway 87 Bridge	033842	Wind Cave	43.58392778	-103.4888306	7/21/2014	7/14/2015	7/27/2016
WICA033842SE	New Property Farmstead	033842	Wind Cave	43.55043333	-103.4114528	7/21/2014	–	7/27/2016
WICA033842SW	Sewage Lagoon	033842	Wind Cave	43.55613611	-103.4605472	7/21/2014	7/14/2015	7/27/2016

Table 22. Non-NABat stationary points metadata and deployment date 2014-15.

Station ID	Station Descriptive Name	Latitude	Longitude	Date Deployed 2014	Date Deployed 2015	Date Deployed 2016
AGFO01	Hoffman House	42.419432	-103.741283	–	6/1/2015	–
AGFO02	Guest Housing by River	42.428425	-103.728973	–	6/1/2015	–
AGFO03	Niobrara River by Old Snag	42.417161	-103.75811	–	6/1/2015	–
AGFO04	Prairie South of Hoffman House	42.415186	-103.737037	–	6/1/2015	–
AGFO05	Niobrara River South Side	42.417317	-103.755798	–	6/1/2015	–
AGFO06	Niobrara River North Side	42.422419	-103.780197	–	6/1/2015	–
AGFO07	North Boundary	42.425942	-103.757347	–	6/1/2015	–
AGFO08	Fisherman's Access	42.420556	-103.755684	–	6/1/2015	–
AGFO09	North Boundary II	42.425878	-103.772957	–	6/1/2015	–
AGFO10	Road	42.422119	-103.772919	–	6/1/2015	–
AGFO11	Road Junction to Hoffman House	42.424144	-103.747323	–	6/1/2015	–
AGFO12	Road Junction to Guest Housing	42.431175	-103.731148	–	6/1/2015	–
AGFO13	Cottonwood Grove East	42.415703	-103.769257	–	6/3/2015	–
AGFO14	Cottonwood Grove West	42.415856	-103.773064	–	6/3/2015	–
AGFO15	North Boundary Stock Tank	42.4260864	-103.765686	–	9/14/2015	–
AGFO16	Prairie N. of Road	42.4259376	-103.7431412	–	9/14/2015	–
AGFO17	Road to Visitor Center	42.4278869	-103.7347946	–	9/14/2015	–
AGFO18	North Side of Niobrara R.	42.4230576	-103.7448959	–	9/14/2015	–
AGFO19	South Side of Niobrara R.	42.4199791	-103.7455597	–	9/14/2015	–
AGFO20	Hoffman House II	42.4188919	-103.7418671	–	9/14/2015	–
AGFO21	South Boundary Prairie	42.408596	-103.7294006	–	9/14/2015	–

Station ID	Station Descriptive Name	Latitude	Longitude	Date Deployed 2014	Date Deployed 2015	Date Deployed 2016
AGFO22	Cottonwood Grove	42.6807174	-103.4113388	–	9/14/2015	–
AGFO23	Visitor Center	42.4254341	-103.7341079	–	9/14/2015	–
AGFO24	Hiking Parking Lot	42.4228592	-103.7908859	–	9/14/2015	–
AGFO25	West Boundary Trees	42.4229965	-103.7909088	–	9/14/2015	–
AGFO26	Oxbow on North Side of Niobrara R.	42.4261894	-103.7654266	–	9/14/2015	–
AGFO27	SE of Fishermen's Parking Lot	42.420606	-103.754120	–	–	6/7/2016
AGFO29	Wetland E of Daemonelix Parking	42.424736	-103.786331	–	–	6/7/2016
AGFO30	Outcropping N of Highway	42.422992	-103.769821	–	–	6/7/2016
AGFO31	Prairie South-central of Park	42.414978	-103.761421	–	–	6/7/2016
AGFO32	Prairie N. of Road	42.424367	-103.755386	–	–	6/7/2016
AGFO33	Prairie N. Boundary	42.431806	-103.736816	–	–	6/7/2016
AGFO34	Floodplain S. of Weather Station	42.424178	-103.736084	–	–	6/7/2016
AGFO35	Outcropping N of Highway	42.425208	-103.745163	–	–	6/7/2016
AGF036	Prairie	42.427878	-103.744064	–	–	6/7/2016
AGFO37	Cottonwood Stand River Oxbow	42.415306	-103.769554	–	–	6/7/2016
AGFO38	Headquarters Building	42.425025	-103.734070	–	–	6/7/2016
AGFO39	Agate Springs Ranch Trees	42.421557	-103.792232	–	–	8/8/2016
AGFO40	Trees Along Cropland W. of Highway	42.426072	-103.791151	–	–	8/8/2016
AGFO41	Antenna Station N. of Highway	42.428707	-103.740761	–	–	8/8/2016
AGFO42	Bluff Extreme NW Corner of Park	42.436522	-103.787225	–	–	8/8/2016
AGFO43	Floodplain W. Hoffman House Rd	42.421872	-103.747697	–	–	8/8/2016
AGFO44	North Boundary Stock Tank II	42.426103	-103.765591	–	–	8/8/2016

Station ID	Station Descriptive Name	Latitude	Longitude	Date Deployed 2014	Date Deployed 2015	Date Deployed 2016
FOLA01	Laramie R. West Boundary	42.2041359	-104.5613708	–	6/17/2015	7/30/2016
FOLA02	Bat House	42.1998939	-104.5604629	–	6/17/2015	7/30/2016
FOLA03	North Platte River	42.2094841	-104.5331192	–	6/17/2015	7/30/2016
FOLA04	Lower Laramie River	42.2006073	-104.5340333	–	6/17/2015	7/30/2016
FOLA05	Canal	42.1984825	-104.5385818	–	6/17/2015	7/30/2016
FOLA06	Fort Grounds	42.203598	-104.5586242	–	6/17/2015	7/30/2016
FOLA07	Bat House W. Side of Road	42.200086	-104.560704	–	–	8/9/2016
FOLA08	Old Guardhouse	42.201359	-104.557356	–	–	8/9/2016
FOLA09	Burt House	42.203458	-104.558199	–	–	8/9/2016
FOLA10	Cavalry Barracks	42.204530	-104.556869	–	–	8/13/2016
FOLA11	Visitor Center	42.203486	-104.556163	–	–	8/13/2016
FOLA12	Captain's Quarters	42.201279	-104.558751	–	–	8/13/2016
FOUS01	Fort Structure	47.9989204	-104.0405655	–	7/16/2015	7/12/2016
FOUS02	Floodplain	47.9979134	-104.0435409	–	7/16/2015	7/12/2016
FOUS03	Maintenance Shop	48.0177917	-103.915390	–	7/16/2015	7/12/2016
FOUS04	Large Parking Lot	48.0006485	-104.0446091	–	7/16/2015	7/12/2016
KNRI01	Visitor Center	47.3312721	-101.3849182	–	7/15/2015	7/12/2016
KNRI02	Knife River	47.3583794	-101.3899002	–	7/15/2015	7/12/2016
KNRI03	Missouri River Forest	47.3252907	-101.3772583	–	7/15/2015	7/12/2016
KNRI04	Woodland	47.3612022	-101.3856582	–	7/15/2015	7/12/2016
MNRR01	MNRR020258SE Discontinued	42.590375	-96.702644	7/28/2014	–	–
MNRR02	MNRR029794SW Discontinued	42.692051	-98.083801	7/29/2014	–	–

Station ID	Station Descriptive Name	Latitude	Longitude	Date Deployed 2014	Date Deployed 2015	Date Deployed 2016
MNRR03	MNRR029794SW Discontinued	42.682381	-98.123856	–	8/18/2015	–
MNRR04	Adams Homestead Forest	42.537437	-96.528633	–	8/19/2015	–
MNRR05	Adams Homestead Oxbow	42.539757	-96.531349	–	8/19/2015	–
MNRR06	Adams Homestead River	42.517269	-96.534958	–	8/19/2015	–
MORU01	Stand of Pines East Side	43.885547	-103.439621	–	6/16/2015	7/26/2016
MORU02	Laferty Gulch	43.882736	-103.44844	–	6/16/2015	7/26/2016
MORU03	Water Treatment Plant	43.879967	-103.452186	–	6/16/2015	7/26/2016
MORU04	Parking Garages	43.875214	-103.453392	–	6/16/2015	7/27/2016
MORU05	Presidential Viewing Terrace	43.876831	-103.455925	–	6/16/2015	7/27/2016
MORU06	Forest South of 244	43.872447	-103.45491	–	6/16/2015	7/27/2016
MORU07	Starling Basin Beaver Pond	43.868721	-103.460210	–	6/16/2015	7/27/2016
MORU08	Old Park Road West Side	43.882167	-103.464645	–	6/16/2015	7/26/2016
MORU09	West Entrance by 244	43.885325	-103.467415	–	6/16/2015	7/26/2016
MORU10	Junction 244 and Iron Mt Rd	43.884414	-103.437172	–	6/16/2015	7/26/2016
SCBL01	Headquarters	41.8290634	-103.7077331	–	6/19/2015 7/29/2015	7/31/2026
SCBL02	Canal	41.8446426	-103.694931	–	6/19/2015 7/29/2015	–
SCBL03	Lower N. Platte Riparian	41.8506698	-103.6862488	–	6/19/2015 7/29/2015	7/31/2026
SCBL04	Upper N. Platte Riparian	41.8556137	-103.705101	–	6/19/2015 7/29/2015	7/31/2026
SCBL05	Park Road Bluff	41.8364448	-103.7085953	–	6/19/2015 7/29/2015	7/31/2026
SCBL06	South of Highway	41.830698	-103.715369	–	–	7/31/2026

Station ID	Station Descriptive Name	Latitude	Longitude	Date Deployed 2014	Date Deployed 2015	Date Deployed 2016
THRO01	Sewage Ponds	46.8956489	-102.7840118	–	7/14/2015	7/13/2016
THRO02	Little Missouri River Bluff	47.6063309	-103.2602997	–	7/14/2015	–
THRO03	Little Missouri R. Campground	47.5940094	-103.3411255	–	7/14/2015	7/13/2016
THRO04	Road Through Badlands	47.6107747	-103.3626175	–	7/14/2015	7/13/2016
THRO05	SU Badlands Knoll	46.910178	-103.440819	–	7/13/2015	–
THRO06	Above Beaver Pond	47.599409	-103.338938	–	–	7/13/2016

Table 23. NABat mobile routes and completed surveys 2014-16.

ID	NABat GRTS ID	Descriptive Cell Name	Starting Coordinates	Ending Coordinates	Distance km	2014 Surveys	2015 Surveys	2016 Surveys
BADL029922RD	029922	Cedar Pass	43.835483 -101.899767	43.907952 -102.059335	38.9	7/16/2014 7/17/2014	7/13/2015 7/16/2015	5/8/2016 5/29/2016
BADL047586RD	047586	Sage Creek Road	43.879730 -102.238852	43.778200 -102.537029	41.0	7/2/2014 7/15/2014	6/30/2015 7/1/2015	6/2/2016 6/9/2016
BADL075712RD	075712	Conata Basin Rd	43.801301 -102.059227	43.806326 -102.278521	26.5	8/25/2014 9/3/2014	8/10/2015 9/1/2015	8/4/2016 8/7/2016
JECA034530RD	034530	Jewel Cave	43.693761 -103.786595	43.724780 -103.866041	37.8	Road Construction	7/28/2015 7/30/2015	7/29/2016 7/31/2016
MNRR020258RD	020258	Ponca State Park	42.562507 -96.705600	42.567005 -96.727027	31.1	7/30/2014 7/31/2014	Surveys Deviated from Route	6/7/2016 6/8/2016
MNRR029794RD	029794	Lower Niobrara River	42.654524 -98.129475	42.684086 -98.012837	38.0	7/27/2014 8/1/2014	8/25/2015	6/9/2016 Road Flooded
MNRR031522RD	031522	Burbank, SD	42.655424 -96.820581	42.716173 -96.952421	23.9	7/28/2014 7/29/2014	8/17/2015 8/26/2015	6/15/2016 6/16/2016
MNRR060194RD	060194	Vermillion Bridge	42.741805 -97.015499	42.775437 -96.931320	28.4	–	6/30/2015 7/8/2015	6/17/2016 6/21/2016
MNRR105833RD	105833	Niobrara State Park	42.815204 -98.079492	42.795367 -98.119286	31.7	–	7/1/2015 7/7/2015	6/22/2016 6/23/2016
NIOB080286RD	080286	Niobrara NWR	42.892699 -100.479101	42.899776 -100.486511	29.3	–	7/27/2015 7/28/2015	7/4/2016 7/5/2016
NIOB097012RD	097012	Rocky Ford	42.868498 -100.074128	42.896432 -100.178403	32.0	–	8/3/2015 8/4/2015	7/7/2016 7/13/2016
THRO061141RD	061141	E. of Missouri River	46.958902 -103.504252	46.914717 -103.527829	45.3	8/11/2014 8/14/2014	7/13/2015 7/14/2015	7/11/2016 7/12/2016
THRO121832RD	121832	W. of Missouri River	47.046373 -103.558221	46.929984 -103.575757	28.7	8/12/2014 8/13/2014	7/20/2015 7/21/2015	7/18/2016 7/19/2016
WICA033842RD	033842	Wind Cave	43.525826 -103.381886	43.629394 -103.370775	47.4	7/23/2014 7/24/2014	7/20/2015 7/22/2015	7/14/2016 7/27/2016

Appendix II. Methods for Deployment and Retrieval of Stationary Monitoring Units

Consistent configuration and deployment of monitoring units is critical as it reduces bias and confounding variables in analysis. Furthermore, a consistent system aids quality control of the data. The following methods were used in this study and are recommended for future surveys. Although some of the steps are redundant in that they are done both at deployment and retrieval following such guidance has proven valuable in quality control of the data and resolving discrepancies.

Steps at Deployment

1. Put batteries into the SM3Bat units. (Unless they are new alkaline batteries use a tester to confirm the charge status. This is especially important for NiMH batteries; even batteries that come off the charger might not be fully charged). The type of batteries used and the charge status should be recorded (see bullet #11 for one way to document batteries used). Fully charged batteries should last about 10 days.

2. Put empty memory cards into the A and B slots (recommend 32 gb Kingston cards).

3. Connect a microphone cable to the recorder (recommend connecting to the top-most port of the recorder: see **Figure 3**).

4. Fully extend the legs of the tripod and fully extend the center pole so that the microphone is about 2.5 m above the ground (see **Figure 4**). The leg angles should be in the middle position which is a good balance between maximum height and stability.

5. Affix the microphone to the top of the pole so that it is horizontal and pointing north (see **Figure 4**). Note that north might not be pointing toward preferred bat habitat (e.g., a pond), nevertheless it's important to be consistent and the microphones are mostly omni-directional and should therefore still capture bat activity to the side and read of the microphone direction. Use electric tape or other tape to affix the microphone to the top of the pole.

6. Push the hard switch to the <u>On</u> position (the switch is underneath the memory-card cover).

7. Configure the unit. Most configurations (e.g., dB trigger levels: see **Table 1** for the entire list) should be imported into all units prior to the field season so only the following need to be updated for field deployments:

    a. Under SETTINGS-LOCATION-PREFIX enter the station ID, e.g., BADL029922NE

    b. Enter the LATITUDE (in decimal format). (The unit uses the location information along with the date and UTC to determine sunrise and sunset.)

    c. Enter the LONGITUDE (in decimal format).

    d. Check the TIMEZONE UTC and adjust if necessary (you need to scroll down to see this setting). Should be -6:00 for Mountain Time zone sites and -5:00 for Central Time zone sites. (In the Network FOUS, KNRI, MNRR and the North Unit of THRO are in the Central Time zone; all others are Mountain Time.)

  e. Under SETTINGS-LOCATION-TIME AND DATE check the time. Make sure the time is correct for time zone the unit is being deployed in.

8. Create and save to a memory card two metadata files for the deployment (these files can facilitate troubleshooting.)

   a. Select the PROGRAM-EXPORT PROGRAM option to save the current software configuration (you will need to scroll down to see this option).

   b. Select the UTILITIES-EXPORT DIAGNOSTICS option to save the current hardware information (this will take a few seconds).

9. Push the **Program Start** button. Unit should say "*Starting*" and then "*Going to sleep until* …" and then the LCD display will turn off.

10. The recorder can be laid on the ground or tied to the base of the tripod. The latter is preferred as it makes the assembly more stable and less prone to being blown over in a strong wind. If the microphone cable is loose snug it to the pole with tape to keep it from flapping in a breeze.

11. Take photographs. Make sure the camera has GPS enabled and the time is accurate (FOUS and the North Unit of THRO are right next to the time zone boundary so smartphone times might need to be manually corrected). Take at least the following photos:

    a. A photo of the serial number label on side of SM3 unit.

    b. A photo of the microphone serial number.

    c. A photo of the LCD display after pushing the **Check Status** button (i.e., the display that shows the date in the upper-left corner, the time in upper right corner, the serial number, firmware, and status of the 4 memory card slots). The photo should also include a handwritten note with the station ID number and the type and status of batteries used (**Figure 8**).

    d. At least two photos of the deployed unit and surrounding habitat, taken from about 10 yards away (see **Figure 4**).

12. These steps usually insure accurate and complete collection of metadata; however, the more information the better. Recording deployment information on datasheets is also recommended.

Steps at Retrieval

1. Push the **Check Status** button. The display should show the date in the upper-left corner, the time in upper right corner, the serial number, firmware, and status of the 4 memory card slots. Take a picture (the display will only stay on for a few seconds so have the camera ready). Make

sure the camera GPS is enabled and working. Even if the LCD is not working take a picture as this documents the non-working status.

2. Take pictures of the unit serial number, the microphone serial number, the LCD display, and two landscape shots (i.e., the same set of photos taken at deployment). Take a photo of the LCD with the recorder showing status information (e.g., amount of data on memory cards); if LCD not working still take a photo as that can be used to assess the data. Taking a second set of photos at retrieval helps in resolving discrepancies and provides redundancy should the step be omitted at deployment. If there is anything unusual (e.g., the unit knocked over or microphone out of position) take photos.

3. Push the **Program Stop** button.

4. Select the UTILITIES-EXPORT DIAGNOSTICS option to save the current operating information (this will take a few seconds).

5. Select the PROGRAM-EXPORT PROGRAM option to save the current software configuration (you will need to scroll down to see this option).

6. Keep the batteries in the unit and return to the office for processing. If batteries are removed from the unit in the field make note of their charge status.

Appendix III. Methods for Conducting Road Surveys

Standardized monitoring is critical as it reduces the number of confounding variables. Furthermore, a good system can better ensure accurate data collection. The following methods were used for road surveys in this study and are recommended for future surveys.

1. Know your route. Ideally a test drive should be done during daylight hours. Have a good map and/or a navigation (i.e., car) GPS with the survey route entered and configured for turn-by-turn directions.

2. Make sure you are at the Start position of the route as all routes must be run in the same direction.

3. Insert fully charged batteries into the EM3+ unit.

4. Insert a memory card (as of this report no road survey used > 1.1 gb of space).

5. Plug a microphone cable into the microphone port and plug a GPS cable into the Ethernet port.

6. Run the microphone and GPS cables through a vehicle window. Affix the microphone and GPS on the roof of the vehicle, ideally in the front center. The microphone should have a horn affix to it and the entire assembly should be pointing straight up (see **Figure 5** and **Figure 6**).

7. Push the **Power** button to turn the unit on. The LCD display should turn on.

8. Push the **X/Y** button to enter the menu settings. Most configuration settings should be set prior to the field season (e.g., trigger kHz and dB: see **Table 1**). Settings that will need to be set for each road survey are:

   a. PREFIX. Entire the name of the route, e.g., BADL029922RD (RD stands for "road")

   b. TIME. Set the local time (be aware of time zone differences). If the unit has not had batteries in it you may need to also set the date.

   c. UTC. Should be -6:00 for MT zone sites and -5:00 for CT sites.

9. Ensure that GPS coordinates are being collected (they will show at bottom of LCD display; if a question mark is shown then GPS coordinates are not being collected: if you are in a new region it might take a minute or so for the GPS to acquire satellites).

10. Test the unit with an ultrasonic calibrator by turning on the calibrator and placing it in the direction the microphone horn is pointing. You should see the signals on the LCD display and hear the audio.

11. There are numerous settings for the LCD display such as adjusting the kHz scale (see the user manual). These are for the user's preference and have no bearing on the recordings. Set as you like.

12. At 30 minutes after sunset start the survey. Press the orange **Record** button and start driving at 20 mph. At the top of the LCD you should see the word "*Wait*" unless a bat is being detected in which case it will say "*Recording*".

13. Record the time when the survey ends. You can do this in writing or you can disconnect the microphone and while holding any of the letter buttons A-D speak into the EM3+ recorder (this will save an audio file of your voice).

14. Document any other noteworthy information, such as interesting bat behaviors, suspect recordings, missed bats (i.e., bats seen flying, but not detected by the recorder), etc.. You can record weather information or that can be collected later from the nearest available station.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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