

Introduction

Bat species benefit human societies and biological systems by being indicators of ecosystem health and providing biological control over problem insect species (Boyles et al. 2011; Kunz et al. 2011). In the last decade, populations of bat species in the United States and Pennsylvania have declined dramatically with the onset and spread of the fungal white-nose syndrome (WNS) (*Pseudogymnoascus destructans*) (Turner et al. 2011, USFWS 2015). The conservation of remnant bat colonies is an increasing priority for research throughout Pennsylvania and North America (Loeb et al. 2015) (Figure 1).

Remote monitoring efforts to identify bat species activity based on recording of bat feeding vocalizations can reduce labor costs in identifying important bat areas. Specific bat species vocalizations can be detected and recorded by ultrasonic microphones and analyzed using automated species identification software (Arnett et al. 2013). The goal of this project was to assess bat species activity, diversity and community similarity for protected areas along the Kittatinny Ridge of Pennsylvania (Figure 2). An additional objective was to establish a permanent data collection kiosk at Hawk Mountain Sanctuary for long-term monitoring and public bat education and outreach (Figure 3).

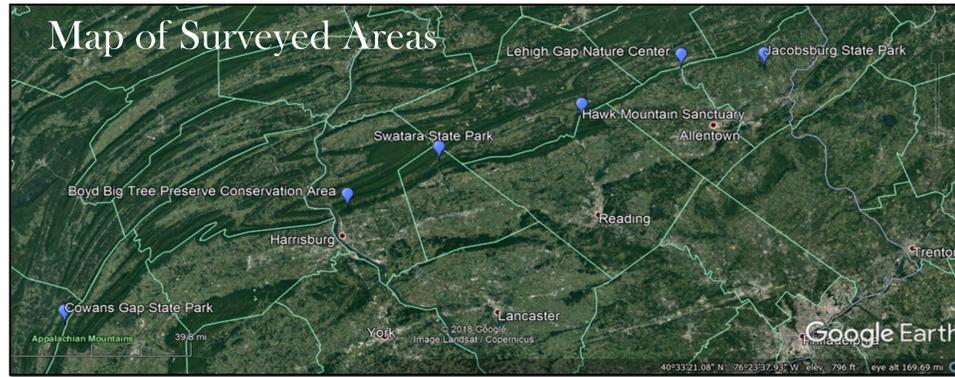


Figure 2. Survey site locations along the Kittatinny Ridge.



Figure 4. Detector locations within each surveyed area.

Methods

Bat surveys were conducted using D500X ultrasound bat recording units (Pettersson Elektronik AB, Uppsala, Sweden; Figure 3) to remotely survey 1 location in each protected area for at least 26 survey nights. Recording devices were placed in areas most suitable for bat ultrasound detection (i.e., free from obstruction within a potential bat feeding flyway; Figure 4). The microphone pole was attached to the trunk using zip ties so that the microphone was ≥ 2.5 meters off the ground, with the external Pettersson recording hard drive stored in a waterproof tackle box (Figure 4). The Pettersson units were formatted to automatically turn on and begin recording data 30 min before sunset, until 30 min after sunrise to record bat foraging activity (Henry 2002; Kunz 1973, USFWS 2018). Once the units were collected from the field, the generated files were downloaded and analyzed using SonoBat auto-classification software (<https://sonobat.com/>) (Figure 3). The SonoBat data wizard scrubbed, batched, and parsed out files above 20 kHz that had bat tonal features. We batched bat acoustic files and appended each file with a species-specific identifier code based on the degree of maximum likelihood of species detection (Table 1).

Results

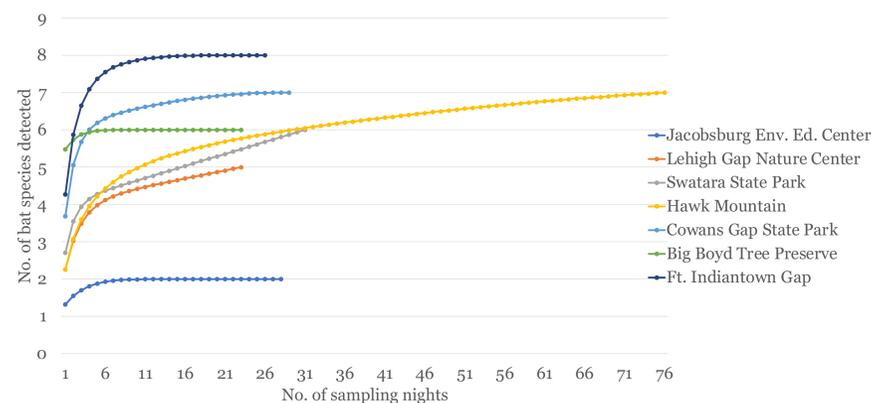


Figure 5. Equipment used in the field to record bat vocalizations.

Results Continued

Table 1. Results for remote acoustic survey of 6 natural areas along the Kittatinny Ridge of Pennsylvania.

Natural Area	Survey Nights	Number of Calls Recorded Per Species										Total Identified Calls	Bat Calls /Night
		Big brown	Red	Hoary	Silver-haired	Evening	Tri-colored	Small-footed	Little brown	Long-eared	Myotis spp.		
1) Cowans Gap	31	1141	114	69	45	16	2	-	31	-	1	1419	46
2) Swatara	26	2144	39	113	121	-	5	-	-	-	2	2424	93
3) Boyd Big	26	3867	697	776	684	-	498	-	20	-	-	6542	252
4) Jacobsburg	31	879	24	-	-	-	-	-	-	-	-	903	29
5) Lehigh Gap	26	2313	14	41	30	-	-	-	-	-	1	2399	92
6) Hawk Mountain	82	1205	141	26	57	-	7	3	-	1	-	1441	18

Table 2. Bat community analysis in natural areas along the Kittatinny Ridge of Pennsylvania. Diversity and mean community similarity indices were calculated in the R 'vegan' package. *Data for *Myotis* spp. were not included in these calculations.

Natural Area	Species Richness	Shannon Diversity Index*	Simpson Diversity Index*	Jaccard Mean Community Similarity Index*
1) Cowans Gap	7	0.776	0.342	46%
2) Swatara	6	0.480	0.211	47%
3) Boyd Big	6	1.252	0.608	74%
4) Jacobsburg	2	0.123	0.052	57%
5) Lehigh Gap	5	0.189	0.069	47%
6) Hawk Mountain	7	0.621	0.288	45%

Discussion & Recommendations

Based on our survey results, we found the Boyd Big Tree Preserve contained the greatest amount of bat activity with high species richness, the greatest species diversity and only one of two sites where the Little brown bat was detected (Table 1 & Table 2). Cowans Gap State Park had the highest species richness, high species diversity and contained rare bat species including the Little brown bat, Evening bat (*Nycticeius humeralis*), Eastern small-footed bat (*Myotis leibii*), and Northern long-eared bat (Table 1 & Table 2). Species accumulation curves reached an asymptote for each survey site (Figure 5).

Populations of rare bat species will have to be verified via trapping efforts in the natural areas. Once populations have been confirmed, management efforts should then be taken to maintain and increase populations to protect roosting and feeding sites. Such management actions would include hibernacula protection, increasing diversity of native forest tree species, increasing structural diversity of snag trees and roost trees, increasing age-class diversity of forest stages and increasing landscape-level diversity to vary the composition of forest and freshwater resources.

Acknowledgements

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Figure 1. Bat Species of Conservation Concern, defined as a species whose populations are classified as vulnerable to extinct and for which Pennsylvania has a high responsibility for its persistence as identified by the Pennsylvania Game Commission (2015).



Figure 3. Equipment and software utilized in this project.