Acoustical Monitoring of Bats on the Oak Ridge Reservation 2014

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Abstract

Information is sparse regarding the distribution and occurrence of bats in the southeastern United States, including knowledge of bat species on the Oak Ridge Reservation (ORR). Although the presence of the federally endangered gray bat has been documented on the ORR, the status of the federally endangered Indiana bat and knowledge of the overall bat community is not well known. Previous ORR bat investigations have been limited to short term surveys of mist-netting and acoustic surveys, and thus no long term, intensive bat monitoring data is available. During the summer of 2014 the Tennessee Department of Environment and Conservation, Division of Remediation (TDEC DOR) continued with an inventory of ORR bat species to provide much needed information to address data gaps where there is little, no, or un-organized bat species data. The investigation was especially designed to identify all bat species but also determine locations where federally-listed endangered species (i.e., Indiana and Gray bats) and the to-be-listed Northern Long-eared bat may be present on the ORR. Bats were monitored using acoustic bat call recording equipment, thus the study did not involve bat captures. Sites monitored on the ORR in 2014 included: (1) Haul Road between East Tennessee Technology Park (ETTP) and the Environmental Management Waste Management Facility (EMWMF) located at the west end of the Y-12 National Security Complex, (2) Tower Shielding area (Oak Ridge National Laboratory) including a cave, (3) Dyllis Orchard area (north of ETTP), (4) building K-1073 (ETTP), and (5) reference sites in Oak Ridge. Over the course of 108 survey nights during 2014, approximately 12,000 files of bat acoustic data were recorded at 81 field stations and were processed with specialized, automated bat identification software (Kaleidoscope PRO) yielding 6,960 bat identifications. An additional 4,006 bats were detected but not identified to species due to poor call quality, inclement weather conditions or field clutter. The 2014 acoustic surveys recorded >100 bat calls at 21 study sites including >300 calls at three sites. Twelve (12) species were detected on the ORR including: *Eptesicus fuscus* (Big Brown bat), *Lasiurus borealis* (Eastern Red bat), *Lasiurus cinereus* (Hoary bat), *Lasionycteris noctivagans* (Silver-haired bat), *Myotis grisescens* (Gray bat), *Myotis leibii* (Eastern Small-footed bat), *Myotis lucifugus* (Little Brown bat), *Myotis septentrionalis* (Northern Long-eared bat), *Myotis sodalis* (Indiana bat), *Nycticeius humeralis* (Evening bat), *Perimyotis subflavus* (Tricolored bat; Eastern Pipistrelle), and *Tadarida brasiliensis* (Brazilian Free-tailed bat). Of these species, the Eastern Red bat (24%), Big Brown bat (18%), Tricolored bat (18%), and the Evening bat (17%) were the dominant combined species detected at all sites. Approximately 5% of all bats detected were federally-listed endangered species (Indiana bat, Gray bat). This research should provide valuable baseline information for the management of natural resources on federal-owned lands and additionally to render useful information for the fight against white nose syndrome (WNS) disease.

Introduction

Bats (Order *Chiroptera*) are the only mammals capable of true, sustained flight and are fundamental ecosystem components for insect suppression, pollination and seed dispersal (Tuttle 1988, Britzke et al. 2011, Ammerman et al. 2012). The earliest confirmed (and surprisingly well preserved) bat fossils (Figures 1-2), dates from the early Eocene (approx. 51 Mya) in North America (Gunnell & Simmons 2005, Teeling et al. 2005) from the Green River Formation, in southwestern Wyoming, but other early taxa are also present in European, African and Australian

fossil deposits. Surprisingly, fossil bats show nearly all the key innovative morphological adaptative elements of extant bat taxa (i.e., fully developed flight and echolocation; Simmons & Geisler 1998). Bats evolved a specialized, modified hand for wings by elongation of the fingers; early bats were believed to be gliders.

Icaronycteris index

Figure 1

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Figure 2

North American bats have the ability to use ultrasonic echolocation as a navigation tool in obstacle avoidance and location of prey items (Simmons and Conway 2003, Britzke 2003).
Echolocating bats typically emit an ultrasonic (>20 kilohertz) pulse, and analyze the returning echo to determine the distance to the object as well as what type of object it is (Fenton 1992). Some researchers hold that echolocation calls of most bats are species specific (Fenton and Bell 1981, O'Farrell et al. 1999), whereas others suggest caution using these calls to identify bats (Barclay 1999). Temperate bat species are nocturnal and exhibit nightly and seasonal activity patterns that vary among species and individuals (Hirshfield et al. 1977, Anthony et al. 1981).
During summer nights, bat roost-emergence activity commonly peaks immediately after sunset and can continue for several hours (Kunz 1973, Barclay 1982). Typically, a lesser activity peak occurs before sunrise as bats return to their diurnal roosts after foraging (Kunz 1973). During the night, bats roost at intervals, either at their diurnal roosts or at night-roosts nearer their foraging areas (Adam and Hayes 2000, Johnson et al. 2002, Daniel et al. 2008).

Preparation for hibernation in most mammals involves deposition of fat reserves which provides the sole source of energy during a prolonged winter fast (Young 1976, Mrosovsky 1985). Bats in the eastern United States typically enter hibernation in mid-September and emerge in mid-April (Figures 3-4; Britzske et al. 2006). Hibernation is a physiological state of inactivity characterized by low body temperature, slow breathing and heart rate (10-20 bpm compared to 600 bpm when aroused), and low metabolic rate. The function is to conserve energy and fat reserves during a period when sufficient food is unavailable (Kunz et al. 1998). Hibernation may last several days, weeks, or months (~80-85 days) depending on the species. Caves, mines, or rock crevices are the most common hibernacula (Kunz et al. 1998, Ammerman et al. 2012).

Indiana bats (*Myotis sodalis*) may forage in forests with intact canopies, floodplains, wetlands, near headwater streams (Menzel et al. 2005, Schirmacher et al. 2007), and within riparian zones and upland forests (Webb 2000, Ford et al. 2005). The Indiana bat is highly migratory and may form maternity roosts in sunlit shaggy-barked trees and snags with exfoliating bark during summer and then hibernate in caves during winter (Figures 5-6; Gardner and Hofmann 1986, Caceres and Barclay 2000, Menzel et al. 2001, Timpone et al. 2010). The sunlight is thought to speed the development of the young pups (French 2009). However, Salyers et al. (1996) discovered two male Indiana bats roosting in a bat box in Indiana, and elsewhere, immature males were captured beneath a concrete bridge (Mumford and Cope 1958). Locally, a male Indiana bat was mist-netted by a University of Tennessee/Oak Ridge National Laboratory (UT/ORNL) team at Freels Bend in June 2013 providing solid proof that Indiana bats are present on the ORR during the non-hibernating season (McCracken et al. 2013). This was the first confirmation of an Indiana bat on the ORR since 1950.

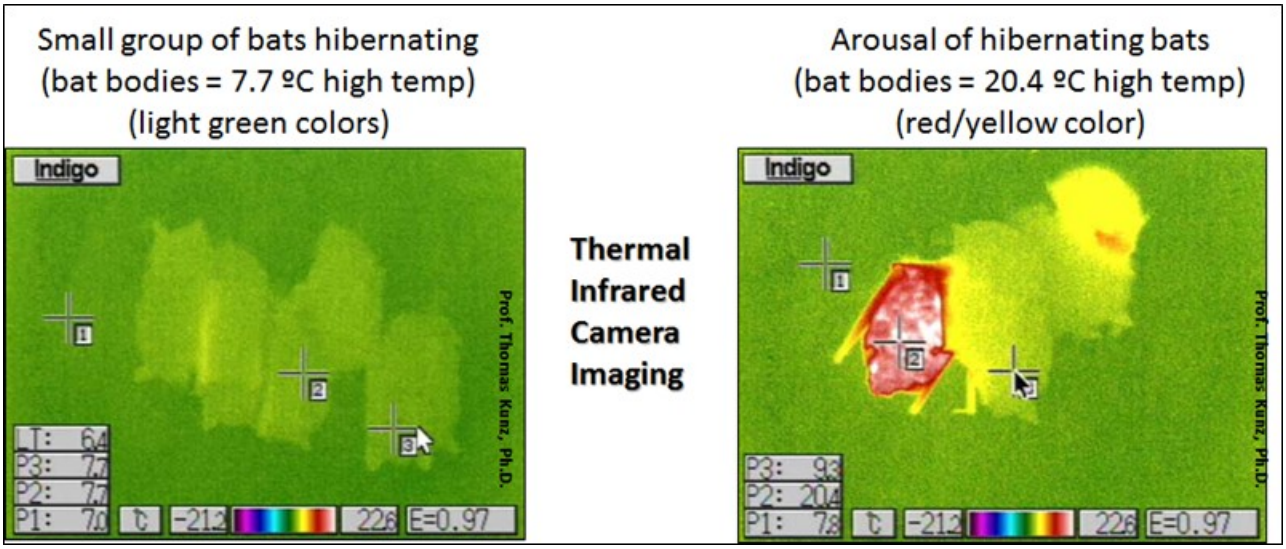

Figure 3 **Figure 4**

Figure 5

Figure 6

Bats of the genus *Myotis* (i.e., mouse-eared bats) are primarily insectivorous (Best et al. 1997). The federally-endangered gray bat is also highly migratory, establishes nursery colonies in warm caves during summer, hibernates in different cold caves during the winter (Gardner and Hofmann 1986, Gore 1992, Decher and Choate 1995), and typically forages almost exclusively over rivers, streams and lakes where insects are abundant, usually within 2 km of their cave or abandoned mine (Tuttle 1976, La Val et al. 1977, La Val and La Val 1980, Mitchell and Martin 2002). They migrate between summer and winter caves and will use transient or stopover caves along the way. One-way migrating distance between winter and summer caves may vary from 10 miles to ≥ 200 miles. An important hibernaculum for gray bats in Tennessee is Hubbards Cave which has been gated since the early 1970s to prevent disturbances of the bat colony (Tuttle 1985, 1986). Gray bats may roost at man-made sites that simulate summer caves, such as old barns (Gunier and Elder 1971) and storm drains (Hayes and Bingham 1964, Timmerman and McDaniel 1992). Factors contributing to the global decline of bat species include stream channelization, farming, habitat losses, insecticides, urban expansion, wind mill plants, and white nose syndrome disease (Gardner and Hofmann 1986, Gargas et al. 2009, Meteyer et al. 2009).

Worldwide there are more than 1,230 known bat species (Figure 7). In the United States there are at least 45 species with 10 being listed as endangered or threatened (Figure 8, Table 1). According to the Tennessee Bat Working Group, there are 16 known bat species in Tennessee including the federally-endangered Indiana bat and the Gray bat (Table 2). However, there is a paucity of information regarding the distribution and occurrence of bats in the southeastern United States, including a lack of bat species knowledge in east Tennessee.

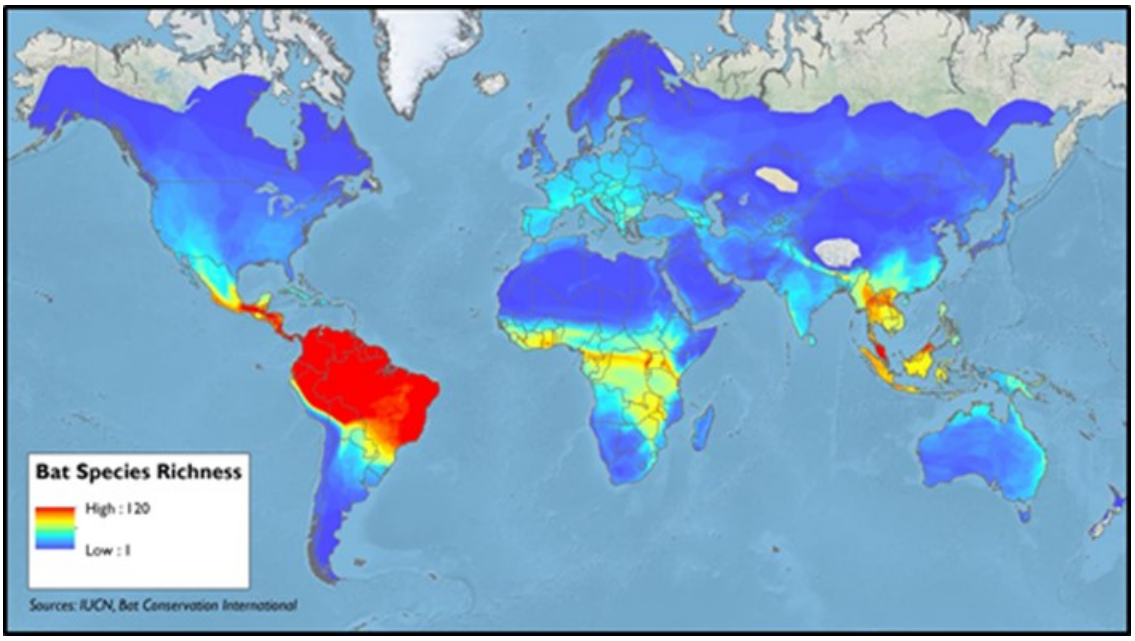

Figure 7

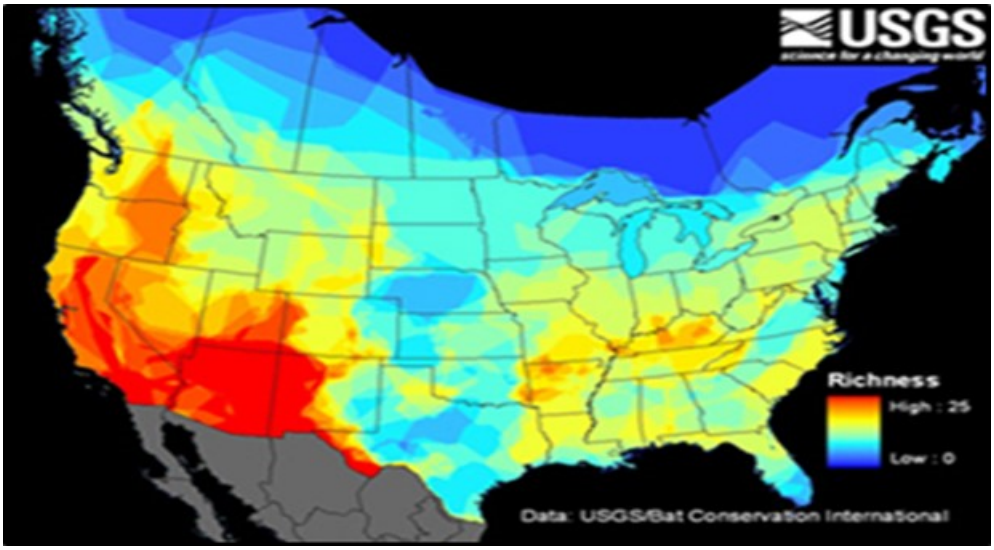

Figure 8

Table 1

Bat Name	Scientific Name	Distribution	Status
Bat, Florida bonneted	Eumops floridanus	U.S.A. (FL)	E
Bat, gray	Myotis grisescens	Central and SE U.S.A.	E
Bat, Hawaiian hoary	Lasiurus cinereus semotus	U.S.A. (HI)	E
Bat, Indiana	Myotis sodalis	Central and SE US	E
Bat, lesser long-nosed	Leptonycteris curasoae yerbabuenae	U.S.A. (AZ, NM), Mexico, Central America	E
Bat, little Mariana fruit	Pteropus tokudae	Western Pacific Ocean_U.S.A. (Guam)	E
Bat, Mariana fruit (=Mariana flying fox)	Pteropus mariannus mariannus	Western Pacific Ocean,U.S.A. (GU, MP)	T
Bat, Mexican long-nosed	Leptonycteris nivalis	U.S.A. (NM, TX), Mexico, Central America	E
Bat, Ozark big-eared	Corynorhinus (=Plecotus) townsendii ingens	U.S.A. (MO, OK, AR)	E
Bat, Virginia big-eared	Corynorhinus (=Plecotus) townsendii virginianus	U.S.A. (KY, NC, WV, VA)	E
		Source: USFWS April 2014	

E = Endangered T = Threatened

Table 2

taxa code	scientific name	common name	Est. Lifespan	Characteristic Frequency**
CORA	*Corynorhinus rafinesquii*	Rafinesque's Long-eared Bat	8-10 yrs	23 kHz (LOW)
COTO	*Corynorhinus townsendii*	Townsend's Big-eared Bat	16 yrs	23.5 kHz (LOW)
EPFU	*Eptesicus fuscus*	Big Brown Bat	19 yrs	28 kHz (LOW)
LABO	*Lasiurus borealis*	Eastern Red bat	12-14 yrs	35 kHz (MID)
LACI	*Lasiurus cinereus*	Hoary Bat	7-14 yrs	20 kHz (LOW)
LANO	*Lasionycteris noctivagans*	Silver-haired Bat	12 yrs	26.5 kHz (LOW)
LASE	*Lasiurus seminolus*	Seminole Bat	No data	35 kHz (MID)
MYAU	*Myotis austroriparius*	Southeastern Bat	8 yrs	43.5 kHz (MYO)
MYGR	*Myotis grisescens*	Gray Bat	15 yrs	45.5 kHz (MYO)
MYLE	*Myotis leibii*	Eastern Small-footed Bat	9 yrs	44.5 kHz (MYO)
MYLU	*Myotis lucifugus*	Little Brown Bat	20 yrs	40 kHz (MYO)
MYSE	*Myotis septentrionalis*	Northern Long-eared Bat	18 yrs	43 kHz (MYO)
MYSO	*Myotis sodalis*	Indiana Bat	14 yrs	41 kHz (MYO)
NYHU	*Nycticeius humeralis*	Evening Bat	5 yrs	38 kHz (MID)
PESU	*Perimyotis subflavus*	Tri-colored Bat (Pipistrelle)	15 yrs	35 kHz (MID)
TABR	*Tadarida brasiliensis*	Brazilian Free-tailed Bat	12-18 yrs	25.5 kHz (LOW)

**1, M. Szewczak, Humboldt State University Bat Lab

Project Scope and Justification

Ultrasonic detectors are widely used for bat censuses (i.e., inventory) and have improved conservation efforts by: (1) providing increased knowledge of bat ecology, and (2) characterizing bat communities (Vaughan et al. 1997, Barataud 1998, Pauza and Pauziene 1998, Avila-Flores and Fenton 2005, Britzke et al. 2011). Numerous researchers have used detectors to conduct bat species surveys and assess habitat use. This method is especially valuable for species that are difficult to capture (Ahlén and Baagøe 1999, Murray et al. 1999, O'Farrell and Gannon 1999, Duffy et al. 2000, Parsons et al. 2000, Russo and Jones 2003, Owen et al. 2004, Britzke et al. 2011). A considerable benefit of acoustic surveys is that bats do not have to be captured and stressed, but identify areas where mist net surveys are needed to obtain positive identifications of endangered species.

Acoustic surveys of bat echolocation calls are often used to model a species' occurrence at a site (i.e., occupancy model, French 2009). Variation in the acoustic structure of bat echolocation calls can often provide sufficient information for reliable and efficient species identification. Acoustic surveying of sites and analysis of corresponding bat files using acoustic libraries built into automated identification software programs provide a consistent and standardized method for surveying areas rapidly (Hughes et al. 2011).

The TDEC DOR investigated and inventoried the bat community present on the ORR during 2014 using ultrasonic acoustic bat call recording equipment. Accordingly, the principal goal of this monitoring project was to assess seasonal use of DOE federal lands by bat species. Particularly the status of federally endangered bats (Indiana bat, Gray bat) in Tennessee is not well known. Acoustic information should be helpful in identifying areas where netting surveys could further build upon bat distribution data, especially where calls of the genus *Myotis* are recorded most frequently. Further, dispersal information is sparse regarding the Northern Long-eared bat which is currently under consideration for listing as an endangered species by the U.S. Fish and Wildlife Service (USFWS). Many bat investigations on federal land have been limited to short term 2-4 night surveys of mist-netting and acoustic surveys to meet the Indiana bat monitoring requirements of Section 7 of the Endangered Species Act. As a result, few bat acoustic surveys have been conducted over the years. Bat data is spotty, inconsistent, or often non-existent in critical habitat areas such as the huge forested NERP (National Environmental Research Park) area of the ORR.

Data from this project will determine ORR bat species present and their distribution. It will also provide valuable information for management of natural resources on federal-owned lands. Lastly, this research will support the protection and conservation of endangered bat species, a major component of the TDEC mission, and it will also support efforts to combat white-nose syndrome (WNS). This study is unique because a serious lack of bat community information was addressed by providing comprehensive, multi-night acoustic surveys at 81 survey stations. This allowed partial characterization of the +30,000 acres of federal lands comprising the ORR. Furthermore, this project, along with a concurrent ORNL Environmental Science Division bat project, represents the first long term, large-scale acoustic bat community investigation on the ORR.

Objectives

1. Conduct field habitat assessments on the ORR and identify likely endangered species roosting habitat for acoustic monitoring. Specifically, Indiana bats may form maternity roosts in sunlit trees and standing snags with exfoliating or loose bark during summer and then hibernate in caves during winter (Menzel et al. 2001, Timpone et al. 2010). Bat habitats for other species will also be identified for acoustic monitoring such as:
    a) Caves & abandoned mine works
    b) Rock bluffs and outcroppings
    c) Bridges & tunnels
    d) Field/forest edge
    e) Culverts/storm sewers
    f) Forest corridors (linear features: fence lines, access roads, trails)
    g) Waterways (wetlands, ponds, streams, rivers)
    h) Abandoned buildings

    (LaVal et al. 1977, Racey 1998, Grindal and Brigham 1999, Menzel et al. 2005)

2. Monitor field stations identified in #1 above utilizing acoustic bat detector equipment and determine all species present on the ORR.
3. Collect bat echolocation calls 24/7 at pre-selected ORR caves (with known bat populations) in an attempt to detect potential erratic behavior which could be an indication of WNS-infected bats.

Bat Echolocation

Most United States bats have the ability to use echolocation as a navigation tool in obstacle avoidance and hunting (Simmons and Conway 2003, Ammerman et al. 2012). Echolocating bats typically emit a series of ultrasonic pulses that vary in properties, and analyze the returning *echoes,* redirect its sonar beam at the target, then determine the distance to the object and identify the object (Fenton 1984, Fenton 1992, Grinnell 1995, Ulanovsky and Moss 2008). Bats use a wide range of ultra-sonic tonal frequencies in echolocation, from ~20,000 Hz (20 kHz, kilohertz) to >200,000 Hz (200 kHz; Figure 9). As the bat flies, it emits frequency sweeps (e.g., 100 kHz down to 30 kHz) into a wide cone of space ahead of it (cone = 120º- 150° wide; Figure 10). Bat calls are produced by a single mode of vibration and consist of a series of harmonics which are multiples of the sound frequencies used by the bat, thus pinpointing the location of insect prey (Figures 11-12: Fenton 1992, Grinnell 1995). The maximum target detection range of the bat echolocation apparatus is about 20 meters (Ammerman et al. 2012).

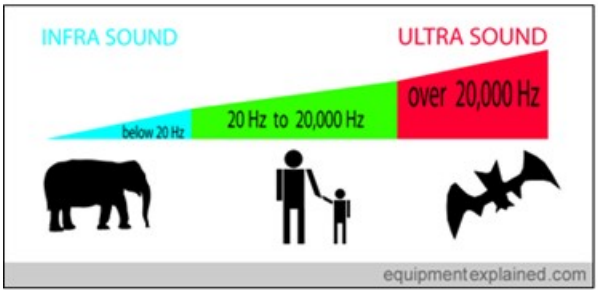

Figure 9

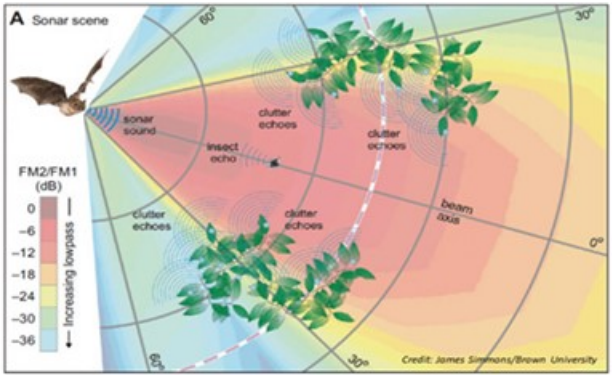

Figure 10

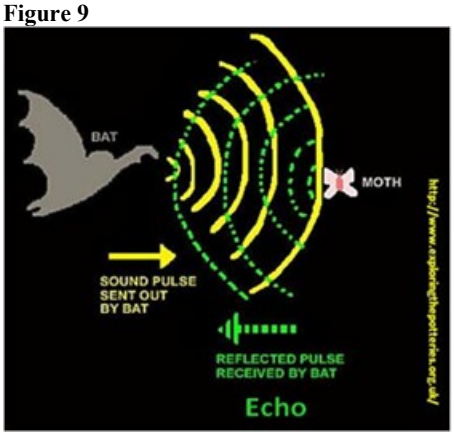

Figure 11

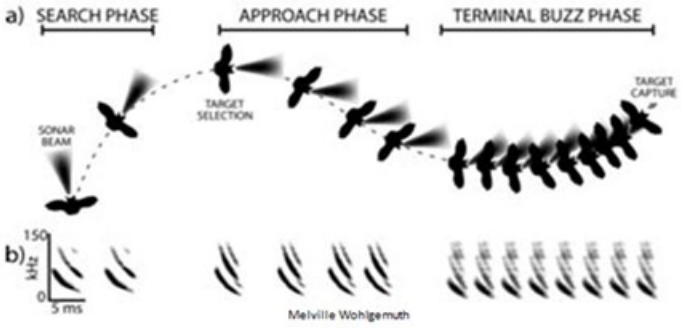

Figure 12

Bats synchronize their echolocation calls with their wing beats (Figure 13).

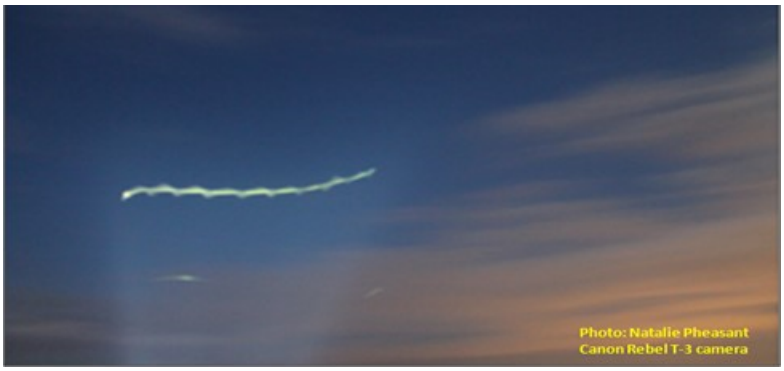

Figure 13: Bat illuminated and photographed in flight (note wing beats)

So, what is a bat call? A bat call is a series of frequency sweeps which the bat emits to aid in navigation and location of prey items (McCracken et al. 2013). Most bat families use short, downward frequency-modulated (FM) sounds that sweep through about an octave; FM calls determine range and distance. An example of an FM bat is the Big Brown Bat. Another common echolocation signal pattern is constant-frequency (CF) signals which determine if prey move towards or away from the bat (Fenton and Bell 1981, Betts 1998, O'Farrell et al. 1999). These signals have a long (10–100 ms) CF component preceding an FM sweep (Grinnell 1995).

Bat calls (echolocation) can be considered as *bio-sonar*. Most of our bats echolocate using their larynx and associated super-fast throat muscles to produce ultrasonic clicks (i.e., >190 signals/sec); in contrast, some species use tongue clicks (Holland and Waters 2005). In bats that use laryngeal echolocation, the stylohyal bone (Figure 14, shown in blue) directly connects the tympanic bone (yellow) with the larynx which allows the bat to generate the outgoing ultrasonic clicks (Veselka et al. 2010). The returning echoes are detected with highly specialized ear structures (Figure 15) which are in turn transmitted to specialized regions of the bat brain for processing and calculation of prey location (Figure 16; Suga and O'Neill 1979). The inner ears of laryngeal echolocating bats show several structural adaptations for detecting ultrasonic echoes; in particular, their cochleae are often enlarged (Suga et al. 1975, Simmons et al. 1975, Suga 1990). The bat broadens the area from which it collects information by moving its head, ears, and tragus while echolocating thus amplifying the returning echo (Ammerman et al. 2012).

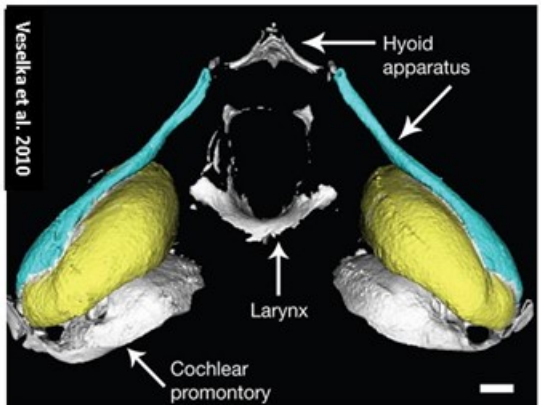

Figure 14

Figure 15

During flight, the dominant constant-frequency (CF) component of the distinctive calls of some bats (e.g., Horseshoe bat, Mustache bat, and other species) is shifted as a result of Doppler effects (Figure 17, Metzner et al. 2002, Hiryu et al. 2005). These bats compensate for even subtle frequency shifts in the echo caused by flight induced Doppler effects by lowering the frequency of their echolocation calls below the resting frequency (the call frequency emitted when not flying and not experiencing Doppler shifts; Schnitzler 1968, Metzner et al. 2002).

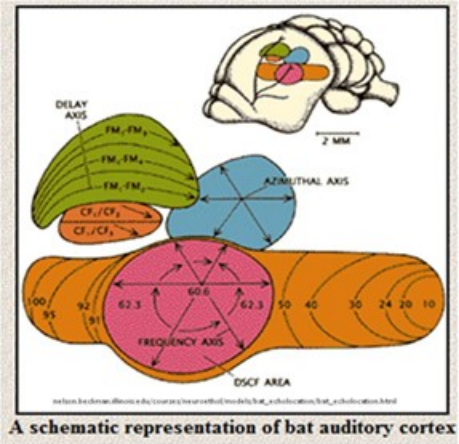

Figure 16

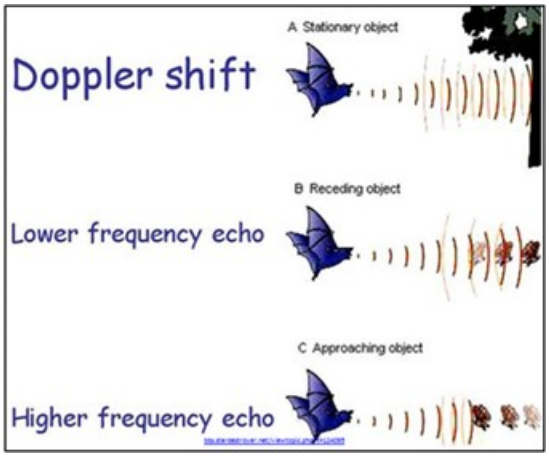

Figure 17

Bat Habitat

Bat *homes* (i.e., roosts, maternity colonies, hibernacula) are illustrated in Figures 18-37. When not foraging for food, bats rest, groom, and interact socially with other bats at sites known as roosts or hibernacula (Ammerman et al. 2012). Bats roost in a variety of naturally occurring and anthropogenic structures such as abandoned buildings, caves, rock bluffs, rock crevices, dead tree snags, trees with exfoliating bark, tree leaves/branches, tree cavities, bridges, abandoned mines, railroad tunnels, forest/field edge, wetlands, utility right-of-ways, ponds, stream riparian zones, lakes, and spring houses (Ammerman et al. 2012).

To capture insect prey items, bats swoop low over the surface of water bodies, snap prey out of the air, and even land on the ground to pursue prey (Ammerman et al. 2012). Insect-eating bats (insectivorous) may use their tail to capture the insect or use their long canines to seize and pierce their prey, which is then reduced to minute fragments by the sharp-edged premolars and blade-like crests of the molar teeth. The sharp cusps and ridges of the opposing teeth act as scissors to cut up the insect food into tiny pieces (Ammerman et al. 2012).

Figure 18

Figure 19

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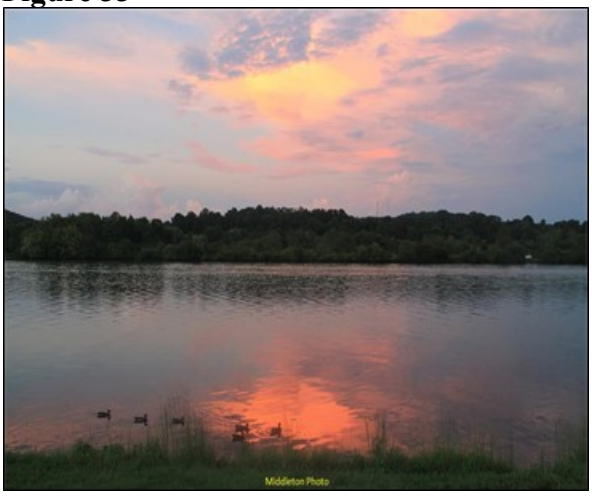


Figure 35

Figure 36

Figure 37

Methods

The Tennessee Oversight Agreement mandates a comprehensive and integrated monitoring and surveillance program for all media (i.e., air, surface water, soil sediments, groundwater, drinking water, food crops, **fish and wildlife, and biological systems**) and the emissions of any materials (hazardous, toxic, chemical, radiological) on the ORR and environs. Accordingly, monitoring the ecological recovery progress of wildlife and the environmental restoration of habitat are important aspects of remedial activities on the ORR.

Following emergence from winter hibernation, bats were surveyed to record echolocation calls using ultrasonic frequency bat detectors. Bat habitat surveyed included trees with loose or peeling bark (e.g., shagbark hickory), dead snags, ponds, wetlands, riparian stream zones, caves, rock bluffs, hiking trails/greenways, gravel access roads, powerline ROWs (right-of-way), anthropogenic structures (i.e., abandoned buildings, bridges, culverts), and field/forest edge (forest corridors). Bat call files obtained from the detectors were analyzed with specialized bat identification software (i.e., Kaleidoscope PRO) to determine species likely present at ORR survey sites. We used a combination of active and passive ultrasonic field surveys that began in mid-April 2014, and continued through late October 2014.

Our project methods followed the bat monitoring guidance and protocols of Kuenzi and Morrison (1998), Murray et al. (1999), Jones et al. (2004), Szewczak 2004, Manley et al. (2006), Britzke et al. (2011), and the U.S. Fish and Wildlife Service (USFWS 2011, 2013). This research was in cooperation with the Division of Natural Areas (TDEC Bureau of Parks and Conservation), Tennessee Wildlife Resources Agency, the Forestry, Wildlife and Fisheries Department of the University of Tennessee, the US Fish and Wildlife Service, and the Oak Ridge National Laboratory Environmental Sciences Division.

Per the Health & Safety Plan, all field work was conducted in teams of two or more biologists (Yard 2013). Appropriate training and pre-exposure rabies vaccinations are required for those individuals that may handle bats while assisting with mist-netting surveys under another researcher's federal collection permit (USFWS 2011).

Field Equipment

Recording and analyzing ultrasonic bat calls present a challenging code-breaking problem, thus modern bat detector technology allows us to tap the bat phone and decipher their bat-speak code. The application of bat ultrasonic monitoring devices such as the zero-crossing Anabat™ SD-2 bat detector and Titley Roost Logger (Titley Scientific USA, Columbia, MO) has allowed ecologists to quickly and efficiently characterize and inventory bat communities at multiple areas (O'Farrell and Gannon 1999, Owen et al. 2004), and transform those calls into frequencies which are audible to humans (Parsons et al. 2000). Newer full spectrum technology such as the Wildlife Acoustics SongMeter SM-2BAT+ and SM-3BAT+ detectors allow a more complete recording of the bat call providing some advantages over the Anabat technology.

We used six types of bat detectors over the course of the project to passively and actively monitor for bat echolocation passes (i.e., a series of echolocation pulses), at carefully selected ORR sites before, during, and after the pregnancy and lactation periods (April through October; Sasse and Perkins 1996). Table 3 lists the bat detectors, associated features for each unit, and the bat identification software programs that are compatible for each detector.

WAC files (*.wac*) = Wildlife Acoustics Audio Compression format is a proprietary audio format produced by Song Meter and Echo Meter recorders. A *.wac* file may contain one or more channels (mono or stereo recordings), and these recordings may be either continuous or triggered. Triggered recordings are used for ultrasonic work (e.g. recording bats) where only periods of detected activity (a triggered event or "bat pass") are recorded.

WAV files (*.wav* format) = Waveform Audio File format is a defacto standard developed by IBM and Microsoft for representing multi-channel audio recordings. There are several flavors of *.wav* file formats that may utilize different forms of audio compression and meta data.

The Zero-crossing (ZC) *.dat* ? (also, *??#*) format is a proprietary format used in Anabat and legacy zero-crossing bat detectors developed in the early 1990s by Chris Corben for Titley Electronics. These are not "recordings" in the conventional sense but, rather, the time between a number (division ratio) of sequential zero crossings stored in the file. With sufficient signal-to-noise ratio, the dominant frequency sweep through time produced by the echolocation calls of bats can be represented.

(http://media.nhbs.com/equipment/Kaleidoscope%20Pro.pdf accessed 3/15/2015)

Additional field equipment:

- Bat detectors
- Waterproof lockable boxes for Anabat equipment
- Tripods & painter poles for microphone extension
- Bungee cords, rope
- Machete, saw
- Toolbox, tools
- Headlamps, high candlepower flashlights, extra batteries
- Security locks & cables to protect detectors from theft or damage
- GPS, field maps, field notebook, etc.
- First aid kit, insect repellent

Table 3

Bat Detectors						
Features ↓	**Anabat SD-2**	**Roost Logger**	**Bat Box**	**SongMeter SM2BAT+**	**SongMeter SM3BAT**	**EchoMeter SM3**
Manufacturer	Titley Scientific	Titley Scientific	Batbox Ltd. (UK)	Wildlife Acoustics	Wildlife Acoustics	Wildlife Acoustics
Programmable	Yes	Yes	No	Yes	Yes	Yes
Technology	Zero-crossing (ZC) / frequency division	Zero-crossing (ZC) / frequency division	Heterodyne / frequency division	Full spectrum / ZC	Full spectrum / ZC	Full spectrum / ZC / Heterodyne
Deployment	Active/Passive	Active/Passive	Active	Passive	Passive	Active
Battery life	30 hrs	>1000 hrs	30 hrs	230 hrs	180-700 hrs	12 hrs
Memory card	CF card	SD card	requires recorder	SD card	SD card	SD card
Directionality	Directional	Directional	Directional	Omni directional	Omni directional	Directional
File output	dat ? Anabat files	dat ? Anabat files	WAV	WAV / WAC / ZC	WAV / WAC / ZC	WAV / WAC / ZC
Frequency (kHz)	5-200 kHz	40-42 kHz	17-125 kHz	8-220 kHz (recommended)	8-220 kHz (recommended)	1-192 kHz
Weatherproof	No	Yes	No	Yes	Yes	No
Microphones	Attached / External on tripod mount	Built-in	Built-in	Attached / External on pole mount	Attached / External on pole mount	Built-in
Compatible Bat ID software*	AN, BE, KP	AN, BE, KP	KP	KP, SB	KP, SB	KP, SB
	*Analook = AN; BCID-East = BE; Kaleidoscope PRO = KP; Sonobat = SB					

Anabat SD-2 detectors are frequency dividing (FD) detectors that provide a broadband frequency down-conversion to generate audio signals with frequencies directly related to those the bat is producing (Corben 2014). The nature of the data generated by Anabat detectors is ideally suited to analysis using Zero-Crossings Analysis (ZCA). The ZCA system counts incoming echolocation calls (pulses) along their oscillations between positive and negative values each time a sound wave passes the zero point at a present number of crossings (i.e., Division Ratio, often 8 or 16), and a time measurement (time-frequency) is made allowing representative species-specific frequencies to be recorded, thus providing efficient analysis of representative call parameters for species identifications (Corben 2014). The Anabat with attached PDA screen provides near instant renderings of the time-frequency portions of bat calls so bats can be observed while sonograms of their calls can be displayed. This aids in identifying bats to species while in the field or during analysis with the Analook-W software program.

The BatBox Duet was used to scan sites for early bat calls prior to initiating recording activities at active survey sites. The Batbox Duet is a dual-functioning bat detector, with both heterodyne and frequency division, which has been designed for single-handed operation. By recording from the frequency division output, no bat can be missed, regardless of the frequency set on the digital counter. The Duet listens to the entire ultrasonic range between 17kHz and 120kHz. This detector also measures the amplitude of the sonar before dividing by ten and then reinstates it at the output. This creates an identical waveform to the original signal but reduces the pitch to an audible frequency (BatBox Ltd. 2015).

The SongMeter SM2BAT+, SM3BAT, and EM3+ bat detectors (Wildlife Acoustics) are versatile and can record frequency-divided (zero-crossing) bat calls, and are also a full-spectrum detector capable of capturing all frequency-time and amplitude-time components of high-frequency bat echolocation. That is, these detectors capture the entire soundscape of an incoming echolocation call either by direct recording methods which instantly digitize the audio, or by time-expansion methods which lower the call in frequency and expand it in time for recording and/or playback in quasi-real-time performance. The main benefit of full-spectrum recordings is that they contain not only the time-frequency components of the bat call, but also the time-amplitude components, including multiple harmonics when present. Thus the information recorded by full-spectrum processes is far richer and has vastly more content upon which to make a confident identification. (http://www.wildlifeacoustics.com/products/song-meter-sm2-bat-plus/training-videos accessed 3/15/2015).

The quantity of echolocation passes recorded is an index of activity and does not necessarily reflect the number of bats being recorded, i.e., one bat can be recorded more than one time (Broders 2003). During 2014, DOEO employed two methods for recording ORR bat calls:

1. Active survey (attended) at fixed-point location(s): Bat echolocation calls were *actively* monitored (i.e., attended) between dusk and midnight (O'Farrell et al. 1999, Sherwin et al. 2000, Johnson et al. 2002). At each location, we aimed the detector toward the sky in the four cardinal directions (45º angle from the horizon) until bat activity was acquired. Then, we oriented the detector towards the general direction of the bat and following its flight path, recorded echolocation calls until the signal was lost. Every attempt was made to capture as complete a call sequence as possible including the search, approach, and feeding buzz segments. Search phase calls are best suited for the acoustical identification of bats because they are the most commonly encountered in the field and have been shown to have species-specific characteristics (Allen et al. 2007). Detectors or detached microphones were extended on tripods or painter poles wherever possible to reduce ground clutter and ultrasonic insect noise (Weller and Zabel 2002). Excessive clutter, such as deploying detectors in dense vegetation, was avoided (detectors were operated in the open as much as possible). We avoided acoustical sampling during evenings when bat activity was likely to be low due to meterological conditions such as high winds, precipitation or temperatures below 10° C (Wear 2004, Ford et al. 2005, Schirmacher et al. 2007).

2. Passive survey (unattended) at fixed-point location(s): Bat echolocation calls were also collected *passively* by deploying the detectors unattended overnight (i.e., 1-3 nights) pre-programmed to record dusk to dawn (Martin and Britzke 2010). Anabat SD-2 detector systems deployed in the field for remote, passive sampling were housed in waterproof containers with an aperture through which the microphone was fitted (Britzke et al. 2010). Detectors were deployed 5-10 feet above the ground on tripods or painter poles to reduce recording ultrasonic insect noise and ground clutter (Weller and Zabel 2002). High clutter areas (i.e., dense vegetation) were avoided to reduce recording ultrasonic insect & ground clutter noise (Weller and Zabel 2002). The Titley Roost Logger™ detector was used to monitor bats at cave sites and usually deployed for 3-5 consecutive nights. Care was taken

during site selection to minimize exposure of the expensive equipment to possible theft or vandalism.

Bat Call Analysis Software Programs

Bat detectors can detect, display, and record the echolocation calls of bats which have a characteristic frequency. These calls can also be displayed as sonograms which can be analyzed and compared to find differences in the calls that an individual bat makes, such as during feeding, socializing, and navigating as well as differences between various species of bats (Ammerman 2012).

Bat call files obtained from the detectors were analyzed with specialized bat identification software [i.e., Kaleidoscope PRO, Wildlife Acoustics, Inc., Concord, MA; Analook-W, Titley Scientific, Columbia, MO] to enable acoustic identification of species. Kaleidoscope PRO has been sanctioned by the USFWS as candidate automated software which has passed the rigorous USFWS standardized test/validation process. The automated programs use a reference library of bat pulses from bats for comparison with species whose identification is unknown, and, using algorithms, assign a probability of identification to unknown bat calls. This method of comparison and analysis decreases chances of false positive identifications, but allows overlapping calls or calls which contain noise to be rejected as NOID(no identification), or calls unidentifiable to species (McCracken et al. 2013). Search phase calls are best suited for the acoustical identification of bats because they are the most commonly encountered in the field and have been shown to have species-specific characteristics (Allen et al. 2007). However, it is not always possible to collect good quality search phase calls which depend on the amount of field clutter, detector/microphone orientation, insect noise, and poor weather conditions.

In the Analook-W software program (Titley Scientific), bat call files can be displayed as sonograms which can be analyzed and compared to find differences in the calls that an individual bat makes, such as during feeding, socializing, and navigating, as well as differences between various species of bats (Ammerman 2012). This software is most compatible with Anabat detectors, but also allows analysis of files recorded by SM2BAT+ recording in native zero-cross mode. Any full spectrum file can be converted to ZC format and viewed in Analook. However, as mentioned above, sound features such as harmonics and peak frequency are lost. Analook provides a full range of parameter extraction and filtering capabilities for making species identification classifications (Corben 2014).

The Kaleidoscope Pro automated bat identification software package allows users to run their raw data from an SM2BAT+, SM3BAT, EM3+ unit, or any other bat detector on the market today including Anabat files, and it will output an automatic species identification classification for each recording. Kaleidoscope Pro saves users enormous amounts of time which would otherwise be spent viewing and post-processing calls, and provides standardized survey results that can be applied across multiple habitats, by various field technicians, and over many years. This software accepts zero crossing and full spectrum recordings, in either WAV or WAC file formats, and will automatically and accurately identify bat recordings to species using a built-in call library. The software automatically creates a summary report that is useful for compiling occupancy data and easily outputting detailed results from deployments (www.wildlifeacoustics.com/products/kaleidoscope-software/webinars accessed 3/15/2015).

Caveats: Bat Auto-ID software has its limitations...it is only as good as the input data. Even high quality recordings are not always identifiable to species. So, the bottom line is we cannot always accept auto-ID output blindly. Although there is considerable debate about the accuracy of bat detectors and automated identification software programs based solely upon echolocation calls, it has been shown that, with experience, the number of 'false-positives' or misidentifications is negligible, and questionable calls must be listed as unidentifiable (Barclay 1999, O'Farrell et al. 1999, Ammerman et al. 2012).

For example, the occasional misidentification of Little Brown calls as Indiana bat calls requires very careful follow-up analysis of the field data. This is because Little Brown and Indiana bats have significant overlap in discrete parameters such as call duration, characteristic frequency, start slope, slope at characteristic frequency, and cumulative normalized slope such that these species sometimes cannot be differentiated (Szewczak 2011). Figure 38 illustrates this overlap of Indiana bat (MYSO) and Little Brown bat (MYLU) call characteristic frequencies (octaves/second) plotted vs. duration (milliseconds; Agranat 2012).

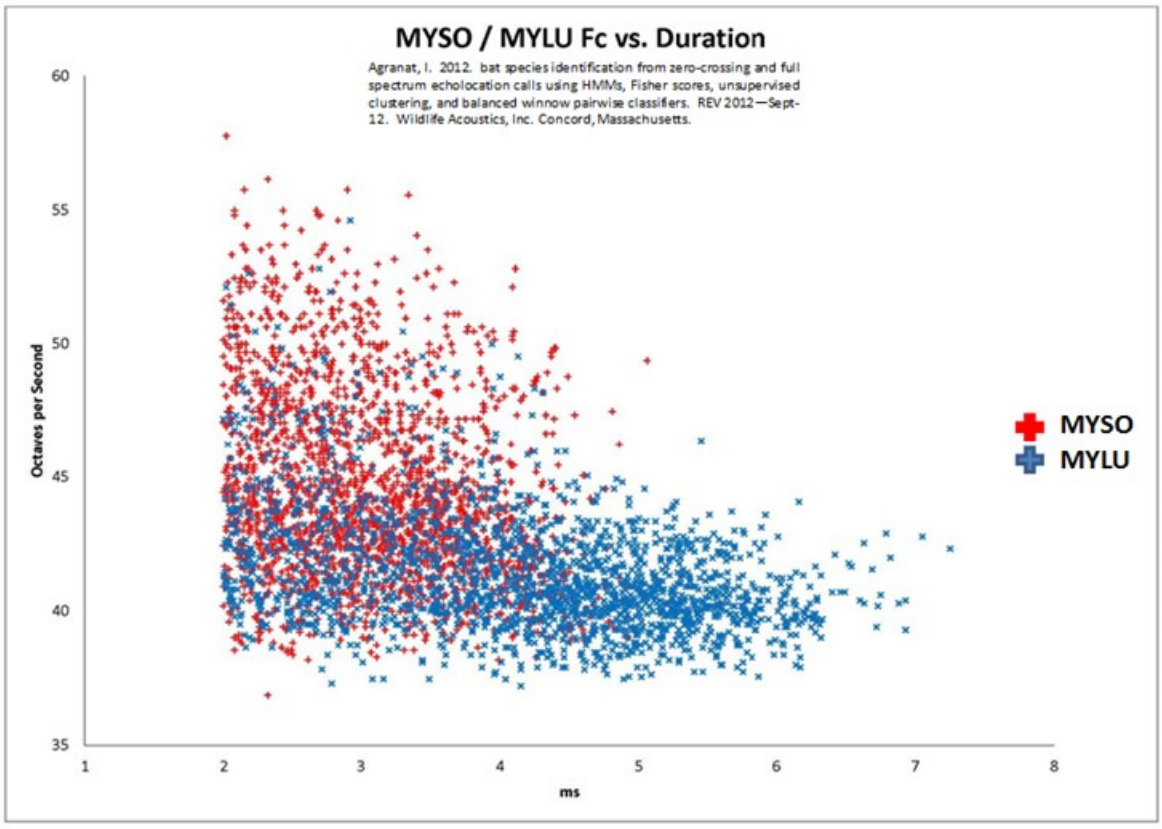


Figure 38

Given these limitations, it is equally important to consider the advantages of using bat detectors to record echolocation calls and application of automated software programs to identify those recorded calls. Bat detectors are ideal for long-term monitoring and censuses of bats and are effective for detecting species that are difficult to catch with mist nets or harp traps (Barataud 1998, Pauza and Pauziene 1998, Ammerman et al. 2012). The application of bat ultrasonic acoustic

detectors and automated identification of recorded calls has allowed ecologists to quickly and efficiently characterize and inventory bat communities at multiple areas (O'Farrell and Gannon 1999, Owen et al. 2004, Hughes et al. 2011). The greatest advantage is that bat captures or disturbance of bat colonies is not necessary.

Study Site

The study was conducted on the Oak Ridge Reservation (ORR) in Anderson and Roane counties of east Tennessee. The ORR consists of approximately 34,500 acres (14,000 ha) and is nestled in the valley and ridge physiographic province and the underlying geology consists of thrust faulted Cambro-Ordovician age sedimentary rocks such as limestones, siltstones, shales and dolostones. The reservation is bound on the north and east by residential areas of the City of Oak Ridge and on the south and west by the Clinch River. More than 20 caves have been identified on the ORR and most are developed within dolostones of the Knox Group. Mitchell et al. (1996) surveyed seven of the caves (Copper Ridge, Flashlight Heaven, Walker Branch, Big Turtle, Little Turtle, Pinnacle, and Bull Bluff), but no gray bats were found. There is an unverified report of ten gray bats roosting in Little Turtle Cave in September 1996 (Webb 2000). Therefore, acoustic bat surveys of ORR cave entrances were conducted on multiple nights to determine species, if present. We should note that ORR caves were not entered at any time due to wildlife health concerns.

Bat acoustic monitoring sites were selected based upon satellite imagery, topographic maps, consultation with the Environmental Sciences Division at the Oak Ridge National Laboratory, the Tennessee Wildlife Resources Agency (TWRA), TDEC Division of Natural Areas, and by following the U. S. Fish & Wildlife Service (USFWS) Indiana bat protocol (USFWS 2011, 2013). Additional site selection criteria included: likely flight paths and roosting/foraging habitats as described in the scientific literature (Barbour and Davis 1969, La Val et al. 1977, Lewis 1995, Kuenzi and Morrison 1998, Racey 1998, Grindal and Brigham 1999, Murray et al. 1999,Adam and Hayes 2000, Johnson et al. 2002, Henry et al. 2002, Jones et al. 2004, Szewczak 2004, Ford et al. 2005, Menzel et al. 2005, Manley et al. 2006, Ormsbee et al. 2007, Schirmacher et al. 2007, Daniel et al. 2008, Menzel et al. 2010, Timpone et al. 2010, Britzke et al. 2011).

DOEO monitored bats at 81 sites during 2014 including:

- Haul Road (ETTP truck scales to Y-12 Bear Creek Burial Grounds)
- Blair Road (ETTP)
- Blair Road quarry
- Perimeter Road (ETTP)
- Building K-1073 (ETTP)
- Copper Ridge Cave (Tower Shielding area, ORNL)
- Shagbark hickory and dead snags (potential Indiana bat roosting trees)
- Poplar Creek (ETTP area)
- Dyllis Orchard greenway (Black Oak Ridge Conservation Easement)

DOEO conducted active surveys (attended) recording bat calls from dusk until midnight and passive surveys (unattended) involving deployment of pre-programmed detectors overnight to record bat calls from dusk until dawn.

Results

TDEC Division of Remediation staff continued to monitor and record bat echolocation calls during the second year of the bat inventory and field monitoring project in 2014. The field season began in late April and continued through late October. The goal was to provide much needed information to address data gaps where there is little, no, or un-organized bat species data. The investigation was especially designed to identify all bat species but also to determine locations where federally-listed endangered species (i.e., Indiana and Gray bats) and the to-be-listed Northern Long-eared bat may be present on the ORR. Bats were monitored using acoustic bat call recording equipment, thus the study did not involve bat captures. Further, we co-deployed detectors with the ORNL Environmental Sciences Division bat ecology staff at several locations in the Tower Shielding area including Copper Ridge Cave. For purposes of the 2014 bat survey, the study area was subdivided into 12 sections:

I. ETTP: Haul Road / Blair Road
II. ETTP: Haul Road / Flannagan Road
III. ETTP: Blair Road / Poplar Creek Greenway @ East Fork Poplar Creek bridge
IV. Haul Road (west Bear Creek Valley) / Highway 95 overpass
V. East Dyllis Orchard area (Blackoak Ridge) / Perimeter Road
VI. Central Dyllis Orchard area (Blackoak Ridge)
VII. West Dyllis Orchard area (Blackoak Ridge)
VIII. ETTP: K-1073 building perimeter
IX. Tower Shielding Area (ORNL)
X. Haul Road (Bear Creek Burial Grounds area/Y-12 National Security Complex)
XI. Haul Road (Reeves Road area)
XII. Reference sites (City of Oak Ridge)

Important note: At the beginning of each section, the following background information is provided:

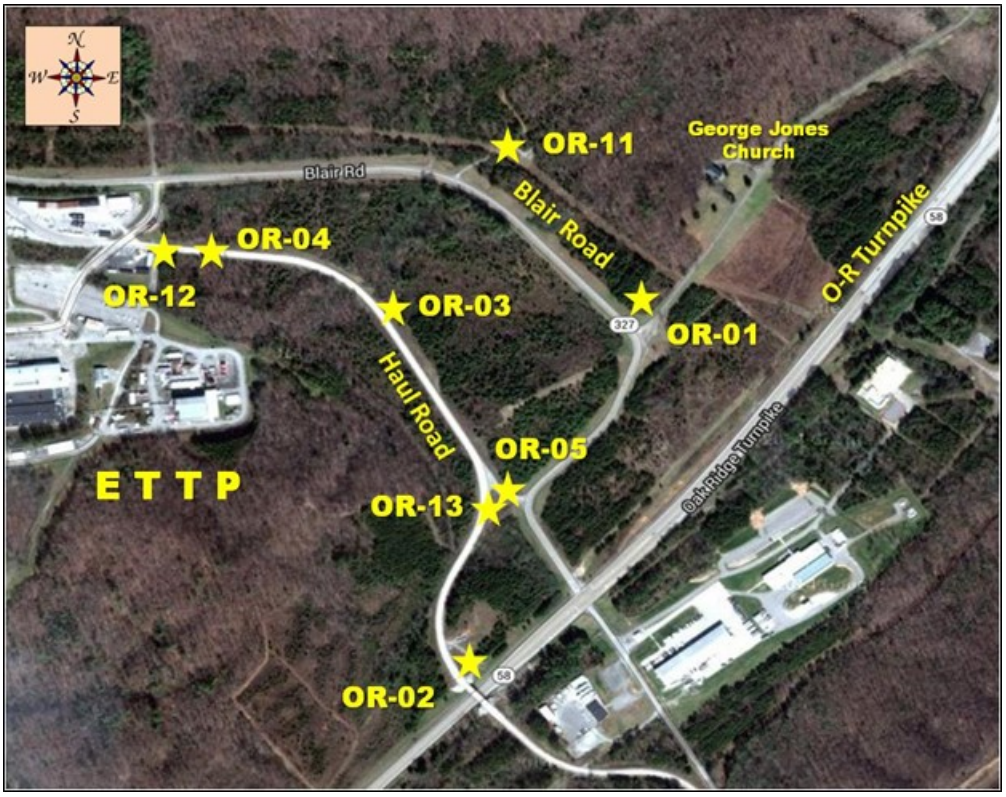
(1) Map showing location of acoustic survey sites (field sites are numbered as follows: OR-01, OR-02, OR-03, etc.),
(2) Table with field data for each site [GPS coordinates, site description, date of survey, time of survey, detector(s) deployed],
(3) Table with bat survey output data for each site (number of bat calls by species and additional software output).

Following the introductory map and tables for each section, data for every individual site is presented as a pie chart (number of bat calls per species) with a corresponding site photograph to the right of every pie chart. Each pie chart and corresponding site photograph is numbered using the survey site reference number, that is, OR-01 chart/OR-01 image, OR-02 chart/OR-02 image, OR-03 chart/OR-3 image, etc. In the bat survey output tables, note that the numbers in each *bat species detected* cell represent the number of bat calls recorded at each monitoring station, <u>not</u> the number of bats present. *Blank boxes* = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A *call* is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). *Pulses* are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. *Noise* = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as *Low (≤ 25kHz),*

Mid (25-35 kHz), or Myotis (≥ 40kHz). All bat files were processed using the Kaleidoscope PRO automated identification software program.

Section I: ETTP: Haul Road / Blair Road

Eight sites were actively monitored for an average of three hours/night to record ultrasonic bat calls on Section One; six sites were investigated along the Haul Road between the truck scales and the Oak Ridge Turnpike bridge overpass and two sites along Blair Road (Map 1, Table 4). These sites were surveyed with Anabat SD-2 detectors on 5/21/2014 (5 sites) and 6/16/2014 (3 sites). Overall bat activity was moderate as a combined total of 482 bat calls were identified to species by the Kaleidoscope PRO program and 46 additional bat calls were recorded, but not identified (Table 5). The dominant species detected in this section was the Eastern Red bat (180 calls), Evening bat (184 calls), and Tri-colored bat (59 calls). In Section One, the highest number of bat calls were recorded at site OR-01 (289 total bat calls) at the Blair Road curve (pullover) near the bar-gated access road to George Jones Church. Site OR-05 (Haul Road access from Blair Road) was surveyed on 5/21/2014 and 14 bat calls were recorded; a follow-up survey (OR-13) at the same location on 6/16/2014 yielded no bat calls. Endangered species activity was low in this entire area as only three combined Gray bat calls were recorded. After Tables 4 & 5, there is a series of plates listed by site identification number as 'OR-01 chart/image' through 'OR-13 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right.



Map 1

Table 4

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-1	35.93679	-84.373573	ETTP/Blair Road (pullover on curve near church)	5/21/2014	4	Anabat SD-2
OR-2	35.933336	-84.374694	ETTP/Haul Road near O-R Turnpike bridge overpass	5/21/2014	3	Anabat SD-2
OR-3	35.93705	-84.377736	ETTP/Haul Road (1.0 mile marker)	5/21/2014	3	Anabat SD-2
OR-4	35.938006	-84.380375	ETTP/Haul Road east of weigh station (scales)	5/21/2014	3	Anabat SD-2
OR-5	35.934566	-84.376051	ETTP/Blair Road (curve at Haul Road bar-gate)	5/21/2014	2	Anabat SD-2
OR-11	35.939343	-84.375547	ETTP/Blair Road/rain gauge station access road (utility ROW)	6/16/2014	3	Anabat SD-2
OR-12	35.937858	-84.381276	ETTP/Haul Road near weigh station (scales)	6/16/2014	3	Anabat SD-2
OR-13	35.934331	-84.376116	ETTP/Blair Road (curve at Haul Road bar-gate)	6/16/2014	3	Anabat SD-2

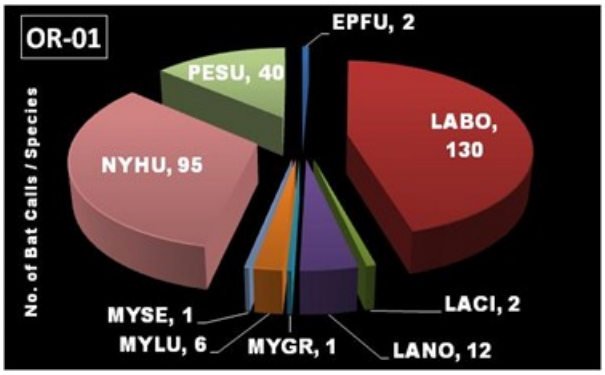
Table 5

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-01	2	130	2	12	1		6	1		95	40		28	44	16	265	8
OR-02		1	3	3						4	5	2	4	12	8	10	
OR-03		6		3	1		1	1		6	1		6	22	3	13	3
OR-04	1	14		12	1					9	4		3	20	13	27	1
OR-05		8					1			2	3		1	35		13	1
OR-11	1	13					1	3		67	4		2	12	1	84	4
OR-12	1	8								1	2		2	16	1	13	
OR-13	no bats					no bats					no bats						
subtotals	5	180	5	30	3		9	5		184	59	2	46	161	42	425	17

[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The red color bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz) , Mid (25-35 kHz), or Myotis (≥ 40kHz).*** All bat files were processed using the Kaleidoscope PRO automated identification software program.

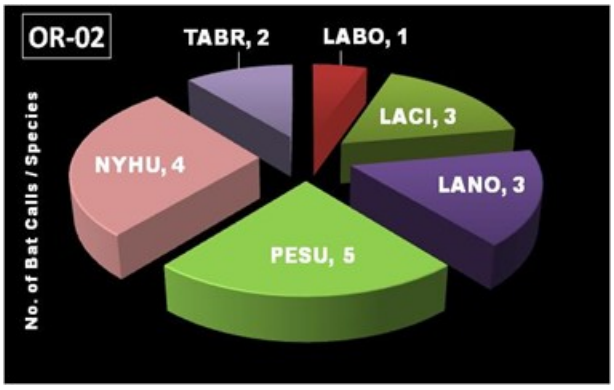
Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

Site Specific Bat Call Data/Pictures (Plates)



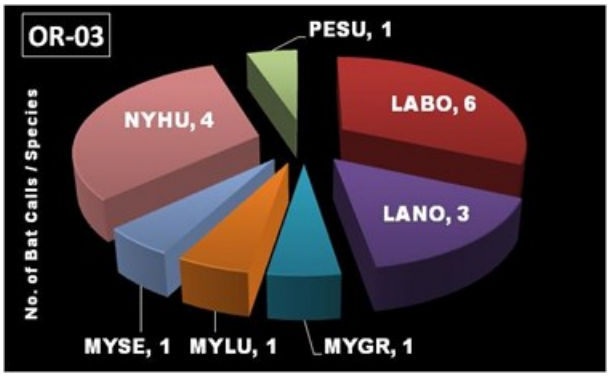
OR-01 chart

OR-01 image



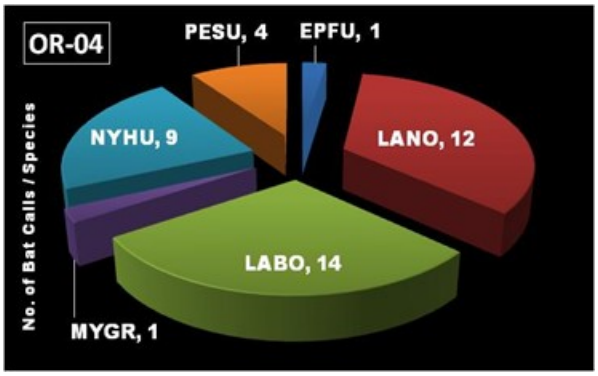
OR-02 chart

OR-02 image

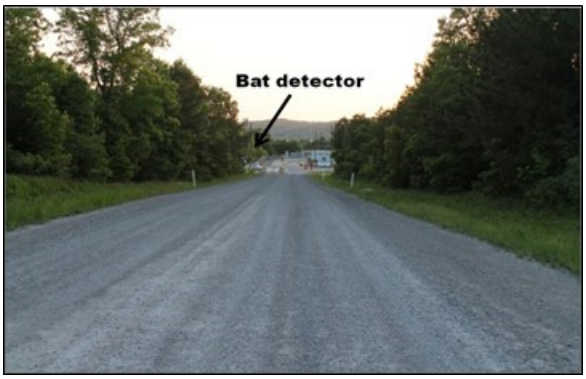


OR-03 chart

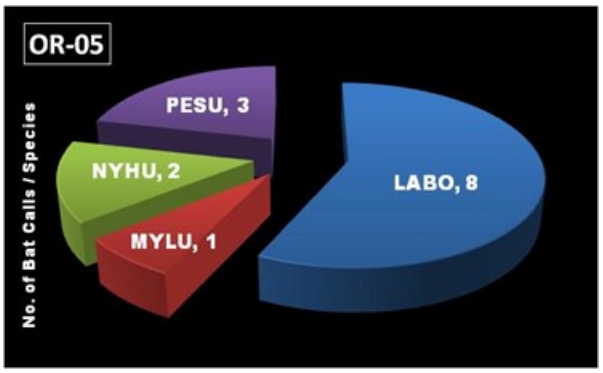
OR-03 image



OR-04 chart

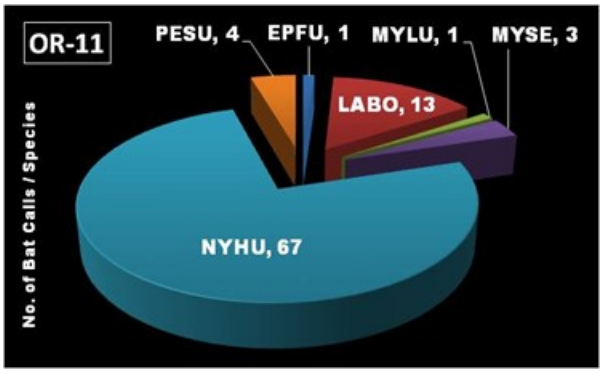


OR-04 image

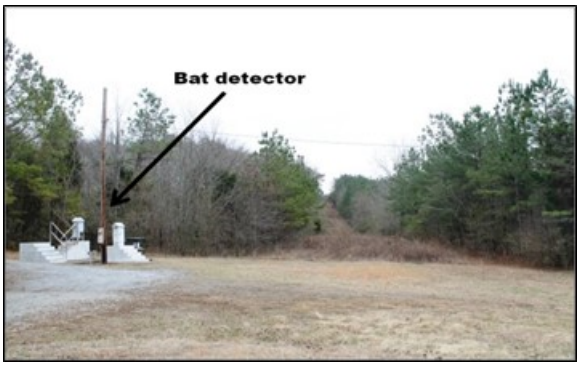


OR-05 chart

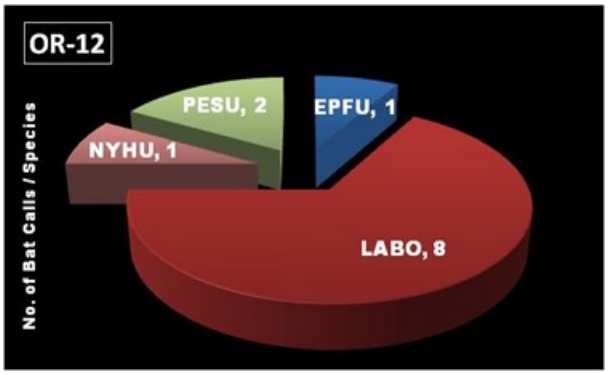
OR-05 image



OR-06 chart

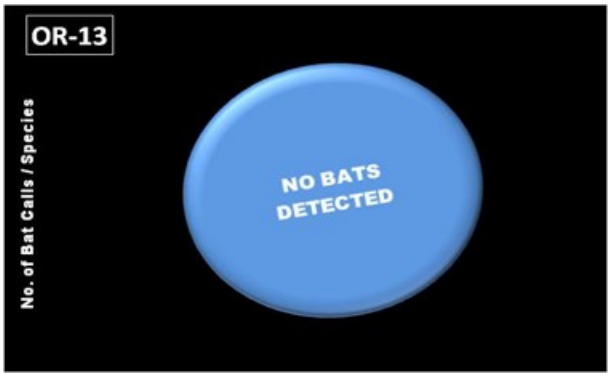


OR-06 image



OR-12 chart

OR-12 image



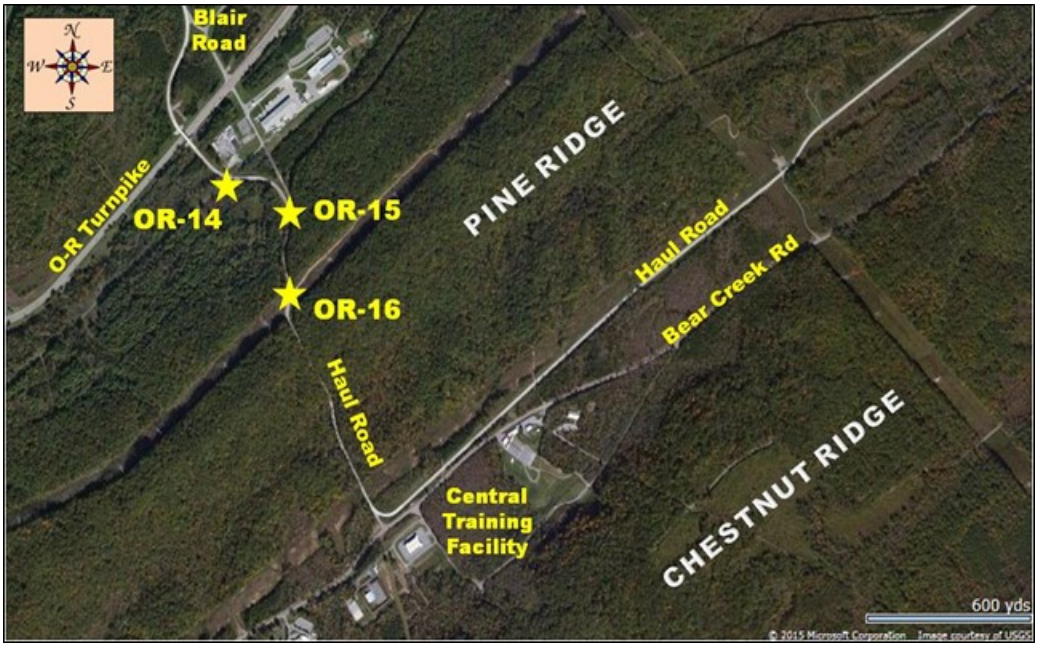
OR-13 chart

OR-13 image

Section II: ETTP: Haul Road / Flannagan Road

Three sites were actively monitored for approximately three hours to record ultrasonic bat calls on Section Two. Surveying was conducted along the Haul Road (Flannagan Road) between the Oak Ridge Turnpike and the forested crest of Pine Ridge to the south. These sites were surveyed with Anabat SD-2 and EchoMeter EM3+ detectors on 6/16/2014. Overall, bat activity was light as only a combined total of 83 bat calls were identified to species by the Kaleidoscope PRO program and 48 additional bat calls were recorded, but not identified. The dominant species detected was the Eastern Red bat (26 calls) and the Evening bat (42 calls). In Section Two, the highest number of bat calls was recorded at site OR-14 (64 total bat calls) located at a bar-gated access road (junction with Haul Road) leading west into the old Happy Valley construction camp. No endangered species bat calls were recorded in this area. After Tables 6 & 7 (below here), there is a series of

plates listed by site identification number as 'OR-14 chart/image' through 'OR-16 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right.



Map 2

Table 6

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-14	35.930487	-84.374683	Haul Road at bar-gated access road to old "Happy Valley" site	6/16/2014	3	Anabat SD-2
OR-15	35.929536	-84.372307	Haul Road at base of Pine Ridge at jct of Old Flannagan Road	6/16/2014	3	Anabat SD-2
OR-16	35.927451	-84.37235	Haul Road at crest of Pine Ridge at powerline ROW	6/16/2014	3	EchoMeter EM3+

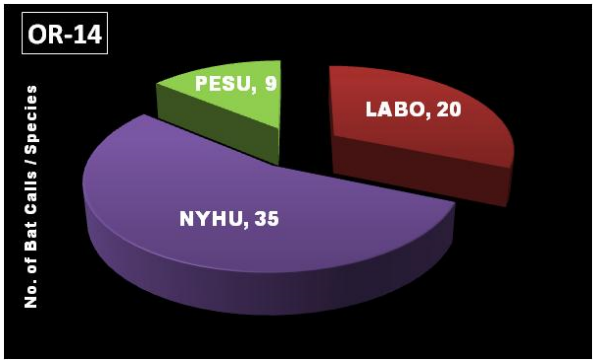
Table 7

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-14		20								35	9		1	20		64	
OR-15		6		1			1			6	2		9	506	1	14	1
OR-16	1									1	1		38	30	1	2	
subtotals	1	26		1			1			42	12		48	556	2	80	1

[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The red color bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz) , Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

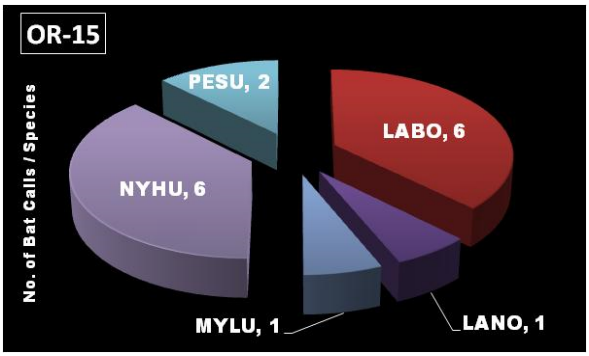
Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

Site Specific Bat Call Data/Pictures (Plates)

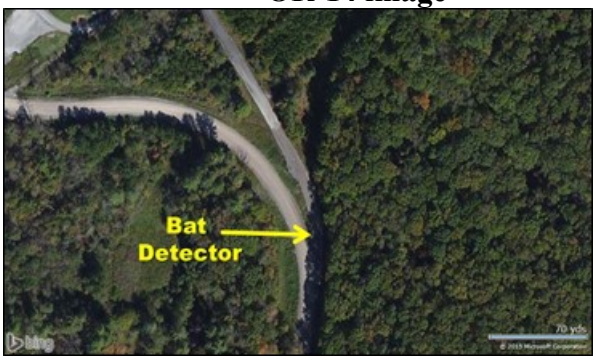


OR-14 chart

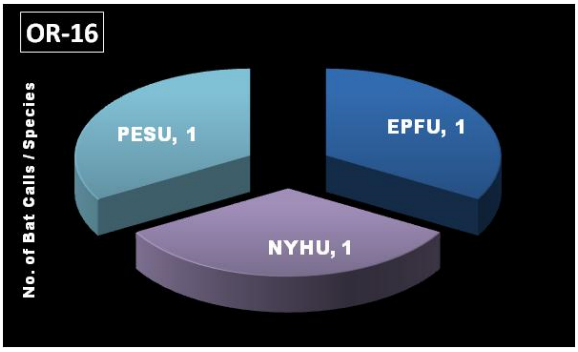
OR-14 image



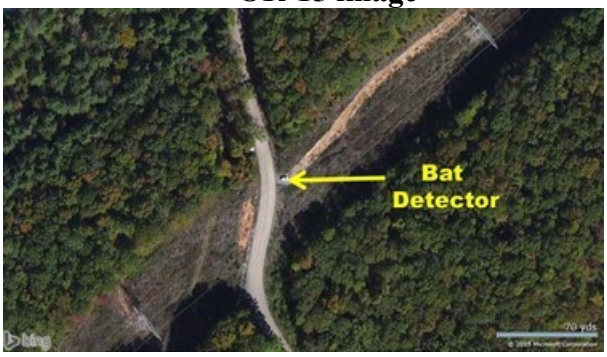
OR-15 chart



OR-15 image



OR-16 chart



OR-16 image

Section III: Blair Road / Poplar Creek Greenway

Three sites were actively monitored for approximately three hours to record ultrasonic bat calls on Section Three. On 6/17/2014, we actively monitored with Anabat SD-2 detectors at Poplar Creek near the old RR bridge (ETTP area) and at Blair Road quarry. There is a known cave located north of the quarry on rocky bluffs above Poplar Creek. On 8/7/2014, we surveyed the Poplar Creek greenway bridge (at its confluence with East Fork Poplar Creek) using two detectors, Anabat SD-2 and the SongMeter SM2BAT+. Overall, bat activity was moderate as a combined total of 249 bat calls were identified to species by the Kaleidoscope PRO program and 152 additional bat calls were recorded, but not identified. The dominant species detected were the Eastern Red bat (33 calls), Hoary bat (68 calls), and the Tri-colored bat (50 calls). In Section Three, the highest number of bat calls recorded was at sites OR-18 (95 calls) and OR-69b (98 calls); OR-18 is the quarry site

and OR-69 is the Poplar Creek/EFPC site. A total of 45 endangered Gray bat calls were recorded in Section Three, with the majority (42 calls) recorded at site OR-69b (bridge at confluence of EFPC with Poplar Creek). Gray bats prefer to forage for insect prey over water and it is possible these bats are roosting and emerged from several caves located <1.5 miles from this location. For quality control and to compare detector results, we monitored with one Anabat SD-2 and one SM2BAT+ at the Poplar Creek/EFPC site (OR-69a/b). Kaleidoscope PRO identified 98 bat calls and 46 no identifications from the Anabat SD-2 files, and 30 identified bat calls and 89 no identifications from the SongMeter SM2BAT+ files. It appears that the Anabat SD-2 recorded calls with sufficient call characteristics (i.e., search, approach, feeding buzz) to enable a greater number of species identifications (instead of no identifications) compared to the SongMeter SM2BAT+. After Tables 8 & 9 (below here), there is a series of plates listed by site identification number as 'OR-17 chart/image' through 'OR-69b chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right.

Map 3

Table 8

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-17	35.942531	-84.389795	ETTP/Blair Rd/ Poplar Creek shore near old RR bridge	6/17/2014	3	Anabat SD-2
OR-18	35.941532	-84.387306	ETTP/Blair Road quarry	6/17/2014	3	Anabat SD-2
OR-69	35.949515	-84.386737	Poplar Creek trail jct w/ East Fork Poplar Creek (bridge)	8/7/2014	2	Anabat SD-2 / SongMeter SM2BAT+

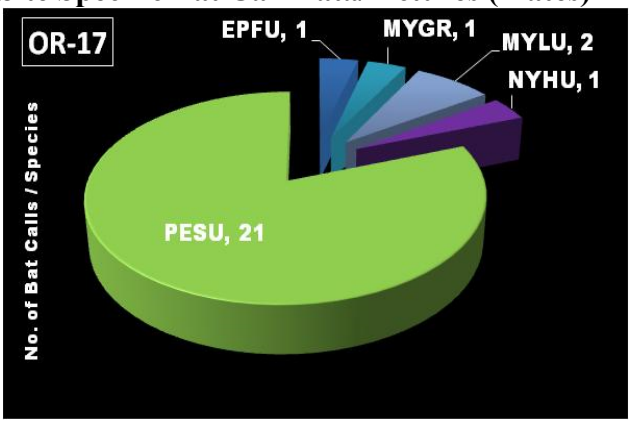
Table 9

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-17	1				1		2			1	21		5	12	1	22	3
OR-18	5	4	65	14						4	3		12	49	84	11	
OR-69a	2	9			2	1	1	1		6	8		89	31	2	23	5
OR-69b	10	20	3		42		2			3	18		46	89	13	41	44
subtotals	18	33	68	14	45	1	5	1		14	50		152	181	100	97	52

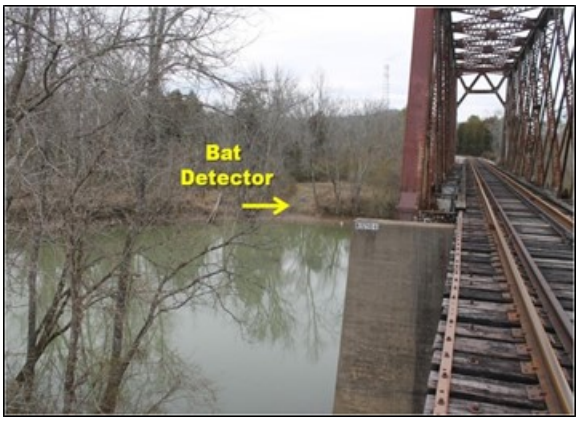
[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, <u>not</u> the number of bats present. ***Blank boxes*** = no bat calls recorded. The red color bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

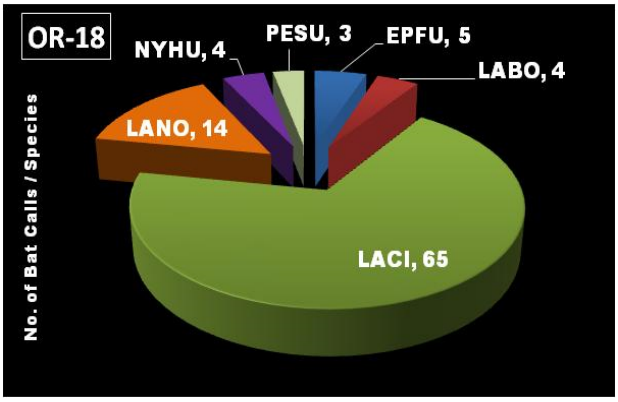
Site Specific Bat Call Data/Pictures (Plates)



OR-17 chart

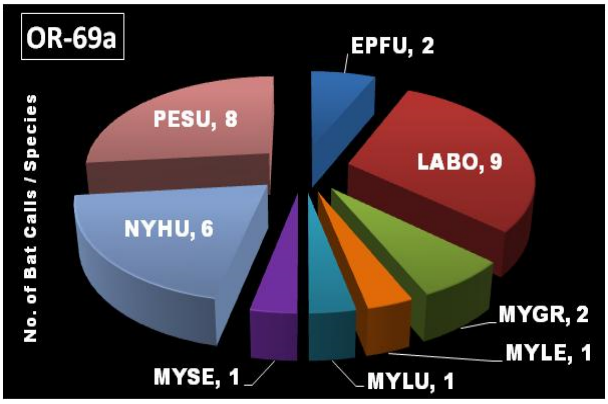


OR-17 image



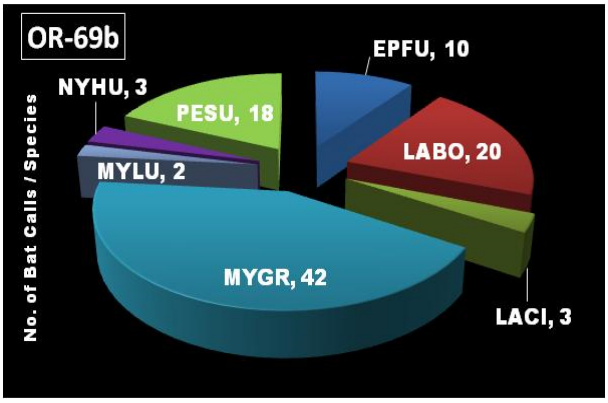
OR-18 chart

OR-18 image



OR-69a chart

OR-69a image

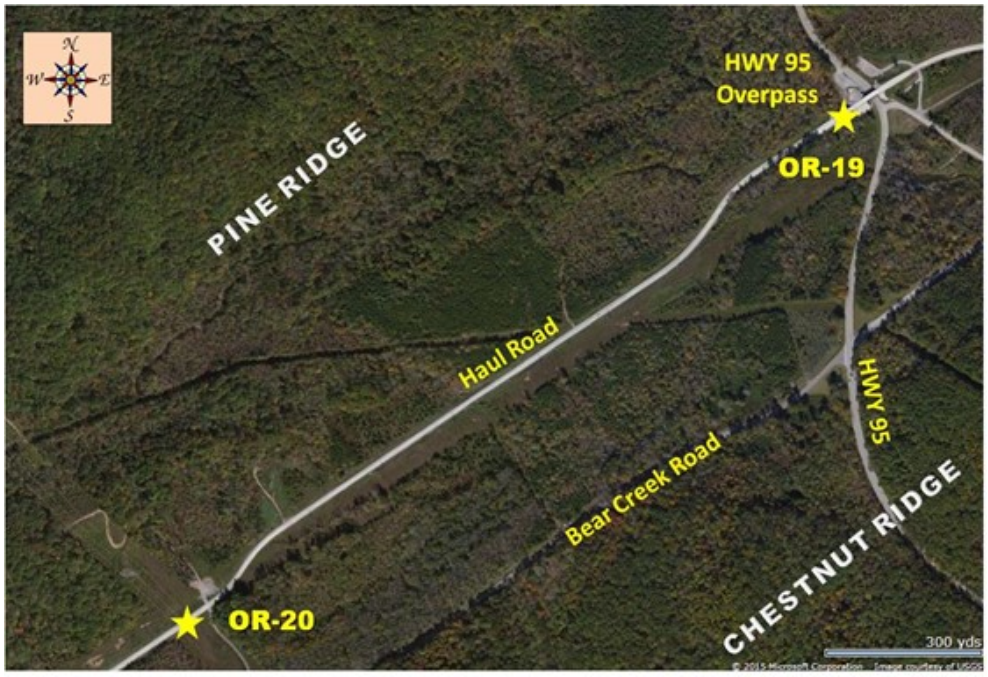


OR-69b chart

OR-69b image

Section IV: Haul Road (central area) near Highway 95 Overpass

Two Haul Road sites were monitored on 6/17/2014 with Anabat SD-2 detectors to record ultrasonic bat calls on Section Four. We deployed one Anabat SD-2 (preprogrammed to passively record dusk-dawn) at the Highway 95 overpass bridge (OR-19). The second detector was used to actively monitor along the Haul Road at the junction of two powerline ROWs (OR-20). Overall, bat activity was light at both sites as a combined total of 130 bat calls were identified to species by the Kaleidoscope PRO program and 29 additional bat calls were recorded, but not identified. The dominant species detected at the overnight site (OR-19) included the Evening bat (11 calls), Hoary bat (14 calls), and the Tri-colored bat (14 calls). The dominant species at site OR-20 was the Tri-colored bat (29 calls). A total of 4 endangered Gray bat calls were recorded at the overnight site (Hwy 95 overpass bridge). They may have been foraging over Bear Creek located beneath the bridge. After Tables 10 & 11 (below here), there is a series of plates listed by site identification number as 'OR-19 chart/image' through 'OR-20 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right.



Map 4

Table 10

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-19	35.93844	-84.341097	Haul Road at HWY 95 overpass bridge	6/17/2014	overnight	Anabat SD-2
OR-20	35.930622	-84.353971	Haul Road (west of Hwy 95) at powerline ROW jct.	6/17/2014	3	Anabat SD-2

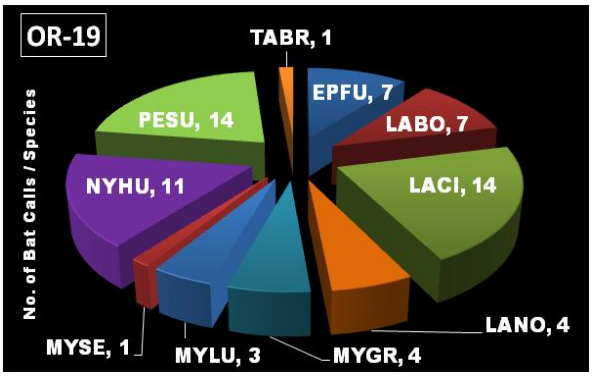
Table 11

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-19	7	7	14	4	4		3	1		11	14	1	6	46	26	32	8
OR-20	5	7	1	4			9	5		4	29		23	26460	1	14	1
subtotals	12	14	15	8	4		12	6		15	43	1	29	26506	27	46	9

[1]**Notes:** The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The red color bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz).** All bat files were processed using the Kaleidoscope PRO automated identification software program.

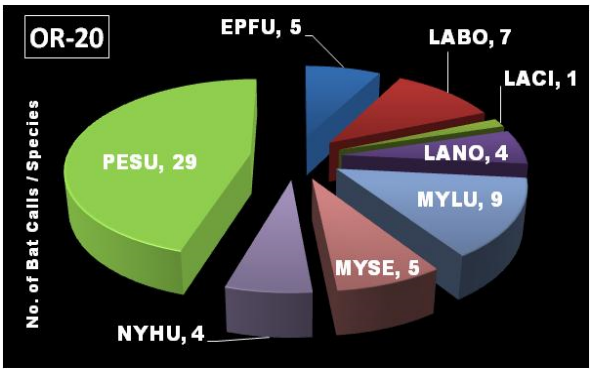
Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

Site Specific Bat Call Data/Pictures (Plates)

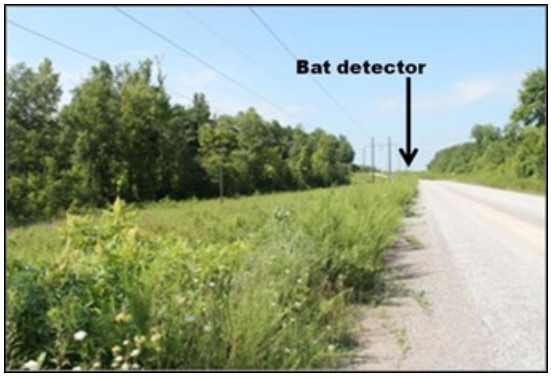


OR-19 chart

OR-19 image



OR-20 chart

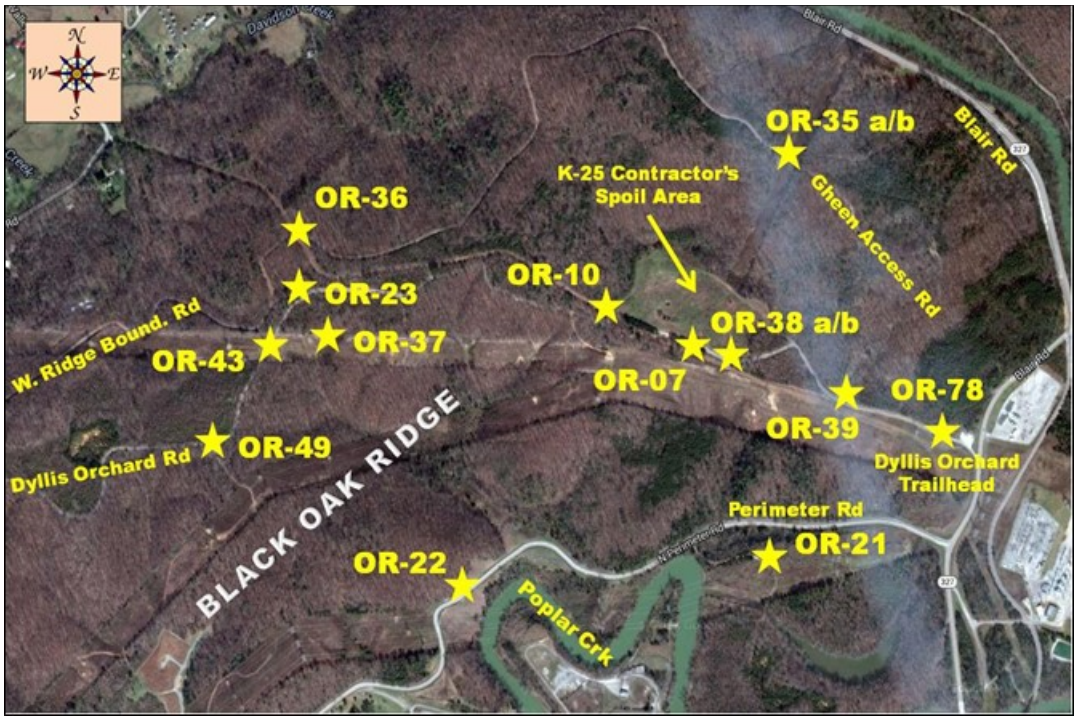


OR-20 image

Section V: East Dyllis Orchard Road (greenway) / Perimeter Road

Section Five consists of the eastern section of the Dyllis Orchard greenway on Black Oak Ridge (Black Oak Ridge Conservation Easement/BORCE) situated north of ETTP. The area is a mix of forest, utility right-of-ways (ROWs), gravel access roads, pre-Manhattan orchards, a woodland hiking/cycling trail (Twisted Beech Trail), and an old landfill site (K-25 Contractor's Spoil Area). The area is also characterized by a rich flora of wildflowers and ferns. There are several pre-Manhattan home sites in this section including the site of a former apple packing depot (site OR-49). Thirteen sites were actively monitored between 6/6/2014-7/26/2014 with Anabat SD-2 detectors at 11 sites and a mix of detectors (Anabats, SongMeter SM2BAT+, SM3BAT) at 2 sites to record ultrasonic bat calls on Section Five. Average survey time was 3.5 hours (dusk to approximately midnight). Overall, bat activity was heavy as a combined total of 1129 bat calls were identified to species by the Kaleidoscope PRO program and 258 additional bat calls were recorded, but not identified. The overall dominant species detected at all sites included the Big Brown bat (420 calls), Eastern Red bat (175 calls), and the Tri-colored bat (197 calls). Insect noise was prevalent at three sites with 885, 1960, and 840 noise files recorded at OR-23, OR-49, and OR-43 respectively. We detected a combined total of 131 *Myotis* spp. calls recorded from all sites. A total of nine endangered species calls (Gray bat, Indiana bat) were recorded at the OR-49 site (former apple packing/shipping depot).

For quality control and to compare detector results, we tested deployment of two Anabat SD-2s at site OR-35 (detectors oriented in opposite directions), and compared the Anabat SD-2 with the SongMeter SM3BAT at site OR-38 (detectors oriented in opposite directions). The results for both tests did not compare favorably, so the assumption is made that the difference in directional orientation of the respective microphones accounts for the discrepancies. Future QA/QC tests will be conducted with detectors oriented in the same direction. Kaleidoscope PRO identified 98 bat calls and 46 no identifications from the Anabat SD-2 files, and 30 identified bat calls and 89 no identifications from the SongMeter SM2BAT+ files. After Tables 12 & 13 (below here), there is a series of plates listed by site identification number as 'OR-07 chart/image' through 'OR-78 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right. Due to the volume of sites and data, the reader is directed to the self-explanatory plates below for additional specific bat call data for each of the 13 survey sites.



Map 5

Table 12

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-7	35.94935	-84.397767	Dyllis Orchard Road/ open field @ K25 landfill	6/6/2014	3	Anabat SD-2
OR-10	35.949866	-84.399628	Dyllis Orchard Rd/ southwest corner of K-25 landfill	6/6/2014	2	Anabat SD-2
OR-21	35.945215	-84.39605	Perimeter Road at powerline acc. rd near oxbow lake	6/17/2014	3	Anabat SD-2
OR-22	35.944451	-84.40341	Perimeter Rd on ridgetop overlooks ETTP (Clinch R.)	6/17/2014	2	Anabat SD-2
OR-23	35.950227	-84.407208	Dyllis Orchard Road / jct. w/ access road	6/21/2014	5	Anabat SD-2
OR-35 a & b	35.952728	-84.395406	Jct of Gheen Access Rd w/ West Boundary Ridge Rd	7/3/2014	4	Anabat SD-2 (2 units)
OR-36	35.95133	-84.40738	Dyllis Orchard: W. Bound Ridge Rd @ gas pipeline ROW	7/3/2014	4	Anabat SD-2
OR-37	35.949211	-84.408002	Dyllis Orchard Rd / powerline ROW	7/3/2014	4	Anabat SD-2
OR-38 a & b	35.949011	-84.397112	Dyllis Orchard Rd: K-25 landfill @ powerline ROW (field)	7/3/2014	4	Anabat SD-2 / SongMeter SM3BAT
OR-39	35. 948294	-84.394258	Dyllis Orchard Road jct w/ Gheen Access Road / ROW	7/3/2014	3	SongMeter SM2BAT+
OR-43	35.949254	-84.407991	Dyllis Orchard Road at powerline ROW	7/15/2014	3	Anabat SD-2
OR-49	35.947413	-84.409418	Dyllis Orchard Rd /former apple storehouse acc. road	7/26/2014	4	Anabat SD-2
OR-78	35.947447	-84.391361	Dyllis Orchard Greenway at bargate near trailhead	7/15/2014	2	Anabat SD-2

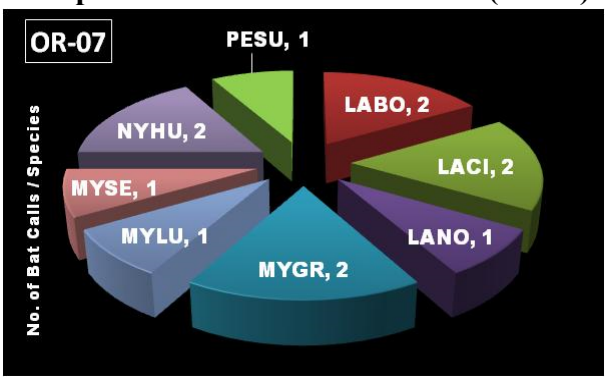
Table 13

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-07		2	2	1	2		1	1		2	1		0	8	3	5	4
OR-10	2	19					1	6		28	19		6	15	2	66	7
OR-21			1								3			14	1	3	
OR-22			1								1				1	1	
OR-23	18	3		8			2			9	14		12	885	26	26	2
OR-35a	8	8	2	4	2		10			4	28		10	412	14	40	12
OR-35b	32	4	6	2				2		2	32		8	42	40	38	2
OR-36	224	23		5			3			29	9		4		229	61	3
OR-37	20	24	4	4			4	4		18	14		6	126	28	56	8
OR-38a	4	8	4	2						2	6		2	46	10	16	
OR-38b	18	8	2				6	10		6	40		155	149	20	54	16
OR-39	4			2									6	8	6		
OR-43	21	13	35	2			3	6		7	15		6	840	58	35	9
OR-49	69	60		2	4		31	30	1	9	14		41	1960	71	83	66
OR-78		3		1			1	1			1		2	1	1	4	2
subtotals	420	175	57	33	8		62	60	1	116	197		258	4506	510	488	131

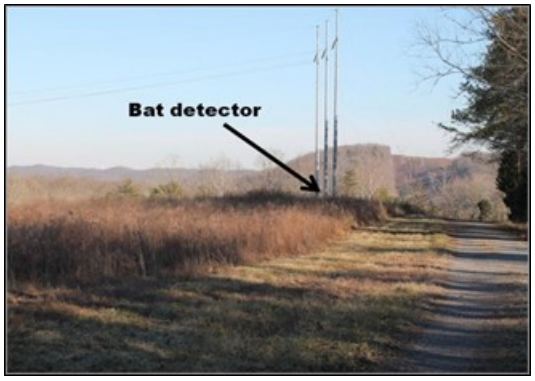
[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The red color bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz) , Mid (25-35 kHz), or Myotis*** **(≥ 40kHz).** All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

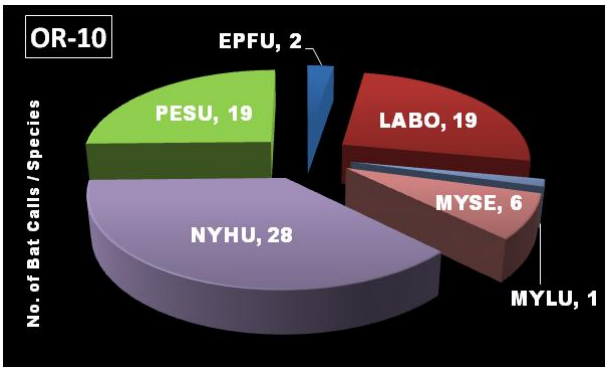
Site Specific Bat Call Data/Pictures (Plates)



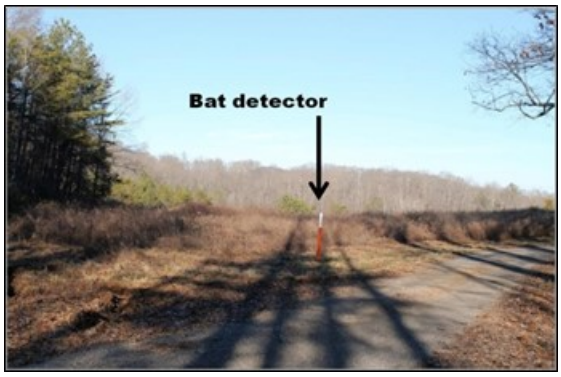
OR-07 chart



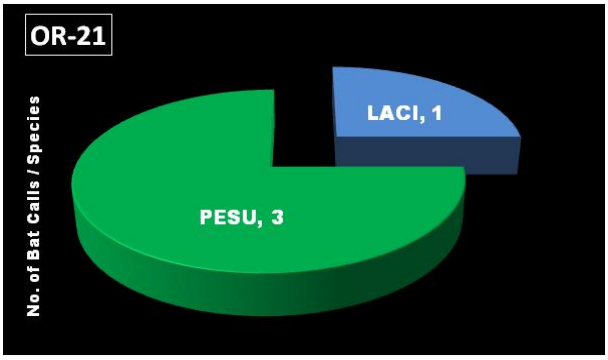
OR-07 image



OR-10 chart

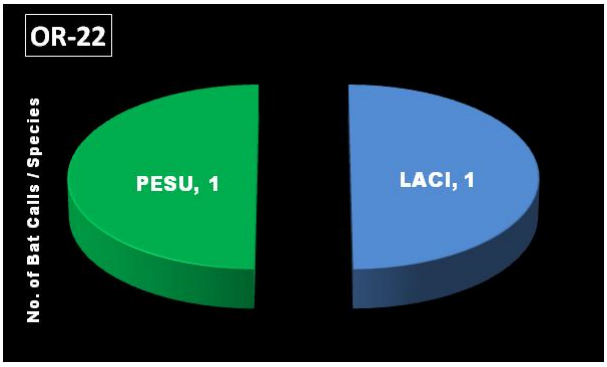


OR-10 image



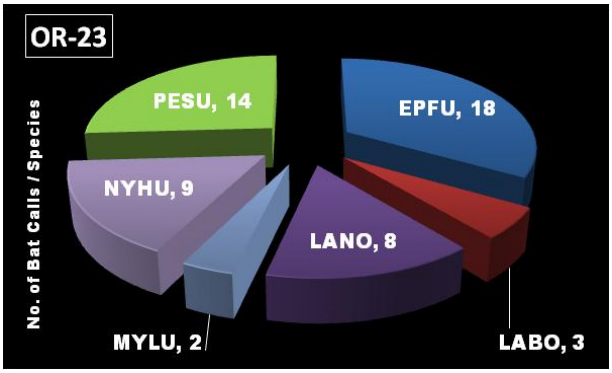
OR-21 chart

OR-21 image



OR-22 chart

OR-22 image



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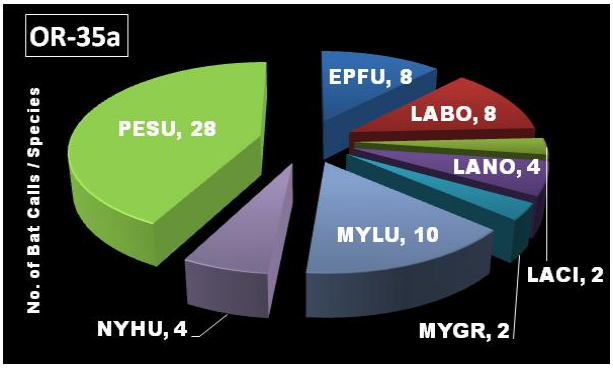
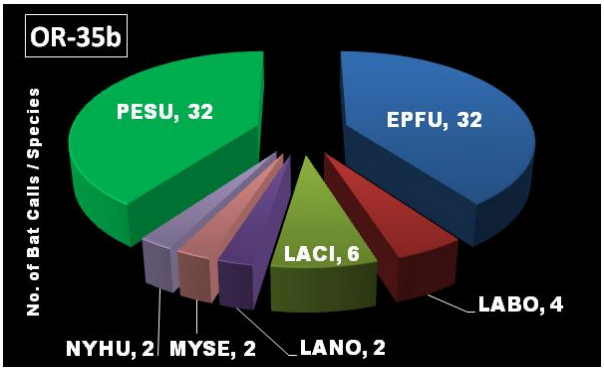
OR-23 image



OR-35a chart

OR-35a image



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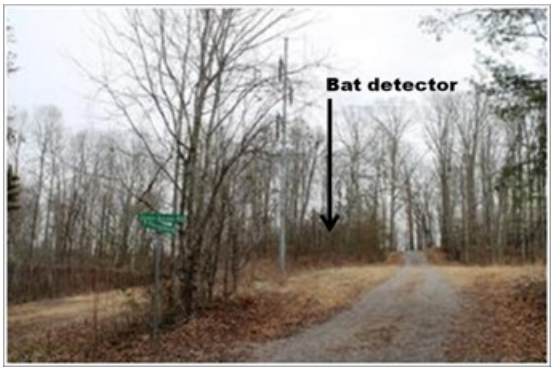

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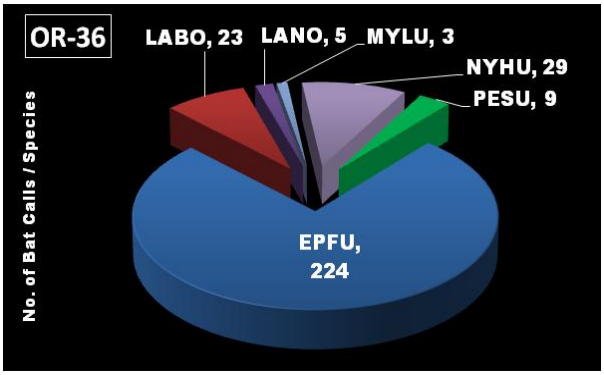
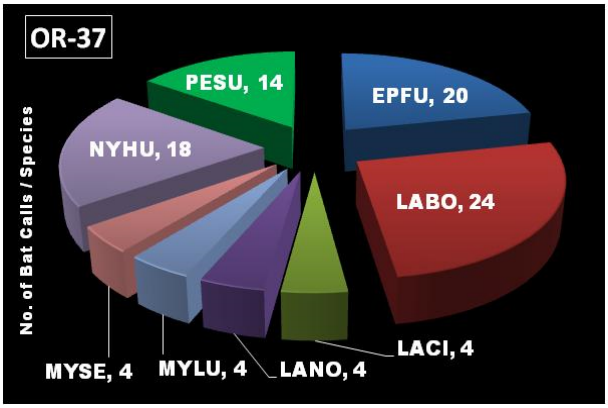


OR-36 chart

OR-36 image



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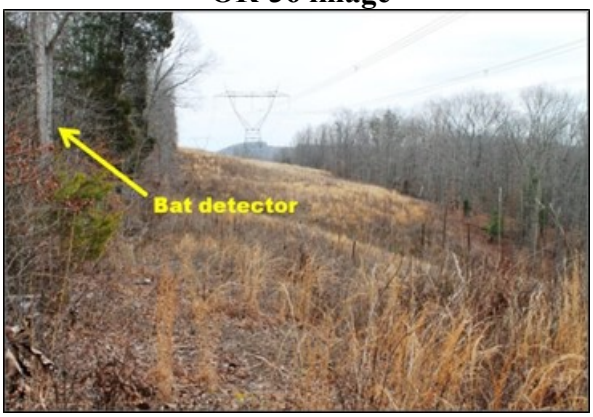

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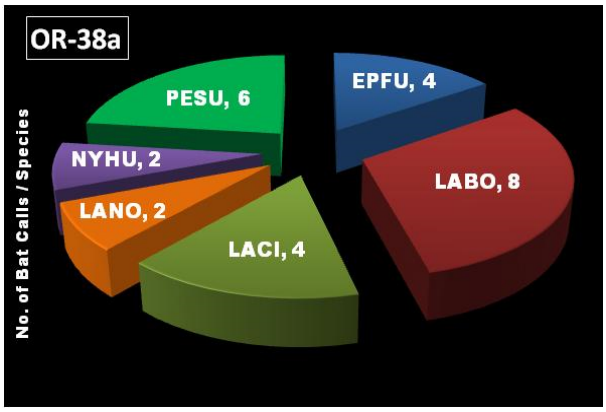
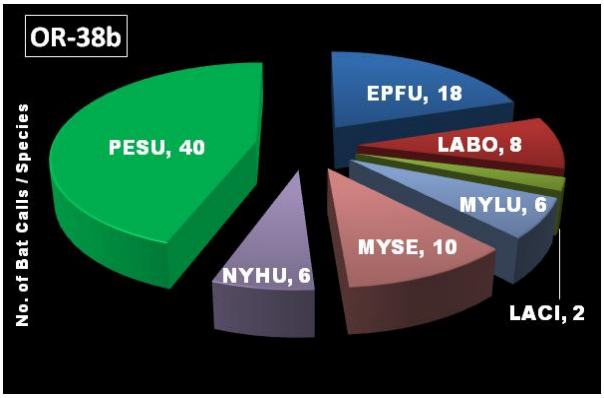


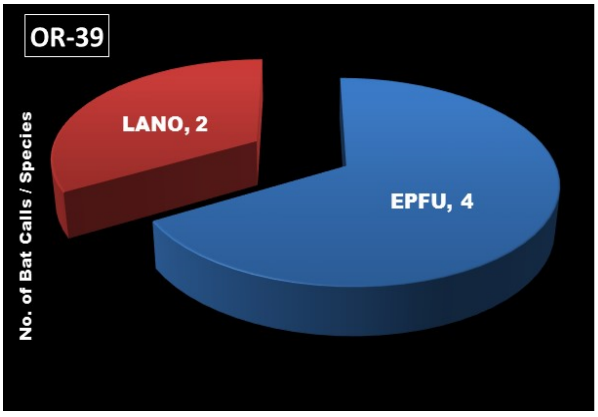
OR-38a chart

OR-38a image



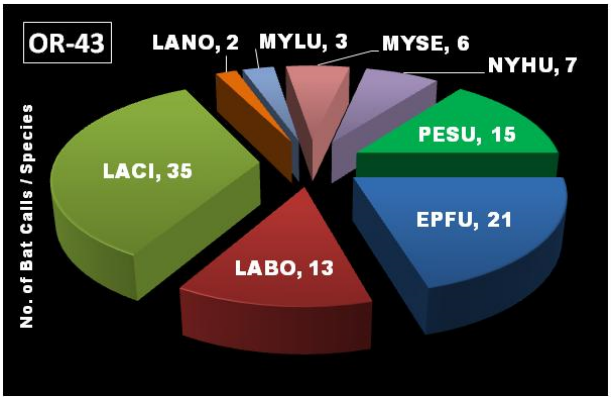
OR-38b chart

OR-38b image

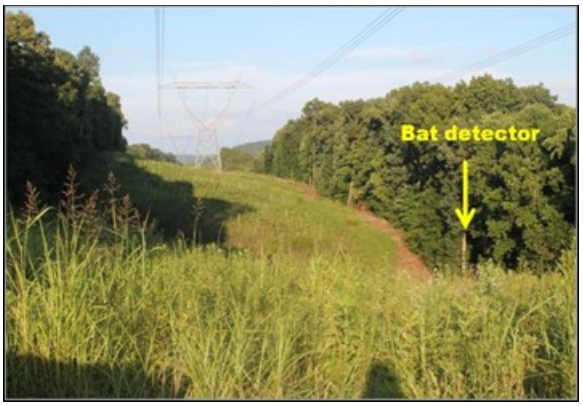


OR-39 chart

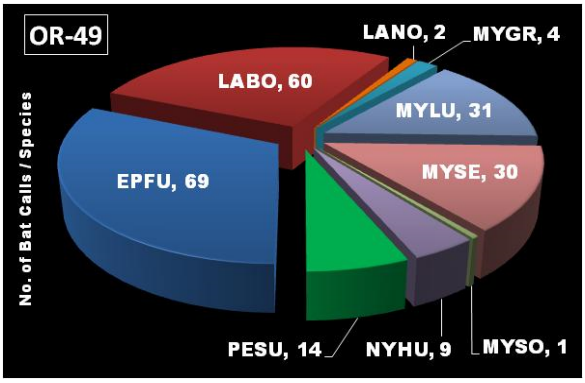
OR-39 image



OR-43 chart

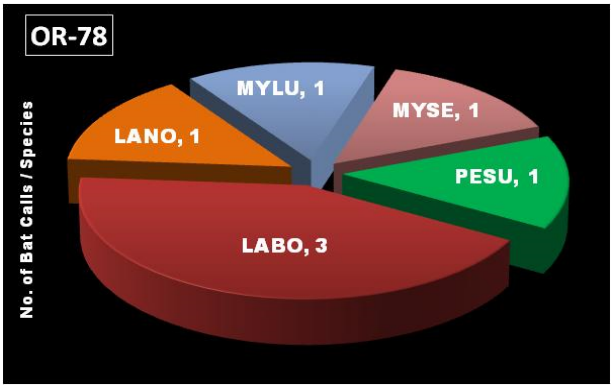


OR-43 image



OR-49 chart

OR-49 image



OR-78 chart

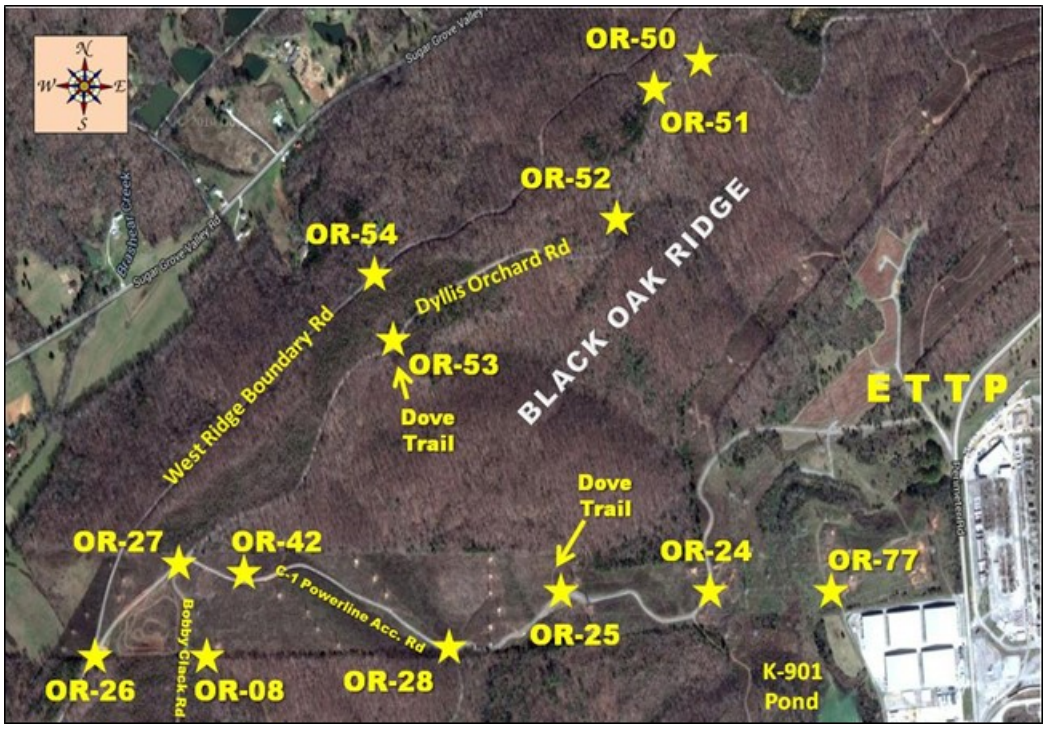
OR-78 image

Section VI: Central Dyllis Orchard Road (greenway)

Section Six consists of the central section of the Dyllis Orchard greenway on Black Oak Ridge (Black Oak Ridge Conservation Easement) situated north of ETTP. The area is a mix of forest, utility right-of-ways (ROWs), gravel access roads, a woodland hiking trail (Dove Trail), and pre-Manhattan orchards. There are several pre-Manhattan home sites in this section. The area is also characterized by a rich flora of wildflowers and ferns. Thirteen sites were monitored between 6/6/2014-9/17/2014 with Anabat SD-2 and SongMeter SM2BAT+ detectors; of these, 12 were actively monitored for approximately 3.5 hours (dusk-midnight) each to record ultrasonic bat calls on Section Six. Station OR-77 (K-901 Pond drainage basin) was monitored passively from dusk-

dawn. Overall, bat activity was heavy as a combined total of 962 bat calls were identified to species by the Kaleidoscope PRO program and 225 additional bat calls were recorded, but not identified. The dominant species detected at all sites included the Big Brown bat (194 calls), Eastern Red bat (207 calls), Little Brown bat (135 calls), Northern Long-eared bat (202 calls), and the Evening bat (106 calls). Insect noise was prevalent at three sites with 1610, 2570, and 928 noise files recorded at OR-51, OR-52, and OR-54 respectively; the noise is likely due to evening insect activity, cicadas, etc. We detected a combined total of 350 *Myotis* spp. calls (mainly Little Brown and Northern Long-eared bats) recorded from all sites. Given the greatest number of *Myotis* bat calls (165) were recorded at monitoring site OR-52 along the forested Dyllis Orchard Road, where are all these *Myotis* bats coming from? Recall that *Myotis* species are predominantly cave bats. There are no documented caves within 0.5-1.0 mile of this site, but it is within 3-5 miles of several known cave locations where these bats may roost; or, is there an unknown cave much closer to this site? We recorded 12 endangered species calls (Gray bat, Indiana bat) from locations on a ridgetop (powerline ROW, OR-30) and near the Clinch River (OR-33).

After Tables 14 & 15 (below here), there is a series of plates listed by site identification number as 'OR-08 chart/image' through 'OR-77 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right. Due to the volume of sites and data, the reader is directed to the self-explanatory plates below for additional specific bat call data for each of the 13 survey sites.



Map 6

Table 14

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-8	35.936946	-84.428022	Dyllis Orchard/ Bobby Clack Road at powerline ROW	6/6/2014	3	Anabat SD-2
OR-24	35.937849	-84.414922	ETTP/C-1 Powerline Road overlooks K-901 Pond basin	6/21/2014	4	Anabat SD-2
OR-25	35.93798	-84.418559	Dyllis/Lower jct. of Dove Trail w/ C-1 Powerline Road	6/21/2014	4	Anabat SD-2
OR-26	35.93705	-84.430393	Dyllis Orchard Rd jct w/ W. Ridge Boundary Rd (ROW)	6/21/2014	3	Anabat SD-2
OR-27	35.938492	-84.427947	ETTP/Dyllis Orchard Rd jct w/ C-1 Powerline Acc. Rd.	6/21/2014	2	Anabat SD-2
OR-28	35.936955	-84.421338	ETTP/Raby Road jct w/ C-1 Powerline Access Rd	6/21/2014	2	Anabat SD-2
OR-42	35.938136	-84.426574	Dyllis Orchard: C-1 Powerline Access Road (ridge)	7/15/2014	3	Anabat SD-2
OR-50	35.94642	-84.41549	Dyllis Orchard Road at curve	7/26/2014	4	Anabat SD-2
OR-51	35.94604	-84.41604	Dyllis Orchard Road at straight-away	7/26/2014	4	Anabat SD-2
OR-52	35.94387	-84.417317	Dyllis Orchard Road / east of DOE warning siren	7/26/2014	4	Anabat SD-2
OR-53	35.94175	-84.42318	Dyllis Orchard Road @ upper Dove Trail (trailhead jct)	7/26/2014	4	SongMeter SM2BAT+
OR-54	35.943148	-84.42328	Dyllis Orchard/West Ridge Boundary Rd (straight-away)	7/26/2014	3	Anabat SD-2
OR-77	35.937493	-84.412154	ETTP/ field west of Fissile Control Bldg (K-901 Pond)	9/17/2014	overnight	SongMeter SM2BAT+

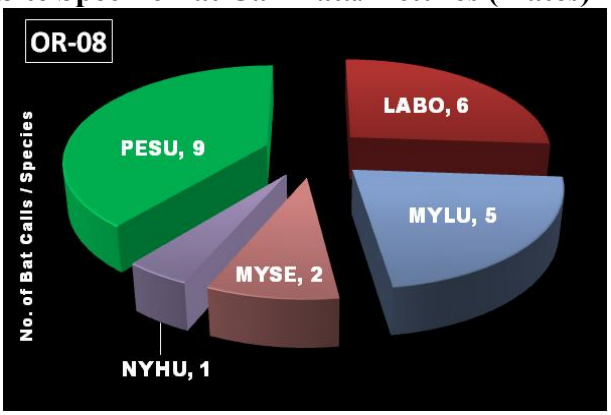
Table 15

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-08		6					5	2		1	9		8	414		16	7
OR-24	5	1		1							2			41	6	3	
OR-25	no bats					no bats					no bats						
OR-26											1			218		1	
OR-27			3										1	5	3		
OR-28	12		1	9									1	20	22		
OR-42	2	1						1			5		4	38	2	6	1
OR-50	31	32	1	2	2	1	21	23		2	1		19		34	35	47
OR-51	28	32		1	2		26	36		16	5		33	1610	29	53	64
OR-52	37	103		1	2		59	102	2	76	16		115	2570	38	195	163
OR-53	no bats					no bats					no bats						
OR-54	72	19		2	1		22	33		5	7		26	928	74	31	56
OR-77	7	13	2	1	3		2	5		6	35		18	143	10	54	10
subtotals	194	207	7	17	10	1	135	202	2	106	81		225	5987	218	394	348

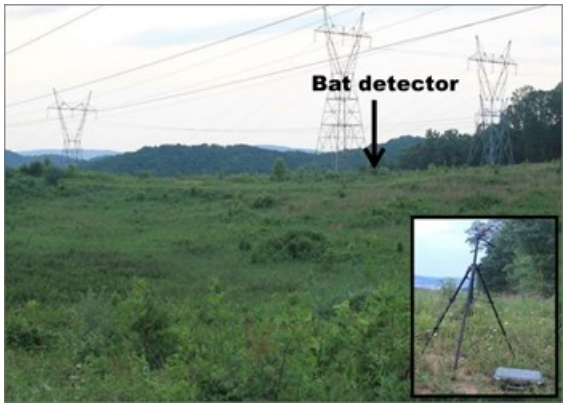
[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz) , Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

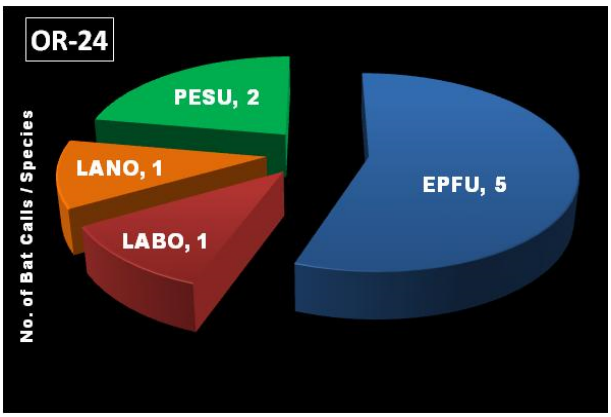
Site Specific Bat Call Data/Pictures (Plates)



OR-08 chart



OR-08 image

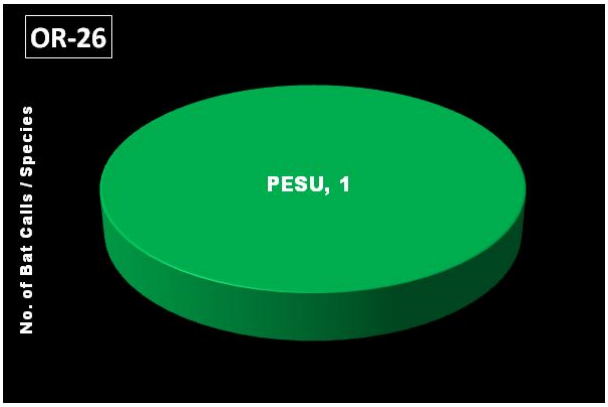


OR-24 chart

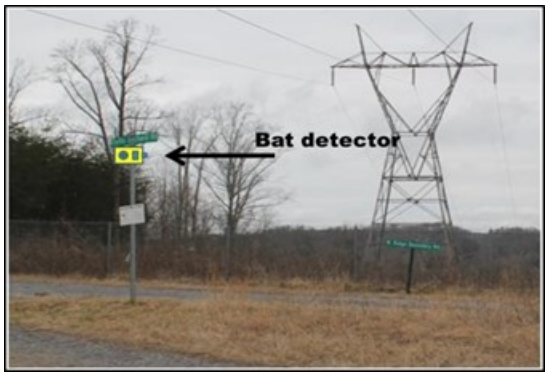
OR-24 image

OR-25 chart

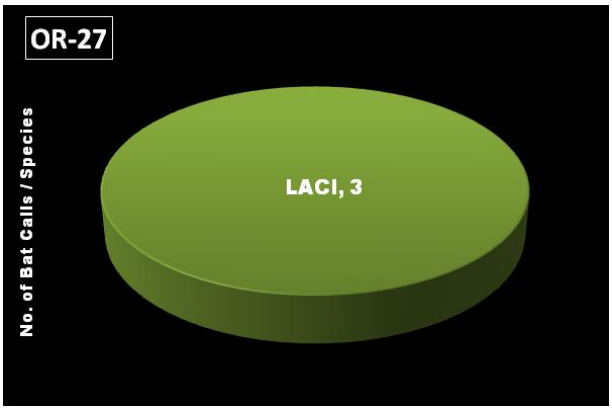
OR-25 image



OR-26 chart

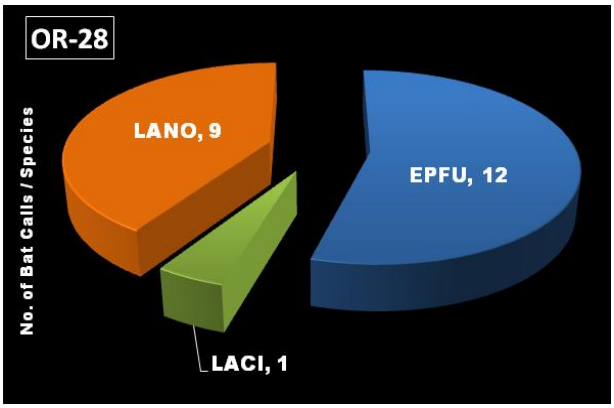


OR-26 image



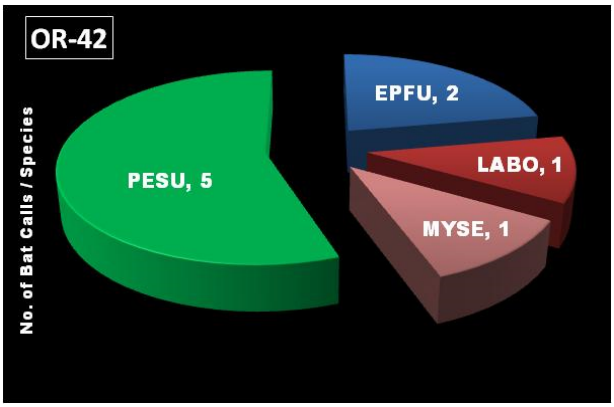
OR-27 chart

OR-27 image

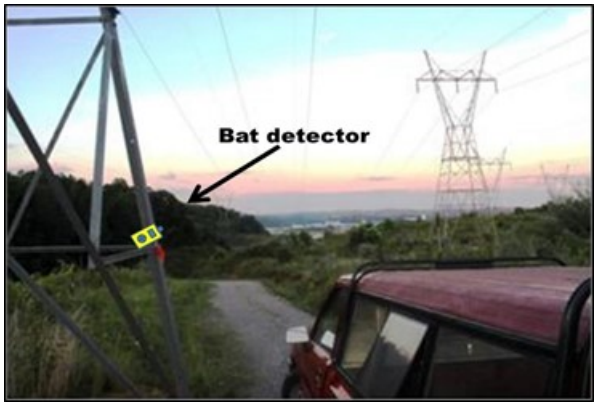


OR-28 chart

OR-28 image



OR-42 chart



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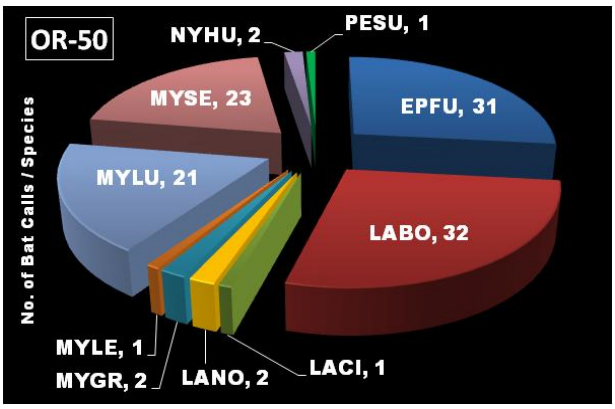
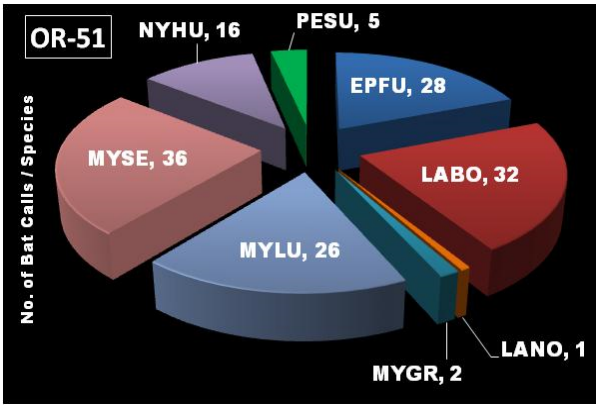
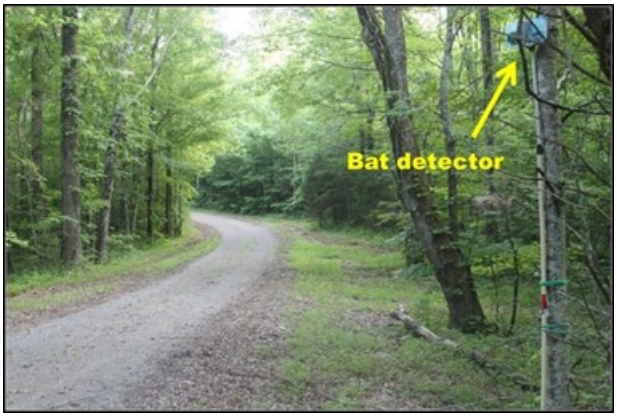


OR-50 chart

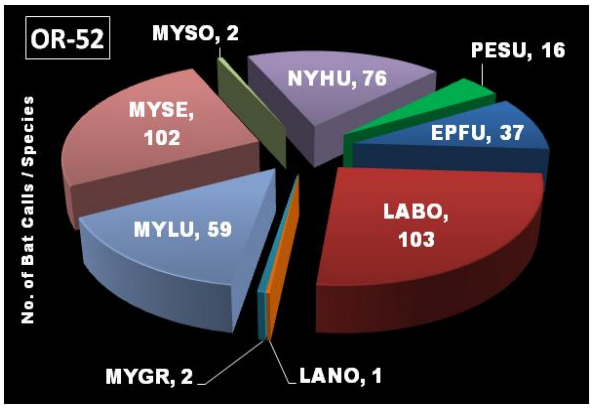
OR-50 image



OR-51 chart



OR-51 image

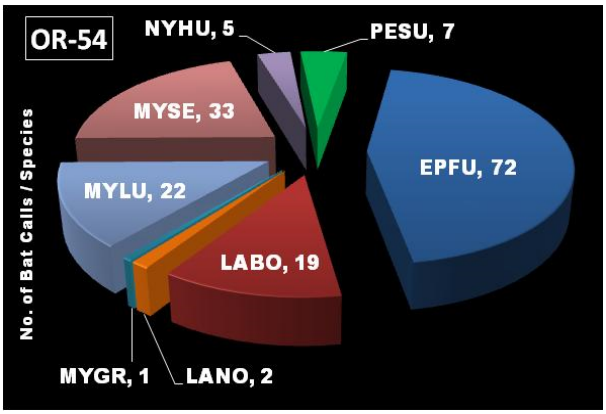


OR-52 chart

OR-52 image

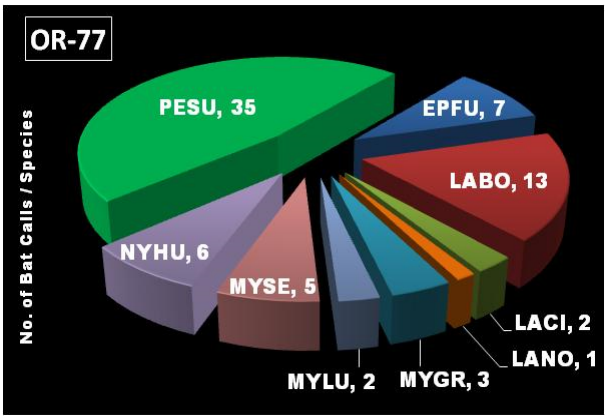
OR-53 chart

OR-53 image



OR-54 chart

OR-54 image



OR-77 chart

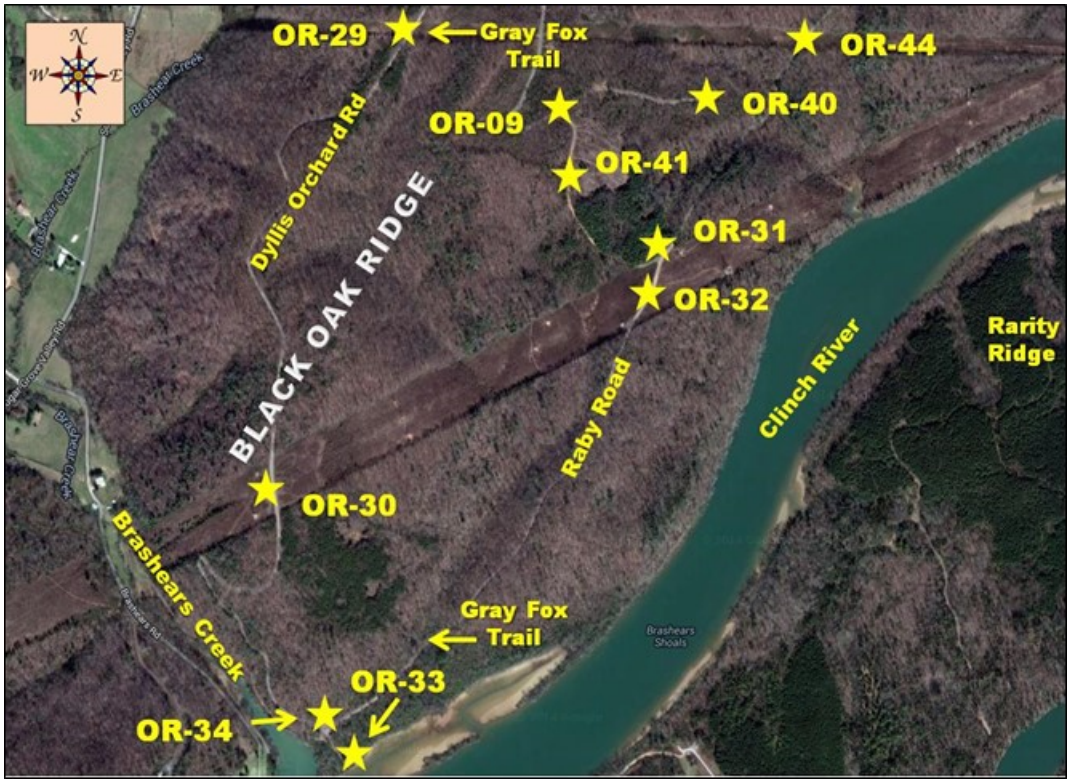
OR-77 image

Section VII: West Dyllis Orchard Road (greenway)

Section Seven consists of the western section of the Dyllis Orchard greenway on Black Oak Ridge (Black Oak Ridge Conservation Easement) situated northwest of ETTP. The area is a mix of forest, utility right-of-ways (ROWs), gravel access roads, a woodland hiking trail (Gray Fox Trail), and pre-Manhattan orchards. There are several pre-Manhattan home sites in this section. The area is also characterized by a rich flora of wildflowers and ferns. Ten sites were actively monitored for an average of 3.5 hours each between 6/6/2014-7/15/2014 with Anabat SD-2 at eight sites,

SongMeter SM2BAT+ at one site, and EchoMeter EM3+ at one site to record ultrasonic bat calls on Section Seven. Overall, bat activity was heavy as a combined total of 656 bat calls were identified to species by the Kaleidoscope PRO program and 1377 additional bat calls were recorded, but not identified. The overall dominant species detected at all sites included the Big Brown bat (193 calls) and Tri-colored bat (323 calls). Insect noise was prevalent at two sites with 509 and 935 noise files recorded at OR-09 and OR-40 respectively. We detected a combined total of 40 *Myotis* spp. calls recorded from all sites. The two most active sites included OR-33 (221 total calls) and OR-44 (145 total calls). We recorded three endangered species calls (Gray bat, Indiana bat) collected at OR-30 and OR-33.

After Tables 16 & 17 (below here), there is a series of plates listed by site identification number as 'OR-09 chart/image' through 'OR-44 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right. Due to the volume of sites and data, the reader is directed to the self-explanatory plates below for additional specific bat call data for each of the ten survey sites.



Map 7

Table 16

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-9	35.933992	-84.427872	Dyllis Orchard/ B. Clack Rd jct. w/ cemetery acc. road	6/6/2014	3	Anabat SD-2
OR-29	35.935556	-84.431477	Dyllis Orchard Rd at jct of Gray Fox Trail	6/30/2014	4	Anabat SD-2
OR-30	35.92699	-84.435124	Dyllis Orchard Rd powerline ROW/Brashears Rd below	6/30/2014	4	Anabat SD-2
OR-31	35.931247	-84.425511	Dyllis Orchard area: jct Raby Rd w/ B. Clack Rd / ROW	6/30/2014	3	Anabat SD-2
OR-32	35.930517	-84.425855	Dyllis Orchard area: Raby Road powerline tower	6/30/2014	4	SongMeter SM2BAT+
OR-33	35.921751	-84.43314	Dyllis Orchard: Raby Road curve / Clinch R. shore	6/30/2014	3	Anabat SD-2
OR-34	35.922499	-84.433622	Dyllis Orchard area: Raby Road curve at ridge base	6/30/2014	3	Anabat SD-2
OR-40	35.934262	-84.424245	Dyllis Orchard area: old cemetery east of B. Clack Rd	7/15/2014	4	Anabat SD-2
OR-41	35.93262	-84.427657	Dyllis Orchard area: large open field along B. Clack Rd	7/15/2014	4	Anabat SD-2
OR-44	35.935408	-84.421864	Dyllis Orchard area: Raby Road south of C-1 Powerline	7/15/2014	3	EchoMeter EM3+

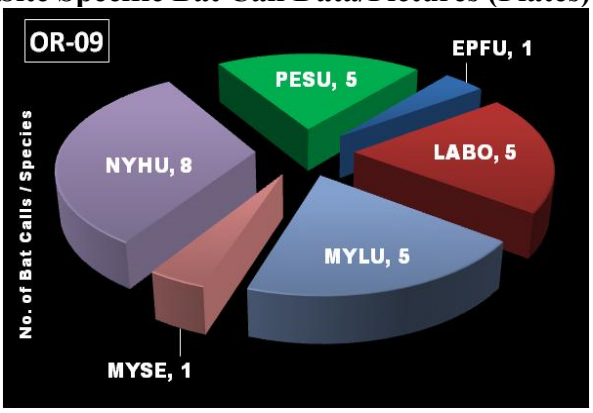
Table 17

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-09	1	5					5	1		8	5		11	509	1	18	6
OR-29	41	2	1	4						2	6		4	37	46	10	
OR-30	1			1					1	2	5		2	14	2	7	1
OR-31	14		1	1							12			24	16	12	
OR-32	11		1										37	15	12		
OR-33	1	12		2	2		1	4			199		21	75	3	211	7
OR-34	24	8	6					1		2	38		5	34	30	48	1
OR-40	15	11	1	2			8	6		3	21		10	935	18	35	14
OR-41	1	2								5	5		2	294	1	12	
OR-44	84	10		4			2	9		4	32		1285	296	88	46	11
subtotals	193	50	10	14	2		16	21	1	26	323		1377	2233	217	399	40

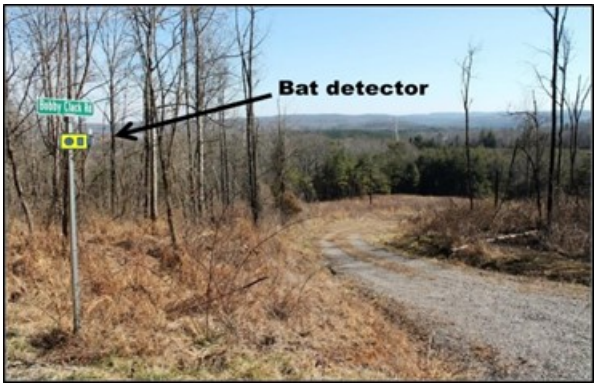
[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis (≥ 40kHz)***. All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

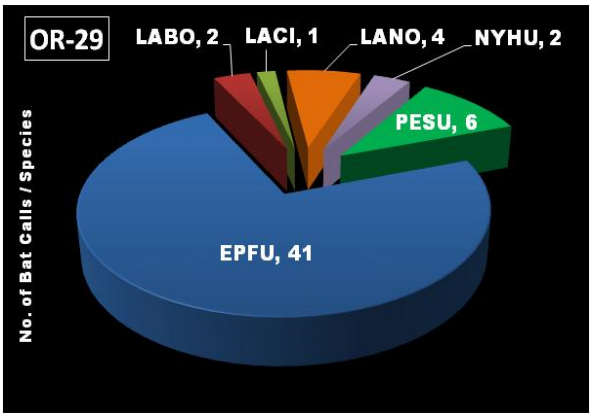
Site Specific Bat Call Data/Pictures (Plates)



OR-09 chart

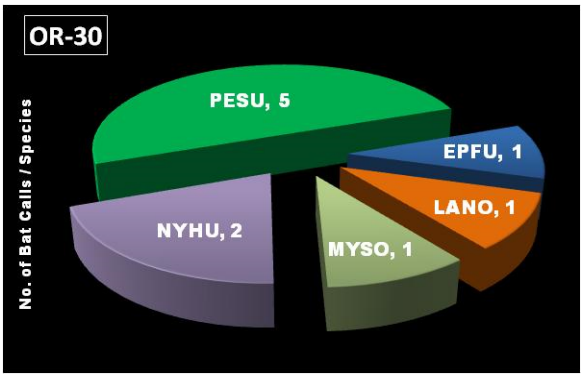


OR-09 image

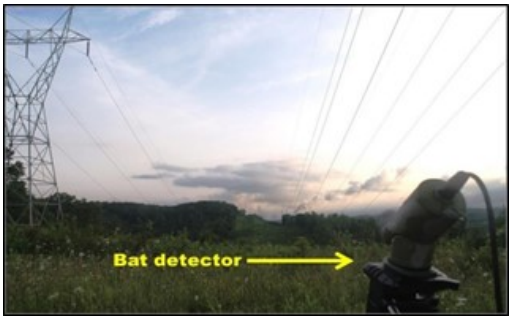


OR-29 chart

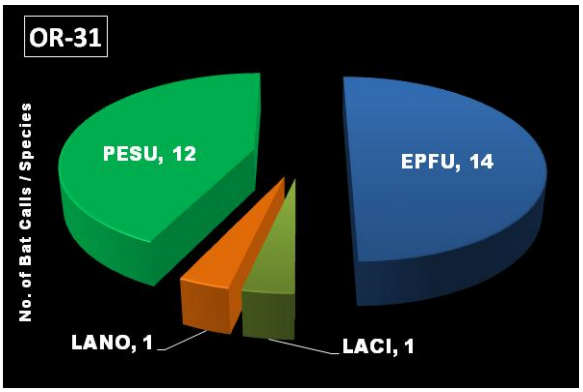
OR-29 image



OR-30 chart

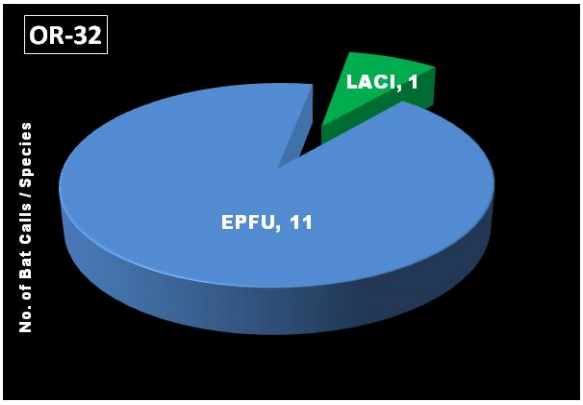


OR-30 image

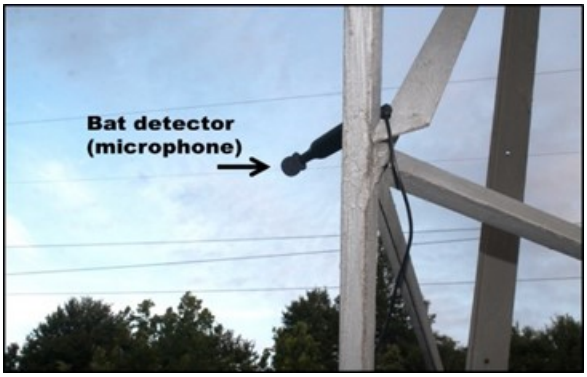


OR-31 chart

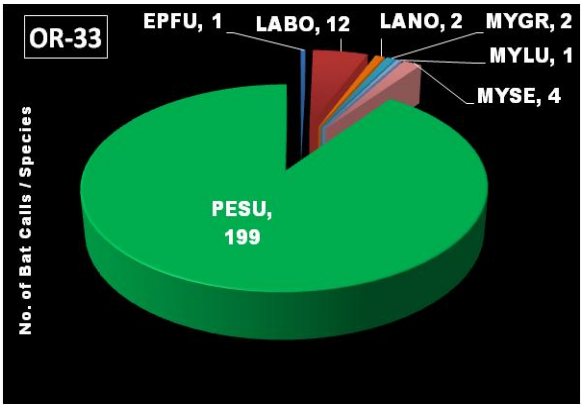
OR-31 image



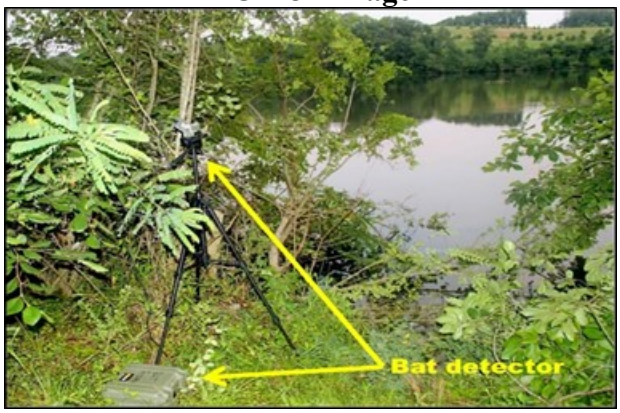
OR-32 chart



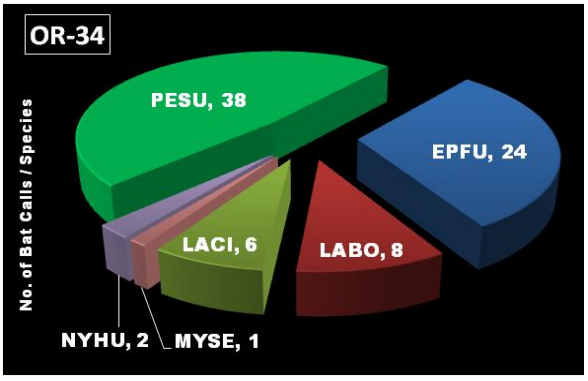
OR-32 image



OR-33 chart

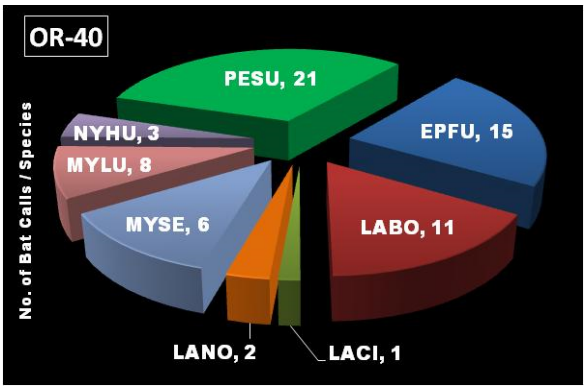


OR-33 image

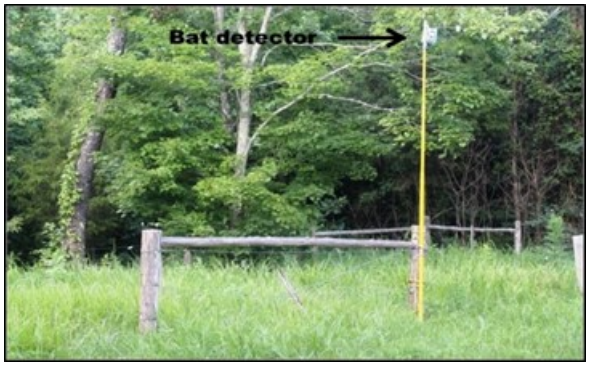


OR-34 chart

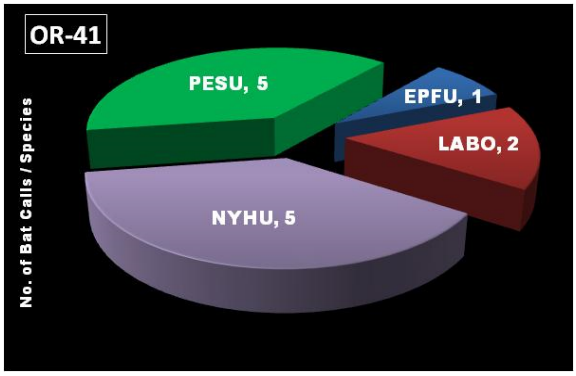
OR-34 image



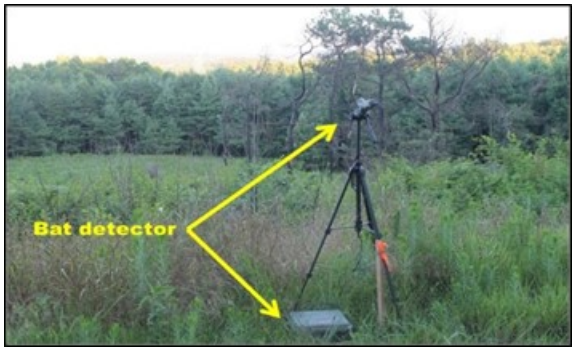
OR-40 chart



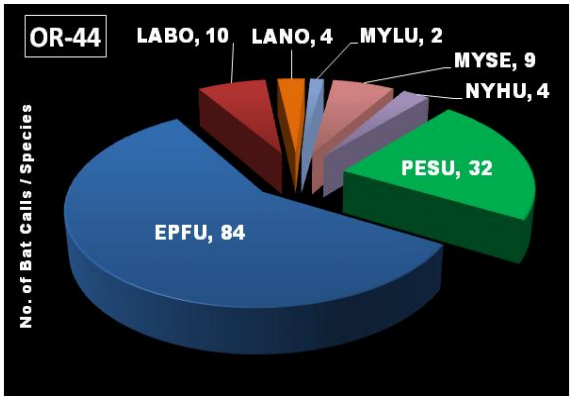
OR-40 image



OR-41 chart



OR-41 image



OR-44 chart

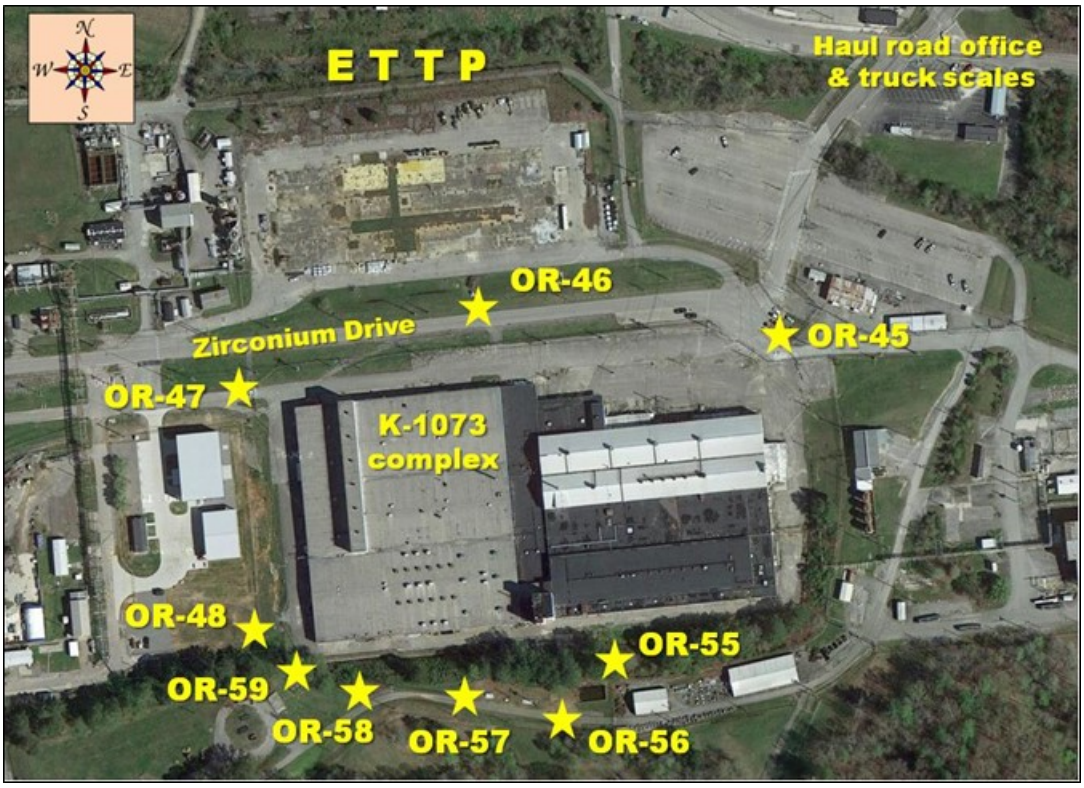
OR-44 image

Section VIII: ETTP / K-1073 building (perimeter of facility)

Section Eight consists of perimeter surveys of building K-1073 at the ETTP facility. The survey was initiated at the request of the office environmental restoration manager to determine if endangered bats may be roosting in the abandoned structure. Nine sites were actively monitored overnight (dusk-dawn) on 7/15/2014 and 7/29/2014 with a combination of Anabat SD-2, SongMeter SM2BAT+, and SongMeter SM3BAT detectors to record ultrasonic bat calls around the building perimeter. Overall, bat activity was heavy as a combined total of 1243 bat calls were identified to species by the Kaleidoscope PRO program and 23 additional bat calls were recorded, but not identified. However, the majority of bat activity was around the southwest portion of the K-1073 building: sites OR-57 (260 calls), OR-58 (689 calls), OR-59 (236 calls). This is an indication that bats may be emerging from the SW side of the building at dusk and returning around

dawn to their roosting habitat inside the building. Dominant species detected for all sites included the Eastern Red bat (683 calls) and Evening bat (497 calls). If bats are indeed using the building as a summer roost, then it is likely the Evening bats because they are known to roost in buildings and the Eastern Red bats are primarily tree bats and are almost never found roosting in buildings (Ammerman et al. 2012). We detected a combined total of 13 *Myotis* spp. calls recorded from all sites. We did not detect endangered species bat calls.

After Tables 18 & 19 (below here), there is a series of plates listed by site identification number as 'OR-45 chart/image' through 'OR-59 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right. Due to the volume of sites and data, the reader is directed to the self-explanatory plates below for additional specific bat call data for each of thenine survey sites.



Map 8

Table 18

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-45	35.936703	-84.382843	K-1073 Bldg. (ETTP) / Zirconium Drive	7/15/2014	overnight	Anabat SD-2
OR-46	35.93685	-84.384656	K-1073 Bldg. (ETTP) / Zirconium Drive	7/15/2014	overnight	SongMeter SM3BAT
OR-47	35.936455	-84.386104	K-1073 Bldg. (ETTP) / Zirconium Dr. / old guardshack	7/15/2014	overnight	SongMeter SM2BAT+
OR-48	35.935243	-84.386024	K-1073 Bldg. (ETTP) / southwest side on embankment	7/15/2014	overnight	SongMeter SM3BAT
OR-55	35.935295	-84.383739	K-1073 Bldg. (ETTP) / south side of building	7/29/2014	overnight	SongMeter SM3BAT
OR-56	35.934935	-84.384227	K-1073 Bldg. (ETTP) / south side of building	7/29/2014	overnight	Anabat SD-2
OR-57	35.935048	-84.384409	K-1073 Bldg. (ETTP) / south side of building	7/29/2014	overnight	SongMeter SM3BAT
OR-58	35.935052	-84.385514	K-1073 Bldg. (ETTP) / south side of building	7/29/2014	overnight	Anabat SD-2
OR-59	35.935061	-84.385793	K-1073 Bldg. (ETTP) / south side of building	7/29/2014	overnight	SongMeter SM2BAT+

Table 19

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-45		1	2							1			2	40	2	2	
OR-46	1	3	2	2				1		2	1	1	1	2	6	6	1
OR-47											1			4		1	
OR-48		2					2				1		3	10		3	2
OR-55		4		1			5			1			5	42	1	5	5
OR-56	1	12	1				1			7	2		3	34	2	21	1
OR-57		99	1	3			1			152	3	1	25	57	5	244	1
OR-58		473		9			2			195	10		28	91	9	678	2
OR-59		89	1	3			1			139	2	1	23	57	5	230	1
subtotals	2	683	7	18			12	1		497	20	3	23	57	30	1190	13

[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

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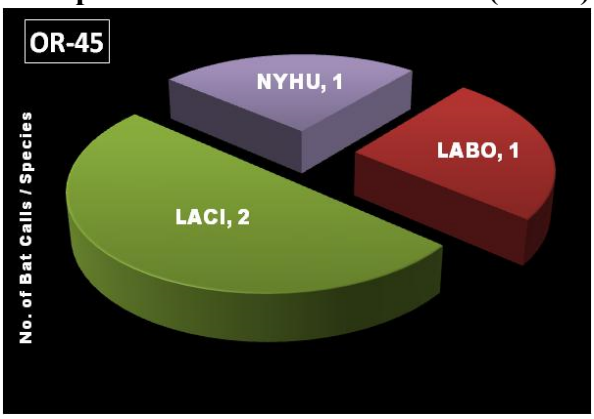
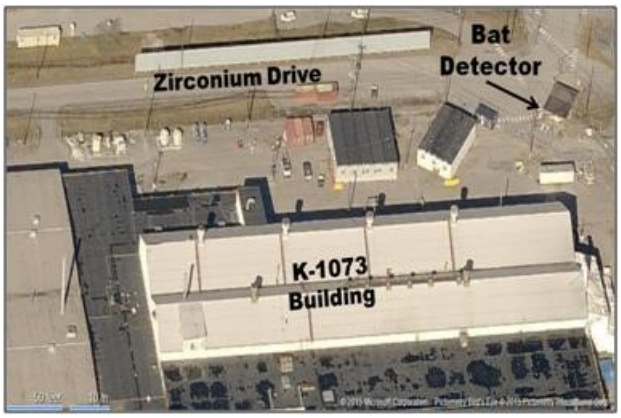
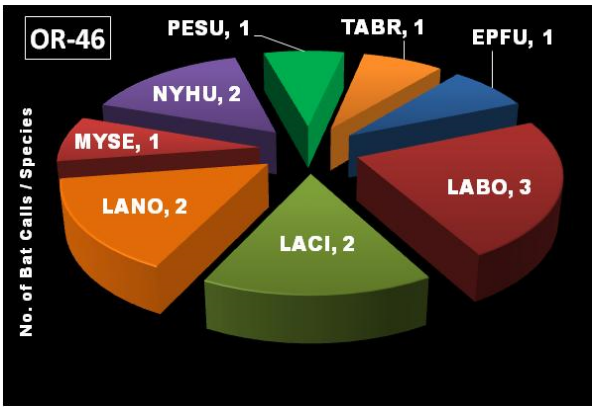
Site Specific Bat Call Data/Pictures (Plates)



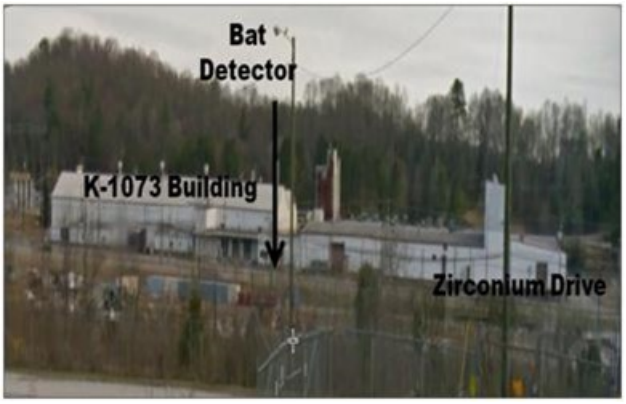
OR-45 chart



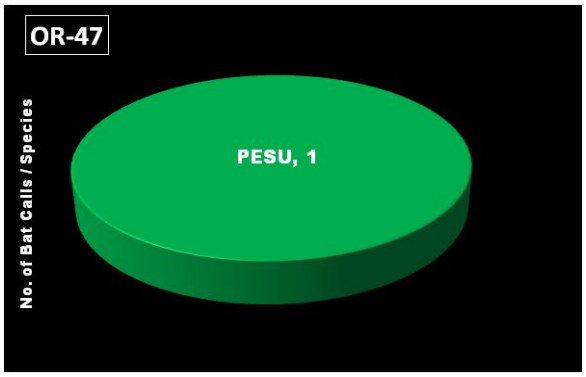
OR-45 image



OR-46 chart

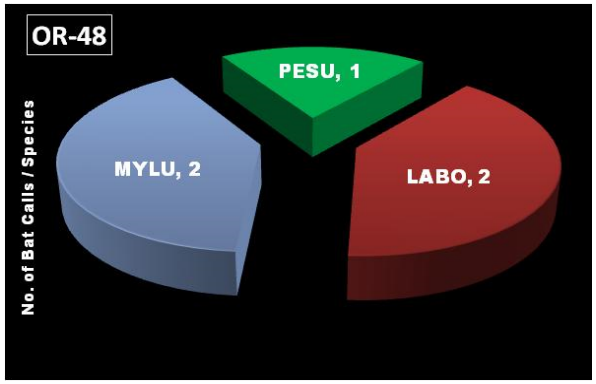


OR-46 image



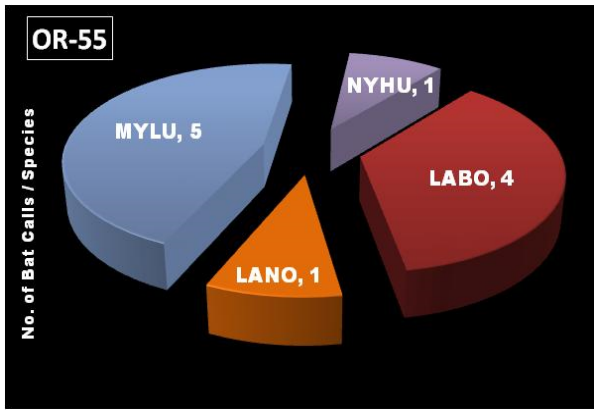
OR-47 chart

OR-47 image

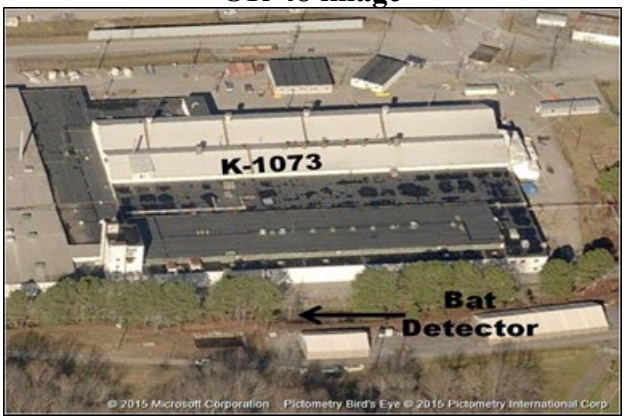


OR-48 chart

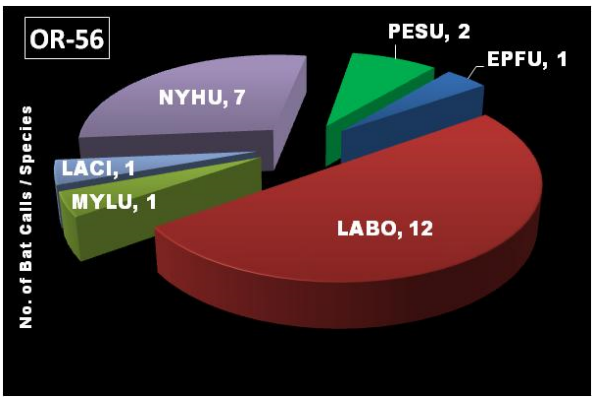
OR-48 image



OR-55 chart

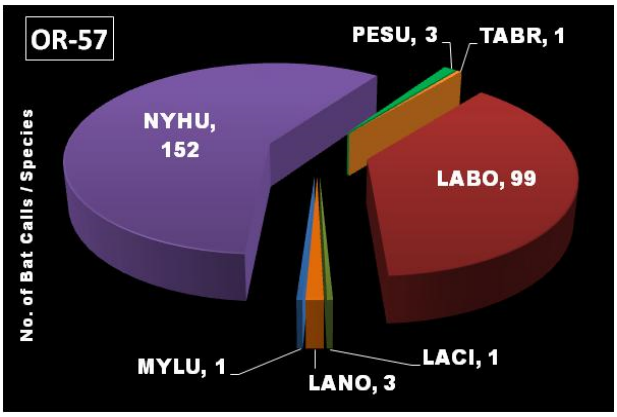


OR-55 image



OR-56 chart

OR-56 image



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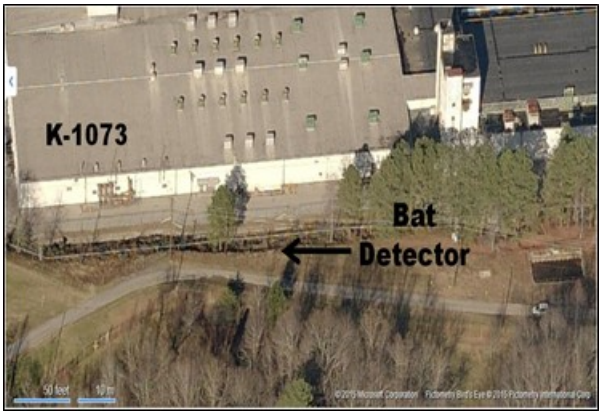
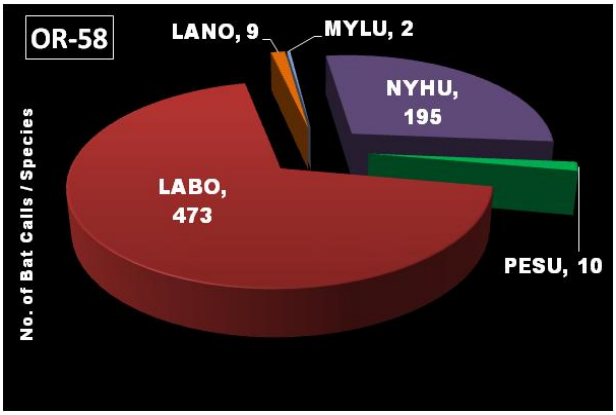
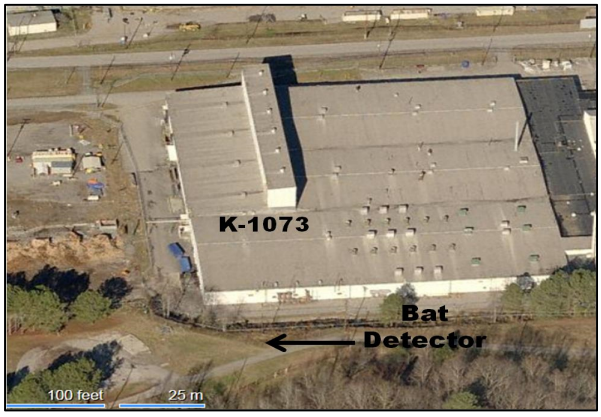


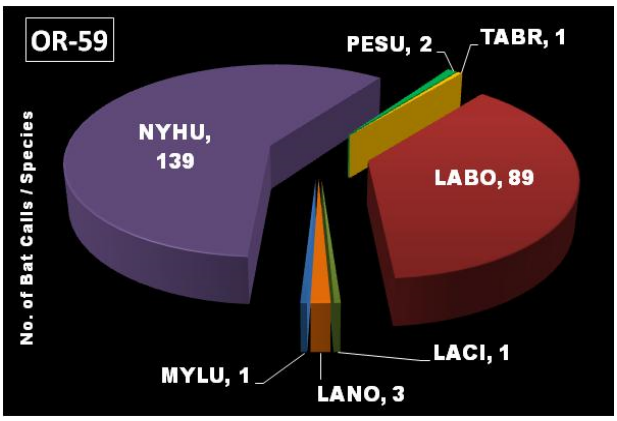
OR-57 image



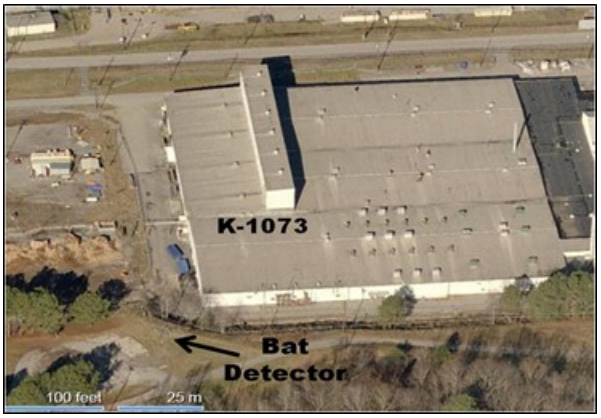
OR-58 chart



OR-58 image



OR-59 chart



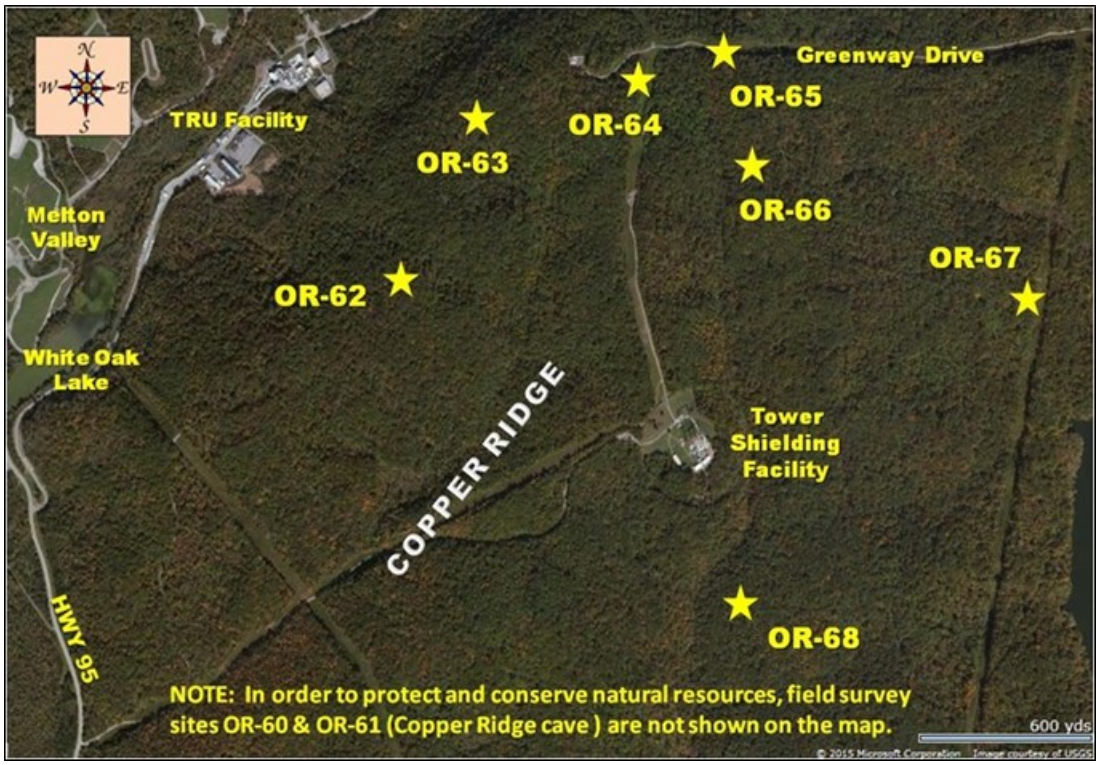
OR-59 image

Section IX: Tower Shielding Area (ORNL)

Section Nine surveys were conducted in the Tower Shielding area of Chestnut Ridge. The majority of this area is forested with lush vegetation and mature oak-hickory trees such as shagbark hickories, an important roost tree for female Indiana bats (endangered species). There are gravel access roads, powerline ROWs, a cell tower facility, caves, and the Tower Shielding facility. The area is also rich with wildlife, wildflowers and fern species. The survey was carried out in cooperation with the ORNL Environmental Sciences Division; detectors were co-deployed at several survey locations including Copper Ridge cave. Nine sites were passively monitored overnight (dusk-dawn) on 8/4/2014 and 9/5/2014 with a combination of Anabat SD-2, SongMeter SM2BAT+, and SongMeter SM3BAT detectors to record ultrasonic bat calls. Overall, bat activity was heavy as a combined total of 1353 bat calls were identified to species by the Kaleidoscope PRO program and 1680 additional bat calls were recorded, but not identified. At the location of monitoring site OR-60 (Greenway Drive, gravel access road), we did not catch any bat calls with our detector. Dominant species detected for all sites included the Big Brown bat (285 calls), Eastern Red bat (243 calls), Gray bat (176 calls), Little Brown bat (153 calls), Northern Long-eared bat (148 calls), Evening bat (179 calls), and the Tri-colored bat (152 calls). Insect noise was prevalent at two sites with 2931 and 12,182 noise files recorded at OR-60 and OR-64 respectively. We detected a combined total of 486 *Myotis* spp. calls recorded from all sites. A combined total of 184 endangered species bat calls were recorded (Gray bats, Indiana bats) from nine sites. Surprisingly, the majority of Gray bat calls were recorded near dead tree snags along Greenway Drive at site OR-65 (44 calls) and site OR-66 (75 calls). However, we did record 24 Gray bat calls and three Indiana bat calls at the location of Copper Ridge cave (sites OR-60, OR-61). In fact, we executed a QA/QC test at the cave by deploying one Anabat SD-2 and one SongMeter SM2BAT+ approximately 75 feet apart with both detector microphones oriented towards the cave entrance. When we ran the respective bat files through the Kaleidoscope PRO program, the output indicated 625 bat call identifications (+263 no IDs) were determined for the Anabat SD-2 files (site OR-61), but only 163 bat call identifications (+93 no IDs) were determined for files recorded with the SongMeter SM2BAT+ (site OR-60).

After Tables 20 & 21 (below here), there is a series of plates listed by site identification number as ‘OR-60 chart/image’ through ‘OR-68 chart/image’ which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site

photograph on the right. Due to the volume of sites and data, the reader is directed to the self-explanatory plates below for additional specific bat call data for each of the nine survey sites.



Map 9

Table 20

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-60	X	X	Tower Shielding / Copper Ridge Cave (codeployed w/ ORNL)	8/4/2014	overnight	SongMeter SM2BAT+
OR-61	X	X	Tower Shielding / Copper Ridge Cave (codeployed w/ ORNL)	8/4/2014	overnight	Anabat SD-2
OR-62	35.903477	-84.31096	Tower Shielding / gravel access road (codeployed w/ ORNL)	8/4/2014	overnight	Anabat SD-2
OR-63	35.90726	-84.30887	Tower Shielding / gravel access road (codeployed w/ ORNL)	8/4/2014	overnight	SongMeter SM2BAT+
OR-64	35.907667	-84.302999	Tower Shielding / gravel access road	8/4/2014	overnight	Anabat SD-2
OR-65	35.909839	-84.297216	Tower Shielding / Greenway Drive near dead snags	9/5/2014	overnight	SongMeter SM2BAT+
OR-66	35.90474	-84.297401	Tower Shielding / Johnson Road near dead snags	9/5/2014	overnight	SongMeter SM2BAT+
OR-67	35.90306	-84.28861	Tower Shielding / Johnson Road at powerline ROW	9/5/2014	overnight	SongMeter SM3BAT
OR-68	35.89243	-84.29944	Tower Shielding / Deep Hollow Trail / Gravel Hill Cem	9/5/2014	overnight	SongMeter SM3BAT

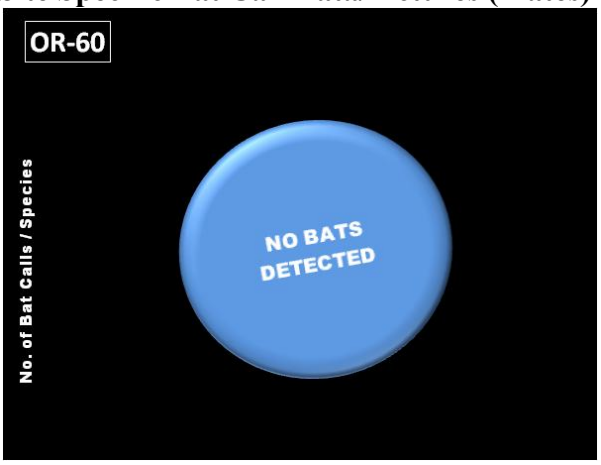
Table 21

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-60	no bats				no bats					no bats							
OR-61	3	27			8	1	19	64	3	6	32		93	2931	3	65	95
OR-62	214	129	1	2	16		46	15		164	38		263	4	217	331	77
OR-63	7	10		1	6		23	26	5		25		1060	22	8	35	60
OR-64	31	44			11		18	30		9	33		71	12182	31	86	59
OR-65	25	10			44		26	6			8		85	119	25	18	76
OR-66	4	21			75		13	5			16		102	148	4	37	93
OR-67	1													36	1		
OR-68		2	4		16		8	2					6	168	4	2	26
subtotals	285	243	5	3	176	1	153	148	8	179	152		1680	15610	293	574	486

[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis (≥ 40kHz)***. All bat files were processed using the Kaleidoscope PRO automated identification software program.

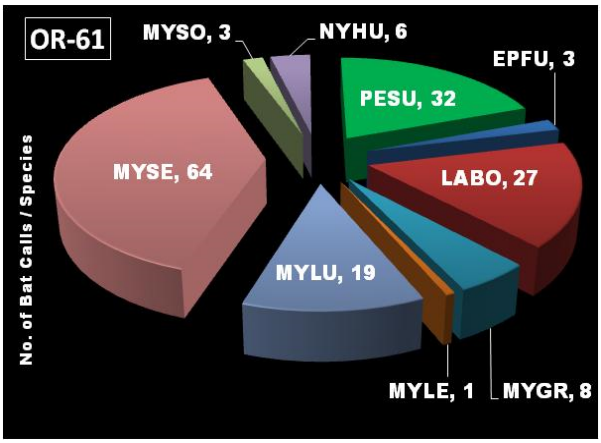
Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

Site Specific Bat Call Data/Pictures (Plates)



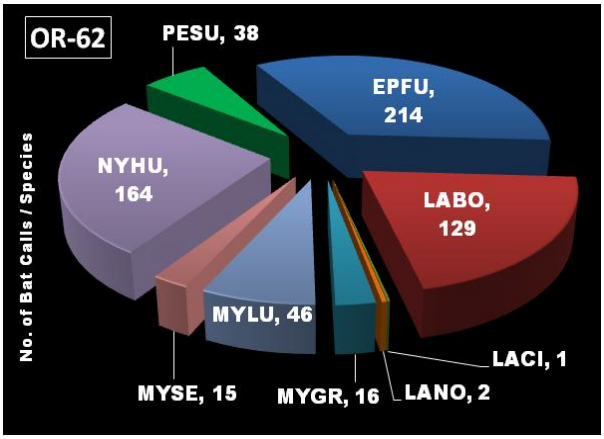
OR-60 chart

OR-60 image



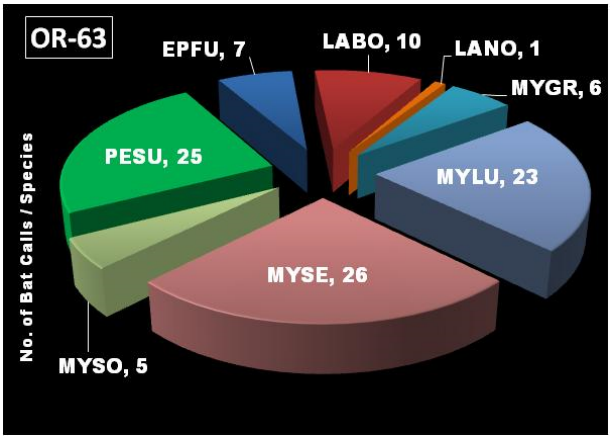
OR-61 chart

OR-61 image



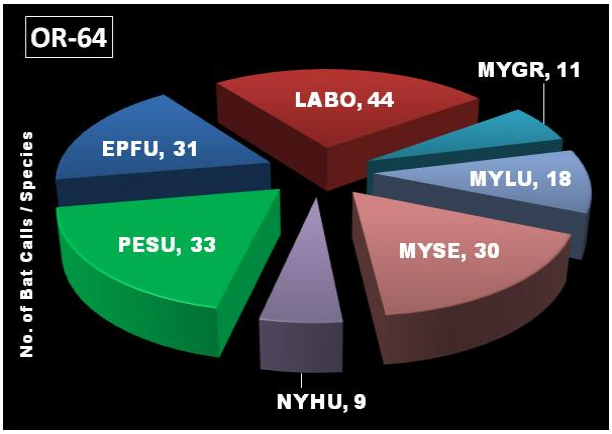
OR-62 chart

OR-62 image

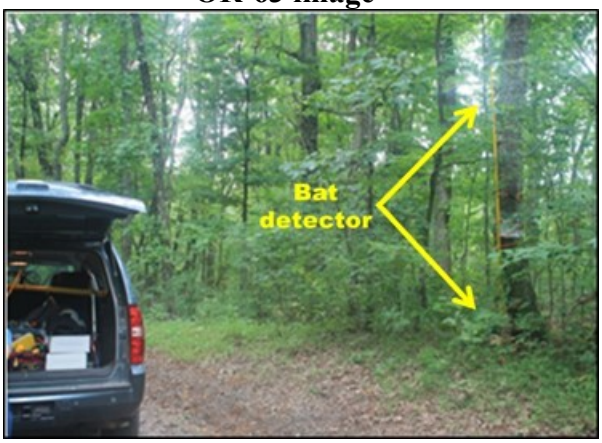


OR-63 chart

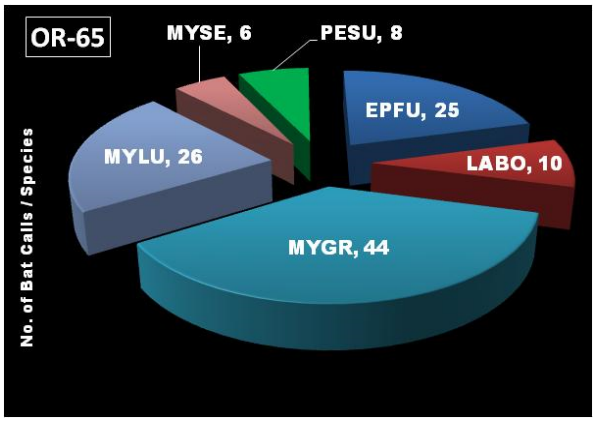
OR-63 image



OR-64 chart

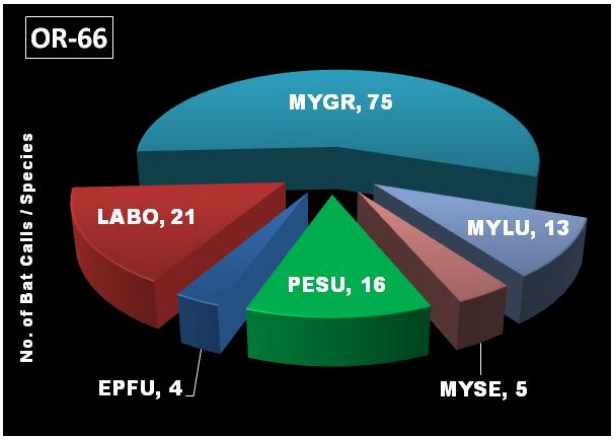


OR-64 image



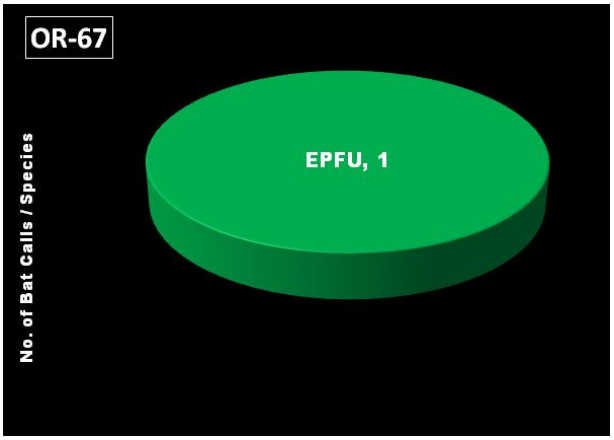
OR-65 chart

OR-65 image

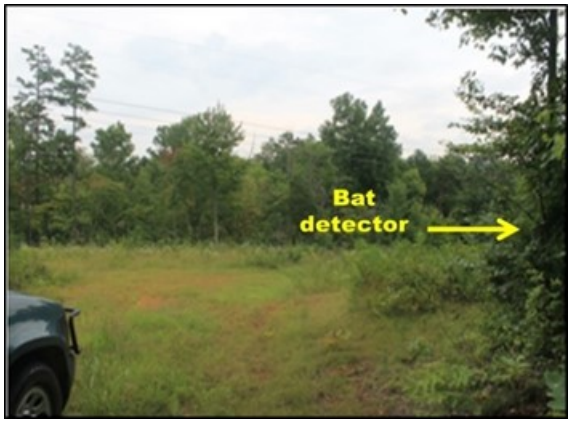


OR-66 chart

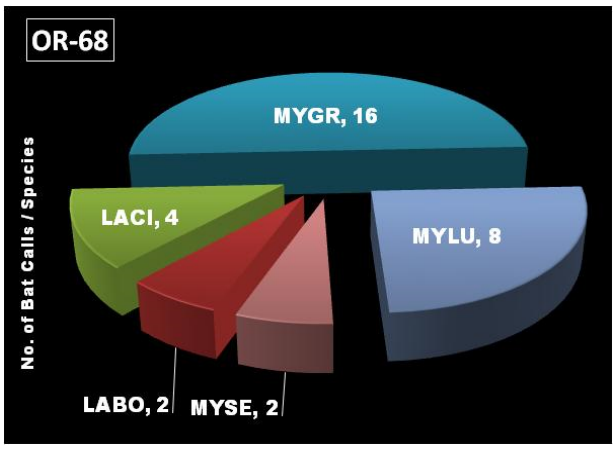
OR-66 image



OR-67 chart



OR-67 image

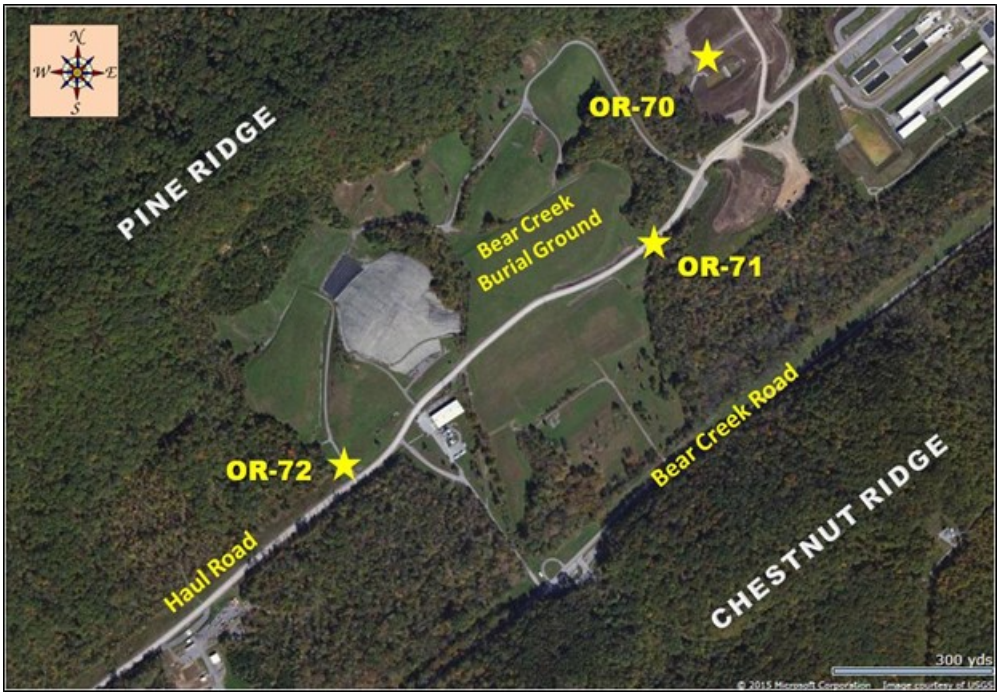


OR-68 chart

OR-68 image

Section X: Haul Road (Bear Creek Burial Grounds area)

Section Ten surveys were executed in Bear Creek Valley west of the Y-12 National Security Complex. The majority of this area is industrial with a huge contaminated landfill (Bear Creek Burial Grounds), the Haul Road, additional access roads, and surrounded by forest/field edge. Three sites were passively monitored overnight (dusk-dawn) on 9/10/2014 with a combination of Anabat SD-2 and SongMeter SM3BAT detectors to record ultrasonic bat calls. Overall, bat activity was quite sparse as a combined total of ten bat calls were identified to species by the Kaleidoscope PRO program and ten additional bat calls were recorded, but not identified. Species were only detected at one of the three sites including the Eastern Red bat (one call), Hoary bat (two calls), Little Brown bat (one call), Silver-haired bat (one call), and the Tri-colored bat (five calls). Insect noise was prevalent at two sites with 10,902 and 3492 noise files recorded at OR-70 and OR-71 respectively. We detected a combined total of one *Myotis* spp. call recorded from all sites. No endangered species bat calls were detected. After Tables 22 & 23 (below here), there is a series of plates listed by site identification number as 'OR-70 chart/image' through 'OR-72 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right.



Map 10

Table 22

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-70	**35.968134**	**-84.293171**	**Haul Road/ large field near pond & GW monitoring wells**	**9/10/2014**	**overnight**	**Anabat SD-2**
OR-71	**35.965286**	**-84.294244**	**Haul Road/ southeast corner of BCBG at fence corner**	**9/10/2014**	**overnight**	**Anabat SD-2**
OR-72	**35.961751**	**-84.300123**	**Haul Road/ southwest corner of BCBG at fence corner**	**9/10/2014**	**overnight**	**SongMeter SM3BAT**

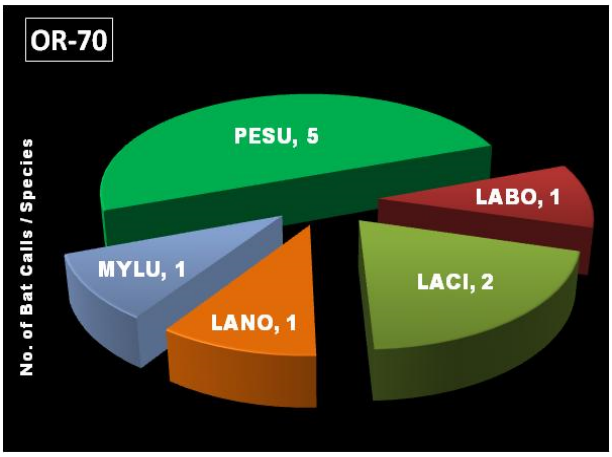
Table 23

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-70		1	2	1			1				5		10	10902	3	6	1
OR-71	no bats					no bats					no bats			3492			
OR-72	no bats					no bats					no bats			26			
subtotals	0	1	2	1			1				5		10	14420	3	6	1

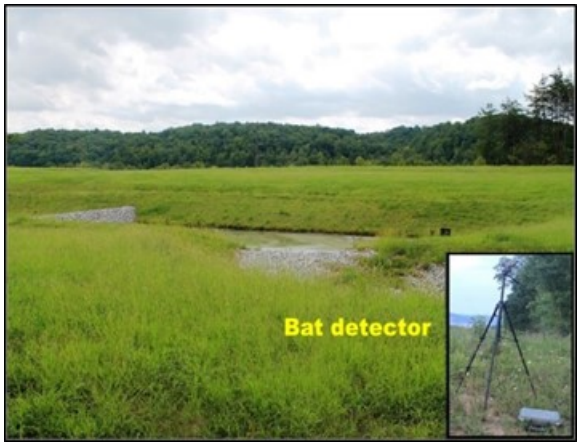
[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

Site Specific Bat Call Data/Pictures (Plates)

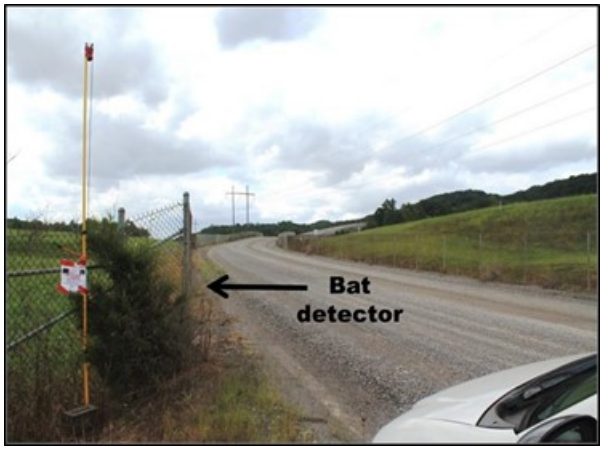


OR-70 chart

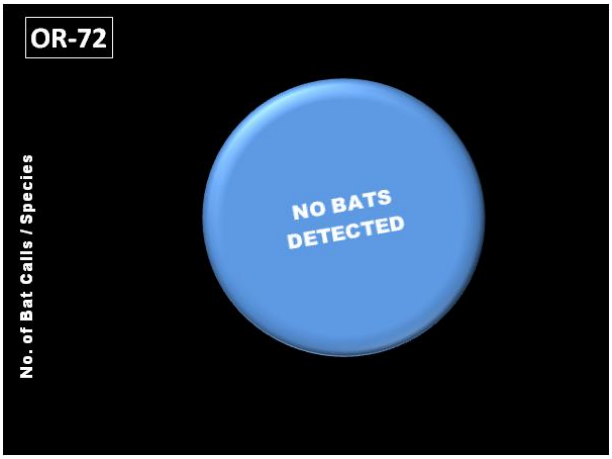


OR-70 image

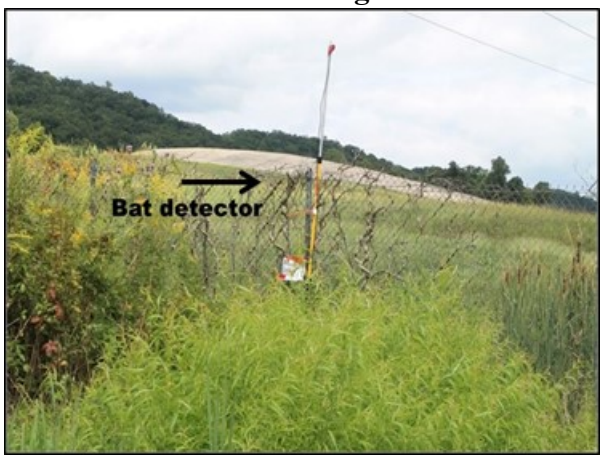
OR-71 chart



OR-71 image



OR-72 chart

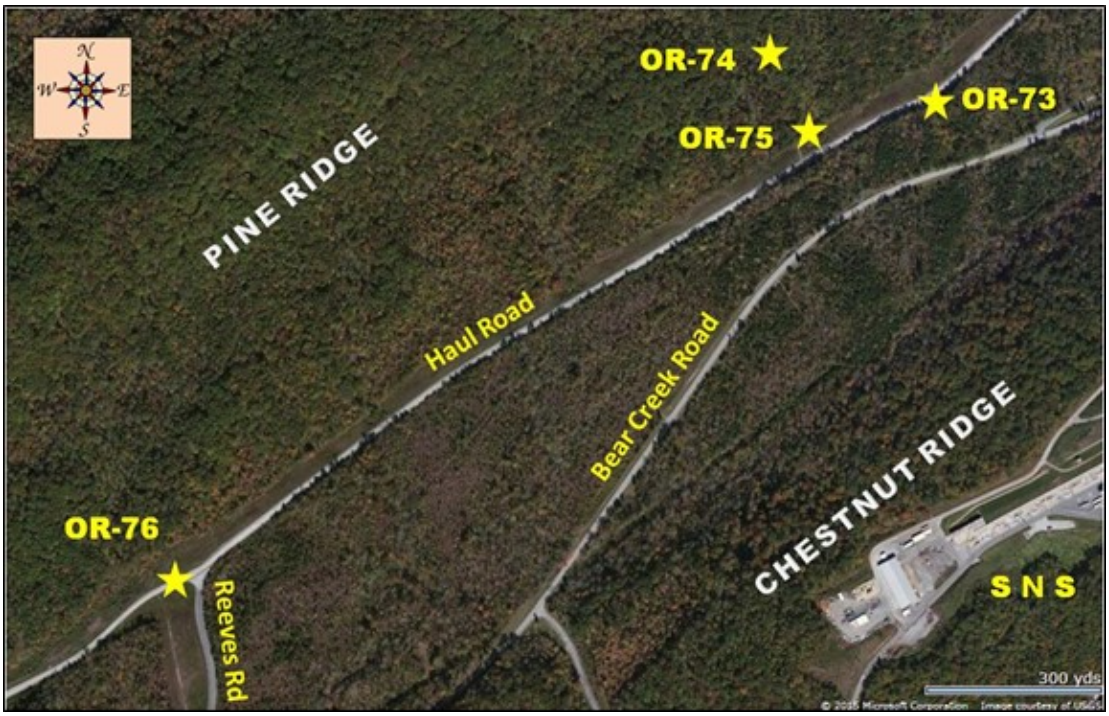


OR-72 image

Section XI: Haul Road (Reeves Road area)

Section Eleven surveys were conducted in Bear Creek Valley west of the Y-12 National Security Complex. The majority of this area is also industrial, including the Haul Road and Reeves Road,

but surrounded by heavy forest. Four sites were passively monitored overnight (dusk-dawn) on 9/10/2014 with a combination of Anabat SD-2, SongMeter SM2BAT+, and SongMeter SM3BAT detectors to record ultrasonic bat calls. Overall, bat activity was quite sparse as a combined total of eight bat calls were identified to species by the Kaleidoscope PRO program and 11 additional bat calls were recorded, but not identified. Species were only detected at two of the four sites including the Northern Long-eared bat (one call) and the Little Brown bat (seven calls. Insect noise was prevalent at one site with 28,721 noise files recorded at OR-75 (deployed in a wetland). We detected a combined total of eight *Myotis* spp. call recorded from all sites. No endangered species bat calls were detected. After Tables 24 & 25 (below here), there is a series of plates listed by site identification number as 'OR-73 chart/image' through 'OR-76 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right.



Map 11

Table 24

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-73	35.957531	-84.305949	Haul Road/ south of road along stream drainage/wetland	9/10/2014	overnight	SongMeter SM2BAT+
OR-74	35.957687	-84.309533	Haul Road/ Douglas Cemetery north of Haul Rd	9/10/2014	overnight	SongMeter SM2BAT+
OR-75	35.956419	-84.30891	Haul Road/ wetland adjacent to Douglas Cem acc. road	9/10/2014	overnight	Anabat SD-2
OR-76	35.950183	-84.320025	Haul Road/ junction with Reeves Road	9/10/2014	overnight	SongMeter SM3BAT

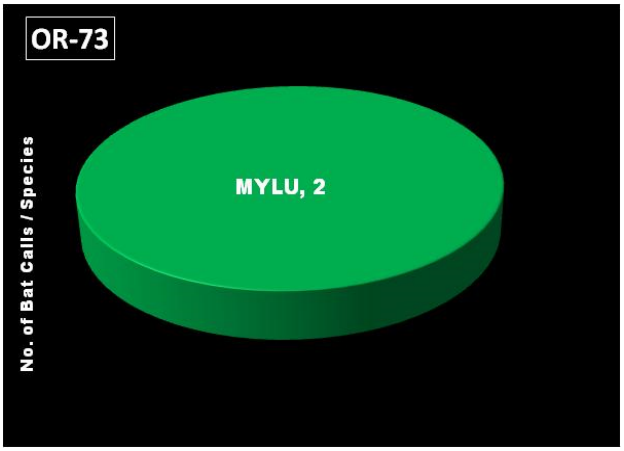
Table 25

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-73							2						6	64			2
OR-74	no bats					no bats					no bats			40			
OR-75							5	1					5	28721			6
OR-76	no bats					no bats					no bats			12			
subtotals							7	1					11	28837			8

[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

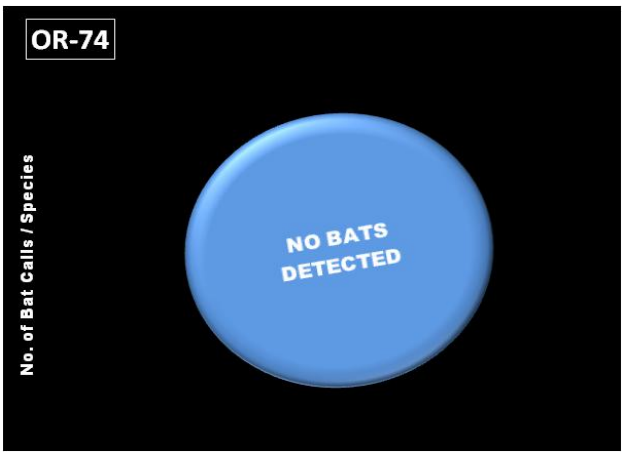
Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

Site Specific Bat Call Data/Pictures (Plates)



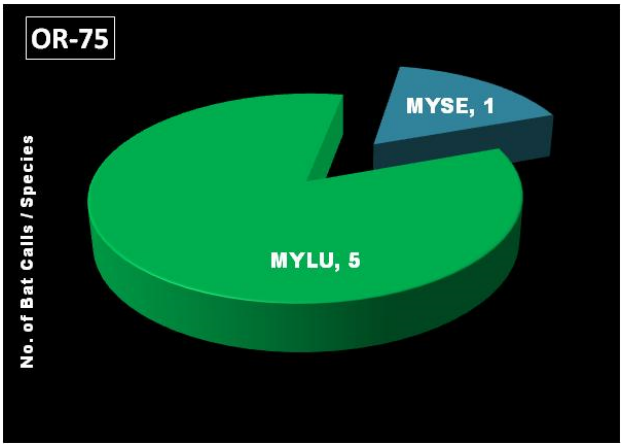
OR-73 chart

OR-73 image



OR-74 chart

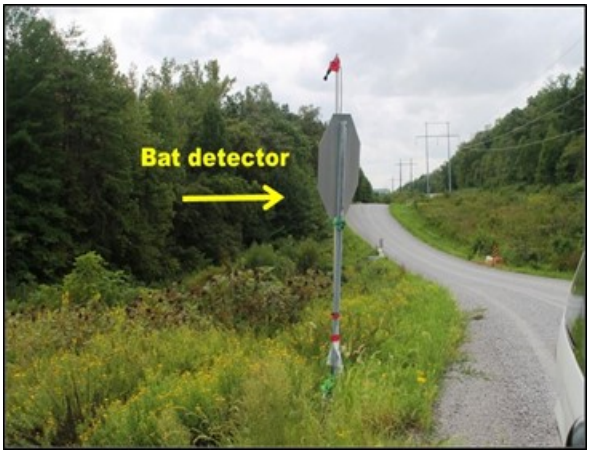
OR-74 image



OR-75 chart

OR-75 image

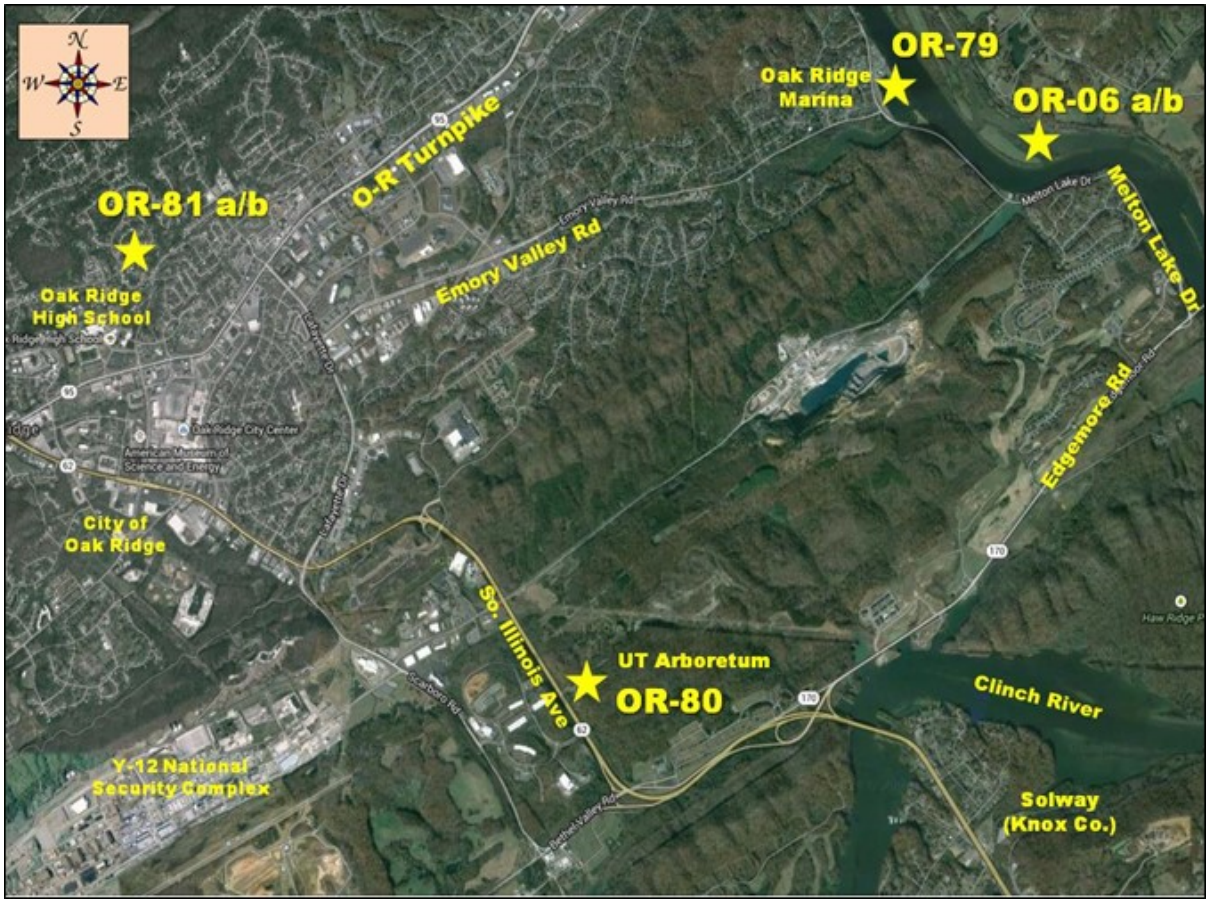
OR-76 chart



OR-76 image

Section XII: Reference Sites (City of Oak Ridge)

Section Twelve surveys were conducted at reference sites in the City of Oak Ridge including two Clinch River sites, the University of Tennessee Arboretum, and a residential neighborhood near Oak Ridge High School. Four sites were actively monitored for approximately three hours between dusk and midnight on 4/23/2014 and 9/4/2014 with a combination of Anabat SD-2s and the EchoMeter EM3+ detectors to record ultrasonic bat calls. At site OR-6a/6b, bat calls were recorded (w/ two Anabats) using a canoe to access a backwater area of the Clinch River near the Oak Ridge Marina; watercraft courtesy of Mr. Gareth Davies. Overall, bat activity was moderate as a combined total of 655 bat calls were identified to species by the Kaleidoscope PRO program and 80 additional bat calls were recorded, but not identified. Dominant species detected included Big Brown bat (123 calls) and the Tri-colored bat (299 calls). Species were only detected at two of the four sites including the Northern Long-eared bat (one call) and the Little Brown bat (seven calls). Insect noise was prevalent at one site with 28,721 noise files recorded at OR-75 (deployed in a wetland). We detected a combined total of 33 *Myotis* spp. calls recorded from all sites. We recorded seven endangered species bat calls (Gray bats) from sites OR-06 and OR-79. After Tables 26 & 27 (below here), there is a series of plates listed by site identification number as 'OR-06a chart/image' through 'OR-81b chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right.



Map 12

Table 26

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-6	36.029631	-84.182138	Reference site: Clinch River near Oak Ridge Marina	5/28/2014	2	Anabat SD-2 (2 units)
OR-79	36.033761	-84.193125	Reference site: Oak Ridge Marina at Clinch River	9/4/2014	2	Anabat SD-2
OR-80	35.994188	-84.219475	Reference site: U. of Tennessee Arboretum (Oak Ridge)	4/23/2014	2	Anabat SD-2
OR-81	36.021267	-84.258571	Ref. site: East Pawley Ln near Oak Ridge High School	6/6/2014	4	Anabat SD-2 / EchoMeter EM3+

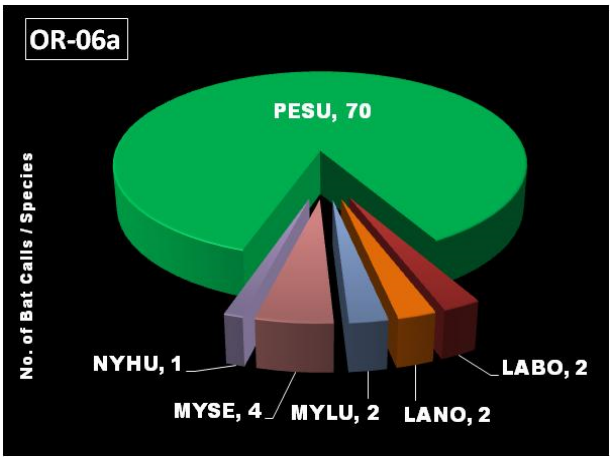
Table 27

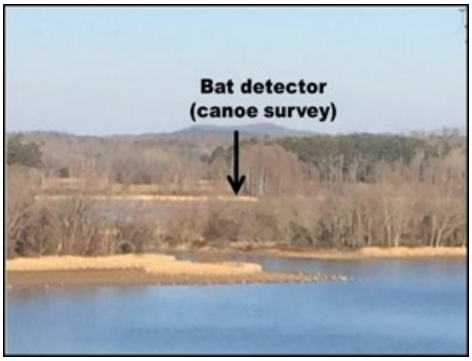
	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-06a		2		2			2	4		1	70		13	12	2	73	6
OR-06b		5	1	3	5		2	3		1	49		8	31	4	55	10
OR-79	1	2	1	1	2					1	137		4	22	3	140	2
OR-80	33	8	1	5			4	4		3	12		6	24	39	23	8
OR-81a	10	12	22	3			1	3		12	16	2	12	317	27	30	4
OR-81b	79	19	40	42			2	1		10	15	1	37	789	162	44	3
subtotals	123	48	65	56	7		11	15		28	299	3	80	1195	237	365	33

[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis (≥ 40kHz)***. All bat files were processed using the Kaleidoscope PRO automated identification software program.

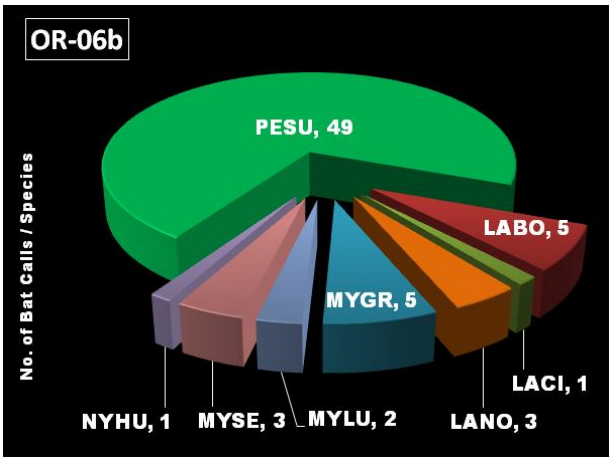
Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

Site Specific Bat Call Data/Pictures (Plates)



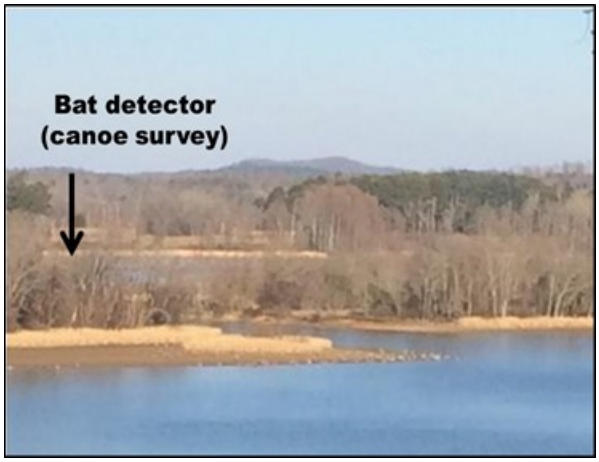


OR-06a chart

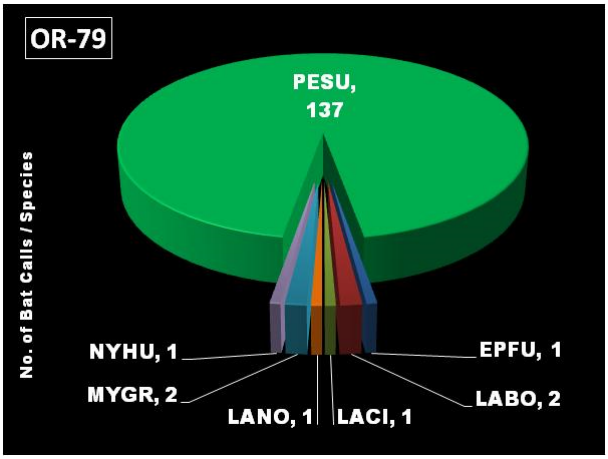


OR-06b chart

OR-06a image

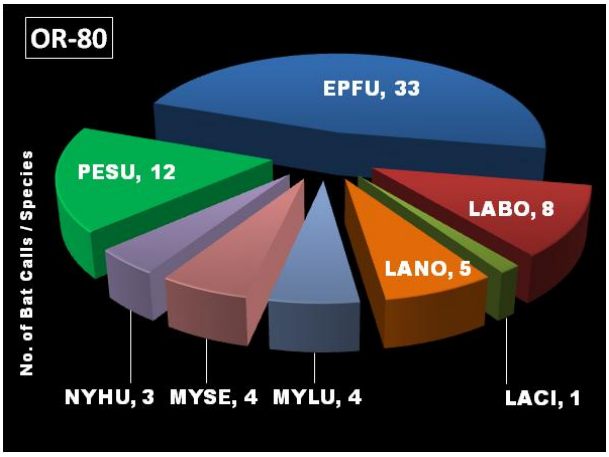


OR-06b image



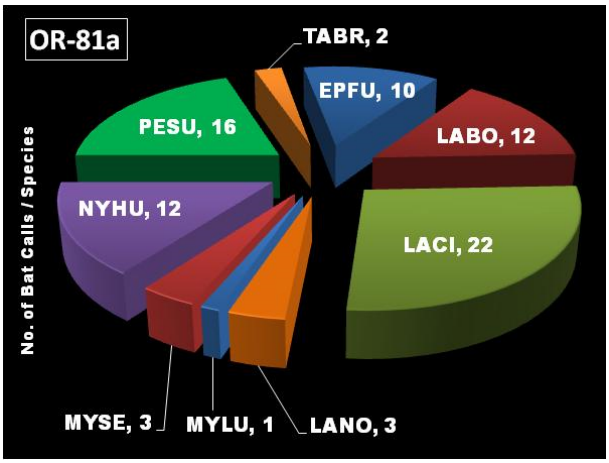
OR-79 chart

OR-79 image



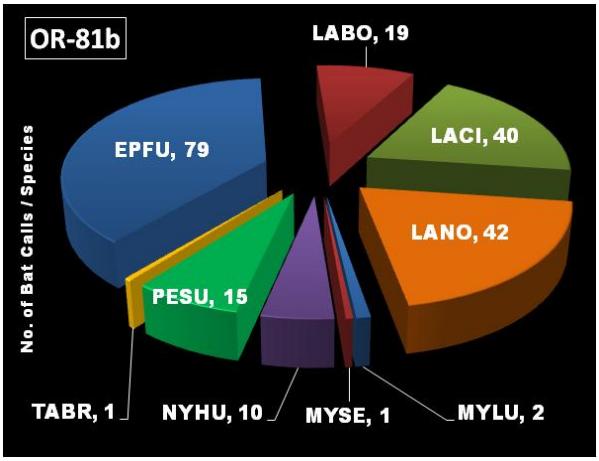
OR-80 chart

OR-80 image



OR-81a chart

OR-81a image



OR-81b chart

OR-81b image

Discussion

We conducted acoustic surveys over 108 survey nights during 2014, and recorded approximately 12,000 files of bat acoustic data collected from 81 ORR field stations. The bat call files were processed with specialized, automated bat identification software (Kaleidoscope PRO) yielding 6,960 bat identifications (Table 28). An additional 4006 bats were detected but not identified to species due to poor call quality, inclement weather conditions or field clutter. Kaleidoscope PRO output data revealed that >100 bat calls were recorded at 21 sites, >200 calls were recorded at ten sites, >300 calls were recorded at three sites, and >600 calls were recorded at two sites (OR-58 and OR-62).

Twelve bat species were detected on the ORR including: *Eptesicus fuscus* (Big Brown bat), *Lasiurus borealis* (Eastern Red bat), *Lasiurus cinereus* (Hoary bat), *Lasionycteris noctivagans* (Silver-haired bat), *Myotis grisescens* (Gray bat), *Myotis leibii* (Eastern Small-footed bat), *Myotis lucifugus* (Little Brown bat), *Myotis septentrionalis* (Northern Long-eared bat), *Myotis sodalis* (Indiana bat), *Nycticeius humeralis* (Evening bat), *Perimyotis subflavus* (Tricolored bat; Eastern Pipistrelle), and *Tadarida brasiliensis* (Brazilian Free-tailed bat). Of these species, the Eastern Red bat (24%), Big Brown bat (18%), Tricolored bat (18%), and the Evening bat (17%) were the

dominant combined species detected at all sites (Figure 39). Approximately 5% of all bats detected were federally-listed endangered species (Indiana bat, Gray bat). The Tower Shielding study site turned out to be the hot spot for endangered bat species as 184 combined calls were recorded (Gray bats, Indiana bats).

We calculated bat call frequency data teased out of the Kaleidoscope PRO output for all species per all 81 sites (see Figure 40). Mid-frequency bat calls (25-35 kHz) represented the dominant frequency range (59% of the total calls) for all 81 sites combined. Mid-frequency bats include Eastern Red bat, Evening bat, and the Tri-colored bat. Low-frequency bats (<25 kHz) were next with 24% of the total calls; these bats include Big Brown bat, Silver-haired bat, Hoary bat, and the Brazilian Free-tailed bat. Lastly, the Myotis-frequency bats (≥40 kHz) represented 17% of all calls; these bats include Gray bat, Indiana bat, Eastern Small-footed bat, Little Brown bat, and the Northern Long-eared bat. Incidentally, this ORR frequency outcome compares very closely with frequency results form a concurrent 2014 State Parks bat study at Cove Lake State Park where mid frequency = 59%, low frequency = 30%, and Myotis frequency = 11% (Middleton 2015).

Large portions of the ORR remain un-surveyed. These include the mainly forested National Environmental Research Park (NERP), west Bear Creek Valley, White Wing area (Hembree marsh), sections of ETTP, Tower Shielding area, Walker Branch, and Chestnut Ridge (ORNL). Our 2014 study, along with a concurrent ORNL Environmental Science Division bat project, continued to add data for the first long-term, large-scale acoustic bat community investigation on the ORR. Information gained from this bat inventory addressed missing data gaps but also provided critical occurrence information for the endangered species and for the Northern Long-eared bat listing which is in process by the US Fish and Wildlife Service.

Table 28

	BAT TAXA DETECTED													ADDITIONAL COMBINED DATA OUTPUT				
BATS →	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	TOTAL BAT CALLS	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
BAT CALL SUBTOTALS	1253	1660	241	195	255	3	424	460	12	1207	1241	9	6960	4006	60283	1698	4108	1154

[1]**Notes:** The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, <u>not</u> the number of bats present. ***Blank boxes*** = no bat calls recorded. The red color bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** (≥ 40kHz). All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

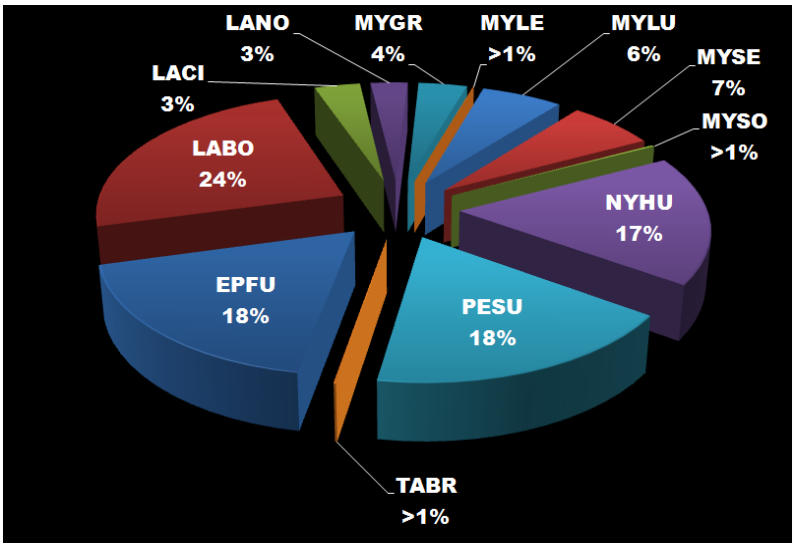


Figure 39: Summary Pie Chart
Combined 2014 Bat Calls Per Species (%)

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat).

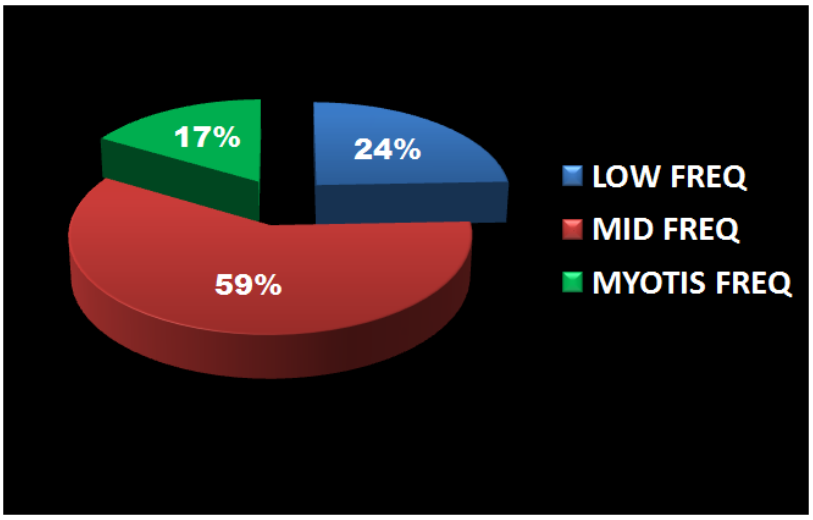


Figure 40: Summary Pie Chart
Combined 2014 Bat Calls Per Frequency (%)

Low Frequency bat calls (characteristic frequency <25 kHz): EPFU = *Eptesicus fuscus* (Big Brown Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat); **Mid Frequency bat calls (characteristic frequency ~25-35 kHz):** LABO = *Lasiurus borealis* (Eastern Red Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle); **Myotis Frequency bat calls (characteristic** frequency ≥40 kHz): MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat).

Summary

- TDEC DOR monitored 81 sites on the ORR with acoustic detectors (27 of 81 survey sites were monitored dusk to dawn)
- Monitored wetlands, caves, rocky ledges, trails, stream riparian, lake shore, buildings, shagbark hickories, gravel access roads, forest edge, powerline ROWs, and open fields
- Recorded/processed >12,000 bat call files collected during 108 survey nights
- Approximately 6,960 bats were identified to species; >4,000 were not identified
- >60,000 combined noise files were recorded (predominantly evening insects, cicadas)
- Bat calls were not detected at eight of 81 field monitoring stations
- We detected 12 of the 16 bat species known to Tennessee (EPFU, LABO, LACI, LANO, MYGR, MYLE, MYLU, MYSE, MYSO, NYHU, PESU, & TABR)
- Endangered bats were detected at 29 of 81 sites surveyed
- Gray bats detected at 24 of 81 sites surveyed
- Indiana bats detected at five of 81 sites surveyed
- Northern Long-eared bat detected at 40 of 81 sites (under consideration for listing as a federally endangered species)
- The forested NERP area of the ORR remains largely uncovered by acoustic surveys
- Mid-frequency bats (LABO, NYHU, & PESU) dominated the call frequencies
- >480 Myotis species calls were recorded at the Tower Shielding area (nine study sites combined)
- ≥350 Myotis-combined species calls were recorded in the central Dyllis Orchard area (13 study sites northwest of ETTP on Black Oak Ridge); within 3-5 miles of several known caves which could provide summer roosts for Gray bats
- ≥130 Myoti- combined species calls were recorded in the eastern Dyllis Orchard area (13 study sites northwest of ETTP on Black Oak Ridge); within 1-3 miles of several known caves which could provide summer roosts for Gray bats
- Endangered species hotspot: We documented 176 MYGR and 8 MYSO bat calls in the Tower Shielding area; bat detector was deployed near shagbark hickory trees and dead snags along Greenway Drive (these trees often used as bat roosts)

Legend: EPFU = Big Brown bat, LABO = Eastern Red bat, LACI = Hoary bat, LANO = Silver-haired bat, MYGR = Gray bat, MYLE = Eastern Small-footed bat, MYLU = Little Brown bat, MYSE = Northern Long-eared bat, MYSO = Indiana bat, NYHU = Evening bat, PESU = Tri-colored bat (Pipistrelle), and TABR = Brazilian Free-tailed bat.

References

Adam, M. D., and J. P. Hayes. *Use of Bridges as Night Roosts by Bats in the Oregon Coast Range*. Journal of Mammalogy 81: 402–407. 2000.

Agranat, I. Bat Species Identification from Zero Crossing and Full Spectrum Echolocation Calls Using HMMs, Fisher Scores, Unsupervised Clustering, and Balanced Winnow Pairwise Classifiers. REV 2012-Sept Report. Wildlife Acoustics, Inc., Concord, Massachusetts. 2012.

Ahlén, I. and H. J. Baagøe. *Use of Ultrasonic Detectors for Bat Studies in Europe: Experiences from Field Identifications, Surveys and Monitoring*. Acta Chiropterologica 1:137-150. 1999.

Allen, C. R., S. Burt, and J. Miller. Environmental Effects on the Echolocation Call Structure of Bats. [Report]. Truman State University NSF-STEP Program. Kirksville, Missouri. 2007. http://www.batcallid.com/ExternalVariables.htm

Ammerman, L. K., C. L. Hice, and D. J. Schmidly. Bats of Texas. Texas A&M University Press, College Station, Texas. 305 pp. 2012.

Anthony, E. L. P, M. H. Stack, and T. H. Kunz. *Night Roosting and the Nocturnal Time Budget of the Little Brown Bat, Myotis lucifugus: Effects of Reproductive Status, Prey Density, and Environmental Conditions*. Oecologia (Berlin) 51:151–156. 1981.

Avila-Flores, R. and M. B. Fenton. *Use of Spatial Features by Foraging Insectivorous Bats in a Large Urban Landscape.* Journal of Mammalogy 86:1193–1204. 2005.

Barataud, M. *Inventaire au de´tecteur d'ultrasons des chiropte`res fre´quentant les zones d'altitude du nord du Parc National du Mercantour (Alpes, France).* Le Rhinolophe 13:43–52. 1998.

Barbour, R. W., and W. H. Davis. Bats of America. University Press of Kentucky, Lexington, Kentucky. 312 pp. 1969.

Barclay, R. M. R. *Interindividual* U*se of Echolocation Calls: Eavesdropping by Bats*. Behavioral Ecology and Sociobiology 10:271-275. 1982.

Barclay, R. M. R. *Bats are not Birds—A Cautionary Note on Using Echolocation Calls to Identify Bats: A Comment.* Journal of Mammalogy 80:290-296. 1999.

BatBox Ltd. BatBox Duet Owners Manual. BatBox Ltd. South Sussex, UK. 2015.

Best, T., M. Kiser, and J. Rainey. *Eumops glaucinus*. Mammalian Species 551:1-6. 1997.

Betts, B. J. *Effect of Inter-individual Variation in Echolocation Calls on Identification of Big Brown and Silver-haired Bats*. Journal of Wildlife Management 62:1003-1010. 1998.

Britzke, E. R. Use of Ultrasonic Detectors for Acoustic Identification and Study of Bat Ecology in the Eastern United States. Dissertation. Tennessee Technological University, Cookeville, Tennessee. 2003.

Britzke, E. R., M. J. Harvey, and S. C. Loeb. *Indiana Bat, Myotis sodalis, Maternity Roosts in the Southern United States*. Southeastern Naturalist 2: 235-242. 2003.

Britzke, E. R., A. C. Hicks, S. L. Von Oettinger and S. R. Darling. *Description of Spring Roost Trees Used by Female Indiana Bats (Myotis sodalis) in the Lake Champlain Valley of Vermont and New York*. American Midland Naturalist 155:181-187. 2006.

Britzke, E. R., B. A. Slack, M. P. Armstrong and S. C. Loeb. *Effects of Orientation and Weatherproofing on the Detection of Bat Echolocation Calls*. Journal of Fish and Wildlife Management 1:136-141. 2010.

Britzke, E. R., J. E. Duchamp, K. L. Murray, R. K. Swihart and L. W. Robbins. *Acoustic Identification of Bats in the Eastern United States: A Comparison of Parametric and Nonparametric Methods*. Journal of Wildlife Management 75:660-667. 2011.

Broders, H. G. *Another Quantitative Measure of Bat Species Activity and Sampling Intensity Considerations for the Design of Ultrasonic Monitoring Studies*. Acta Chiropterologica 5:235–241. 2003.

Caceres, M. C., and R. M. R. Barclay. *Myotis septentrionalis*. Mammalian Species 634:1–4. 2000.

Corben, C. Hoary Bat. http://users.lmi.net/corben/ 2014.

Daniel, S., C. Korine, and B. Pinshow. *Central-place Foraging in Nursing, Arthropod-gleaning Bats*. Canadian Journal of Zoology 86:623–626. 2008.

Decher, J. and J. R. Choate. *Myotis grisescens*. Mammalian Species 510:1-7. 1995.

Duffy, A., L. F. Lumsden, C. Caddle, R. R. Chick, and G. Newell. *The Efficacy of Anabat Ultrasonic Detectors and Harp Traps for Surveying Microchiropterans in South-eastern Australia.* Acta Chiropterologica 2:127–144. 2000.

Fenton, M. B. and G. P. Bell. *Recognition of Species of Insectivorous Bats by Their Echolocation Calls.* Journal of Mammalogy 62:233-243. 1981.

Fenton, M. B. *Sperm Competition? The Case of Vespertilionid and Rhinolophid Bats.* In: Sperm Competition and the Evolution of Animal Mating Systems. (R. L. Smith, ed.). pp. 573-587. Academic Press, New York, New York. pp. 573-587. 1984.

Fenton, M. B. Communication in the Chiroptera. Indiana University Press. Bloomington, Indiana. 174 pp. 1985.

Fenton, M. B. Bats. Revised edition. Facts on file, New York, New York, USA. 207 pp. 1992.

Ford, W. M., M. A. Menzel, J. L. Rodrique, J. M. Menzel and J. B. Johnson. *Relating Bat Species Presence to Habitat Measures in a Central Appalachian Forest*. Biological Conservation 26:528-539. 2005.

French, A. C. The Effects of Changing Forest Dynamics in the Northern Cumberland Plateau on the Indiana Bat (Myotis sodalis). Thesis. Department of Forestry, Wildlife and Fisheries, University of Tennessee, Knoxville, Tennessee. 2009.

Gardner, J. E. and J. E. Hofmann. Preliminary Investigations into Indiana Bat (Myotis sodalis) and Gray Bat (Myotis grisescens) Occurrence, Distribution and Status in the Shawnee National Forest, Illinois. Illinois Natural History Survey, Section of Faunistic Surveys and

Insect Identification Technical Report 1986(1). Harrisburg, Illinois. 39 pp. 1986.

Gargas, A., M. T. Trest, M. Christensen, T. J. Volk, and D. S. Blehert. *Geomyces destructans* sp. *nov*. Associated with White-nose Syndrome. Mycotaxon 108:147-154. 2009.

Gore, J. A. *Gray Bat.* In: Rare and Endangered Biota of Florida. R. Humphrey (ed.). University Presses of Florida. Gainesville, Florida. pp. 63-70. 1992.

Grindal, S. D. and R. M. Brigham. *Impacts of Forest Harvesting on Habitat Use by Foraging Insectivorous Bats at Different Spatial Scale.* Ecoscience 6:25-34. 1999.

Grinnell, A.D. *Hearing in Bats: An Overview.* In: Hearing by Bats. (Popper, A.N. and R. R. Fay, eds). Springer Verlag Publishers, New York, New York. pp. 1-36. 1995.

Gunier, W. J. and W. H. Elder. *Experimental Homing of Gray Bats to a Maternity Colony in a Missouri Barn*. American Midland Naturalist 86:502-506. 1971.

Gunnell, G. F. and N. B. Simmons. *Fossil Evidence and the Origin of Bats*. Journal of Mammalian Evolution 12:209-246. 2005.

Hayes, H. A. and D. C. Bingham. *A Colony of Gray Bats in Southeastern Kansas*. Journal of Mammalogy 45:150. 1964.

Henry, M., D. W. Thomas, R. Vaudry, and M. Carrier. *Foraging Distances and Home Range of Pregnant & Lactating Little Brown Bats* (*Myotis lucifugus*). Journal of Mammalogy 83:767-774. 2002.

Hirshfield, J. R., Z. C. Nelson, and W. G. Bradley. *Night Roosting Behavior in Four Species of Desert Bats*. Southwestern Naturalist 22:427–433. 1977.

Hiryu, S., K. Katsura, L. K. Lin, H. Riquimaroux, and Y. Watanabe. *Doppler-shift Compensation in the Taiwanese Leaf-nosed Bat (Hipposideros terasensis) Recorded with a Telemetry Microphone System During Flight*. Journal of the Acoustic Society of America 118:3927-3933. 2005.

Holland, R. A. and D. A. Waters. *Echolocation Signals and Pinnae Movement in the Fruit Bat Rousettus aegyptiacus*. Acta Chiropterologica 7:83-90. 2005.

Hughes, A. C., C. Satasook, P.J.J. Bates, P. Soisook, T. Sritongchuay, G. Jones, and S. Bumrungsri. *Using Echolocation Calls to Identify Thai Bat Species: Vespertilionidae, Emballonuridae, Nycteridae, and Megadermatidae*. Acta Chiropterologica 13:447-455. 2011.

Jones, G., N. Vaughan, D. Russo, L.P. Wickramasinghe, and S. Harris. *Designing Bat Activity Surveys Using Time Expansion and Direct Sampling of Ultrasound*. Pages 64-70 In: Bingham, R. M., E.K.V. Kalko, G. Jones, S. Parsons, and H.J.G.A. Limpens, eds. Bat Echolocation Research: Tools, Techniques and Analysis. Bat Conservation International. Austin, Texas.

2004.

Johnson, J.S., D.M. Reeder, J.W. McMichael III, M.B. Meierhofer, D. W. F. Stern, S.S. Lumadue, L.E. Sigler, H.D. Winters, M.E. Vodzak, A. Kurta, J.A. Kath, and K.A. Field. *Host, Pathogen, and Environmental Characteristics Predict White-nose Syndrome Mortality in Captive Little Brown Myotis* (*Myotis lucifugus*). PLoS ONE 9(11): e112502 (9 pages). doi:10.1371/journal.pone.0112502. 2014.

Kuenzi, A.J. and M.L. Morrison. *Detection of Bats by Mist-nets and Ultrasonic Sensors*. Wildlife Society Bulletin 26:307-311. 1998.

Kunz, T. H. *Resource Utilization: Temporal and Spatial Components of Bat Activity in Central Iowa*. Journal of Mammalogy 54: 14–32. 1973.

Kunz, T. H., J. A. Wrazen, and C. D. Burnett. *Changes in Body Mass and Fat Reserves in Pre-hibernating Little Brown Bats* (*Myotis lucifugus*). Ecoscience 5:8-17. 1998.

La Val, R. K., R. L. Clawson, M. L. Laval and W. Caire. *Foraging Behavior and Nocturnal Activity Patterns of Missouri Bats, with Emphasis on the Endangered Species Myotis grisescens and Myotis sodalis*. Journal of Mammalogy 58:592-599. 1977.

La Val, R. and M. L. La Val. Ecological Studies and Management of Missouri Bats, with Emphasis on Cave-dwelling Species. Terrestrial Report 8. Missouri Department of Conservation, Jefferson City, Missouri, USA. 1980.

Lewis, S. E**.** *Roost Fidelity of Bats: A Review*. Journal of Mammalogy 76:481-496. 1995.

Manley, P.N., B. Van Horne, J. K. Roth, W. J. Zielinski, M. M. McKenzie, T. J. Weller, F. W. Weckerly, and C. Vojta. Multiple Species Inventory and Monitoring Technical Guide. General Technical Report WO-73. U.S. Department of Agriculture, Forest Service, Washington Office. 204 pp. Washington, DC. 2006.

Martin, C. O. and E. R. Britzke. Mammalian Survey Techniques for Level II Natural Resource Inventory on Corps of Engineers Projects (Part II-Bats). ERDC TN-EMRRP-S1-35. Ecosystem Management and Restoration RESEARCH Program. U.S. Army Corps of Engineers. 2010.

McCracken, K., N. Giffen, A. Haines and J. Evans. Bat Summer Survey Report for ORNL: Bat Species Distribution on the Oak Ridge Reservation with Emphasis on the Endangered Indiana Bat. Environmental Sciences Division, Oak Ridge National Laboratory. Oak Ridge, Tennessee. 2013.

Menzel, M. A., W. M. Ford, J. M. Menzel, T. C. Carter and J. W. Edwards. Review of the Forest Habitat Relationships of the Indiana Bat (Myotis sodalis). Research Note NE-284. United

States Department of Agriculture, US Forest Service, Newtown Square, Pennsylvania. 22 pp. 2001.

Menzel. J. M., W. M. Ford, M. A. Menzel, T. C. Carter, J. E. Gardner, J. D. Garner and J. E. Hofmann. *Summer Habitat Use and Home-range Analysis of the Endangered Indiana Bat*. Journal of Wildlife Management 69:430-436. 2005.

Meteyer, C.U., E. L. Buckles, D. S. Blehert, A. C. Hicks, D. E. Green, V. Shearn-Bochsler, N. J. Thomas, A. Gargas, and M. J. Behr. *Histopathologic Criteria for Confirming White-nose Syndrome in Bats*. Journal of Veterinary Diagnostic Laboratory Investigations 21:411-414. 2009.

Metzner, W., S. Zhang, and M. Smotherman. *Doppler-shift Compensation Behavior in Horseshoe Bats Revisited: Auditory Feedback Controls Both a Decrease and an Increase in Call Frequency*. The Journal of Experimental Biology 205:1607-1616. 2002.

Middleton, R. G. Tennessee State Parks Bat Acoustic Survey (2014). Unpublished data. 2015.

Mitchell, J. M., E. R. Vail, J. W. Webb, J. W. Evans, A. L. King and P. A. Hamlett. Survey of Protected Terrestrial Vertebrates on the Oak Ridge Reservation, Final Report. ES/ER/TM-188-R1. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 1996.

Mitchell, W. A. and C. O. Martin. Cave- and Crevice-dwelling Bats on USACE Projects: Gray Bat (Myotis grisescens). ERDC TN-EMRRP-SI-25. EMRRP Technical Notes Collection, U. S. Army Engineer Research and Development Center, Vicksburg, Mississippi. 2002.

Mrosovsky, N. *Cyclical Obesity in Hibernators: The Search for the Adjustable Regulator*. Pages 45-56 In: J. Hirsch and T. Van Itallie (eds.). Recent Adventures in Obesity. Vol. 4. Libbey, London, UK. 1985.

Mumford, R. E. and J. B. Cope. *Summer Records of Myotis sodalis in Indiana.* Journal of Mammalogy 39:568-587. 1958.

Murray, K.L., E.R. Britzke, B. Hadley and L.W. Robbins. *Surveying Bat Communities: a Comparison Between Mist Nets and the Anabat II Bat Detector System*. Acta Chiropterologica 1:105-111. 1999.

O'Farrell, M. J. and W. L. Gannon. *A Comparison of Acoustic Versus Capture Techniques for the Inventory of Bats*. Journal of Mammalogy 80:24–30. 1999.

O'Farrell, M. J., B. W. Miller, and W. L. Gannon. *Qualitative Identification of Free-flying Bats Using the Anabat Detector*. Journal of Mammalogy 80:11–23. 1999.

Ormsbee, P. C., J. D. Kiser, and S. I. Perlmeter. *Importance of Night Roosts to the Ecology of Bats.* pp. 129–151. In: Bats in Forests: Conservation and Management. M. Lacki, J. Hayes,

And A. Kurta (eds.). The Johns Hopkins University Press. Baltimore, Maryland. 329 pp. 2007.

Owen, S. F., M. A. Menzel, J. W. Edwards, W. M. Ford, J. M. Menzel, B. R. Chapman, P. B. Wood and K. V. Miller. *Bat Activity in Harvested and Intact Forest Stands in the Allegheny Mountains*. Northern Journal of Applied Forestry 21:154-159. 2004.

Parsons, S., A. M. Boonman, M. K. Obrist. *Advantages and Disadvantages of Techniques for Transforming and Analyzing Chiropteran Echolocation Calls*. Journal of Mammalogy 81: 927-938. 2000.

Pauza, D. H. and N. Pauziene. *Bats of Lithuania: Distribution, Status and Protection*. Mammal Review 28:53–67. 1998.

Pickett, Bob. Bats: Order *Chiroptera*. http://www.bobpickett.org/order_chiroptera.htm. Accessed January 25, 2015.

Racey, P.A. *Ecology of European Bats in Relation to Their Conservation*. Pages 249-260 In: Bat Biology and Conservation. (T. H. Kunz and P. A. Racey, eds.). Smithsonian Institution Press, Washington, D.C. 1998.

Russo, D., and G. Jones. *Use of Foraging Habitats by Bats in a Mediterranean Area Determined by Acoustic Surveys: Conservation Implications*. Ecography 26:197–209. 2003.

Salyers, J., K. Tyrell, and V. Brack. *Artificial Roost Structure Use by Indiana Bats in Wooded Areas in Central Indiana*. Bat Research News 37:148. 1996.

Sasse, D. B. and P. J. Perkins. *Summer Roosting Ecology of Northern Long-eared Bats (Myotis septentrionalis) in the White Mountain National Forest*. In: Barclay, R.M.R.; Brigham, R. M. eds. Bats and Forest Symposium, Working Paper 23/1996. Ministry of Forests. Pages 91- 101. Victoria, BC: British Columbia. 1996.

Schirmacher MR, Castleberry SB, Ford WM, Miller KV. *Habitat Association of Bats in South-central West Virginia*. Proceedings of the Annual Conference of the Southeastern Fish and Wildlife Association 61:46–52. 2007.

Schnitzler, H. U. *Die Ultraschallortungslaute der Hufeisennasen- Fledermäuse (Chiroptera, Rhinolophidae) in verschiedenen Orientierungssituationen*. Zeitschrift für vergleichende Physiologie 57:376–408. 1968.

Simmons, J. A., D. J. Howell, and N. Suga. *Information Content of Bat Sonar Echoes*. American Scientist 63:204-215. 1975.

Simmons, N. B. and T. M. Conway. *Evolution of Ecological Diversity in Bats.* In: Kunz TH, Fenton MB, eds. Bat Ecology. Pages 493–535. University of Chicago Press. Chicago,

Illinois. 2003.

Simmons, N. B. and J. H. Geisler. *Phylogenetic Relationships of Icaronycteris, Archaeonycteris, Hassianycteris, and Palaeochiropteryx to Extant Bat Lineages, with Comments on the Evolution of Echolocation and Foraging Strategies in Microchiroptera*. Bulletin of the American Museum of Natural History 235:1-182. 1998.

SmartDraw. SmartDraw software program 2014 ver. SmartDraw, LLC. San Diego, California. 2014.

Steece, R. and J. S. Altenbach. *Prevalence of Rabies Specific Antibodies in the Mexican Free-tailed Bat (Tadarida brasiliensis mexicana) at Lava Cave, New Mexico*. Journal of Wildlife Diseases 25:490-496. 1989.

Suga, N., J. A. Simmons and P.H.S. Jen. *Peripheral Specialization for Fine Analysis of Doppler Shifted Echoes in the "CF-FM" Bat Pteronotus parnellii*. Journal of Experimental Biology 63: 16l-192. 1975.

Suga, N. and W. E. O'Neill. *Neural Axis Representing Target Range in the Auditory Cortex of the Mustache Bat*. Science 206:351-353. 1979.

Suga, N. *Bisonar and Neural Computation in Bats*. Scientific American 262:60-68. 1990.

Szewczak, J. M. *Advanced Analysis Techniques for Identifying Bat Species*. In: Bat Echolocation Research: Tools, Techniques & Analysis. pp. 121–127. Bat Conservation International, Austin, Texas. 2004.

Szewczak J. Acoustic Ambiguity of Myotis lucifugus and M. sodalis [Conference presentation] //North Eastern Bat Working Group Annual Meeting. - Carlisle, Pennsylvania. 2011.

Teeling, E. C., M. S. Springe, O. Madsen, P. Bates, and S. J. O'Brien. *A Molecular Phylogeny for Bats Illuminates Biogeography and the Fossil Record*. Science 307:580–584. 2005.

Tennessee Bat Working Group. http://www.tnbwg.org/index.html. 2014.

Timmerman, L. and V. R. McDaniel. *A Maternity Colony of Gray Bats in a Non-cave Site*. Arkansas Academy of Science 46:108-109. 1992.

Timpone, J. C., J. G. Boyles, K. L. Murray, D. P. Aubrey and L. W. Robbins. *Overlap in Roosting Habits of Indiana Bats (Myotis sodalis) and Northern Bats (Myotis septentrionalis).* American Midland Naturalist 163:115-123. 2010.

Tuttle, M. D. *Population Ecology of the Gray Bat (Myotis grisescens): Factors Influencing Growth and Survival of Newly Volant Young.* Ecology 57:587-595. 1976.

Tuttle, M. D. *Population Ecology of the Gray Bat (Myotis grisescens): Philopatry, Timing, and Patterns of Movement, Weight Loss During Migration, and Seasonal Adaptive Strategies*. Occasional Papers of the Museum of Natural History, University of Kansas 54:1-38. 1976-b.

Tuttle, M. D. *Joint Effort Saves Vital Bat Cave.* Bats 2:34. 1985.

Tuttle, M. D. *Endangered Gray Bat Benefits from Protection.* Bats 4:1-3. 1986.

Tuttle, M. D. *America's Neighborhood Bats*. University of Texas Press, Austin, Texas. 96 pp. 1988.

Ulanovsky, N. and C. F. Moss. *What the Bat's Voice Tells the Bat's Brain*. Proceedings of the National Academy of Science 105: 8491-8498. 2008.

U. S. Fish and Wildlife Service, Kentucky Field Office and the Kentucky Department for Fish and Wildlife Resources. Indiana Bat Survey Guidance for Kentucky. Frankfurt, Kentucky. 2011.

U. S. Fish & Wildlife Service. Range-Wide Indiana Bat Summer Survey Guidelines. Falls Church, Virginia. 2013. http://www.fws.gov/midwest/endangered/mammals/inba/inbasummersurveyguidance.html

U. S. Fish & Wildlife Service. Range-wide Indiana Bat Summer Survey Guidelines. Falls Church, Virginia. 2014. http://www.fws.gov/midwest/endangered/mammals/inba/surveys/pdf/2014IBatSummerSurveyGuidelines13Jan2014.pdf .

Veselka N, D. D. McErlain, D. W. Holdsworth, J. L. Eger, and R. K. Chem. *A Bony Connection Signals Laryngeal Echolocation in Bats*. Nature 463: 939–942. 2010.

Wear, M. S. Diversity and Distribution of Bat Species on Chuck Swan Wildlife Management Area, Tennessee. Thesis. Department of Forestry, Wildlife and Fisheries, University of Tennessee, Knoxville, TN. 2004.

Webb, W. Gray and Indiana Bats: Assessment and Evaluation of Potential Roosting and Foraging Habitats. Anderson and Roane Counties, Tennessee. In: Environmental Assessment for Selection and Operation of the Proposed Field Research Centers. Appendix G. US DOE, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee. 2000.

Weller, T. J. and C. J. Zabel. *Variation in Bat Detections Due to Detector Orientation in a Forest*. Wildlife Society Bulletin 30:922-930. 2002.

Yard, C.R. Health and Safety Plan. Tennessee Department of Environment and Conservation, Department of Energy Oversight Office. Oak Ridge, Tennessee. 2014.

Young, R. A. *Fat, Energy, and Mammalian Survival*. American Zoologist 16:699-710. 19