**Habitat Selection and Use by *Nycticeius humeralis* in**

**North-Central Arkansas**

**Megan L. Buckley**

M.S. Thesis Proposal

Department of Biological Sciences

Arkansas State University

Introduction

Bats (order: Chiroptera) are an extremely important taxon facing numerous obstacles in their fight for survival. Worldwide, bats have great value as biological indicators, because they show functional and taxonomic diversity and are widely distributed (Jones et al., 2009). Some of the important functions that bats perform include pollination, seed dispersal, and insect control. In North America, the primary role that bats play is pest insect management. It is estimated that insectivorous bats save the agriculture industry as much as $53 billion dollars annually and this estimate only includes the reduced costs of pesticides as bats perform this ecological service (Boyles et al. 2011). Maintaining these ecosystem services requires a full understanding of bat ecology, including risks to their survival.

Bats are sensitive to human-influenced changes in habitat quality and the changes in climate (Fenton 1997). Habitat loss, collisions with wind turbines, and disease have caused a drastic reduction in numbers of individuals present worldwide (Larsen and Madsen 2000; Turner et al. 2011; Thogmartin et al. 2012b; U.S. Fish and Wildlife Service 2012). Although the spread of White Nose Syndrome (WNS), a fungal disease responsible for the death of millions of bats, has caused cave bats to decline at a devastating rate, habitat loss in the form of timber harvest and conversion to agriculture that has become the focus for land managers in both the public and private sectors. Disease and habitat loss, in addition to their slow reproductive rates and relatively long life span in relation to body size, (Wilkinson and South 2002) result in slow recovery of devastated bat populations.

*Nycticeius humeralis* (NYHU), does not seem to be susceptible to WNS due to several factors such as a roosting ecology that does not involve caves (Menzel, M. A., T. C. Carter, W. M. Ford, and B. R. Chapman. 2001a.). A full understanding of the destruction facing bat populations makes it clear why conserving species, which may not face these risks, is so essential.

While WNS is decimating bat populations across North America, bats that use caves for roosts and hibernacula such as tricolored bats (*Perimyotis subflavus*), Indiana bats (*Myotis sodalis*), little brown bats (*Myotis lucifugus*) and Northern long-eared bats (*Myotis septentrionalis*), appear to be the bats most affected by the disease to date (Blehert 2009). Tree-obligate bats remain largely unaffected and therefore are important species to understand and protect as overall bat numbers continue to decline. Interestingly, NYHU in particular have not shown effects of WNS. Pannkuk et al. (2013) found that evening bats have higher free fatty acid and lower sterol ratios in sebum compared to all the other species tested, which may have disease resistance implications. In addition to higher free fatty acid and lower sterol ratios in the sebum, evening bats also show higher cholesterol. The high percentage of cholesterol in evening bats may be due to low percentages of lanosterol detected, considering lanosterol is a common intermediate in the biochemical conversion of squalene to cholesterol (Moran et al. 2012). This difference in lipid content could also explain the peculiar odor that researchers describe NYHU emitting, especially the males. However, NYHU roost in underground cavities (Boyles 2005) and may also roost in leaf litter on the forest floor (Moorman 1999). Thus the question remains: are NYHU susceptible to WNS while roosting or does their unique lipid profile a natural immunity?

The evening bat is a medium-sized vespertilionid with a geographic range that historically extended from the Gulf of Mexico north to the southern Great Lakes (Watkins 1972; Kurta et al. 2005). This species is easily identifiable by its dark coloration of both skin and fur. They resemble a smaller version of the Big Brown Bat (*Eptesicus fuscus*), distinguishable by its two upper incisors as opposed to *E. fuscus*, which has four. Individuals of the northern areas of the range typically migrate south for the winter. This bat begins foraging for insects shortly before or after sunset and has a slow, steady flight (Sealander and Heidt 1990). Evening bats prefer to hunt over water, but will hunt above the tree line until it becomes completely dark (Grindal et al. 1998). Evening bats tend to be temporally bimodal in their hunting patterns with a spike of activity immediately after leaving the roost, then little to no activity throughout the night, with another peak of activity approximately 9-10 hours after sunset. Their diet consists of beetles (Order Coleoptera), moths (Order Lepidoptera), and leafhoppers (Order Hemiptera)(Whitaker and Clem 1992). Although males remain solitary, females tend to form maternity colonies and communal nursing has been documented in this species (Watkins and Shump 1981, Istvanko et al. 2016). Because female evening bats are never found alone and apparently take advantage of the experience of colony members to locate suitable habitat, sharing milk with non-descendant female young may result in delayed benefits to a lactating female. Young are born in late May or early June and are volant within 30 days (Wilkinson 1992.

Evening bats are strict forest dwellers, commonly roosting beneath exfoliating bark on snags within mature hardwood stands (Itstvanko et al. 2016). Although they occasionally roost in abandoned human structures located in rural areas, evening bats always roost near water. Several factors can influence the evening bats’ choice of roost. The first factor in roost selection is season. Research has shown that Evening bats did not select the same winter roost trees as they did during the summer (Wilkinson 1992). During the spring and summer seasons, females roost communally in maternity colonies for the birthing and raising of young. The maternity roost must have the ability to provide several options for thermoregulation such as temperature gradients across the roost, be able to hold humidity, and provide adequate protection from predators. As NYHU and other tree roosting species appear to be unaffected by WNS their conservation and protection should receive focus and study as overall bat populations continue to decline. Thus a focus on the traditional threat of habitat loss is crucial.

White Nose Syndrome (WNS) is a fungal pathogen of European origin that is devastating bat populations in North America. A recently discovered psychrophilic (cold-loving) fungus, *Pseudogymnoascus destructans*, has consistently been isolated from bats that meet the pathologic criteria for WNS, including colonization of skin by fungal hyphae causing characteristic epidermal erosions and ulcers that can progress to invasion of underlying connective tissue (Wibbelt G. et al. 2010). WNS has been characterized as a condition of hibernating bats and was named for the striking white fungal growth on muzzles, ears, and/or wing membranes of affected bats (Blehert et al. 2008). In 2008, Blehert et al.performed necropsies on affected individuals and found that over half of the individuals affected had little to no fat reserves necessary to carry them through winter hibernation. A more in-depth look by Turner in (2011) shows that either starvation and/or loss of electrolytic homeostasis could potentially explain these losses. WNS is spread by contact, either through bat-to-bat contact or through contact with the fungal spores on roost surfaces. Current morbidity estimates approach 7 million, impacting more than 200 hibernacula within 27 states and five Canadian provinces (FightWNS 2016).

Some bat species in North America that roost solely in trees and/or leaf litter face a different threat that is posed by the expanding wind energy industry. It is estimated that 888,000 bats/year are killed at wind energy facilities in the United States (Smallwood 2011). These two recently emerged threats highlight the need to conserve all species.

Habitat

A habitat is defined as any space that offers resources and surroundings that promote residence by a species. Habitats can be viewed as species-specific or scale-dependent. Scale-dependent is defined as while the whole (macro) habitat such as a forest appears to be suitable, only a small part (microhabitat) such as a stand of trees may be useful (Kotliar & and Wiens, 1990; Danell, Edenius & Lundberg, 1991; Bergin, 1992; Schmidt, 1993; Ward and Saltz, 1994). The study of habitats allows researchers and wildlife managers to gather information about what species are using an area and how studying animals’ habitats is important factors of habitat change including human impact on an environment. The knowledge gained from studies that focus on habitat influence conservation and management techniques.

Habitat Selection

Habitat selection is the behavior, both learned and inborn, by which an animal chooses which habitat and resources to use. Factors that influence habitat selection include the availability of food, shelter, mates, and nest sites for raising young. Another method animals use to select their habitats is experience or natal circumstances (Stamps and Swaisgood 2006). For example, when young inherit a habitat from its parents.

Habitat Use

Habitat use is simply defined as how a living organism uses the resources and conditions of their habitat they have selected. In general, habitat use is measured as a comparative amount of time spent in separate zones within a habitat.

For researchers, defining available habitat is typically an arbitrary decision which has a major effect on data analysis. Studies either assume all habitats encompassed by a predetermined study are available to all individuals (designs I and II; of Thomas and Taylor 1990), or a different area of available habitat, such as a home range, may be defined for each individual (design III). Either way, available habitat is defined once and applied to all observations of habitats used by the study species.

Effects of Forest Management on Habitats

Forest management impact bats and their habitats by changing forest composition which is responsible for several factors that influence bat populations. Forest management techniques include tree harvest (clear cutting through single tree selection) and burning. Cutting and burning can have effects on bats directly, for example by removing living roost trees and snags, or indirectly, for example by altering stand age which influences characteristics of potential roost trees (ie cavity availability). Open habitat such as meadows and stands less than ten years old are also frequently used as activity areas. These areas are most likely prefered as foraging and commuting areas due to reduced clutter and increased prey abundance (Lacki et al. 2007).

One of the direct impacts include roost availability. Forest bats prefer to use older, and therefore larger, diameter trees and snags as roost sites. Under intensive management the live trees are the desired commodity while the dead snags are removed for safety and fuel management purposes, thereby tree harvesting may reduce the number of roosts available. Forest management can also change the conditions in which the roost occurs. The most important aspect of this would be the change of the microclimate of available roosts influenced by selectively reducing large trees. Sedegely in 2001found that temperatures and humidity in used roosts were consistently higher than in potential, but unused sites.

Another important effect of forest management is how management plans affect clutter that may impair access to forage and travel areas for bats. As bat species in North America tend to avoid using highly cluttered habitat, forest management that reduces clutter can directly improve habitat suitability for bats. Some of the alterations of habitats by prescribed fire are similar to those of thinning, and thus, in terms of clutter, this may be most important in young and mid-aged forests may have effects on vegetative structure similar to thinning (Peterson and Reich 2001). However, prey availability and other factors are influenced by clutter as well. Bats frequently use edge habitat for commuting and foraging, presumably as a consequence of low tolerance to clutter due to morphological characteristics in combination with prey availability (Furlonger et al. 1987; Clark et al. 1993; Walsh and Harris 1996; Wethington 1996;Grindal and Brigham 1999;Zimmerman and Glanz 2000).

Prey population and therefore availability are influenced by management practices such as prescribed fire, wildfires, fire suppression and fire management. Some studies have examined influences of forest structure and forest management on insect populations (Burford et al. 1999; Humphrey et al. 1999; Lewis and Whitefield et al. 1999), but the high diversity of insect taxa, the variation in response to forest structure, and regional variability have precluded determination of general patterns that are useful for predicting bat response (Lacki et al 2007).

Managing bat populations involves more than altering forest structure. The availability and quality of aquatic habitat is crucial to bat populations. Bats have relatively high rates of evaporative water loss and consequently require intake of water to maintain their water balance (Kurta et al. 1989, 1990; McLean and Speakman 1999,and Webb 1995). Also, various studies have shown that riparian zones have high levels of foraging and commuting activity, which is most likely due to high insect density.

Statement of the Problem

Although bat populations are in decline, evening bats are less affected by WNS and wind energy. Therefore, promotion of habitats for NYHU will be of the utmost importance to maintain bats in eastern forests of North America. Previous research efforts (Itsvanko et al 2016) have produced data on the home range of *Nycticeius humeralis* in north-central Arkansas. However, **habitat selection in relation to habitat availability was not addressed by this study,** even though data are readily available to do so. Thus, my study will extend the data of Itsvanko on home range of the Evening bat to e**xamine past habitat management and habitat variables such as elevation and slope and aspect in regards to roost sites and foraging locations.**

Objectives

I aim to evaluate roost characteristics based on previous home range and roost data to gain a better understanding of habitat selection and use by the evening bat. Specifically, I aim to evaluate habitat selection and use based on sex and reproductive status, evaluating habitat selection and I will address these aims by considering: 1) forest management techniques such as burning and harvesting; and 2) habitat types with emphasis on stand species and age.

My research will answer the following questions:

1. What habitat types are evening bats selecting in relation to habitat availability of NYHU in north-central Arkansas?
2. Does sex and reproductive status influence habitat selection and use?
3. What forest management techniques could influence habitat selection and use?

**Hypothesis One:** Roost trees and foraging locations are located primarily in pine and oak dominated tree stands

**Prediction A:** Roost trees and foraging locations will be located in pine and oak trees stands because they are typically large diameter trees with cavities, giving several options for tree roosting bats as well as providing foraging habitat.

In 2006 Boyles and Robbins found evening bats roosting primarily in tree cavities, which typically were located in mature pine, mixed pine-hardwood, and hardwood stands. Mature forest stands provide numerous tall, large-diameter trees in later stages of decay suitable for cavity-roosting bats (Cryan et al. 2001).

**Hypotheses Two:** Roost trees and foraging locations are located in older tree stands

Historically, abundant large trees and lightning-strike-created snags in longleaf forests likely provided habitat for cavity- and bark-roosting bats (Miles et al 2006).

**Prediction A:** Roost trees will be primarily located in the older oak and pine stands which contain large trees and snags. Test: a t-test to compare the stand roost trees are located in to stands selected at random using a paired t-test design.

The older stand structure of the natural site (i.e., most stands 70-90 yr old) provided numerous snags and large, live trees, suitable as roost sites, throughout the landscape (Miles et al. 2006; Hein et al. 2009). These data show that the roost trees and foraging areas are located in both pine and oak dominated stands (Itsvanko et al. 2016).

**Hypothesis Three:** Foraging sites and roost trees are located closer to the forest edge and roadsthan a random location

Evening bats use Spanish moss (Tillandsiausneoides; Jennings 1958), exfoliating bark of snags (Jennings 1958, Chapman and Chapman 1990, Menzel et al.1999, 2001), tree cavities (Menzel et al. 1999, 2001), and buildings (Chapman and Chapman 1990, Wilkinson 1992) as diurnal roosts.

**Prediction A:** Foraging sites and roost trees are located at forest edges and roads due to ease of traveling due to flight corridors and ease of navigation.

Foraging activity was greatest in edge habitat where flight and orientation are likely easier due to reduced spatial clutter (Kalko & Schnitzler 1993; Brigham et al. 1997). Moreover, an edge habitat may provide bats with a flight corridor or navigational reference (Limpens & Kapteyn, 1991).

Evening bats select roosts with specific characteristics; and specifically will tend to be found in trees with exfoliating bark, cavities, or as an alternative, even buildings.

**Hypothesis Four:** Forest management will influence habitat selection and use.

Forest management techniques vary greatly and are commonly responsible for influencing the behavior of the forests’ residents.

**Prediction A:** Burned and thinned stands should influence feeding behavior as most North American bats prefer to forage in open areas due to their size.

NYHU also devour their prey on the wing, a behavior commonly known as hawking. Due to this strategy they tend to forage under the canopy in open space rather than in cluttered areas (Menzel et al. 2005).

**Prediction B:** Forest management will impact roost availability.

Although research has demonstrated the general conservation value of managed pine stands in the Southeast for a variety of species, including use by bats (e.g., Wigley et al., in press), intensive management of these forests should increase open areas under the canopy to create foraging habitat but may limit development of large trees and snags across the landscape and could limit roost opportunities for cavity- and bark-roosting bats (Miles et al 2006).

**Prediction C:** Forest management will influence travel corridors.

Bats frequently use edge habitat for commuting and foraging, presumably as a consequence of low tolerance to clutter in combination with prey availability (Furlonger 1987; Clark et al. 1993; Walsh and Harris 1996; Wethington et al. 1996; Grindal and Brigham 1999; Zimmerman and Glanz 2000; Hogberg et al. 2002).

**Prediction D:** Aquatic habitat availability will be influenced by forest management.

Commuting and foraging activity is typically higher in riparian areas than in upland sites (Kurta et al. 1989, 1990; Webb 1995; McLean and Speakman 1999) and some species spend significant proportions of their nightly activity foraging and commuting in riparian areas (LaVal et al. 1977; Barclay 1991; Brigham et al. 1992; Waldien and Hayes 2001; and Fellers and Pierson 2002).

**Hypothesis Five:** Female home ranges will be of high quality and present less variability

The sum of an individual’s spatial movements is dependent upon resource distribution (Carter 1998) and reproductive status (Wilkinson 1992; Clem 1993). Sex will influence habitat selection and use as males and females have different dietary needs as well as different roost criteria. Also, females tend to exhibit smaller home ranges due to pup care and feeding where males are solitary and use multiple roost sites (Itsvanko 2016). Thus, males exhibit larger home ranges.

**Prediction A:** The quality of home ranges can be defined by size. Where, smaller home ranges are of higher quality than larger ones.

Increases in food abundance or decreases in variation in food availability may directly affect the size of home ranges by allowing individuals to obtain sufficient energy to meet life requisites over smaller areas (McGloughlin et al. 2000).

Study Area

The study area is located at the USDA Forest Service’s Sylamore Ranger District, Ozark

National Forest, approximately 10 km northwest of Mountain View, Arkansas (35.8683° N,

92.1175° W).



The Sylamore Ranger District encompasses approximately 53,000 hectares within the counties of Stone, Searcy, Marion, Baxter, and Izard in the Ozark Highlands Ecoregion of north-central Arkansas. The low- elevation district, at around average of 98 meters, is composed of hardwood and pine forests, and characterized by steep mountainous slopes consisting of limestone and sandstone ridges. The high- elevation district can extend upwards to 381 meters in elevation. The main drainages of the district are North Sylamore Creek, South Sylamore Creek, and the White River. The warmest month is July, and average temperature of this area is approximately 27°C. The average summer rainfall is 10 cm. Wildlife management practices on Sylamore are a cooperative effort between the Arkansas Game and Fish Commission and U.S. Forest Service. These practices are intended to enhance habitat by manipulating wildlife openings and timber management. Timber management practices range from small regeneration cuts to seed tree and shelter wood cuts. Some burning is done in the timber to reduce fuel and stimulate new growth. The emphasis of wildlife management practices are primarily focused on the deer and turkey populations, with some large field systems being managed for quail and rabbit (AGFC, 2011).

Methods

Data Origin and Program Information

I will use data collected by from my colleague Daniel Itstvanko’s work from June to early August of in 2013 and again in 2014 which yielded home range data on 28 individuals and a total of 71 roost locations. These data will be integrated these data into ArcGIS in order to examine the habitat availability and use on both a macro habitat and a micro habitat scale by comparing habitat types, management history, locations of water and roads, and home range data. Habitat information has been provided by the U.S. Forest Service. Program R will be used for my statistical analyses and to generate figures.

**Data Analysis**

Analyses will include percent composition of forest types, cover classes, habitat availability versus habitat used, size distribution of available trees and snags vs random, size class in cover classes, treatment history, slope position, distance to roads and forest edges. To compare habitat use with availability, I will be using the order of selection process Johnson described in 1980 as follows: Where first-order selection can be defined as the selection of physical or geographical range of a species. Within that range, second-order selection determines the home range of an individual or social group. Third-order selection pertains to the usage made of various habitat components within the home range. Finally, if third-order selection determines a feeding site, the actual procurement of food items from those available at that site can be termed fourth-order selection (Johnson, 1980). Of these orders my study will focus on orders two and three. This method will be combined with a compositional analysis that compares percentages of available land cover types with percentages of used habitat to determine a rank of habitat use at any of the given scales (Aebishcher, 1993). A paired *t*-test will be used to compare differences in habitat use between sexes, years, and habitat types. I will use t-test will be used to compare Target analysis will include percent composition of forest types, cover classes, habitat availability versus habitat used, size distribution of available trees and snags vs random, size class in cover classes, treatment history, slope position, distance to roads and forest edges. This method will be integrated with a compositional analysis that compares percentages of available land cover types to percentages of used habitat to determine a rank of habitat use at any of the given scales (Aebishcher, 1993). A *t*-test, either paired or two sample, will be used to compare differences in habitat use between sexes, years, and habitat types. These analyses will be performed by Program R (R Core Development Team 2014). ArcGIS will be used to show habitat types, management history, locations of water and roads, and home range data.

Significance of work.

When completed this work will yield unique information on habitat use by foraging evening bats. Moreover, these findings will be examined by sex. Thus I will produce novel and important information on the behavior of this species that can be used by managers to enhance habitat.

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