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Natural Resource Stewardship and Science

Acoustic Bat Surveys at Tallgrass Prairie National Preserve, 2014-15

Natural Resource Report NPS/TAPR/NRR—2016/1350

ON THE COVER
Photograph of Tallgrass Prairie National Preserve (NPS Photo).

Acoustic Bat Surveys at Tallgrass Prairie National Preserve, 2014-15

Natural Resource Report NPS/TAPR/NRR—2016/1350

Daniel S. Licht
National Park Service
231 East Saint Joseph Street
Rapid City, South Dakota 57701

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Abstract

Bats have recently become a taxon of elevated conservation concern in part because of the non-native disease white-nose syndrome (WNS). WNS was first detected in 2006 in hibernating bats in a cave in New York State and has since killed an estimated 6-7 million individuals. The disease and the causal fungus are now known to be present in several Midwestern states. As a result, the National Park Service has committed resources to better understand the status of bats in the region.

Tallgrass Prairie National Preserve is a 10,894-acre park located in the tallgrass biome of east-central Kansas. Park personnel used field-deployed automated equipment to record the echolocation calls of bats in September 2014 and in July-October 2015. A total of 49,028 recordings, of which 90% had detectable bat pulses, were collected from 13 monitoring stations over 360 survey-nights.

Automated software analysis of the recordings indicates that the big brown, eastern red, hoary, silver, tri-colored, and Mexican (Brazilian) free-tailed bats were present in the park, and the evening and little brown bats were likely present. I used the software to look for evidence of the endangered Indiana and gray bats and the threatened northern long-eared myotis, even though the park is outside the known range of the former two species. There was negligible evidence of the Indiana bat and the northern long-eared myotis. The latter was reported from a 2004 acoustic survey; however, the sample size was apparently small and acoustic surveys are problematic for definitive species identification. Surprisingly, the software indicated the gray bat was present. Vetting of the suspect calls by an expert was inconclusive. Mist-netting is needed for confirmation. The software assigned about ½ of the recordings to the eastern red bat suggesting it's the most abundant species in the park.

The average number of bat detections per night was 122 (using Kaleidoscope software); however, there were substantial differences between sites. The highest rate of bat activity was recorded at a large stock pond in the prairie (311 detections per night) followed by a site in the Fox Creek riparian forest and a site at the park headquarters (about 230 detections per night for each). Bat activity showed a modest peak in the 1-2 hours after sundown; however, night-time activity patterns varied by monitoring station. The stock pond mentioned above showed a dramatic peak in activity in the 1-2 hours following sundown whereas the forested Fox Creek riparian and headquarter sites had the major peak in the few hours before sunup. This could be due to the former being used for drinking and foraging whereas the latter two sites were used more for social behavior and daytime roosting.

Bat activity was highest in July to mid-August with substantially fewer recordings from mid-August to early October. It's possible the July to early August recordings included volant young that dispersed by late summer. All 10 stations monitored in September of both 2014 and 2015 showed fewer detections in 2015. The decline was statistically significant. It appeared to be driven by a decrease in the eastern red and evening bats, the most commonly detected species. Those species are not known to be vulnerable to WNS so the reason for the decline is not easily explained.

The bat community at the park appears healthy, although the decline from September 2014 to 2015 is cause for concern. The surveys reported here should be replicated in future years to monitor changes over time. Old trees and surface water in the park should be conserved for the benefit of bats.

Acknowledgments

Hardware for the study was loaned to the park by the Northern Great Plains Inventory & Monitoring Program in Rapid City, South Dakota. Patrick Moore donated his time to manually vet some suspect recordings. His assistance is greatly appreciated. Michelle Verant, Tabitha Gulley, and Kristen Hase reviewed this report; however, the content, results, conclusions are the responsibility of the author.

Introduction

The conservation of bats is a high priority within the National Park Service (NPS). North American bat populations appear to be in decline, probably due to a myriad of reasons including habitat loss, pesticides, exotic species, and other factors (see Loeb et al. 2015). However, a new and perhaps more serious threat is the recent occurrence of the disease white-nose syndrome (WNS: U. S. Fish and Wildlife Service 2016). The disease was first detected in North America in the winter of 2006 when dead bats where observed in a cave near Albany, New York. The deceased bats had a whitish powdery substance on their nose; it was ultimately determined that the disease is caused by the non-native fungus *Pseudogymnoascus destructans*, which likely came from Europe. The disease has since killed an estimated 6-7 million bats in North America and has spread throughout much of the eastern half of the continent. As a result, the NPS is taking conservation measures including protecting cave habitats, educating the public about WNS, promoting the ecological value of bats, and monitoring bat populations (National Park Service 2016). The agency has made funds available to parks for monitoring bat populations.

Tallgrass Prairie National Preserve (TAPR) lies in Chase County in east-central Kansas (**Figure 1**), just north of the towns of Cottonwood Falls and Strong City. The site is within the Flint Hills tallgrass physiographic region. Historically, the site was used for cattle ranching. On November 12, 1996, the 10,894-acre park was established, to be managed in partnership with The Nature Conservancy. Bison (*Bison bison*) were subsequently reintroduced to a portion of the park. The park periodically conducts prescribed burns to maintain the health of the tallgrass prairie. A scattering of anthropogenic ponds exist on the site, a relic of the ranching history. Trees are found along Fox and Palmer Creek, but are otherwise mostly absent.

Figure 1. Location of Tallgrass Prairie National Preserve.

The bat community at the park is poorly studied. In the summer of 2004, Robbins (2005) used mist nets and acoustic monitoring equipment to survey the population. He captured one species and found acoustic evidence of the presence of three others. However, Sparks and Choate (2000) concluded that eight species were present in the county in which the park is located.

Acoustic monitoring for bats consists of using sophisticated equipment to record the ultrasonic calls that bats emit when echo-locating (Loeb et al. 2015). The calls can often be assigned to species, either manually or by software using multi-parameter algorithms. In the fall of 2014 and in the summer-fall of 2015 the park deployed recording devices in the field. This report describes that effort, presents results, and provides management recommendations.

Methods

Bats were monitored at the park using acoustic monitoring methods (see Brigham et al. 2004, Loeb et al. 2015). Acoustic monitoring consists of using field-deployed hardware to automatically detect and record a bat's ultrasonic echolocation calls as the animal passes in the vicinity of the recorder (generally within 30-50 yards). The recordings are subsequently downloaded to a computer where they can be auto-analyzed by software or manually by people looking at a spectrogram of the calls (**Figure 2**). Software packages use complex proprietary algorithms to estimate what species made the calls; however, many species have similar calls, individual bats can vary calls, and call quality varies, so misidentifications do occur. Nevertheless, the method is widely used to survey bats and is the basis for the incipient North American Bat Monitoring Program (NABat: Loeb et al. 2015).

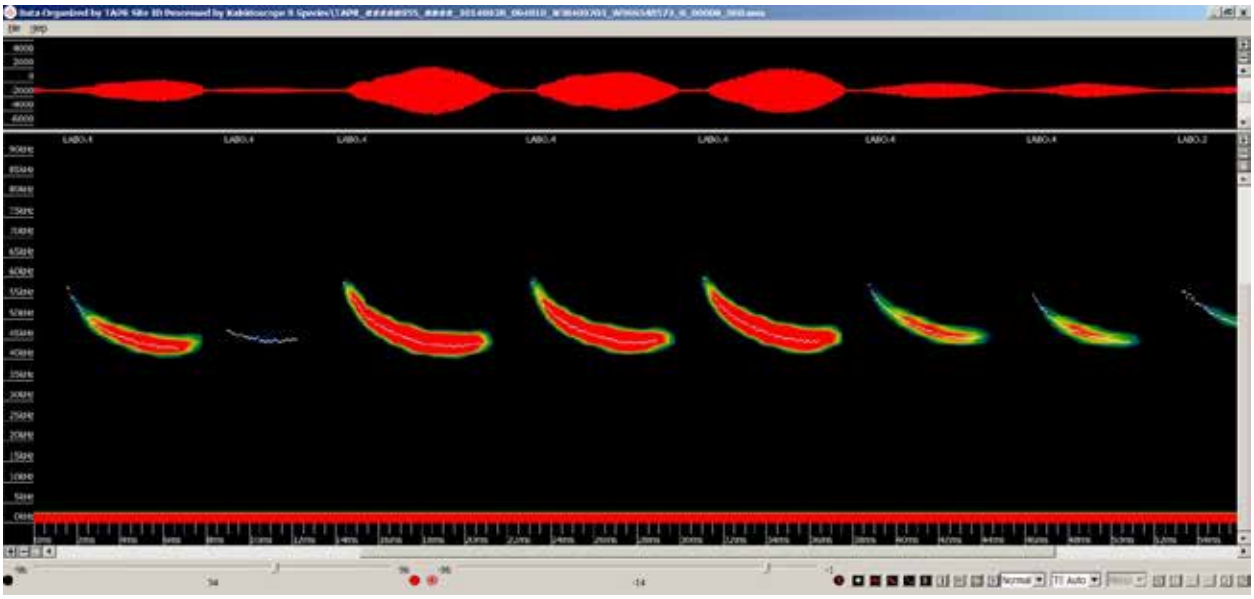

Figure 2. A spectrogram of a series (i.e., a pass) of eastern red bat calls.

Four Wildlife Acoustics SM3Bat recorders and four Wildlife Acoustics SM3-U1 ultrasonic microphones were loaned to the Tallgrass Prairie National Preserve each year.[1] The equipment was the property of the NPS Northern Great Plains Inventory & Monitoring Program in Rapid City, SD. Prior to sending the equipment to the park I programmed the units. For example, the recorders were programmed to turn on (i.e., wake up) 15 minutes before sundown and to turn off 15 minutes after sunrise. Other settings were generally the default settings for the recorders. A complete list of hardware configuration settings can be found in **Appendix I**.

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

Under the direction of Kristen Hase, the park Chief of Resources, park staff deployed, maintained, and retrieved the units in 2014-15 (see **Appendix II** and **IV** for locations and dates). They established 13 acoustic monitoring stations in the park; however, data was only collected from 12 sites (**Figure**, **Figure 4**). Deployment sites were selected based on their likelihood to have bats present, the park's desire to understand bat use at the site, accessibility, and other non-random considerations. Six of the sites had surface water within 50 yards of the deployment station and nine had large woody vegetation nearby (**Appendix II**). Due in part to the small size of the park use of the 10x10 km^2 NABat sampling grid/design was not considered; however, the collected data might still have corroborating value to that program (Loeb et al. 2015).

Figure 3. Deploying a bat recorder at Site 045.

The recorder units were deployed on or near the ground with the connected microphone placed several feet above the ground, typically attached to a fencepost or other structure (**Figure 3**). The microphones were omni-directional so orientation was inconsequential other than microphones were deployed horizontally or facing slightly downward to reduce the likelihood of rainfall damaging the units.

At the conclusion of the study the park returned the recorders and data to the Northern Great Plains I&M Program in Rapid City, South Dakota. The acoustic data (i.e., the "wav" files) were transferred to and stored on the I&M Program server in Rapid City, under the direction of the author. They are available for use by other researchers.

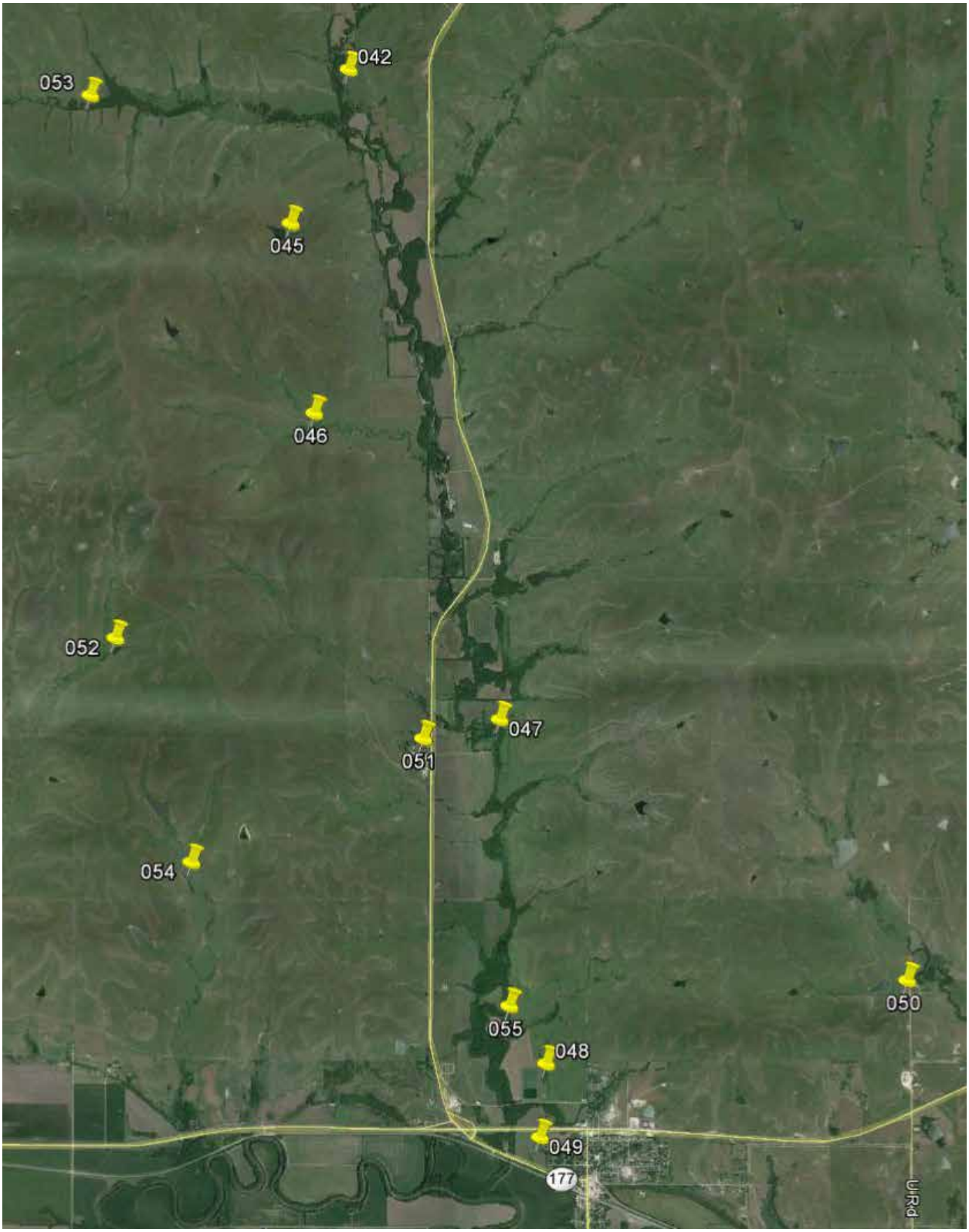

Figure 4. Location of bat survey stations.

For purposes of analyzing the park's bat recordings I evaluated four software packages; **BCID** version 2.7d by Bat Call Identification, Echoclass 3.1 by Eric Britzke, **Kaleidoscope** 3.1.7 by Wildlife Acoustics, and **Sonobat** 4.1.0 by Sonobat. As part of my evaluation I ran 85 known-species recordings (all species found in the Midwest) through the programs. BCID and Echoclass can only process zero-cross files so I used Kaleidoscope to convert the full spectrum wav files to the zero-cross format for runs through those two packages. I evaluated the configuration settings for the packages, but ultimately used the default values for each package (**Appendix III**). For BCID and Kaleidoscope I customized the list of species the software should discriminate among to the nine species in my testing catalog. The Sonobat Midwest package also matched those nine species. However, Echoclass did not have a predefined filter set that matched the nine species so I used Species Set 1; that set included filters for the nine species in my testing catalog as well as filters for the gray bat, eastern small footed myotis (*Myotis leibii*), and southeastern myotis (*Myotis austroriparius*). I compared the species outputs from the four packages to the actual composition of the catalog. Sonobat provides several types of output based on varying criteria, such as a "consensus" and "corrected" counts. These outputs tend to be more conservative than the other software packages making side-by-side comparisons problematic. Therefore, for Sonobat I used the classification in the more liberal "1st" column in the output as this resulted in a classification rate comparable to the other software. Also, Sonobat 4 classifies some passes as "LUSO", a hybrid classification saying it could be either the little brown bat or Indiana bat: for my analysis I treated those as unclassified. In my analysis Sonobat differed on average from the number of known species recordings by 11%, Kaleidoscope by 14%, BCID by 38%, and Echoclass by 45%, when weighted by the species sample size (**Figure 5**). However, it is important to note that some of my known-species recordings might have been used to "train" the software, specifically, Kaleidoscope and Sonobat, so the results could be biased in favor of those two packages and therefore should not be construed as a definitive measure of superiority, real world accuracy, or endorsement. Although Echoclass had three more species to choose from in its filter set it did not inaccurately assign recordings to those three species.

A critical pre-processing decision in the use of software auto-identification is to determine what bat species to include, i.e., to ask the software to consider. A large species list can increase the rate of misidentifications whereas a small list might exclude species that are actually present in the dataset. I reviewed several sources of information to develop a list of bat species that could be at the park. BCID and Kaleidoscope both included default lists for Kansas (**Table 1**), although the programs recommend customizing the lists when appropriate. Sparks and Choate (2000) conducted a review of bats in Kansas: they suggested that eight species might occur in Chase County, the jurisdiction the park lies within (**Table 1**). The National Park Service NPSpecies database listed six species as being *Present* or *Probably Present* within the park and another three as *Unconfirmed* (**Table 1**). Those conclusions were apparently based in part on a summer 2004 inventory at the park by Robbins (2005) who conducted mist-netting and acoustic surveys (**Table 1 1**). The USGS Gap program uses a combination of known species range and habitat associations to model species distribution: it predicted that eight species should occur within the park (**Table 1**). I ultimately filtered for eight species in most of my analyses of the park data (**Table 1**). However, three species excluded from my base list are species of management concern, i.e., the federally-listed endangered gray and Indiana

bats and the threatened northern long-eared myotis (see **Table 1** for species names). Therefore, I also conducted runs that included those species for evidence of their presence at the park.

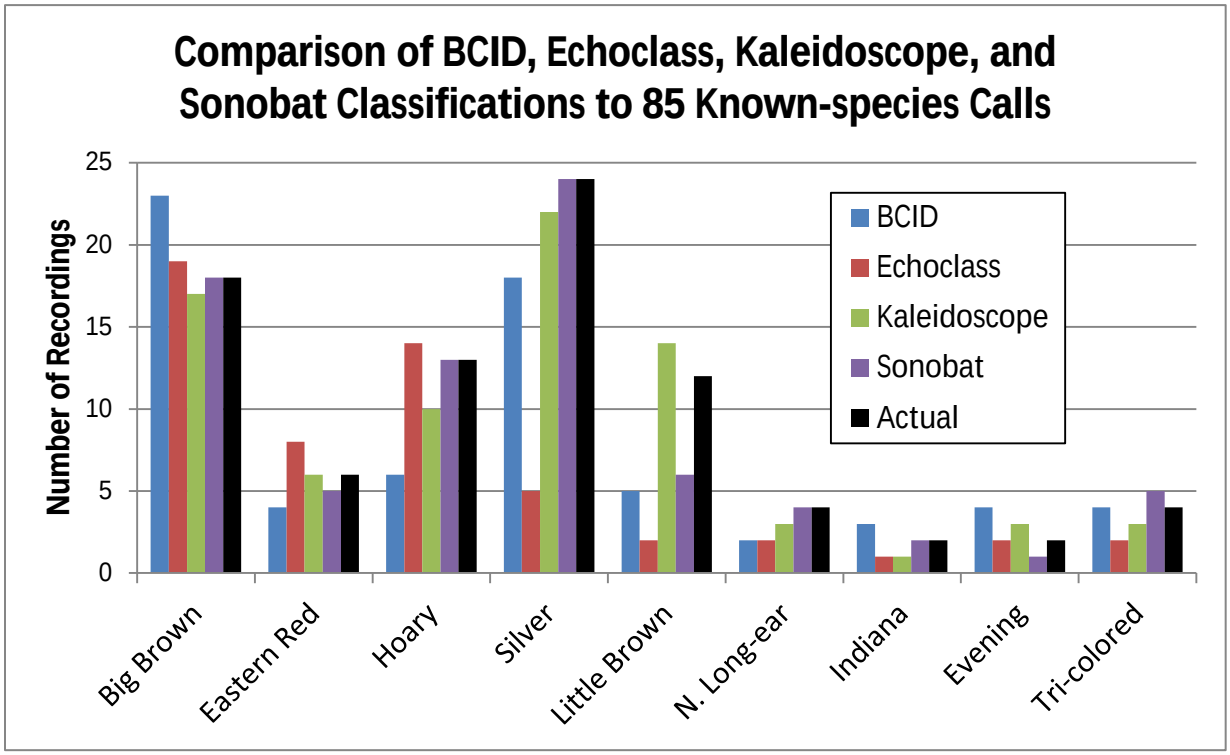

Figure 5. Comparison of four software packages to 85 known-species recordings.

My decision to filter for eight species (**Table 1**) predisposed me to use Kaleidoscope as my primary software as only that package allowed me to customize for those eight species. However, I also ran the park data through the other software packages so readers can better understand the variability in the results or can view output from software they are most comfortable with. Ultimately, the choice of software to use, the settings configured for the software, and how to interpret the output should be dictated in large part by objectives (e.g., confirming a rare species). I did not systematically conduct manual vetting of the recordings due to the lack of resources and time. However, I did recruit a gray bat expert to vet recordings the software assigned to that species.

I considered, but generally did not run, statistical tests in part because the study design was not appropriate for most tests. For example, there were inadequate replicates for a robust statistical analysis of habitat use (Fischer et al. 2009). Nevertheless, the descriptive statistics, summaries, and graphic output should suffice to give management a good sense of bat diversity, habitat use, and temporal activity at the park. I did test for differences in overall bat activity between 2014 and 2015. Because there were seasonal differences in activity (based on the 2015 data) and between sites I use only the September nightly averages for the 10 sites that were monitored in September of both years. The nightly counts were not normally distributed nor were the variances equal, so I used the non-parametric Wilcoxon Signed Rank Test to test for significant differences between years.

Table 1. Bat species considered for auto-identification analysis.

Common Name	Scientific Name	4-Digit Code	Kaleid-oscope	BCID	Sparks and Choate	NPS NPSpecies	Robins	USGS Gap	Used to Compare Software	Used in Primary Analyses
Big Brown Bat	Eptesicus fuscus	EPFU	Yes	Yes	Most of state	Present	Acoustic	All Habitat	ü	ü
Big Free-tailed Bat	Nyctimnomops macrotis	NYMA		Rare	Extreme southwest			Not in county list		
Cave Myotis	Myotis velifer	MYVE		Rare	South central area			Not in county list		
Eastern Red Bat	Lasiurus borealis	LABO	Yes	Yes	Anywhere, especially in east	Present	Acoustic detection and mist net	Riparian	ü	ü
Evening Bat	Nycticeius humeralis	NYHU	Yes	Yes	Eastern 2/3rds	Unconfirmed	Questionable	Riparian	ü	ü
Gray Bat	Myotis grisescens	MYGR		Rare	Rare in extreme southeast			Not in county list		
Hoary Bat	Lasiurus cinereus	LACI	Yes	Yes	Statewide	Probably Present	Expected	All Habitat	ü	ü
Indiana Bat	Myotis sodalis	MYSO	Yes		No records			Outside of Distribution	ü	
Little Brown Bat	Myotis lucifugus	MYLU	Yes	Yes	In eastern third	Unconfirmed	Questionable	Riparian	ü	ü
Mexican Free-tailed Bat[1]	Tadarida brasiliensis	TABR	Yes	Rare[2]	Scattered throughout state	Probably present	Expected	All Habitat		ü
Northern long-eared Myotis	Myotis septentrionalis	MYSE		Yes	Rare but may be in east 2/3rds	Present	Acoustic detection	Not in county list	ü	

[1] Also known as the Brazilian free-tailed bat

[2] The software lists the Mexican free-tailed bat for Nebraska, but does not include a filter for the species.

[3] Formerly called eastern pipistrelle (*Pipistrellus subflavus*)

Table 1 (continued). Bat species considered for auto-identification analysis.

Common Name	Scientific Name	4-Digit Code	Kaleid-oscope	BCID	Sparks and Choate	NPS NPSpecies	Robins	USGS Gap	Used to Compare Software	Used in Primary Analyses
Pallid Bat	Antrozous pallidus	ANPA		Rare	Few records in south-center of state			Not in county list		
Silver-haired Bat	Lasionycteris noctivagans	LANO	Yes	Yes	Scattered; common in migration	Unconfirmed	Expected	Riparian	ü	ü
Townsend's big-eared Bat	Corynorhinus townsendii	COTO		Rare	Three counties in south-center of state			Not in county list		
Tri-colored Bat[3]	Perimyotis subflavus	PESU	Yes	Yes	Eastern 2/3rds	Present	Acoustic detection	Riparian	ü	ü
Western small-footed Myotis	*Myotis ciliolabrum*	MYCI	Yes	Rare	Rare in west			Not in county list		

[1] Also known as the Brazilian free-tailed bat

[2] The software lists the Mexican free-tailed bat for Nebraska, but does not include a filter for the species.

[3] Formerly called eastern pipistrelle (*Pipistrellus subflavus*)

Results and Discussion

Four Wildlife Acoustics SM3Bat monitoring devices were deployed at Tallgrass Prairie National Preserve from September 11 to 29, 2014, and from July 7 to October 7, 2015. A total of 49,282 recordings were made. I deleted 251 recordings from partial nights, i.e., the units appear to have shut down some time during the night based on observer field notes and a review of temporal patterns in the recordings. Although the censored recordings could possibly have some value (e.g., looking for detections of rare species), I viewed this as unlikely and outweighed by the complexity and bias they would have caused other analyses (e.g., hourly activity rates). I deleted another 3 files that had zero bytes of information, leaving 49,028 files for analyses. (Of the 49,028 files, 2,229 files, all recorded in 2014, had information from both stereo channels so I purged the information from the second channel. It's unclear why these recordings were in stereo; however, after the recorder configuration was changed from "auto" to "channel 0" the problem no longer occurred.) The total number of complete survey nights was 360 (57 in 2014 and 303 in 2015: note that a survey night covers two calendar days). Of the retained recordings, 4,877(10%) were from 2014 and 44,151 (90%) from 2015.

I ran the 2014-15 recordings through BCID, Echoclass, Kaleidoscope, and Sonobat auto-identification software using the approached described in the Methods section. As described in the Methods section such side-by-side comparisons are complicated by several factors including the fact that some software packages force the operator to use a fixed regional species list that can differ from the fixed lists in other software packages. Nevertheless, such analysis can show patterns and, when the software is in agreement, increase confidence in the classifications. The results from the park data showed much more disparity between the software packages (**Figure 6**) than did my between-software test of 85 known bat passes (see the Methods section). This was probably due in part to the quality of the recordings (with the park data including more poor quality recordings) and the fact that the park recordings were not used to "train" the software as might have been the case for my catalog of known bat calls. In part because of uncertainty about which software was most accurate I mostly avoid presenting quantitative species-specific results.

Of the 49,028 recordings retained for analyses, Kaleidoscope assigned 32,614 to a specific species (67%), 11,618 (24%) as a bat but not to the species level, and 4,796 (10%) as noise files. There were differences between sites in terms of the quality of the recordings (**Table 2**). Site 050 had by far the highest percentage of recordings classified as noise; the reason is unclear. Interestingly, Site 051 at the park headquarters had the lowest rate of noise files. Several sites that had a high rate of bat detections that could not be identified to species occurred in woodland areas (e.g., 047, 055), an unsurprising result as trees can degrade the quality of recordings. Yet other sites also had many recordings that could not be classified to species level, but were in prairie areas (e.g., 046 and 054).

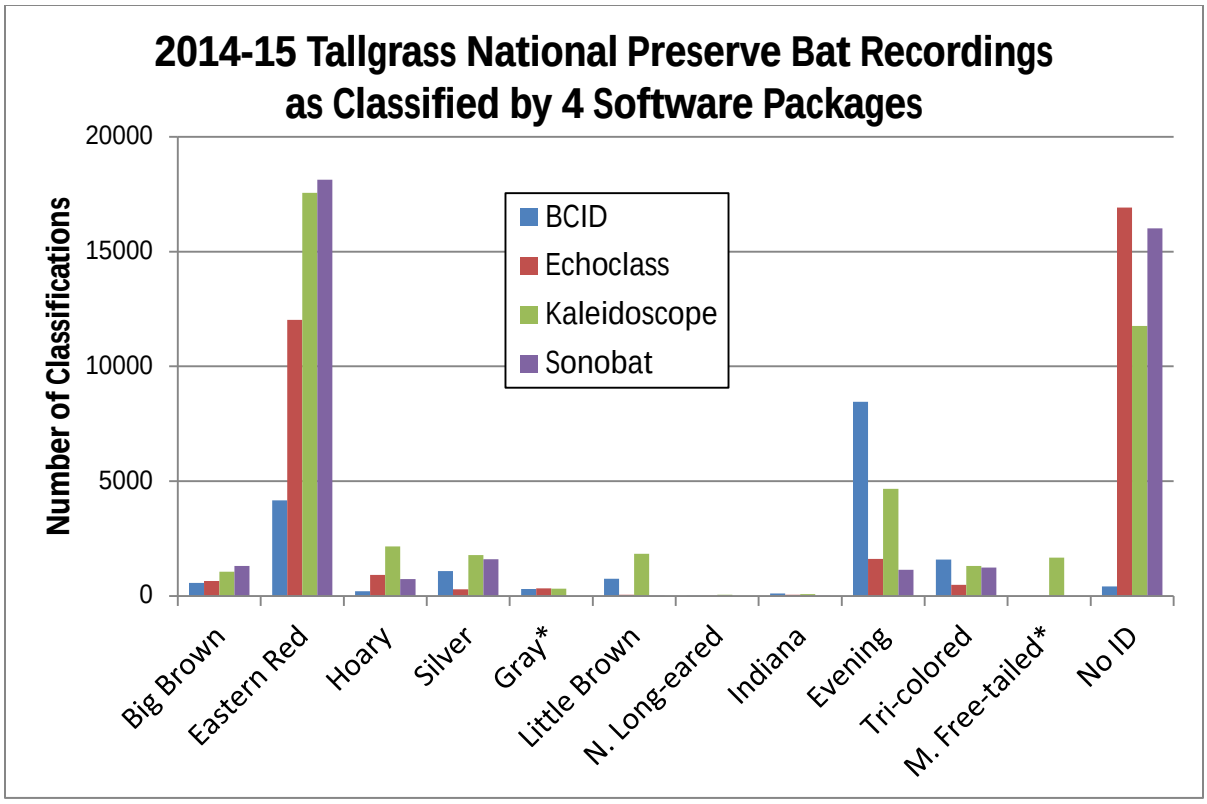

Figure 6. Comparison of 2014-15 data using BCID, Echoclass, Kaleidoscope, and Sonobat software. * Gray bat not included in Sonobat and Mexican free-tailed bat not included in BCID, Echoclass, and Sonobat.

Table 2. Quality of recordings by site when processed with Kaleidoscope.

	042	045	046	047	048	049	050	051	052	053	054	055
% Noise	8%	4%	18%	18%	24%	19%	42%	0%	2%	12%	10%	24%
% No ID	24%	16%	48%	36%	33%	15%	30%	5%	12%	24%	46%	36%
% ID'd	68%	80%	34%	46%	43%	65%	28%	95%	86%	64%	43%	40%
# Files	9,135	11,385	952	6,357	488	368	601	5,815	3,834	2085	2,938	5,070
# Nights	43	35	18	23	30	24	30	25	30	38	32	32

BCID, Echoclass, Kaleidoscope, and Sonobat all output a statistical estimate of the probability of species presence based on the uniqueness of the specie's call, number of classifications, and other factors. I ran the 2014-15 park recordings through the four software packages for purposes of reporting these probability outputs. For the analysis I configured BCID and Kaleidoscope to also look for the endangered Indiana and gray bats and the threatened northern long-eared myotis as there is a slight chance they could be in the vicinity of the park and they are species of high conservation concern. Sonobat did not include the gray bat in the classifier packages I used. Only Kaleidoscope included the Mexican free-tailed bat in the runs. The software packages were in concurrence that the big brown, eastern red, hoary, silver, and tri-colored bats were present (**Table 3**). Kaleidoscope

concluded that the Mexican free-tailed bat was present. The evening bat is probably present at the park, but for some inexplicable reason Kaleidoscope and Sonobat were not definitive, even though Kaleidoscope classified 4,666 recordings to the species. Sonobat did not conclude that the little brown bat was present, although the other packages did.

Perhaps the biggest surprise, and the most difficult finding to accept, is that some of the software packages indicated that the three federally listed bats were present (**Table 3**). Yet the park is generally considered out of the range of two of those, the gray and Indiana bats. The software was mixed regarding the Indiana bat, as it was for the northern long-eared myotis, yet the three packages that included a filter for the gray bat all outputted that it was present. Furthermore, BCID, Echoclass, and Kaleidoscope assigned 294, 335, and 316 recordings, respectively, to the species, a substantial amount. All of the software developers caution about relying on the probabilistic estimators for definitive species presence, especially when sample sizes are large. A subset of the recordings classified as gray bat were manually vetted by Patrick Moore; he stated that a couple of the calls looked like gray bats, but he was not confident and recommended mist netting (pers. comm.).

Table 3. Probability of presence at the park as outputted by the software packages.

	BCID	Echoclass[1]	Kaleidoscope[1]	Sonobat	Author's Conclusion
Big Brown Bat	1.00	1.00	1.00	1.00	Present
Eastern Red Bat	1.00	1.00	1.00	1.00	Present
Evening Bat	1.00	1.00	0.00	0.74	Probably Present
Gray Bat	1.00	1.00	1.00	na	Uncertain
Hoary Bat	1.00	1.00	1.00	1.00	Present
Indiana Bat	1.00	1.00	0.00	0.00	Likely Absent
Little Brown Bat	1.00	1.00	1.00	0.00	Probably Present
Mex. Free-tailed	na	na	1.00	na	Present
North. Long-eared	1.00	1.00	0.00	0.00	Likely Absent
Silver-hair Bat	1.00	1.00	1.00	1.00	Present
Tri-colored Bat	1.00	1.00	1.00	1.00	Present

1 Values inverted for consistency between software outputs. A 1.00 indicates significant evidence of presence.

Over ½ of the recordings classified to species by Kaleidoscope were assigned to the eastern red bat with the evening bat comprising about 1/4th (**Figure 7**). The hoary, silver, little brown, tri-colored, Mexican free-tailed, and big brown all comprised about 1/8th or less. However, as shown in **Figure 6** there was variability between the software packages. For example, Sonobat assigned a much smaller relative frequency of recordings to the little brown and evening bats. Even within packages the relative frequency of species classifications could change depending on the software settings.

A frequent criticism of acoustic monitoring is that a single bat can repeatedly fly by the recorder giving a false impression of abundance. To overcome this it has been suggested that multiple recordings made by the same species within a minute of each other be considered a single detection, and the resulting tally be used as an "activity index" (Miller 2001). When I did this it reduced the

number of bat recordings by 27% (**Table 4**). The number of hoary bat recordings was reduced by almost a half whereas the number of little brown bat recordings was reduced by only 8%. However, when I compared the results of this modified dataset to what I got using all bat recordings (e.g., **Figure 7**) I found the differences negligible in terms of relative species classifications, temporal patterns, and habitat use. Therefore, the subsequent analyses and results are from the entire dataset.

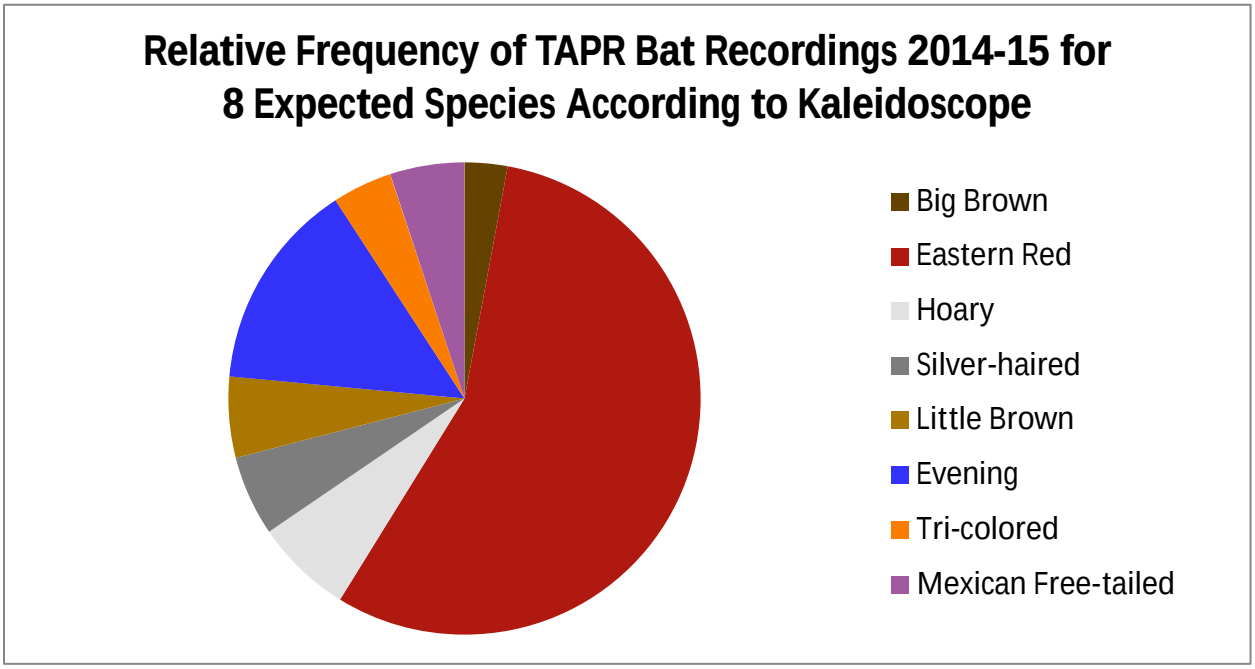

Figure 7. Relative frequency of detections by species according to Kaleidoscope.

Table 4. Raw Kaleidoscope classifications and number retained after using an activity index.

	All Records	Without Duplicates < 1 minute	Percent Retained
Big Brown Bat	957	692	72%
Eastern Red Bat	18,228	11,929	65%
Evening Bat	4,671	3,663	78%
Hoary Bat	2,171	1,193	55%
Little Brown Bat	1,810	1,671	92%
Mex. Free-tailed	1,663	1,434	86%
Silver-hair Bat	1,782	1,322	74%
Tri-colored Bat	1,332	1,080	81%
No ID	11,618	9,403	81%
Total	44,232	32,387	73%

The average number of bat recordings (classified to species level and unclassified) per night was 122; however, the number varied substantially by deployment site and time. For example, Site 051, located at the park headquarters, had the most bat activity during the July 7 to August 15 summer period (711 recordings per night: **Figure 8**). Most of that activity was comprised of the eastern red

bat. Site 045, located next to a large stock pond, also had substantial bat activity during the summer period, but other species comprised a larger portion of the activity. Conversely, when I included September and October nights (i.e., all nights, both years), Site 045 had the most nightly detections followed by Site 047 located in the Fox Creek drainage and then Site 051 at the park headquarters (**Figure 9**). Site 048 was one of the least productive sites which is somewhat surprising because it was next to the Strong City sewage ponds: sewage ponds have generally been associated with high bat activity at parks in the Northern Great Plains (Licht in prep.). Similarly, Site 050 was near a stock pond yet had low activity; perhaps because it was on the downstream side of the dike (Kristen Hase, pers. comm.). (See later in this section for additional discussion of seasonal changes.)

Species presence at the 13 sites generally followed patterns that would be expected based on known habitat preferences for the bats. For example, the hoary and Mexican free-tailed bats are open country foragers; at Tallgrass Prairie National Preserve they were more commonly found at open-country deployments (e.g., Sites 045 and 054 in **Figure 9**). The big brown bat often uses buildings and anthropogenic structures for roosting; it showed its highest relative frequency near the park headquarters (Site 051). The eastern red bat was also common around the headquarters area; however, it's likely that activity was due more to foraging than it was to roosting as that species does not typically roost at buildings, but rather, roosts in trees.

Bat detections for the eastern red and evening bats, the most commonly recorded species, peaked at TAPR around 9-10 pm; however, other species and the large group of unidentified bats did not show this pattern, rather, their activity was relatively constant throughout the night (**Figure 10**). This is surprising as bat communities generally show a peak in bat activity in the hour or two after twilight (Licht in prep.).

However, an analysis of bat activity at TAPR by deployment site provides some more insight (**Figure 11**). Site 045 showed a dramatic peak of activity from 9-10 pm, followed by a precipitous drop. That site was next to a large stock pond. It's reasonable to conclude that bats left their daytime roosts and flew directly to the pond where they drank (water is especially important for nursing females) and foraged. Conversely, Sites 047 and 051 were located in the Fox Creek riparian area and the nearby park headquarters area, respectively. Bat activity at the two sites gradually increased throughout the night until about 5 am and then experienced a dramatic drop. This phenomenon is harder to explain. These could be sites where bats were resting following the night-time feeding activity and/or they could be sites of social activity. The two night-time activity charts illustrate that bat activity can vary by hour of night, with some species having differing temporal patterns, and also by habitat. I also evaluated night-time temporal activity patterns by month, but the patterns were similar to **Figure 10** and **Figure 11**.

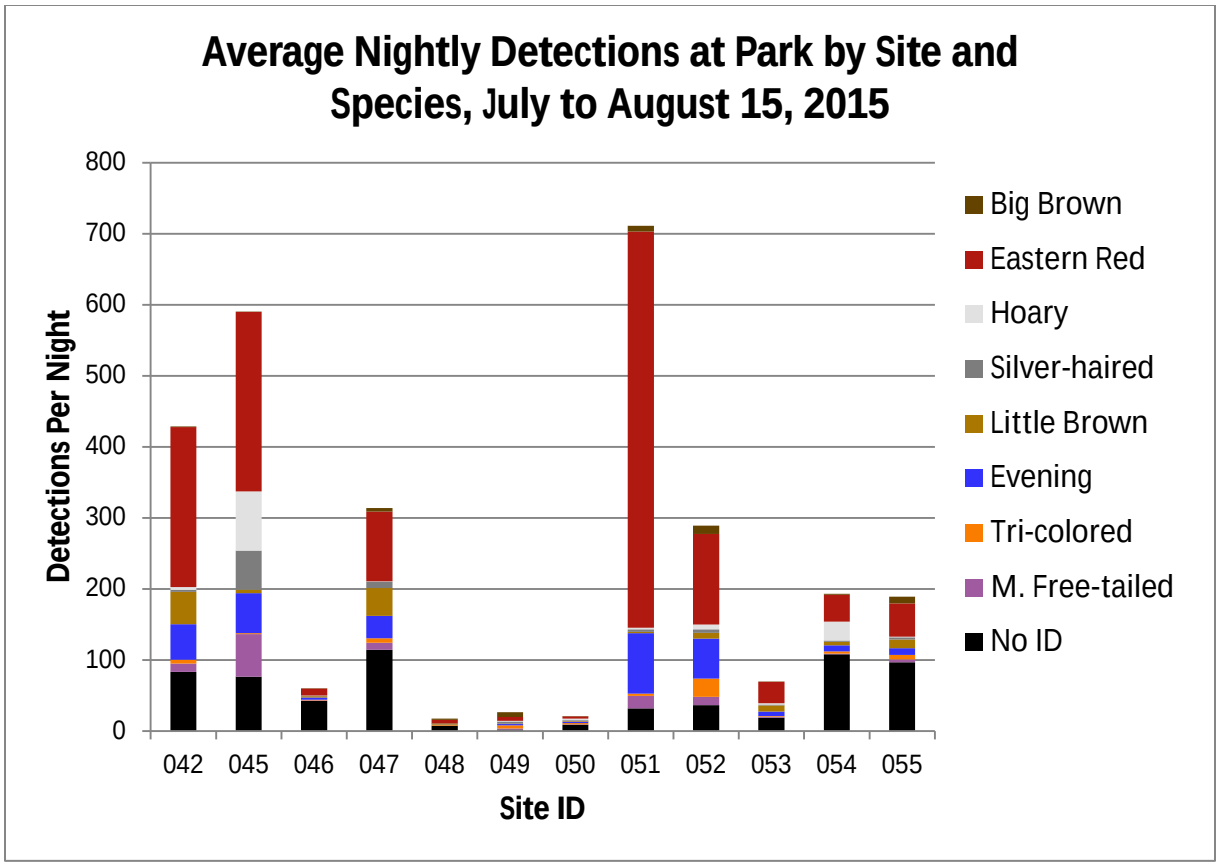

Figure 8. Average nightly detections July 7 to August 15 2015, by survey site using Kaleidoscope.

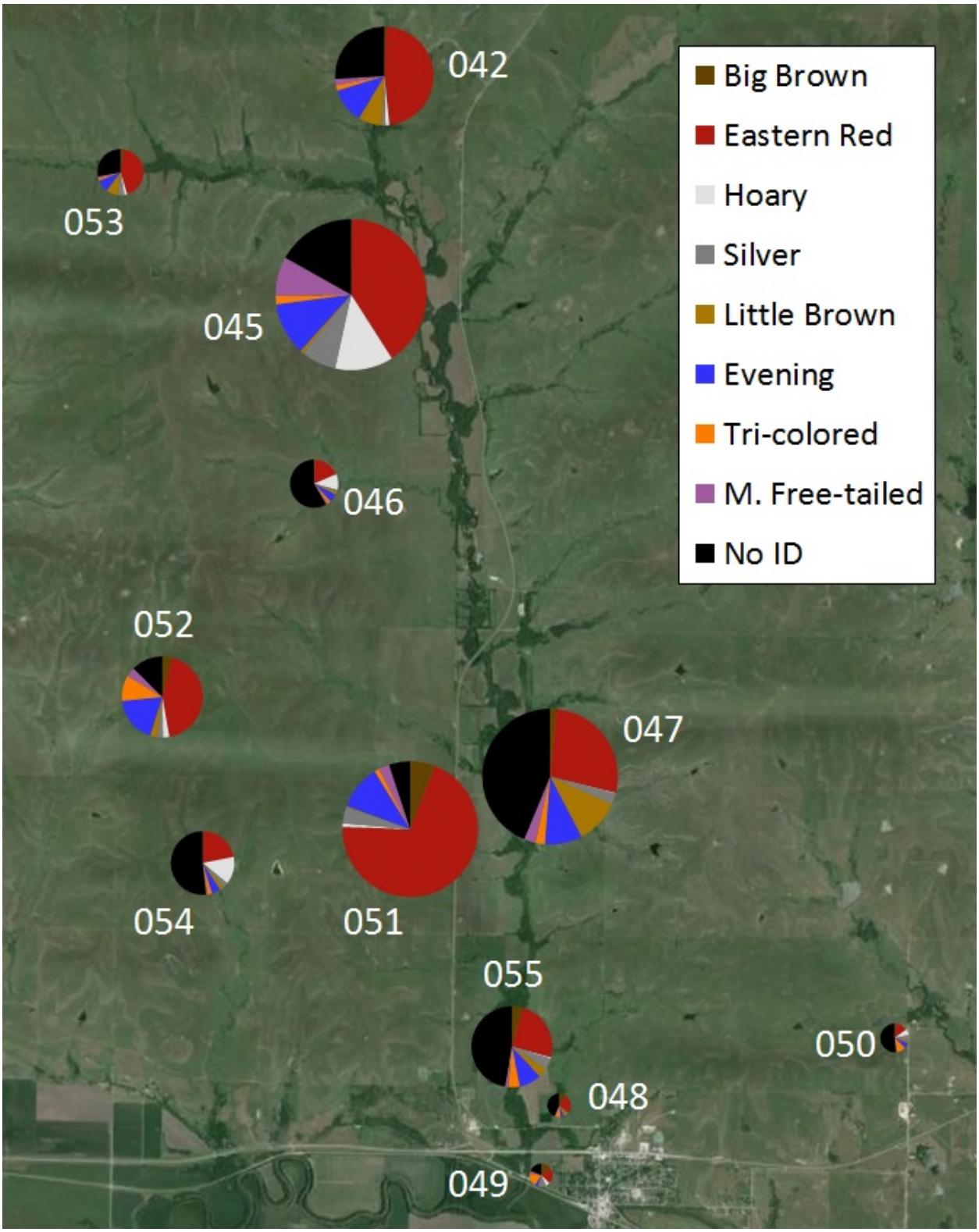

Figure 9. Relative bat activity and species composition at stations, all dates 2014-15. The size of the circles correlates to the average number of recordings per night.

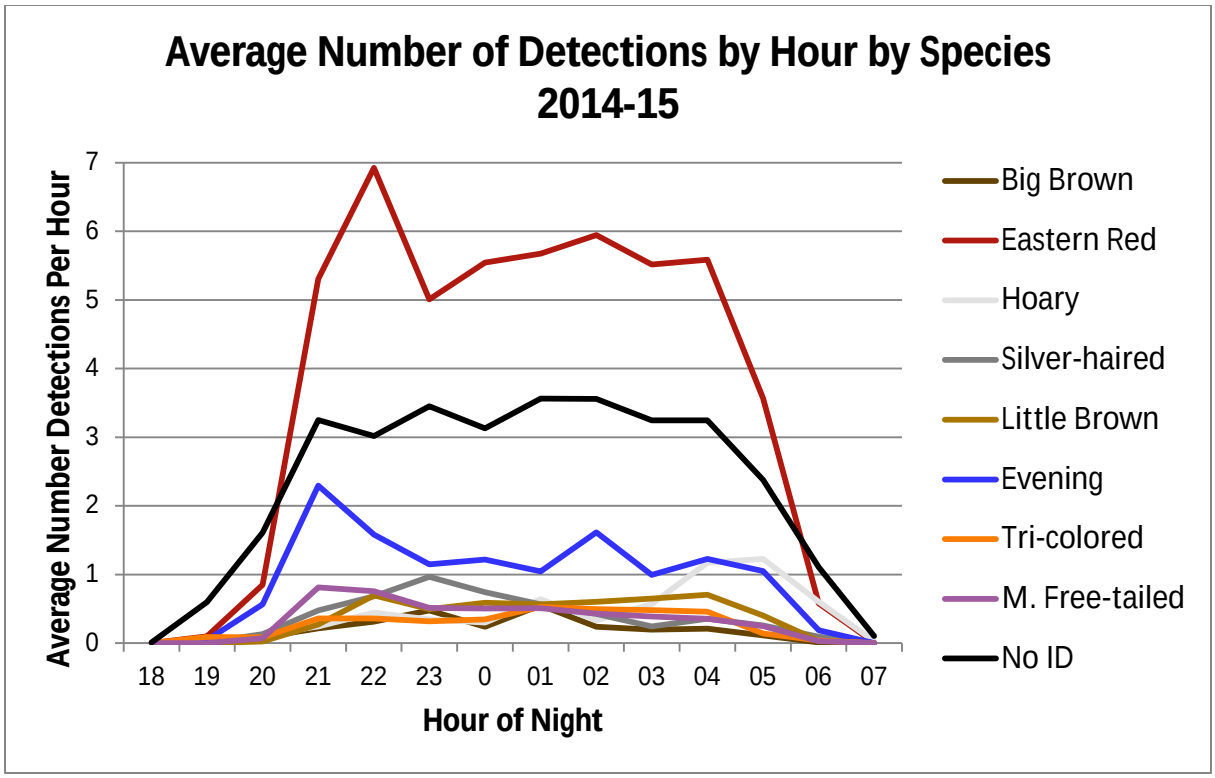

Figure 10. Bat activity by species and hour of night.

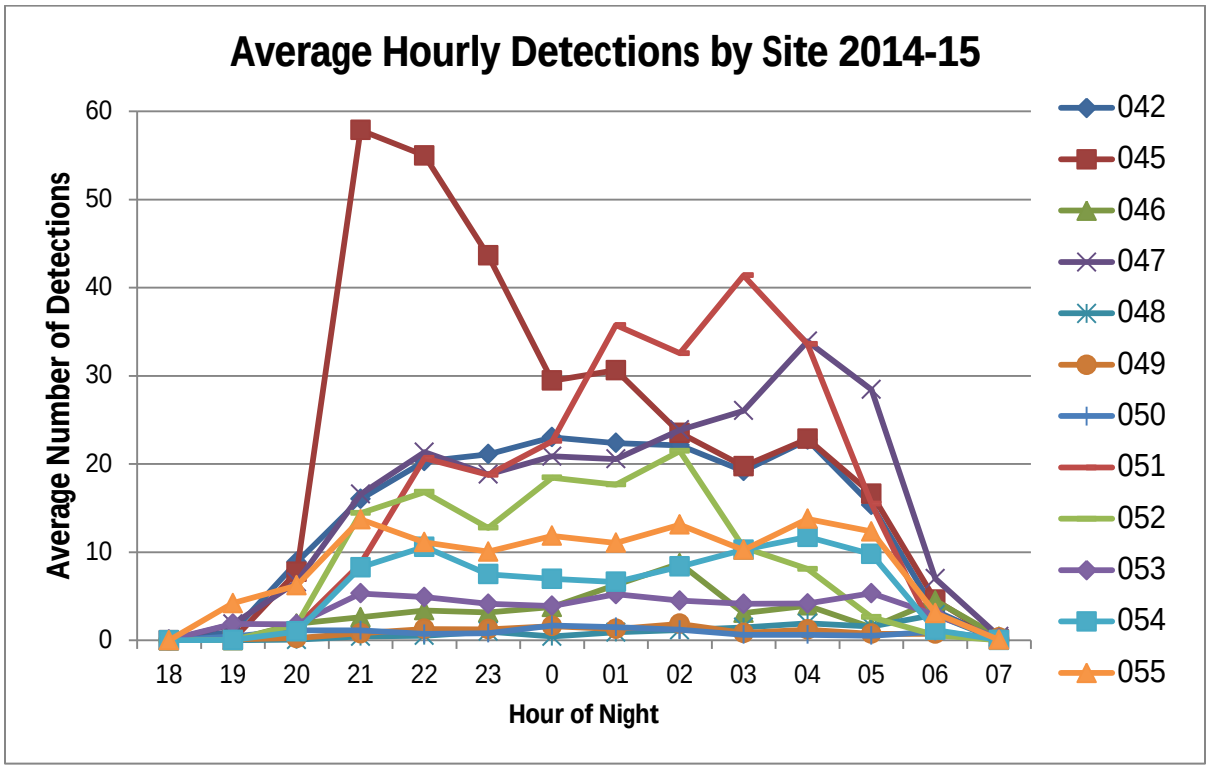

Figure 11. Bat activity by species and hour across deployment sites.

Bat activity also varied over the July to October sampling period. Two sites, 042 and 053 were monitored in the same five weeklong sessions over the July 7 to October 5, 2015 time period, so I combined the weeklong nightly averages from the two stations to look for patterns in bat seasonal changes at the park. The average nightly rate of bat detections dropped dramatically at the two stations from early July until mid-August, for almost species combined and for most species individually (**Figure 12**). The eastern red, little brown, and evening bats all showed about a 90% decline in activity from the early July session to the early October session. The Mexican free-tailed bat essentially disappeared from the park: it went from 23 detections per night among the two stations in early July to essentially zero detections per night from mid-August on. Conversely, the big brown, silver, and tri-colored bats all held constant throughout the five sessions, although at low levels compared to other species. Short-term weather could have played some role in these patterns (e.g., a night of thunderstorms); however, the recording sessions were for 6-7 days each which should have attenuated the impact of short-term weather affects. Moon phase could have also played a role; however, the scientific literature is inconclusive about the effect of lunar cycles on temperate bats. It's possible that the high activity in July and early August was due to volant young that subsequently dispersed in late August along with adults. Season-long mist netting would shed more light on this pattern as would summer-through-fall acoustic monitoring in additional years.

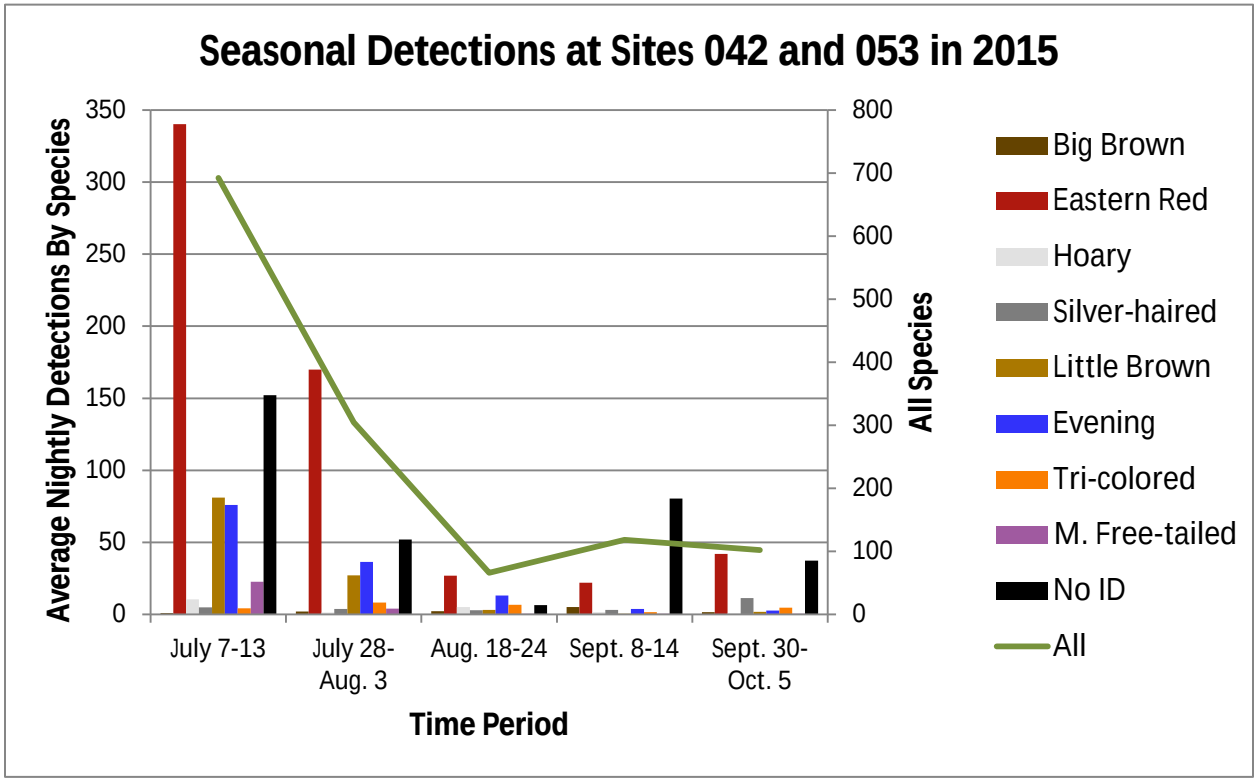

Figure 12. Bat activity at two sites from July to October 2015.

To evaluate year-to-year changes in bat abundance at TAPR I compared the number of detections per site/night in 2014—all from September—to the September 2015 values for the 10 sites that were monitored in both years. Every site showed fewer nightly detections in 2015 (**Figure 13**). The difference was statistically significant at $P<0.05$ using the non-parametric Wilcoxon Signed Rank Test. Site 055, located in the Fox Creek riparian area showed a substantial drop in bat activity between years that was greater than the other sites. The reason for the relatively greater decline is not known.

To better understand what species contributed to the decline from 2014 to 2015 I compared the average number of nightly detections per species in September for the 10 sites monitored in both years (see the x-axis in **Figure 13**). The analysis found that much of the decline from 2014 to 2015 can be attributed to substantially fewer detections of the eastern red bat, evening bat, and the recordings that could not be classified to species (**Figure 14**). Neither the eastern red bat or evening bat are known to be affected by white-nose syndrome. The little brown and tri-colored bats—both species that are vulnerable to WNS and apparently suffering range-wide declines in abundance—also showed declines > 50%; however, the number of detections made by Kaleidoscope for both species were small in both years. The hoary bat was the only species to show an increase in 2015, but it too was comprised of a small sample size.

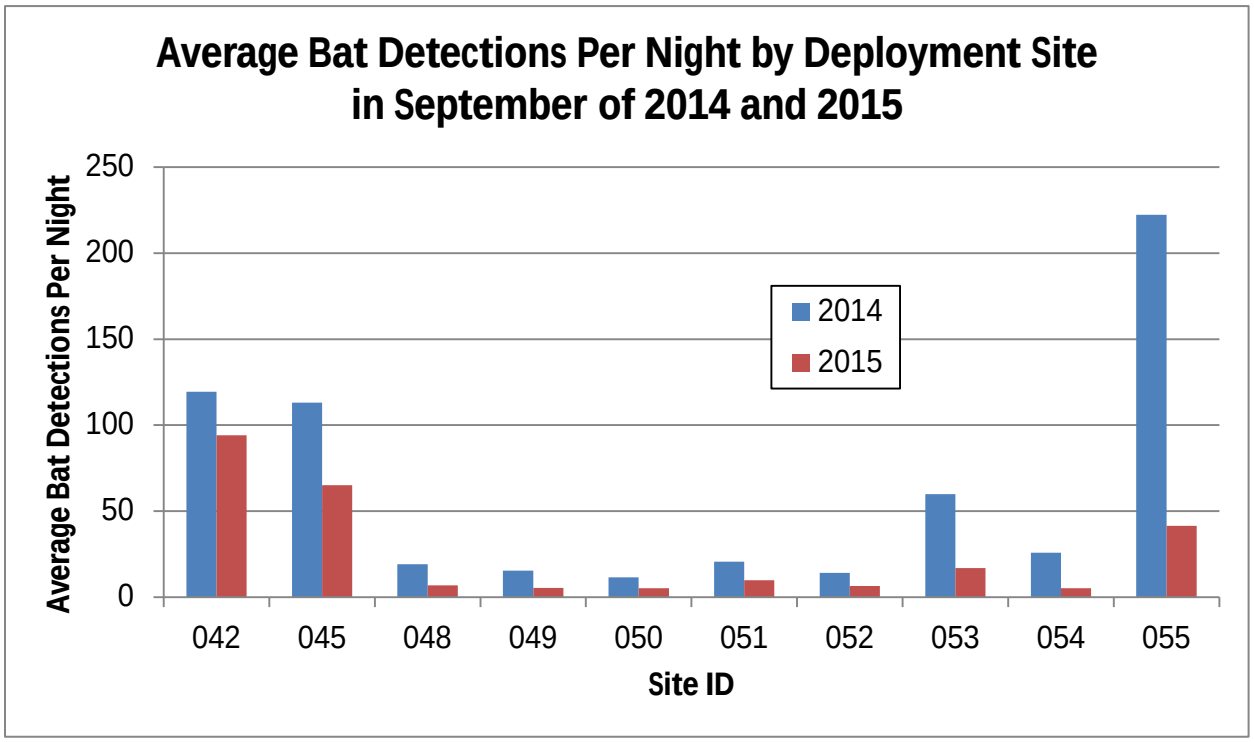

Figure 13. Average bat detections per night at sites monitored in September of 2014 and 2015.

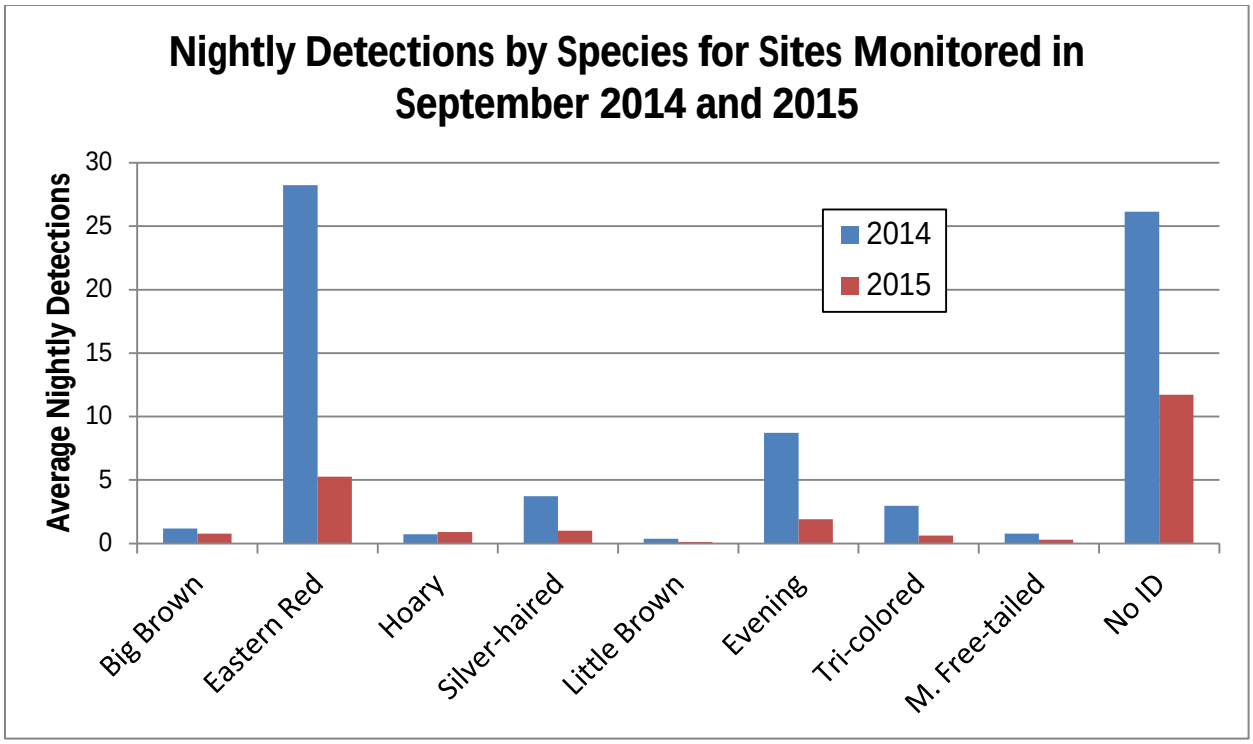

Figure 14. Average bat detections per night by species in September of 2014 and 2015.

Summary

The results of acoustic monitoring for bats should be interpreted cautiously as there are many caveats. For example, species misidentification is problematic. This is especially true between closely related species such as the various *Myotis*, but can occur between more distantly-related species such as the big brown and the silver-haired bats. Hence, species misidentification is one of the most commonly cited criticisms of acoustic monitoring (Fritsch and Bruckner 2014, Lemen et al. 2015, Loeb et al. 2015). This study used four software packages to analyze the park recordings and found large differences in the species classification rates. Furthermore, it's important to consider that some bat species, such as the "tree bats" (hoary, eastern red, silver), can be detected well past 50 yards whereas others are quieter and can only be detected when closer to the recorder (detection range is a function both of the decibel volume when emitted and the frequency as low-frequency calls tend to carry farther). Also, readers should always keep in mind that the data is a measure of bat activity, i.e., flyovers, which might not be correlated with bat abundance at the site as some species can be more active flyers. Rather than assume absolute precision in species identification and a tight correlation to abundance, readers are advised to look at general trends and patterns.

With those caveats in mind, it appears that the eastern red is the most active bat in and near the Tallgrass Prairie National Preserve, followed by the evening bat. The big brown, hoary, silver-haired, little brown, tri-colored, and Mexican free-tailed bat all appear to make up a small proportion of the July-October bat community at the park. Some of the software packages assigned a small number of recordings to the federally-listed gray, Indiana, and northern-long eared bats; however, that is not conclusive evidence of presence. The park is generally believed to be outside the range of the gray and Indiana bats (Sparks and Choate 2000), moreover, the gray bat relies heavily on caves which are not known from the vicinity of the park (although the lone Kansas roosting site where the species is documented is a sewer beneath the city of Pittsburgh, Kansas). Conversely, gray bats are known to travel long distances from caves in southwest Missouri (Elder and Gunier 1978) so their presence in eastern Kansas cannot be ruled out. Manual vetting should be done on these recordings and, ideally, a capture should be made before the species are listed as confirmed for the park.

The results presented here are generally consistent with what Robbins (2005) found at the park in June-August of 2004 using acoustic surveys and mist netting. Based on his acoustic surveys he concluded that the big brown, eastern red bat, northern long-eared, and tri-colored bat were present, with the eastern red bat being the most common. Conversely, I did not find persuasive evidence that the northern long-eared myotis was present. The only species he caught mist netting was the eastern red bat, the most commonly classified species in this study. The results presented here are also generally consistent with the review of bats in Kansas done by Sparks and Choate (2000). They noted that the little brown bat was a peripheral species in Kansas; this study found evidence of the species being present in the park although in low abundance. Likewise, this study found evidence of the big brown bat in low abundance; they noted that few specimens of the species came from the Flint Hills, but thought that could be due to the area being under-surveyed. Conversely, in extreme eastern Kansas the big brown bat was the most commonly captured species in mist nets, although that might have been due in part to the presence of buildings for roosting (Brack et al. 2007).

Nightly bat activity was highest at a stock pond out in the prairie, a woodland site in the Fox Creek riparian area, and near the park headquarters. Prairie sites generally had fewer detections per night than other sites unless water was present. Individual species tended to use the park's habitat in a manner consistent with their ecology. For example, hoary bats were relatively more common in open areas and the big brown bat showed its greatest relative activity near the park headquarters. Big brown bats often roost in anthropogenic structures and feed near outdoor lights that attract insects. Surprisingly, there was very little bat activity near the Strong City sewage ponds; sewage ponds have been associated with high bat activity in North Great Plains parks (Licht in prep.). The results from this study should be interpreted carefully for habitat use and habitat importance at the park. For example, this study monitored night-time activities only; during daylight hours it's possible that essentially all of the park's bats roosted in the forested Fox Creek riparian area. That critical habitat should be protected for bats. However, in one unusual and inexplicable case a park employee found an eastern red bat roosting in daylight hours in tall herbaceous prairie vegetation (**Figure 15**).

Figure 15. An unusual use of herbaceous vegetation by a daytime roosting eastern red bat (National Park Service photo).

This study found that nocturnal bat activity at the park generally peaked 1-2 hours after sunset, although the peak was less pronounced than what is observed in the Northern Great Plains (Licht,

unpub. data). However, temporal patterns varied by site and habitat. In this study there was a peak of activity the few hours after sundown at a large stock pond (Site 045). It's reasonable to conclude that bats flew directly to the site shortly after sundown for drinking and feeding. Conversely, a site in the forested Fox Creek riparian area (Site 047) showed a peak of activity in the hours before sunup, perhaps because bats were socializing and preparing for daytime roosting.

The data reported here were collected in September of 2014 and early-July to early October 2015. There was a dramatic drop in bat activity starting around mid-August, based on the 2015 data. It's reasonable to assume that detections up to that time period were generally made by resident animals, including young-of-the-year volant animals. The big brown, eastern red, evening, hoary, little brown, and tri-colored bats are likely breeders in the vicinity of the park. The Mexican free-tailed bat is known to breed only from a single site in Kansas (Kunz et al. 1980, Sparks and Choate 2000); however, they are long-distance flyers and bats in the vicinity of the park are probably non-breeders and dispersers (Hibbard 1934, Birney and Rising 1967). Conversely, the silver-haired bat is not known to breed in Kansas (Sparks and Choate 2000) and is probably only a disperser or migrant in the vicinity of the park; the 2015 data did show a modest increase in silver-hair activity in September whereas most every other species showed a dramatic decrease in recordings in that month. Sparks and Choate (2000) reported that most silver-haired bat captures in Kansas occurred in May and September and Jones et al. (1967) reported that the fall migration period of the silver-haired bat in Kansas was mid-September to mid-October.

Because of the strong seasonal influence on bat activity at the park I used only September data to compare counts from 2014 to counts in 2015. All of the 10 sites that were monitored in both years showed a lower rate of nightly activity in 2015, a decline that was statistically significant. But interestingly, the decline seemed to be driven by substantially fewer detections of the common eastern red and evening bats, two species that are not known to be susceptible to WNS. The park species that are known to be affected by the disease, the little brown and tri-colored bats, showed about a 50% decline from 2014 to 2015; however, the sample sizes were small.

Tallgrass Prairie National Preserve appears to have a healthy bat community. Some species might even be more abundant that prior to European settlement. Sparks and Choate (2000) suggested that nine of the 15 bat species known to occur in Kansas have likely increased in distribution following settlement due to anthropogenic changes such as the proliferation of buildings, planting of shelterbelts, and suppression of tree-killing fires, all of which provide roosting habitat. However, the increase in upland forests might be offset by a decrease in forested riparian areas due to water withdrawals from streams and lowering water table (Sparks and Choate 2000). The proliferation of anthropogenic surface water might also benefit bats in Kansas, as was found in this study where a stock pond had relatively high bat activity. Managers need to consider the benefits of these anthropogenic habitats. When natural habitat is lost managers should consider mitigating actions. For example, artificial bat houses can mitigate for a loss of riparian roosting habitat and can increase bat abundance in Great Plains ecosystems (Licht in prep.).

Management Recommendations

I recommend that the park:

- Continue acoustic monitoring of bat populations. Sites established for this study should be periodically revisited in July-September. Sites 042, 045, 047, and 051 collected large sample sizes, had low rates of noise, and represented various habitats and therefore should be the highest priority for monitoring. Spring and early summer acoustic surveys, and perhaps even winter surveys, should also be conducted to better understand seasonal bat use at the park.

- Conduct mist netting. Mist netting results in more definitive species list and can provide demographic and health information. Bats captured in winter or early spring can be swabbed for evidence of the WNS fungus. Bats captured in late summer can provide information on breeding within the park. Mist netting might also confirm the presence of the gray bat as manual vetting of the suspect calls by an expert was inconclusive.

- Protect woody habitat within the Fox Creek riparian area, with an emphasis on large and decadent trees with loose and exfoliating bark. Consider conserving stock ponds and other anthropogenic surface water for the benefit of bats (although that needs to be weighed against the fact that the stock ponds are unnatural and can be detrimental to some native species, e.g., the Topeka shiner [*Notropis topeka*]).

- Consider the establishment of a bat house (primarily beneficial to the big brown and little brown bats). Some NPS units have successfully established bat houses with the result being higher bat densities than other comparable parks (Licht, unpub. data); however, there is currently some debate and indecisiveness within the agency about the appropriateness of placing such structures on NPS lands. Therefore, the park should consult with other agency offices before taking such an action.

- Promote bat conservation in interpretive programs. The park has the potential to educate and inform the public about the ecological value of bats. Evening programs can be conducted that use real-time bat acoustic monitoring equipment for an interactive experience.

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Appendix I. Recorder Configuration

Below are the settings used in the 2014-15 field seasons for the Wildlife Acoustics SM3Bat recorders. The recorders can be configured directly on the recorder using the buttons and LCD display or by using the SM3 Configurator software and transferring the configuration file to the hardware.

High Pass Filter= 16 kHz

Gain= 12.0 dB

WAV format 256kHz

Frequency Minimum= 16 kHz

Frequency Maximum= 192 kHz

Duration Minimum= 1.5 ms

Duration Maximum= 50.0 ms

Target Level= 12 dB

Target Window= 2.0 s

Trigger Maximum= 5.0 s

Sunset= - 15 minutes

Sunrise= + 15 minutes

Continue= Forever

Appendix II. Deployment Information

Metadata provided by park personnel. Some deployment locations might have moved slightly from 2014 to 2015; however, the changes were generally within a few yards of the recorded coordinates.

Table 5. Description of deployment sites.

Site ID	Descriptive	Latitude	Longitude	Water[1]	Trees[1]
042	Fox Creek Riparian	38.494111	-96.567033	Yes	Yes
043[2]	Floodplain of Tributary	38.493466	-96.590397	No	No
045	Stock Pond	38.480138	-96.573714	Yes	No
046	Floodplain of Small Tributary	38.462964	-96.570970	No	Yes
047	Fox Creek Riparian	38.435377	-96.549644	Yes	Yes
048	Sewage Lagoon	38.404561	-96.544383	Yes	Yes
049	Town	38.397996	-96.545090	No	Yes
050[3]	Stock Pond	38.411984	-96.503046	Yes	No
051	Headquarters	38.433654	-96.558431	No	Yes
052	Stock Pond	38.442681	-96.593774	Yes	No
053	Floodplain of Palmer Creek	38.491760	-96.596874	No	Yes
054	Small Spring and Tributary	38.422570	-96.584987	No	Yes
055	Fox Creek Riparian	38.409703	-96.548572	Yes	Yes

[1] Feature within 50 yards of deployment. Does not include small amounts of surface water.

[2] No usable data collected 2014-15.

[3] Unit deployed on downstream side of dam.

Appendix III. Software Settings

The settings in **Table 6** were used in the four software packages. Unless noted, the analyses in the report were conducted using output from Kaleidoscope. The settings were the default settings for the software. If not explicitly listed below the setting was likely disabled. Echoclass does not provide customization. See the software packages for parameter definitions and uses. Other analyses and objectives might warrant different settings.

Table 6. Software settings.

	BCID 2.7d	Echoclass	Kaleidoscope	Sonobat
Smoothness	12			
Ignore Fragments if Shorter than	2200			
Join Fragments if Gap Less than	2000			
Fc (kHz)	4 to 300			
Sc (OPS)	-9999 to 9999			
Tc (ms)	0 to 999			
Fk (kHz)	16 to 110			
TK (ms)	0 to 999			
Fmin (kHz)	16 to 60			
Fmax (kHz)	17 to 120			
Sweep (kHz)	3 to 90			
Fmean (kHz)	16.5 to 110			
Min. Percentage Pulses for ID	0			
Min. Discriminant Probability	0			
S1 (OPS)	-9999 to 9999			
Dur (ms)	1 to 20			
Minimum Number of Calls	5 within 15 sec.			
Signal of Interest kHz			8 to 120	
Signal of Interest ms			2 to 1000	
Minimum Number of Calls			1	
Advanced Signal Enhancement			Yes	
Classifiers			Balanced -Neutral	
Autofilter				Selected
5 kHz				Selected
Acceptable Call Quality				0.8
Sqnc Decision Threshold				0.9
Max # of Calls to Consider				16

Appendix IV. Nightly Counts by Site, 2014-15

Table 7 was generated by Kaleidoscope 3.1.7 using default settings. Other settings and software will likely generate different results. The output includes recordings classified to species as well as recordings where the software detected a bat, but did not assign a species. The output does not include noise files and data from incomplete nights, i.e., nights when the unit appeared to such down because of malfunction. The dates are for a complete night, e.g., the row 9/11/2014 includes the evening of the 11th as well as the early morning hours of the 12th. Null values mean no deployment.

Table 7. Bat detections by site and night as outputted by Kaleidoscope.

Sites	042	045	046	047	048	049	050	051	052	053	054	055
9/11/2014	84	14										
9/12/2014	14	2										
9/13/2014	109	9										
9/14/2014	739	3										
9/15/2014				53	14	23	7					
9/16/2014				101	12	7	21					
9/17/2014				110	36	16	5					
9/18/2014				163	14		13					
9/19/2014		296						22	5			
9/20/2014		202						15	8			
9/21/2014		107						8	19			
9/22/2014		271						26	32			
9/23/2014								32	6			
9/24/2014	23									51	36	239
9/25/2014	21									47	12	255
9/26/2014	25									41	30	216
9/27/2014	25									56	25	252
9/28/2014	35									104	26	150
7/7/2015	280	233	22							48		
7/8/2015	544	628	65							53		
7/9/2015	862	313	96							73		
7/10/2015	531	166								52		
7/11/2015	790	130								53		
7/12/2015	677	315								80		
7/13/2015	731	906								72		

Sites	042	045	046	047	048	049	050	051	052	053	054	055
7/14/2015				403				308	210		307	
7/15/2015				751				567	91		158	
7/16/2015				706				832	239		463	
7/17/2015				775				820	254		269	
7/18/2015				644				848	86		118	
7/19/2015				206				1036				
7/20/2015				333				568				
7/22/2015					27		17					420
7/23/2015					21		44					374
7/24/2015					1		27					260
7/25/2015					7		5					272
7/26/2015					2		13					193
7/27/2015					9							250
7/28/2015	158	835	70							104		
7/29/2015	193	854	55							120		
7/30/2015	358	849	79							88		
7/31/2015	279	881	53							109		
8/1/2015	209	971	63							30		
8/2/2015	185	482	67							51		
8/3/2015	206	705	32							41		
8/4/2015				82					694		81	
8/5/2015				72					189		246	
8/6/2015				68					644		491	
8/7/2015				96					525		41	
8/8/2015				94					232		76	
8/9/2015				60					154		28	
8/10/2015				102					151		40	
8/11/2015					28	41	21					92
8/12/2015					27	23	18					59
8/13/2015					16	20	36					67
8/14/2015					18	27	15					46
8/15/2015					35	21	16					46
8/16/2015					24	38	28					45
8/17/2015						23	7					54

Sites	042	045	046	047	048	049	050	051	052	053	054	055
8/18/2015	38	70							15	34		
8/19/2015	31	307							20	7		
8/20/2015	37	180							39	8		
8/21/2015	107	534							30	4		
8/22/2015	39	61							8	45		
8/23/2015	19	92							23	13		
8/24/2015	63	110							48	18		
8/25/2015			101	22				146			23	
8/26/2015			23	185				256			12	
8/27/2015			26	113				165			0	
8/28/2015				52				50			86	
8/29/2015				14				19			2	
8/30/2015											20	
9/1/2015					3	6	2					3
9/2/2015					0	0	1					161
9/3/2015					4	5	0					81
9/4/2015					3	0	6					5
9/5/2015					1	1	3					8
9/6/2015					1	0	0					11
9/7/2015					8	1	0					8
9/8/2015	294	26	1							17		
9/9/2015	14	75	3							5		
9/10/2015	7	61	15							38		
9/11/2015	35	33	5							17		
9/12/2015	26	164	2							14		
9/13/2015	24	31								5		
9/14/2015	331								3		1	
9/15/2015								16	5		3	
9/16/2015								4	1		1	
9/17/2015								6	2		1	
9/18/2015								19	16		25	
9/19/2015								10	11		9	
9/20/2015								12			1	
9/21/2015								3			2	

Sites	042	045	046	047	048	049	050	051	052	053	054	055
9/22/2015								8			3	
9/23/2015					0	2	1					32
9/24/2015					17	4	4					46
9/25/2015					14	4	7					103
9/26/2015					6	8	8					39
9/27/2015					4	3	11					25
9/28/2015					4	8	7					32
9/29/2015					16	16	6					25
9/30/2015	51									58		
10/1/2015	115									41		
10/2/2015	12									39		
10/3/2015	37									32		
10/4/2015	27									86		
10/5/2015	26									89		
Average	**195.6**	**311.9**	**43.2**	**226.3**	**12.4**	**12.4**	**11.6**	**231.8**	**125.3**	**48.5**	**82.4**	**120.9**
Nights	**43**	**35**	**18**	**23**	**30**	**24**	**30**	**25**	**30**	**38**	**32**	**32**

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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National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

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