Acoustic bat survey kiosk for public outreach and research

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Abstract: The negative stereotypes and myths associated with bats can adversely affect efforts toward their conservation. A way to overcome these preconceived notions is through environmental education and public outreach. The goal of this project was to establish a system for monitoring bat activity at Hawk Mountain Sanctuary, with a component of environmental education included. This was accomplished through the establishment of a bat acoustic detector at Hawk Mountain Nature Center that was linked to a publicly accessible, interactive kiosk. The Hawk Mountain Bat Kiosk runs automated species identification software that compiles nightly bat activity into reports so that visitors can learn about the bat species that were present in the area the night before. The data were saved and analyses run to determine activity trends, indices of diversity, and species richness. We hope to establish additional kiosks to continue monitoring bats and provide public outreach for bat conservation education.

Keywords: bat, acoustic monitoring, education, kiosk, survey

The ecological and economic benefits provided by bats are numerous, including seed dispersal, pollination, insect suppression, nutrient distribution, and contribution to the maintenance of global biodiversity (Kunz et al. 2011; Fenton et al. 2020). To replace the agricultural insect pest control provided by bats in

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North America alone would cost $22.9 billion/year (Boyles et al. 2011). Despite the integral role that bats play in their ecosystems, they face many compounding threats that have led to contractions and extinction of local populations (Frick et al. 2010; Ingersoll, Sewall, and Amelon 2013; Alves, Terribile, and Brito 2014). Threats include disease (e.g., white-nosed syndrome), destruction of old growth forests, modification and loss of hibernacula, climate change, and accumulation of environmental pollutants (Alves, Terribile, and Brito 2014; Gannon and Bovard 2016).

A less seen threat to bat species is the imposed stigma put upon them through popular culture and media based on their relatively cryptic life history and claims as major vectors of human disease, such as rabies (Olnhausen and Gannon 2004) and coronavirus disease 2019 (Fenton et al. 2020). A lack of knowledge of bat biology and the ecological services of bats hinders bat conservation, particularly in terms of funding and public support (Frick, Kingston, and Flanders 2019). It also leads to unnecessary reprisal and eradication of their populations (Hoffmaster, Vonk, and Mies 2016). The first step in combating these stigmas is through environmental education and public outreach. Trewhella et al. (2005) conducted a study of environmental education programs on western Indian Ocean islands, home to three species of critically endangered fruit bats. Postprogram success was evaluated, and the findings showed an increased awareness of bat biology, local participation in bat survey work, establishment of new reserves with protection of old growth forests, and the foundation of community-based environmental groups to regulate hunting and enact measures of protection (Trewhella et al. 2005).

Nature and environmental education visitor centers provide a unique opportunity to reach a diverse audience and allow visitors to learn about and engage with nature and promote environmentally responsible behavior (Nisbet, Zelenski, and Murphy 2009). These centers can provide interactive displays and exhibits that improve the public's understanding of environmental issues (McCrudden and Rapp 2017). By analyzing postvisit surveys, Falk and Storksdieck (2005) found that time and intensity of public exhibit engagement were positively correlated to increased knowledge of science. The use of high-quality and interactive displays in nature centers can serve to provide desired environmental connection between the public and wildlife (Falk and Storksdieck 2005; McCrudden and Rap 2017; Browning et al. 2018). For example, in the United States, Whiting, Doering, and Pennock (2019) used an ultrasound bat detector to increase public education about bats at the Idaho Falls Zoo. During the monitoring period, zookeepers held weekly presentations to discuss with visitors the importance of bat conservation and their monitoring efforts. Engaging exhibits such as this can result in an increased retention of

presented information and foster a positive attitude toward local populations of bats (Whiting, Doering, and Pennock 2019).

The goal of this study was to establish a unique interactive acoustic monitoring system of bat activity at Hawk Mountain Sanctuary, which has been identified as an important mammal area in the state of Pennsylvania, and has a long history of public education and conservation (Hawk Mountain Global Raptor Conservation 2021). The first objective of this study was to install a permanent acoustic bat detector device with remote data download capabilities to monitor bat activity as part of an interactive kiosk in the Hawk Mountain Nature Center. The second objective was to use data recorded at the bat kiosk to identify active bat species and quantify their monthly and nightly activity patterns around the nature center for summer and fall 2019.

MATERIALS AND METHODS

The Hawk Mountain Sanctuary Nature Center is located in Kempton, Pennsylvania along the Kittatinny mountain range. The auditory data collection unit was located on the roof (figure 1) of the Nature Center, and consisted of an AR125EXT microphone (Binary Acoustic Technology, Tucson, AZ) connected by 100' of ethernet to a Beelink mini-PC running a user-friendly version of

Figure 1. Placement of the ultrasonic AR125EXT microphone (Binary Acoustic Technology, Tucson, AZ) located on the roof of the Hawk Mountain Sanctuary Nature Center located along the Kittatinny Mountain Ridge in Kempton, Pennsylvania.

an automated acoustic bat identification program called SonoBatLIVE (Acadia, CA; https://batmanagement.com/products/sonobatlive). The AR125EXT had a 1-kHz to 125-kHz frequency range and a 90-dB dynamic range. The microphone was situated at a 45° angle to the sky to increase the amount of surveyed airspace and the quality of recordings (figure 1). The auditory unit began recording 30 min prior to sunset and continued to record data until 30 min after sunrise to capture bat nocturnal foraging activity. For this project, a recording length of 4 s and a sampling frequency of 300 kHz was used to detect bat feeding vocalizations.

To serve as a bridge between scientific research and dissemination of that research to a nonscientific audience, at night, SonoBatLIVE constantly analyzed incoming ultrasonic sound streams picked up by the microphone. SonoBatLIVE automatically separated recorded audio files containing bat call features from noise files to select those that met the quality threshold for bat call identification. Only high-quality calls with a frequency of ≥20 kHz were considered for analysis. SonoBatLIVE ranked potential bat calls in each audio file according to strength, completeness, and clarity. Based on a library of known bat species calls, the program then compared the structural and tonal features of high-ranked calls with the library and, if possible, attributed a species name to recorded bat calls based on the maximum likelihood of appropriate identification (acceptable call quality = 0.60, sequence decision threshold = 0.90; figure 2). Attributed bat calls were recorded on the kiosk mini-PC hard drive. We verified species identification by visually comparing identified call structure with a library of known calls.

Identified calls were displayed visually in spectrogram form (figure 2). These spectrograms were compiled into nightly reports that were browsed by visitors the next day to show which bat species were present in the area the previous night. The display interface also contained pictures of the bats found in Pennsylvania, as well as some biological and ecological information on their critical role in proper ecosystem functioning (figures 3 and 4).

The SonoBatLIVE program allowed remote data download capabilities and saving information on the date and time of each identified call. The bat kiosk system was also online, which allowed remote download through the TeamViewer program (TeamViewer n.d.). Data recorded remotely from the Hawk Mountain Bat Kiosk saved time and resources compared to manually collecting and downloading data. Downloaded auditory bat call data were analyzed to determine bat species, species richness, and Shannon species diversity

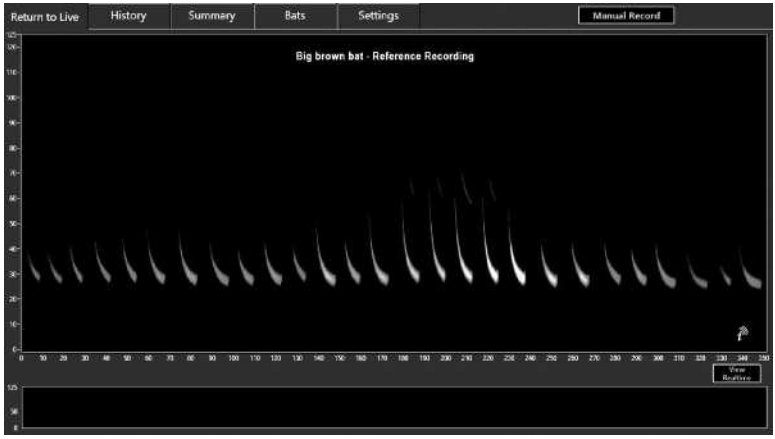

Figure 2. Spectrogram of a big brown bat (*Eptesicus fuscus*) from the reference library of SonoBatLIVE. The height of the call structure indicates the frequency range; the length indicates time and color indicates call intensity (i.e., volume).

Figure 3. Interactive screen of the Hawk Mountain Bat Kiosk displaying the program SonoBatLIVE and a reference screen for natural history information on native bat species.

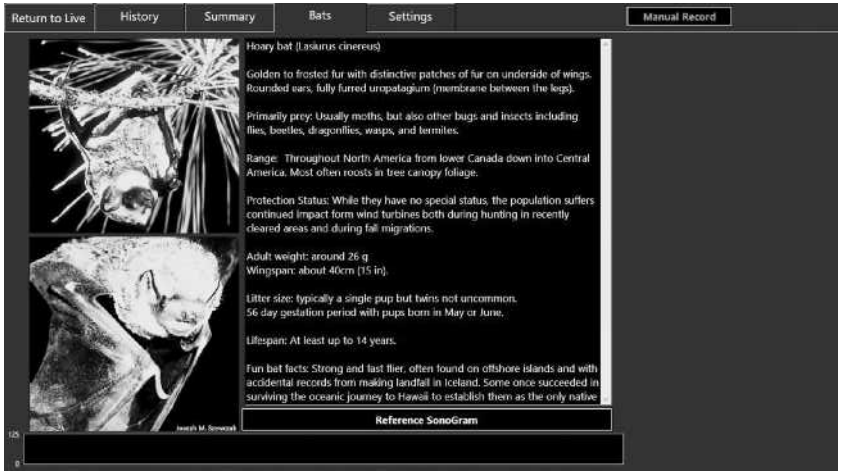

Figure 4. Hawk Mountain Bat Kiosk reference page for natural history information on the hoary bat (*Aeorestes cinereus*).

indexes. We analyzed bat call data to determine monthly and nocturnal trends in bat activity through the summer and fall season of 2019. Due to power outages within the Nature Center caused by severe thunderstorms, the unit did not collect data on the following dates: June 9 to July 21, 2019; August 30 to September 7, 2019; September 17 and 18, 2019; and September 21 to October 6, 2019.

RESULTS AND DISCUSSION

From June to November 2019, the Hawk Mountain Bat Kiosk identified 730 total bat calls to species over 63 evenings, with a mean of ≈13 identified calls/evening for seven, possibly eight, identified species of bats: big brown bat (*Eptesicus fuscus, "Epfu"*), eastern red bat (*Lasiurus borealis, "Labo"*), silver-haired bat (*Lasionycteris noctivagans, "Lano"*), little brown/Indiana bat (*Myotis lucifugus* and/or *Myotis sodalis, "Luso"*), hoary bat (*Aeorestes cinereus,* "*Aeci*"), eastern small-footed bat (*Myotis leibii, "Myle"*), and tricolored bat (*Perimyotis subflavus,* "*Pesu*"). (See Table 1.) The vocalizations of the little brown and Indiana bats are very similar and thus difficult to discern using the SonobatLIVE program, as well as manual vetting. Therefore, we were unable to determine if only one or both species were present. The State Wildlife Action Plan for Pennsylvania has listed the big brown bat, tricolored bat, eastern small-footed bat, Indiana bat, little brown bat, and silver-haired bat as species of greatest conservation concern (PGC-PFBC 2015). Four of these species were

Table 1. Mean number of identified bat calls per month (with standard error) based on recordings from the Hawk Mountain Bat Kiosk, Kempton, PA, June–October 2019

		Mean number of identified bat calls/evening/bat species (standard error)									
Month	*Number of evenings with identified recorded bat calls*	*Epfu*	*Labo*	*Lano*	*Luso*	*Aeci*	*Myle*	*Pesu*	*Total mean identified bat calls/ evening*	*Species richness*	*Species diversity*
June	5	3.80	0.60	0.20	0.00	0.00	0.00	0.00	4.60	3	0.56
		(0.73)	(0.40)	(0.20)	(0.00)	(0.00)	(0.00)	(0.00)			
July	10	2.70	0.20	0.20	0.00	0.00	0.10	0.00	3.20	4	0.60
		(0.83)	(0.20)	(0.13)	(0.00)	(0.00)	(0.10)	(0.00)			
August	29	6.45	1.28	0.66	0.03	0.03	0.03	0.03	8.52	7	0.78
		(1.47)	(0.33)	(0.19)	(0.03)	(0.03)	(0.03)	(0.03)			
September	10	36.70	0.10	0.70	0.00	0.00	0.00	0.00	37.50	3	0.11
		(14.48)	(0.10)	(0.40)	(0.00)	(0.00)	(0.00)	(0.00)			
October	9	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.22	1	0.00
		(0.00)	(0.15)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)			
Mean	12.80	9.93	0.48	0.35	0.01	0.01	0.03	0.01	10.81	3.60	0.41

Note: Epfu = big brown bat, Labo = eastern red bat, Lano = silver-haired bat, Luso = little brown and/or Indiana bat, Aeci = hoary bat, Myle = eastern small-footed bat, Pesu = tricolored bat.

* Shannon Diversity Index.

definitively documented in our data. The Indiana, little brown, and tricolored bats are listed as endangered in the state of Pennsylvania (Pennsylvania Game Commission 2021), and the Indiana and northern long-eared bats are federally listed under the Endangered Species Act (ECOS Environmental Conservation Online System, U.S. Fish and Wildlife Service n.d.).

Since individual bats cannot be identified based on collected audio data, we used the number of collected calls to serve as an index of bat activity. We recorded the greatest number of identified calls for big brown, red, and silver-haired bats (figure 5A) and found that big brown activity peaked 0–2 h after sunset, while red and silver-haired bats exhibited no distinct nocturnal activity patterns. Our results were similar to those of Brooks (2009), Johnson, Rodrigue, and Ford (2013), and Schimmp, Li, and Kalcounis-Rueppell (2018), who found that big brown bat activity peaked early in the evening, with a reduction in activity through the night. In addition, Johnson, Rodrigue, and Ford (2013), Adams et al. (2015), and Schimmp, Li, and Kalcounis-Rueppell (2018) found that rural red bats did not exhibit distinct nocturnal activity patterns in the fall. Schimmp, Li, and Kalcounis-Rueppell (2018) found that both big brown and silver-haired bats reduced their activity through the evening in response to reduced prey activity; however, we did not find a distinct nocturnal activity pattern for silver-haired bats. This may have been due to our small sample size of silver-haired bat calls (figure 5A) and to temperature appearing more of a predictor of bat nocturnal activity than number of hours after sunset (Schimmp, Li, Kalcounis-Rueppell 2018; Muthersbaugh et al. 2019).

We found that bat species richness and diversity peaked during the month of August (Table 1), with the greatest number of mean identified bat calls per evening recorded in September (primarily big brown bat calls) and a cessation in recorded mean bat calls occurring in October, with no identified calls in November (Table 1). Muthersbaugh et al. (2019) documented the greatest bat activity in early autumn, when big brown bat activity was more prevalent than that of *Myotis* spp., which have greater activity in the summer. Both Reimer et al. (2014) and Muthersbaugh et al. (2019) reported a cessation of foraging activity in October. In comparison, Brooks (2009) reported the highest levels of bat activity in early summer, the lowest in late summer, and intermediate levels in late spring. This was observed for both large-bodied and *Myotis* bats. Brooks (2009) stated that increased activity in early summer corresponds to increased foraging activity by females to meet the energy requirements of lactation after birthing pups, while low activity levels in early fall could be attributable to migration to regional winter hibernacula. We also found that bat nocturnal activity during early summer (June–July) differed from that observed in early fall (August–September; figure 5B). Breeding activity,

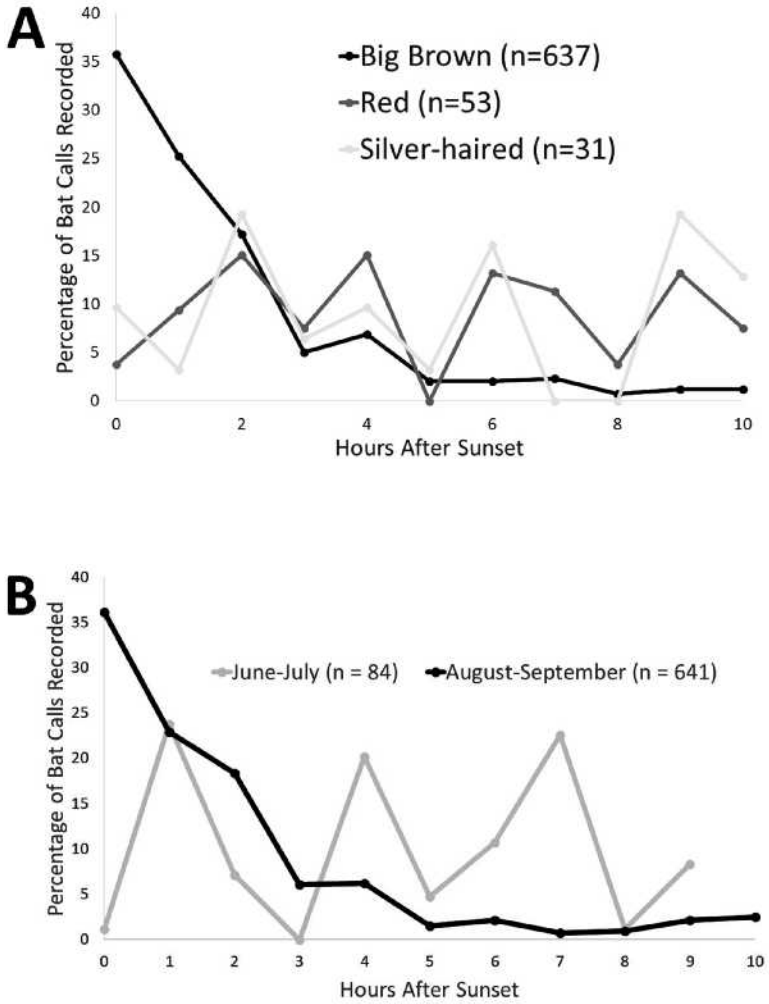

Figure 5. Percentage of recorded bat calls for each nocturnal hour (i.e., hours after sunset, where 0 = sunset) showing relative activity for (A) big brown, red, and silver-haired bats recorded at the Hawk Mountain Bat Kiosk from June to October 2019 with number of recorded calls indicated and (B) the relative activity of all species during the breeding period (June–July 2019) compared with early migration (August–September 2019).

which includes maternity colony activity, parturition, and early juvenile activity, required bats to feed during more hours of the evening than in early fall (August–September), which is associated more with migratory behavior

(Brooks 2009). However, thunderstorms that caused electrical power outages at the Nature Center created large gaps in our survey periods. This inconsistency in number of evenings with identified recorded bat calls (Table 1) may have limited our estimates of bat species richness and diversity during early summer as well as of observed nocturnal activity patterns (figure 5B). Thus, we recommend additional monitoring efforts to verify bat activity patterns, including estimates in species richness and diversity.

The Hawk Mountain Bat Kiosk will continue to collect bat call data, and we plan to archive data to monitor and detect changes in bat populations over a larger temporal scale. We also plan to determine species-specific seasonal trends in activity such as during spring or early summer to document potential spring migration return of bats to their summer maternity grounds. In addition, results from this study and future monitoring efforts will be reported on the Bat Acoustic Monitoring Portal (BatAMP; see BatAMP 2021).

Based on bat species detected by the Hawk Mountain Bat Kiosk (Table 1), we recommend that the following management activities be considered to improve bat habitat around the Hawk Mountain Nature Center. Any caves and crevices found to be bat hibernacula should be sealed with exclusionary gating to prevent entry and limit anthropogenic spread of disease such as white-nose syndrome or WNS (Pennsylvania Game Commission and Pennsylvania Fish & Boat Commission 2015; Hefferman and Turner 2016). Management efforts that minimize disturbance to hibernating bats are critical to reduce overwinter mortality, particularly in WNS-affected areas (Bearer, Duchamp, and Hassinger 2016). Snag trees and trees with shagging bark, such as shagbark hickory (*Carya ovata*), should also be retained, as these are utilized heavily as roosts during the bat reproductive period for multiple species such as red, hoary, and silver-haired bats and other bat species of conservation concern (Bearer, Duchamp, and Hassinger 2016). In addition, deciduous/mixed forested areas containing rock outcrops and talus will be important habitat for eastern small-footed bats (Pennsylvania Game Commission and Pennsylvania Fish and Boat Commission 2015). Areas immediately surrounding bat roosts and hibernacula should be buffered by diverse stands of native trees to conserve the microclimate and support an insect prey base (Bearer, Duchamp, and Hassinger 2016).

The combination of acoustic monitoring of bats and public education can help improve public engagement for bat conservation (Whiting, Doering, and Pennock 2019). The interactive nature of the Hawk Mountain Bat Kiosk provides a way to get people interested in bats. The role of environmental education, public outreach, and citizen science in the conservation of bat species cannot be overlooked. Integration of education is necessary to dispel persisting

bat myths and to get the public invested in the protection of bats (Prokop, Fančovičvá, and Rubiato 2009; Whiting, Doering, and Pennock 2019). The Hawk Mountain Bat Kiosk will continue to be accessible to guests. We hope to expand on these efforts and establish additional bat kiosk systems at other natural areas. Plans are currently in the works to establish a new version of the Hawk Mountain Bat Kiosk and establish another kiosk at Lehigh Gap Nature Center in Slagtington, Pennsylvania (Lehigh Gap Nature Center n.d.).

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