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ENHANCED MONITORING OF IMPERILED BAT SPECIES ON DOD INSTALLATIONS USING AERIAL ACOUSTIC TECHNOLOGY

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ACRONYMS AND ABBREVIATIONS

DoD- Department of Defense
ABDT- Aerial Bat Detection Technology
AAARS- Autonomous Aerial Acostic Recording System
BONWR- Big Oaks National Wildlife Refuge
FLW- Fort Leonard Wood
CMPR- Camp Robinson
AAFB- Arnold Air Force Base
CF- Compact Flash
LABO- *Lasiurus borealis* (red bat)
NYHU- *Nycticeius humeralis* (evening bat)
PESU- *Perimyotis subflavus* (tri-colored bat)
EPFU- *Eptesicus fuscus* (big brown bat)
LANO- *Lasionycteris noctivagans* (silver-haired bat)
CORA- *Corynorhinus rafinesquii* (Rafinesque's big-eared bat)
LACI- *Lasiurus cinereus* (Hoary bat)

ABSTRACT

The Department of Defense (DoD) regularly monitors bats on installations as part of their responsibilities under the Endangered Species Act, Sikes Act, and National Environmental Policy Act. However, there are limitations to current bat monitoring methods that affect probability of species detection, and in turn determination of species presence, relative abundance, and occupancy. To overcome these limitations, an improved monitoring method is needed that can survey bats in flight and provide more accurate data for population analysis. We used an Aerial Bat Detection Technology (ABDT) to monitor bats in flight at varying altitudes (25, 50, 75, and 100m) on 4 DoD installations. Acoustic recordings of bat calls were analyzed for species identification using SonoBat Automated Bat Call Identification software V4.0.6. Calls collected by the ABDT were compared to calls collected from a ground-based acoustic bat detector run simultaneously throughout the collection periods. Out of the 44 sampling nights, the ABDT recorded species missed by the ground-based detector on 20 nights and ground-based detector recorded species missed by the ABDT on 3 of the 44 nights. Almost all species that were missed on the ground-based detector were recorded at >50m on the ABDT. There was no difference in the total number of calls recorded by the two methods ($P = 0.1223$, $\alpha = 0.05$) however, the ground-based detector recorded more calls per hour (calls/hr) when the ABDT was flown at the 50 – 100m levels ($P = 0.017$, $P = 0.001$ and $P = 0.005$, respectively). This suggests that using ground-based monitoring methods alone to examine population dynamics of bats may lead to an incomplete sample of species richness and relative abundance.

INTRODUCTION

Acoustic monitoring of bat populations has been extensively used for many years and provides a non-invasive, cost-effective method for collecting large amounts of data on bat species presence and relative abundance (Barclay 1999; Adams et al. 2012; Blejwas et al. 2014; Froidevaux et al. 2014). With continually improving technologies, researchers can now analyze echolocation call dynamics and have the ability to “hear” what a bat hears when echolocating, which provides the knowledge needed to improve the capabilities of acoustic detectors (Jones et al. 2007). Understanding population trends in any species is important for conservation purposes but monitoring population trends is especially important for bats due to the threats many of the species face from habitat loss and disease (Whitby et al. 2014). When monitoring bat species that are endangered or threatened, a comprehensive examination of species presence is needed, as failing to detect or capture one species can have severe consequences.

Recent technological advances have resulted in increased bat detector sensitivity and recording rate of ground-based acoustic detectors (Adams et al. 2012; Froidevaux et al. 2014). Even with recent advances, issues still arise when conducting acoustic monitoring, such as misidentification of bat calls and unknown detection distance of most detectors. Misidentification of bat calls has led to the research and development of more sophisticated software for automated call identification (Clement et al. 2014) in hopes of focusing conservation efforts in areas where populations are in peril. Each species of bat exhibits a wide range of calls and call structures, which are highly dependent on the ecological niche filled by that particular species and on the purpose of the call (Fenton et al. 2000; Jones et al. 2007). Calls are optimized depending on activity, such as foraging, navigation, or communication (Stahlschmidt et al. 2012). Foraging calls change depending on the environment in which the bat is foraging, such as an open field or a cluttered forest (Lacki et al. 2007; Hügel et al. 2017). However, even with increased detector sensitivity and better call identification, monitoring a flying species over a large spatial scale still limits the use of acoustic detectors for population monitoring. Monitoring a flying mammal with very directional echolocation calls from a stationary ground point greatly limits the area from which calls may be recorded.

With misidentification of bat calls being reduced through technological improvements and calls being species specific (Stahlschmidt et al. 2012), identification of bat populations in an area is possible using a single acoustic detector (Fenton et al. 2000; Lacki et al. 2007; Surlykke et al. 2008). With this specificity in species calls and the number of calls a single bat produces, there is a high likelihood of detecting multiple species of bats in a single night with a single acoustic detector (Adams et al. 2012). The problem with inconsistencies in sampling methodologies and the high spatial and temporal variability in a bat's activity level (Whitby et al. 2014; Froidevaux et al. 2014) still exists and needs to be addressed. Because the distance at which acoustic detectors can record bats is largely unknown (Hourigan et al. 2008), a detector placed at ground-level may not be recording all bats flying above its microphone, allowing for an incomplete documentation of bat species richness and biased estimates of activity levels as a measure of relative abundance. Detectors placed at altitudes above ground level (10m) and above tree canopy level (>30m) have recorded greater bat activity than those at ground level (Menzel et al. 2012). In order to address the issues of recording species with high variation in spatial activities and the unknown detection distances of acoustic detectors, we designed an Aerial Bat Detection Technology (ABDT) to record echolocation calls of bats in flight at various altitudes. The design of the ABDT was based on the Autonomous Aerial Acoustic Recording System (AAARS), which was designed to monitor threatened and endangered birds in inaccessible areas of military installations (Hockman 2018). The ABDT consists of a 300g weather balloon used to place an acoustic bat detector and data acquisition payload at various altitudes above ground level to record bats in flight. The payload contains a GPS unit for location tracking and failsafe devices to recover any lost balloons and transmit locations to a base station (Hockman 2018).

The objectives of this study were to:

1. Design and test a novel ABDT that could be flown at various altitudes to record bat echolocation calls; and
2. Test the capabilities of the ABDT as compared to ground-based monitoring by surveying bat populations at various DoD installations across the southeastern United States.

METHODS

Study Areas

Our study was conducted at 4 U. S. military installations across the southeastern United States: Big Oaks National Wildlife Refuge BONWR), Indiana (Formerly Jefferson Proving Grounds, a retired Army installation); Fort Leonard Wood (FLW), Missouri; Camp Robinson (CMPR), Arkansas; and Arnold Airforce Base (AAFB), Tennessee. Three study sites were selected within each of these 4 locations for a total of 12 study sites. Each study site was chosen based on its proximity to water, where insect swarms would be greatest to attract bats for monitoring and where there would be less structural clutter for initial ABDT testing (Hügel et al. 2017).

Acoustic Bat Sampling

From mid-May through mid-August 2016, depending on weather conditions and range operations, ground-based and aerial echolocation call monitoring was conducted at each installation for 5 to 6 days per month. Each installation was visited once per month and each of the 3 study sites within an installation were surveyed a minimum of 3 times per visit. This allowed for sampling at the 12 study sites at least 3 times per month, for a total of 36 sampling periods per month.

Aerial Acoustic Sampling- Aerial echolocation calls were collected by deploying the ABDT at altitudes between 25 – 100 m above ground level. Each ABDT consisted of a modified Pettersson D500X acoustic bat detector (Pettersson Elektronik AB, Sweden) attached to an electronic data acquisition payload suspended from a 300-gram, helium-filled weather balloon Hockman 2018), all of which was tethered to the ground using 75 lb braided fishing line. The tether attached to the ABDT was used to raise and lower the entire unit during each sampling period. The ABDT's payload contained GPS tracking, a modem for communication from a ground station that controlled the helium valves and location transmission, and an automatic recovery system that was based on GPS position in case the balloon broke tether. All components inside the payload of the ABDT were the same as those used in the AAARS (Hockman 2018), with modifications made to remove a ballast dropping system and to incorporate the Pettersson acoustic bat detector for echolocation monitoring. The GPS unit within the payload monitored the ABDT altitude and horizontal location throughout the night, with information saved on a mini SD card contained within the payload. The valve attached to the balloon could be opened and closed remotely in case an emergency dump of helium was required or for venting small amounts of helium to lower the balloon. These systems were all powered by an 8-volt battery contained within the payload. Real-time altitude and horizontal location data were transmitted from the payload via a RF module to a base station laptop computer. The computer software LabVIEW (National Instruments LabVIEW, Austin, TX) controlled the payload operation. Through LabVIEW, we could control the valves in the payload and put the balloon in emergency mode if it crashed or broke from tether.

The Pettersson D500X bat detector was modified for attachment to the payload to make it more lightweight and suitable for suspension from the balloon. All hardware was removed from the metal housing and the detector was placed into a lightweight plastic box. The microphone jack and D500x external microphone were attached to the bottom of the new housing and pointed downward towards the ground when in flight. All modified Pettersson units were tested before use to ensure consistent performance compared to unmodified units. These detectors were used to record bat calls throughout the night at varying altitudes. The detector was programed to start recording 15 minutes before sunset and ended recording after all sampling periods were completed. The total sampling period lasted 4 hours per night and sampling altitudes were 25 m, 50 m, 75 m, and 100 m. The ABDT was deployed for 30 min at each altitude, twice per night (i.e., total of 1 hr at each altitude/night). The order in which the four altitudes were monitored was randomized each night (i.e. the 25 m altitude was not necessarily always monitored first). Calls recorded during the times when the ABDT was being raised or lowered between altitude periods were not included in analysis. Calls recorded by the ABDT were stored on compact flash (CF) cards contained within the Pettersson unit.

Ground-Based Acoustic Sampling- A ground-based Pettersson D500X bat detector was placed under the tethered ABDT, with the detector's microphone placed on a 3-m pole at a 45° angle (Armitage and Ober 2012). GPS Coordinates for placement of the ground-based detector were recorded at the beginning of the study at each sampling site so that the detector could be placed in the same location during all subsequent sampling periods. Ground-based detectors were programmed to begin recording at the same time as the ABDT, 15 min before sunset, and ended recording when all recording periods for ABDT were completed. All calls recorded on the detector were also stored on CF cards.

Two different sites were sampled each night whenever possible, with one ABDT and one ground-based detector at each site. Time of sunset, site name, the number of the detector and payload used, wind conditions, start and stop times for each altitude interval and any abnormalities were recorded each night for each sampling location. The ABDT was returned to the ground once sampling at all altitude intervals was completed.

Data Analysis

All calls recorded by the ABDT and ground-based detector were batch processed through SonoBat (Szewczak 2010) to identify species and saved as Excel spreadsheets. Species were identified with >90% accuracy, according to SonoBat's call analysis software. Forty-four of the 62 sampling nights were retained for comparison, with 18 sampling nights being removed from analysis for technical issues, weather issues, or because range operations did not allow for sampling to take place. Data was tested for normality and a two-sampled t-test was conducted in Program R statistical software (R Development Core Team 2008) to examine differences in the number of calls and species recorded by the ABDT versus the ground-based detector. Sampling units were nights of successful simultaneous recording using both the ABDT and the ground-based detector (N = 44). To conduct the t-tests on the nightly total number of species and calls recorded by the ABDT compared to the ground-based detector, the total successful sampling nights (N= 44) were divided by successful sampling nights at each location for BONWR (n= 11), FLW (n= 12), CMPR (n= 10) and AAFB (n= 11).

The data for each night was broken down further to compare the number of calls collected by the ABDT at each altitude interval to calls collected by the ground-based detector during the corresponding hour. Two-tailed t-tests were used to test for differences. We also compared the number of high and low frequency calls recorded at each altitude interval to the number of high and low frequency calls recorded by the ground-based detector. Bat calls were classified as high frequency if they were identified by SonoBat as a *Myotis* species, *Lasiurus borealis* (LABO), *Nycticeius* humeralis (NYHU), or *Perimyotis* subflavus (PESU). Calls were classified as low frequency if they were identified as *Eptesicus fuscus* (EPFU), *Lasionycteris noctivagans* (LANO), *Corynorhinus rafinesquii* (CORA) and *Lasiurus cinereus* (LACI; Cox et al. 2016).

RESULTS

There were 44 successful nights of sampling from mid-May through mid-August 2016. For the entire sampling period (n= 44), a total of 2,490 calls were recorded by the ABDT, with a mean of 57.4 calls recorded per night. A total of 3,842 calls were recorded by the ground-based detector, with a mean of 87.3 calls recorded per night (Table 1). The total number of calls recorded over the sampling period decreased dramatically as the ABDT increased in altitude until the 100m altitude, when the number of calls recorded increased slightly (Figure 1). There was no difference in the total number of calls collected by the ABDT and the ground-based detector during the entire sampling period (P = 0.1223).

The total number of high and low frequency calls recorded by each method did not differ (P= 0.075) with the mean number of high and low frequency calls being 19.6 and 24.5, respectively. Of the 2490 calls recorded by the ABDT, 1984 were identified with >90% accuracy. Of these 1984 calls, 1102 (55.6%) were from low frequency species (EPFU, LANO, CORA, and LACI) and 882 (44.5%) were from high frequency species (*Myotis*, LABO, NYHU, and PESU. The number of high and low frequency calls recorded each hour by each method did not vary greatly, only changing when a species was recorded by the ABDT but missed by the ground-based detector and vice versa. Of the calls missed by the ABDT that were identified to the species level, 21 were classified as high frequency calls and 25 of them were classified as low frequency calls.
After separating the total calls into calls/hr, there was no difference in the ability of either method to record low or high frequency calls. There were some differences in the number of calls/hr at the various altitudes. The two-tailed t-tests showed no difference in the number of hourly calls for the ABDT at 25 m vs ground-based detector but the number of calls recorded were significantly lesser for the ABDT compared to the ground-based detector at greater altitudes (Table 7).

The total number of species recorded by the ABDT did not differ compared to the number recorded by the ground-based detectors (P= 0.6756). The average number of species recorded by the ABDT at each location varied as did the average number recorded by the ground-based detector (Figures 2 — 5). The average number of species recorded by the ABDT per night at each location was greater at CMPR and BONWR but less than the average number recorded by the ground-based detector at FLW and AAFB (Figure 6).

Overall, the ground-based detector recorded 10 species and the ABDT recorded 8 species (Table 2). Of the 44 total sampling nights, there were 20 nights where the ABDT recorded the same species as the ground-based detector, plus additional species missed by the ground-based detector (Tables 2 — 6). There were 11 days where different species were detected by the ground-based detector compared to the ABDT (i.e., the ground-based detector recorded species missed by the ABDT and the ABDT recorded some missed by the ground-based detector). There were 10 days where the ABDT and the ground-based detector recorded the same species. There were 3 days where the ground-based detector performed better than the ABDT (i.e., recorded the same species as the ABDT plus additional species missed by the ABDT).

DISCUSSION

This study serves as the first systematic test of a novel aerial acoustic bat detector's capabilities in recording bat calls at different altitudes for use by the DoD. It is also the first to compare the capabilities of an aerial acoustic bat detector with standard ground-based acoustic monitoring commonly used on DoD installations. Because the technology was new, additional evaluation is needed to develop an optimized aerial monitoring system. However, the results still provide compelling evidence that demonstrates the value of positioning acoustic detectors aloft when implementing a comprehensive bat monitoring strategy.

The ABDT provides a means to collect bat calls at altitudes unattainable when using only ground-based acoustic detectors. With a strong difference already present in an acoustic detector's ability to record bat calls based on frequency, distance and angle of the call (Adams et al. 2012), recording bat calls aerially will help provide a more complete species inventory. Most of the species that were missed on the ground-based detector were recorded at 50 m or higher, which may be out of the range of detection for a ground-based acoustic detector.

During multiple sampling days, several species of bats were recorded by the ABDT but not by the ground-based detector and some were recorded by the ground-based detector but not the ABDT with many of these species recorded at the 50 m altitude and above. Even though the ABDT recorded more calls at the 25 m altitude, most of the species missed by the ground-based detector were recorded at the 50 m and 75 m altitude. Some species such as *Myotis grisescens* (MYGR) were only recorded at 50 m and above, when the ground-based detector failed to record them, suggesting that some bats are not foraging low enough to be detected, or captured, using traditional ground-based methods. Of the 44 sampling nights, there were 3 nights where the ground-based detector recorded species that the ABDT missed, with these 3 nights having wind speeds >10.5 kph at ground level. Because of the increased ground-level wind speed, there may have been less bat activity since bats are known to forage less during adverse weather conditions (Dina et al. 2017). It is possible that the increased wind speed could have interfered with the recording capabilities of the detector (swaying of the ABDT on tether). There were 6 days (12%) not included in the

44-night analysis where ambient noise such as insect activity prevented the ground-based detector from recording echolocation calls clear enough to be identified using automated software.

Call frequency (i.e., high or low) did not seem to affect the performance of either the ABDT or the ground-based detector. Overall, there was only a slightly greater number of low-frequency calls recorded than high-frequency calls, which could be attributed to either detector capabilities or species composition in the sampling area. After separating the total calls into calls-per-hour, there was no difference in the ability of either method to record low or high frequency calls. The number of calls recorded per hour by the ABDT at the 25-m interval when compared to the data from the ground-based detector during the corresponding hour was very similar. There were decreases in detections per hour when the ABDT was at 50 – 100 m when compared to detections by the ground-based detector for the corresponding hours. This can possibly be attributed to greater bat activity at lower altitudes. While this data shows that a stationary ground-based detector will record more calls than a detector placed at greater altitudes, a more complete species richness may be obtained with a combination of both methods.

The ABDT, while providing valuable echolocation data, still has some limitations for bat monitoring. The device requires constant monitoring, unlike ground-based detectors that can be left unattended in the field, someone must always be present when using the ABDT. Any kind of adverse weather, such as winds, rain or mist, and atmospheric thermal inversions, will prevent the use of the ABDT or make it difficult to operate at a consistent altitude. The amount of helium used, and transportation of helium tanks must also be considered when using the ABDT. There is also the possibility of a balloon breaking or falling due various environmental hazards, atmospheric conditions such as thermal inversions or poor manufacturing, causing a loss of time and possibly data depending on the altitude and location of the ABDT. Also, with only one microphone on the unit, it is impossible to determine the exact altitude at which a bat was recorded, only altitude estimates can be obtained. These limitations should be considered before beginning surveys.

When using an aerial method for echolocation monitoring, a targeted altitude approach may be advantageous when monitoring for a single species. The altitude at which bats are recorded depends greatly on foraging activity of each species, making a varying altitude sampling regime somewhat detrimental for a targeted species approach. However, if the goal is to determine the species richness of an area, using an aerial method such as the ABDT at varying altitudes throughout the sampling period will be more successful. With foraging area size dependent on sex and species (Lacki et al. 2011), finding a targeted sampling location and altitude would be beneficial for a single-species study.

With many acoustic sampling plans, it is common practice to place more than one detector in a sampling area to increase the probability of detecting more species. However, this approach only increases the area sampled horizontally. When studying a volant species, it is important to know the volume of airspace being sampled and increase that sample area vertically whenever possible (Adams et al. 2012; Corben and Fellers 2001; Fenton 2000). Increasing the detection distance vertically is becoming important, especially where bat mortalities are being caused by above-ground structures, such as wind turbines. Many studies are using acoustic monitoring to sample not only areas where turbines are already present but also in areas proposed for wind turbine construction (Kunz et al. 2007). If ground-based methods alone are used, an incomplete profile of bat species richness and activity would be used in decisions regarding turbine siting. Poor siting decisions could have disastrous implications for some species which have already seen extremely high mortalities due to white-nose syndrome (WNS). Based on our results, implementing an aerial sampling component in any bat monitoring program would provide a non-invasive means to gather large quantities of data and obtain a better inventory of species richness in a given area.

In 2017, we received funding from DoD Environmental Security Technology Certification Program (ESTCP) to demonstrate a more advanced ABDT system with a payload that contains an acoustic sensor head containing 5 microphones. This sensor head is capable of recording calls detected by all 5 microphones simultaneously and increases the volume of airspace being monitored for bats. This project is ongoing and demonstration of the advanced ABDT system will occur at military installations during summer 2021.

PROJECT MILITARY BENEFIT

The results of this project indicate the ABDT may offer a new monitoring technique to better assess the presence and relative abundance of bat populations. As a result it may provide military installation land managers a more effective strategy to monitor populations and determine presence of at-risk species (TER-S) bats. This will allow them to more easily adhere to various environmental regulations governing TER-S species and help ensure military readiness and operations. The new advanced ABDT, which is being developed and demonstrated as part of a DoD ESTCP project will, based on its simpler functioning, improve accessibility and use by military installation personnel. Information on the ABDT will be disseminated to installations via factsheets and webinars. Trainings on the new advanced ABDT system can be requested once field demonstration have been completed.

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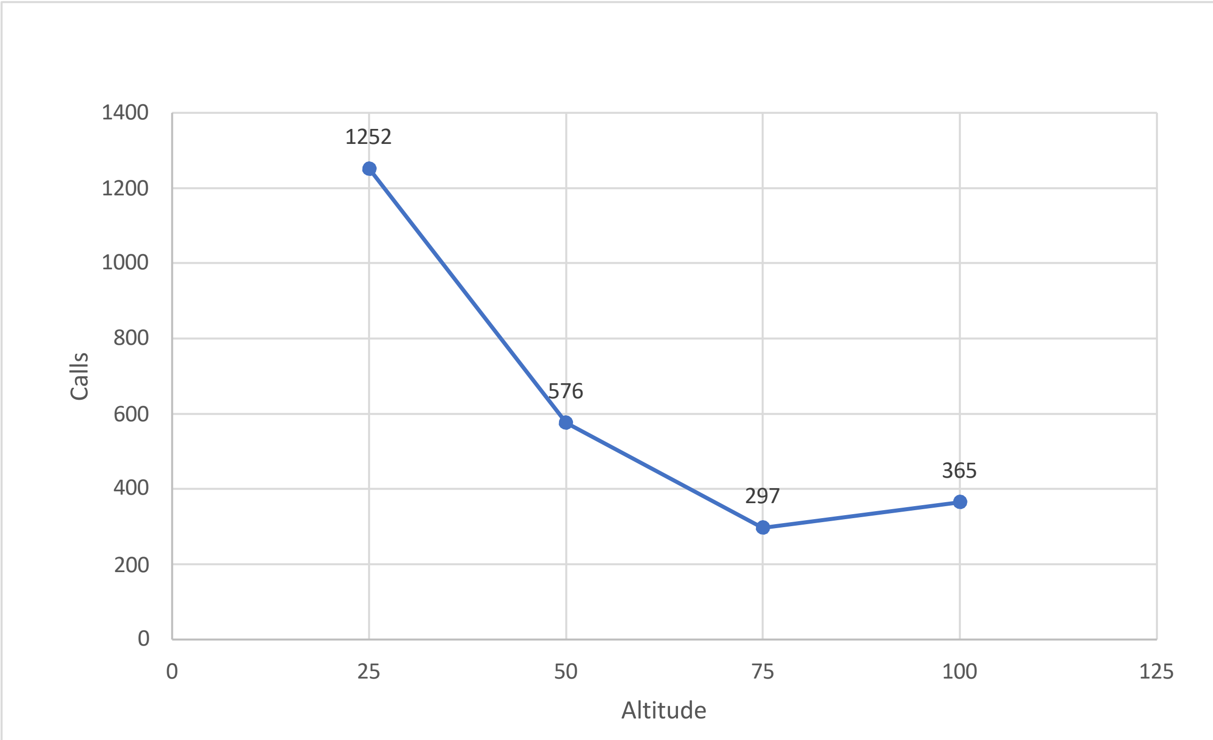

Figure 1: Total bat echolocation calls recorded by an Aerial Bat Detection Technology flown at 4 altitudes above ground level (25m, 50m, 75m and 100m) at Big Oaks National Wildlife Refuge, IN; Fort Leonard Wood, MO; Camp Robinson, AR; and Arnold Airforce Base, TN; summer 2016.

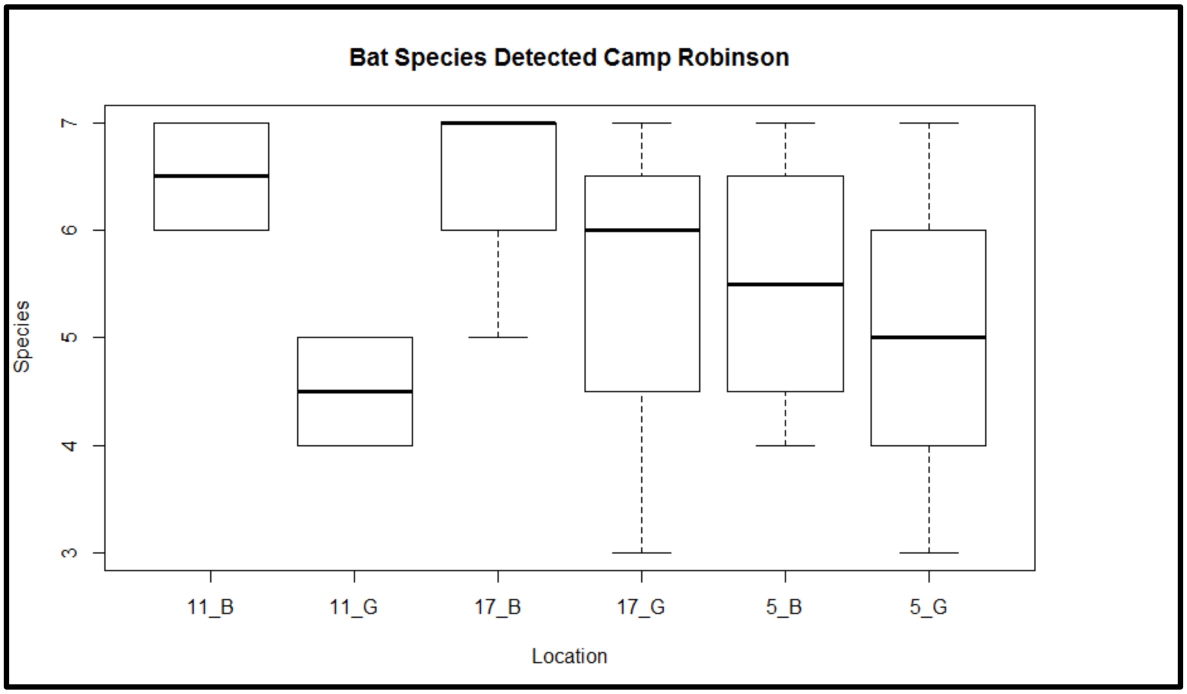

Figure 2: Number of bat species detected at Camp Robinson, AR by a ground-based acoustic detector (G) and the Aerial Bat Detection Technology (B) at each of three locations (sites 11, 17, and 5), summer 2016.

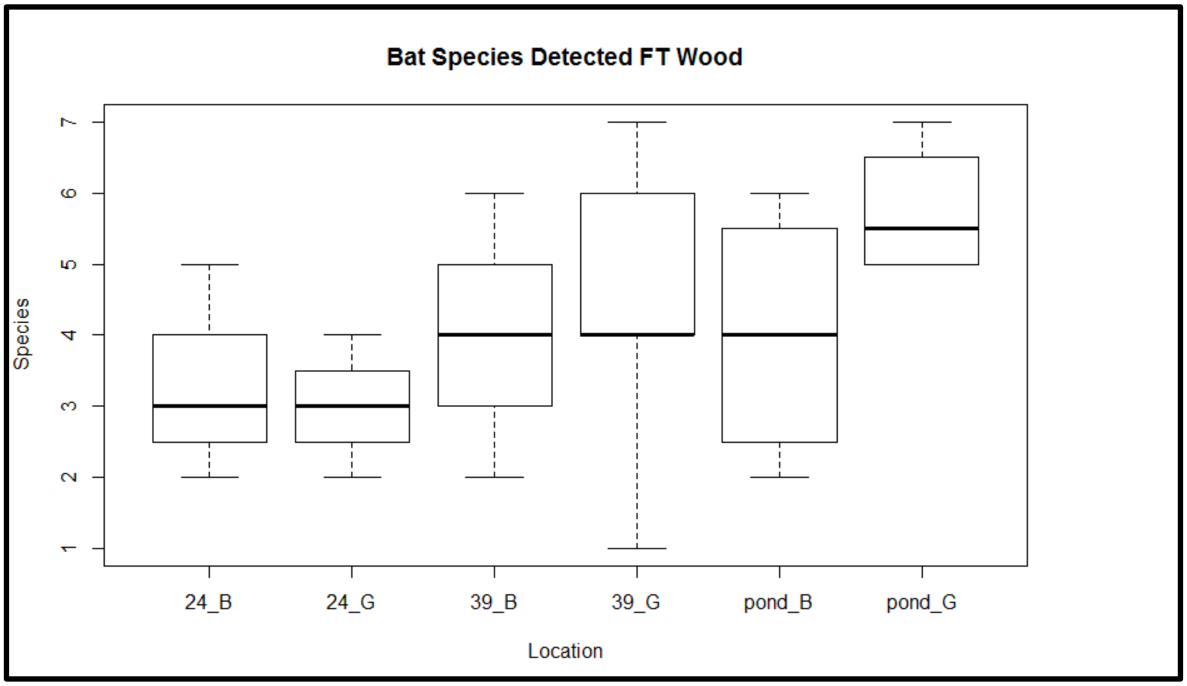

Figure 3: Number of bat species detected at Fort Leonard Wood, MO by a ground-based acoustic detector (G) and the Aerial Bat Detection Technology (B) at each of three locations (sites 24, 39, and McCaan Pond), summer 2016.

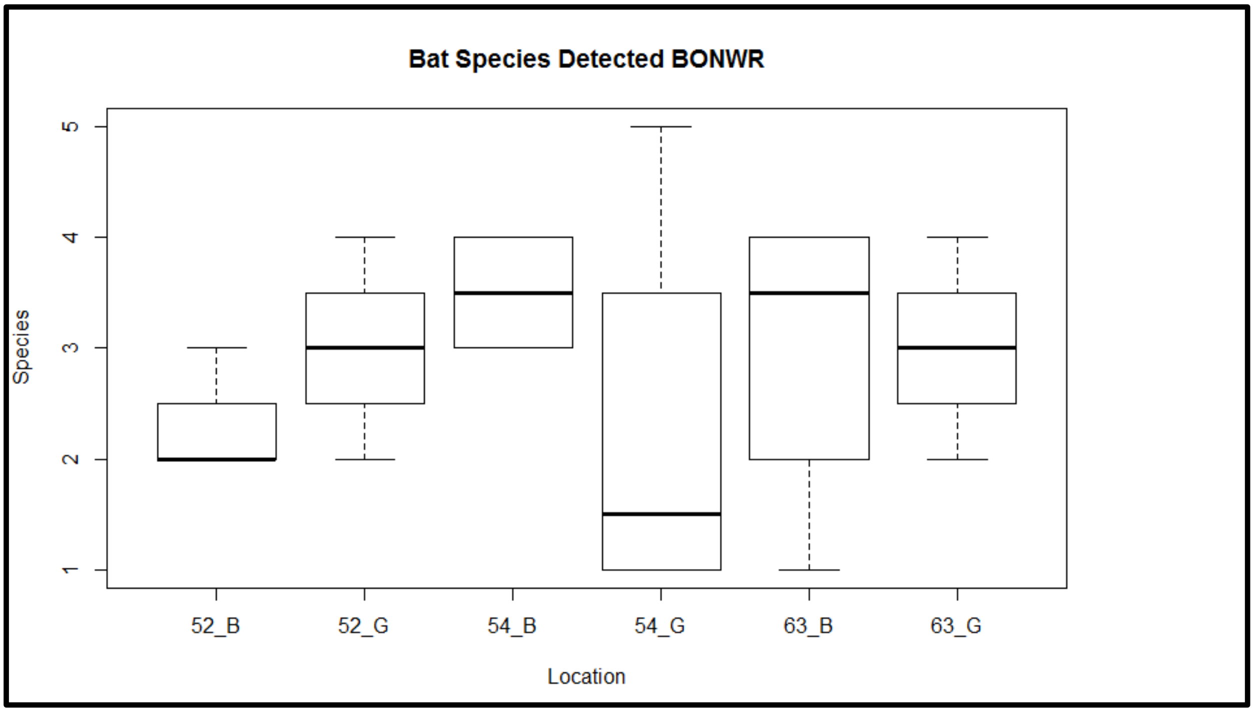

Figure 4: Number of bat species detected at Big Oaks National Wildlife Refuge, IN, by a ground-based acoustic detector (G) and the Aerial Bat Detection Technology (B) at each of three locations (sites 52, 54, and 63), summer 2016.

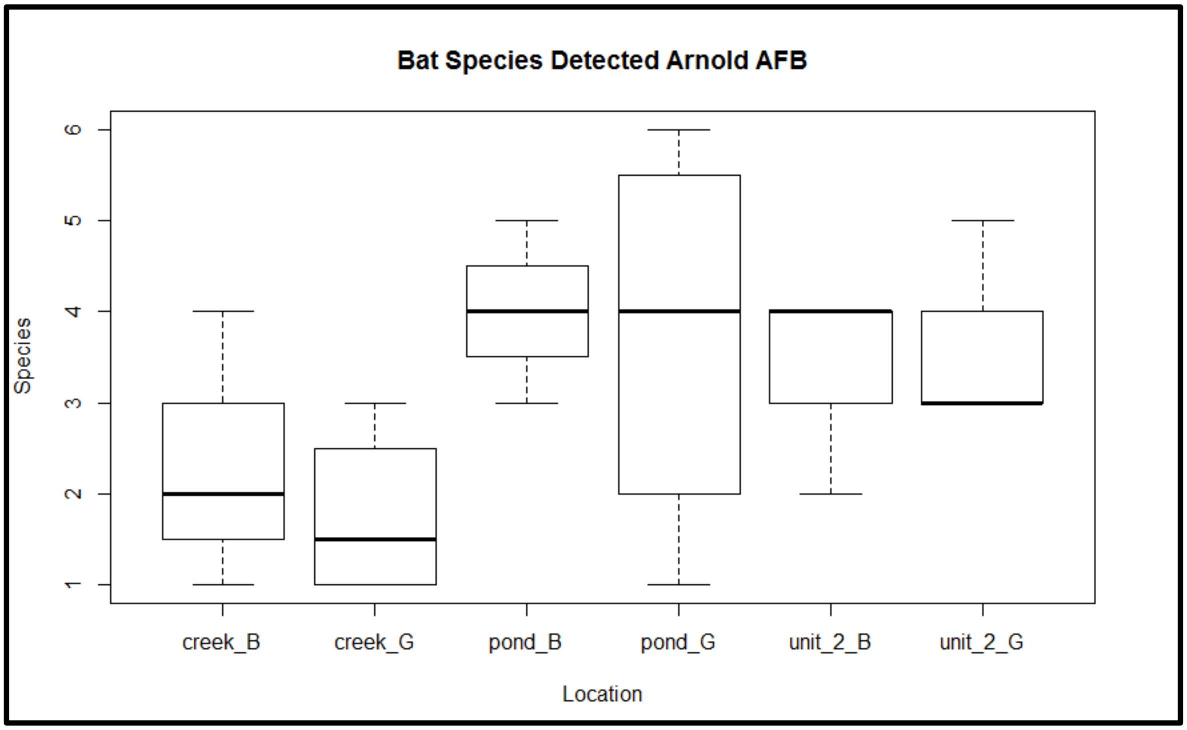

Figure 5: Number of bat species detected at Arnold Airforce Base, TN, by a ground-based acoustic detector (G) and the Aerial Bat Detection Technology B) at each of three locations (sites Huckleberry Creek, Sinking Pond, and Unit 2), summer 2016.

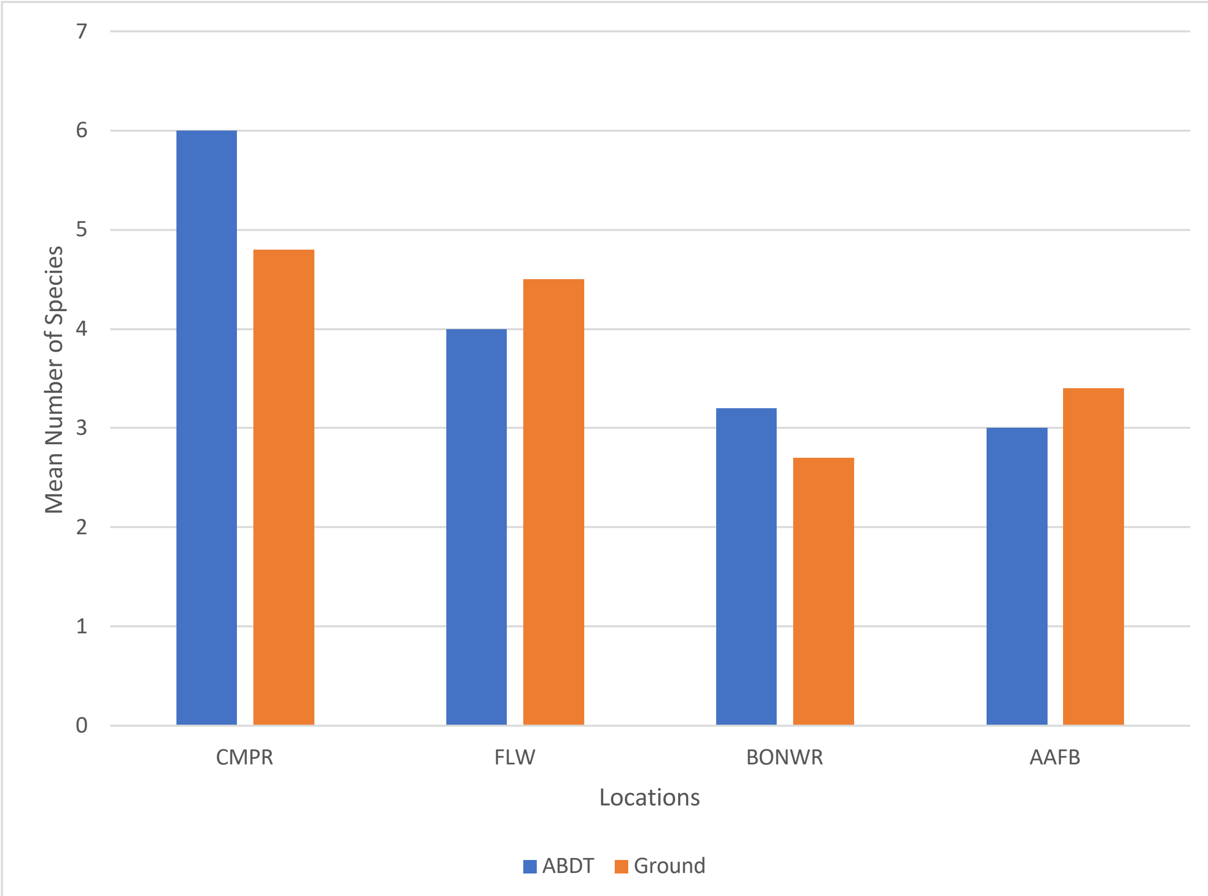

Figure 6: Mean number of bat species recorded per night by an Aerial Bat Detection Technology (ABDT) and a ground-based acoustic detector (Ground) at Camp Robinson (CMPR), AR; Fort Leonard Wood (FLW), MO; Big Oaks National Wildlife Refuge (BONWR), IN; and Arnold Airforce Base (AAFB), TN; summer 2016.

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Table 1: Total number of calls recorded at Big Oaks National Wildlife Refuge (BONWR), IN; Fort Leonard Wood (FLW), MO; Camp Robinson (CMPR), AR; and Arnold Airforce Base (AAFB), TN by an aerial bat detection technology (ABDT) and ground-based acoustic detector (ground), summer 2016.

Location	Total	Mean
BONWR		
ABDT	398	36.181
GROUND	536	48.727
FLW		
ABDT	599	49.917
GROUND	1382	91.7
CMPR		
ABDT	1245	65.88
GROUND	1461	73.21
AAFB		
ABDT	248	28.4
GROUND	463	46.3

Table 2: Bat species recorded at Big Oaks National Wildlife Refuge, IN; Fort Leonard Wood, MO; Camp Robinson, AR; and Arnold Airforce Base, TN by an Aerial Bat Detection Technology (ABDT) and ground-based acoustic detector (Ground), summer 2016.

Species	
Ground	**ABDT**
Eptesicus fuscus	*Eptesicus fuscus*
Lasiurus borealis	*Lasiurus borealis*
Lasiurus cinereus	*Lasiurus cinereus*
Lasionycteris noctivagans	*Lasionycteris noctivagans*
Myotis grisescens	*Myotis grisescens*
Myotis leibii	None
Myotis sodalis	None
Nycticeius humeralis	*Nycticeius humeralis*
Perimyotis subflavus	*Perimyotis subflavus*
Corynorhinus rafinesquii	*Corynorhinus rafinesquii*

Table 3: Species recorded by an Aerial Bat Detection Technology that were not recorded by a ground-based acoustic detector at Camp Robinson, AR, summer 2016.

Date	Sample area	Species[1]	Altitude (m)
13-JUN-16	TA11	MYGR	50
13-JUN-16	TA11	LANO	100
14-JUN-16	TA17	MYGR	100 and 75
13-JUL-16	TA17	LACI	75
13-JUL-16	TA17	NYHU	75
16-JUL-16	TA11	LACI	25,50, and 75
16-JUL-16	TA11	LANO	75
11-AUG-16	TA5	LANO	100
12-AUG-16	TA17	LANO	50
12-AUG-16	TA17	CORA	50 and 75
12-AUG-16	TA5	EPFU	25, 50, and 75

[1]MYGR= *Myotis grisescens,* EPFU= *Eptesicus fuscus,* LACI= *Lasiurus cinereus,* NYHU= *Nycticeius humeralis,* LANO= *Lasionycteris noctivagans,* CORA= *Corynorhinus rafinesquii*

Table 4 Species recorded by an Aerial Bat Detection Technology that were not recorded by a ground-based acoustic detector at Fort Wood, summer 2016.

Date	Sample area	Species[1]	Altitude (m)
8-JUN-16	Range 24	MYGR	75
8-JUN-16	Range 24	PESU	50
8-JUN-16	Range 24	NYHU	75
2-AUG-16	Range 39	CORA	50
2-AUG-16	Range 39	LANO	50
3-AUG-16	Range 24	NYHU	75
6-AUG-16	McCaan Pond	LANO	100

[1]MYGR= *Myotis grisescens,* NYHU= *Nycticeius humeralis,* LANO= *Lasionycteris noctivagans,* CORA= *Corynorhinus rafinesquii*, PESU= *Perimyotis subflavus*

Table 5: Species recorded an Aerial Bat Detection Technology that were not recorded by a ground-based acoustic detector at Big Oaks National Wildlife Refuge (BONWR), IN, summer 2016.

Date	Sample area	Species[1]	Altitude (m)
25-JUN-16	TA 63	PESU	100 and 25
25-JUN-16	TA 63	PESU	75
26-JUN-16	TA 63	LANO	75
27-JUN-16	TA 52	LANO	75
27-JUN-16	TA 54	LANO	75
27-JUN-16	TA 54	LACI	75 and 25
30-JUL-16	TA 52	LABO	50
31-JUL-16	TA 63	LABO	25
31-JUL-16	TA 63	LABO	100

[1]LANO= *Lasionycteris noctivagans,* PESU= *Perimyotis subflavus,* LABO= *Lasiurus borealis,* LACI= *Lasiurus cinereus*

Table 6: Species recorded by an Aerial Bat Detection Technology that were not recorded by a ground-based acoustic detector at Arnold Airforce Base (AAFB), TN, summer 2016.

Date	Sample area	Species[1]	Altitude (m)
16-JUN-16	Sinking Pond	PESU	100
21-JUL-16	Unit 2	LABO	50 and 25
21-JUL-16	Unit 2	LACI	75
22-JUL-16	Unit 2	LANO	50 and 25
22-JUL-16	Unit 2	CORA	100
17-AUG-16	Sinking Pond	LABO	50
17-AUG-16	Sinking Pond	NYHU	50
17-AUG-16	Sinking Pond	PESU	50
19-AUG-16	Huckleberry Creek	LABO	50

[1]NYHU= *Nycticeius humeralis,* LANO= *Lasionycteris noctivagans,* CORA= *Corynorhinus rafinesquii*, PESU= *Perimyotis subflavus,* LACI= *Lasiurus cinereus,* LABO= *Lasiurus borealis*

Table 7 Comparison of the number of bat calls recorded per hour by an Aerial Bat Detection Technology (ABDT) and ground-based acoustic detector (Ground) at Big Oaks National Wildlife Refuge, IN, Fort Leonard Wood, MO, Camp Robinson, AR, and Arnold Airforce Base, TN, summer 2016.

	Mean Number of Calls		
Altitude	**ABDT**	**Ground**	***P***
25m	27.8	25.8	0.697
50m	12.6	22.0	0.017
75m	6.6	22.3	0.001
100m	8.1	18.0	0.005