

January 2011

Bat Species Diversity in Old-Growth vs. Second Growth Forests in Lilley Cornett Woods, Letcher County, Kentucky

Lindsay R. Conley
Eastern Kentucky University

Follow this and additional works at: <https://encompass.eku.edu/etd>



Part of the [Zoology Commons](#)

Recommended Citation

Conley, Lindsay R., "Bat Species Diversity in Old-Growth vs. Second Growth Forests in Lilley Cornett Woods, Letcher County, Kentucky" (2011). *Online Theses and Dissertations*. 47.
<https://encompass.eku.edu/etd/47>

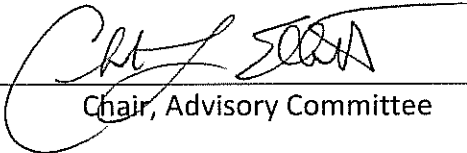
This Open Access Thesis is brought to you for free and open access by the Student Scholarship at Encompass. It has been accepted for inclusion in Online Theses and Dissertations by an authorized administrator of Encompass. For more information, please contact Linda.Sizemore@eku.edu.

Bat Species Diversity in Old Growth vs. Second Growth Forests in Lilley Cornett Woods,
Letcher County, Kentucky

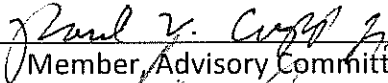
By

Lindsay R. Conley

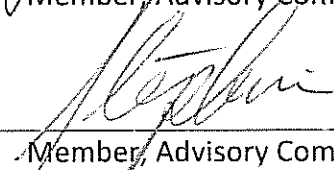
Thesis Approved:



Chair, Advisory Committee



Member, Advisory Committee



Member, Advisory Committee



Dean, Graduate School

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a Master's degree at Eastern Kentucky University, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of the source is made. Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in his absence, by the Head of Interlibrary Services when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature Lindsay R Conley

Date 11-18-2011

Bat Species Diversity in Old-Growth vs. Second Growth Forests in Lilley Cornett Woods,
Letcher County, Kentucky

By

Lindsay R. Conley

Bachelor of Science
Eastern Kentucky University
Richmond, Kentucky
2008

Submitted to the Faculty of the Graduate School of
Eastern Kentucky University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
December, 2011

ACKNOWLEDGMENTS

First and foremost I would like to thank my major advisor, Dr. Charles L. Elliott, for his continuing support, guidance and encouragement throughout my past 6 years at EKU; his knowledge and passion of the wildlife field has guided me through my Bachelor's degree and now to my Master's degree. Especially over the last year, while I was no longer on campus, Dr. Elliott has continued to be insightful and has provided thoughtful comments and discussions. I would also like to thank my other graduate committee members, Dr. Paul V. Cupp and Dr. Stephen Sumithran, whose comments and guidance have also helped push this project to completion. This project would not have been possible without the assistance and advice of Brooke Hines, Bat Ecologist with the Kentucky Department of Fish and Wildlife Resources. Brooke provided valuable logistical support, netting and acoustic equipment, and expertise in running Anabat analysis. I also owe thanks to the Eastern Kentucky University Division of Natural Areas and Dr. Melinda Wilder for allowing me to conduct my research at Lilley Cornett Woods Appalachian Ecological Research Station, and Robert Watts for his help in the field and knowledge of the land. I would like to thank Dr. Alice Jones and the Eastern Kentucky University Environmental Research Institute for hiring me as a Graduate Assistant, and providing a field vehicle in 2010. Thank you to Mike Armstrong, with the U.S. Fish and Wildlife Service, who assisted with mist netting efforts in 2009; and Eco-tech Consulting (Frankfort, KY) for providing equipment during mist netting. I would like to thank my mother, Kelly Allen, for her assistance in data collection during summer 2010; even while almost stepping on a copperhead and getting lost, she still had high spirits. Thanks also to Bradley Wenclewicz for providing comedic relief, as well as hauling equipment up and down the mountain. Finally, I would like to thank my family for always encouraging and pushing me while in college, my success would have not been possible without you.

ABSTRACT

Bat activity in old-growth forests (+150 years) is a subject that is poorly understood. The majority of old-growth forests are located in the northwestern portion of the United States, and with current silviculture practices, many forests are being cut. There have been no published studies that specifically examine bat use of old-growth forests in Kentucky. The objective of this study was to determine the diversity of bat species associated with old-growth (+150 years) and second growth forests within the Lilley Cornett Woods Appalachian Ecological Research Station, Letcher County, Kentucky. This study was conducted over 2 field seasons; 2009 and 2010. Mist netting was conducted during July 2009, consisting of 13 sites (6 in old-growth, 7 in second growth forests). A total of 26 individuals, representing 5 species were captured. The little brown bat (*Myotis lucifugus*) was the most abundant bat captured (n=11, 42%). The tri-colored bat (*Permyotis subflavus*) (n=6, 23%), northern bat (*M. septentrionalis*) (n=6, 23%), big brown bat (*Eptesicus fuscus*) (n=2), and hoary bat (*Lasiurus cinereus*) were also captured during mist net surveys. Only 15% of bats were captured in old-growth forest sites, while 85% of captures occurred in second growth forest. Acoustical monitoring was conducted from 22 May – 21 August 2010, with acoustic sampling occurring nightly and continuously for 85 nights. Anabat II ultrasonic bat detectors with ZCAIM units were deployed in old-growth and second growth forest locations for two week sampling periods (23 sampling locations; 14 in old-growth and 9 in second growth). There were 34,536 identified echolocation passes recorded from 10 different

bat species, i.e., tri-colored bat, little brown bat, northern bat, big brown bat, hoary bat, Indiana bat (*M. sodalis*), gray bat (*M. grisescens*), eastern red bat (*Lasiurus borealis*), eastern small-footed bat (*M. leibii*), southeastern bat (*M. austroriparius*), evening bat (*Nycticeius humeralis*). The second growth forest recorded more bat passes than the old-growth forest (61% and 39%, respectively), with the tri-colored bat being the most frequently recorded bat in the old-growth forest; while the little brown bat was the most frequently recorded bat in the second growth forest. There was very little similarity in terms of the species captured using mist nets and the species detected using Anabat; and between the bat species captured during mist netting in the old-growth forest vs. second growth forest ($S_j = 0.36$ and 0.20 , respectively). The region which comprises the Lilley Cornett Woods Appalachian Ecological Research Station supports a diverse population of bat species. It is recommended the forested habitat within the facility be maintained, especially the old-growth segment, and the riparian community associated with Line Fork Creek be preserved in order to maintain the area's Chiropteran community.

TABLE OF CONTENTS

CHAPTER	PAGE
I. Introduction	1
II. Study Area.....	5
III. Materials and Methods	7
Mist Netting.....	7
Acoustical Sampling.....	8
IV. Results.....	11
V. Discussion	14
Literature Cited	21

LIST OF TABLES

TABLE	PAGE
1. Bats captured in mist nets in Lilley Cornett Woods, Letcher County, Kentucky, July 2009	11
2. Bats captured using mist nets in old-growth and second growth forests in Lilley Cornett Woods, Letcher County, Kentucky, July 2009	12
3. Total number of bat echolocation passes recorded at Lilley Cornett Woods, Letcher County, Kentucky, May 22 – August 21, 2010.....	13

CHAPTER 1

INTRODUCTION

The Order Chiroptera (bats) is an important component of biodiversity found throughout the world and on nearly every continent. When present in an area, bats play a very important ecological role. They are pollinators of many flowering plants, serve as pest control while eating many insects at night, and their guano can be used as a very nutrient rich fertilizer (Pisarowicz 2006). Each species of bat has different habitat requirements. However, bats are usually underrepresented in conservation plans because of a lack of knowledge concerning population status and habitat requirements (Weller and Lee 2007). In order to manage for bats properly, it is essential to determine what species are present in the area.

There are 45 species of bats in the United States; 16 of which occur in Kentucky (KBWG 2001). The most commonly used method to catch flying bats is to use mist nets (MacCarthy et al. 2006). Advantages of the mist net include: ease of set-up, portability, and relatively low cost (Flaquer et al. 2007). Disadvantages of using mist nets to determine the bat species in an area include: (1) the need to constantly tend the net, (2) captured bats have to be removed individually from the net (Kunz et al. 1996), and (3) if netting is conducted over a period of more than one night, bats may become aware of the mist net location (Robbins et al. 2008). An indirect method for determining the presence of bats in an area has been gaining popularity. When implemented correctly, the use of ultrasonic detectors is one of the most non-invasive ways to survey bat

species (Kuenzi and Morrison 1998; Weller and Zabel 2002). Ultrasonic detectors are easier to set up and take down than standard mist nets; detect more species than mist nets, can sample a wider range of habitat types, and do not require constant surveillance (Murray et al. 1999; O'Farrell and Gannon 1999; Robbins et al. 2008). However, there are some limitations to using acoustic monitoring: (1) the detectors can only tell the observers what species is present in the area, not the quantity (e.g. there could be one bat flying above the detector or there could be a colony of bats flying by); (2) there is no way to determine physical parameters (e.g., age, sex, reproductive status); (3) some bat calls are hard to distinguish between species (Cohn 2007); and (4) the microphone orientation and weatherproofing design associated with the field placement of ultrasonic systems can influence the data collected (Britzke et al. 2010).

Many studies have been published which examine the influence of silvicultural treatments on bat activity in the United States and Canada [see review by Hayes and Loeb (2007)]; but few studies have been conducted that address bats which inhabit old-growth forests. One study found the median index of bat activity was higher in old-growth forests than in unthinned forest stands (Humes et al. 1999). In old-growth redwoods (*Sequoia sempervirens*) of northern California, researchers found basal redwood hollows to be important roost sites for cavity-roosting bats. Basal hollows were used more during the summer months than in winter (Gellman and Zielinski 1996). Of the bats found in the California redwoods study, some are present in Kentucky [i.e., little brown bat (*Myotis lucifugus*), big brown bat (*Eptesicus fuscus*), silver-haired bat

(*Lasionycteris noctivagans*); Gellman and Zielinski (1996)]. Mazurek (2001) used Anabat ultrasonic bat detectors to monitor bat activity in old-growth California redwood forests. He found the mean number of bat passes was 9.5 times greater in old-growth than in thinned second growth stands; and 12 times greater than in unthinned second growth stands (Mazurek 2001).

Within Kentucky, there have been few studies which directly or indirectly examine bat species presence in relation to forest age or silvicultural practices. Moosman (2001) conducted a mist net bat survey of fragmented and intact woodlands in Central Kentucky. He caught 6 species of bats: Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), big brown bat, eastern red bat (*Lasiurus borealis*), little brown bat, northern bat (*Myotis septentrionalis*), and tri-colored bat (*Perimyotis subflavus*) [formerly known as eastern pipistrelle (*Pipistrellus subflavus*)]. There was no difference in bat species richness between the two types of forests surveyed (Moosman 2001). Lacki and Schwierjohann (2001) reported forest management practices that sustain a diversity of tree species and snags is important in maintaining habitat for northern bats occupying mixed mesophytic forests in northeastern Kentucky. MacGregor et al. (1999) reported that two-age shelterwood harvest on the Daniel Boone National Forest in Kentucky could produce different amounts of autumn roosting habitat for Indiana bats depending on the harvests' snag retention. Within the Cumberland Plateau region of Kentucky (in which the study area for this project, Lilley Cornett Woods, is located), Hutchinson and Lacki (2000) examined the selection of day

roosts by red bats in a second growth (70-80 year old) forest. They reported the choice of day roosts by *Lasiurus borealis* inhabiting tracts of mature contiguous forest differed from those in fragmented habitats.

There have been no published studies specifically examining the use of old-growth forests by bats in Kentucky. Lacki and Schwierjohann (2001) noted northern bats in mixed mesophytic forests in northeastern Kentucky roosted in habitats with larger-diameter stems, suggesting a preference for roosting in older forest. Since timber harvest is expected to increase considerably within the next decades due to development (Loeb and O'Keefe 2006), it is necessary to understand habitat needs and manage all southeastern forests in a way that conserves bat habitat (Taylor 2006).

The objective of this study was to determine the diversity of bat species associated with old-growth (+150 years) and second growth forests within the Lilley Cornett Woods Appalachian Ecological Research Station located in southeastern Kentucky. There is currently no published information regarding bat assemblages in this area of the Commonwealth. With the threat of white-nose syndrome (WNS) and possible loss of regional bat populations (Blehert et al. 2009; Frick et al. 2010; USFWS 2010), an understanding of the Chiropteran population within the boundaries of the research station is vital for long term monitoring.

CHAPTER 2

STUDY AREA

This study was conducted in Lilley Cornett Woods Appalachian Ecological Research Station (Letcher Co., KY) located 45.5 km (28 miles) southeast of Hazard, KY. Lilley Cornett Woods is the first old-growth forest preserved and owned by the Commonwealth of Kentucky (DNA 1998), and Eastern Kentucky University currently manages the site. The study area encompasses 224 ha (554 ac); 101 ha (252 ac) of which is considered old-growth (+150 years; DNA 1998) and is located within the Cumberland Plateau in southeastern Kentucky (McEwan et al. 2005). Line Fork Creek runs through Lilley Cornett Woods and flows into the North Fork of the Kentucky River (Barels 1985).

The Lilley Cornett Woods study area is considered a Mixed Mesophytic Forest (DNA 1998). The Mixed Mesophytic Forest Region is characterized by a rich understory of deciduous tree species including, American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), tuliptree (*Liriodendron tulipifera*), several magnolia species (*Magnoliaceae* spp.), northern red oak (*Quercus rubra*), white oak (*Q. alba*), white ash (*Fraxinus americana*), eastern hemlock (*Tsuga canadensis*), and evergreen species (*Pinaceae* spp.; Jones 2005). Elevations at Lilley Cornett Woods range from 588m (1960 ft) to 315m (1052 ft), from the highest ridge to the floodplains, respectively (Barels 1985).

The old-growth forest within Lilley Cornett Woods is located in the Big Everidge Hollow watershed and is comprised of steep sloping terrain, debris, leaf litter, fallen trees and a diverse age structure among the standing trees (McEwan and Muller 2006). The oldest trees in the old-growth forest date back to 1660 AD; the majority of trees that have been aged date back to 1710 AD (NOAA 2008). Based on previous studies in Lilley Cornett Woods (Muller 1982; McEwan and Muller 2006), there are three distinct ecological communities within the old-growth forest; a lower slope beech community, dominated by *Fagus grandifolia*; a mixed Mesophytic community found on mid-slopes, characterized by *A. saccharum* and *Tilia americana* L.; and an upper-slope oak community in which *Quercus Montana* and *A. rubrum* are important species.

The old-growth portion of Lilley Cornett Woods has never been logged; but prior to the property being purchased by the state of Kentucky in 1968, the old-growth section was subject to livestock grazing and periodic burning on the upper slopes. Like all other forests of the Cumberland Plateau and Mountains, Lilley Cornett Woods was affected by the blight that killed American chestnut (*Castanea dentata*) prior to World War II. Lilley Cornett Wood's bottomland area was used for pasture and hay production until 1971. The secondary forest currently found within Lilley Cornett Woods arose following abandonment of agricultural practices, coal mining and logging in the 1940s (DNA 1998). There was a fire approximately one hectare in size in the old-growth forest portion of Lilley Cornett Woods in the spring of 2010. The fire primarily burned understory vegetation on the lower slopes but did kill some large trees on the ridge top.

CHAPTER 3
MATERIALS AND METHODS

Mist Netting

In July 2009, 13 locations within Lilley Cornett Woods (LCW) were sampled to determine what bats were present. Seven mist nets were located along the ridge top and trails within the old-growth forest, and six mist nets were located in conjunction with Line Fork Creek, and along trails and roads within the second growth forest. Mist nets [2-ply, 50-denier nylon or polyester with a mesh size of 38mm (1.5 in); (Avinet, Inc. Dryden, NY)] were stacked (placed one on top of the other) two high, for a height of 6m (20 ft.). Mist net sampling procedures followed the protocol outlined in the Indiana Bat Survey Guide (USFWS 2007). Due to the threat of white nose syndrome, the Disinfection Protocol for Bat Field Research/Monitoring (USFWS 2009) was followed to prevent contamination at net sites. Nets were tended (checked) every 10-15 minutes from dusk until five hours after sunset.

Once captured, a bat was removed from the mist net and identified to species, weighed, right forearm length determined, aged, sexed, and reproductive condition assessed. Bats were identified based on external morphology including; fur coloration, body size, forearm length, ear length and shape, body weight, and the presence or absence of a calcar (BCI 2001). Age was determined by shining a light behind the fingers of the bats to see if the cartilaginous, epiphyseal growth plates were fused. Adults will have completely fused joints, while the joints of juveniles are visibly not fused (Anthony

1988). Reproductive condition of female bats was evaluated to see if they were pregnant (distinct palpation of the abdomen), lactating (teats enlarged and hairless), or post-lactating (visible regrowth of hair surrounding teats; Lacki and Schwierjohann 2001). Males with descended testes were considered to be reproductive adults. All bats were banded with Kentucky Department of Fish and Wildlife Resource (KDFWR) bat bands and released at the capture site. Procedures related to bat capture and handling were reviewed by Eastern Kentucky University's Institutional Animal Care and Use Committee and approved as Protocol #008-2009.

Acoustical Sampling

The second season of bat sampling was conducted from 22 May – 21 August 2010, with acoustic sampling occurring nightly and continuously throughout the season. No mist netting was conducted in 2010. Twenty-three different locations were designated as acoustic sampling sites; 14 in old-growth forest and 9 in second growth forests. Sites were chosen in order to maximize the probability of detecting bat activity and obtaining the best possible call sequences (Weller and Zabel 2002). Echolocation calls were sampled using Anabat II bat detectors (Titley Electronics, Ballina, New South Wales, Australia) and recorded onto a compact flash card (CF card) with a Zero-Crossings Analysis Interface Module (ZCAIM; Titley Electronics, Ballina, New South Wales, Australia). This configuration of equipment stores echolocation call files with the associated data (time and date of bat call) in order for later downloading onto a personal computer. Anabat detectors were programmed to automatically switch on 30

minutes before sunset and off 30 minutes after sunrise. Each detector unit was powered by 4-AA batteries and each ZCAIM unit by one 9-V battery, permitting operation for up to 2 weeks.

The Anabat detector and ZCAIM units needed to be protected from the elements while spending extended time outdoors, so they were placed in specially constructed waterproof containers with a 45° angle PVC pipe attached to one end for the microphone. This method, shown to be more efficient in detecting the most bats, is illustrated in Britzke et al. (2010). The containers were placed on tripods approximately 1.5m (5ft) above the forest floor. Containers (each housing an Anabat detector and ZCAIM unit) were placed at a sampling location for 2 weeks (recording nightly) and rotated throughout the LCW study area. Efforts were made to place an equal number of Anabat units in both habitat types to lower the bias of seasonal bat activity (e.g., 2 units in old-growth forest and 2 units in second growth forest.)

Data was collected and analyzed following the procedure of Britzke et al. (2010). Bat acoustic data from the CF cards were uploaded using the program CFCread (<http://www.hoarybat.com>) to a computer and stored for later identification. Bat calls were analyzed using the program Analook (version 4.9j, Titley Electronics, <http://www.hoarybat.com>) and filters designed for eastern U. S. bat species. Parameters from the call sequences were saved in a text file and identified through a known call library using a mixed discriminant function analysis model in the statistical program R (v. 2.2.1; <http://www.r-project.org>); giving the output of species of bat, and

how many times that call sequence was recorded (“hits”) by the Anabat unit. To identify bats to species, factors such as minimum, maximum and mean call note frequency, call note curvature, and call note slope were used (Ford et al. 2006).

The Jaccard Coefficient of Similarity (S_j) was used to determine how similar bat species assemblages were between the mist netting technique and acoustical monitoring; and between the bat species captured in the old-growth forest and second growth forest.

CHAPTER 4

RESULTS

A total of 26 individuals, representing 5 species, was captured during the summer 2009 mist net season (Table 1). The little brown bat, tri-colored bat, and northern bat comprised 42%, 23%, and 23% of the total captures, respectively (Table 1). Out of 26 total captures at 13 net sites (6 in second growth, 7 in old-growth forest), 15% of the bats were captured in old-growth forest sites and 85% in second growth forest (Table 2). Overall, bats were captured at 8 of 13 mist net locations. The only species captured in both habitats was *Myotis septentrionalis*.

Table 1. Bats captured in mist nets in Lilley Cornett Woods, Letcher County, Kentucky, July 2009.

Species	# Captures	Male		Female	
		Adult	Juvenile	Adult	Juvenile
<i>Perimyotis subflavus</i>	6	4	-	2	-
<i>Myotis lucifugus</i>	11	5	-	6	-
<i>Lasiurus cinereus</i>	1	1	-	-	-
<i>M. septentrionalis</i>	6	-	-	3	3
<i>Eptesicus fuscus</i>	2	2	-	-	-
TOTAL	26	12	0	11	3

During the 85 nights of continuous acoustic monitoring, there were 34,566 echolocation passes recorded from 10 different bat species (Table 3). However, 34,536 of the calls were analyzed because only species echolocation calls with more than 2 hits

per site were used. Two of the Anabat units did not record any bat passes while deployed in the field (one from each habitat type).

Table 2. Bats captured using mist nets in old-growth and second growth forests in Lilley Cornett Woods, Letcher County, Kentucky, July 2009.

Species	# Captures	Old-Growth	Second Growth
<i>Perimyotis subflavus</i>	6	-	6
<i>Myotis lucifugus</i>	11	-	11
<i>Lasiurus cinereus</i>	1	-	1
<i>M. septentrionalis</i>	6	4	2
<i>Eptesicus fuscus</i>	2	-	2
TOTAL	26	4	22

All bat species detected with Anabat were found to occur within each of the habitat types surveyed. The second growth forest recorded more bat passes than the old-growth forest (61% and 39%, respectively, Table 3). The tri-colored bat was the most frequently recorded bat in the old-growth forest (Table 3); while the little brown bat was the most frequently recorded bat in the second growth forest (Table 3). The number of calls per site ranged from 11 as a low, to a high of 10,728 calls along Line Fork Creek.

There was very little similarity ($S_j = 0.36$) in terms of the species captured using mist nets and the species detected using Anabat. Between the bat species captured during mist netting in the old-growth forest and second growth forest, there was also very little similarity ($S_j = 0.20$).

One hoary bat (*Lasiurus cinereus*) was captured in a mist net in 2009 (Table 2); however, there was an insufficient number of echolocation calls ($n \leq 2$) to include the species in the acoustical analysis. Two federally endangered species, the Indiana bat (*Myotis sodalis*) and gray bat (*Myotis grisescens*), were only detected using Anabat and were found in both forested habitat types (Table 3).

Table 3. Total number of bat echolocation passes recorded at Lilley Cornett Woods, Letcher County, Kentucky, May 22 – August 21, 2010.

	Old-Growth Forest	Second Growth Forest	Total
PESU	10,860	6,093	16,953
MYLU	237	12,028	12,265
MYSO*	437	1,558	1,995
LABO	963	265	1,228
MYSE	698	349	1,047
MYLE	165	287	452
MYGR*	8	240	248
EPFU	38	173	211
MYAU	16	95	111
NYHU	15	11	26
Total	13,437	21,099	34,536

EPFU = *Eptesicus fuscus*; LABO = *Lasiurus borealis*; MYAU = *Myotis austroriparius*; MYGR = *Myotis grisescens*; MYLE = *Myotis leibii*; MYLU = *Myotis lucifugus*; MYSE = *Myotis septentrionalis*; MYSO = *Myotis sodalis*; NYHU = *Nycticeius humeralis*; PESU = *Perimyotis subflavus*; *= Federally Endangered Species

CHAPTER 5

DISCUSSION

Hayes and Loeb (2007) reviewed a number of studies related to bat use of old-growth forests and noted a trend of higher use when compared with younger aged forests. They noted the high use of old-growth stands by bats appears to be related to the presence of roosts (see also Pierson 1998), especially those provided by large-diameter snags. As pointed out by Pierson (1998), "Current silvicultural practices, which favor even-age monospecific stands, short rotation times, and selective removal of dead and dying trees, leave little roosting habitat for most tree-dwelling species." In addition to roost sites, the structural complexity of old-growth forests, the response of bats to clutter (Hayes and Loeb 2007), and the variety of bat foraging areas found within structurally complex old-growth forest; may contribute to the high levels of bat activity noted in old aged forests [Hayes and Gruver (2000) *cited in* Hayes and Loeb (2007)].

Within the Lilley Cornett Woods study area, the little brown bat and the tri-colored bat were the two species most commonly captured and documented through ultrasonic detection. Both are relatively small in body size and would be able to maneuver easily through a cluttered interior forest (Slack2009). These bats are also found to occupy caves or tree cavities in the summer (BCI 2001) and to be associated with stream corridors (Davis and Mumford 1962; Schirmacher et al. 2007). In South Carolina, Loeb and O'Keefe (2006) reported the tri-colored bat was generally found in early successional forests characterized by sparse understory vegetation.

The northern bat was only captured in the old-growth forest portion of Lilley Cornett Woods (specifically along the top of a ridge, near large rock formations) and mainly detected acoustically in the old-growth habitat. This is consistent with the findings of Lacki and Schwierjohann (2001), who found northern bat roosting sites in northeastern Kentucky tended to be situated on mid-to-high elevation slopes and in large diameter trees and snags... prompting the authors to suggest a preference for roosting in older forests. The northern bat is adapted to hunting in a cluttered environment, and tends to forage along cliffs, ridges, and forested hillsides (BCI 2001). Owen et al. (2003) noted that *Myotis septentrionalis* in the Allegheny Mountains appeared to be an interior-forest obligate, greatly influenced by within-stand conditions; similar to what was observed by Loeb and O'Keefe (2006) in the southern Appalachians of South Carolina.

Although the ultrasonic data indicated the big brown bat did utilize the old-growth forest at Lilley Cornett Woods (Table 3), the majority of echolocation passes and all mist net captures occurred in second growth forest (Tables 2 and 3). The ubiquitous nature of the habitat utilized by *Eptesicus fuscus* at Lilley Cornett Woods is probably a reflection of the animal's association with open habitats, or forested habitats with a more sparse midstory structure, that are typically associated with riparian areas (Schirmacher et al. 2007; Ford et al. 2005, 2006); and the generalist nature of the bat's diet. The animal has been reported to forage in many different habitat types, e.g., over

water and open fields, within forest openings and urban and suburban areas (Barbour and Davis 1969).

The hoary bat was never detected ultrasonically at Lilley Cornett Woods; but it was captured at a second growth forest mist net site. The hoary bat may have eluded the ultrasonic bat detector because it has low-frequency echolocation calls, which can make it difficult to detect ultrasonically (O'Farrell and Gannon 1999). The hoary bat is a large, solitary, forest dwelling bat, often roosting behind the foliage of trees (Barbour and Davis 1969). Being the largest bat in the United States, it has trouble maneuvering through the forest, so it prefers to forage in more open areas, along woodland edges and above the tree canopy (Brack et al. 2010).

Indiana bat and gray bats at Lilley Cornett Woods tended to occur in second growth forest. *Myotis sodalis* was mainly associated with the riparian corridor adjacent to Line Fork Creek; a situation that has been noted by other researchers (Ford et al. 2005; Carter 2006). Indiana bats are opportunistic foragers, and will forage in upland and floodplain forests (Brack 1983; LaVal and LaVal 1980; Gardner et al. 1991; Kiser and Elliott 1996). Humphrey et al. (1977) suggested that Indiana bats only forage in riparian areas that have some vertical structure. Brack (1983) reported that forest stand structural components significantly influence Indiana bat captures, with the probability of capturing an Indiana bat increasing if the habitat is riparian with a low density understory. The optimal foraging habitat of gray bats is riparian areas (i.e., habitat found along Lilley Cornett Wood's Line Fork Creek); where the bats often fly over bodies of

water and in the protection of forest canopy (Tuttle 1976). Gray bats were detected, almost exclusively, along Line Fork Creek.

Eastern red bats tend to be solitary animals, roosting mostly in trees (Shump and Shump 1982). Within Lilley Cornett Woods, the red bat was ultrasonically detected most often in the old-growth forest. However, research has indicated the eastern red bat exhibits a great deal of diversity when it comes to the habitat it is associated with; foraging in uncluttered and cluttered environments (Carter et al. 2004), uplands (Ford et al. 2005), and riparian areas (Owen et al. 2004).

Echolocation calls for the eastern small-footed bat (*Myotis leibii*) at Lilley Cornett Woods indicated the species used the second growth forest habitat more than the old-growth forest (Table 3). This observation is similar to what has been reported for a radio-tagged *Myotis leibii* in western Maryland, i.e., compared to random locations, the bat foraged farther from railroads, a river, and wetlands; but closer to paved roads, pastures, coniferous forest, and mixed forest (Johnson et al. 2009). The apparent selection for second growth forest by eastern small-footed bats at Lilley Cornett Woods may be more of a reflection of the availability of rocky habitat than the forest type. Johnson et al. (2011) noted the importance of rock habitat with high solar exposure near protective cover and water in day-roost selection by eastern small-footed bats in the Appalachian Ridge and Valley region of West Virginia.

The southeastern bat (*Myotis austroriparius*) was detected acoustically most often in conjunction with the Line Fork Creek drainage. The southeastern bat is usually

associated with ecological communities near water (Jones and Manning 1989). *Myotis austroriparius* has been observed to emerge from roosting places late in the evening and fly to nearby ponds and streams to forage; flying very close to the surface of the water while feeding (Barbour and Davis 1969; Lowery 1974).

The evening bat (*Nycticeius humeralis*) was ultrasonically detected in both of the forested habitats (i.e., old-growth and second growth) surveyed at Lilley Cornett Woods (Table 3). The presence of *Nycticeius humeralis* may have been a reflection of the availability of roost sites and foraging habitat. Evening bats tend to roost in trees typically located in association with riparian habitat (species of maples, oaks, and hickories; Timpone et al. 2006), and forage along waterways, edges of woods, and agricultural fields (Duchamp et al. 2004).

The second season of field work, which incorporated the Anabat system, was crucial to this study. The acoustic monitoring added six more species to the inventory of bats in Lilley Cornett Woods. It has been reported (Murray et al. 1999; O'Farrell and Gannon 1999; Kalko and Handley 2001; Sampaio et al. 2003; Flaquer et al. 2007; Robbins et al. 2008; Slack 2009) the best results for documenting bat presence/absence and estimating Chiropteran biodiversity are obtained when incorporating both mist nets and ultrasonic detectors in a sampling protocol. One of the recognized drawbacks with the Anabat ultrasonic system in terms of accurate identification of bat echolocation calls is the similarity, in terms of call structure and call properties, between some of the *Myotis* species (Cohn 2007). Because of this difficulty, state guidelines developed for

surveying for the endangered Indiana bat (USFWS and KDFWR 2011) dictate that if the analysis of collected ultrasonic calls results in the identification of calls of endangered species, then additional mist netting should be conducted as close to the acoustical sampling site as possible. I did not have the opportunity to conduct mist net surveys during the Anabat survey portion of this study. I strongly recommend a more intensive mist net survey be conducted at Lilley Cornett Woods, focusing efforts at my Anabat unit locations and in conjunction with Line Fork Creek, to confirm the presence of the endangered Indiana and gray bat, and those species for which Lilley Cornett Woods would represent a Kentucky range extension, e.g., evening bat, southeastern bat.

In their review of the influences of forest management on bats in North America, Hayes and Loeb (2007) summarized that it is highly unlikely bats respond directly to the age of a forested stand. They postulated it is more likely bats are responding to the structural characteristics and habitat factors present within a forested stand and, on a more macro-scale, the land management practices employed in the surrounding region. Although a portion of the Lilley Cornett Woods study area was old-growth forest and may be structurally different from the surrounding second growth timber, I do not believe the old-growth segment covered enough of the area to influence the large-scale use of the region by bats. However, at the fine scale level, e.g., roost site selection, the old-growth segment at Lilley Cornett Woods may be of great value to the tree roosting bats found in the region...a possibility that needs further investigation.

The presence at Lilley Cornett Woods of a number of bat species whose foraging activity has been documented to be associated with riparian areas prompts me to echo the conclusion of Schirmacher et al. (2007) that; "...protection and maintenance of riparian health and integrity will concomitantly provide protection of bat foraging habitat." To maintain the diverse bat assemblage associated with Lilley Cornett Woods Appalachian Ecological Research Station, it is recommended the forested habitat within the facility be maintained, especially the old-growth segment; and every effort be made to preserve the riparian vegetation associated with Line Fork Creek.

Literature Cited

- Anthony, E.L.P. 1988. Age determination in bats. Pages 47-58 *in* T.H. Kunz (ed.).
Ecological and Behavioral Methods for the Study of Bats. Smithsonian Institution
Press, Washington, D.C.
- Barbour, R.W., and W.H. Davis. 1969. Bats of America. The University Press of Kentucky,
Lexington, Kentucky. 286pp.
- Barbour, R.W., and W.H. Davis. 1974. Mammals of Kentucky. The University of Press of
Kentucky, Lexington, Kentucky. 322pp.
- Barels, G. J. 1985. A study of the small mammal populations of Lilley Cornett Woods,
Letcher County, Kentucky. M.S.Thesis, Eastern Kentucky University, Richmond,
Kentucky.
- BCI (Bat Conservation International, Inc). 2001. Bats in Eastern Woodlands. Bat
Conservation International, Inc., Austin, Texas.
- Blehert D. S., A. C. Hicks, M. Behr, C. U. Meteyer, B. M. Berlowski-Zier, E. L. Buckles, J. T.
H. Coleman, S. R. Darling, A. Gargas, R. Niver, J. C. Okoniewski, R. J. Rudd, W. B.
Stone. 2009. Bat white-nose syndrome: an emerging fungal pathogen? *Science*
323:227.
- Brack, V. 1983. The non-hibernating ecology of bats in Indiana, with emphasis on the
endangered Indiana bat, *Myotis sodalis*. Ph.D. Dissertation, Purdue University,
West Lafayette, Indiana.
- Brack Jr., V., D. W. Sparks, J. O. Whitaker Jr., B. L. Walters, A. Boyer. 2010. Bats of Ohio.
Indiana State University Center for North American Bat Research and
Conservation. 92 pp.
- Britzke, E. R., B.A. Slack, M.P. Armstrong and S.C. Loeb. 2010. Effects of orientation and
weatherproofing on the detection of bat echolocation calls. *Journal of Fish and
Wildlife Management* 1: 136-141.
- Carter, T.C., B.R. Chapman, and K.V. Miller. 2004. Partitioning of food resources by
syntopic eastern red (*Lasiurus borealis*), Seminole (*L. seminolus*) and evening
(*Nycticeius humeralis*) bats. *American Midland Naturalist* 151:186-191.

- Carter, T.C. 2006. Indiana bats in the midwest: The importance of hydric habitats. *Journal of Wildlife Management* 70:1185-1190.
- Cohn, J. P. 2007. Building a better bat detector. *BioScience* 57:640.
- Davis, W.H., and R.E. Mumford. 1962. Ecological notes on the bat *Pipistrellus subflavus*. *American Midland Naturalist* 68:394-398.
- DNA (Division of Natural Areas). 1998. Lilley Cornett Woods Final Resource Management Plan. Division of Natural Areas, Eastern Kentucky University, Richmond, Kentucky.
- Duchamp, J.E., D.W. Sparks, and J.O. Whitaker, Jr. 2004. Foraging-habitat selection by bats at an urban-rural interface: comparison between a successful and a less successful species. *Canadian Journal of Zoology* 82:1157-1164.
- Flaquer, C., I. Torre, and A. Arrizabalga. 2007. Comparison of sampling methods for inventory of bat communities. *Journal of Mammalogy* 88:526-533.
- Ford, W.M., M.A. Menzel, J.L. Rodrigue, J.M. Menzel, and J.B. Johnson. 2005. Relating bat species presence to simple habitat measures in a central Appalachian forest. *Biological Conservation* 126:528-539.
- Ford, W. M., J.M. Menzel, M.A. Menzel, J.W. Edwards, and J.C. Kilgo. 2006. Presence and absence of bats across habitat scales in the upper Coastal Plain of South Carolina. *Journal of Wildlife Management* 70:1200-1209.
- Frick, W. F., J.F. Pollock, A.C. Hicks, K.E. Langwig, D.S. Reynolds, G.G. Turner, C.M. Butchowski, T.H. Kunz. 2010. An emerging disease causes regional population collapse of a common North American bat species. *Science* 329:679-682.
- Gardner, J. E., J. D. Garner, and J. E. Hofmann. 1991. Summer roost selection and roosting behavior of *Myotis sodalis* (Indiana bat) in Illinois. Unpublished report. Illinois Natural History Survey, Champaign, Illinois.
- Gellman, S. T., and W.J. Zielinski. 1996. Use by bats of old-growth redwood hollows on the north coast of California. *Journal of Mammalogy* 77: 255-265.
- Hayes, J.P., and J.C. Gruver. 2000. Vertical stratification of bat activity in an old-growth forest in western Washington. *Northwest Science* 74:102-108.

- Hayes, J.P., and S.C. Loeb. 2007. The influences of forest management on bats in North America. Pages 297-235 in M.J. Lacki, J.P. Hayes, and A. Kurta (eds.). *Bats in Forests- Conservation and Management*, The Johns Hopkins University Press, Baltimore, Maryland.
- Humes, M. L., J.P. Hayes, and M.W. Collopy. 1999. Bat activity in thinned, unthinned, and old-growth forests in western Oregon. *Journal of Wildlife Management* 63:553-561.
- Humphrey, S.R., A.R. Richter, and J.B. Cope. 1977. Summer habitat and ecology of the endangered Indiana bat, *Myotis sodalis*. *Journal of Mammalogy* 58:334-346.
- Hutchinson, J. T., and M.J. Lacki. 2000. Selection of day roosts by red bats in mixed mesophytic forests. *Journal of Wildlife Management* 64:87-94.
- Johnson, J.B., J.E. Gates, and W.M. Ford. 2009. Notes on foraging activity of female *Myotis leibii* in Maryland. U. S. Dept. of Agriculture, Forest Service, Northern Research Station Research Paper NRS-8.
- Johnson, J.S., J.D. Kiser, K.S. Watrous, and T.S. Peterson. 2011. Day-roosts of *Myotis leibii* in the Appalachian Ridge and Valley of West Virginia. *Northeastern Naturalist* 18:95-106.
- Jones, C., and R. W. Manning. 1989. *Myotis austroriparius*. *Mammalian Species* 332:1-3.
- Jones, R. L. 2005. *Plant life of Kentucky: An illustrated guide to the vascular flora*. University Press of Kentucky, Lexington, Kentucky.
- Kalko, E. V., and C.O. Handley. 2001. Neotropical bats in the canopy: Diversity, community structure, and implications for conservation. *Plant Ecology* 153:319-333.
- KBWG (Kentucky Bat Working Group). 2001. The bats of Kentucky . Retrieved February 2, 2009, from <http://www.biology.eku.edu/bats.htm>.
- Kiser, J. D. and C. L. Elliot. 1996. Foraging habitat, food habits, and roost tree characteristics of the Indiana bat, *Myotis sodalis*, during autumn in Jackson County, Kentucky. Final Report, Kentucky Department of Fish and Wildlife Resources, Frankfort. 65 pp.
- Kuenzi, A. J., and M.L. Morrison. 1998. Detection of bats by mist-nets and ultrasonic detectors. *Wildlife Society Bulletin* 26:307-311.

- Kunz, T. H., C.R. Tidemann, and G.C. Richards. 1996. Small volant mammals. Pages 122-143 in D. E. Wilson, F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster (eds.). Measuring and monitoring biological diversity. Smithsonian Institution Press, Washington, D.C.
- Lacki, M. J., and J.H. Schwierjohann. 2001. Day-roost characteristics of Northern bats in mixed mesophytic forest. *Journal of Wildlife Management* 65:482-488.
- LaVal, R. K. and M. L. LaVal. 1980. Ecological studies and management of Missouri bats, with emphasis on cave dwelling species. Terrestrial Series 8. Missouri Department of Conservation, Jefferson City, Missouri. 52pp.
- Loeb, S. C., and J.M. O'Keefe. 2006. Habitat use by forest bats in South Carolina in relation to local, stand, and landscape characteristics. *Journal of Wildlife Management* 70: 1210-1218.
- Lowery, G.H., Jr. 1974. The Mammals of Louisiana and its Adjacent Waters. Louisiana State University Press, Baton Rouge. 565pp.
- MacCarthy, K. A., T.C. Carter, B.J. Steffen, and G.A. Feldhamer. 2006. Efficacy of the mist-net protocol for Indiana Bats: A video analysis. *Northeastern Naturalist* 13:25-28.
- MacGregor, J., J.D. Kiser, M.W. Gumbert, and T.O. Reed. 1999. Autumn roosting habitat of male Indiana bats (*Myotis sodalis*) in a managed forest setting in Kentucky. Pages 169-170 in J. W. Stringer and D.L. Loftis (eds.). Proceedings 12th Central Hardwood Forest Conference, U.S. Forest Service, General Technical Report SRS-24.
- Mazurek, M. J. 2001. A comparison of bat activity among thinned and unthinned second growth and old-growth redwood stands in northwestern California. M.S. Thesis, Humboldt State University, Humboldt, California.
- McEwan, R. W., and R.N. Muller. 2006. Spatial and temporal dynamics in canopy dominance of an old-growth Central Appalachian Forest. *Canadian Journal of Forest Research* 36:1536-1550.
- McEwan, R. W., R.D. Paratley, R. N Muller, and C.L. Riccardi. 2005. The vascular flora of an old-growth mixed mesophytic forest in southeastern Kentucky. *Journal of the Torrey Botanical Society* 132:618-627.

- Moosman Jr., P. R. 2001. Bat communities of fragmented and intact woodlands in central Kentucky. M.S. Thesis, Eastern Kentucky University, Richmond, Kentucky.
- Muller, R. N. 1982. Vegetation patterns in the mixed mesophytic forest of eastern Kentucky. *Ecology* 63:1901-1917.
- Murray, K. L., E.R. Britzke, B.M. Hadley, and L.W. Robbins. 1999. Surveying bat communities: A comparison between mist nets and the Anabat II bat detector system. *Acta Chiropterologica* 1:105-112.
- NOAA (National Oceanic and Atmospheric Administration). 2008. NOAA tree ring data: Lilley Cornett Woods. Retrieved March 18, 2011, from <http://www.ncdc.noaa.gov/paleo/metadata/noaa-tree-2991.html>
- O'Farrell, M. J., and W.L. Gannon. 1999. A comparison of acoustic versus capture techniques for the inventory of bats. *Journal of Mammalogy* 80: 24-30.
- Owen, S.F., M.A. Menzel, W.M. Ford, B.R. Chapman, K.V. Miller, J.W. Edwards, and P.B. Wood. 2003. Home-range size and habitat used by the northern myotis (*Myotis septentrionalis*). *American Midland Naturalist* 150:352-359.
- Owen, S.F., M.A. Menzel, W.M. Ford, J.W. Edwards, J.M. Menzel, B.R. Chapman, P.B. Wood, and K.V. Miller. 2004. Bat activity in harvested and intact forest stands in the Allegheny Mountains. *Northern Journal of Applied Forestry* 21:154-159.
- Pierson, E. 1998. Tall trees, deep holes, and scarred landscapes: Conservation biology of North American bats. Pages 309-325 in T.H. Kunz and P.A. Racey (eds.). *Bat Biology and Conservation*, Smithsonian Institution Press, Washington, DC.
- Pisarowicz, J. 2006. What do you know about bats? Retrieved February 2, 2009, from <http://www.nps.gov/archive/wica/bats.htm>.
- Robbins, L. W., K.L. Murray, and P.M. McKenzie. 2008. Evaluating the effectiveness of the standard mist-netting protocol for the endangered Indiana Bat (*Myotis sodalis*). *Northeastern Naturalist* 15:275-282.
- Sampaio, E. M., E.V. Kalko, E. Bernard, B. Rodriguez-Herrera, and C.O. Handley. 2003. A biodiversity assesment of bats (Chiroptera) in a tropical lowland rainforest of Central Amazonia, including methodological and conservation considerations. *Studies on Neotropical Fauna and Environmental* 38:17-31.

- Schirmacher, M.R., S.B. Castleberry, W.M. Ford, and K.V. Miller. 2007. Habitat associations of bats in south-central West Virginia. Proceedings Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 61:46-52.
- Shump, K.A., Jr., and A.U. Shump. 1982. *Lasiurus borealis*. Mammalian Species 183:1-6.
- Slack, B. A. 2009. Determining the presence of bat species within interior deciduous forested areas using ANABAT II and mistnetting. M.S. Thesis, Eastern Kentucky University, Richmond, Kentucky.
- Taylor, D. A. 2006. Forest management and bats. Retrieved March 20, 2011, from <http://www.batcon.org> .
- Timpone, J.C., J.G. Boyles, and L.W. Robbins. 2006. Potential for niche overlap in roosting sites between *Nycticeius humeralis* (Evening Bat) and *Eptesicus fuscus* (Big Brown Bat). Northeastern Naturalist 13:597-602.
- Tuttle, M.D. 1976. Population ecology of the gray bat (*Myotis grisescens*): factors influencing growth and survival of newly volant young. Ecology 57:587-595.
- USFWS (U.S. Fish and Wildlife Service). 2007. Indiana bat survey guidance for the Commonwealth of Kentucky. U.S. Fish and Wildlife Service, Frankfort, Kentucky.
- USFWS (U.S. Fish and Wildlife Service). 2009. Disinfection protocol for bat field research/monitoring. U.S. Fish and Wildlife Service, Hadley, MA .
- USFWS (U.S. Fish and Wildlife Service). 2010. White-Nose Syndrome. Retrieved October 27, 2010, from <http://www.fws.gov/whitenosesyndrome/>.
- USFWS and KDFWR (U.S. Fish and Wildlife Service and Kentucky Department of Fish and Wildlife Resources). 2011. Indiana Bat Survey Guidance for Kentucky. U.S. Fish and Wildlife Service-Kentucky Field Office and Kentucky Department of Fish and Wildlife Resources, Frankfort. 35pp.
- Weller, T. J., and D.C. Lee. 2007. Mist net effort required to inventory a forest bat species assemblage. Journal of Wildlife Management 71:251-257.
- Weller, T. J., and C.J. Zabel. 2002. Variation in bat detections due to detector orientation in a forest. Wildlife Society Bulletin 30:922-930.