Effect of Habitat Restoration on Bats in Metropolitan Areas

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INTRODUCTION

Urbanization and human encroachment are familiar issues in wildlife conservation. Cities reduce biodiversity through habitat destruction, invasion of introduced species, roads, pesticide use, and contamination of air and water (e.g. Adams and Dove 1989, Ceballos and Ehrlich 2002, Czech and Krausman 1997, Geggie and Fenton 1985, Gilbert 1989, Heynen 2003, Kurta and Teramino 1992). These problems are confounded as the United States human population expands. In July 2003, the U.S. Census Bureau predicted the population to be at 290 million people, which increases every 3 years by roughly 3 percent. Approximately 8.8 million acres of land were converted from rural or agricultural habitats into suburban and metropolitan centers during 1997-2001 (Natural Resources Conservation Service 2003). This drastic change of landscapes seriously affects a region by fragmenting and isolating its natural habitats. Various wildlife and plant species become increasingly susceptible to predation, pollution, disease, and competition, which will often restrict their presence from cities.

However, several authors have suggested that metropolitan areas are capable of producing adequate resources to sustain a conglomeration of flora and fauna (Adams and Dove 1989, Adams 1994, Dickman 1987, Gehrt and Chelsvig 2003, Leedy et al. 1978, ed. Laurie 1979, Raedeke and Raedeke 1995). In addition to the typical species seen in urban areas, which includes members of Emberizidae, Sciuridae, Columbidae, and Cricetidae, cities can also be inhabited by an assortment of other wildlife. For example, in the downtown region of the capital of Texas, there resides one of the largest Mexican free-tailed bat (*Tadarida brasiliensis*) colonies. Peregrine falcons and other birds of prey utilize skyscrapers and telephone poles for perches while searching for prey. In the southwest, some communities host peccaries, which use backyard trees to shade themselves (Adams 1994). A variety of wildlife species utilize available open spaces provided by city parks, bridges, cemeteries, right-of-ways, woodland lots, "rooftop gardens", wildlife refuges, and residential buildings. As long as food, cover, water, and space are available for wildlife, then it is possible for some wildlife to maintain viable populations within an urban environment. To provide these resources, there has been a recent movement to incorporate forest reserves within cities and to use green corridors to connect natural regions (Soulé et al. 1986, Adams and Dove 1989, Moskovits et al. 2002). Local governments are purchasing remnant woodlands and are creating parks and other recreational areas. Typical urban parks have sparsely distributed trees and are routinely mowed. Many also host a wide range of invasive/exotic species. In contrast, new metro parks attempt to resemble historical landscapes. Native vegetation is planted and prescribed burning plans are implemented. In general, riparian regions are chosen to link remaining natural habitat fragments because of the variety of benefits that it can offer. For example, maintenance of watersheds preserves water quality, provides aesthetic and recreational values, and controls erosion. Using rivers and streams as corridors effectively allows wildlife to travel between remaining habitat patches and thus ensures genetic diversity in wildlife populations. Ultimately, however, for greenways to be successful it is essential for the public to understand the goals and values of ecological planning and to support greenway concepts.

One of the largest conurbations in the country has undertaken the challenge of integrating greenways into an already heavily developed region. With the help of its residents and public and private organizations, Chicago, IL developed "a new force in urban conservation" known as the Chicago Wilderness (Moskovits et al. 2002). Citizens from the region united to form a comprehensive plan, which would preserve and connect greenways from southeastern Wisconsin to northeastern Illinois to western Indiana. Lake County, IL is a part of this area and is currently restoring approximately 10,000 hectares of land. The county has a population of 700,000 people with a 2.6% growth rate per year, and it is incorporating the principles of ecology into development decisions. Small parcels of land are being purchased by the county and are subsequently undergoing intensive habitat management. Land management includes invasive species control, fen restoration, tree and shrub clearing, supplemental seeding, reforestation, draintile disablement, prairie restoration, and resaturation of wetlands.

LITERATURE REVIEW

The social aspect of having access to forest preserves permits people to interact with their natural environment and to feel like they are contributing to maintaining a healthy ecosystem. With urban expansion, involving the public and retaining natural landscapes will become increasingly more important for wildlife. Habitat loss is one of the primary causes for wildlife population declines, so conserving and connecting wildlife habitat within human inhabited regions is essential to the propagation and movement of wildlife. As of yet, there have been no studies that have determined the success of restoring woodland wildlife habitat in an urban setting. However, there have been numerous publications that describe wildlife adapting to cities and remnant woodlots (e.g. Gaisler and Bauerova 1985-1986, Gaisler et al. 1998). If scientific research provided evidence that wildlife populations could be stimulated given appropriate habitats in an urban environment, then governments could be influenced to modify development decisions for the benefit of urban wildlife. Previous restoration studies have noted an increase or a neutral effect on plant and bird species after an area has undergone restoration (Rood et al. 2003, Yates et al. 2000, Wilkins et al. 2003, Lane and Raab 2002). However, none of the studies referred to mammal populations nor were the study sites within of a large city.

Lake County is an optimal site to study this phenomenon, because it currently is undergoing numerous restoration projects. The forest preserve district has been restoring land for 20 years but has substantially increased their efforts within the last nine years. In addition, Lake County currently has more endangered and threatened species than any other county in Illinois (approximately 50 species).

Bats (Chiroptera) were selected as the biological group to be monitored, because they have a wide range of desirable characteristics (Fenton 2003). Chiroptera is second only to rodents (Rodentia) in number of species, and they inhabit nearly every habitat type. Uncharacteristic of small mammals, bats typically have a long life span with some living up to 30 years in the wild (Keen and Hitchcock 1980, Altringham 1996). Since they are capable of flight, bats have the ability to navigate between urban structures and to discover new favorable environments. Although they are found in nearly every region, bats have relatively narrow habitat requirements for roosting and foraging needs (Tuttle 2004). This makes them an indicator species for urban environments (Fenton 2003). In

addition, bats are key to a variety of ecosystems because they help control insect populations, disperse fruits/seeds, and produce nutrient rich fertilizer.

Each level of a forest is effectively utilized by a particular species of bat. For example, red bats often forage close to forest edges while pipistrelles prefer the forest interior (Carter 2004, Amelon 2004). Probably the most convincing reason to study bats is due to the fact that approximately 56% of North American bat species are currently declining. Because bats are extremely valuable to the ecosystem in which humans live, it is essential to determine ways to prevent the extirpation of such a significant taxonomic group.

Bat population declines are a result of a variety of factors. Current research suggests that lack of adequate roosting structures may be primarily responsible for population declines (e.g. Barclay and Kurta 2004, O'Shea and Vaughn 1999). Roost selection is related to the bats' need for warm nursery sites. Several species, such as evening bats and *Myotis* spp., prefer older (a.k.a. taller and wider) trees that have exfoliating bark or cavities. These types of trees provide adequate amounts of space and have controlled microclimates, which is desirable in reproductive colonies. Suitable roosting trees are susceptible to natural or anthropogenic felling. Since roost tree sites have a direct effect on raising young, it is logical to see why felling tall, wide trees could negatively impact bat populations.

Pesticides sprayed on lawns and agricultural fields have also affected bats. When ingested, the chemicals accumulate in the body and can become toxic, especially during times of stress when the bats' fat reserves are depleted (Geluso et al. 1981, McCracken 1986). Insecticides can have a serious impact on bat populations, especially when considering their low reproductive output.

Kurta and Teramino (1992) suggested that urban areas were incapable of supporting the same amount of species diversity as rural regions. Geggie and Fenton (1985) believe a lack of insects in urban environments caused *Eptesicus fuscus* to spend more time foraging and less time at roosts, indicating lower reproductive success. Everette et al. (2001) found that *E. fuscus* roosted in the center of Detroit, MI but traveled nightly to forage in a nearby wildlife refuge. Thus cities may fail to provide the four basic necessities needed for survival: food, water, cover, and space. However, woodland restoration has the opportunity to provide bats with multiple roosting sites and with optimal foraging habitats.

Gehrt and Chelsvig (2003, 2004) studied bat activity patterns in several counties in the Chicago area and noted a positive relationship between bats and woodlands. It was observed that bat activity was positively related to distance between trees. They also found a variety of bat species utilizing urban landscapes. However, they did not determine the vegetation characteristics preferred by bats in wooded sections nor whether manipulation of the forest would affect bat occupancy. Their study and a similar project conducted in Britain (Walsh and Harris 1996) suggested that conditions at the local level were more important for bat occupation than features at the landscape level.

Many forest preserves in Lake County have a thick understory component in the forests, which can impede bat use. High densities of foliage (clutter) can negatively affect bats' ability to navigate (Brigham et al. 1997, Humes et al. 1999), thus reducing activity in the area. By removing dense understory and reducing basal area, we postulate that the area will encourage an assortment of bat species to inhabit the woods. Erickson

and West (2003) and Gehrt and Chelsvig (2003) observed a negative relationship between bat activity and tree density. Timber harvesting practices reduce basal area and create large open patches. Several studies have investigated the effect of various harvesting methods on bats (e.g. Grindal and Brigham 1999, Humes et al. 1999, Swystun et al. 2001) and have found increased activity at forest edges and in thinned stands. Menzel et al. (2002) observed more activity in forest gaps and in harvested bottomland forest than in unharvested bottomland forests. Timber harvest studies agree that spatial heterogeneity is important for bats (Grindal and Brigham 1999, Patriquin and Barclay 2003, Humes et al. 1999). Urbanization tends to create homogeneous landscapes, but restored metro parks may provide a composite of tree species and structure that is suitable to bats. Little attention has been aimed at determining if restoration projects will encourage inhabitation by once extirpated species or if it will stimulate bat activity. In an attempt to determine the effect of restoration on bats, we will complete the following objectives.

OBJECTIVES

1. Perform a comprehensive survey of the bat species located within Lake County, Illinois forest preserves during mid-summer to early autumn for 2 consecutive seasons.
   Working Hypothesis: Identified bat species will resemble species found in Hoffmeister (1989) and Gehrt and Chelsvig (2004).
2. Investigate the effect of restoration practices on forest structure.
   Working Hypothesis: Restored study sites will have higher vegetation diversity, lower basal area, thinner understory, and patchier canopy cover compared to non-restored sites.
3. Determine habitat characteristics optimal for bat foraging and roosting in woodlots.
   Working Hypothesis: Bat activity will have a correlation with habitats that host several large snags and have a low density understory.

METHODS

Study Areas

Lake County, IL is located northwest of Chicago, IL along the Wisconsin state line. The land consists of agriculture, industrial and residential property, savannahs, wetlands, and deciduous forests. The county has 39 forest preserves totaling more than 10.117 hectares. Nine parks were selected as study sites for this study. They include Sequoit Creek, Ethel's Woods, Marl Flats, Gander Mountain, Grant Woods, MacArthur Woods, Ryerson Woods, Wadsworth Savanna, and Wright Woods Forest Preserves. Sequoit Creek, Marl Flats, and Wright Woods will serve as the controls for the study. The control sites consist of approximately 243 hectares of forests that have not undergone any restoration management, such as brush clearing or tree removal. Wright Woods has been burned at portions of the site, but areas that were frequently burned were not included in the study. Sections of Wright Woods that were only burned once and at a low intensity

were not removed from the study. A low intensity burn failed to alter the understory brush, so it was deemed suitable as a control site.

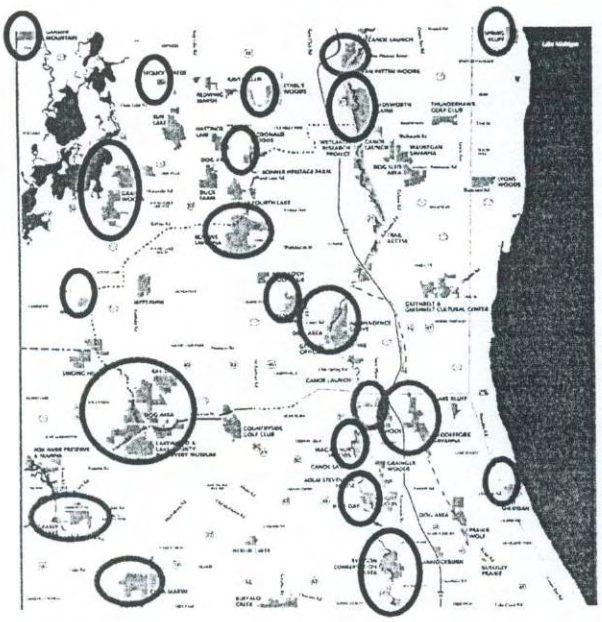

Figure 1. Map of Research Sites (circled blue) and Survey Sites (circled red) in Lake County, IL.

Sequoit Creek, a recent addition to the forest preserve system, has not undergone any restoration management. The 54-hectare park is a mixture of old crop fields, grasslands, wetlands, and woodlands. The forest covers 28% of the total area and it is bisected by a meandering stream. Hardwood species, in particular *Quercus* sp., dominate the forest's overstory. In wetland areas, boxelder (*Acer negundo*), is the primary tree species. The dense understory is almost singularly comprised of an invasive species known as buckthorn (*Cathartica* sp.).

Marl Flats Forest Preserve is 84 hectares of wetlands, grasslands, shrublands, and forests. Hydrological regimes heavily influence the landscape of this park. In addition to the presence of a lake, the western portion of the park is mostly covered by permanent wetlands, including a fen wetland. Ephemeral wetlands are found on the west side of the park and on the east side. Shrublands are prevalent around the larger, more permanent wetlands. Bottomland and upland forests cover 23 hectares of the park and are represented by trees species such as boxelders, elms, hickories, and oaks. Buckthorn is the main species found in the thick understory. Marl Flats is transected by a paved road and is surrounded by agriculture fields, residential housing and office buildings. It has not been restored, so invasive species and anthropogenic litter are present in high quantities.

Wright Woods is a control site located in the Des Plaines River floodplain. Most of the site is woodland habitat (217 hectares), consisting of upland, bottomland, and flatwood forests. This control site differs from the previous controls, because it does not have a significant buckthorn understory. Flooding restricts the presence of buckthorn, but promotes other species, which are more adapted to saturated conditions. Sugar maple (*Acer saccharum*), a native species, pervades the area and out-competes other tree species for sunlight. It is the most commonly found tree species in all age classes for Wright Woods. The absence of fire has encouraged the growth of the forest and has restricted the presence of prairies. Prairies cover 18 hectares of the forest preserve.

The remaining sites (Ethel's Woods, Gander Mountain, Grant Woods, MacArthur Woods, Ryerson Woods, and Wadsworth Savanna) have been restored to varying degrees. Each site was categorized as low, medium, or high restoration. Category selection was qualitatively assessed on the amount of tree thinning, the removal of buckthorn, and the frequency and intensity of prescribed burning. The areas are distributed throughout the county and represent the vegetative types found in the region.

Ethel's Woods is primarily woodland habitat, although sedge meadows, cultural grasslands, and marshes also dot the landscape. Ethel's Woods has had extensive habitat restoration, such as clearing, reforestation, high intensity prescribed burning, draintile disablement, supplemental seeding, and invasive species control. Portions of Ethel's Woods have not had any restoration attempts, so these sections will not be used in the study. However, 88 hectares of the forested region have been restored. These restored sections meet our category requirements and are considered to have a high level of restoration.

Gander Mountain is located in the northwest section of the county and adds 120 hectares to the forest preserves system. A little less than half of the park is dominated by forested habitat. The remaining area of the park consists of prairies, savannahs, and cultural grasses. There has been no large-scale removal of buckthorn or trees, but volunteers have attempted to remove them in small areas (usually less than 0.4 hectares). Although there has not been a substantial effort to mechanically remove the undergrowth, there have been numerous attempts at burning. The forested area has been burned frequently at varying intensities (mostly at a moderate level). Burnings have covered almost all of the woodlands and areas have been repeatedly burned since the year 1995. This has had a significant impact in top-killing of shrubs, so Gander Mountain is considered to have a low to moderate restoration level.

Grant Woods is a mixture of several habitat types and a large portion of the park is a state nature preserve. Its land cover ranges from bogs, marshes, and lakes to savannahs, prairies, forests, and cultural grasslands. Restored forests cover approximately 162 hectares. Large tracts of the park have undergone brush clearing, tree thinning, supplemental seeding, prairie restoration, and several prescribed burns ranging in intensity. Restoration projects, including prescribed burning, have been in progress since 1988 and continue to date. Grant Woods has a high level of restoration.

MacArthur Woods is located along the Des Plaines River and 96% of the park consists of forests. Upland forest is the most common type of woods on the property, comprising more than half of the total area. Flatwood forests and forests in the floodplain occupy the remaining woodland types. The non-forested areas (4%) are mainly cultural grasslands and streams. MacArthur Woods hosts a number of endangered and threatened species, in particular plant species.

Currently, MacArthur Woods is undergoing an extensive clearing project that will remove mature hickory and oak. The area is being reforested with native tree species, but there will not be any supplemental seeding. In conjunction with restoring the woodland habitat, a large draintile disablement project was initiated to rehydrate many of the wooded wetlands, especially in the flatwoods. Also, several areas in the upland forests have been repeatedly burned at high intensities since 1998. Deer browsing is being monitored to estimate their damage on foliage. When there is a noticeable effect on vegetation, then excess deer are harvested. Because large-scale management, excluding

burning, has only recently been implemented, the site is classified as having a moderate level of restoration.

The formation of Ryerson Woods began in 1966 when local residents donated land to the county. Ryerson Woods is part of the Illinois Nature Preserve System because of its high habitat quality. Vegetation types in this preserve include northern flatwood and upland forests. Ryerson Woods is located in the Des Plaines River floodplain. This park houses many state endangered and threatened species, including Veery Thrush (*Catharus fuscescens*), Cooper's hawk (*Accipiter cooperii*), and purple-fringed orchids (*Platanthera psycodes*). Ryerson Woods has been maintained over the years with minimal intervention. Deer have been harvested to minimize vegetation damage. According to Lake County Forest Preserve personnel, Ryerson Woods is considered to be at a high level of quality, so it essentially is serving as a goal for other restoration projects.

Wadsworth Savanna Forest Preserve is a component of the Des Plaines River Greenway. It surrounds a northwestern portion of the Des Plaines River and it encompasses 486 hectares. Wadsworth Savannah is an amalgamation of grasses and forests. Over the last ten years, the preserve has had multiple prescribed burnings with variable intensity. Restoration efforts have included supplemental seeding, timber clearing, snag creation, and invasive species removal. The understory of the forest is abundant with native grasses and shrubs and the overstory is a composite of oaks, ashes, hickories, aspens, and cherries. Wadsworth Savannah was assessed as a moderate quality site.

Bat Species Monitoring

Bats will be monitored from mid-June to early September in 2004 and during mid-May to end of August in 2005. Monitoring will include mist netting and recording echolocation passes using broadband ultrasonic bat detectors (AnaBat II detectors; Titley Electronics, Ballina, New South Wales, Australia) with audiocassette recorders (Optimus model, Radio Shack, Fort Worth, Texas, USA) (Kunz 1988). Bats will be opportunistically surveyed at additional forest preserves that are not part of the restoration study.

To determine the relationship between restored woodlands and bat activity, echolocation detectors will be randomly distributed throughout restored and non-restored forested regions. Sample points will be randomly chosen using ArcView 3.2. There will be four sample points per study site per sample night. Each study site will have 5 sample nights. The nine study sites will be randomly selected without replacement to determine order of sampling initially. Each site will be monitored within nine days of the other sites to ensure equal participation throughout the study season. One site will be monitored per sampling night. A transect, consisting of four recording devices each, will be derived from each sample point. Transect direction will be randomly determined, and they will be 30 m in length. Detectors will be placed 10 m apart. The four detectors within a transect will be positioned to face opposite directions. Transects located along the forest edge will have detectors oriented towards the woodlands interior. Overall, there will be a total of 45 sampling nights per field season. Comparison between restored and non-restored habitats will be measured using the mean number of passes emitted by foraging bats.

All detectors will be placed in a protective box and mounted ~1.5m above the ground. The detectors will be angled at 145 degrees from the ground. Detectors will be calibrated

before each field season and checked routinely throughout the season. The sensitivity will be fixed at 8 and the division ratio at 16. Global positioning system (GPS) will be used to obtain the coordinates for each sample point, which later will be incorporated into GIS.

The detectors and recorders will operate on a voice-activated approach. Once the equipment detects echolocation passes or insect noise, then it will record until the sound has dissipated. Detectors will be remain at each transect for four hours, beginning at sunset. The equipment will be checked after 1.5 hours of sampling to change batteries or tapes as needed. If there is equipment failure or inclement weather during sampling, the data will be removed from analysis. Computer software packages, AnaBat V Zero Crossing Analysis Interface Module and AnaBat6, will be used to analyze the call frequencies. Collected passes will be compared to a local reference call library and subsequently identified to genus and species, if possible (Gehrt and Chelsvig 2003, Gehrt and Chelsvig 2004).

Using AnaBat detectors is an effective way to gather data about elusive, small flying mammals, but it has caveats (Gannon, et al. 2003). Sampling with echolocation detectors provides a relative index of bat activity in a narrow region and is not indicative of bat abundance. In addition, there is a non-independence factor that is associated with collecting passes (Thomas and West 1989). It does not identify individual bats and identifying bats to species can prove to be extremely difficult (O'Farrell et al. 1999). In some instances, species identification is impossible although it is capable of identifying individuals to genus. In addition, due to species and individual variation of echolocation calls, some species may be either under- or over-represented (Barclay 1999). Atmospheric conditions, vegetation clutter, and detector settings can all influence echolocation passes collected (Barclay 1999, Broders et al. 2004, Fenton et al. 1998).

Capture and Handling

Bats will be captured using 4-tier mist nets (Kunz 1982). Nets will be placed in open areas, over watering holes, along paths, on the forest edge, and within the forest interior. Captured bats will be identified, weighed, measured, and sexed. In 2005, bats will be affixed with 0.35 g radio-transmitters (Holohil Systems Ltd., Carp, Ont., Canada). Transmitters will be glued to the back of each adult bat using Skinbond® adhesive. Before attachmant, the fur will be clipped between the scapulae. After the bat is identified and a transmitter is attached, then we will release the bat unharmed. All trapping locations will be documented using GPS and integrated into GIS.

Radio-telemetry Protocol

Radio-telemetry will be used to locate individual bat roosts. Bats will be radio-tracked daily for 7-10 consecutive days depending on equipment reliability. We will use Advanced Telemetry System R2000 receivers and three-element Yagi antennaes to locate bat roosts. For each roost site, we will record roost entrance height and aspect, tree height, tree dbh, decay stage, percentage of bark remaining, distance to nearest tree that is of equal height, canopy height, horizontal distance to edge/opening, distance to water, and percentage of canopy closure (Brigham and Barclay 1995).

Habitat Monitoring

Landscape elements were identified from digital orthophotos of each of the study sites. Cover types, such as water, grass, shrubs, or trees, were delineated using ArcView 3.2. Water and grass landscapes were classified as open spaces and woodland habitat was characterized as a land area having more than 75% tree cover. Stand structure was measured by obtaining tree species, tree height, tree diameter, basal area, and canopy cover. All trees were classified as having a diameter at breast height (dbh) > 7.6 cm. Shrubs have a dbh < 7.6 cm but were at least 1.5 m in height. Vegetation sampling was conducted at each of the random sample points for echolocation detection. Woody stems were identified to species and counted every 3 m along the quadrants (Blake and Karr 1987). Each quadrant was 30 m in length and 2 m in width.

Canopy cover will be estimated by using a spherical densiometer at 5 alternating points along each transect. In addition, the occurrence of foliage will be recorded every 5 m along the transects (Karr 1971) at the following height classifications: 1-3 m, 3-6 m, 6-9 m, 9-12 m, 12-15 m. A 14 m tall pole will be marked to indicate various height intervals. Within each height category, subsections will be drawn, each 0.25m in height. A subsection will be counted when foliage or stems touches the pole at that height. Center point quarter method will be used to measure tree species diversity, tree height, and basal area. The center point will be the sample point used for placing echolocation detectors. The size classes of trees are as follows: small trees ≥ 7.6 cm, medium trees ≥ 20 cm, large trees ≥ 33 cm, snags ≥ 12 cm.

Objects Measuring/Identifying	Method Used to Measure	Number of Samples
Bat Species	mist netting and echolocation detectors	dependent on captures
Bat Foraging	4 echolocation detectors/sample pt	20 total sampling pts/study site
Bat Roosting	radio-telemetry	dependent on captures
Tree Diversity	center point quarter method	16 total sampling pts/study site
Woody Stem Diversity	transect count	16 total sampling pts/study site
Clutter Density	foliage/stem count	16 total sampling pts/study site

Table 2. Methods for Studying Habitat Restoration and Its Effects on Bats.

Data Analyses

Objective 1.

All collected echolocation passes will be identified to species, if possible, using AnaBat V Zero Crossing Analysis Interface Module and AnaBat5 (version 5.7). The number and identity of species observed in each location will be recorded and the sampling points will be integrated into ArcView 3.2 (GIS). This data will be combined with results obtained from mistnetting, where bats were identified in hand.

Objective 2.

Because of variation in restoration levels, we will use one-way ANOVA and Fisher's pairwise comparison to determine a significant difference between restored and non-restored study sites. Study sites were ranked based on level of restoration.

Objective 3.

Bat use and habitat characteristics will be compared in woodlands of varying restoration levels. Because our hypothesis suggests there will be a relationship between

level of restoration and number of bat passes, we will use linear regression to test statistical significance. Akeike's information criteria (AIC) will be used to determine suitable variables for our habitat model.

RESULTS

Forest preserves were monitored between June 15-September 10, 2004 and between May 20-August 31, 2005. Within each forest preserve, twenty transects were randomly located for placement of echolocation detectors. Transect locations were the same for both years. Each forest preserve was sampled 10 nights, which culminated in a total of 4,284 hours of detection. In 2004, we collected 4,084 bat echolocation passes. Data from 2005 has been transcribed to a computer and is currently undergoing analysis. The mean number of bat passes from each forest preserve was compared to site restoration using one-way ANOVA and Fisher's LSD pairwise comparison (See Figure 1). All bat activity data was double log-transformed and sites were ranked by level of restoration. Bat activity was significantly higher at Grant Woods and Ethel's Woods, sites with high restoration, and lower at Sequoit Creek, an unrestored forest preserve (p-value <0.05). There was no significant difference amongst low to moderately restored sites.

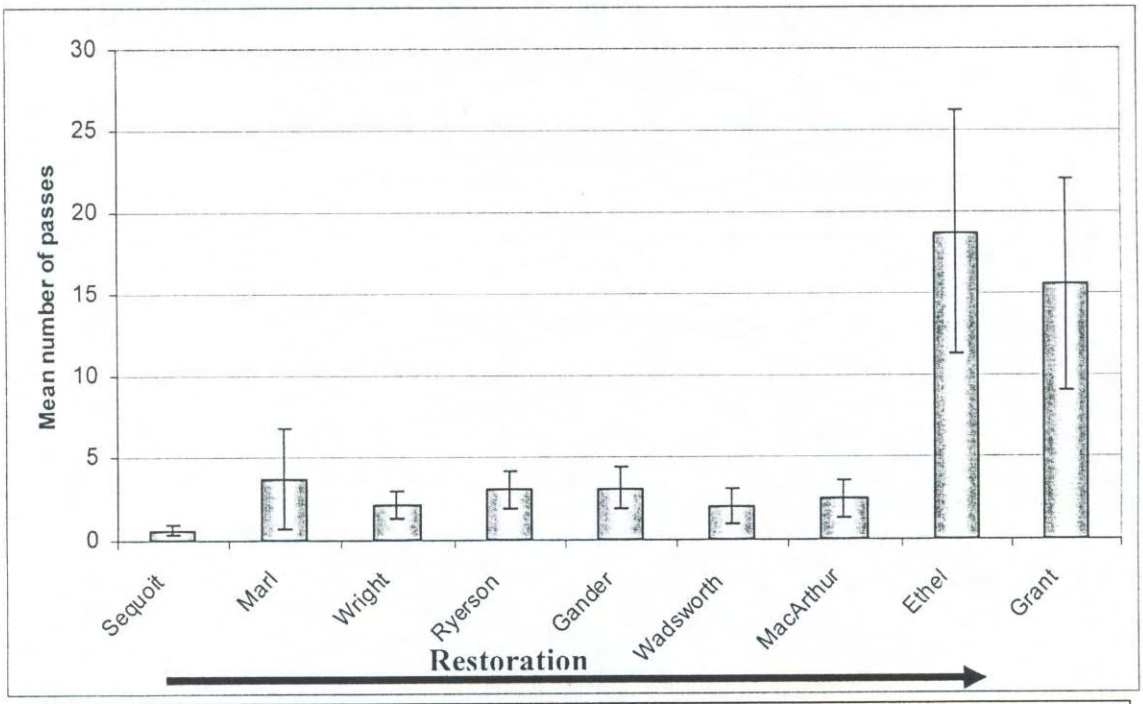

Figure 1. Bat activity in Lake County Forest Preserves, IL, which have various levels of restoration (2004).

Vegetation data was gathered from 16 of the 20 transects in each forest preserve. Tree density, shrub density, and clutter were compared between sites using one-way ANOVA and Fisher's LSD pairwise comparison. Subsequently, vegetative variables were individually compared to bat activity using simple linear regression.

Tree density was measured using the point-centred quarter method. To be counted, trees had a minimum 7.6 cm DBH. Between sites, tree density was significantly different at Grant Woods. Of all the forest preserves, Grant Woods had the lowest tree density. Tree density did not have a strong relationship with level of restoration (Refer to Figure 2). However, bat activity showed a slight inverse relationship with density of trees (See Figure 3). With an increase in tree density, bat activity decreased (R-sq=54.4%).

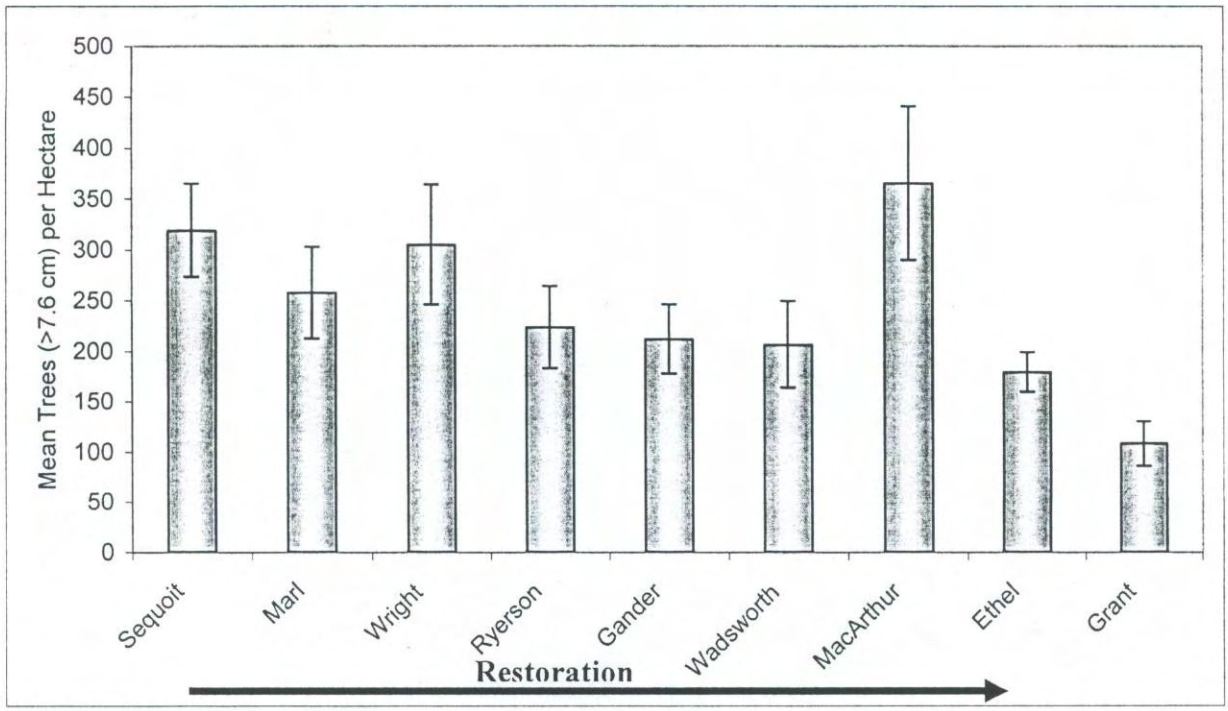

Figure 2. Comparison of tree density between Lake County Forest Preserves, IL (2005).

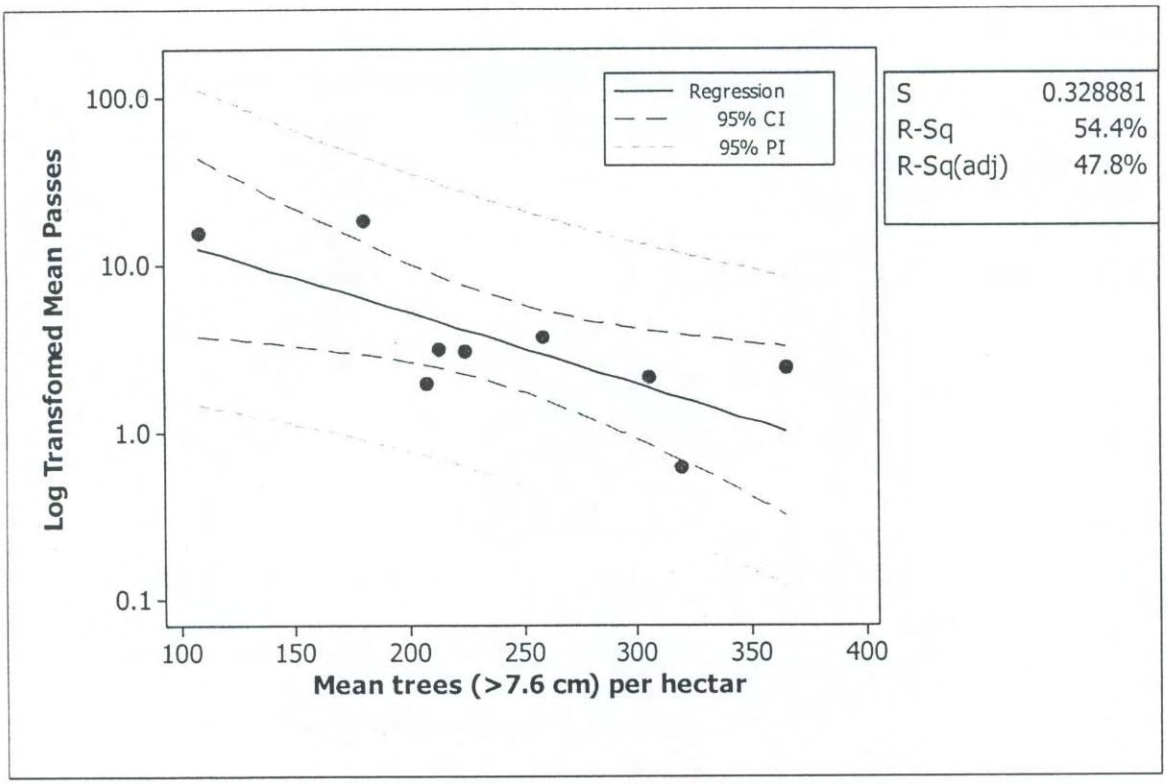

Figure 3. Regression of bat activity and tree density (2005).

Shrub density was significantly higher at Marl Flats and Sequoit Creek, sites with no restoration (Refer to Figure 4). Grant Woods's shrub density was significantly lower than any other site. When compared to bat activity, there was a strong correlation between shrub density and activity levels (R-sq=87.3%). With a decrease in shrub density, there was a significant increase in bat activity (See Figure 5).

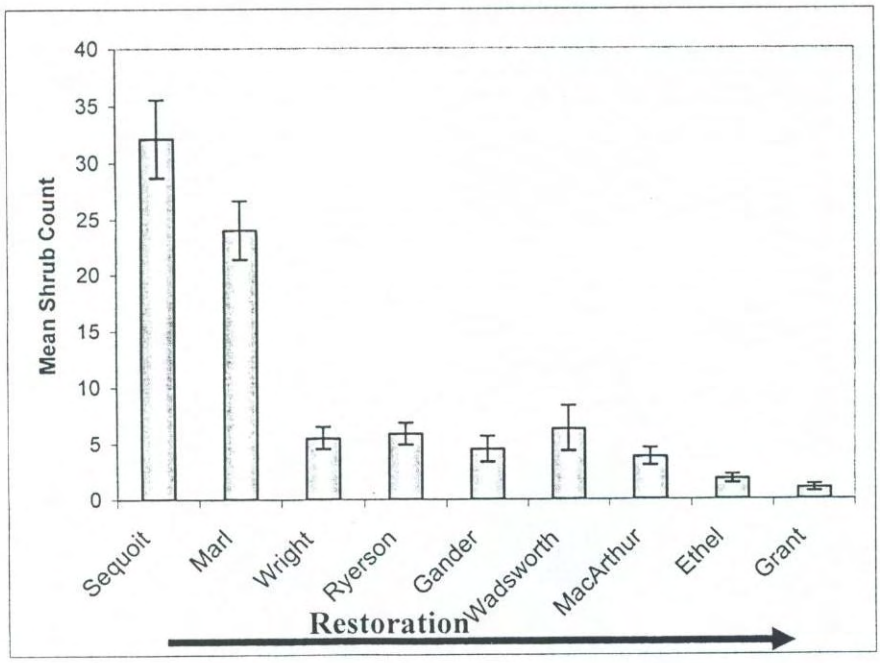

Figure 4. Comparison of shrub density between Lake County Forest Preserves, IL (2005).

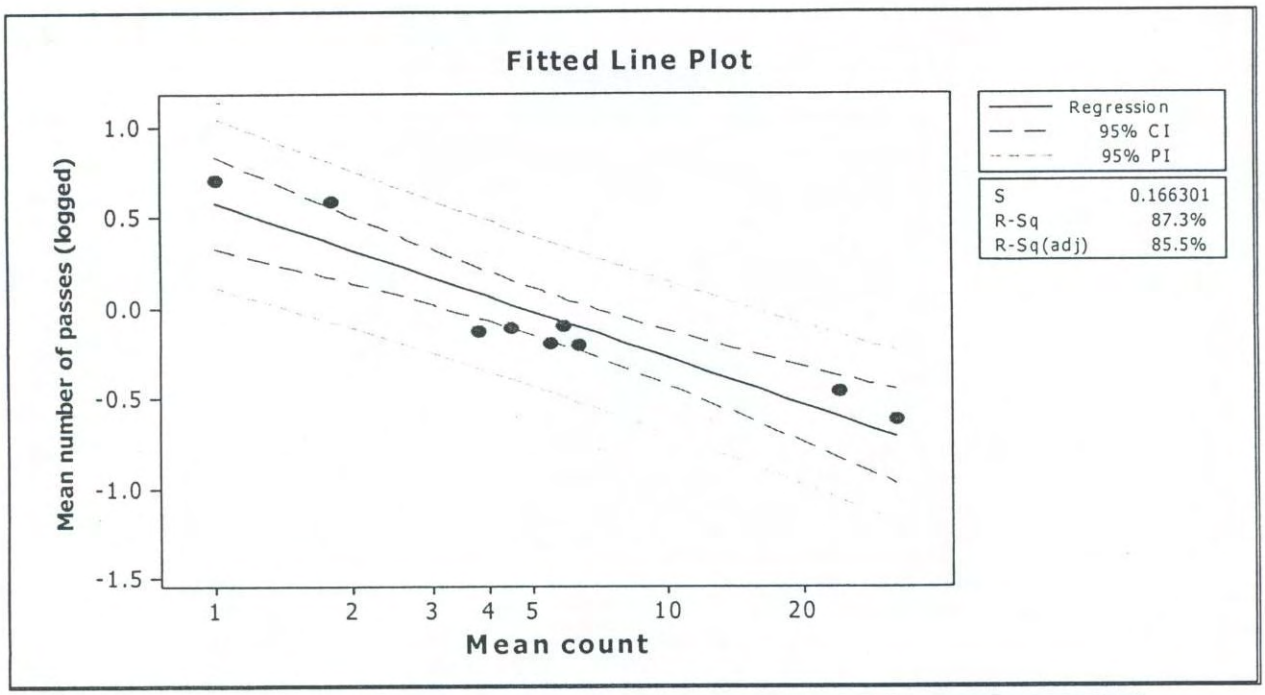

Figure 5. Regression of bat activity and shrub counts (2005).

Overall, clutter decreased with an increase in restoration level (See Figure 6). Each height interval was measured and preliminarily analyzed. Because of interaction terms, further analysis is needed. However, the cumulative effect of all heights was a general decline in clutter with increase in level of restoration. Bat activity was strongly related to the quantity of clutter (Refer to Figure 7; R-sq=71.9%). As clutter decreased, bat activity levels increased. Further analysis is needed to determine the height interval most likely associated with bats.

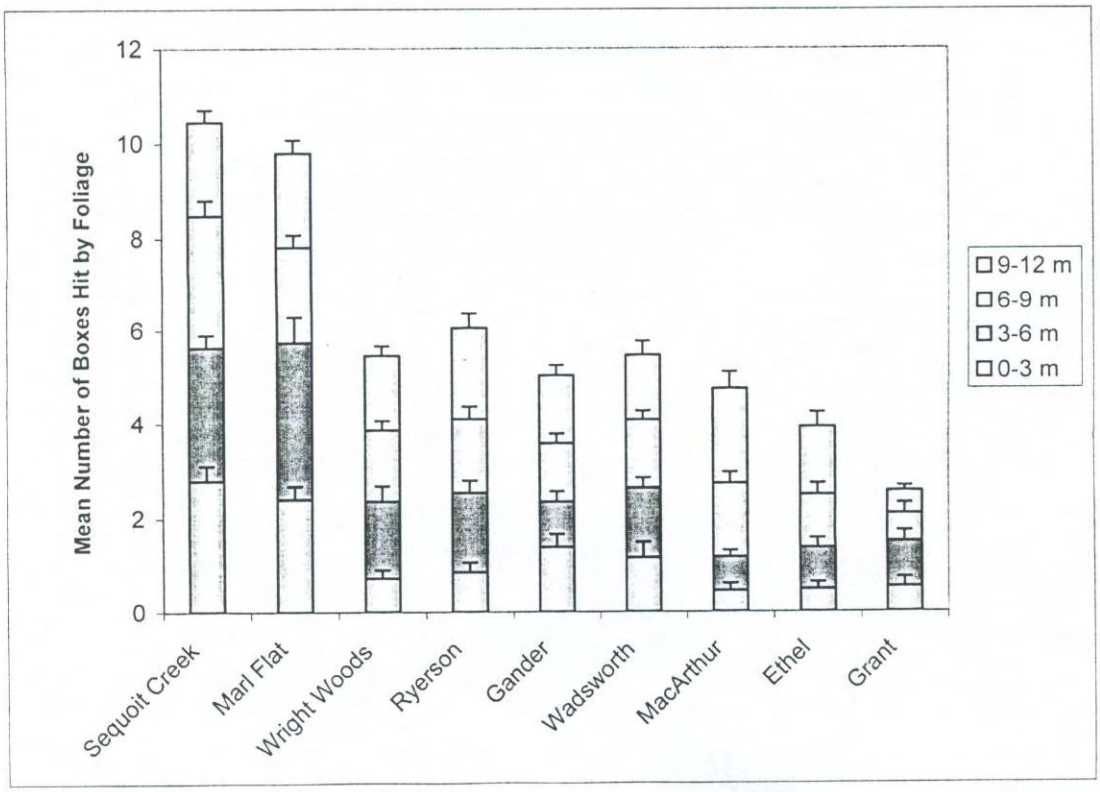

Figure 6. Relationship between clutter and various levels of restoration in Lake County Forest Preserves (2005).

In 2004 and 2005, bats were captured and identified to species. Species captured included red bats, little brown bats, silver-haired bats, big brown bats, and northern myotis. In 2005, we attached radio-transmitters to 2 big brown bats, 9 red bats, and 5 northern myotis. A total of 44 roosts were identified to a particular habitat type. Four bats (3 red bats and 1 big brown) were never located to a roost. Thirteen roosts were found in trees on residential lawns. All residential areas inhabited by bats were in close proximity to a forest preserve. Four roosts were in restored portions of a forest preserve and 21 roosts were located in unrestored areas on both public and private land. Red bats had an average of 5.2 roosts per bat. Northern myotis averaged 2.4 roosts per bat. One big brown bat never changed from its original roost. All radio-telemetry data is currently being compiled and will be subsequently analyzed.

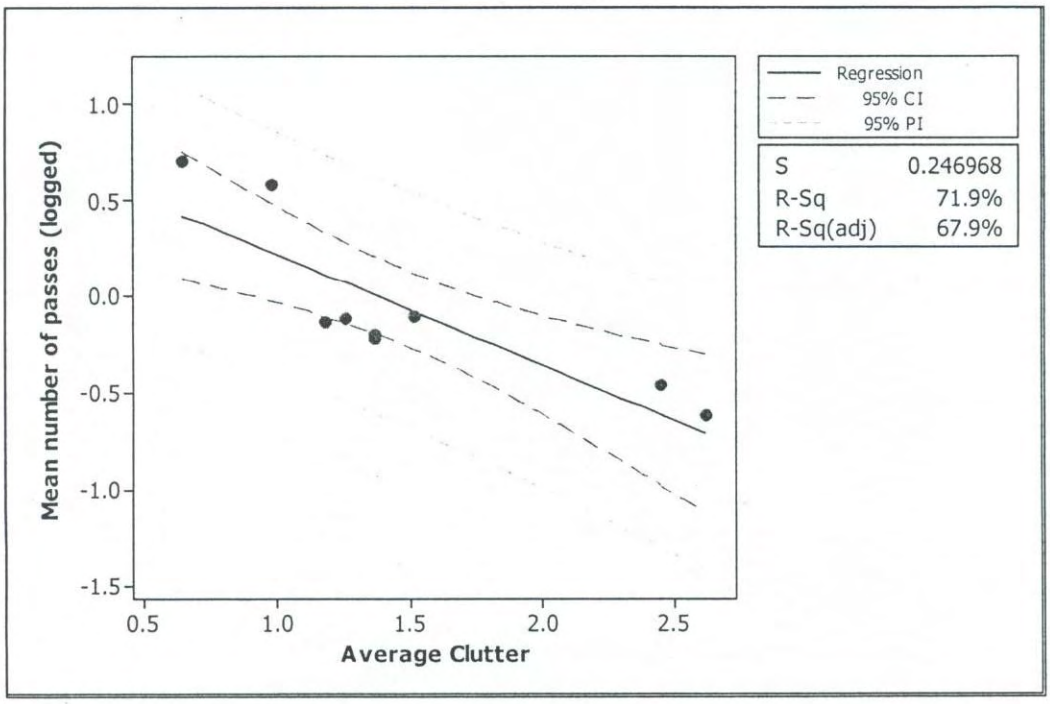

Figure 7. Regression of clutter and bat activity (2005).

DISCUSSION

From these preliminary results, restoration practices are affecting the structure of forests. With an increase in restoration, the forest understory is reduced. Study sites with high levels of restoration have had large quantities of invasive shrub species removed. Shrub removal lowers the amount of clutter at lower height intervals (e.g. 0-9 m). With less shrub vegetation, there are more open areas and fewer obstacles for bat flight. Thus, there is an increase in bat activity at sites with the lowest shrub and clutter densities. Sites with a dense understory have the lowest levels of bat activity. Moderately restored sites do not have high bat activity, but they may be important for particular species or for other bat behavior, such as roosting. It is important to note that bats were observed in all forest preserves, regardless of restoration level. Radio-telemetry data suggests that bats

are using residential, restored and non-restored habitats. However, further analysis is needed to determine a relationship between land use, habitat preference, and roost selection. Multi-variate analysis is needed to determine which variables are more important in bat habitat selection. We will also look at microhabitat variation within sites and at species-specific variation within and between sites. All work will be encompassed into a master's thesis.

LITERATURE CITED

Acharya, Lalita and M. B. Fenton. 1999. Bat attacks and moth defensive behaviour around street lights. Canadian Journal of Zoology 77: 27-33.

Adam, M.D. and J.P. Hayes. 2000. Use of bridges as night roosts by bats in the Oregon Coast Range. Journal of Mammalogy 81(2): 402-407.

Adams, L. W. 1994. Urban Wildlife Habitats: A Landscape Perspective. University of Minnesota Press, Minneapolis, MN, USA.

Adams, Lowell and Louise Dove. 1989. Wildlife reserves and corridors in the urban environment: a guide to ecological landscape planning and resource conservation. National Institute for Urban Wildlife. Columbia, Maryland, USA.

Agosta, S.J. and D. Morton. 2003. Diet of the big brown bat, *Eptesicus fuscus*, from Pennslyvania and western Maryland. Northeastern Naturalist 10(1): 89-104.

Altringham, J. D. 1996. Bats: biology and behaviour. Oxford University Press, London, United Kingdom.

Amelon, Sybill et al. 2004. Foraging habitat use by forest bats in the central hardwood region. In 2nd Bats and Forests Symposium and Workshop. Hot Springs, Arkansas.

Anthony, Edythe and Thomas Kunz. 1977. Feeding strategies of the little brown bat, *Myotis lucifugus*, in southern New Hampshire. Ecology 58 (4): 775-786.

Arnett, E.B. and J.P. Hayes. 2000. Bat use of roosting boxes installed under flat-bottom bridges in western Oregon. Wildlife Society Bulletin 28(4): 890-894.

Barclay, Robert. 1999. Bats are not birds-a cautionary note on using echolocation calls to identify bats: a comment. Journal of Mammalogy 80 (1): 290-296.

Barclay, Robert and Allen Kurta. 2004. Day roosting ecology of bark and cavity roosting forest bats-synthesis. In 2nd Bats and Forest Symposium and Workshop. Hot Springs, Arkansas.

Blake, John and James Karr. 1987. Breeding birds of isolated woodlots: area and habitat relationships. Ecology 68 (6): 1724-1734.

Brigham, R. M. and R. Barclay. 1995. Bats and Forests. In: Barclay, R.M.R., Brigham, R.M. (Eds.), Bats and Forests Symposium. Victoria and British Columbia, Canada, pp. xi-xiv.

Brigham, R.M., et al. 1997. The influence of structural clutter on activity patterns of insectivorous bats. Canadian Journal of Zoology 75: 131-136.

Britzke, Eric et al. 2003. Indian bat, *Myotis sodalis*, maternity roosts in the southern United States. Southeastern Naturalist 2 (2): 235-242.

Broders, Hugh, et al. 2004. Effects of clutter on echolocation call structure of *Myotis septentrionalis* and *M. lucifugus*. Journal of Mammalogy 85 (2): 273-281.

Campbell, Lori et al. 1996. Conservation of bats in managed forests: use of roosts by *Lasionycteris noctivagans*. Journal of Mammalogy 77 (4): 976-984.

Carter, Timothy et al. 2004. Day-roosting ecology of North American foliage-roosting bats. In 2nd Bats and Forest Symposium and Workshop. Hot Springs, Arkansas.

Ceballos, G. and P. R. Ehrlich. 2002. Mammal population losses and the extinction crisis. Science 296: 904-907.

Cryan, Paul, et al. 2001. Roosting habits of four bat species in the Black Hills of South Dakota. Acta Chiropterologica 3 (1): 43-52.

Czech, Brian amd Paul Krausman. 1997. Distribution and causation of species endangerment in the United States. Science 277 (5329): 1116-1117.

Dickman, C. R. 1987. Habitat fragmentation and vertebrate species richness in an urban environment. Journal of Applied Ecology 24(2): 337-351.

Easterla, D. A. 1973. Ecology of the 18 species of Chiroptera at Big Bend National Park, Texas. Part II. Northwest Missouri State Univ. Studies 34: 54-165.

Erickson, Janet and Stephen West. 2003. Associations of bats with local structure and landscape features of forested stands in western Oregon and Washington. Biological Conservation 109: 95-102.

Everette, A., et al. 2001. Bat use of a high-plains urban wildlife refuge. Wildlife Society Bulletin. 29(3): 967-973.

Fenton, M. B et al. 1998. Compromises: sound frequencies used in echolocation by aerial-feeding bats. Can. J. Zool. 76: 1174-1182.

Fenton, M. B. 1995. Constraint and flexibility-bats as predators, bats as prey. Pages 277-289. In Paul Racey and Susan Swift, eds. Symposia of the Zoological Society of London No. 67, Clarendon Press, Oxford.

Fenton, M. B. 2003. Science and the conservation of bats: where to next? Wildlife Society Bulletin 31 (1): 6-15.

Fenton, M. B. 1982. Echolocation, insect hearing, and feeding ecology of insectivorous bats. Pages 261-285. In Thomas Kunz, ed. Ecology of Bats. Plenum Press, New York and London.

Fenton, M. B., et al. 1995. Signal strength, timing, and self-deafening: the evolution of echolocation in bats. Paleobiology 21 (2): 229-242.

Findley, James. 1993. Bats: a community perspective. Cambridge University Press, Great Britain.

Gaisler, J. et al. 1998. Habitat preference and flight activity of bats in a city. J. Zool., Lond. 244: 439-445.

Gaisler, J. and Z. Bauerova. 1985-1986. The life of bats in a city. Myotis 23-24: 209-215.

Gannon, William, Richard Sherwin, and Shauna Haymond. 2003. On the importance of articulating assumptions when conducting acoustic studies of habitat use by bats. Wildlife Society Bulletin 31 (1): 45-61.

Geggie, J. F. and M. B. Fenton. 1985. A comparison of foraging by *Eptesicus fuscus* (Chiroptera: Vespertilionidae) in urban and rural environments. Canadian Journal of Zoology 63: 263-267.

Gehrt, Stanley and James Chelsvig. 2004. Species-specific patterns of bat activity in an urban landscape. Ecological Applications 14(2): 625-635.

Gehrt, Stanley and James Chelsvig. 2003. Bat activity in an urban landscape: patterns at the landscape and microhabitat scale. Ecological Applications 13(4): 939-950.

Geluso, K.N., S. Altenbach, and D.E. Wilson. 1981. Organochlorine residues in young Mexican free-tailed bats from several roosts. Amer. Midl. Nat. 105:249-257

Gilbert, O. L. 1989. The ecology of urban habitats. Chapman and Hall, New York, New York, USA.

Griffin, Donald. 1958. Listening in the dark. Yale University Press, United States.

Grindal, Scott and R. Mark Brigham. 1999. Impacts of forest harvesting on habitat use by foraging insectivorous bats at different spatial scales. Ecoscience 6(1): 25-34.

Heynen, Nikolas. 2003. The scalar production of injustice within the urban forest. Antipode: 981-998.

Hoffmeister, D. F. 1989. Mammals of Illinois. University of Illinois Press, Chicago, Illinois, USA.

Humes, M.L. et al. 1999. Bat activity in thinned, unthinned, and old-growth forests in western Oregon. Journal of Wildlife Management 63: 553-561.

Hurst, Tracy and Michael Lacki. 1999. Roost selection, population size and habitat use by a colony of Rafinesque's big-eared bats (*Corynorhinus rafinesquii*). American Midland Naturalist 142: 363-371.

James, Frances and Henry Shugart, Jr. 1970. A quantitative method of habitat description. Audubon Field Notes 24 (6): 727-736.

Kalko, Elisabeth. 1995. Echolocation and foraging in emballonurid bats. Pages 259-273. In Paul Racey and Susan Swift, eds. Symposia of the Zoological Society of London No. 67, Clarendon Press, Oxford.

Karr, James. 1971. Structure of avian communities in selected Panama and Illinois habitats. Ecological Monographs 41(3): 207-233.

Keen, R. and H. B. Hitchcock. 1980. Survival and longevity of the little brown bat (*Myotis lucifugus*) in southeastern Ontario. Journal of Mammalogy 61: 1-7.

Kunz, Thomas. 1982. Roosting ecology of bats. Pages 1-55. In Thomas Kunz, ed. Ecology of Bats. Plenum Press, New York.

Kurta, Allen and Joseph Teramino. 1992. Bat community structure in an urban park. Ecography 15: 257-261.

Lane, Cynthia and Sara Raab. 2002. Great River greening: a case study in urban woodland restoration. Ecological Restoration 20 (4): 243-251.

Laurie, Ian (ed.). 1979. Nature in cities: the natural environment in the design and development of urban green space. John Wiley & Sons, Chichester, New York.

Lee, Jay and David Wong. 2001. Statistical Analysis with ArcView GIS. John Wiley and Sons, Inc., New York.

Leedy, Daniel, Robert Maestro, and Thomas Franklin. 1978. Planning for wildlife in cities and suburbs. Report for U. S. Fish and Wildlife Service, contract number 14-16-0008-2040.

McCracken, Gary. 1986. Why are we losing our Mexican free-tailed bats? Bats 3 (3): 1-2.

Menzel, Michael, et al. 2002. Effects of group selection silviculture in bottomland hardwoods on the spatial activity patterns of bats. Forest Ecology and Management 162: 209-218.

Moskovits, Debra, et al. 2002. Chicago Wilderness: a new force in urban conservation. Annals of the Botanical Garden 89: 153-163.

Natural Resources Conservation Service. 2003. Urbanization and development of rural land. Natural Resources Inventory Annual NRI.

Nowak, Ronald. 1994. Walker's bats of the world. John Hopkins University Press, Baltimore, Maryland, USA.

O'Farrell, M. J., B. W. Miller, and W.L. Gannon. 1999. Qualitative identification of free-flying bats using the Anabat detector. Journal of Mammalogy 80: 11-23.

O'Shea, T. J. and T. A. Vaughn. 1999. Population changes in bats from central Arizona: 1972 and 1997. Southwestern Naturalist 44: 495-500.

Patriquin, Krista and Robert Barclay. 2003. Foraging by bats in cleared, thinned and unharvested boreal forest. Journal of Applied Ecology 40: 646-657.

Raedeke, Dorothy and Kenneth Raedeke. 1995. Wildlife habitat designs in urban forest landscapes. In Urban forest landscapes: integrating multidisciplinary perspectives. ed. by Gordon Bradley. University of Washington Press, Seattle, OR, USA and London, UK.

Robbins, Lynn et al. 2004. Fall, winter, and spring roosting behavior of eastern red bats (*Lasiurus borealis*) and evening bats (*Nycticieus humeralis*). In 2nd Bats and Forests Symposium and Workshop. Hot Springs, Arkansas.

Rood, Stewart, et al. 2003. Flows for floodplain forests: a successful riparian restoration. BioScience 53 (7): 647-656.

Schnitzler, Hans-Ulrich and Elisabeth K. V. Kalko. 1998. How echolocating bats search for food. Pages 183-204. In Thomas Kunz and Paul Racey, eds. Bat Biology and Conservation. Smithsonian Institution Press, Washington and London.

Schulz, Martin. 2000. Diet and foraging behavior of the golden-tipped bat, *Kerivoula papuensis*: a spider specialist? Journal of Mammalogy 81 (4): 948-957.

Soulé, M. E. 1986. Conservation biology: the science of scarcity and diversity. Sinauer Associates, Inc., Publishers, Sunderland, Massachussetts, 584 pp.

Swystun, Michael, et al. 2001. The influence of residual tree patch isolation on habitat use by bats in central British Columbia. Acta Chiropterologica 3(2): 197-201.

Thomas, D. W. and S. D. West. 1989. Sampling methods for bats. In A. B. Carey and L. F. Ruggiero (ed.). Wildlife-habitat relationships: sampling procedures for Pacific Northwest vertebrates. U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, General Technical Report PNW-243, Portland, Oregon.

Tuttle, Merlin. 2004. Ecological Role of Bats in Forest Ecosystems. In 2nd Bats and Forests Symposium and Workshop. Hot Springs, Arkansas.

Tuttle, Merlin. 1976a. Population ecology of the gray bat (*Myotis griescens*): philopatry, timing, and patterns of movement, weight loss during migration, and seasonal adaptive strategies. Occas. Pap. Mus. Nat. Hist. Univ. Kansas 54: 38.

Verboom, B. 1997. The use of edge habitats by commuting and foraging bats. M.S. thesis.

Walsh, A.L. and S. Harris. 1996. Foraging habitat preferences of vespertilionid bats in Britain. Journal of Applied Ecology 33: 508-518.

Wilkins, S., D. Keith, and P. Adam. 2003. Measuring success: evaluating the restoration of a grassy eucalypt woodland on the Cumberland Plain, Sydney, Australia. Restoration Ecology 11 (4): 489-503.

Yates, C. J., R. J. Hobbs, and L. Atkins. 2000. Establishment of perennial shrub and tree species in degraded *Eucalyptus salmonophloia* (Salmon Gum) remnant woodlands: effects of restoration treatments. Restoration Ecology 8 (2): 135-143.