Bat Habitat Use and Roost Tree Selection for Northern Long-eared Myotis (*Myotis septentrionalis*) in North-Central Ohio

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TABLE OF CONTENTS

Page Number

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Understanding roosting behavior and habitat use of bats is an important component when unraveling life histories and their ecology. Ohio remains under-represented in published information of bats compared to surrounding states. This large scale survey in 2002–2003 and *Myotis septentrionalis* radio telemetry study in 2005 is one of the few conducted within the state and is the first in Ohio's North-Central region. It is also the first study conducted where net sites were chosen randomly and spatially distributed to adequately survey bat populations within Cuyahoga Valley National Park and Cleveland Metroparks. This survey documented seven species ($n = 668$), with the most abundant species being *Eptesicus fuscus* ($n = 250$) and *Myotis septentrionalis* ($n = 210$), which was unexpected. Whereas habitat preference is known for many bat species, there was an unexpected and significant stratum preference depending on sex for *Eptesicus fuscus, Myotis septentrionalis* and *M. lucifugus,* which has not been previously published. Male *E. fuscus* preferred either Upland Near Stream or Upland habitats, whereas females strongly preferred Floodplain ($p < 0.0001$). *Myotis septentrionalis* demonstrated a significant preference for stratum type between sexes, as females preferred Upland, whereas males preferred Upland Near Stream habitats ($p = 0.01$). Lastly, *M. lucifugus* females preferred Floodplain, whereas males preferred Upland ($p = 0.001$). There was a temporal trend for increased capture rates throughout the summer, as more *Lasiurus borealis* were captured in August ($n = 33$) than May–July combined ($n = 27$). The skewed sex ratio of more males than females in *L. borealis* and the temporal increase in number of captures is an indicator that there is an influx of male *L. borealis* into the population.

A total of eight lactating female *Myotis septentrionalis* were radio tracked to 21 roost trees. *Myotis septentrionalis* primarily roosted in dead trees (snags), as 19 of the 21 trees (90%) were dead, and bats were located most often roosting under exfoliating bark (17 of the 21 roost trees, 81%), which is unusual for this species as they are most often documented roosting in tree hollows. One individual was located behind a large vine of *Toxicodendron radicans* (Poison Ivy) on a dead *Robinia pseudoacacia* (Black Locust), and is the first documentation of *M. septentrionalis* roosting behind a vine. The majority of roosts were located within the genus *Quercus* (Oaks), with 15 of the 21 (71%) of all roost trees from this genus. Other roost tree species included: *Fraxinus americana* (White Ash, n = 1); *Juglans nigra* (Black Walnut, n = 1); *Carya sp.* (Hickory, n =1); *Acer saccharum* (Sugar Maple, n = 2); and *Robinia pseudoacacia* (Black Locust, n = 2).

These results provide valuable information on Ohio bats and indicate that there is still a considerable amount of work that remains to be conducted on bats, habitat use, and preference to ensure understanding of their complete life histories, allowing conservation efforts to be more effective. This study demonstrated that even though a species can have a stratum preference, there is a preference between sexes within some species and when considering conservation efforts both male and female bats need to be treated separately. The conservation of widespread and abundant species, such as *Myotis septentrionalis*, is critical for protection of entire ecosystems.

Background

Understanding roosting behavior and habitat use of bats is an important component when unraveling life histories and their ecology. Roosts provide locations to rest, sleep, digest meals, hide from predators and weather, and provide suitable microclimates to either conserve energy (allowing the bats to enter a state of torpor) or maintain a high metabolic rate when nursing and raising young. Bat roosts can be as variable as the species themselves and, depending on seasonality or reproductive activity, bats select roosts that best fulfill their needs. All species of Ohio bats are relatively small, camouflaged, and secretive in their behaviors, which make them very difficult to study. With advancing technology in radio telemetry, especially reduction of size and weight of transmitters less than 0.5 grams in the past 10 years, it has become possible and effective to radio tag and track bats even small as 4–8 grams, such as *Perimyotis subflavus* (Tricolored Bat) to their roosting sites. This technology has greatly advanced the understanding of roost selection, foraging behavior, home range, and even migration patterns for many forest dwelling bats; however, even with these advancements there still are limitations with the technology.

Short transmitter life, (usually less than 14 days) only provides a glimpse of the total roosting requirements, and it continues to prove difficult to perform long-term studies as recapture and replacement of transmitters is very difficult in bats. There continue to be very few manipulative experiments of roosting behavior of bats due to the difficulty and space requirements in keeping bats in captivity. Studies have been limited to bats roosting in structures, bat houses and bat condominiums (Agosta, 2002;

Butchkosiki and Hassinger, 2002; Kunz and Kurta, 1988). In the last decade there has been a rapid increase in the primary literature on roost selection, including many of the bat species of the Great Lake States; however, very little information is available for bats residing in Ohio (Belwood, 1998).

Thirteen species of bats have been documented in Ohio. Two species, *Myotis grisescens* (Grey Bat) and *Tadarida brasiliensis* (Brazilian or Mexican Free-tailed Bat), are considered accidental. Both are commonly found in the southern eastern United States. Eleven of the thirteen species occur regularly in Ohio, or historically have had populations in Ohio (Belwood, 1998) including: *Myotis lucifugus* (Little Brown Bat); *M. septentrionalis* (Northern Long-eared Bat); *M. sodalis* (Indiana Bat); *M. leibii* (Small–footed Myotis); *Eptesicus fuscus* (Big Brown Bat); *Nycticeius humeralis* (Evening Bat); *Perimyotis subflavus* (Tricolored Bat, recently changed from Eastern Pipistrelle); *Lasiurus borealis* (Red Bat); *L. cinereus* (Hoary Bat); *Lasionycteris noctivagans* (Silver-haired Bat); and *Corynorhinus rafinesquii* (Rafinesque's Big-eared Bat). Nine of these species are encountered regularly on an annual basis. The remaining two species (*M. leibii* and *C. rafinesquii*) have very limited habitat requirements, with few documented Ohio records, and are most likely very rare or currently extirpated from the state. Ohio bats typically can be separated by their roosting behavior into two groups: 1) solitary foliage roosting bats or "tree bats" including, *L. borealis*, *L. cinereus* and *L. noctivagans*; and 2) social roosters, or "cave bats", because of their use of caves for hibernation, these bats frequently form very large maternity colonies of up to several thousand individuals (e.g., *M. lucifugus*).

Sexual separation is common in many solitary roosting bats (Mager and Nelson, 2001; Perry et al., 2007) and social roosting bats (Broders and Forbes, 2004; Perry and Thill, 2007a; Perry and Thill, 2007b), as males and non-reproductive females typically roost singly and pregnant or females with young form aggregate maternity colonies.

Considerable resources have been made available by the United States Fish and Wildlife Service to determine specific habitat needs of the federally-endangered *Myotis sodalis.* Conservation efforts and most research projects have focused on females, which have more specific roost requirements, hence limiting the number of potential roost locations. This is believed to be one critical aspect to protect endangered populations through legislation. The research on these endangered species and has led to much of what is currently known about bat roosting behavior and has become a springboard to understanding the ecology of other more common species. Historically, before human-made structures were available, most Ohio bats were considered tree roosting species, where social bats would have roosted inside large hollow trees, woodpecker holes, or under exfoliating tree bark. However, as the environment has been altered by human activity, bats have adapted to utilize human structures for their roosting needs. The two main benefits of roosting in human-structures are constant warmer roost temperatures, allowing more rapid growth of young, and lowering predation risk (Lausen and Barclay, 2006). These benefits may have driven roosting behavior in this direction. Currently, some of our most common bat species, such as *Eptesicus fuscus* and *M. lucifugus* rely heavily on human structures as roosts, and it is currently uncommon to find them roosting in natural structures. On occasion even the federally-endangered *M. sodalis* (Butchkoski and Hassinger, 2002) and *M. leibii* (Barbour and Davis, 1969) have been documented roosting in human-made structures.

Life history of *Myotis septentrionalis*

Myotis septentrionalis is a small (5–8 grams) forest-dwelling bat species that was considered to be uncommon in Ohio (Belwood, 1998; USDA Report, 2006). Surveys conducted in the early 1980's, documented very few *M. septentrionalis;* however, this may be an artifact of earlier survey methods and the fact the surveys were primarily conducted over water (Lacki and Bookhout, 1983). More recent research has proven this incorrect, and currently this species is considered relatively common in some areas (van Zyll de Jong, 1985; Harvey et al., 1999), if not throughout Ohio's forests (Kiser and Bryan 1997; Krynak, *unpublished data*). Historically referred to as a subspecies of Keen's Myotis (*M. keenii septentrionalis*) (Miller and Allen, 1928), this species was elevated to species as *M. septentrionalis* (van Zyll de Jong, 1979) and has had several common names, including: Northern Bat; Northern Myotis; Northern Long-eared Myotis; and most commonly the Northern Long-eared Bat. *Myotis septentrionalis* is a small "Vesper" bat with a body mass of 5–8 grams (van Zyll de Jong, 1985) and has a longer tail and larger wing area than other *Myotis* of the same mass. These structural adaptations are associated with gleaning behavior, as they capture prey items directly from foliage (Caceres and Barclay, 2000). They also allow *M. septentrionalis* to be more maneuverable during slow flight and are beneficial adaptations for bats flying in more spatially complex areas, such as forests.

Myotis septentrionalis can be found hibernating in caves and abandoned mines from late October–April in Ohio. Their numbers often are underrepresented in hibernacula surveys, as they prefer to hibernate in colder regions of hibernacula, alone, and often in cracks and crevices, making them difficult to observe and document. However, during fall swarming and spring emergence surveys, *M. septentrionalis* regularly is encountered and often at numbers equal to *M. lucifugus* (Perdicas, 2004).

Myotis septentrionalis, like the sympatric *M. lucifugus,* has a wide US and Canadian distribution that ranges from the Atlantic to British Columbia and as far north as southern Northwest Territory (Figure 1). In the United States, *M. septentrionalis* is found from Florida to Maine and to western North Dakota. *Myotis septentrionalis* is considered a resident of mature forests. Henderson et al. (2008) demonstrated that for every increase of 100 hectares of deciduous forest size, the probability of *M. septentrionalis* being present increased by 1.60 times. Owen et al. (2003) also indicated that *M. septentrionalis* prefers "intact" forests, and that they select habitats with a higher degree of vertical structure than more open habitat types; additionally they suggest that the small size and morphological and acoustical structures that allow *M. septentrionalis* to successfully forage in these types of habitats, which contain a considerable amount of clutter. Depending on the region, this species appears to utilize a variety of roosts trees and human structures; however, when compared to random trees, *M. septentrionalis* roosts typically are found in intact, older forests (Carter and Fledhamer, 2005; Lacki and Schwierjohann, 2001). Typically, it is believed that tree cavities are the preferable roosting locations for *M. septentrionalis*, as demonstrated by Lacki and Cox (2009) in Kentucky. *Myotis septentrionalis* were 88.9 % more likely to use a cavity or crevice for roosting, which is similar to the results of Johnson et al. (2009), in which it was demonstrated that *M. septentrionalis* can use tree cavities over exfoliating bark in the central Appalachian Mountains. Menzel et al. (2002) supported the hypothesis that this species prefers tree cavities over exfoliating bark in West Virginia by using radio telemetry to track lactating females to roost trees. All roosts were in hardwood species of trees and eleven of the twelve bats that were tracked were found in cavities of these trees. A variety of tree species have been documented as roosts for *M. septentrionalis*, including: *Robinia pseudoacacia* (Black Locust) (Ford et al., 2006); *Acer rubrum* (Red Maple); *Tsuga canadensis* (Eastern Hemlock); *Betula alleghaniensis* (Yellow Birch); *Acer saccharum* (Sugar Maple); *Fraxinus pennsylvanica* (Green Ash); *Pinus echinata* (Shotleaf Pine); *Ulmus americana* (American Elm); *Fagus grandifolia* (American Beech); *Oxydendrum arboreum* (Sourwood); *Pinus ponderosa* (Ponderosa Pine); *Quercus spp.* (Oaks), and *Betula papyrifer* (White Birch). Additionally, roost switching is a common behavior for tree-roosting bats, and for this species has been reported every 1–6 days (Johnson et al., 2009) and every two days in Michigan (Foster and Kurta, 1999). Roost switching is predicted to be a behavior that may limit parasite loads, lessen predation risks, and provides optimum thermal radiation. However, it is more likely that it is a behavior that evolved as a result of the ephemeral nature of their roosts, as bark is rapidly shed and snags regularly fall (Schultes, 2002). Roost trees often are clustered together, and frequently are located a considerable distance away from foraging areas (Sasse and Pekins, 1996). In Arkansas, *M. septentrionalis* did not avoid any habitat class; however, most bats roosted in mature hardwood stands greater than 100 years old, and 88% of roosts were in snags (Perry and Thill, 2007a).

A meta-analysis of summer roost characteristics of *Myotis septentrionalis* from seven states (Illinois, Michigan, Kentucky, West Virginia, Indiana, Arkansas, and New Hampshire, but none for Ohio) included a total of 230 roosts (Lacki and Cox, 2009). This analysis indicates that bats preferred trees with a mean diameter at breast height (DBH) of 30 cm (SE ± 5.4) and a roost height of 6.95 meters (SE ± 1). Schultes (2002) work in the Wayne National Forest in southern Ohio found similar results with a roost tree mean DBH of 24 cm (SE ± 3.7).

Although *Myotis septentrionalis* prefers to roost in trees, there are numerous documents that report this species uses human-made structures, including under cedar shingles and in buildings (Caceres and Barclay, 2000), in which case less than 60 individuals usually are found. In Ohio, a lactating female that was radio tagged in Cleveland Metroparks, South Chagrin Reservation was tracked to a home in Bentleyville, Ohio approximately 2 kilometers from the capture location where emergence counts revealed 95 and 96 bats on successive nights (Krynak, *unpublished data*). To my knowledge this is the largest colony reported in Ohio for this species.

As additional information is becoming available for roosting behavior of bats, it is becoming clear that roost selection is much more complex than the idea that each species of bats, utilize one type of roost environment, in one location, for the entire summer period. Data suggest that multiple roost are necessary for each bat species, and it remains unclear what may be a minimum number of roosts needed to support a tree roosting species, such as *Myotis septentrionalis*. By studying more common and widespread species, such as *M. septentrionalis,* it may be possible to make correlations to less common and even endangered bat species to assist in future conservation efforts. Bat populations are declining due to multiple threats such as habitat destruction, forest fragmentation, increasing insecticide and pesticide use, and in the Eastern Unites States, the recently emerging pathogen *Geomyces destructans* (White Nose Syndrome) (Blehart et al., 2009). Continued research is critical in ensuring populations can withstand these current threats.

Introduction

A vast amount of information has become available for roost selection, behavior, and habitat requirements for North America bats in the last decade. As additional information is being gathered about these small mammals, it seems that bats are predictable in roost selection, yet more and more exceptions to these rules are being documented. For example, *Myotis sodalis*, a tree roosting species, has been documented roosting in association with 30,000 *M. lucifugus* in an abandoned church in Pennsylvania (Butchkoski and Hassinger, 2002). Another example is *Lasionyteris noctivagans*, which typically is considered a solitary tree species, has been documented forming a maternity colony of 55 bats in South Dakota (Matson et al., 1996). There remains a considerable amount of work that needs to be conducted to construct complete life histories of Ohio bats and gain a better understanding of their ecology, as they have distinct summer and winter behaviors. Long-term studies are necessary, as bats are long lived animals (Wilkinson and South, 2002) that utilize relatively large home ranges that cover two distinct summer and winter habitats and have specific temperature and humidity requirements that change seasonally. Additionally, there is a need for additional landscape analyses, studies of minimum forest size requirements, and an understanding of how forest fragmentation affects bats to determine the extent of their roosting requirements (Lacki et al., 2007). An understanding of bat biology in these areas is lacking in the primary literature, likely due to the difficulties in studying aspects of these small nocturnal animals. With the advancement in remote sensing and geographic information systems (GIS) these questions are beginning to be answered (Perry et al., 2007; Swihart et al., 2006); however, Ohio continues to be a void in the accumulated knowledge of bats (Brack and Duffey, 2006), as there remains very little research beyond general species presence and absence surveys for Ohio. This likely is due to the lack of university professors in Ohio with a focus on bats, and the limited resources and staffing available in the Ohio Department of Natural Resources, Division of Wildlife.

It has been demonstrated that bats behave differently depending on available resources (roost availability, forest type, and disturbance) in their geographic range (Bell 1980; Cryan et al., 2000). I suggest that Ohio bats exhibit a very unique blend of roosting requirements, because Ohio's unique physical landscape include: the glaciated northeast; unglaciated southeast; northern lake-plain region; and the western agricultural flatlands. The geology associated with these landscapes is a unique blend that includes: sandstone and shale outcroppings; limestone caves; abandoned mines; and the strip coal mining region of the southeast, in which there are hundreds of mines that have yet to be surveyed for bats.

The geologic history of the bedrock within the study area ranges from the oldest Devonian aged Chagrin and Cleveland Shale found in North Chagrin, South Chagrin and Bedford Reservations to the Bedford Formation and Berea Sandstone found in Bedford and Brecksville Reservations and the northern section of the Cuyahoga Valley National

Park (CVNP), which are Mississippian aged deposits. The youngest bedrock deposits of Pennsylvanian age are the Sharon Conglomerate formation that forms the distinct ledges in both CVNP and Hinckley Reservation, consisting of coarse sand and round quartz pebbles. The soils are primarily low lime, glacial drift of Wisconsin age and form the Mahoning-Ellsworth Association in the Rocky and Chagrin watersheds and the Geeburg-Glenford Association in the Cuyahoga Valley (ODNR, 1973) giving rise to the diverse mesophytic forests types of northern Ohio (Williams, 1949).

Until recently, it was believed that bats did not hibernate in northern Ohio; however, concentrations of several thousand individuals of four species (*Eptesicus fuscus, Myotis lucifugus, M. septentrionalis,* and *Perimyotis subflavus*) have been documented utilizing Sharon Conglomerate outcroppings in Summit (Perdicas, 2004) and Medina (Krynak, *unpublished data*) counties. Sharon Conglomerate outcroppings are a unique northern Ohio formation demonstrating the potential of new discoveries that are possible. Ohio is positioned in a geographic location that is critical to understanding bat populations and roosting requirements, as the state lies in the center of the ranges of most species found in Ohio (Harvey et al., 1999; Belwood, 1998), and is the transition zone from the Appalachian Mountains in the east, into prairie flatlands to the west, the boundary of glaciated northern section of the state to the unglaciated southeast (Williams, 1949).

With the emergence of a new fungal pathogen *Geomyces destructans* (White Nose Syndrome) in some adjacent states (Gargas et al., 2009), information on roost selection becomes very important for future conservation efforts, not only for *Myotis septentrionalis*, but for all bat species in the northeastern United States. *Myotis lucifugus*, *Perimyotis subflavus* and *Eptesicus fuscus.* All relatively common species, these bats are exhibiting a 90–100 percent mortality rate in infected hibernation locations (Blehart et al., 2009). It has been estimated that over one million bats have died since discovering the fungus in New York in 2006. Protection of roosts will be critical in ensuring remaining survivors will have an adequate opportunity to raise offspring successfully, as their remaining populations will require ideal roosting sites to rebuild the rapidly declining populations.

My study was separated into two parts: Part 1, the general bat survey; and Part 2, the radio telemetry study of *Myotis septentrionalis*. The entire study occurred over a 4-year period from 2002–2005. Part 1, was conducted from 01 June, 2002 to 18 August, 2003 and covered 45 sites of 4 stratum types surveyed to ensure a spatially-dispersed and thorough sampling of bat populations within the study area. The two main goals were: 1) documenting species presence, abundance, and distribution within the Cuyahoga Valley and Cleveland Metroparks park systems; and 2) determining stratum preference of documented species.

Part 2, of the study was the radio telemetry portion focusing on roost tree selection and habitat use for *Myotis septentrionalis,* as the unexpected high numbers of captured bats in the initial survey in 2002–2003 led to additional questions. The radio telemetry portion was conducted from 23 June – October, 2005. Goals included: 1) documenting roost tree preference and description of roosts and landscape surrounding roosts for lactating female *Myotis septentrionalis;* and 2) gaining insight of roosting behavior and requirements that provides background knowledge for future research and conservation efforts of bats within Ohio.

This research will provide valuable information on Ohio bats, especially within the northern region of the state, for which these data are lacking in the primary literature. Additionally, this is the first intensive multi-year project, in which net sites were chosen randomly and not biased by the researcher choosing net locations.

Materials and Methods

Study area

The study area encompasses both the Cuyahoga Valley National Park (CVNP) and Cleveland Metroparks, both located in northeast Ohio. The CVNP is located between Cleveland and Akron and encompasses a variety of land ownership including: federal and county Metroparks; scout camps; ski resorts; Blossom Music Center; and other public and private entities totaling over 33,000 acres, with the Cuyahoga River as the main feature. Cleveland Metroparks is a 93 year old park district with over 21,000 acres in five counties (Cuyahoga, Medina, Summit, Lake and Lorain) surrounding the Greater Cleveland area (Figure 2). The majority of holdings are found within three main watersheds (Cuyahoga, Chagrin and Rocky Rivers).

These parks contain a diverse mosaic of natural vegetation types interspersed among a variety of human-developed land uses. Located in the glaciated Alleghany Plateau of northeastern Ohio, the natural vegetation of the parks is comprised of mature, mixed-mesophytic, secondary growth oak-hickory, beech-maple and hemlock-beech associations. Additionally, the park contains scrub-oldfield, wet meadows and a variety of Category 1–3 wetlands scattered throughout (Sampson, 1930; Williams, 1949;

Durkalec et al., 2009). The forests are heavily fragmented by roads, suburban development, recreational areas, utility corridors and agricultural lands.

Time period

Part 1, the general bat survey, was conducted in the summers from 01 June, 2002–18 August, 2003. May 15–August 15 is considered the time period when bats are residents in Northeastern United States (USFWS, 1999). Upon discovering a large unexpected population of *Myotis septentrionalis* during this general survey, Part 2, a radio telemetry study was conducted in the summer 2005. For this part of the study, mist-netting occurred from 23 June–22 July, targeting the period when female *M. septentrionalis* would be lactating, allowing radio tracking to locate maternity roost trees. Vegetation data collection for both Part1 and Part 2 continued into early October in all years.

Part 1 – General bat survey

Net site selection

Potential survey sites for the 2002–2003 general bat survey initially were identified by querying existing Geographic Information System (GIS) spatial layers including park boundaries, vegetation cover, water and road features, property ownership, two-foot contour topography, and digital orthoquad imagery, A uniform 1-km grid was established and grid points falling on private ownership were eliminated. The remaining grid points were categorized into three sampling stratum to systematically and thoroughly survey such a large area within the two-year project time frame: 1) points within the floodplain (defined as the area between the toe of the slope of the valley walls of the Cuyahoga River and major tributaries of the Chagrin and Rocky Rivers); 2) points in uplands (defined as areas above the toe of the valley walls) within 30 meters of a perennial stream; and 3) points in uplands (defined as before) more than 30 meters from a perennial stream. In 2003, three sample sites at small (1 acre) ponds also were chosen at random to be included as a potential missing habitat feature in the initial design.

Sites within 100 meters of a major highway were eliminated because of potential avoidance of these areas by bats due to noise and disturbance. Each grid point was examined using digital orthoquad (DOQ) imagery layers in GIS to determine proximity to a linear feature such as a stream, trail, old road, and utility corridor to ensure suitable mist netting corridors. Only points that fell within 100 meters of relatively mature forests (those > 12 meters tall) and closed canopy forest (as determined by GIS) were considered. This was to further ensure adequate flight corridors for netting and efficient capture success.

Once selected in GIS, potential sites were visited to verify suitability of mist-netting bats, based on access, forest canopy characteristics, and feasibility of net placement in flight corridors. Sites were determined suitable at the original point or within 100 meters of the original point. If a suitable point was not located within 100 meters of the original point, that particular site was eliminated. Final sites were separated by a minimum of 1 kilometer, in accordance with the USFWS (1999) recommendations for sampling *Myotis sodalis* (Indiana bat) populations, an accepted standard to adequately survey for presence and absence of bat species in northeastern United States. In total, 45 sites were sampled (Figure 3), half in 2002, and the reaming in 2003. These included 11 sites in the Floodplain, 18 in the Upland, 13 in the Upland Near Stream, and 3 over or near Ponds (only in 2003). The higher number of sites in Upland and Upland Near Stream was due to the difficulty of randomly locating suitable net sites in Floodplains. This stratum type was considerably more open and contained numerous meadows and agricultural fields making it difficult to locate adequate bat flight corridors.

Sampling procedure

The first part of this two-part study consisted of the general bat inventory. Mist-net surveys were conducted in two successive years from 01 June–18 August, 2002 and 15 May–15 August, 2003, using standard procedures established by the Indiana Bat Recovery Team and recommended by the U.S. Fish and Wildlife Service (USFWS, 1999). Bats were captured using nylon mist-nets placed across linear corridors (trails, old roads, streams and bridle trails), perpendicular to potential flight lanes of foraging bats in areas where surrounding and overhanging vegetation constricted flight paths and concealing nets forming a "funnel" for bats. Mist-nets were constructed of 50-denier, 2-ply nylon, and were 6–18 meters long, depending upon the requirements of each site (due to width of travel corridor), and 2.5 meters tall, with a 32–38 millimeter mesh size. The number of nets placed at each site ranged from 2–7 (usually 4–6), distributed among 2–5 net plot locations (depending on the number of suitable netting locations present). At each site, at least 2 net-plots of two vertically-stacked nets on pulley systems (Kunz and Kurta, 1988) were deployed to capture species that commonly forage higher in the stratum. At any site, net-plots were separated by at least 30 meters to minimize detection of mist-nets. Mist-nets were monitored over a 5-hour period beginning at sunset for two consecutive nights. If inclement weather resulted in less than a 5-hr netting period on a given night, the site was revisited on the next scheduled night to obtain at least 10 hours of netting per site. The nets were checked approximately every 20–30 minutes. All captured bats were identified to species (Belwood, 1998; Schwartz and Schwartz, 2001) and the following data was collected: time of capture; net set number; sex; mass; age (determined by degree of ossification of epiphyseal plates in the finger bones (Anthony, 1988)); reproductive condition, if pregnant (by examination of distention and palpation of abdomen in pregnant females), lactating (status of mammary glands to determine if lactating, post-lactating, or non-reproductive if no signs of suckling was present (Racey, 1988)). In males, reproductive activity was documented as active if testes were enlarged and descended or non-active if testes were not enlarged and not descended. All bats were released at site of capture within 30 minutes. Net sites were switched by stratum type and location (north to south) within study area to limit any temporal and spatial bias for one stratum throughout the study.

For this study, a Federal Fish and Wildlife permit (TE004812-0) was granted to Timothy J. Krynak, who was considered an agent of Ohio Division of Wildlife. This permit allowed bat surveys to be conducted, and included the federal-endangered *Myotis sodalis* (Indiana bat) within the study area during the entire duration of the four-year study.

Vegetation-plot data collection

Due to time restrictions in collecting vegetation data only 35 of the 45 net sites were inventoried for vegetation surrounding nets to assist in the interpretation of stratum preference of documented bat species in Part 1 of the general survey. The sampling protocol was modified from the CVNP (1999) long-term ecological monitoring plan for Cleveland Metroparks, to allow meaningful comparisons of vegetation between the two agencies. The vegetation data consisted of 7 sites in the Floodplain, 15 sites in Upland, 10 sites in Upland Near Stream and 2 Ponds sites. Each of these sites had 2–7 net locations, but typically 2–4 nets sites. Vegetation data were recorded for each net placement at each site and included: distance to large edge (canopy opening > 1,000 m^2 or > 30 meters wide); distance to small edge (canopy opening < 1,000 m^2 or > 30 meters wide); type of edge (stream, road, field or development); distance to surface water; and surface water depth in meters estimated from the center of each net. Four 5-meter radius vegetation sub-plots were constructed at 15-meters perpendicular to each net pole (Figure 4). At each of the four sub-plots, slope (measured with handheld clinometer), canopy height (measured with an extension pole), and percent canopy cover (determined by handheld densitometer). In each of the 5-meter sub-plots, all species of woody plants were identified to genus and to species when possible (Gleason and Conquist, 2001). Diameter at breast height (DBH) in centimeters was estimated by using a 20-factor forestry prism. Vegetation was separated into the following classes of trees > 1.5 meters tall of maximum DBH of centimeters: < 2.5, 7.5, 15, 23, 30, 38, 53 and >53. Vegetation data were pooled from the four sub-plots at each of the 35 net sites to create a species matrix of woody plants, with all non-woody vegetation removed for analysis. The species matrix was analyzed with an Ordination technique (to find patters within the data) utilizing Principle Component Analysis (PCA) to demonstrate that sites chosen randomly by GIS, (designated as one of the four stratum types; Floodplain, Upland, Upland Near

Stream and Pond), were unique in structure and vegetation composition, allowing for comparison of species and sex between stratum types.

Part 2 – Radio telemetry

Sampling procedure

Sites that had a documented a large population, determined by the number of individuals of lactating female *Myotis septentrionalis* captured during the 2002–2003 general survey (Figure 5), were revisited during June–July, 2005. Bats were captured using similar mist-net techniques described in the 2002–2003 general survey, concentrating net sites in areas with lower canopies and denser clutter. These areas were determined to be more successful in capturing *M. septentrionalis* during the general survey. One lactating female captured at each site and weighing at least 7.0 grams (determined by a 5% rule for attaching radio transmitters (Gardner et al., 1991)), were radio tagged with LB-2 model transmitter (0.47–0.52 g) (Holohil Systems Limited, Carp, Ontario, Canada) and attached with non-toxic SkinBond surgical adhesive (Smith and Nephew United Inc., Largo, Florida, USA). Transmitters were placed on bats between the mid-scapular region after a small amount of fur was removed with scissors as described in the methods of Adam et al. (1994). All bats were released at the point of capture within 45 minutes from removal of the net, allowing ample time for the adhesive to set. Bats initially were tracked upon release to ensure that the transmitter was working properly, bats were flying adequately, and to provide a potential direction of travel for additional tracking. Bats were tracked the following morning to roost trees using an ATS Model R4000 Scientific Receiver and 3 Element Folding Yagi Antenna initiated at the point of capture. If no signal was received at the point of capture, the search area was expanded by driving nearby roads until a signal was detected. Once a signal was received, bats were tracked by foot. Each bat was located daily for 10–14 days, or until the transmitter failed or a detached transmitter was located. Once a roost tree was located the following data were collected: tree species; live or dead; roost substrate (bark, crevice or tree hollow); substrate height; DBH; snag decay class (Stabb, 2005) (Figure 6); percent bark cover; percent bark exfoliating; slope; aspect; percent canopy cover; distance to large edge (canopy opening > 1,000 m^2 or > 30 meters wide, if > 200 meters, 200 was recorded); distance to small edge (canopy opening < 1,000 m^2 or < 30 meters wide, if > 100 meters, 100 was recorded); type of edge (field, river or stream, forest opening, wetland, road and development); distance to surface water (river, stream, pond or lake, marsh and swamp); and surface water depth in centimeters.

At each identified roost tree, four 5-meters vegetation sub-plots were located at standard orientations (North, East, South and West) of the tree, and similar vegetation data was collected as net sites previously described to be utilized in describing preferred forest structure of roost selection.

Forest block size analysis

The size of the forest blocks of *Myotis septentrionalis* locations were calculated using ArcGIS 9.2. Forest blocks were identified using the National Land Cover Database (NLCD) 2001 (Homer et al., 2004) by identifying all areas in the NLCD with forest canopy coverage greater than 50%. *Myotis septentrionalis* locations were then overlain to identify the forest block size in which they fell. Pseudo-replicates for forest blocks were identified and each forest block was given a unique number identifier to determine when points were nested within a same forest block. A total of 27 capture locations and 18 roost trees were analyzed separately. Points nested within a forest block were treated as one forest for analysis. A total of 5 forest blocks for capture locations and 3 forest blocks for roost trees were analyzed.

Statistical Analysis

Three statistical programs were utilized depending upon the data being analyzed including: SPSS 16.0; PC-ORD 5.1; and MINITAB 12.23 (in Part 1 of the general survey of 2002–2003 and Part 2 of the radio telemetry portion of 2005). SPSS was utilized to provide descriptive statistics for all species data in Part 1 and reported as (± SE).

To determine differences of forest structure between strata, vegetation data were pooled from the four sub-plots and averaged per net site for percent canopy cover and canopy height. Means were analyzed with an ANOVA to test the null hypothesis that means of percent canopy cover and canopy height were equal for the four strata types. Significance level was set at $p = 0.05$ and reported as (F (degrees of freedom) = F statistic, $p = 0$)).

An ordination technique was utilized to determine vegetation patterns within each of the four strata types assisting in describing the forest composition. Species of woody vegetation documented in each of the 4 sub-plots were pooled into one species list per net for analysis. A presence-absence species matrix was created and an analysis was conducted in PC-ord. A Principal Component Analysis was utilized with a cross-product matrix set to variance-covariance centered and scores were calculated as distance-base bi-plot, reported as percent of variance.

To determine if there was a species stratum preference between male and female bats, Chi-square Goodness of Fit was utilized testing the null hypothesis that male and female bats would occur in equal numbers in each of the four strata types. The significance level was set at p = 0.05 and reported as (X^2 (degrees of freedom, N = 0) = Pearson's chi-square value, p = 0).

Descriptive statistics for Part 2 (*Myotis septentrionalis* roost tree characteristics and forest block size for the telemetry portion of data) were calculated with the statistical program MINITAB. A two-tailed t-test was utilized to test the null hypothesis that percent canopy cover at roost trees was equal to percent canopy cover at a distance of 15 meters from roost trees in surrounding forest. The significance level was set at p = 0.05 and reported as (t (degrees of freedom) = t statistic, p = 0).

Results

Part 1 - General mist-net survey

Overall, a total of 668 bats were captured from 45 sites including four strata types (Upland, Upland Near Stream, Floodplain and Pond), with a substantial total effort of 452 mist-net nights and a success rate of 0.3 bats/hour/net during the general survey in 2002–2003. A total of seven species were documented (Table 1 and Table 2) with the most abundant species being *Eptesicus fuscus* (n = 250, 37% of total bats captured). *Myotis septentrionalis* was the second-most encountered species (n = 210, 31% of total bats captured), which was unexpected, as they were previously thought to be uncommon in

Ohio (Belwood, 1998). The remaining species that were captured included: *M. lucifugus* (n = 130, 19% of total bats captured); *Lasiurus borealis* (n = 61, 9% of total bats captured); *Perimyotis subflavus* (n = 14, 2% of total bats captured); *L. cinereus* (n = 2, 0.3% of total bats captured); and *M. sodalis* (n = 1, 0.15% of total bats captured).

The greatest numbers of bats were captured in the Upland stratum (n = 345 bats captured, success rate of 0.38 bats/hour/net) (Table 3); however, this stratum did contain the highest number of sites (n = 18), which represents five more sites than any other stratum, likely contributing to the higher number of captured bats. The most-abundant species in this stratum was *Myotis septentrionalis* (n = 151, 42% of total bats captured). The second-most abundant species was *Eptesicus fuscus* (n = 128, 37% of bats captured). The remaining species that were captured included: *M. lucifugus* (n = 38, 11%); *Lasiurus borealis* (n = 24, 7%); and *Perimyotis subflavus* (n = 4, 1%).

The Floodplain stratum was the second-most productive in terms of captures, having a total of 155 bats captured, with *Eptesicus fuscus* comprising the majority of bats captured (n = 56, 36% of bats captured, success rate of 0.28 bats/hour/net) (Table 4). *Myotis lucifugus* was the second-most abundant species in this stratum (n = 46, 30% of captures), which was somewhat expected as this species is considered to prefer this habitat type (Fenton and Barclay, 1980). *Myotis septentrionalis* was the fourth-most abundant bat captured within this stratum (n = 20, 13% of the captures). This stratum was equally productive in terms of capturing *Lasiurus borealis* (n = 24, 16% of bats captured), with 7 fewer sites surveyed than Uplands, the next most-productive stratum for this species (n = 13), and male *L. borealis* were captured nearly two-to-one over females. The Floodplain was the most-productive stratum for captures of *Perimyotis subflavus* (n

= 8, 5% of the bats captured), twice the number of individuals here than in the remaining strata. The low sample size (n = 14) did not allow for determination of stratum preference for this species. The reaming species captured in this stratum included one *L. cinereus* (n = 1, 0.7%) an infrequently encountered species in Ohio mist-net surveys.

Upland Near Stream stratum sites captured a total of 153 bats (success rate of 0.23 bats/hour/net), with *Eptesicus fuscus* (n = 56, 37%) the most-abundant (Table 5). *Myotis lucifugus* and *M. septentrionalis* had similar capture rates (*M. lucifugus* (n = 42, 27% bats captured and *M. septentrionalis* n = 38, 25% bats captured). This stratum yielded the only capture of *M. sodalis* (n = 1, 0.65% of bats captured), a federally-endangered species captured at Deer Lick Cave (20 June, 2002) in Brecksville Reservation of Cleveland Metroparks. At the time, this lone male *M. sodalis* was only the third record of this species for Cuyahoga County. The remaining species captured included: *Lasiurus borealis* (n = 13, 9%); *Perimyotis subflavus* (n = 2, 1%); and *L. cinereus* (n = 1, 0.65% of bats captured).

The three Ponds had a total of 15 individual bats captured (success rate of 0.1 bats/hour/net) (Table 6). *Eptesicus fuscus* (n = 10, 67% bats captured) was the most abundant at these sites followed in number by *Myotis lucifugus* (n = 4, 27% of bats captured) and *M. septentrionalis* (only one individual captured for 7% of bats captured in this stratum).

Comparing rates of captures between males to females of each species in each stratum, and testing the null hypothesis that there are an equal number of males to females of each species in a given stratum, there appears to be an unexpected and significant preference for stratum between sexes, in several species, including: *Eptesicus* *fuscus; Myotis septentrionalis;* and *M. lucifugus,* rejecting the null hypothesis for these species. Male *E. fuscus* preferred either Upland Near Stream or Upland, whereas females strongly preferred Floodplain (X^2 (1, N = 184) = 23.82, p < 0.0001), (X^2 (1, N = 111) = 16.80, p < 0.0001). *Myotis septentrionalis* demonstrated a significant preference for stratum type between sexes, as females preferred Upland, whereas males preferred Upland Near Stream (X^2 (1, N = 189) = 6.67, p = 0.01). Lastly, *M. lucifugus* females preferred Floodplain, whereas males preferred Upland (X^2 (1, N = 84) = 11.68, p = 0.001). This was unexpected as *M. lucifugus* typically are known to forage over water including streams. *Lasiurus borealis* did not demonstrate a significant stratum preference between males and females in any stratum type (X^2 (2, N=60) = 0.89, p = 0.642). The remaining species, *L. cinereus, Perimyotis subflavus,* and *M. sodalis,* where not captured in high enough numbers to allow for determination of stratum preference between males and females.

There were more than twice as many male *Lasiurus borealis* captured (n = 42) than females (n= 19) in the general survey, and males outnumbered females in all stratum types except at Ponds, where no *L. borealis* were captured. There was a temporal trend for increased capture rates throughout the summer, as more *L. borealis* were captured in August (n = 33) than May–July combined (n = 27) (Figure 7).

Vegetation analysis

The first of two Ordinations, Principle Component Analyses (PCA), were conducted with vegetation from all nets-sites pooled to stratum level in one presence-absence species data matrix. This PCA demonstrates a clear separation for each stratum, with greater variability between Floodplain and Upland, and Upland Near Stream, which were more similar, with 86% of the variation occurring within the first axis, 8% in the second axis and 6% in the third axis (Figure 8, displaying Axis 1 and Axis 2). The second PCA, where vegetation was pooled per site into one species presence-absence data matrix, demonstrated that there is vegetation overlap between strata. This would be expected in natural communities as boundaries are not distinct, as one community transitions in to the adjacent community (Figure 9, displaying Axis 1 and Axis 3). There was not a clear separation, especially between the Upland and Upland Near Stream; however, grouping did occur of net sites and was most evident in the Floodplain stratum. This analysis did not accomplish the goal of demonstrating a clear separation in stratum types; however, it did show patterns. There was a greater difference between Floodplain and Upland Near Stream, whereas there was less variation between Uplands and Upland near stream, with 26% of the variation described in the first axis, 16% in the second axis, and 10% in the third with a total of ten axes described. Though this analysis did not reveal distinct separation it is still valuable information that can be utilized in describing the relationships between strata and describe bat stratum preferences.

Canopy height and percent canopy cover were used to assist in describing differences in vegetation structure of stratum, allowing for comparisons of bat species and species stratum preference. Canopy height overall was lowest in Floodplains, with a mean height of 17.46 meters (SE ± 0.98) and became successively higher in the Uplands (mean canopy height of 19.44 meters (SE ± 0.68)), Ponds (mean canopy height of 20.33 meters (SE ± 0.64)), and Uplands Near Stream (mean canopy height of 22.09 (SE ± 0.61)) (Figure 10). An ANOVA of canopy heights comparing means between stratum types demonstrated a significant different overall in the main effect (F (3,124) = 5.56, *p* = 0.001)), indicating that there are differences in the structure in forest types rejecting the null hypothesis that canopy height is equal in all stratum types.

Percent canopy cover is an indicator of how “open” a particular stratum may be. The lower the percent canopy cover, the more open and less structured the stratum. Canopy cover was lowest in the Floodplain (with a mean canopy cover of 68.40%, SE ± 3.08), and successively higher in the Pond (mean canopy cover of 69.08%, SE ± 12.58), Upland (mean canopy cover of 78.45 %, SE ± 1.67), and highest in Upland Near Stream (mean canopy cover of 83.24 %, SE ± 1.31) (Figure 11). An ANOVA to compare the means of percent canopy cover demonstrated that there was strong significant difference in the main effect for percent canopy cover, (F (3,124) = 7.75 p < 0.0001)), rejecting the null hypothesis that percent canopy cover is equal in all stratum types.

GIS forest block analysis for *Myotis septentrionalis* for capture locations

From the total of 27 capture locations for *Myotis septentrionalis,* five individual forest blocks were identified. The mean forest size was 2,120 hectares (SE ± 1,009 hectares). The smallest forest block in which *M. septentrionalis* was documented was 86 hectares and was located near Hillside Road, the northern section of CVNP. This site only contained one capture location. The largest forest block was 5,954 hectares and was located in North Chagrin Reservation of Cleveland Metroparks and surrounding forests, and contained 3 capture locations.

Part 2 - *Myotis septentrionalis* telemetry study

A total of 108 bats of five species were captured from 23 June–22 July, 2005 during the radio telemetry portion of the study, including: *Eptesicus fuscus* (n = 46); *Myotis septentrionalis* (n = 43); *M. lucifugus* (n = 16); *Lasiurus borealis* (n = 2); and *Perimyotis subflavus* (n = 1) (Table 7). From these individuals, nine lactating females of *M. septentrionalis* (each weighing at least 7.0 g) were fitted with radio transmitters. All but one individual was successfully tracked to roost trees (the remaining bat was located on private property), and I was not able to gain permission to access the property. The remaining 8 females were tracked to a total of 21 roost trees (Figure 12) (Table 8 and Table 9). *Myotis septentrionalis* utilized 1–5 trees, with a mean of 2.6 (SE ± 0.5) trees per bat during the duration of transmitter life. *Myotis septentrionalis* primarily roosted in dead trees (snags), as 19 of the 21 trees (90%) were dead and were identified as Decay Class 3–4 (Figure 13). Bats were most often located roosting under exfoliating bark (17 of the 21 roost trees, 81%), and two bats were located roosting in crevice in the main trunk of the tree. One crevice was a result of the crown of the tree breaking off at about 10 meters above the ground (Figure 14) and the other a possible lighting strike. One individual was located behind a large vine of *Toxicodendron radicans* (Poison Ivy) on a dead *Robinia pseudoacacia* (Black Locust) (Figure 15). This is the first documentation of *M. septentrionalis* roosting behind a vine. In this instance a juvenile *M. septentrionalis* was located and observed for only one day, and was not relocated after that initial observation. The remaining bat was located in a hollow branch of an *Acer saccharum* (Sugar Maple). This was the only bat documented to be utilizing a tree hollow as a roost throughout the study.

The majority of roosts were located in Oak trees (*Quercus spp.*), with 15 of the 21 (71%) of all roost trees from this genus. Other roost tree species included: *Fraxinus americana* (White Ash, n = 1); *Juglans nigra* (Black Walnut, n = 1); *Carya sp.* (Hickory, n =1); *A. saccharum* (Sugar Maple, n = 2); and *Robinia pseudoacacia* (Black Locust, n = 2).

Roost trees were large, with a mean DBH of 55.8 cm (n = 20, SE ± 4.7), and ranged from DBH of 25–113 centimeters. Fourteen of 20 roost trees contained greater than 50% bark cover, and 10 of 20 trees had greater than 50% of the remaining bark exfoliating. Substrate height ranged from 3–25 meters with a mean height of 19.5 meters (n = 20, SE ± 1.2).

Analysis of slope did not reveal a preference for selecting roost trees, as slope ranged from 0–34 degrees, with a mean slope of 7.06 degrees (n = 18, SE ± 2.33). Thirteen trees had slopes of < 10 degrees, and were located in areas of flat terrain, whereas five trees were located on slopes of > 10 degrees and were located on areas of moderately hilly terrain. *Myotis septentrionalis* did not demonstrate a preference for any slope aspect, as trees were found facing in all orientations (N = 1, NW = 5, NE = 2, E = 1, SE =1, S = 2, SW = 1, W = 1), and the remaining 3 trees were located on flat terrain with no aspect recorded.

The mean canopy cover at roost trees was 71% (n = 17, SE ± 2.8), which was significantly lower (t (30) = -2.08, p = 0.047) than the surrounding forest canopy cover of 79% (n =16, SE ± 2.7). Surrounding canopy was measured 15 meters from roost trees, indicating that *M. septentrionalis* preferred roost trees that were more open than surrounding forest.

Distance to a large edge ranged from 12–200 meters, with a mean of 122 meters (n = 18, SE ± 18.8). This can be misleading because if the distance to a large edge was greater than 200 meters, 200 meters was recorded as estimating greater distances would be unreliable. This would considerably underestimate the actual distance to a large edge. Roost trees were located in close proximity to small two-meter wide streams, with mean a distance of 68.5 meters (n = 20, SE ± 9.6), and may indicate the possibility that *M. septentrionalis* uses streams as flight corridors as they travel to and from foraging areas.

Roost switching was common with 5 of 8 bats utilizing multiple roosts (2–5 roost trees) throughout the life of the transmitters, with a mean of 2.6 (SE ± 0.5) roost trees per bat. Additionally, individual bat's roost trees were "clumped" together as distance between roosts ranged from 73–859 meters. This may have been due to the large number of snags available, as they were the most often encountered woody plant in each of the vegetation plots of all roost trees. Distances between roost trees and points of capture varied from 158–1,550 meters (Figure 16).

Vegetation data were pooled from the four 5-meter subplots to a single presence-absence species matrix to determine the top twelve tree species that best describe forest composition directly surrounding roost trees. Species surrounding roost tress (listed from most abundant to least abundant), and included: Snags (standing dead tree); *Prunus serotina* (Black Cherry); *Acer rubrum* (Red Maple); *A. saccharum* (Sugar Maple); *Carpinus caroliniana* (Musclewood); *Carya sp.* (Hickory); *Fagus grandifolia* (American Beech); *Fraxinus americana* (White Ash); *Ostrya virginiana* (Hophornbeam); *Quercus rubra* (Red Oak); *Q. alba* (White Oak); and *Q. velutina* (Black Oak) (Table 10 and Table 11)

Forest block size for roost trees

From a total of 18 *Myotis septentrionalis* roost trees, three individual forest tracts were identified, with the remaining trees nested within these blocks. The mean forest size was 2,078 hectares (SE ± 1,458 hectares). The smallest forest block in which M. *septentrionalis* roost trees were documented was 1,226 hectares, and was located in the Brecksville Reservation of Cleveland Metroparks. The largest forest block in which *M. septentrionalis* roost trees were documented was 5,954 hectares, and was located in Bedford Reservation of Cleveland Metroparks.

Discussion

Part 1

General mist-net survey

The first goal for Part 1 was to document presence-absence of bat species in north-central Ohio. Ohio remains under-represented in published bat research compared to neighboring states, and this multi-year study is the first in the north-central region of Ohio, and the first in which sites were chosen randomly within Ohio. With 452 mist-net nights of effort, 45 total sites, spatial distribution of sites, four strata types, and temporal distribution from mid-May to mid-August, this survey provides an excellent non-biased representation of bat populations and distributions in the Greater Cleveland metropolitan region. The documentation of three species demonstrating a significant sexual preference for stratum type for uses other than roost selection (Broders and Forbes, 2004; Perry and Thill, 2007a; Perry and Thill, 2007b; Perry et al., 2008), has not been previously published, and emphasizes the need to better understand habitat requirements of both male and female bats for conservation efforts. The species richness of seven species documented in the general survey is consistent with what others have documented in Ohio. Schultes (2002) documented eight species in the Wayne national Forest, Brack and Duffey (2006) documented six species in Ravena Training and Logistics site (Portage and Trumbull Counties) and Perdicas (2004) documented eight species (Summit County). *Eptesicus fuscus* was the most abundant bat species, comprising over 37% of all bats captured in this study. This is similar to Schultes (2002) work, where *E. fuscus* was the most abundant species captured (n = 136, 26% of total captures) and in Brack and Duffey (2006) survey of the Ravenna Training site (n = 122, 45% of total captures). *Myotis septentrionalis* was more abundant than expected, as it was assumed to be an uncommon bat in Ohio (Belwood, 1998); however, this species was documented as the second-most abundant species, with over 31% of the total bats captured. This is similar to the results of mist-net surveys that were conducted in 1997 and 1999 in the Wayne National Forests in southern Ohio where *M. septentrionalis* was the most encountered bat (Kiser and Bryan, 1997 and Kiser et al., 1999). My results may be a reflection of the higher number of Upland sites sampled (n = 18), compared to the other types of stratum (n = 11, Floodplain) (n = 13, Upland Near Stream) (n = 3, Pond). The addition of more Upland sites in the design is atypical for bat surveys as often researches focus efforts netting over water, whereas in my study Upland sites were over trails, old roads, and bridle trails. The ratio or percentage of bats captured in each stratum provides a more precise indication of species abundance and distribution, and the total number of sites (n = 45) in this study is robust enough to eliminate bias of species abundance in any one stratum type. This survey design allowed for a more accurate documentation of species richness, abundance and strata preference than what has previously been published for bats in Ohio (Schultes, 2002; Brack and Duffey, 2006).

The analysis of vegetation surrounding each net location was valuable in demonstrating that sites chosen randomly using GIS in each of the four stratum types did represent a statistical difference in both percent canopy cover ($p = 0.047$) and canopy height ($p < 0.0001$), rejecting the null hypothesis that the strata were equal and allowing for conclusions of species stratum preference to be described.

Myotis septentrionalis was most often encountered in the Upland stratum type (42% of bats captured) and consistently proved to be the most abundant species encountered, nearly 5% more often than *Eptesicus fuscus* (the overall most abundant species), and four times greater than any other species documented. In the Upland Near Stream stratum, *Myotis septentrionalis* represented just under 25% of the bats captured. This result is not surprising as these two strata were more similar than the Floodplain described in the ordination results. This species was found less often in Floodplains, with only 13% of the bats encountered. These results indicate that *M. septentrionalis* prefers the Upland stratum type to forage or utilize corridors when traveling from foraging to roosting locations. These results are similar to what others have found in habitat preference studies for this species (Schultes, 2002; Owen et al., 2003; Carter and Fledhamer, 2005; Perry et al., 2008).

Myotis septentrionalis demonstrated stratum type preference dependent on sex, as females were found to be significantly more abundant in Uplands and males were found to be significantly more abundant in the Upland Near Stream ($p = 0.01$). This result was unexpected as habitat selection (such as roosting preference) is common in many bats species, including *M. septentrionalis* (Perry and Thill, 2007a; Mager and Nelson, 2001; Perry and Thill, 2007b); however, stratum preference between sexes, has not been published for this species. For conservation efforts is necessary to evaluate both male and female habitat preference. This difference may be explained if males were using streams as flight corridors, traveling from roosting sites to foraging areas. Perry et al. (2008) described *M. septentrionalis* utilizing roads and trails for this purpose and may be a similar behavior for *M. septentrionalis* utilizing the nearby streams.

Males of *Myotis lucifugus* were significantly more abundant in Uplands and females were more abundant in Floodplains ($p = 0.001$). This may be a result of males roosting in this stratum type and traveling to other strata where they were captured, as it has been documented that *M. lucifugus* prefers to forage over water (Fenton and Barclay, 1980) and that males have less strict roosting requirements than females and will often roost alone (Broders and Forbes, 2004).

Eptesicus fuscus was equally abundant at all strata types with no significant preference ($p = 0.642$), as they contained 36–37% percent of bats captured in Floodplains, Uplands, and Upland Near Streams. This may indicate that this species is more of a generalist (Agosta, 2002) than other Ohio species in selecting foraging areas and roosting sites. However, there was a strongly significant preference of stratum type dependent on sex ($p > 0.0001$). Males were found nearly twice as often in Upland strata and females were twice as likely to be found in Floodplain strata. This could be an indicator that males were roosting in Uplands and traveling through this stratum on their way to a foraging site, as they often forage in open areas, over open water, and near streetlights (Harvey et al., 1999) and not an indicator of stratum foraging preference.

Nonetheless, this is an indicator that multiple strata are important to this common and abundant species (Whitaker et al., 2002).

Lasiurus borealis was encountered in three of the four stratum types and these bats were more likely to be found in the Floodplain, as they made up over 15% of the bats captured in this stratum, and only (7%) in Uplands and (9%) Upland Near Streams. This is likely due to this stratum consisting of more open space, as was demonstrated with the lowest percent canopy cover of all four strata types, with a mean of 68%. *Lasiurus borealis* has long-narrow wings that have evolved for rapid, direct flight, and are not as agile as other forest dwelling bats; therefore, they require more open space to successfully forage (Farney and Flehardy, 1969). This is consistent with what Elmore et al. (2004) found in Mississippi, where *L. borealis* preferred open pine stands for both roosting and foraging.

The significant difference in sex ratio, where males were captured nearly three to one over females, could be an indicator of early migrant male *Lasiurus borealis* arriving in Ohio. Sex ratios skewed towards higher numbers of males than females have been reported in northern portions of this species range (Cryan, 2003); however, in my study there was an increase in capture rates in late July–early August, were more than half of all *L. borealis* were captured within this time period. Another possibility for the increase in capture rate could be an influx of juvenile bats into the population as they become volant. Captures of juveniles began appearing in July, and their increase in mist-nets was documented in August as well; however, the total number of adults outnumbered total number of juveniles by nearly three to one. This is a good indicator of an influx of adults into the population, rather than just an increase in recruitment of young. This is supported by Cryan's (2003) work, which examined migratory patterns for *L. borealis* utilizing museum specimens and indicated an increase of *L. borealis* in northern US, mostly farther west in Wisconsin; however, there were very few records for Ohio. This is most likely due to museums' collections focusing on specific taxa, which may not have included bats. This study does confirm that there is an increase of *L. borealis* into northern Ohio beginning in late July and peaking in August–September (Figure 17) and confirming that there are more males in the population during this time period.

Perimyotis subflavus demonstrated a slight preference for the Floodplain stratum type as twice as many individuals were captured in the Floodplain (n = 8) than in Uplands (n = 4) and three times as many as in Upland Near Stream (n = 2). With the small sample size (n = 14), no significant conclusions could be made on stratum preference for this species. Others have found that *P. subflavus* prefers to forage in Floodplains and forest edges (Harvey et al. 1999), and would support the higher numbers that were documented in Floodplains during this study.

These results indicate that there remains much work to be conducted on bats and their habitat use and preference to ensure complete understanding of life histories. This study demonstrated that even though a species can have a stratum preference, there can be a preference between sexes. When considering conservation efforts both male and female bats need to be considered separately, allowing conservation efforts to be more effective.

Part 2

***Myotis septentrionalis* Radio Telemetry: roost tree selection**

In the second part of this study, I sought to document roost tree preference for *Myotis septentrionalis,* describe roost characteristics, and describe surrounding landscape characteristics. *Myotis septentrionalis* preferred roost trees primarily within the genus *Quercus*, with 15 of 21 (71%) roost trees from this genus. This is similar to Schultes (2002) study in the Wayne National Forest in southern Ohio, where *M. septentrionalis* demonstrated a preference for trees within the genus *Quercus*, and was found in 10 out of the 21 (48%) of roost sties documented. Multiple tree species have been documented as roosts for this species, including: *Robinia pseudoacacia* (Black Locust); *Acer rubrum* (Red Maple); *Tsuga canadensis* (Eastern Hemlock); *Betula alleghaniensis* (Yellow Birch); *Acer saccharum* (Sugar Maple); *Fraxinus pennsylvanica* (Green Ash); *Pinus echinata* (Shotleaf Pine); *Ulmus americana* (American Elm); *Fagus grandifolia* (American Beech); *Oxydendrum arboreum* (Sourwood); *Pinus ponderosa* (Ponderosa Pine); *Quercus spp.* (Oaks), and *Betula papyrifera* (White Birch) (Ford et al., 2006; Lacki and Cox, 2009; Menzel et al., 2002; Johnson et al., 2009; and Foster and Kurta, 1999). This preference for *Quercus spp.* in my study could be a result of a devastating *Lymantria dispar* (Gypsy Moth) outbreak in years prior (Liebhold et al., 1997) which resulted in abnormally high number of oak snags available for *M. septentrionalis* to utilize as roosts. Thus, *Quercus* may not be a tree species preference for this species, but may represent an opportunistic roost habitat. This has been suggested by others (Johnson et al., 2009; Broders and Forbes, 2004; Carter and Feldhammer, 2005), as it appears *M.*

septentrionalis is more of an opportunistic species than having specific species roost tree requirements and can be supported by my results.

Previous studies indicate that *Myotis septentrionalis* prefers to roost more often in tree hollows and crevices than under exfoliating bark (Lacki and Cox, 2009; Schultes, 2002; Johnson et al., 2009; Menzel et al., 2002; Perry et al., 2008). However, my results indicate that *M. septentrionalis* preferred exfoliating bark over hollows and crevices, as they roosted under exfoliating bark in 17 out of 21 (81%) documented roost trees. The only documented tree hollow roost was a single hollow branch (approximately 70 cm in diameter) of *Acer saccharum* (Sugar maple). Two roosts were documented in crevices in main trunks, one from a broken tree, and another from a presumed lighting strike. This is a good indicator that *M. septentrionalis* are opportunistic in selecting roosts and not necessarily preferential to certain tree characteristic such as species, hollows, crevices, or exfoliating bark if alternate roost were available. However, alternate available roosts, such as tree hollows, were not taken into account or evaluated in the study, and exfoliating bark roosts could have been the only roosts available. This information would prove valuable in future research for *M. septentrionalis*.

Supporting my conclusion that *Myotis septentrionalis* are an opportunistic species when selecting a roost, is the size of selected trees during my study. The mean DBH for all roost trees was 55 .8 cm and is similar to what Foster and Kurta (1999) described in Michigan (DBH = 65 cm); however, 25 cm greater than the mean DBH of roost trees described in Lacki's (2009) meta-analysis, and what Schultes (2002) documented in the Wayne National Forest in Southern Ohio. This could possibly be a result the high number of available of larger diameter trees that died during the gypsy moth outbreak and not a result of size preference.

Roost switching is a common behavior for this species and has been reported every 1–6 days in the Appalachian Mountains (Johnson et al., 2009), every two days in Michigan (Foster and Kurta, 1999), and 1–7 days in Arkansas (Perry et al., 2008). Roost switching is predicted to be a behavior that may limit parasite loads, lessen predation risks, and provide optimum thermal radiation, but it is more likely that it is a behavior that evolved because of the ephemeral nature of their roosts as bark is rapidly shed and snags regularly fall (Schultes, 2002). The total number of roost that may be utilized in a given year remains unknown; however, Lackie et al. (2007) suggest that it could be higher than 8–20 trees. Roost trees often are clustered together and frequently are located a considerable distance away from foraging areas (Sasse and Pekins, 1996). This was evident in my study as four bats were captured over a kilometer away from roost trees; 1,550 meters, 1,230 meters, 1,100 meters and 1,093 meters.

Larger diameter roost trees may provide a greater variability in microclimates, yielding a more suitable roost for *Myotis septentrionalis* in a given tree, and minimizing the need to switch roosts. This was found to be true in *M. sodalis,* in which roost switching was similar, but lower than what others have described (Kurta et al., 2002). The result in my study (mean of only 2.6 roosts per bat) could be a result of the larger DBH roost trees being a more suitable for bats and providing a greater diversity of microclimates in each roost, proving to be unnecessary and less energy efficient to switch roosts. This has been demonstrated in *Perimyotis subflavus,* as colony size is larger in human-made structures (Whitaker, 1998), which have been shown to provide greater variability in microclimates (Ferrara and Leburg, 2005). This is taken to extremes in *M. lucifugus* as they often form very large maternity colonies of up to thousands of individuals in human-made structures (Butchkoski and Hassinger, 2002). These large colonies are often found very large structures such as attics, barns, and old churches that provide multiple available roosting microclimates. These types of roosts often receive more solar radiation and may be too hot for *M. septentrionalis;* however, if a suitable human-made roost was shaded by trees, it could provide high quality roosts where roost switching would not need to occur, and colony size might be expected to be larger. This may be the case for one *M. septentrionalis* roost located in a home in Bentleyville, Ohio in 2003. The home is located on a heavily wooded lot with a north facing aspect (Krynak, *unpublished data*) providing a cooler microclimate that preferred by *M. lucifugus*, but ideal for *M. septentrionalis*. An emergence count on successive nights revealed an average of 95.5 individuals, and is the largest reported colony for this species in Ohio (Krynak, *unpublished data*). Though roosting in human-made structures for this species is not common, it has been documented previously (Caceres and Barclay, 2000). A roost of this size is unusual and most likely is an exception to the normal.

Roost switching may be an indicator of roost quality, providing more available and stable microclimates, and as the quality of roosts increases the need to relocate to another roost should decrease. Roost switching documented in this study (mean of 2.6 roosts per bat), could possibly be an indicator that these larger roost trees were in fact a more suitable roost, and *Myotis septentrionalis* did not have to switch as often. Therefore, it appears in northern Ohio that *Myotis septentrionalis* will utilize a variety of roosts within Upland stratum, including exfoliating bark, crevices, tree hollows, and even human-made structures. However, when available, *M. septentrionalis* will choose roost sites of larger diameter trees, with greater available microclimates providing advantages in conserving energy by not having to switch roosts while raising young. Additional long-term studies that would track individuals throughout the entire summer would be valuable in confirming these patterns observed during the short transmitter life of this study.

Roost tree vegetation analysis

Vegetation analyses at net sites demonstrated a preference for Uplands stratum type over Floodplain, Upland Near Stream and Ponds, and provides an initial step to describing the vegetation preference for *Myotis septentrionalis* in northern Ohio. For each located roost tree the vegetation analysis allowed tree community associations to be described and can be used as an indicator of preference for those species. There was a preference to upland tree species, as the most common species that were associated with net sites were similar to tree species associated with roost trees. The most common described tree species is similar to what others have reported (Schultes, 2002; Foster and Kurta, 1999; Lacki and Schwiierjohann, 2001 Perry et al., 2008); however, because of the large number of species and individuals of *Quercus spp.* that were available, caution should be taken, as the association of surrounding trees may simply be a result of the habitat or stratum that these species typically prefer. The results may demonstrate which tree species that are good indicators of upland mesophytic forest of well-drained soils (*Acer saccharum* (Sugar Maple); *Ulmus americana* (American Elm); and *Quercus spp.*

(Oaks), and they indicate a preference of *M. septentrionalis* for roosting, travel corridors, and possibly foraging habitat.

Although sample sizes were small, the forest block analyses revealed that *Myotis septentrionalis* preferred large tracts of forests, with the mean forest size of 2,120 hectares (SE ± 1,009). This was not unexpected as *M. septentrionalis* has been recorded to utilized large forests by other researchers. Henderson et al. (2008) demonstrated that for every increase of 100 hectares of deciduous forest size, the probability of *M. septentrionalis* being present increased by 1.60 times. Owen et al. (2003) also indicated that *M. septentrionalis* prefers “intact” forest and may select habitats with a higher degree of vertical structure than more open habitat types. Additionally, they suggest that due to their small size and morphological and acoustical structures allowing *M. septentrionalis* to successfully forage in these types of habitats (containing a considerable amount of clutter) , my results support these findings as well. Although there was no relationship between numbers of *M. septentrionalis* captured and increase in forest size. This is an indicator that forest fragmentation and development could be very detrimental in maintaining a healthy population of *M. septentrionalis* within Northern Ohio, as urban sprawl continues.

Conclusion

Agosta (2002) states that there are two issues that complicate the ability to understand the conservation needs of bats: 1) the structure and dynamics of bat populations have yet to be described; 2) there is an understanding of factors that negatively affect bats; however, the natural history of many species remains poorly understood. Though a great deal of research has been conducted on endangered species, it is often the common species that have a higher ecological role in ecosystems. The conservation of widespread and abundant species is critical for protection of ecosystems as a whole, and is often where more endangered species can be found. My research revealed that *Myotis septentrionalis* is an abundant species, at least locally in larger forest tracts of North-Central Ohio, and is likely a very important component in a healthy forest ecosystem; via control of insect populations, and the cycling nutrients back into the forest. The documentation of *M. septentrionalis* primarily utilizing exfoliation bark as roosts is unique from previous published work, and is an example that much work remains to be conducted on common species to fully understand their total ecological requirements.

. Even though *Myotis septentrionalis* may be locally abundant, it is reliant on large upland forest tracts with a higher canopy height and canopy cover than other species for roosting and foraging. This study is the first to explore this aspect in this region of Ohio, and has led to more questions to be answered (impact of forest fragmentation) with additional research before this species is fully understood.

Research often leads to unexpected results, and the segregation of male and female by stratum type was unexpected in my study. These findings conclude that male and female behaviors need to be considered separately for conservation decisions, as their behaviors are very complex. Currently, conservation efforts tend to focus on reproductive females; however, the result of sex segregation indicates that there may be additional considerations to successfully protect and reclaim endangered species. There remains much work to be conducted on bats and this study can be utilized as a springboard to future work, as it begins to fill a gap of knowledge of bats from the state of Ohio.

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Table 1: Four letter species codes, scientific names, and common names for all bat species captured in Part 1 of the general survey and Part 2 of the *Myotis septentrionalis* radio telemetry study.

Species Code	Scientific Name	Common Name
PESU	*Perimyotis subflavus*	Tricolored Bat
MYSO	*Myotis sodalis*	Indiana Bat
MYSE	*Myotis septentrionalis*	Northern Long-eared Bat
MYLU	*Myotis lucifugus*	Little Brown Bat
LACI	*Lasiurus cinereus*	Hoary Bat
LABO	*Lasiurus borealis*	Eastern Red Bat
EPFU	*Eptesicus fuscus*	Big Brown Bat

Table 2: Total bats captured in Part 1, the general bat survey (2002–2003), containing all strata types and 45 sites combined by species, sex and percent of total capture. The "unknown" refers to bats that escaped before all data could be obtained.

Total bats captured

Species	EPFU	LABO	LACI	MYLU	MYSE	MYSO	PESU	TOTAL
Male	139	41	2	61	96	1	5	345
Female	110	19	-	69	114	-	9	321
Unknown	1	1	-	-	-	-	-	2
Total	250	61	2	130	210	1	14	668
Percent	37.43	9.13	0.30	19.46	31.44	0.15	2.10	100

Table 3: Bats captured in the Upland stratum by species, sex, and percent of total bats captured of each species in the Part 1, the general survey (2002–2003).

Upland

Species	EPFU	LABO	LACI	MYLU	MYSE	MYSO	PESU	TOTAL
Male	82	15	-	24	64	-	3	188
Female	46	9	-	14	87	-	1	157
Unknown	-	-	-	-	-	-	-	
Total	128	24	-	38	151	-	4	345
Percent	37.10	6.96	-	11.01	42.03	-	1.16	100

Table 4: Bats captured in the Floodplain stratum by species, sex, and percent of total bats captured of each species in the Part 1, the general survey (2002–2003).

Floodplain

Species	EPFU	LABO	LACI	MYLU	MYSE	MYSO	PESU	TOTAL
Male	14	18	1	12	7	-	1	53
Female	42	6		34	13		7	102
Unknown	-	-	-	-	-	-	-	-
Total	56	24	1	46	20	-	8	155
Percent	36.13	15.48	0.65	29.68	12.90	-	5.16	100

Table 5: Bats captured in the Upland Near Stream stratum by species, sex, and percent of total bats captured of each species in the Part 1, the general survey (2002–2003). "unknown" refers to bats that escaped before all data could be obtained.

Near Stream

Species	**EPFU**	**LABO**	**LACI**	**MYLU**	**MYSE**	**MYSO**	**PESU**	**TOTAL**
Male	35	8	1	21	25	1	1	92
Female	20	4	-	21	13	-	1	59
Unknown	1	1	-	-	-	-	-	1
Total	56	13	1	42	38	1	2	153
Percent	36.60	8.50	0.65	27.45	24.84	0.65	1.31	100

Table 6: Bats captured in the Pond stratum by species, sex, and percent of total bats captured of each species in the Part 1, the general survey (2002–2003).

Pond

Species	**EPFU**	**LABO**	**LACI**	**MYLU**	**MYSE**	**MYSO**	**PESU**	**TOTAL**
Male	8	-	-	4	-	-	-	12
Female	2	-	-	-	1	-	-	3
Unknown	-	-	-	-	-	-	-	-
Total	10	-	-	4	1	-	-	15
Percent	66.67	0	0	26.67	6.67	0	0	100

Table 7: Total bats captured during the *Myotis septentrionalis* radio telemetry study from 2005 by species and sex.

Species	EPFU	LABO	MYLU	MYSE	PISU	Total
Male	18	2	10	12	-	42
Female	28	-	6	31	1	66
Total	**46**	**2**	**16**	**43**	**1**	**108**

Table 8: Part 1 of roost tree description for *Myotis septentrionalis* and surrounding forest characteristics of 8 bats captured and radio tracked to a total of 21 roost trees listed alphabetical by tree species displaying mean and (SE).

Tree Number and Species	Alive or Dead	DB H (cm)	Substrate Height (m)	Snag Decay Class	% Bark Cover	% of Exfoliating Bark	Slope (deg)	Aspect	Canopy Cover (%)	Distance to Large Edge (m)
1.ACSA	LIVE	50	25	LIVE	D	A	10	N	87	25
2.ACSA	DEAD	25	3	-	-	-	-	-	-	-
3.CARY	DEAD	60	22	3	C	D	2	NW	63	200
4.FRAM	DEAD	58	14	4	A	B	0	-	73	160
5.JUNI	DEAD	35	19	4	C	D	0	-	43	12
6.QUAL	DEAD	69	23	3	D	C	2	NW	57	200
7.QUAL	DEAD	56	21	4	D	C	2	SE	81	16
8.QUAL	DEAD	61	21	3	D	C	3	NW	71	190
9.QUAL	DEAD	41	21	4	D	C	2	NE	75	200
10.QUAL	DEAD	62	22	3	D	D	3	NE	78	120
11.QUAL	DEAD	69	22	3	C	C	3	NW	71	80
12.QUAL	DEAD	-	-	3	-	-	25	S	-	-
13.QURU	DEAD	85	11	4	B	B	2	W	81	200
14.QURU	DEAD	53	12	5	B	C	20	S	58	200
15.QURU	DEAD	113	25	3	-	-	-	-	-	50
16.QURU	DEAD	25	20	2	-	-	-	-	-	-
17.QURU	DEAD	68	24	3	D	B	2	SE	79	27
18.QURU	DEAD	51	23	4	D	B	15	SW	64	200
19.QUVE	DEAD	68	24	3	D	B	2	NW	64	200
20.ROSA	DEAD	30	19	3	D	C	34	E	87	18
21.ROSA	LIVE	37	20	LIVE	D	A	0	-	74	110
Mean (SE)		55.8 (4.7)	19.5 (1.2)	3.4 (0.2)			7.1 (2.3)		70.9 (2.8)	122.7 (18.8)
A= 0-25% B=25-50% C=50-75% D=75-100%										

Table 9: Part 2 of roost tree description for *Myotis septentrionalis* and surrounding forest characteristics of 8 bats captured and radio tracked to a total of 21 roost trees listed alphabetical by tree species displaying mean and (SE).

Tree Number and Species	Distance to Small Edge (m)	Distance to Water (m)	Water Type	Width (m)	Water Depth (m)	Mean Canopy Cover of Subplots (%)	Mean Canopy Height of Subplots (m)	Type of Large Edge
1.ACSA	-	40	Stream	2	2	87.50	26.00	Development
2.ACSA	-	-	Stream	-	-	-	-	-
3.CARY	50	140	Stream	2	2	93.25	26.75	-
4.FRAM	-	60	Stream	2	2	81.75	24.50	FIELD
5.JUNI	-	10	Stream	2	2	49.25	16.75	ROAD
6.QUAL	100	140	Stream	2	2	70.50	22.00	-
7.QUAL	-	80	Stream	3	2	79.50	28.00	ROAD
8.QUAL	-	80	Stream	2	2	87.75	27.75	Development
9.QUAL	100	60	Stream	2	2	-	-	-
10.QUAL	-	40	Stream	1	1	73.00	23.75	ROAD
11.QUAL	-	80	Stream	2	2	78.00	22.25	FIELD
12.QUAL	-	3	Stream	-	-	-	-	-
13.QURA	40	120	Stream	2	2	82.00	26.00	-
14.QURA	100	15	Stream	3	2	90.25	27.75	-
15.QURA	15	98	Stream	1.5	1	88.00	29.50	FIELD
16.QURA	-	45	Stream	-	-	-	-	-
17.QURU	-	80	Stream	-	2	-	-	ROAD
18.QURU	100	30	Stream	1	1	84.33	24.58	-
19.QUVE	100	80	Stream	2	2	76.25	26.75	-
20.ROSA	-	140	River	20	4	76.25	21.5	ROAD
21.ROSA	-	30	Stream	2	1	67.25	20.25	FIELD
Mean (SE)	75.6 (12.4)	68.6 (9.6)		5.0 (1.4)	3.9 (0.9)	79.1 (2.7)	24.6 (0.8)	

Table 10: Woody vegetation species presence-absence matrix of 12 most encountered species encounter pooled from the four 5-meters sub-plots of *Myotis septentrionalis* roost trees including SNAGs (standing dead wood) listed alphabetical by tree species.

Roost Tree	ACRU	ACSA	CACA	CARY	FAGR	FRAM	OSVI	PRSE	QUAL	QURU	QUVE	SNAG
1	1	1	0	0	0	1	0	0	1	1	0	1
2	1	0	0	1	1	0	1	1	0	1	1	1
3	1	1	0	0	1	1	1	1	1	1	0	1
4	0	1	1	0	1	0	1	1	1	1	1	1
5	0	0	0	0	0	0	0	0	0	0	0	1
6	0	1	0	0	1	1	0	1	0	0	0	1
7	0	0	0	0	0	1	0	1	0	0	0	1
8	0	1	1	1	0	0	1	0	0	1	0	1
9	0	1	0	1	0	1	0	1	1	1	1	1
10	1	1	0	0	1	0	1	1	0	0	1	1
11	0	1	1	0	1	0	1	1	1	0	0	1
12	0	1	0	0	1	0	1	1	1	1	0	0
13	0	1	1	0	1	0	1	1	1	1	0	1
14	0	1	1	1	1	0	0	0	1	1	0	1
15	0	1	0	0	0	1	0	1	0	0	0	0
16	1	1	1	1	1	0	1	1	1	0	1	1
17	0	1	0	1	0	0	1	1	0	1	0	1
18	1	0	1	1	1	1	0	1	0	0	1	0
Total	**6**	**14**	**7**	**7**	**11**	**7**	**10**	**14**	**9**	**10**	**6**	**15**

Table 11: Four letter species codes, scientific names, and common names for 12 most occurring tree species in the four 5-meter sub-plots of *Myotis septentrionalis* roost trees.

Species Code	Scientific Name	Common Name
ACRU	*Acer rubrum*	Red Maple
ACSA	*Acer saccharum*	Sugar Maple
CACA	*Carpinus caroliniana*	Musclewood
CARY	*Carya spp*	Hickory
FAGR	*Fagus grandifolia*	American Beech
FRAM	*Fraxinus americana*	White Ash
OSVI	*Ostra virginiana*	Hophornbeam
PRSE	*Prunus serotina*	Black Cherry
QUAL	*Quercus alba*	White Oak
QURU	*Quercus rubra*	Red Oak
QUVE	*Quercus velutina*	Black Oak
SNAG	Non-applicable	Standing Dead Tree

Figure 1: Generalized *Myotis septentrionalis* range distribution map in North America modified from Harvey et al. (1999)

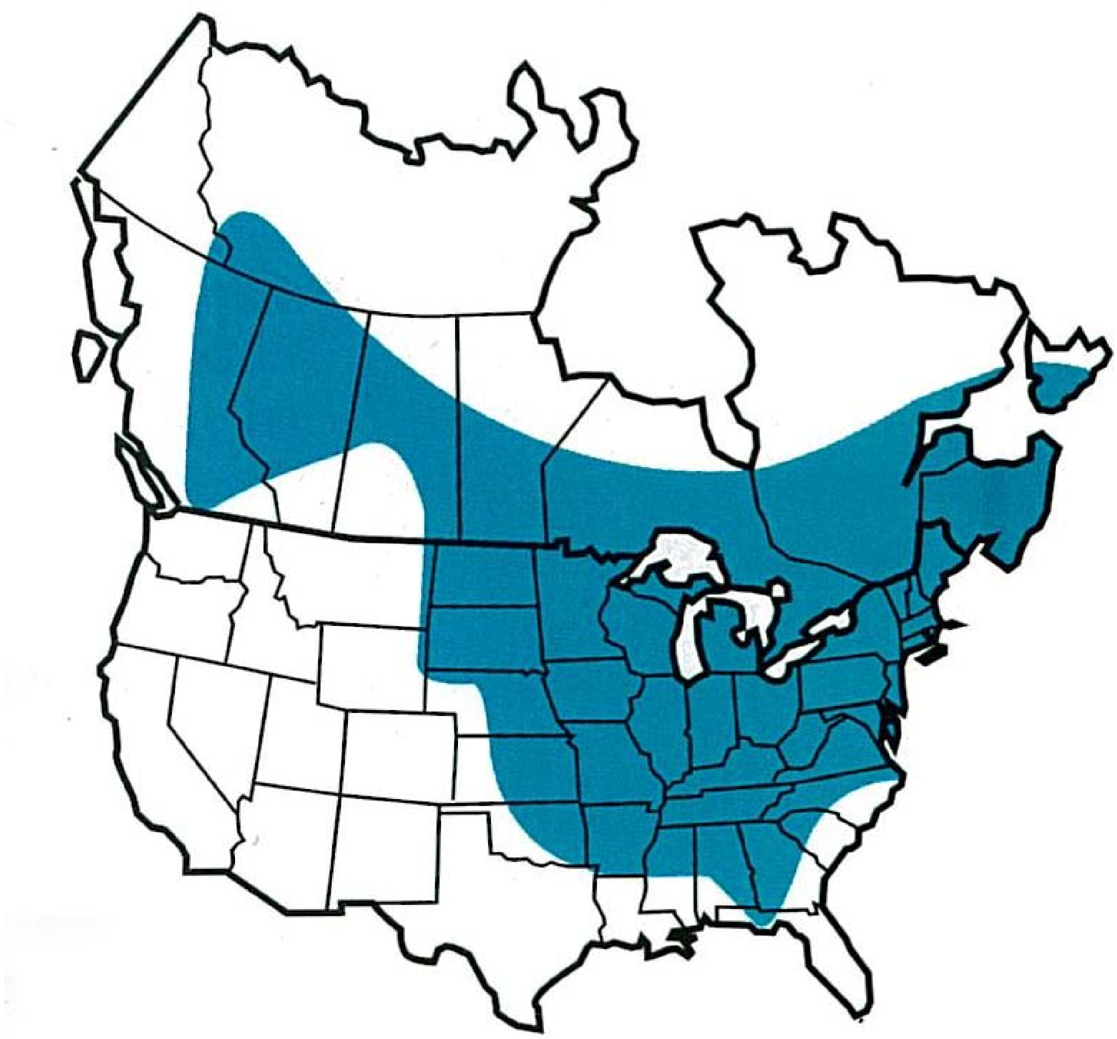


Figure 2: Map of four county areas with box indicating location of the study area for Part 1, the general bat survey and Part 2 the *Myotis septentrionalis* radio telemetry study.

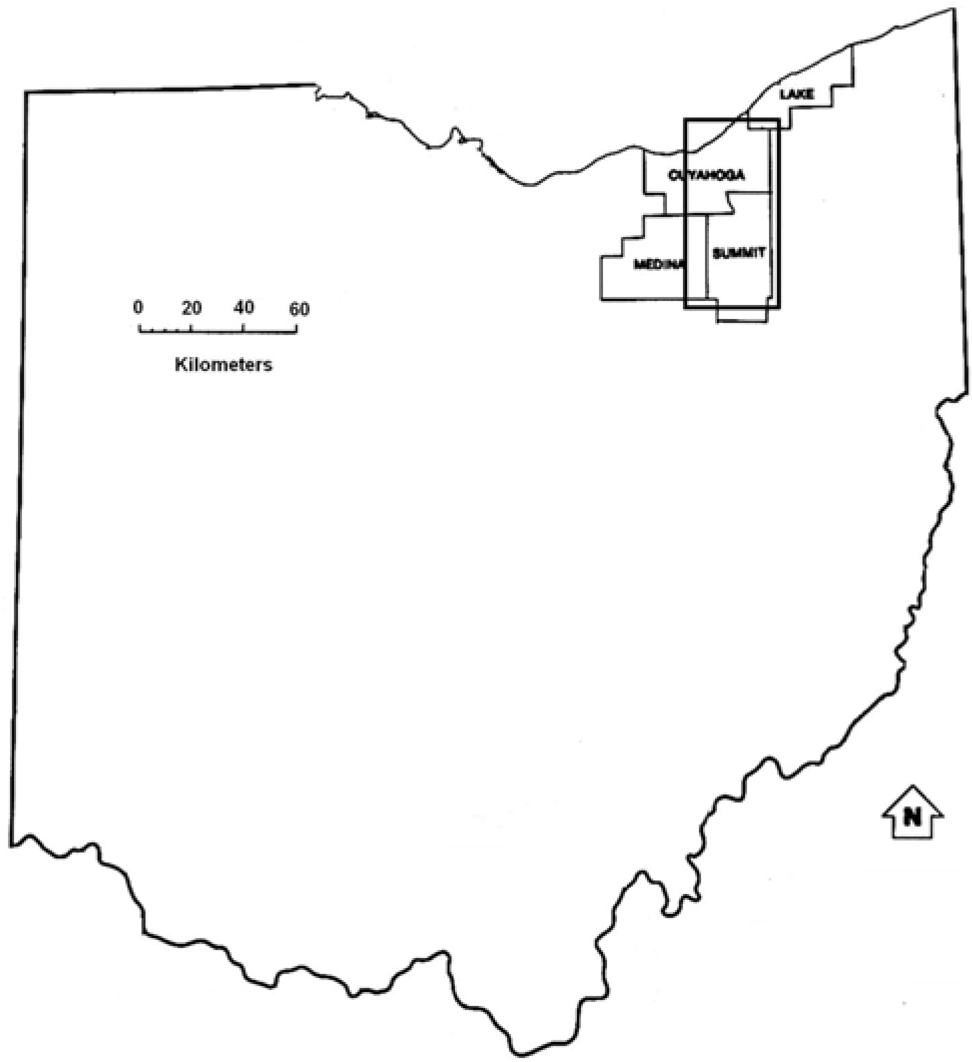


Figure 3: Map of 45 net sites from Part 1, the general bat survey within Cleveland Metroparks and Cuyahoga Valley National Park, distributed in the four strata types (Upland, Upland Near Stream, Floodplain, and Pond) located in the Cuyahoga, Rocky and Chagrin watersheds.

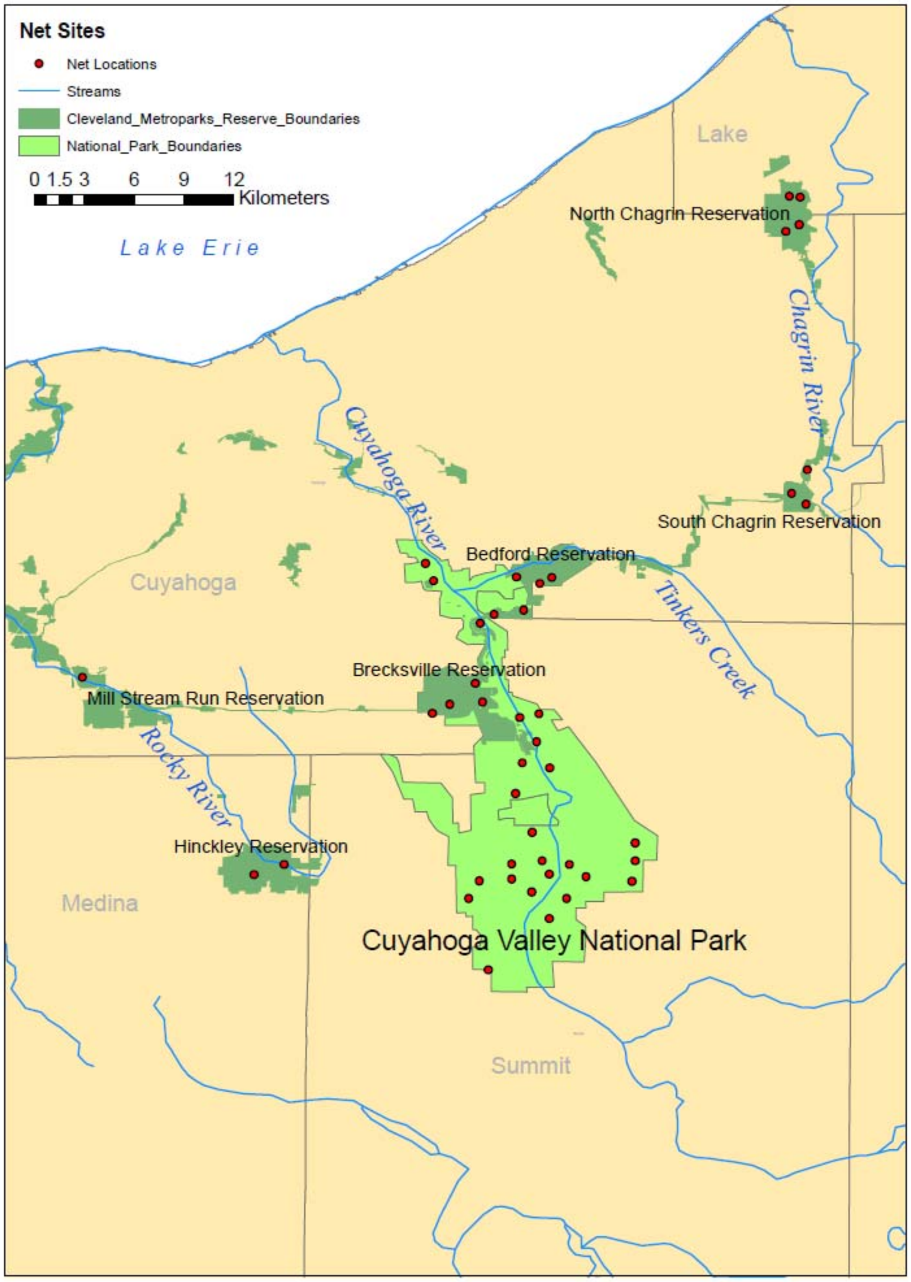


Figure 4: Illustration of vegetation sub-plot placement at each net site of 35 out of 45 total net sites in Part 1, the general survey.

PLACEMENT OF 5-M-RADIUS VEGETATION PLOTS (Pages 3-4)

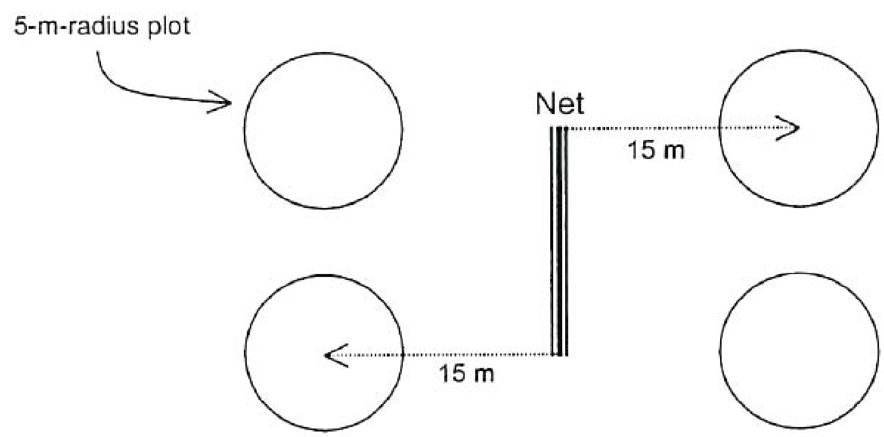


Figure 5: Map of net sites where *Myotis septentrionalis* were captured and indicating number of individuals, directing targeted areas for Part 2, the radio telemetry portion of the study.

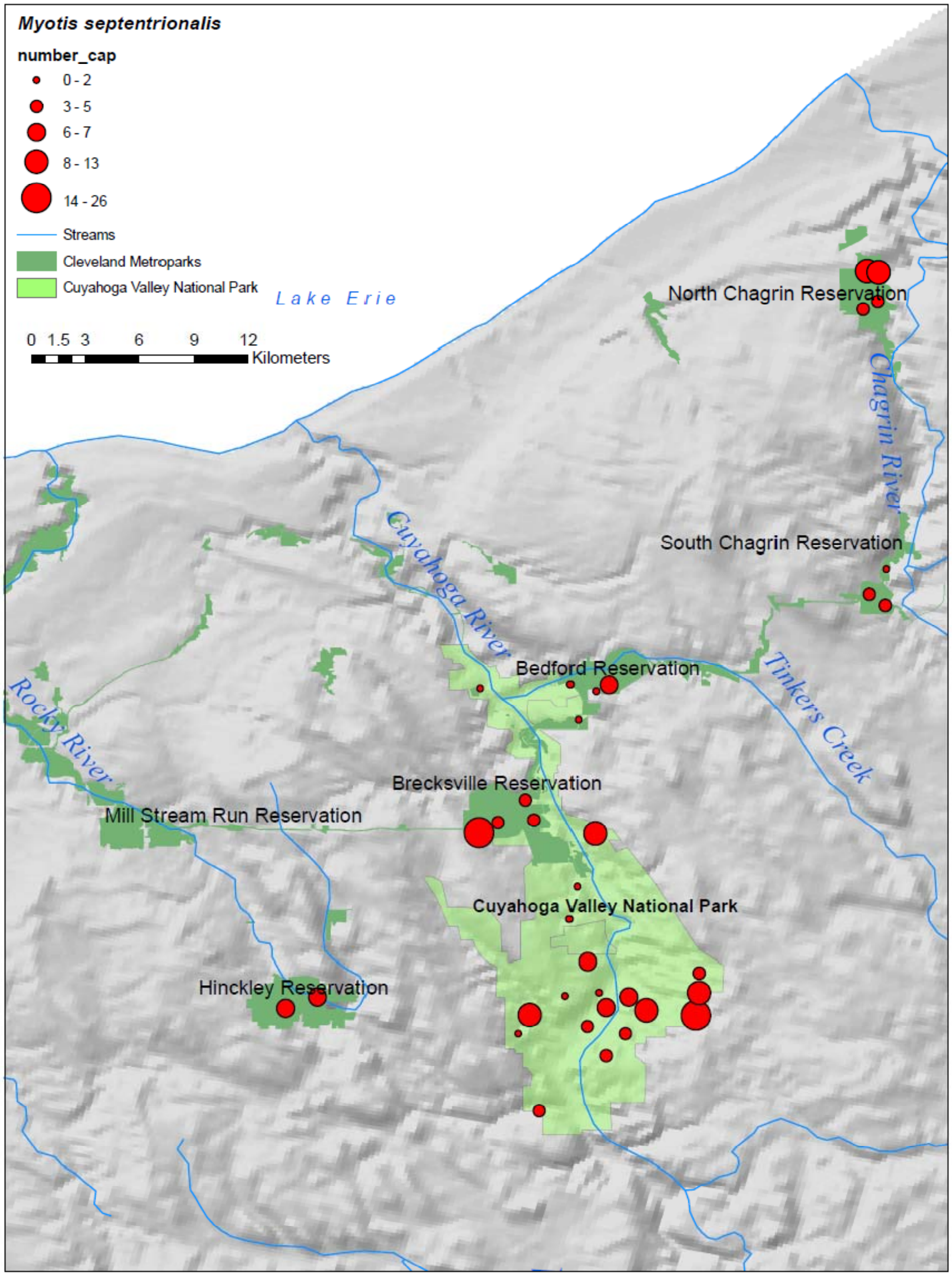
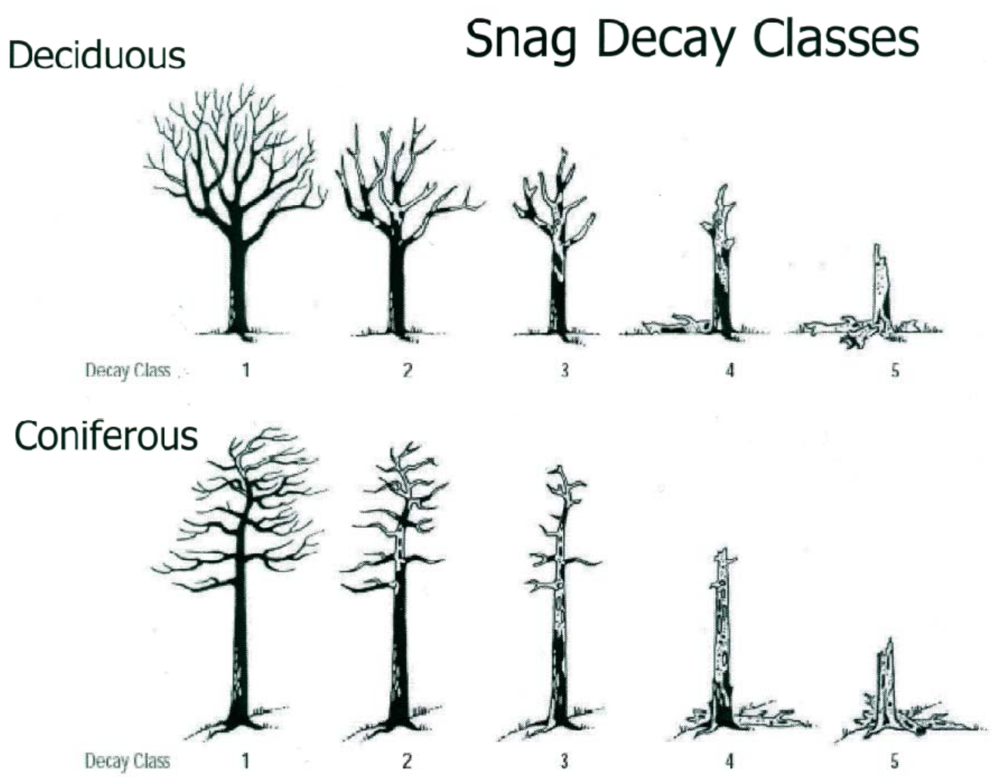


Figure 6: Illustration of snag decay class designation modified from Stabb, M. (2005) where majority of *Myotis septentrionalis* roost trees fell between decay class 3 and 4.



Field Sign	LIVE TREE with dead and dying branches or broken top	Decay Class 1	Decay Class 2	Decay Class 3	Decay Class 4	Decay Class 5
Tree top	-Broken top or dead stub on tree top	-Tree top intact and just recently dead	-Tree top intact	-Tree top intact	-Top broken off	-Top broken to a stub less than 6 m high
Branches	-Many or most branches still alive -About 25 percent of canopy still dead	-Recently dead Fine branches still present	-Fine branches gone Less than half of large branches gone	-More than half of large branches gone	-All large branches gone	-All large branches gone
Bark	-Bark or trunk intact -Bark or branches may be dead	-Bark mostly intact	-Bark loosening	-Bark usually falling off	-Bark nearly gone	-Bark and wood deteriorating

Figure 7: Graph of the accumulated number of *Lasiurus borealis* captured by month from May–August 2002–2003 combinded, demonstrating a temporal increase in capture rates throughout the study period.

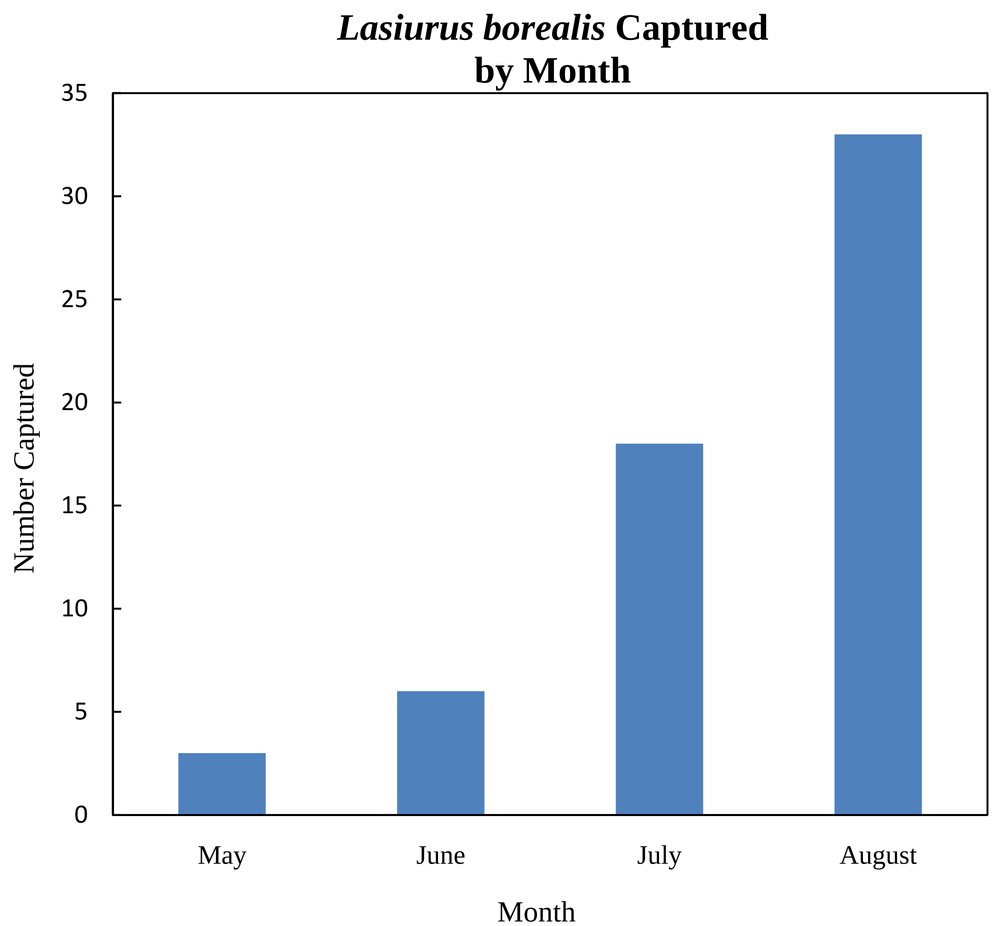


Figure 8: Two dimensional Principal Component Analysis (PCA) ordination graph of all vegetation plots pooled by stratum displayed as triangles displaying Axis 1 and Axis 2 demonstrating a clear separation of stratum, allowing for determination of bat species preference.

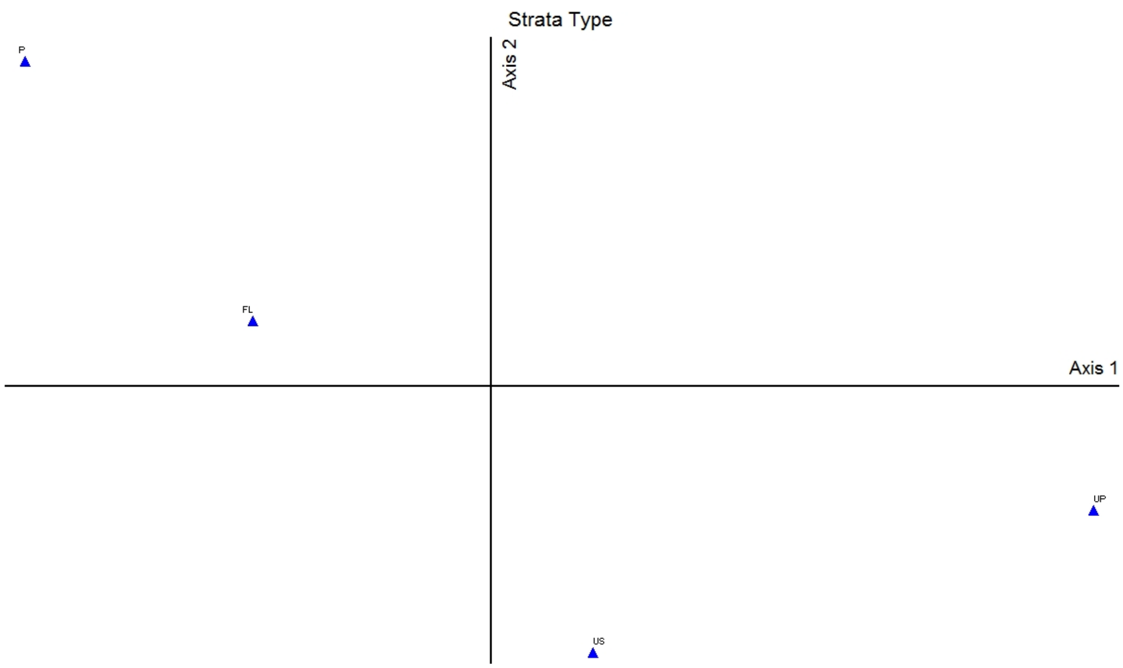


Figure 9: Two dimensional Principal Component Analysis (PCA) ordination graph of vegetation plots pooled per site displayed as triangle labeled FL (Floodplain), US (Upland Near Stream), UP (Upland) and P (Pond) rotated to display Axis 1 and Axis 3. Graph demonstrates that there is a pattern in the vegetation, but an overlap between stratum types.

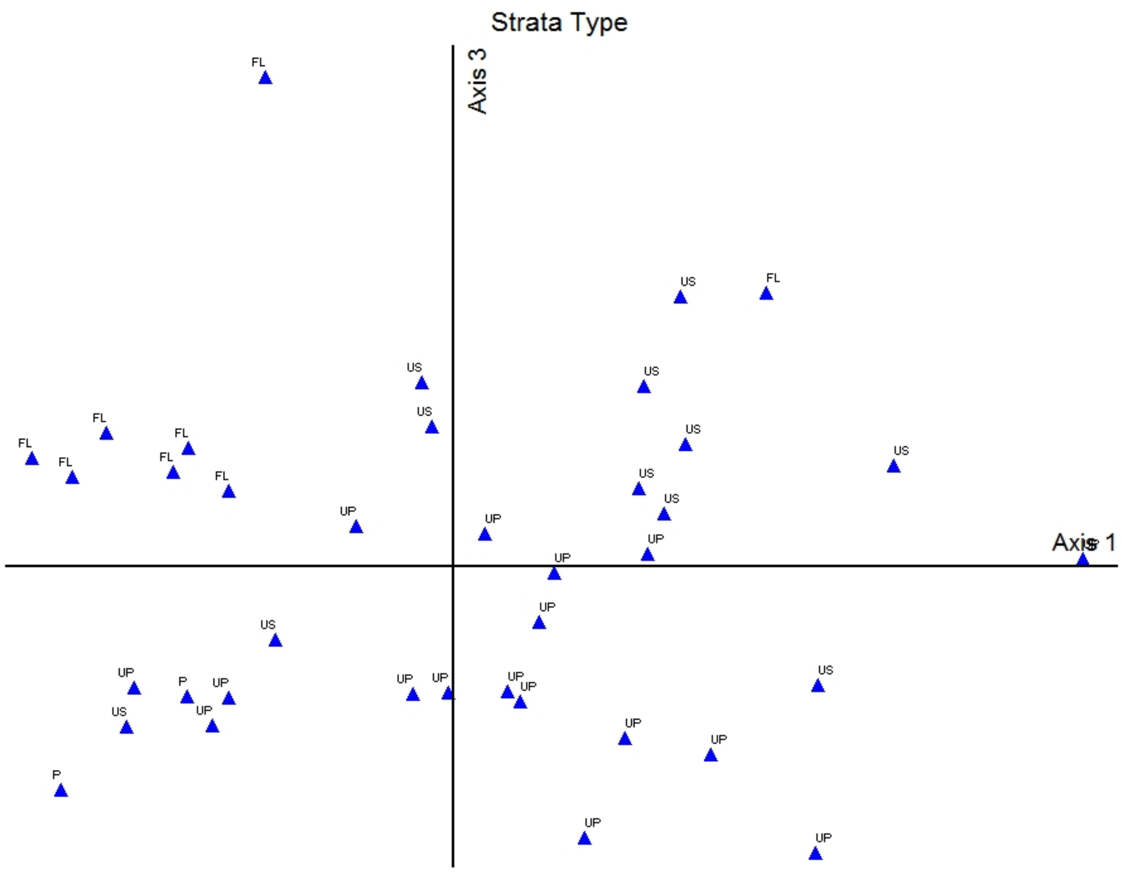


Figure 10: Graph of mean canopy height in meters where four vegetation sub-plots were pooled per site for all four strata types demonstrating a significant difference between canopy heights of strata (p = 0.001).

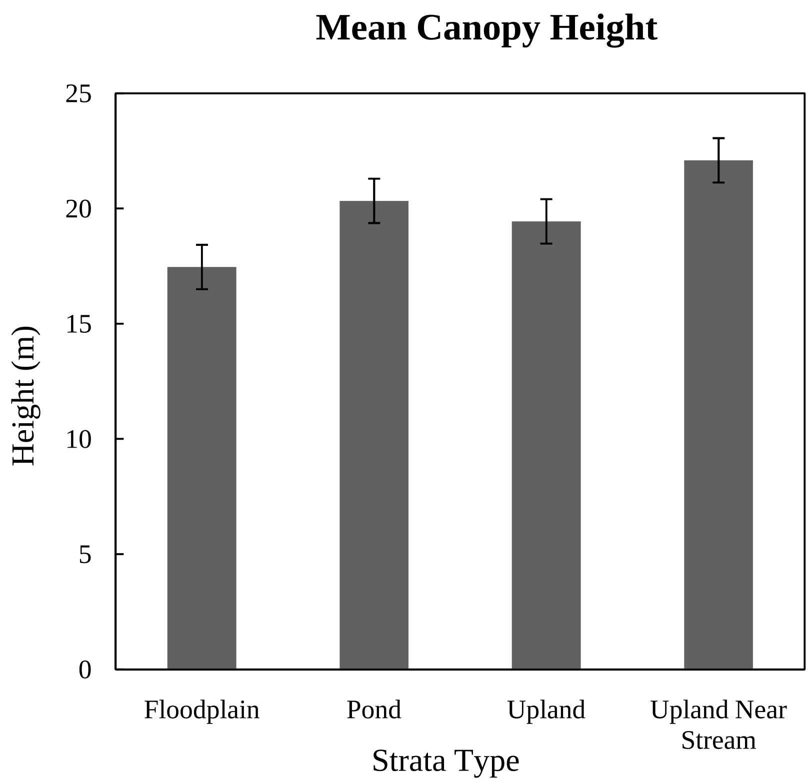


Figure 11: Graph of mean percent canopy cover of four vegetation sub-plots pooled per site for all four strata types demonstrating a significant difference of percent canopy cover between strata ($p > 0.0001$).

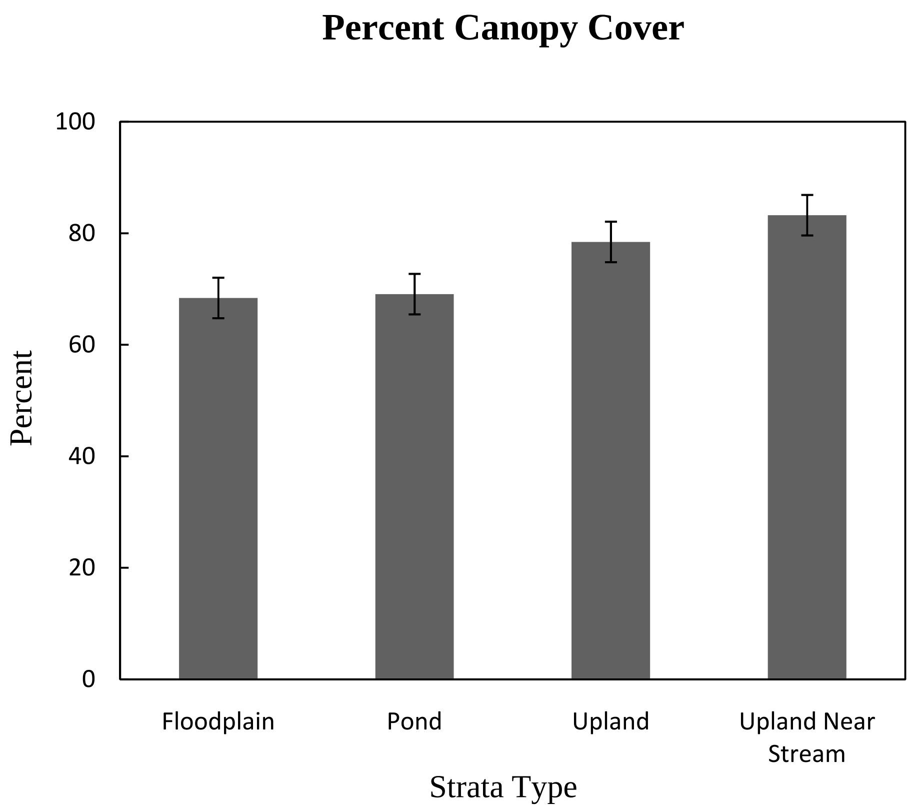


Figure 12: *Myotis septentrionalis* roost tree map of 8 bat capture locations and 21 located roost trees. Numbers indicate unique individual identification numbers of radio tagged bats depending on frequency of transmitter.

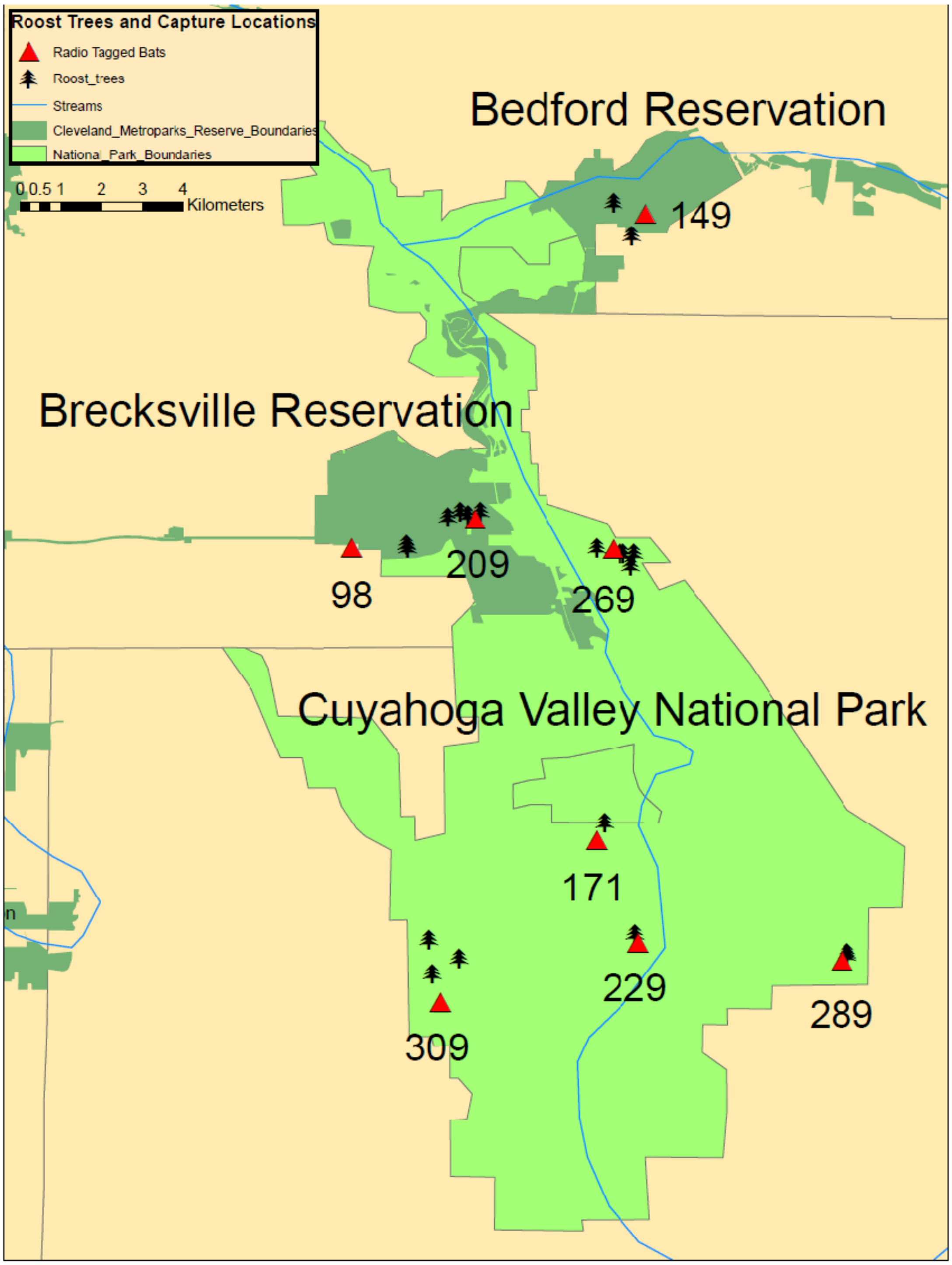


Figure 13: Photograph of *Myotis septentrionalis* roost tree of decay class 3.

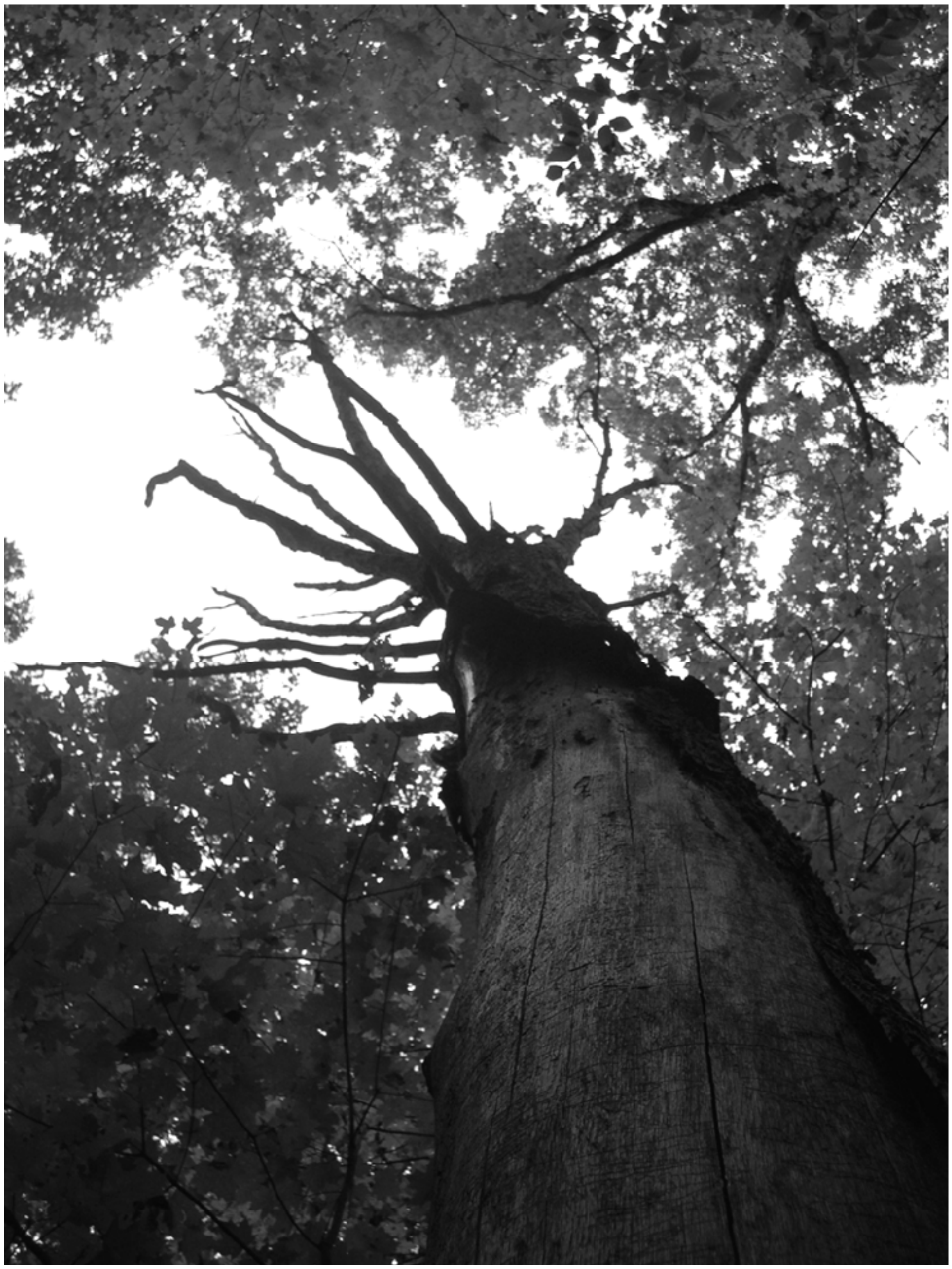


Figure 14: Photograph of broken tree where *Myotis septentrionalis* was located roosting in crevice.

Figure 15: Photograph of *Robinia pseudoacacia* (Black Locust) tree and Poison Ivy vine where adult and juvenile *Myotis septentrionalis* were located roosting behind. This is the first documentation of *M. septentrionalis* roosting behind a vine.

Figure 16: *Myotis septentrionalis* radio tagged bats # 209 and #269's roost trees and capture location demonstrating the range of 73–859 meters between roost trees and the and the greatest distance from capture location and roost tree in bat # 98 of 1,550 meters.

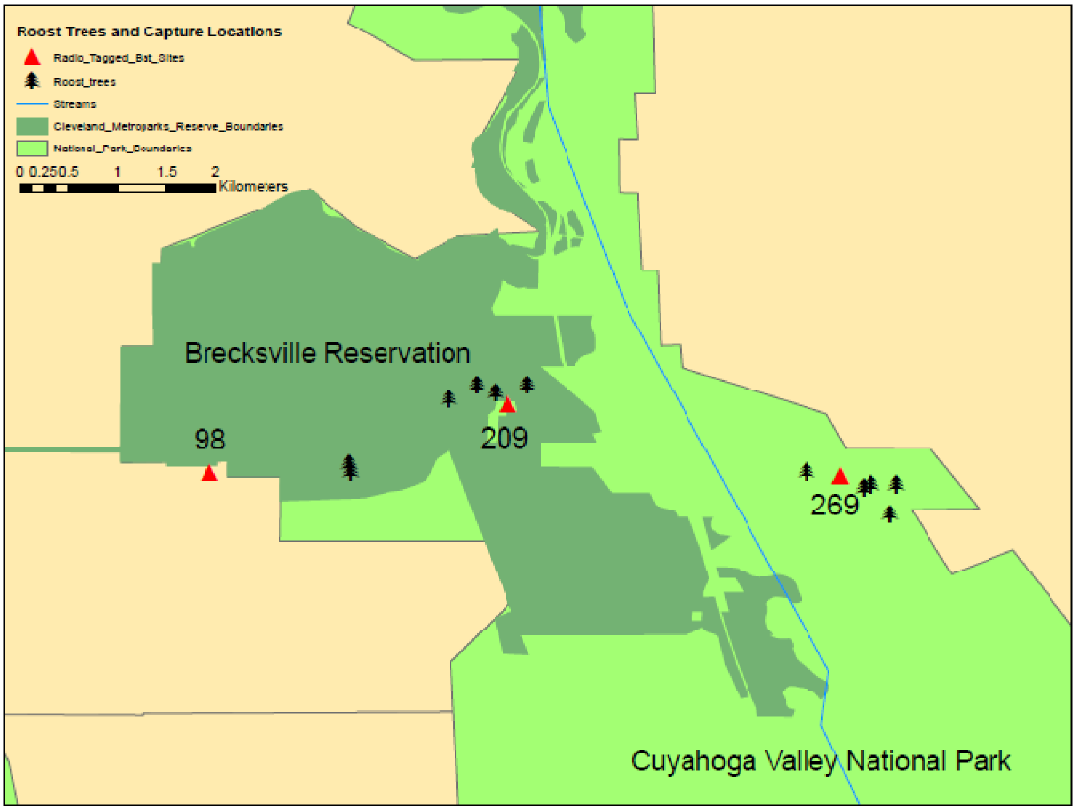


Figure 17: Graph of the number of adult and juvenile *Lasiurus borealis* captured by month (May–August, 2002–2003 combined) demonstrating the influx of *L. borealis* adults into the population.