A MUTLIDISCIPLINARY APPROACH TO BAT CONSERVATION IN THE OAK OPENINGS REGION OF NORTHWEST OHIO

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ABSTRACT

Dr. Karen V. Root, Advisor

The Oak Openings Region of Northwest Ohio is unique in terms of the flora and fauna that exists within a relatively fragmented area. It contains more rare and endangered plant species than any other area of its size in Ohio and much is known about a number of terrestrial and aquatic animals in the area as well. One group of animals that has not been studied is that of the order Chiroptera, bats. Bats are threatened on many fronts, from the effects of human persecution, to habitat loss, to the recent effects of a deadly fungus, White Nose Syndrome. The Oak Openings is an ideal area to study this group of animals because of its unique composition that includes many natural areas, including that of oak savannas, within an urban/suburban/agricultural matrix. My research objectives included 1) developing a spatially explicit habitat model of bat presence within protected areas of the oak openings region 2) determine the relative difference in activity and presence between forest and savanna sites within the oak openings region and 3) determine the knowledge and attitudes people of the area hold in regards to bats and then develop educational opportunities to increase knowledge and attitudes about bats.

Ecological knowledge regarding bats within protected areas, and potential habitat needs, is lacking so I began by acoustically surveying for bats using the Anabat bat detector to determine bat presence within protected areas. I then developed Maxent species distribution models for each of seven species of bats. These models were then tested using citizen science collected data. Models for all seven species performed well when tested with this data, demonstrating the use of Maxent modeling and citizen science collected data for refinement and testing of data sets. With these models I was able to determine areas of potential importance

both within and outside of current protected areas as well as critical habitat characteristics for bat presence. Second, I again used Anabat acoustic devices to survey bat presence and relative activity in forest and savanna sites. Differences among these sites were apparent but differed across species. Bat species richness was not higher at forest or savanna sites, but results demonstrate that savannas are potentially used for foraging, commuting and roosting.

Third, I developed surveys that investigated the knowledge about and attitudes towards bats that the human inhabitants of the Oak Openings Region have towards bats to determine if a relationship exists between these two constructs. From the information gained from these surveys, and the knowledge gained from the ecological portion of this work, I developed and initiated educational outreach about bats. I then investigated the differences in gains in knowledge and attitudes between different types of outreach. This resulted in a multidisciplinary and holistic approach to bat conservation in the Oak Openings Region.

This work is dedicated to my husband, Allyn (1977-2012).

Only through his love, support, and dedication

was any of this possible.

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REVIEW INTRODUCTION

The Oak Openings of Northwest Ohio is a unique mix of natural, semi-natural and human made features in which no study of bats has ever been systematically conducted. Bats are facing a current extinction crisis as are many other terrestrial mammals in the world. Bats are the only flying mammal and constitute a fifth of the mammal world, yet little is known about them. This lack of knowledge restricts our ability to preserve areas important for critical life history characteristics. Not only this, but bats require more space for those traits as they fly over large areas and conduct foraging, roosting, hibernating and mating in different areas. Bats are also one of the most reviled and disliked animals by people. Globally bats face persecution from hunting (Mickleburgh, Waylen and Racey 2009), pesticide accumulation (Fenton and Rautenbach 1996) and direct eradication (Hart 2009).

In this dissertation I have utilized a novel approach to conservation biology by combining the study of the ecology of bats and the education of people about bats. The goals of this research were: to increase our ecological understanding of habitat needs of native bat species; increase the awareness of local human residents of the importance of protecting these species; and to develop tools to inform conservation and education for this important taxa. The research is presented as three stand-alone chapters with a chapter of general and interwoven conclusions at the end. The purpose of Chapter I was to develop a spatially explicit habitat model for bat species within the Oak Openings Region of Northwest Ohio and then to test that model with data collected by citizen science volunteers. Through this approach I identified critical habitat characteristics that were associated with the presence of native bat species and their activity. This region lends itself well to the study of how bats are utilizing protected areas within a larger fragmented matrix. The citizen science volunteer program was initiated in conjunction with the

Metroparks of the Toledo Area and continues today. This chapter is formatted for submission to *Ecological Applications*.

The aim of Chapter II was to investigate another unique feature of the Oak Openings Region, that of the globally imperiled oak savanna ecosystem. While bats in the Midwestern United States are known as mostly forest dwellers, no studies have been conducted in Midwestern oak savanna and I investigated the difference in relative activity and presence between forest and savanna sites within the Oak Openings Region. This chapter is formatted for submission to the *American Midland Naturalist*.

Chapter III was created to merge the ecological study of bats with broader social impacts and create a truly multi-disciplinary project. This study was first designed to understand the knowledge and attitudes that people within the Oak Openings Region hold regarding bats as well as investigate any correlation between these two constructs. I then used what I had learned from surveys given to different groups of people, and the knowledge gained during the ecological portion of this work, to create unique educational opportunities for participants to inform, educate, and enlist individuals of the Oak Openings Region. This Chapter is formatted for submission to *Anthrozoos*.

CHAPTER I

DEVELOPING MACROHABITAT MODELS FOR BATS IN PROTECTED AREAS USING MAXENT AND TESTING THEM WITH CITIZEN SCIENCE COLLECTED DATA

ABSTRACT

Protected areas may function as islands of habitat in otherwise hostile environments for many species of North American animals. How to maintain habitat that is suitable for foraging bats within these areas is unclear because studying a nocturnal and highly vagile group of species within these systems is difficult. Using both previous literature and data collected from acoustically surveyed sites within protected areas in the Oak Openings Region of Northwest Ohio, a biodiversity hotspot, we developed spatially explicit macrohabitat models using maximum entropy modeling (Maxent). We then used citizen science collected data to test these models to determine the success of the models in predicting species presence as well as the utility of citizen science collected data in studying this group of animals. We found that the models were successful at predicting the occurrence of the seven species in which models were developed, *Myotis lucifugus*, *Perimyotis subflavus*, *Lasiurus borealis*, *Lasiurus cinereus*, *Myotis septentrionalis, Nycticeius humeralis* and *Lasionycteris noctivagans* but that further testing outside of protected areas is warranted. Within protected areas it is important to manage for heterogeneous habitat composition at this intermediate scale to maintain potential for foraging areas for all occurring bat species. Citizen science collected data is a useful way to gather data to test spatially explicit models and could potentially be used to monitor long term changes in bat species composition in this system and across regions.

INTRODUCTION

Long term conservation of bats requires an understanding of all factors that affect their persistence, including habitat requirements that may affect survival and fecundity (Pierson 1998). The identification of habitat requirements for summer foraging is chief among these (Keeley et al. 2003), as there is a lack of understanding of the underlying mechanisms (Lacki et al. 2007). Studies of summer foraging are often based in relatively forested and intact systems (Brigham 2007), and data on activity in human dominated systems is lacking (but see Avila-Flores and Fenton 2005, Dixon 2011, Duchamp et al. 2004, Gehrt and Chelsvig 2003, 2004, Sparks et al. 2005). It is evident from better understood species that activity and behavior will differ depending on the landscape context (Estes and Mannan 2003), even in the case of highly vagile taxa such as bats.

Human dominated systems are typified by habitat loss from increased urbanization that leads to habitat homogeneity and increased fragmentation (McKinney 2006). Within this matrix, protected areas in the form of metroparks and parkland exist in pockets of relative isolation (Donnelly et al. 2004, Rothley et al. 2004). How bats utilize these protected areas is up for debate, but it appears that they continue to maintain higher species diversity within their boundaries compared to what is found outside (Avila-Flores and Fenton 2005, Duchamp and Swihart 2008, Glendell and Vaughn 2002, Jung and Kalko 2011). The landscape context of the park may be important since although species diversity appears to be lower in urban rather than rural parks (Johnson et al. 2008, Kurta and Termino1992, Loeb et al. 2009), protected areas do seem to act as refugia (Glendell and Vaughan 2002, Loeb et al. 2009).

If these refugia play a critical role in maintaining species diversity, then it becomes necessary to understand the important elements that exist within the park since there is often more variability in bat activity and presence within a park than between parks (Gehrt and Chelsvig 2003, 2004, Johnson et al. 2008). Not all potentially occurring bat species will utilize the same habitat characteristics (Lacki et al. 2007) due to differences in morphology and echolocation (Aldridge and Rautenbach 1987). In general, these differences are predictive of where a bat will forage, but behavior may vary depending on the location (Kurta and Whitaker 1998) and many species show plasticity in their foraging (Ratcliffe and Dawson 2003).

Understanding these differences in behavior and species presence is critical in determining potential effects of management, habitat changes, and prioritizing areas for protection. Predictive models previously attempted for bats have often been conducted at the landscape scale, which by their nature are relatively coarse, placing up to 1km buffers around survey points (Ford et al. 2006). This provides limited insight as to the characteristics of the area immediately surrounding the foraging environment, and it is this intermediate macrohabitat (Saab 1999) scale which is often the target of management within protected areas (Abella et al. 2001).

A compounding problem with understanding summer foraging is the difficulty of studying a highly mobile and nocturnal species (O'shea et al. 2003). Mist netting and radio-telemetry methods gather the most detailed data concerning numbers of individuals, reproductive condition, etc. (Weller 2007), but are difficult to conduct within the constraints of park systems (Gehrt and Chelsvig 2004). Acoustic surveys, on the other hand, can be conducted in places where capturing bats through mist netting is difficult to impossible. Moreover, in many situations acoustic devices are better at discovering the full species assemblage (MacSwiney et al. 2008, Murray et al. 1999, O'Farrel and Gannon 1999, Ochoa et al. 2000), and the number of files collected from acoustic surveys is also often similar to the percentage of bats captured from mist netting (Johnson and Gates 2008). There are inherent biases when using acoustic surveys (Fenton 2003), but acoustic data has been successfully used to model species presence in association with habitat characteristics (Brooks and Ford 2005, Erickson and West 2003, Ford et al. 2005, Ford et al. 2006, Francl et al. 2004, Johnson and Gates 2008, Loeb and O'Keefe 2006, Zimmerman and Glanz 2000).

Acoustic surveys also lend themselves well to citizen science participation as the equipment itself is relatively easy to use. Recorded echolocation files still need to be analyzed by someone trained in acoustic analysis, but recent advances in computer generated analysis software have reduced the need for this expertise. Automated analysis also decreases the issues of observer bias that is often cited in citizen science data acquisition (Conrad and Hilchey 2011, Dickinson et al. 2010). Acoustic surveys of bats conducted by volunteers has been a way of monitoring bat trends in England for a number of years (Walsh et al. 1993), but has not been widely used in the United States.

The original goals of citizen science programs were education and outreach, but large amounts of scientifically useful data can also be collected (Bonney et al. 2009) provided assumptions are clearly stated and a scientific goal established before the onset of data collection. Examples of this abound in the United States in which large scale studies of birds are quite successful (Lepczyk 2005). Citizen science is now increasingly used in studies from classifying star systems (Raddick et al. 2010) and monitoring seismic activity (Cochran et al. 2009) to wildlife sightings on major roads (Lee et al. 2006). Many of these studies have been country or statewide, but we wanted to demonstrate their local use in testing predictive models, a critical component of spatial modeling. Our approach is in contrast to many situations where testing occurs using a subset of the original data, when independent testing is more important (Guisan and Zimmerman 2000).

Maximum entropy modeling and the program Maxent use similar statistical tools to that of generalized linear models, but Maxent is a robust way in which to model species distribution using presence-only data (Phillips et al. 2006) with small sample sizes (Hernandez et al. 2006). It has been used to model the distributions of a range of taxa - plants (Schetter 2012, Kumar and Stohlgren 2009), exotic ant species (Ward et al. 2007), birds (Elith et al. 2006), geckos (Pearson et al. 2007), as well as African (Lamb et al. 2008), Asian (Hughes et al. 2012), and European (Rebelo et al. 2010) bats. This program takes the user defined environmental layers within a geographic area and estimates the probability distribution of maximum entropy (or closest to uniform). Maxent has also been found to perform better (i.e. have lower omission rates) than many other types of modeling techniques (Phillips et al. 2006, Ward et al. 2007, Elith et al. 2006, Pearson et al. 2007). For our purposes, the citizen science collected data is also easily added to the program and analyzed using “Area Under the Curve” (AUC) of a “Receiver Operating Characteristics” (ROC). This procedure provides an understanding of the test data versus what would be predicted at random.

Our goals were to develop a macrohabitat model of bat presence for all occurring bat species at the macrohabitat level using Maxent, and then demonstrate the usefulness of testing these models with citizen science collected data.

STUDY AREA

The Oak Openings Region of Northwest Ohio is a 476km² area characterized by soil types from post glaciation events and containing a heterogeneous mix of habitats including vulnerable or imperiled plant communities (Noss et al. 2005) such as the critically endangered oak savanna (Brewer and Vankat 2004). Considerable fragmentation has occurred due to increased urbanization and agricultural expansion (Brewer and Vankat 2004) (Figure 1). This region remains an area of high biodiversity as it contains 143 state endangered, threatened, or potentially threatened plant species (ODNR Division of Natural Areas and Preserves 2008), 24 state endangered, threatened, or 'of concern' animal species (ODNR Division of Wildlife 2008), and one federally endangered species (Karner blue butterfly, *Lycaeides melissa samuelis*). Protected areas within the region are also considered critical stopover locations for migrating birds (Ewert et al. 2005) and potentially bats (V. Bingman, personal communication).

METHODS

Acoustic monitoring to determine species presence

From June 1st to September 2nd, 2009, we acoustically surveyed 32 sites five times each with a broadband acoustic device (Anabat, Titley Electronic, Ballina, New South Wales, Australia). These sites were within two of the main protected areas within the region, an area of 1722 ha, comprising approximately 10% of the natural area remaining. These protected areas are owned and maintained by the Metroparks of The Toledo Area and are both within Lucas County, Ohio. Sites within these metroparks were chosen because they encompassed all possible habitat types (Ford et al. 2005, Loeb and O'Keefe 2006) and were within 0.5 km of water on which most bats rely (Francl 2008, Vaughan et al. 1997). We chose to sample fewer locations, but more often, because of the number of samples needed to adequately account for temporal variation in bat activity (Hayes 1997).

Methods of echolocation monitoring followed those previously well established (Brooks and Ford 2005, Brooks 2009, Johnson and Gates 2008, Johnson et al. 2008, Ford et al. 2005, Ford et al. 2006, Francl et al. 2004, Francl 2008) for the Anabat SD1 broadband, frequency division acoustic monitor. Monitoring began approximately 0.5hr after sunset and ended three hours thereafter, covering the time frame when bat activity is reported to be most homogeneous (Hayes 1997). Four sites in close geographic proximity to each other were surveyed in the same night and each was actively surveyed for 20 minutes. All sites were greater than 100 meters apart, which is well outside the reception area of the Anabat (Livengood 2003). We also avoided sampling during times of strong wind (e.g., > 3 on Beaufort scale) or rain.

All files with more than three calls were analyzed and taxa determined (by the primary author) to species level, both qualitatively (Analook version 3.7w), and quantitatively (Allen, BATcall ID version 2.0.5.2). When the two methods disagreed on identification the call file was qualitatively inspected again and the primary author determined identification. Each species was considered present if it was detected at least once in during the five surveys.

Macrohabitat Characteristics

We derived macrohabitat characteristics using ArcMap 9.2 software (ESRI, Redlands, California, USA). The original landcover map for the Oak Openings Region was developed by Schetter and Root (2011) using 30m pixel Landsat data and contains a total of 15 different land classes, including asphalt, turf, residential, swamp, floodplain and upland forest, savanna, wet prairie, prairie, barren, meadow, shrub/scrub, conifer, crop, and pond. We excluded wet prairie, barren and shrub/scrub in further analysis due to their low sample size and relatively low frequency within the Oak Openings Region. We excluded conifer cover for the same reason and because no bats occurred within conifer areas.

We used the program FRAGSTATS (McGarigal and Marks 1995) and a 60m circular moving window to determine the percentage of landcover type around each 30m pixel as well as measures of fragmentation including cohesion, number of patches, landscape shape index, and the Simpson diversity index for types of land cover. We also determined distance to nearest road, stream (US Census Bureau, 2009), residential and agricultural area.

Model Development

We first ran correlation analysis on all environmental variables and those that were correlated $r > 0.6$, $p<0.05$ were assessed and variables chosen *a priori*. Distance to residential area, distance to roads, and the percentage of residential cover were all correlated. We chose to use distance to roads in all models since the roads are a critical feature in this fragmented landscape that indicate human influence on the landscape, might facilitate migration, and/or may influence foraging as ditches are commonly adjacent to most major roads in the area. Measures of fragmentation and heterogeneity were also found to be highly correlated so we only included the number of patches as a general measure of fragmentation in model development.

Included in models for all species were distance to stream, distance to agriculture, and number of patches, as these variables have been found to be important for bats in general (Yates and Muzika 2006, Either and Fahrig 2011, Grindal et al. 1999) and particularly those in urban/agricultural matrices (Gehrt and Chelsvig 2004, Duchamp and Swihart 2008). Percentage of savanna was included in all models because of its unique status in this region.

Bat species in the Eastern United States range in foraging habit from the open adapted hoary bat (*Lasiurus cinereus)* to the forest obligate northern long-eared (*Myotis septentrionalis)*. We decided to retain all measures of forest (viz., upland, swamp and floodplain), along with measures of open cover (e.g. meadow and prairie) for all species as all rely on forests to various extents. We then ran ten replicates with the default settings (Phillips and Dudik 2008) on the Maxent program (v.3.3.3k, Phillips et al. 2006) to develop habitat distribution models for each bat taxon that was recorded during our acoustic surveys. The model outputs were on a logistic scale in which each map pixel was assigned a number between 0 (low habitat suitability) and 1 (high habitat suitability). Each model was then combined into an overall species richness model. This was done by averaging the model output for each of the seven species with a resulting map made up of pixels ranging in number from zero to seven. A zero represents no species likely present, while a seven would be all species likely present. Our methodology did allow us to gather absences but due to the potential pitfalls of absence data (Anderson 2003) we chose to use the presence only Maxent method. However, we also conducted Wilcoxon-signed rank tests between the presence and absence of each species in association with the environmental variables to further support the Maxent models.

Model Testing

From June-August of 2010 a citizen science program held in conjunction with the Metroparks of the Toledo Area was initiated. Volunteers walked along ten park trails that were chosen by the primary author and that occurred within the two protected areas in which data was originally collected, as well as two smaller areas not previously surveyed. At the beginning of the volunteer experience participants were given training in which they were instructed on how to hold the acoustic monitor while walking, the pace at which to walk, and the trails they would be asked to walk. Volunteers began walking the trails between 15 minutes and a half hour after sunset and concluded 45 minutes to 1 hour later. Each volunteer walked the trails holding the acoustic monitor attached to a GPS and each trail was surveyed between 1 and 5 times from June 1st to August 15th.

The presence/absence data for each species along these trails was used to test the relevant macrohabitat model. GPS coordinates corresponding to the detection of each species were taken and entered into Maxent as test data. The model performance in terms of the test data was evaluated using the area under the relative operating characteristic (ROC) curve (i.e. AUC). ROC curves balance both omission and commission errors in a model set generating a graph line that represents a random level of performance (Fawcett 2006). The AUC are between 0 and 1 and values of 0.5 are considered a random prediction (Fawcett 2006). A second evaluation of the test data given by the Maxent program is a threshold dependent evaluation (ROC is threshold independent). This uses a χ^2 test to determine the difference between the proportions of predicted area generated by the model, versus what would be predicted from random (Phillips et al. 2006).

RESULTS

Species detected

During the initial 2009 surveys, a total of 1 570 call files were recorded and identified to species. Species detected included big brown (*Eptesicus fuscus)* (1,195 files), Eastern red (*Lasiurus borealis)* (118 files), little brown (*Myotis lucifugus)* (81 files), tri-colored (*Perimyotis subflavus)* (54 files), northern long-eared (*Myotis septentrionalis* (39 files), silver-haired (*Lasionycteris noctivagans)* (34 files), hoary (*Lasiurus cinereus)* (26 files), and evening (*Nycticeius humeralis)* (23 files). Three files keyed out to the endangered Indiana bat (*Myotis sodalis)*, but because of the difficulty of distinguishing the calls of this species from the little brown bat (Britzke et al. 2002) we could not definitively determine its presence. Mist netting occurred during 2010 and 2011 to obtain a local call library and through this, as well as wildlife occurrences reported to the local wildlife rehabilitation center, we confirmed the presence of all but the evening bat and Indiana bat. The evening bat, however, was netted at one location by park officials ~7 years prior to our data collection (Karen Menard, pers communication).

Big browns have been found to be ubiquitous in many urban situations (Loeb et al. 2009; Johnson et al. 2008), and we had similar results. Big browns were present in every location in both the originally collected data and the citizen science collected data; therefore we dropped them from further habitat modeling. The remaining seven species were present at a low of five sites for the hoary bat to a high of 19 sites for the little brown bat.

Developed models

The percentage of contribution of the ten environmental variables to the Maxent models are shown in Table 1, while Figure 2a and 2b show the suitable area for each species. Those environmental factors associated with urban/agricultural areas, including distance to roads, distance to agriculture and the number of patches, had varying importance in models for each species. Presence of northern long-eared, little brown, tri-colored and eastern red bats was greatest at intermediate distances from agriculture. The largest percentage of contribution was for the models for little brown and eastern red bats while this variable contributed virtually nothing to the models for silver-haired and hoary bats. Evening bats were more likely closer to agricultural areas.

Distance to roads was a negligible contribution to all models, while the number of patches contributed to the models for evening and silver-haired bats. As the number of patches increased the likelihood of presence also increased. Not surprisingly the distance to water was a large contribution to all seven species and presence was more likely closer to water.

The type of forest cover that contributed to each species model generally aligned with expectations for that species based on previous literature. Northern long-eared and little brown bat models had contributions from upland forests, although by far the largest contributions were distance to water and agriculture. Open adapted bats (silver-haired, eastern red and hoary) had combinations of contributions from upland forest, prairie, meadow and savanna.

The importance of water as a contributing variable was stronger in the Maxent results than that of the Wilcoxon-signed rank tests between presence and absence of the environmental variables for each species (Table 1 versus Table 2). There was a significant difference between distance to water for only northern-long-eared and tri-colored bats. Distance to agriculture was only significantly different between presence and absence for the silver-haired bat, while this is not a large contribution to the Maxent model; however, number of patches was a significant/large predictor in both cases for this species.

The multi-species model (Figure 3) demonstrates locations throughout the Oak Openings Region that are potentially suitable for all seven species both within and outside of the currently protected areas.

<u>Model testing</u>

The developed models for all seven species were significantly better than random when considering the threshold dependent χ^2 test at the 1,5 and 10% omission thresholds (a proxy measure for the amount of suitable habitat misclassified as unsuitable), as well as when commission and omission rates are balanced (Table 3). In all cases the models were significantly better than a random model at predicting suitable habitat. The predicted amount of suitable habitat at the 10% threshold ranges from a low of 12.6% for the northern long-eared bat to a high of 48.1% for the hoary bat.

The models using the training data all exceeded the "very good" threshold of 0.9 based on the threshold independent AUC tests (Swets 1988); however, only two models using the test data met this threshold. The remaining models using the test data were still well above the cutoff of 0.75, though, which indicates that the discrimination ability of the model was still considered useful (Elith et al. 2006).

DISCUSSION

For seven bat species that occur within the Oak Openings Region of Northwest Ohio we successfully developed a macrohabitat model that predicted presence in the protected areas and increased our understanding of the critical habitat components. We wanted to develop models for each species at the intermediate habitat model scale that could be used in a straightforward manner, could give us a better understanding of where bats are present within a rural/urban landscape, and potentially aid in managing those areas. In general, habitat characteristics of each species were similar to what we would expect based on morphology and echolocation characteristics (Norberg and Rayner 1987), and the results indicate a need to maintain heterogeneity in habitat types. It appears that protected areas within the Oak Openings Region can support a suite of species when considering foraging activity as long as a variety of successional states are maintained.

At this macrohabitat scale, and within protected areas, the fragmentation and development that we measured did not deter the presence of these species, although very few areas outside of these protected areas appear to be suitable habitat. Distance to roads had a negligible contribution to all species models, although when considering the Wilcoxon-signed rank tests, tri-colored were more likely farther from roads, while eastern red bats were closer to them. Further consideration of road type and traffic pattern would be warranted (Berthinussen and Altringham 2011).

The contribution of agriculture to the evening bat model is consistent with findings that they forage on agricultural pests (Feldhamer et al. 1995). The presence of this species within the oak openings region is not considered definitive, although maternity colonies have been found in southeastern Michigan (Kurta et al. 2005). Further mist netting would be necessary to confirm the occurrence of this species as this area is outside of its currently recognized range.

While measures of forest cover were not large predictors for the taxa generally considered to be forest obligate (northern long-eared and little brown bats), the presence of open areas - prairie and savanna - did contribute a small percentage to the model for little brown bats. This could indicate that northern-long eared will be present at forest near water, while little brown bats require some type of forest gap or edge. The presence of little brown bats has been found to be more likely away from urban development (Duchamp and Swihart 2008) but we actually found their presence closer to roads. Indeed, the largest contribution this factor made to any model was to that of the little brown bat model. Roads could serve as commuting area to and from roosting structures as this species often roosts in human structures (Riskin and Pybus, 1998). Roads could also potentially serve as insect hot spots due to heat retention, or could serve the same function as prairies and savannas and act as openings within forests. The concentration of suitable habitat in the northern part of the Oak Openings Region follows the drainage ditches that are unique to this area, which are also associated with roads.

Previous research regarding northern long-eared bats has demonstrated that maintenance of forested areas is also necessary for roosting, as their roosting locations are often found under high canopy cover (Timpone et al. 2009). The question of roosting is an important consideration for all occurring species and further research in the area needs to determine roosting availability as this may be the more limiting factor (Pierson 1998). Studies conducting radio-telemetry, although time consuming and expensive, would help elucidate roosting locations and preferential foraging areas as well as how males and females may be utilizing the foraging space differently (Broders et al. 2006).

Prairie and meadow contributed to models for the evening, silver-haired, eastern red and hoary bats, while the percentage of prairie made the largest contribution to the model for the tri-colored bat. Tri-colored bats are considered a generalist species (Johnson et al. 2010) due to their ability to maneuver through a wide range of cluttered and uncluttered habitats (Norberg and Rayner 1987) and our findings are similar to that of Ford et al (2006) that found this species closer to open areas near water.

There was a large portion of predicted habitat under the % threshold for evening, tri-colored, silver-haired and hoary bats and this relates directly to the lack of large association between these species and agricultural areas, which make up 27% of the land cover in the Oak Openings Region (Schetter and Root 2011). Tri-colored, northern long-eared, eastern red and little brown bats were associated with agricultural areas, and areas of agricultural/forested edges are known to have an increase in bat activity (Wolcott and Vulinec 2012) because of foraging and roosting opportunities.

Similar to Johnson et al. (2008) and Loeb et al. (2009) we found big brown bats were located in most, if not all, habitats and locations. We agree with the suggestion of Loeb et al. (2009) that the abundance of big brown bats may be a cause for concern and may lead to a loss of the other unique species from the urban parks; however, our mist netting efforts did confirm that the oak openings region has breeding populations of northern long-eared, little brown, and eastern red bats.

This macrohabitat modeling with Maxent was successful whereas studies at the landscape scale have failed to find predictive ability (Ford et al. 2006, Gehrt and Chelsvig 2004). Bats are highly vagile and can find suitable microhabitats within a landscape (Johnson et al. 2008) and this may be why landscape indices tend to fall short. Microhabitats, however, are generally hard to assess at a regional scale in a quick fashion. We have demonstrated that models at the macrohabitat level can be developed and independently tested. Although the selected environmental variables are by no means exhaustive, we now have models within for this region that will allow us to aid managers in finding potentially important foraging sites.

This work also demonstrates the usefulness of citizen science collected data in testing a spatially explicit model. Despite limitations on where volunteers could go within the parks and how often trails could be walked, we were able gather a large data set in a relatively short amount of time. This type of data not only helped in testing these models, but may have helped to increase the public's awareness of bat species, a critical component to conservation (Walsh and Morton 2009), in much the same way it has helped with birds and frogs (McCaffrey 2005, Ebersole 2003). This work can be replicated across years and outside of protected areas to continue to refine models, discover temporal changes, and find areas that might be used by bats to commute between protected areas.

The usefulness of Maxent modeling to bat presence was two-fold. First, Maxent utilizes only presence data and is robust to small sample size (Kumar and Stohlgren 2009). Although we had absence data for our sites, this data can be misleading as we cannot be confident that these are true absences (Anderson 2003). We were also able to model all species, even those with relatively small sample, such as the Hoary bat for which we had only five presence records. Second, we were able to easily integrate the citizen science collected data into the models.

Now that we have developed these models they can and have (Lipps, unpublished data) been used them to identify places for priority conservation within the protected areas themselves, and for future land protection of potentially useful areas (Turner et al. 1995). This benefit cannot be understated as we were able to collect the data with minimal intrusion on either land management activities or the bats themselves. Also, now that there is an ongoing citizen science initiative this region can continue to be monitored over time and changes in relative use can be documented.

Continued and long-term monitoring of this region is necessary to understand these potential changes, as well as how management may increase (e.g., by removing structural clutter; Tichenell et al. 2011), or decrease (e.g., through loss of canopy cover; Smith and Gehrt 2010), the presence of these species. Citizen science may be one way in which to address this need not only within these ecosystems, but also to understand large scale differences in occurrences across many landscapes (Walsh et al 1995, Walsh and Harris 1996a, 1996b).

CONCLUSIONS

Bats are an integral part of North American ecosystem survival as the main predators of night flying insects, and as such, it is important that we understand how to maintain populations of these organisms across diverse contexts. This is an important consideration within protected areas as they are often considered islands of suitable habitat. Through this work we found that the scale of consideration is important and may differ across species, but that the macrohabitat scale is generally predictive of species presence and can be used in predicting species occurrence within protected areas of this region. In terms of management, heterogeneity of land covers and successional states is important in supporting a diverse group of species. Using the combined approach of Maxent modeling and model testing using citizen science collected data, we were able to increase our understanding of the important habitat components for bat species in protected areas to assist in conservation and management, while engaging and educating the local stakeholders.

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Table 1. Percentage of contribution of ten environmental variables to Maxent species distribution models developed within the Oak Openings region for each of seven species of bats.

Environmental variable	**Northern long-eared**	**Little brown**	**Tri-colored**	**Evening**	**Silver-haired**	**Eastern Red**	**Hoary**
Distance to roads (m)	0.2 +	2.9 +	0.1 n	0.3 n	0 +	2 n	0.1 n
Distance to agriculture (m)	23.2 +/-	39.9+/-	16 +/-	12 +	1.3 -	39.4 +/-	1.2 n
Distance to water (m)	66.5 -	42.4 -	56.5 -	37.9 -	64.4 -	35.1 -	49.2 -
Floodplain forest (%)	0.1 +	1.6 +	5.4 +	0 n	0.8 +	0.9 +	0 n
Swamp forest (%)	0 +/-	0.1 +/-	1.2 n	9.8 -	0.1 n	0.2 -	0 n
Upland forest (%)	9.1 +	4.8+	1.5 +	12.5 +	0.2 +	8.9 +	27.5 +
number of patches	0.6 n	0.4 +	1.6 +	17.9 +	14.4 +	2.7 +	2.8 n
Prairie (%)	0.3 -	0.7 +/-	11.3 +	1.5 +	0.2 +	3 +	0.3 +
Meadow (%)	0 -	0.2 +	0.6 n	2.8 +	9.2 +	0.1 +	18.6 +
Savanna (%)	0 -	7 +	5.8 +	5.3 +	9.5 +	7.6 +	0.3 -

Symbols that follow each percentage indicate the response curve given to each environmental variable by Maxent. “+” indicates increasing, “-“ indicates decreasing, “+/-“ indicates an initial increase followed by a decrease and “n” is no change.

Table 2. Wilcoxon-signed rank test between the presence and absence of seven bat species across ten environmental macrohabitat variables. Tests were conducted on data collected at 32 acoustic survey sites in two protected areas within the Oak Openings Region in 2009.

	Present			Absence			z	p.
	Mean	SE	n	Mean	SE	n		
Northern long-eared			10			16		
Number of patches	3.38	0.44		4.13	0.44		0.997	0.31
Distance to Agriculture (m)	2221.63	324.24		1516.25	324.24		-1.451	0.14
Distance to road (m)	235.09	38.07		238.98	38.07		0.169	0.86
Distance to water (m)	75.19	26.03		174.14	26.03		2.129	**0.03**
Floodplain forest (%)	29.69	6.22		15.81	6.22		-1.23	0.21
Swamp Forest (%)	13.06	3.63		4.81	3.63		-1.088	0.27
Upland Forest (%)	37.31	8.82		29.00	8.82		-0.618	0.53
Meadow (%)	1.44	5.02		12.50	5.02		1.431	0.15
Prairie (%)	0.48	2.35		8.65	2.35		2.429	**0.01**
Savanna (%)	0.00	4.05		13.13	4.05		2.355	**0.01**
Little brown			22			10		
Number of patches	3.64	0.38		4.00	0.57		0.558	0.57
Distance to Agriculture (m)	2190.77	267.29		1160.90	396.45		-1.484	0.13
Distance to road (m)	242.23	32.42		225.62	48.09		-0.386	0.69
Distance to water (m)	116.94	24.60		141.66	36.48		0.304	0.76
Floodplain forest (%)	24.55	5.49		18.80	8.14		-0.852	0.39
Swamp Forest (%)	9.50	3.22		7.70	4.78		-0.563	0.57
Upland Forest (%)	34.18	7.57		30.90	11.23		-0.020	0.98
Meadow (%)	8.39	4.42		3.85	6.56		0.257	0.79
Prairie (%)	3.49	2.17		6.92	3.21		1.230	0.21
Savanna (%)	7.55	3.73		4.40	5.54		0.225	0.82
Tri-colored bat			12			20		
Number of patches	3.83	0.52		3.70	0.40		0.455	0.64
Distance to Agriculture (m)	2068.33	386.15		1749.30	299.11		0.506	0.61
Distance to road (m)	175.63	41.61		273.88	32.23		-1.849	0.06
Distance to water (m)	85.21	32.21		148.34	24.95		-1.966	**0.04**
Floodplain forest (%)	36.83	6.73		14.30	5.21		2.009	**0.04**
Swamp Forest (%)	8.25	4.37		9.35	3.38		-0.292	0.77
Upland Forest (%)	17.42	9.59		42.60	7.43		-2.054	**0.03**
Meadow (%)	3.20	5.96		9.23	4.62		0	1
Prairie (%)	5.13	2.97		4.23	2.30		0.102	0.91
Savanna (%)	2.75	4.99		8.85	3.87		-0.892	0.37

Table 2 continued.

Evening bat			10			22		
Number of patches	4.10	0.57		3.59	0.38		0.765	0.44
Distance to Agriculture (m)	2016.80	424.76		1801.73	286.37		-0.040	0.96
Distance to road (m)	143.31	43.51		279.64	29.34		-2.337	**0.01**
Distance to water (m)	156.94	35.98		109.99	24.26		1.158	0.24
Floodplain forest (%)	14.30	7.97		26.59	5.38		-1.039	0.29
Swamp Forest (%)	2.20	4.55		12.00	3.07		-1.573	0.11
Upland Forest (%)	26.50	11.14		36.18	7.51		-0.687	0.49
Meadow (%)	13.85	6.42		3.85	4.33		1.511	0.13
Prairie (%)	8.46	3.14		2.80	2.12		2.059	**0.03**
Savanna (%)	10.00	5.50		5.00	3.71		0.482	0.62
Silver-haired bat			11			21		
Number of patches	4.64	0.51		3.29	0.37		2.180	**0.02**
Distance to Agriculture (m)	1042.64	360.97		2301.76	261.25		-2.440	**0.01**
Distance to road (m)	209.29	45.49		251.57	32.92		-0.476	0.63
Distance to water (m)	126.86	34.96		123.52	25.30		-0.515	0.60
Floodplain forest (%)	23.00	7.81		22.62	5.65		0.953	0.34
Swamp Forest (%)	9.00	4.57		8.90	3.31		-0.068	0.94
Upland Forest (%)	19.00	10.23		40.57	7.40		-1.504	0.13
Meadow (%)	18.18	5.76		1.10	4.17		2.291	**0.02**
Prairie (%)	9.09	2.93		2.20	2.12		1.774	0.07
Savanna (%)	8.00	5.29		5.81	3.83		1.067	0.28
Eastern red bat			19			13		
Number of patches	4.00	0.41		3.38	0.49		-1.073	0.28
Distance to Agriculture (m)	1719.58	306.08		2087.23	370.03		1.247	0.21
Distance to road (m)	194.91	32.79		298.60	39.64		1.880	0.06
Distance to water (m)	127.39	26.59		120.68	32.15		0	1
Floodplain forest (%)	20.89	5.92		25.46	7.15		0.019	0.98
Swamp Forest (%)	7.53	3.45		11.00	4.17		1.285	0.19
Upland Forest (%)	28.47	8.04		40.00	9.72		0.727	0.46
Meadow (%)	8.10	4.78		5.33	5.77		-0.910	0.36
Prairie (%)	7.28	2.23		0.59	2.69		-1.943	**0.05**
Savanna (%)	10.47	3.87		0.85	4.68		-1.092	0.27
Hoary bat			5			27		
Number of patches	3.40	0.81		3.81	0.35		-0.448	0.65
Distance to Agriculture (m)	1914.20	602.39		1860.56	259.23		-0.415	0.67
Distance to road (m)	245.14	68.09		235.54	29.30		0.3633	0.71
Distance to water (m)	90.83	51.43		130.93	22.13		-0.571	0.56
Floodplain forest (%)	15.40	11.49		24.11	4.94		-0.318	0.75
Swamp Forest (%)	4.40	6.71		9.78	2.89		-0.779	0.43
Upland Forest (%)	37.60	15.87		32.33	6.83		0.478	0.63
Meadow (%)	23.08	8.76		3.99	3.77		1.683	0.09
Prairie (%)	4.61	4.60		4.56	1.98		0.648	0.51
Savanna (%)	0.00	7.75		7.78	3.33		-0.985	0.32

Table 3. Results of Maxent models and "Area Under the Curve" ROC analysis for each of seven species of bats within the oak openings region of northwest Ohio. Also displayed are the percent of predicted area under 1,5, and 10% omission thresholds.

	Northern long-eared	**Little brown**	**Tri-colored**	**Evening**	**Silver-haired**	**Eastern red**	**Hoary**
Training AUC	0.978	0.983	0.959	0.983	0.95	0.98	0.974
Test AUC	0.85	0.891	0.863	0.93	0.819	0.903	0.839
1%	0.45	0.446	0.744	0.785	0.842	0.537	0.778
5%	0.209	0.222	0.51	0.584	0.66	0.297	0.595
10%	0.126	0.138	0.375	0.434	0.531	0.197	0.481

The original acoustic data was used to determined the training AUC and this was what was used to develop the model. The test AUC used the citizen science collected acoustic data. Maxent statistically compares test data against a random prediction with the same fractional predicted area. All test data was significantly better than random at the <0.001 level for all omission thresholds.

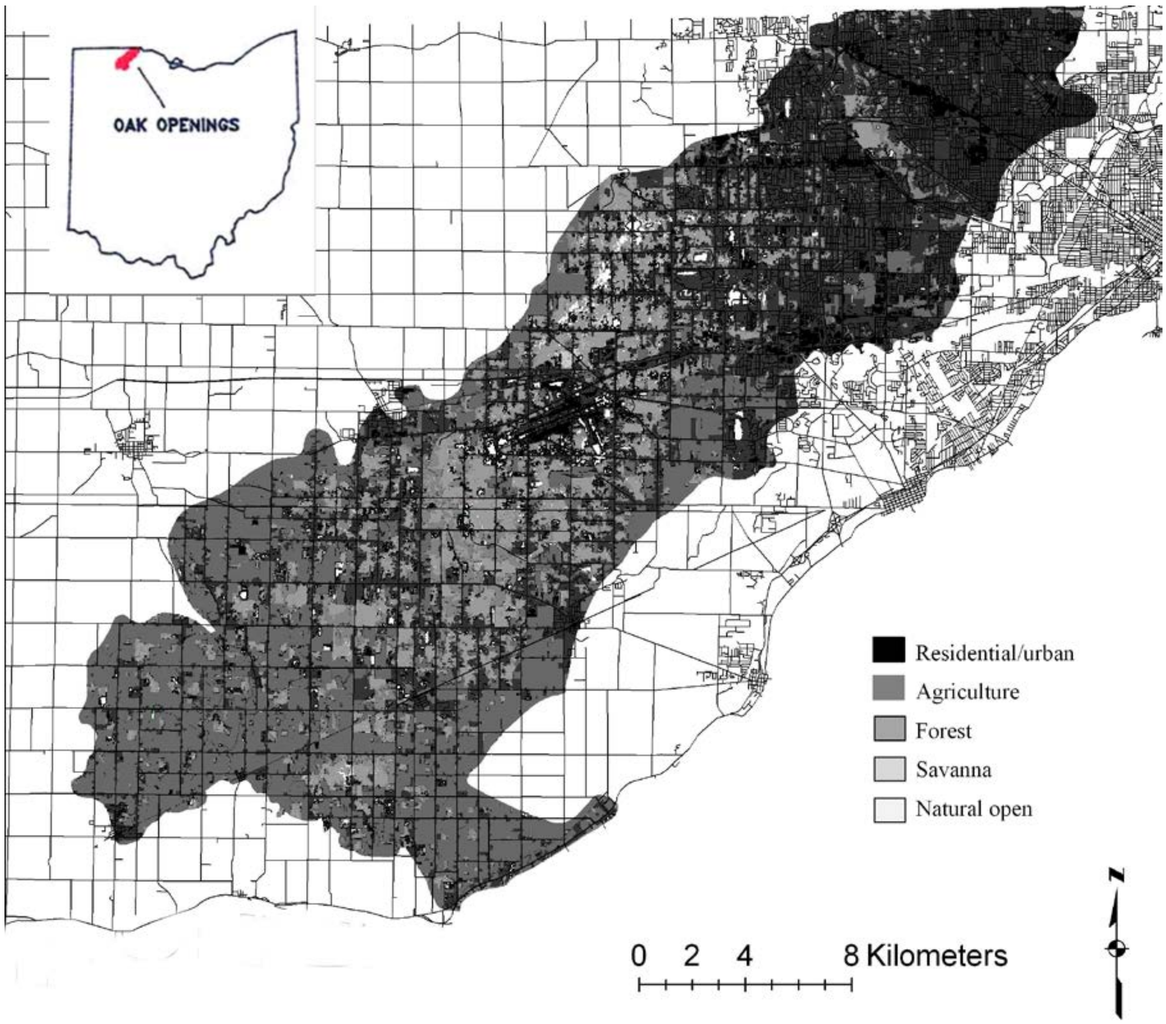

Figure 1. Map of the Oak Openings Region showing the extent of fragmentation caused by roads (lines), agriculture and urban areas (inset of location within Ohio).

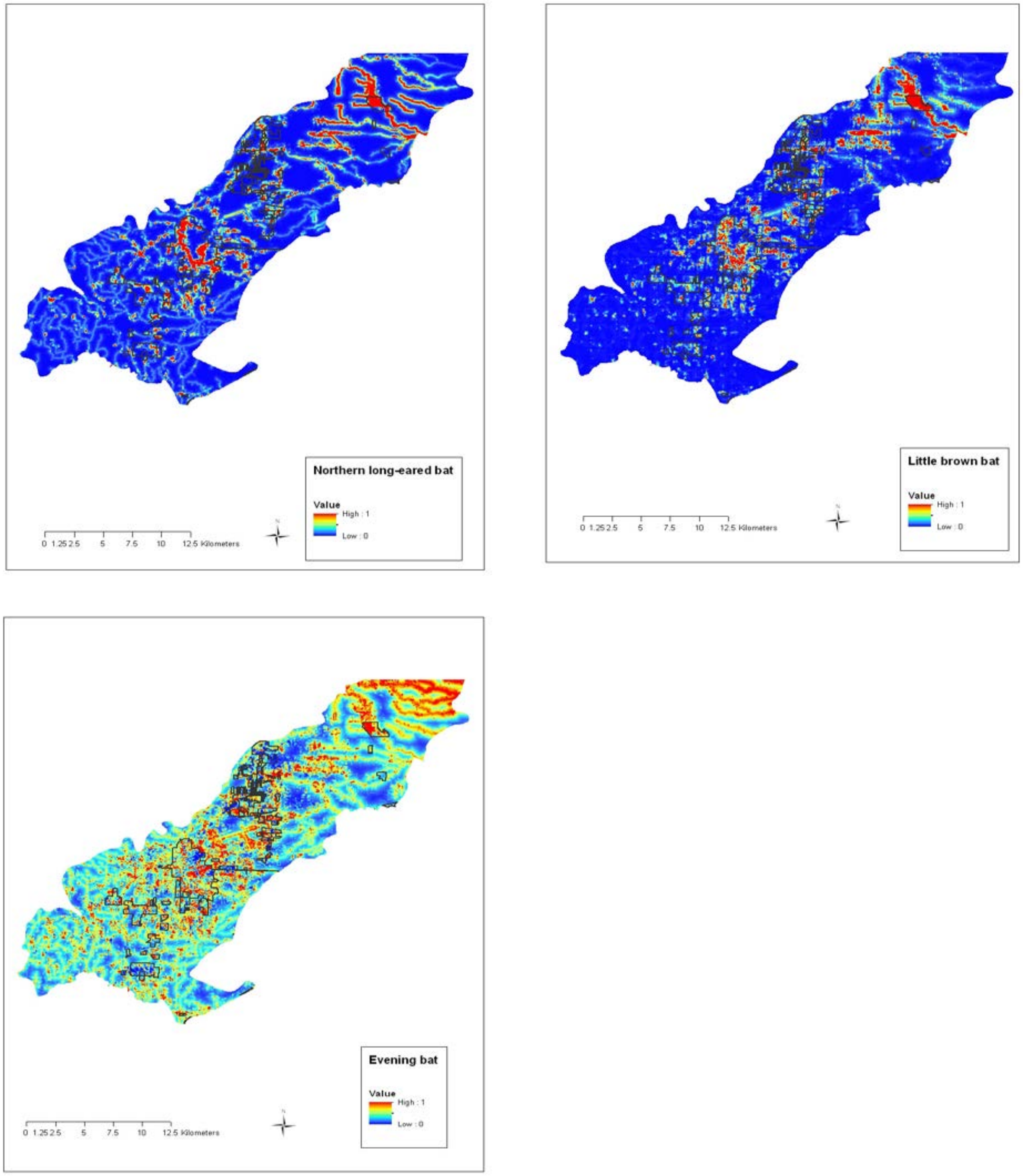

Figure 2a. Maxent model results for the three species that are considered forest adapted of the bats within the Oak Openings Region of Northwest Ohio. Map showing both the full extent of the Oak Openings and that within protected areas.

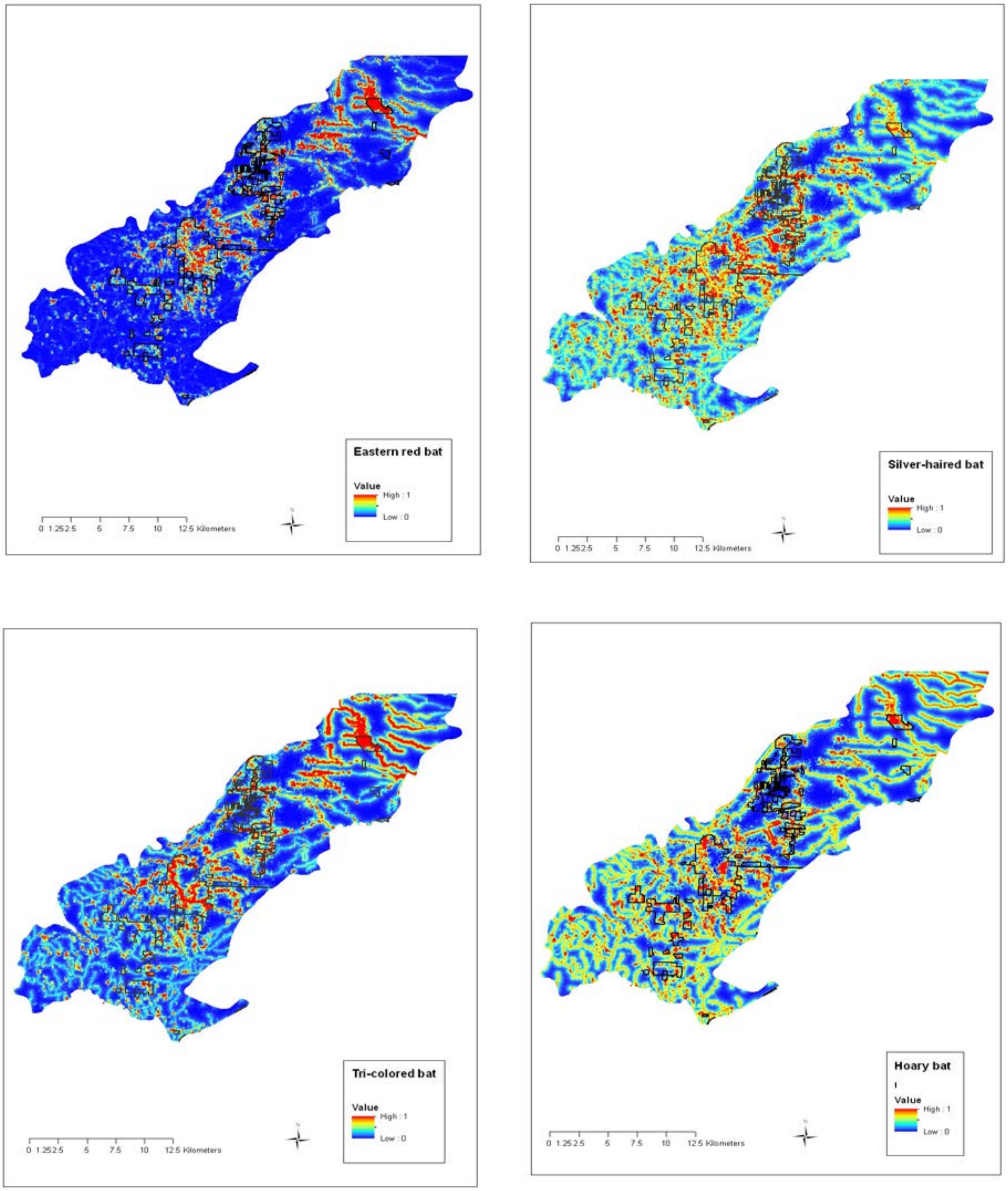

Figure 2b. Maxent model results for the four species that are considered open adapted of the bats within the Oak Openings Region of Northwest Ohio. Map showing both the full extent of the Oak Openings and that within protected

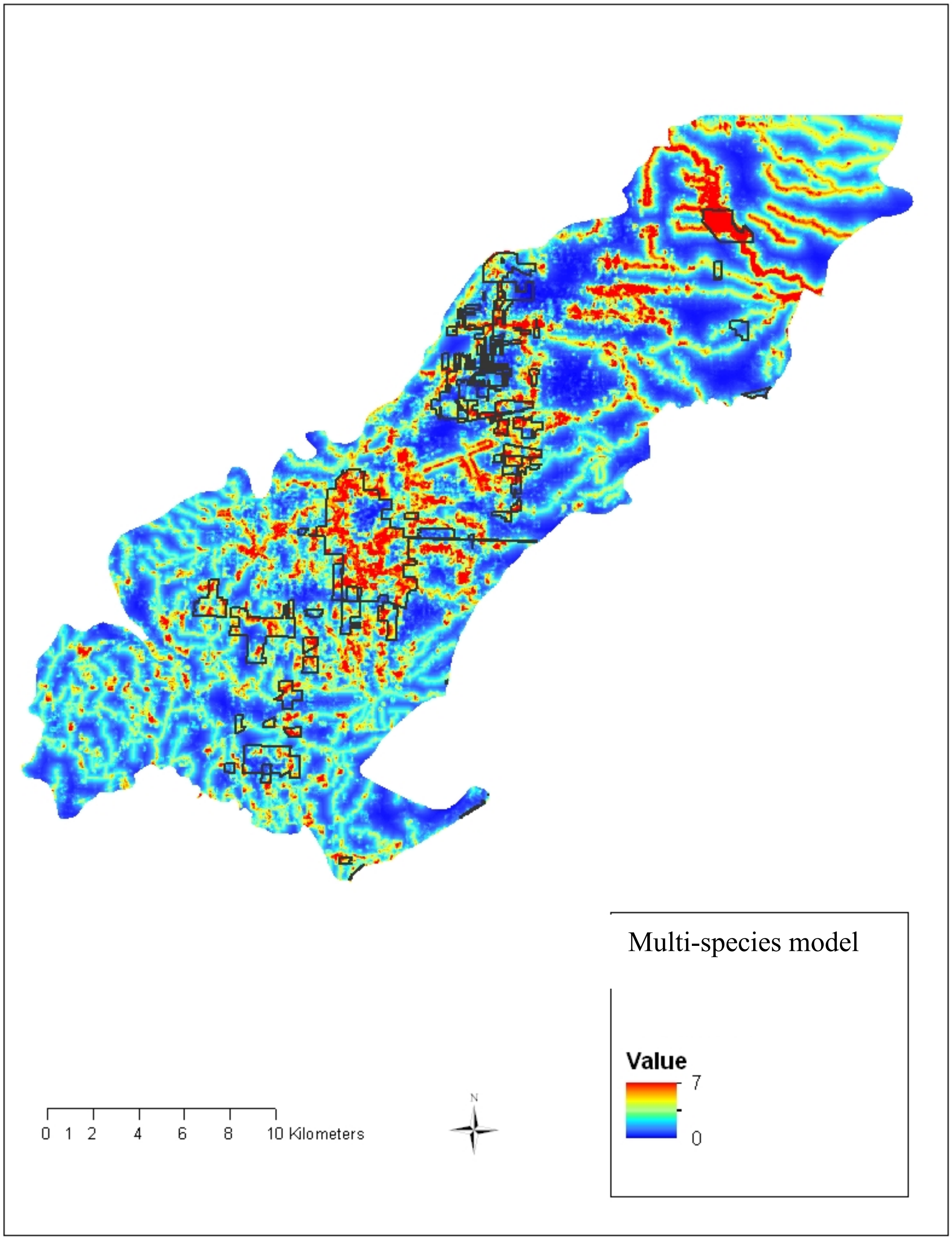

Figure 3. Multispecies bat model with all protected areas indicated within the Oak Openings Region of northwest Ohio. Model developed by combining each individual species model from Maxent. Zero indicates no species likely present to a high of all seven species likely presence.

CHAPTER II

DIFFERENTIAL USE OF OAK SAVANNAS AND FORESTS BY BAT SPECIES IN THE OAK OPENINGS REGION OF NORTHWEST OHIO

ABSTRACT

Midwestern oak savanna occurs in remnant locations in what is known as the Oak Openings Region of northwest Ohio. This habitat type was once 43% of the region, while today it is only a fraction of this. Oak savannas are useful habitat for a wide range of terrestrial animals, but little to nothing is known about the use of these areas by bats. Bats in the Midwest and northeast are generally found within forested areas, with use of forest edges openings and clearings for foraging. We paired 32 savanna and 32 forest sites that were within close spatial proximity to each other and located within two protected areas within the oak openings region. We then acoustically surveyed these sites for bats using Anabat bat detectors 14 times over two years. We analyzed data across spatial and temporal scales and found that little brown, northern long-eared and evening bats were more likely present in areas characterized as forest, while hoary, silver-haired, eastern red and tri-colored bats were more likely present in areas characterized as savanna. There was no significant difference between sites in terms of species richness. Temporal and spatial results demonstrate that the use of savannas and forests depends on the species as all species were found in both types of habitat, but that structural composition and relative insect activity was related to the use of these areas. Savanna sites provide potentially important habitat to bats, and further work should investigate their use over forest clearcuts and openings.

INTRODUCTION

Midwestern oak savanna is part of the woodland-savanna complex that exists across the Midwest. Oak savanna is a distinctive vegetative type that exists between the prairies of the west and the hardwood forests of the east (Nuzzo, 1986). It once occurred through much of the Midwestern states from Minnesota to Ohio (Nuzzo, 1986). This ecosystem is generally characterized by its wide grassy areas with interspersed large oak trees, a heterogeneous and developed ground layer (Leach and Givnish, 1999), and large gaps between and within the canopy (Grundel et al., 2007). Exact definitions, however, are often lacking and encompass a large range of intermediate canopy cover levels (Nuzzo, 1986).

In Ohio, oak savannas occur in the northwestern corner of the state within what is known as the Oak Openings Region (Brewer and Vankat, 2004). This region encompasses 478-km^2 (Schetter and Root 2011; see Figure 1). Several areas have been selectively managed for oak savannas by both the Metroparks of the Toledo Area and The Nature Conservancy, but only 0.8 % savanna cover remains (Schetter and Root, 2011) in an area that once covered 43% (Brewer and Vankat 2004). These oak savanna areas were once interspersed with oak woodlands and floodplain forests and while these forests and woodland areas still remain they have increased in number but the overall tree composition has changed with an increase in canopy cover, loss of herbaceous cover and increased leaf litter (Brewer and Vankat, 2004).

Historically oak savannas were thought to be maintained by fire and grazing (Asnjornsen et al. 2005), but alterations in disturbance regime, including fire suppression, lead to conversion to dense forests (Nuzzo 1986; Grossman and Mladenoff 2007). Oak savanna is now considered a critically endangered ecosystem (Noss et al. 1995). To restore this ecosystem, historic savanna areas are now intensively managed with burning and mowing (Peterson and Reich 2001), which significantly increases the vegetative ground cover of savanna areas and decreases canopy cover (Tester, 1989; Peterson and Reich 2001).

Significant work has been done examining how different taxa utilize Midwestern oak savannas in general, and the Oak Openings Region in particular, including turtles (Lipps, unpublished data, birds (e.g., lark sparrows, Coulter 2008) and small terrestrial mammals (Kappler et al. 2012). Brawn (2006) found that breeding bird diversity was higher in recently restored savanna areas compared to forests in the same region. The endangered Karner Blue Butterfly is also considered a savanna obligate and its extirpation from the area was partly due to the loss of savanna areas (US Fish and Wildlife Service, 2003).

In tropical regions bat diversity and activity are higher in areas characterized as savanna than forest (Bernard and Fenton, 2002), however, no studies, that we are aware of, have systematically looked at bats and their use of Midwestern oak savannas. Bats (order Chiroptera) are a significant contributor to ecosystem processes in North American forests through their removal of millions of tons of insects (Boyles et al., 2011). As populations across the northeast decline due to the effects of white nose syndrome (Cohn, 2008) on those species that hibernate, it becomes imperative to understand important habitat elements for summer foraging as this is a critical time for building up important fat reserves (Kunz et al., 1998).

Many bat species in the northeastern and Midwestern US forage in areas structurally similar to these savanna areas, including gaps, clearings, and forest edges (Lacki et al., 2007). Gaps, in particular, are twice as likely in savanna areas as they are in forests (Robertus and Burns, 1997). However, the eight species of bats that are known to occur within this region (Sewald and Root, chapter 1), differ in their morphology and flight ability, potentially limiting types of habitat they are often located within (Aldridge and Rautenbach, 1987, Norberg and

Rayner, 1987). These range from the large bodied Hoary bat (*Lasiurus cinereus*), which is a slow, low maneuverable bat often associated with large open areas (Barclay, 1985), to the Northern long-eared bat (*Myotis septentrionalis*) a small, highly maneuverable bat associated with very forested areas (Brooks and Ford, 2005). The remaining species lie along a continuum and include the silver-haired (*Lasionycteris noctivagans*), eastern red (*Lasiurus borealis*), tri-colored (*Perimyotis subflavus*), little brown (*Myotis lucifugus*) and evening bat (*Nycticeius humeralis*). Indeed most of these species are morphologically equipped to forage in forested areas (Lacki et al., 2007), however, early to mid successional habitats may be important (Loeb and O'keefe, 2011) due to increased insect activity (Swengel, 2001) and commuting ability (Hayes and Loeb, 2007).

Our goal for this study was to determine the relative difference in use and presence of each occurring bat species between sites characterized as oak savanna and forests. We hypothesized that the Hoary bat would not be present in either area, but that the northern long-eared would be more active and more likely in areas characterized as forests while the remaining species would be more active and more likely in areas characterized as oak savanna.

METHODS

Acoustic surveys

Between May and August of 2010 and 2011 we acoustically surveyed 23 sites characterized as forest and 23 as oak savanna (determined by landcover map developed for the region, Schetter and Root, 2011, Figure 1) using an Anabat SD1 broadband, frequency division acoustic monitor (Titley Electronics, Ballina, New South Wales, Australia). Acoustic monitors allowed us to gather large amounts of data over a short period of time and collect data in areas where the traditional method of mist netting is difficult (Kunz and Kurta, 1988), including in more open areas such as savannas. Acoustic devices are also better at detecting full species assemblage (MacSwiney et al., 2008; Murray et al., 1999).

All sites were within the two main preserves that contain the greatest proportion of protected savanna and forests, Kitty Todd Nature Preserve, owned and maintained by the Nature Conservancy, and Oak Openings Metropark, owned and maintained by the Metroparks of the Toledo Area. Each oak savanna area was paired with a forest area and they were acoustically surveyed on the same night, at the same time. Each habitat was located near each other, but at least a 100m apart to avoid any potential overlap in detection by the Anabat (Livengood, 2003). In pairing sites we are able to control for effects of local and landscape characteristics and directly compare the activity of each site.

In 2010 and 2011 each site was surveyed seven times. Each survey period began 0.5 hours after sunset during times of low wind activity and no rain. Between 4 and 8 pairs of sites were surveyed each night and the order in which they were surveyed was randomly determined; however, those within close geographic range of each other were surveyed on the same night. Each site was surveyed for 20 minutes before moving onto the next survey site (Brooks and Ford, 2005; Brooks, 2009; Johnson and Gates, 2008; Ford et al., 2005; Francl et al., 2004). Surveys ended three hours after dark, which is the time when bat activity is found to be most homogeneous (Hayes, 1997). To determine if this temporal range differed across the nighttime hours we also placed Anabats in weatherproof enclosures (bat hats) at four pairs of sites for two 48 hour periods in 2011. The Anabats were set to record at sunset and end recording at sunrise.

The Anabat system records 15 second files that can include one to many bat calls. Files containing greater than three calls were analyzed to species (Analook version 3.7w) first quantitatively (Allen, BATcall ID version 2.0.5.2) and then each file was inspected by the primary author comparing the frequency, slope and curvature (Gannon et al., 2004) of known calls collected in the area and call files from libraries collected elsewhere (Corben and O'Farrell, O'Farrell Biological Consulting, unpublished data). When the two methods disagreed on identification the call file was qualitatively inspected again and the primary author determined identification. The number of call files can be used to represent relative activity at a given site (Brooks and Ford, 2005). We used both overall presence (at least 1 call file over both years at a site is considered present) and relative activity (# of call files) in our analysis.

Habitat Data

We also collected data across scales to determine if other factors were associated with bat presence/activity, such as insect activity, or structural and compositional differences between sites, as well as differences in surrounding landcover.

Nightly Variables. Temperature, barometric pressure, humidity, and wind speed were collected with a Brunson Atmospheric Data Center and recorded at the beginning of each monitoring period. Cloud cover and % of moon visible was visually estimated and again taken at the beginning of each monitoring period.

To understand relative differences in insect activity between all sites, we estimated insect activity using sweep net sampling (Ford et al., 2006) and then related the number of insects collected to the presence and activity of bats between savanna and forest sites. Fifty sweeps through vegetation and 50 through the air were conducted at each site after acoustic surveys were completed. Insects were then collected and saved for later identification to insect order.

For all nightly variables we conducted Wilcoxon-signed rank tests between the presence and absence of all occurring bat species for each survey for all sites combined, and then only savanna and only forest sites.

Stand Variables. The collection of structure and composition at the microhabitat scale occurred at five locations, one at the listening point (i.e., where the Anabat monitor was placed) and at 15m in each cardinal direction from the listening point. At each of these locations we collected data on live tree density (total number of trees > 10cm DBH within 20m²), canopy cover, herbaceous cover and structural clutter.

Canopy cover was determined by taking a picture of the sky with the camera placed at 4ft and facing up. We then imported the images in Image J (Abramoff et al., 2004) and converted the pictures to black and white pixels with a percentage of dark representing total canopy cover (Klingenbock et al., 2000). Clutter was determined using a modified cover board (Yates and Muzika, 2006) that measured 9m by 0.3m with 10 by10 cm squares covering it. The number of squares visible from 0-3m (low clutter), 3-6m and 6-9m was determined from pictures and converted to a percentage for each height.

Ground cover was determined by placing a 1m² quadrat at each of the 5 locations. A picture was taken of each quadrat and imported into Adobe Photoshop (Adobe Systems version 7.0). The pictures were then gridded and each grid was assigned a value (or category) that corresponded to general types of ground covers. The percentage of grids that contained ferns, dead fall, bare ground or leaf litter were placed in a forest understory category, while the percentage of grids that contained grasses, forbs and saplings were categorized as vegetative cover ground. These categories were based on the correlation of the individual ground covers with each other as well as their correlation with the respective cover type.

Macrohabitat variables. We used ArcGIS 9.3 software to determine the amount and type of surrounding landcover in a 60m buffer, the distance to the nearest human-made or agricultural feature, the nearest water and road. We also used indices from the program FRAGSTATS

(McGarigal and Marks, 1995) to measures the landscape within the 60m buffer. Measures that we included in analysis included the number of patches of different cover types (NP, four neighbor rule), Simpson index of cover types, and cohesion (Co) that measures amount of connection across each focal land cover type.

Bat activity is known to fluctuate between and within years (Hayes, 1997) so we combined the two years of surveys to capture a more complete picture of bat presence/relative activity in association with habitat characteristics. If a call file for a species was detected at least once during the fourteen surveys (seven in 2010 and seven in 2011) then that species was considered present. We also averaged the total number of call files for the fourteen surveys to gather an average relative activity measure for each site. Before combining this data, however, we used Wilcoxon signed-rank test to determine differences in number of call files across years. After combining the two years of data, we conducted Wilcoxon matched pairs signed rank tests to investigate the differences between the matched sites in terms of relative activity for each species in association with all stand and macrohabitat characteristics.

RESULTS

A total of 4,046 call files identifiable to species were recorded between 2010 and 2011. Based on the Wilcoxon signed-rank test there was a significant increase in the number of call files recorded in 2011 compared to 2010, (5.58 vs 7.52, $z = -2.006$, $p = 0.045$). In 2010 a total of 1,669 identifiable files were recorded, while in 2011 2,377 were recorded.

There were also differences in the number of files recorded per species across the two years. The mean number of files attributed to big brown bats significantly increased, (4.04 vs. 5.64, $z=-2.395$, $p= 0.016$). Big brown bats were also the most common species detected on call files in both years (2010, 69%, 2011, 75%). The eastern red bat was the second most common bat detected (2010: 5%; 2011: 8%) but the mean number of calls for this species did not significantly increase between years (0.48 vs. 0.58, z= -0.6235, p=0.53).

In 2010 the little brown bat was the second most common species (6%) but the seventh most common in 2011 (2.5%). Although the mean number of call files attributed to this species did not significantly differ between years, there was a decrease in 2011 from 2010 (0.37 vs. 0.19, z=1.55, p=0.12). This decrease was also evident for a second *Myotis* species, the northern long-eared (0.33 vs. 0.23, z=0.56, p=0.5), (2010: 5%; 2011: 3% of calls). The third *Myotis* species known to be in the Northeastern United States is the federally endangered Indiana bat (*Myotis sodalis*) and we did identify this species to six call files in 2010 and 13 in 2011. However, because of the difficulty in distinguishing this species from the little brown bat by call alone (Britze et al., 2002) we excluded this species from further analysis, but its potential presence is noted.

The number of silver-haired (1.5%-4.4%), and hoary bat (0.8%-3%) call files significantly increased between 2010 and 2011 (silver-haired, 0.089 vs. 0.33, z= -3.219, p=0.0013; hoary, 0.0511 vs. 0.243, z= -2.44, p= 0.014) while the mean number of calls for the tri-colored bat (2010: 0.7% in 2010, 2011 0.8%) and evening bat (2010: 3%; 2011: 3%) remained the same.

<u>Within night differences</u>

During both years we also captured a total of 2,625 insects from ten different orders, the majority of these being Diptera (69%), but also included were Lepidoptera, Hemiptera, Orthoptera, Coleoptera, Blattodea, Neuroptera, Placoptera, Hymenoptera, and Dermoptera. Due to small sample size we only included Diptera, Orthoptera, Coleoptera and Lepidoptera in analysis, which constitute a large portion of what is found in bat fecal analysis (Feldhamer et al., 2009) and we did include all orders for a measure of insect richness.

Few nightly variables were significantly different when combining savanna and forest sites (Table 1). There were differences in presence based on barometric pressure for the big brown, hoary and little brown bat. Differences in presence based on pressure were significant for these species in savanna sites, but not forest sites. In terms of other environmental conditions, higher temperatures were associated with the presence of big brown bats in overall habitat conditions, while the percentage of humidity was associated with the presence of evening and hoary bats, with evening bats significantly more likely with decreased humidity and hoary bats increased humidity. The percentage of moon illumination was only significant for eastern red bats in savanna areas; increased moon illuminated significantly increased likelihood of presence.

Relative insect activity was significantly associated with the presence of big brown (Orthoptera for overall, savanna and forest sites), little brown (Diptera in savanna sites), evening (Orthoptera in savanna sites), tri-colored (Diptera, Lepidoptera, Orthoptera and insect richness in all habitat conditions, and Diptera, Orthoptera and insect richness in savannas) and silver-haired bats (Lepidoptera, Orthoptera and insect richness in forest sites).

<u>Differences between savanna and forest sites</u>

We were successful at matching sites that were not significantly different in any ways except those that would be expected based on their designation as a forest or savanna site (Table 2). Matched sites differed at the microhabitat scale with forest sites having more forest understory cover, higher clutter at the low and high levels (0-3m and 6-9m) and more canopy cover. They also varied in terms of insect richness (# of insect orders present) with savannas having a higher number of insect orders.

At the macrohabitat scale (60 meter buffer surrounding the site) forest sites were surrounded by more swamp and upland forest, while savannas were surrounded by more savanna and meadow/prairie. Because the matched forest/savanna sites were in close spatial proximity to each other the matched sites did not significantly differ in their proximity to water, roads, residential or cropland areas (Table 2).

Wilcoxon matched pairs signed rank tests between the matched sites in terms of relative bat activity for each species (Figure 2) demonstrate that tri-colored and silver-haired were significantly more active in the savanna sites (tri-colored t= -37.50, p=0.0259; silver-haired, t= -68.00, p <0.0001), as was the big brown (t= -77.000, p=0.0155), eastern red (t=-50.00,p=0.0408) and hoary bat (t= -43.00,p=0.0005). Northern long-eared, little brown and evening bats were significantly more active in forested sites (northern long eared, t=115.00, p < 0.0001; little brown, 67.00, p= 0.0257, evening bat, t= 39.00,p=0.032). Although not significant, there was a trend for greater bat species richness in savanna sites than in forest sites (5.43 vs. 4.8, t= -32.500,p=0.0676).

These results remained consistent when we used a Pearson χ^2 test to determine the differences in presence between forest and savanna sites (but not matched) for all but the little brown bat and evening bats which were present in both savanna and forest sites (Table 3). The hoary, tri-colored, silver-haired and eastern red bats were more likely to be present in savanna sites while northern long-eared bats were more likely to be present in forest sites (See Table 3). We did not conduct this analysis for the big brown bat, as this species occurred at least once at all survey sites.

No species of bat occurred exclusively in only savanna or only forest sites so we examined differences within forests or savannas to determine important habitat characteristics.

We conducted analysis for each species within only savanna sites and only forest sites. We conducted Wilcoxon signed rank test to determine differences between presence and absence for each species that was present in greater than 75% of forest or savanna sites. We also conducted Spearman rank correlations on average activity and habitat characteristics to determine if relative activity differed from presence only. Table 4 demonstrates the differences between presence and absence at forest and savanna sites for those species that were more likely in forests, while Table 5 demonstrates these differences for species that were more likely in savanna areas. All environmental variables were originally tested, but only those variables that were significant in savanna or forests are presented.

Principal components further examined where these eight species occur in terms of relative activity along the forest/savanna continuum (Figure 3) when all sites are considered regardless of designation as forest or savanna. Big brown, eastern red, silver-haired, hoary and tri-colored bat are positioned on the axis near meadow/prairies, savannas, while northern long-eared, little brown and evenings bats are near higher canopy cover, forest understory and upland and swamp forest.

<u>Overnight activity differences between savanna and forest sites</u>

A total of 5,455 call files were recorded over a total of 28 nights (14 at 4 savanna sites and 14 at 4 forest sites) in 2011. 3,881 of these were recorded at the savanna sites and 1,575 at the forest sites. Of the total number of files, 89% were attributed to big brown bats. We investigated four species across the nighttime hours, two species that were more frequent at savanna sites during our active surveys, big brown and eastern red bats, and two species found to be more likely in forest sites, little brown and northern long-eared bats.

We broke the nighttime hours into three segments, early: 9pm-midnight, late: midnight-3am, and morning: 3am-6am and then conducted a repeated measures two-way anova after conducting an aligned-rank transformation (Wobbrock et al., 2011). No significant interaction existed between time and type of habitat for the four species (Figure 4a-4d), and no main effect for time. Relative activity did not significantly differ between the three time blocks for any species. Big brown and eastern red bats were significantly more active in savanna sites, while northern long-eared were active in forested sites, and little browns did not differ between the two.

DISCUSSION

By systematically pairing savanna and forest sites we were able to elucidate patterns in activity and presence both spatially and temporally within the Oak Openings Region of Northwest Ohio. There was an increase in relative bat activity between the two years of surveys, but for those species in which calls increased, this was to be expected as even though we had the same number of surveys, more surveys took place during the peak of maternity activity in 2011 and this also coincides with increased average temperatures in 2011 compared to 2010, which could be related to increased insect activity. The decrease in number of calls for both little brown and northern-long-eared is of concern and potentially attributable to the effects of white-nose syndrome.

On a nightly basis, we found very few significant differences between environmental variables and the presence of each bat species, but this did change somewhat when we took into consideration only savanna or forest sites. For instance, eastern red bats were more likely present in savanna sites with higher percentage of moon illumination. This is, at first, counterintuitive from the popular opinion that bat activity drops off around the full moon due to predator avoidance (Ciechanowski et al., 2007). However, Lang et al. (2006) found that bats were active earlier during times of full moon to coincide with the activity of preferred insects. This could be a potential explanation for the increase in eastern red bat presence because our surveys only occurred in the three hours after sunset. Why this was not seen in the other species could be due to species specific differences.

There was a general increase in the likelihood of bat presence for five of the bat species studied in relation to insect activity. The most interesting difference to note is that little brown bats were more likely present in savanna areas with higher insect richness, but this was not the case in forest areas. Of course, we conducted a very general sampling of insect activity that is by no means complete or a measure of what the bats are actually preying upon. Further investigation of the interaction between habitat use and insect activity would be warranted.

Overall, bat activity and the presence of these eight species of bats differed between savanna and forest sites. While northern long-eared and evening bats were more likely in forest sties, eastern red, hoary, tri-colored and silver-haired were more likely in savanna sites and little brown bats were present in both. These results were consistent when average relative activity was taken into account except in the case of the little brown bat which had significantly more call files attributed to it in forest sites.

Although these findings are generally consistent with what we would expect based on wing and body morphology (Norberg and Rayner, 1987), there were differences in types of forest stand structure for those species more likely present in forested areas, while very specific habitat characteristics existed for the use of savannas by these species, particularly little brown and northern-long-eared bats. Little brown bats were in savannas further from roads, and with less diversity in cover and greater cohesion, while northern long-eared bats were more likely present in savannas with a greater number of patches. This could demonstrate species specific differences with little browns utilizing the space for foraging and long-ears for commuting. Savanna sites are also areas with great potential for roosting as both species roost in tree hollows, crevices and under the bark of dying trees that have adequate sun exposure (Broders and Forbes, 2004; Menzel et al., 2002) and in roost trees which are often found near gaps and openings (Kalcounis-Rueppel et al., 2005).

For those species characterized as more likely in savanna areas, the percentage of canopy cover was a significant variable for the presence of hoary, eastern red and tri-colored bats in forest sites indicating that they are present in these areas, but only open forests. Research regarding tri-colored bats has been inconsistent in assigning them to floodplain forests or open forest gaps (open gaps: Ford et al., 2006; closed forest: Farrow and Broders, 2011; Lockingbill et al., 2010). Our results demonstrate that in this area they are found more often in savanna than forested sites, but distance to water may still a determining factor (chapter 1).

Aside from the silver-haired bat, the type of surrounding cover type was not significant for either forest or savanna species. This indicates that the designation as savanna or forest at this scale was adequate at differentiating between these species. Although studies at the landscape scale generally fail to find associations between bat presence and landscape indices (Ford et al., 2006; Gehrt and Chelsvig, 2004), looking at an intermediate scale between macrohabitat and landscape for this particular question may be of value, especially for those species like the little brown bat that was found in both habitats. It could be that for bats to be present in a savanna it has to be surrounded at a larger scale by forest or that a more detailed analysis of the vegetative structure is warranted (Jung et al., 2012).

Our overnight data provided further information about differences in relative activity between savanna and forest sites. There were large differences between each of the chosen surveyed sites (as evidenced by large standard errors) and this is probably a result of the limited number of surveys completed. However, even though not significant, the changes across time between the two habitat types indicate possible temporal differences in habitat utilization. This could be due to changes in diurnal and nocturnal roosts (Anthony et al., 1981), insect activity (Rydell et al., 1996) or a combination of these factors.

Each of these species is present in areas that we would predict based on their wing morphology but there are differences between species in how these areas are being utilized. Radio telemetry is necessary to determine exact usage but these results demonstrate that savannas could be used for foraging (tri-colored) commuting (northern long-eared) or roosting (little brown bat, northern long-eared). Even those species that were found almost exclusively in savanna sites (hoary and eastern red bats), are also present in open canopy forests, again potentially for access to roosting sites. The potential for interspecific competition between species cannot be over looked, especially in light of the ubiquitous nature of the big brown bat. Duchamp et al. (2004) found that the evening bat was more restricted in its foraging in urban areas compared to the big brown bat. Smaller, less maneuverable bats may find it more difficult to move between fragmented areas. Indeed, Jones et al. (2003) found that these smaller less maneuverable bats were at a higher risk of extinction.

These results are not only helpful in understanding more about the important habitat characteristics for bats in general, but also for managers as they decide on habitat alterations within the Oak Openings Region. This area is intensively managed for savannas, and specifically habitat for the Karner Blue Butterfly (Peterson and Reich, 2001). But managing for high bat diversity forests may also be important as bats also play a vital role within these systems. They are thought to increase nitrogen through their guano deposits at roost trees and across the landscape (Pierson, 1998) and have demonstrated control over plant herbivory (Kalka et al., 2012).

Our results demonstrated that intact forest blocks, although small, continue to provide opportunities for bats such as the northern long-eared bat that has consistently been found in highly forested areas, while a combination of savanna and forest areas could be utilized by both more forest obligate (evening and little brown bats) and open adapted species (silver-haired, hoary, big brown and eastern red bats). This habitat type appears to be important for a suite of bat species and a range of life history characteristics. How these savanna sites differ from other types of forest openings is critical to further determine their absolute value in this system. They could potentially be better than clearings or clearcuts because of their increased edge habitat, insect activity and availability of roosts.

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Table 1. Results of differences in ten environmental variables based on Wilcoxon-signed rank test between the presence and absence of eight bat species determined present by means of acoustical surveys during June-August of 2010 and 2011

	Overall					Savanna					Forest				
Parameter	**Present**		**Absent**			**present**		**Absent**			**Present**		**Absent**		
	n	mean	N	mean	p	n	mean	n	mean	p	n	Mean	n	mean	p
Big brown bat															
Barometric pressure	351	29.25	246	29.19	**0.00**	209	29.24	83	29.16	**0.00**	142	29.25	163	29.21	0.11
Cloud cover	356	24.32	252	19.01	0.14	213	23.82	85	17.79	0.25	143	25.05	167	19.62	0.31
Humidity	351	78.96	246	78.29	0.27	209	79.36	83	77.49	0.08	142	78.36	163	78.70	0.85
Temperature	351	20.69	246	19.93	**0.02**	209	20.62	83	19.66	0.07	142	20.79	163	20.06	0.11
moon illumination	369	43.06	260	46.20	0.76	221	41.26	88	51.36	0.09	148	45.76	172	43.56	0.26
Coleoptera	322	0.39	223	0.22	0.08	187	0.52	72	0.35	0.28	135	0.20	151	0.16	0.46
Diptera	322	3.39	223	3.35	0.38	187	3.84	72	3.11	0.11	135	2.76	151	3.46	0.98
Lepidoptera	322	0.31	223	0.25	0.94	187	0.41	72	0.24	0.27	135	0.18	151	0.26	0.05
Orthoptera	322	0.09	223	0.04	**0.03**	187	0.14	72	0.04	**0.03**	135	0.02	151	**0.03**	0.58
Insect richness	321	1.50	222	1.28	0.06	186	1.63	72	1.31	0.11	135	1.31	150	1.27	0.49
Eastern red bat															
Barometric pressure	109	29.18	488	29.24	0.25	68	29.13	224	29.25	0.39	41	29.26	264	29.22	0.39
Cloud cover	107	19.37	501	22.70	0.45	68	19.75	230	22.80	0.59	39	18.71	271	22.62	0.59
Humidity	109	77.83	488	78.88	0.29	68	78.17	224	79.03	0.73	41	77.27	264	78.74	0.18
Temperature	109	20.73	488	20.30	0.27	68	20.61	224	20.27	0.52	41	20.93	264	20.32	0.31
moon illumination	113	48.58	516	43.44	0.19	71	52.73	238	41.57	**0.03**	42	41.57	278	45.03	0.58
Coleoptera	96	0.44	449	0.29	0.94	59	0.58	200	0.44	0.93	37	0.22	249	0.17	0.86
Diptera	96	2.82	449	3.49	0.25	59	3.20	200	3.77	0.46	37	2.22	249	3.27	0.42
Lepidoptera	96	0.20	449	0.31	0.22	59	0.20	200	0.41	0.07	37	0.19	249	0.22	0.98
Orthoptera	96	0.06	449	0.07	0.49	59	0.10	200	0.12	0.53	37	0.00	249	0.03	0.27
Insect richness	96	1.40	447	1.41	0.75	59	1.41	199	1.58	0.34	37	1.38	248	1.28	0.67

Table 1 continued.

Little brown bat															
Barometric pressure	92	29.17	505	29.24	0.10	33	28.98	259	29.25	0.92	59	29.27	246	29.22	**0.03**
Cloud cover	93	23.39	515	21.88	0.89	34	26.78	264	21.50	0.38	59	21.44	251	22.29	0.38
Humidity	92	77.96	505	78.82	0.58	33	78.58	259	78.86	0.44	59	77.61	246	78.77	0.21
Temperature	92	20.04	505	20.44	0.36	33	20.52	259	20.32	0.79	59	19.77	246	20.56	0.16
moon illumination	95	41.8	534	44.82	0.48	35	37.54	274	44.98	0.31	60	44.28	260	44.65	0.91
Coleoptera	80	0.41	465	0.30	0.56	31	0.81	228	0.43	0.18	49	0.16	237	0.18	0.81
Diptera	80	3.84	465	3.29	0.07	31	5.26	228	3.42	**0.00**	49	2.94	237	3.17	0.87
Lepidoptera	80	0.18	465	0.31	0.19	31	0.32	228	0.37	0.70	49	0.08	237	0.25	**0.04**
Orthoptera	80	0.04	465	0.08	0.41	31	0.10	228	0.12	0.89	49	0.00	237	0.03	0.19
Insect richness	81	1.49	462	1.40	0.49	31	2.06	227	1.47	0.03	50	1.14	235	1.32	0.47
Northern long-eared															
Barometric pressure	91	29.28	506	29.22	0.58	13	29.24	279	29.22	0.89	78	29.28	227	29.21	0.56
Cloud cover	94	25.23	514	21.54	0.40	13	23.65	285	22.03	0.60	81	25.49	229	20.94	0.46
Humidity	91	78.28	506	78.76	0.90	13	82.45	279	78.66	0.21	78	77.59	227	78.87	0.76
Temperature	91	20.37	506	20.38	0.83	13	19.42	279	20.39	0.24	78	20.53	227	20.36	0.82
moon illumination	94	42.48	535	44.69	0.62	13	43.85	296	44.15	1.00	81	42.26	239	45.36	0.55
Coleoptera	78	0.23	467	0.33	0.11	8	1.25	251	0.45	0.57	70	0.11	216	0.20	0.15
Diptera	78	2.97	467	3.44	0.98	8	2.88	251	3.66	0.84	70	2.99	216	3.18	0.77
Lepidoptera	78	0.32	467	0.28	0.88	8	1.00	251	0.34	0.78	70	0.24	216	0.21	0.66
Orthoptera	78	0.03	467	0.08	0.20	8	0.13	251	0.12	0.73	70	0.01	216	0.03	0.43
Insect richness	77	1.32	466	1.42	0.63	8	2.00	250	1.53	0.51	69	1.25	216	1.31	0.90

Table 1 continued

Evening bat															
Barometric pressure	66	29.27	531	29.22	0.33	33	29.25	259	29.22	0.78	33	29.29	272	29.22	0.28
Cloud cover	66	22.33	542	22.09	0.81	32	20.97	266	22.24	0.80	34	23.62	276	21.94	0.56
Humidity	66	75.78	531	79.05	**0.00**	33	76.78	259	79.09	**0.05**	33	74.78	272	79.00	**0.02**
Temperature	66	20.72	531	20.33	0.39	33	20.60	259	20.32	0.59	33	20.84	272	20.35	0.49
moon illumination	67	48.04	562	43.92	0.38	33	53.00	276	43.08	0.16	34	43.24	286	44.74	0.89
Coleoptera	55	0.42	490	0.31	0.27	26	0.62	233	0.45	0.45	29	0.24	257	0.17	0.40
Diptera	55	2.98	490	3.41	0.87	26	3.19	233	3.69	0.89	29	2.79	257	3.17	0.96
Lepidoptera	55	0.24	490	0.29	0.41	26	0.38	233	0.36	0.91	29	0.10	257	0.23	0.18
Orthoptera	55	0.13	490	0.06	0.25	26	0.27	233	0.10	**0.05**	29	0.00	257	0.03	0.34
Insect richness	55	1.47	488	1.40	0.56	26	1.54	232	1.54	0.88	29	1.41	256	1.28	0.49
Tri-colored bat															
Barometric pressure	29	29.25	568	29.22	0.92	23	29.25	269	29.22	0.84	6	29.23	299	29.23	0.95
Cloud cover	30	28.90	578	21.76	0.31	24	20.71	274	22.23	0.84	6	61.67	304	21.35	0.07
Humidity	29	79.94	568	78.62	0.35	23	81.47	269	78.60	0.15	6	74.12	299	78.63	0.39
Temperature	29	20.98	568	20.35	0.25	23	20.79	269	20.31	0.39	6	21.70	299	20.38	0.35
moon illumination	31	35.71	598	44.81	0.14	24	34.04	285	44.99	0.10	7	41.43	313	44.65	0.99
Coleoptera	26	0.50	519	0.31	0.76	19	0.68	240	0.45	0.50	7	0.00	279	0.18	0.26
Diptera	26	5.92	519	3.24	**0.02**	19	7.26	240	3.35	**0.02**	7	2.29	279	3.15	0.56
Lepidoptera	26	0.50	519	0.28	**0.04**	19	0.58	240	0.35	0.10	7	0.29	279	0.22	0.40
Orthoptera	26	0.19	519	0.06	**0.03**	19	0.26	240	0.10	**0.05**	7	0.00	279	0.03	0.66
Insect richness	26	2.23	517	1.37	**0.00**	19	2.37	239	1.48	**0.02**	7	1.86	278	1.28	0.21

Table 1 continued

Silver-haired bat															
Barometric pressure	46	29.26	551	29.22	0.59	41	29.27	251	29.21	0.90	5	29.17	300	29.23	0.09
Cloud cover	49	24.99	559	21.86	0.36	44	22.49	254	22.04	0.71	5	47.00	305	21.72	0.08
Humidity	46	77.99	551	78.74	0.63	41	77.48	251	79.05	0.34	5	82.18	300	78.49	0.41
Temperature	46	20.02	551	20.41	0.39	41	20.05	251	20.40	0.50	5	19.80	300	20.41	0.58
moon illumination	50	45.30	579	44.28	0.64	45	47.89	264	43.50	0.98	5	22.00	315	44.94	0.16
Coleoptera	35	0.46	510	0.31	0.39	31	0.52	228	0.46	0.51	4	0.00	282	0.18	0.39
Diptera	35	2.89	510	3.40	0.70	31	2.74	228	3.76	0.57	4	4.00	282	3.12	0.47
Lepidoptera	35	0.29	510	0.29	0.58	31	0.23	228	0.38	0.58	4	0.75	282	0.21	**0.05**
Orthoptera	35	0.11	510	0.07	0.14	31	0.10	228	0.12	0.89	4	0.25	282	0.02	**0.01**
Insect richness	35	1.71	508	1.39	0.18	31	1.65	227	1.53	0.72	4	2.25	281	1.28	**0.05**
Hoary bat															
Barometric pressure	28	29.22	569	29.22	0.13	25	29.24	267	29.22	0.48	3	29.11	302	29.23	**0.02**
Cloud cover	27	23.09	581	22.07	0.87	24	22.23	274	22.09	0.70	3	30.00	307	22.05	0.13
Humidity	28	79.75	569	78.63	0.68	25	78.86	267	78.83	0.66	3	87.13	302	78.46	**0.03**
Temperature	28	21.18	569	20.34	0.26	25	20.87	267	20.30	0.52	3	23.73	302	20.37	0.08
moon illumination	29	45.31	600	44.32	0.94	26	48.62	283	43.72	0.75	3	16.67	317	44.84	0.28
Coleoptera	22	0.59	523	0.31	0.08	20	0.65	239	0.46	0.13	2	0.00	284	0.18	0.55
Diptera	22	3.86	523	3.35	0.71	20	3.75	239	3.63	0.67	2	5.00	284	3.12	0.78
Lepidoptera	22	0.27	523	0.29	0.70	20	0.25	239	0.37	0.75	2	0.50	284	0.22	0.22
Orthoptera	22	0.09	523	0.07	0.49	20	0.10	239	0.12	0.88	2	0.00	284	0.03	0.82
Insect richness	22	1.73	521	1.40	0.39	20	1.80	238	1.52	0.50	2	1.00	283	1.29	0.75

Table 2. Differences between measured variables across matched savanna and forest sites for microhabitat (data collected at the place where Anabat acoustic equipment was placed) and macrohabitat (ArcGIS 60m buffers and FRAGSTATS indices) variables

Habitat condition	Savanna	Forest	t	p.
Average insect activity				
# of Lepidoptera	0.37	0.20	-48.50	0.144
# of Diptera	3.59	3.13	-10.00	0.77
# Orthoptera	0.110	0.03	-56.00	0.0059**
# Coleoptera	0.46	0.176	94.500	0.0002**
# of insect orders	1.55	1.26	-69.500	0.201
Microhabitat variables				
% Canopy cover	33.10	50.35	76.75	<0.001*
% Low clutter	38.49	50.35	39.500	0.0319*
% Mid-clutter	18.14	27.21	31.00	0.07*
% High-clutter	13.19	30.70	34.00	0.041*
% Forest understory	31.29	52.38	95.500	0.0003*
% Forbs/grasses	65.85	73.75	76.500	<0.0001*
Macrohabitat				
Distance to water (m)	588.89	561.72	-16.500	0.495
Distance to road (m)	241.29	234.24	-6.500	0.79
Distance to crop (m)	959.71	974.98	-32.500	0.167
Distance to residential (m)	102.29	101.13	-1.500	0.966
% upland forest	16.05	67.90	69.000	0.0014**
% swamp forest	1.235	11.111	14.00	0.016**
% floodplain forest	4.30	8.63	8.500	0.27
% savanna	52.44	4.92	-76.500	<0.0001**
% meadow/prairie	11.068	0.611	-18.000	0.0078**
% asphalt/residential	2.9	0.9	-1.500	0.500
Simpson index diversity of cover	0.4405	0.3866	-12.500	0.417
Number of patches	4.111	3.444	-17.500	0.379
Landscape shape index	1.643	1.570	-20.000	0.3975
Cohesion	71.57	75.24	26.00	0.4413

*sig. at 0.05 level 1-tailed wilcoxon matched pairs signed rank test
**sig. at 0.05 level 2-tailed wilcoxon matched pairs signed rank test

Table 3. Contingency table and chi-square results for presence and absence of each of seven species of bats across both 2010 and 2011 between 23 sites characterized as forest and 23 as oak savanna within the oak openings region of northwest Ohio

Species	Forest		Savanna		χ^2	p.
	Presence	Absence	Presence	Absence		
Little brown	19	4	15	8	1.8313	0.1760
Northern long eared	21	2	11	12	11.110	0.0009*
Eastern red	17	6	22	1	4.605	0.0319*
Evening	15	8	9	14	3.173	0.0749
Hoary	4	19	13	10	7.857	0.0051*
Tri-colored	6	17	15	8	7.299	0.0069*
Silver-haired	5	18	17	6	13.195	0.0003*

*significant at 0.05

Table 4. Results of Wilcoxon signed rank between presence and absence in habitat characteristics across savanna and forest sites for those species characterized as forest species and that were present or absent at least 75% of the time in savanna or forest, as well as spearman rank correlations for those species in which there was enough variation in relative activity to warrant a correlation. Only those variables significantly different in either forest or savanna are presented.

Forest	Species	Present	Absent	z	P	Spear	P
	Little brown						
	Canopy cover	71.59	80.66	0.662	0.09*	-0.44	0.035*
	Distance to road	208.20	265.52	0.851	0.39	-0.14	0.54
	Simpson diversity	0.43	0.30	-0.53	0.5	0.27	0.22
	Cohesion	74.55	78.49	0.285	0.78	0.20	0.35
	Northern-long-eared						
	# of patches	-	-	-	-	-0.34	0.113
	Evening bat						
	% low clutter cover	36.10	56.33	1.904	0.005	-	-
	Distance to water (m)	390.93	726.02	2.22	0.03	-	-
Savanna	Little brown						
	Canopy cover	28.9	27.73	-0.097	0.93	0.12	0.59
	Distance to road	263.83	130.30	-2.356	0.02*	0.45	0.03*
	Simpson diversity	0.41	0.54	1.133	0.26	-0.47	0.03*
	Cohesion	74.93	65.25	-1.26	0.21	0.47	0.03*
	Northern long-eared						
	# of patches	5.18	3.16	1.962	0.04*	0.44	0.035*
	Evening bat						
	% low clutter cover	33.11	42.00	-0.724	0.49	-	-
	Distance to water	500.24	589.10	-0.787	0.43	-	-

Table 5. Results of Wilcoxon signed rank between presence and absence in habitat characteristics across savanna and forest sites for those species characterized as savanna species and that were present or absent at least 75% of the time in savanna or forest, as well as spearman rank correlations for those species in which there was enough variation in relative activity to warrant a correlation. Only those variables that were significantly different in either forests or savanna are presented

Savanna	Species	Present	Absent	z	P	spear	P
	Big brown						
	% low clutter coverage	-	-	-	-	-0.21	0.33
	Distance to road	-	-	-	-	0.50	0.01*
	Distance to water					0.05	0.8
	Eastern red						
	% forbs/grasses cover	-	-	-	-	0.19	0.27
	% canopy cover					0.15	0.50
	Silver-haired						
	% canopy cover	22.32	46.03	2.135	0.03*	-	-
	# of Diptera	4.27	1.61	-2.145	0.02*	-	-
	% upland forest	9.8	0.20	0.681	0.49	-	-
	Distance to residential	88.00	78.00	0.00	1.00	-	-
	Simpson diversity	0.47	0.44	-0.175	0.86	-	-
	Hoary						
	% canopy cover	22.55	36.24	1.519	0.12	-	-
	Distance to residential	56.30	123.72	1.95	0.04	-	-
	Simpson diversity	0.47	0.43	-0.62	0.53	-	-
	Tri-colored						
	% canopy cover	20.18	44.11	2.03	0.04*	-	-
	# Diptera	4.27	2.27	-1.839	0.065	-	-
	# of patches	3.4	5.3	1.698	0.08	-	-

Table 5 continued

Forest	Big brown						
	% low clutter coverage	-	-	-	-	-0.48	0.02*
	Distance to road					0.25	0.24
	Distance to water					-0.54	0.007*
	Eastern red						
	% forbs/grasses cover	42.25	25.42	-1.95	0.045	0.44	0.034*
	% canopy cover	71.70	82.40	1.88	0.05	-0.36	0.09
	Silver-haired						
	% canopy cover	68.27	74.90	-1.085	0.28		
	# of Diptera	3.11	3.14	0.035	0.97		
	% upland forest	91.00	0.56	1.971	0.04*		
	Distance to residential	143.83	91.95	1.785	0.07		
	Hoary						
	% canopy cover	63.05	76.59	-2.00	0.04		
	Distance to residential	71.40	113.00	-1.15	0.25		
	Simpson diversity	0.60	0.36	1.740	0.07		
	Tri-colored						
	% canopy cover	65.63	75.82	-2.135	0.03		
	# Diptera	2.92	3.19	-0.245	0.80		
	# of patches	4.3	3.3	0.965	0.33		

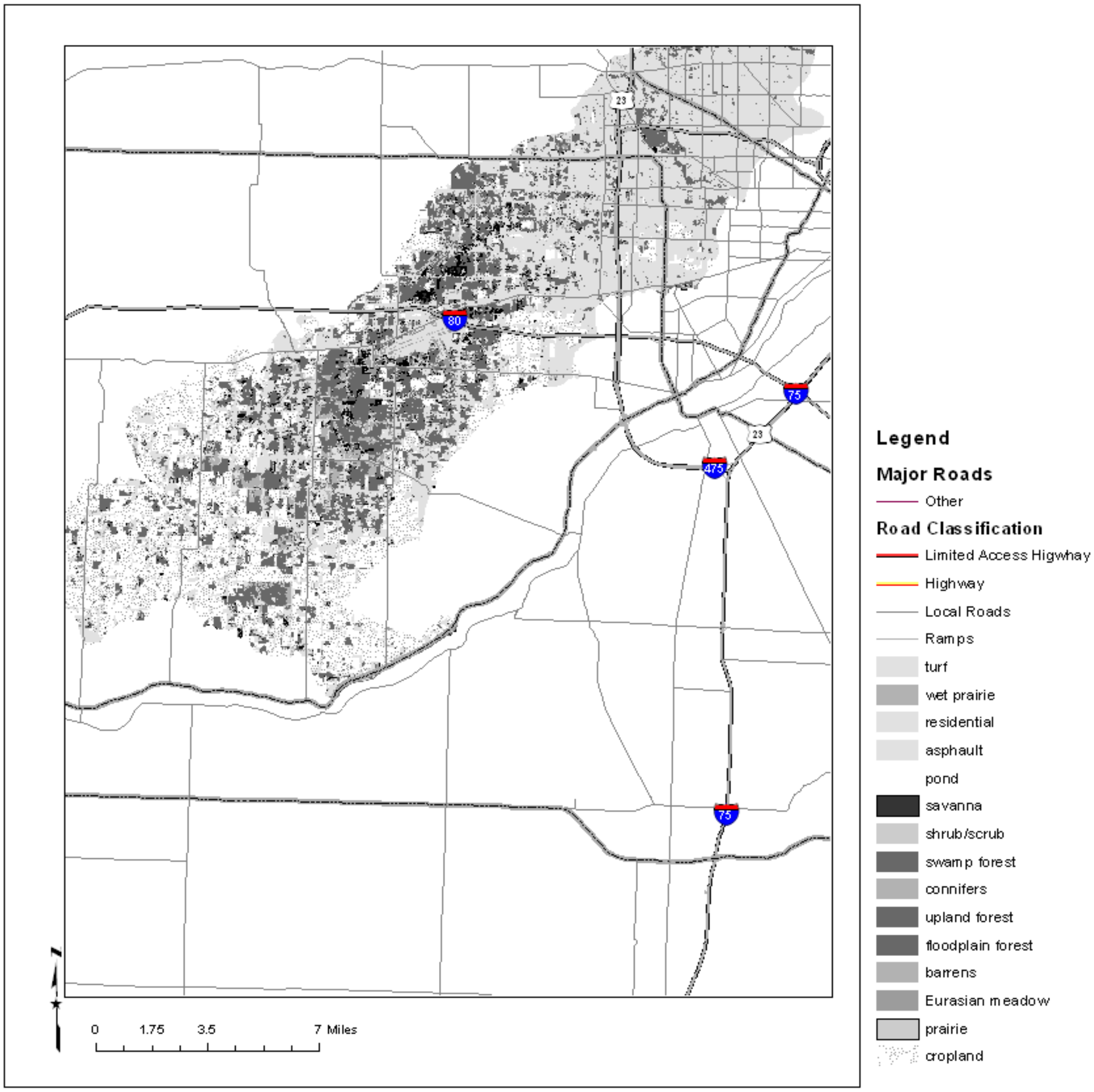


Figure 1. Map of extent of Oak Openings Region within Northwest Ohio with the 15 different types of land classes (based on Schetter and Root 2011) as well as major and minor roads.

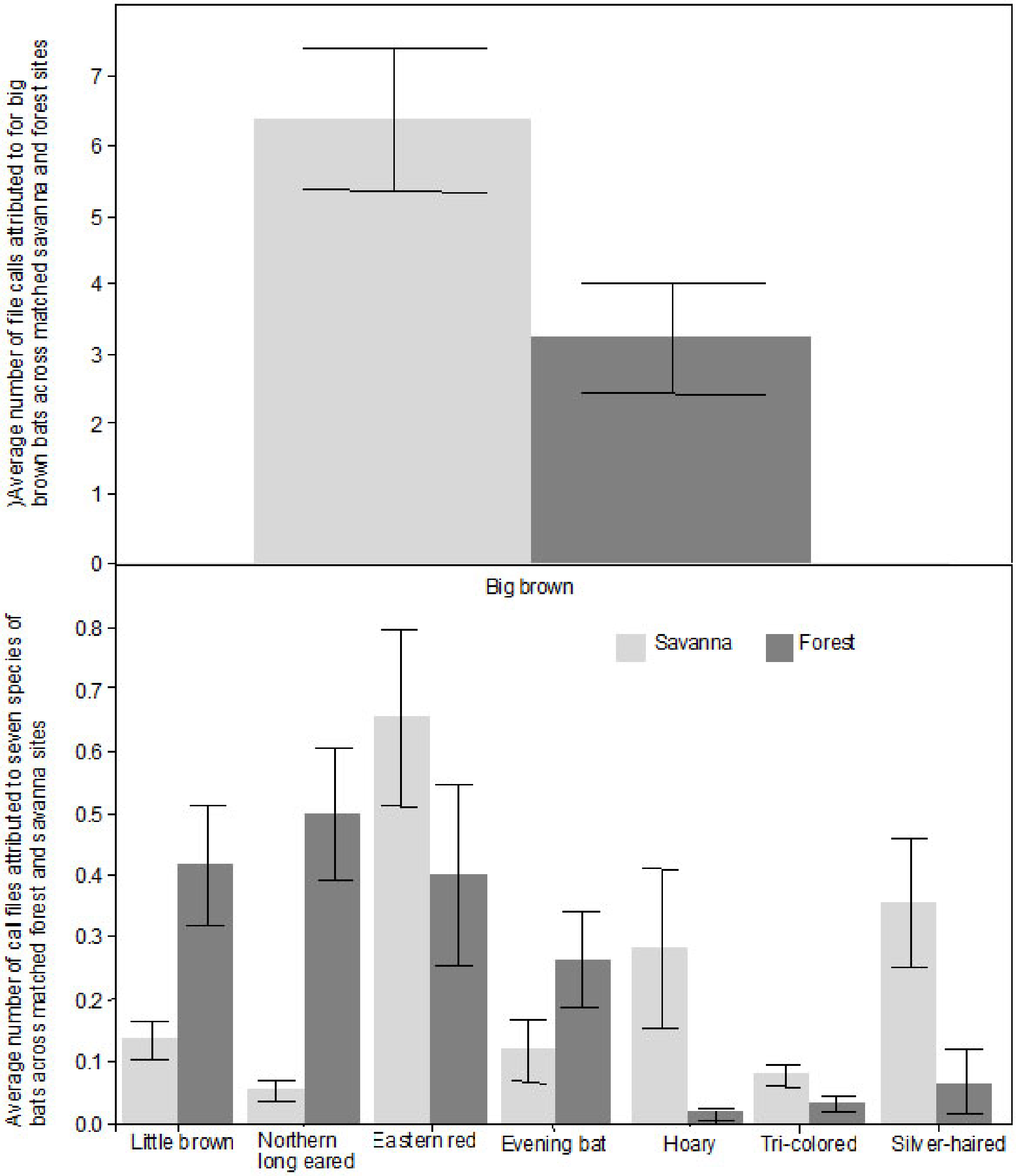


Figure 2. Differences in average activity for eight bat species across 23 matched savanna and forest sites in the Oak openings Region of Northwest Ohio. All pairs significantly different, Wilcoxon matched pairs signed-rank at p< 0.05

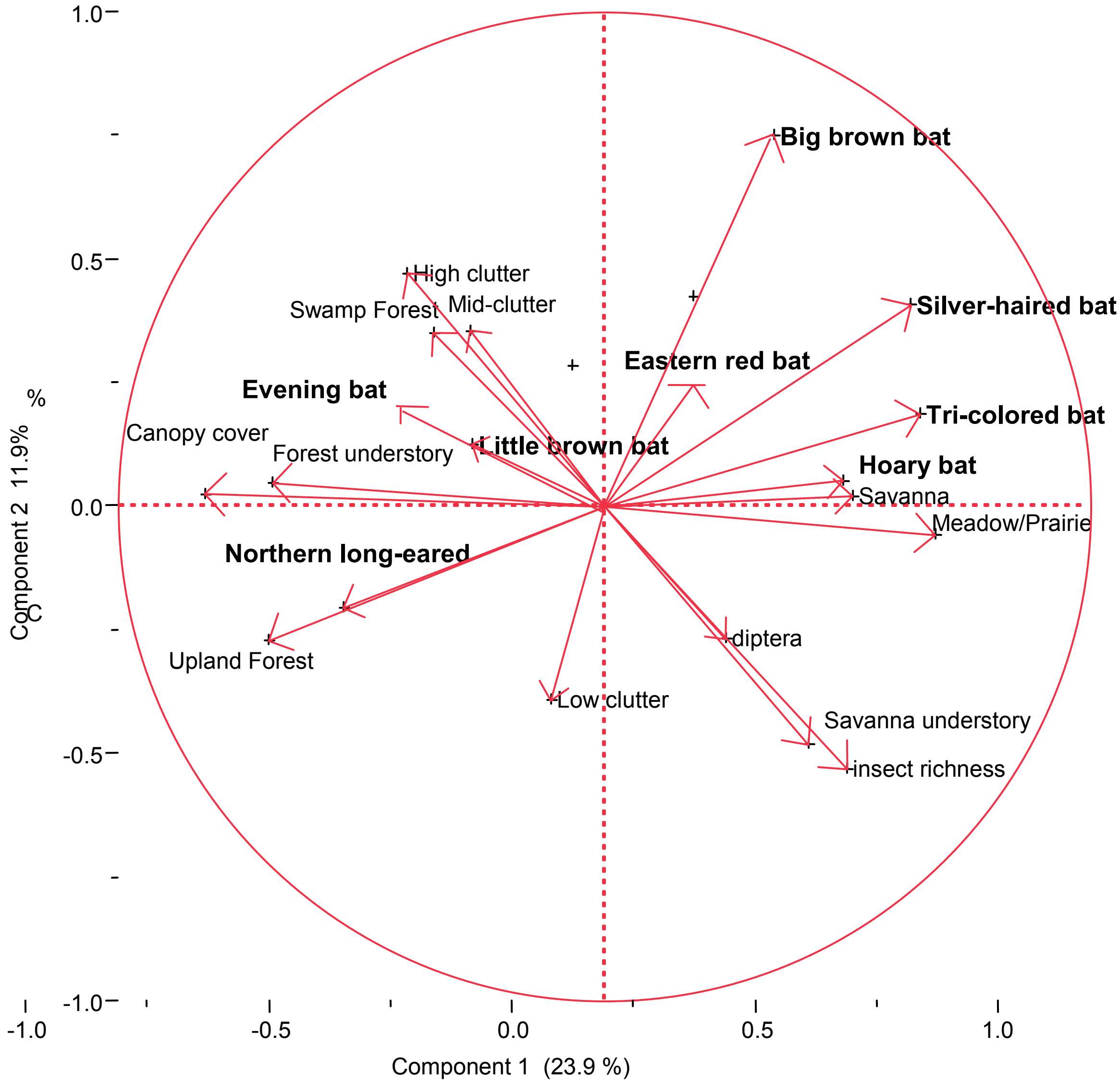
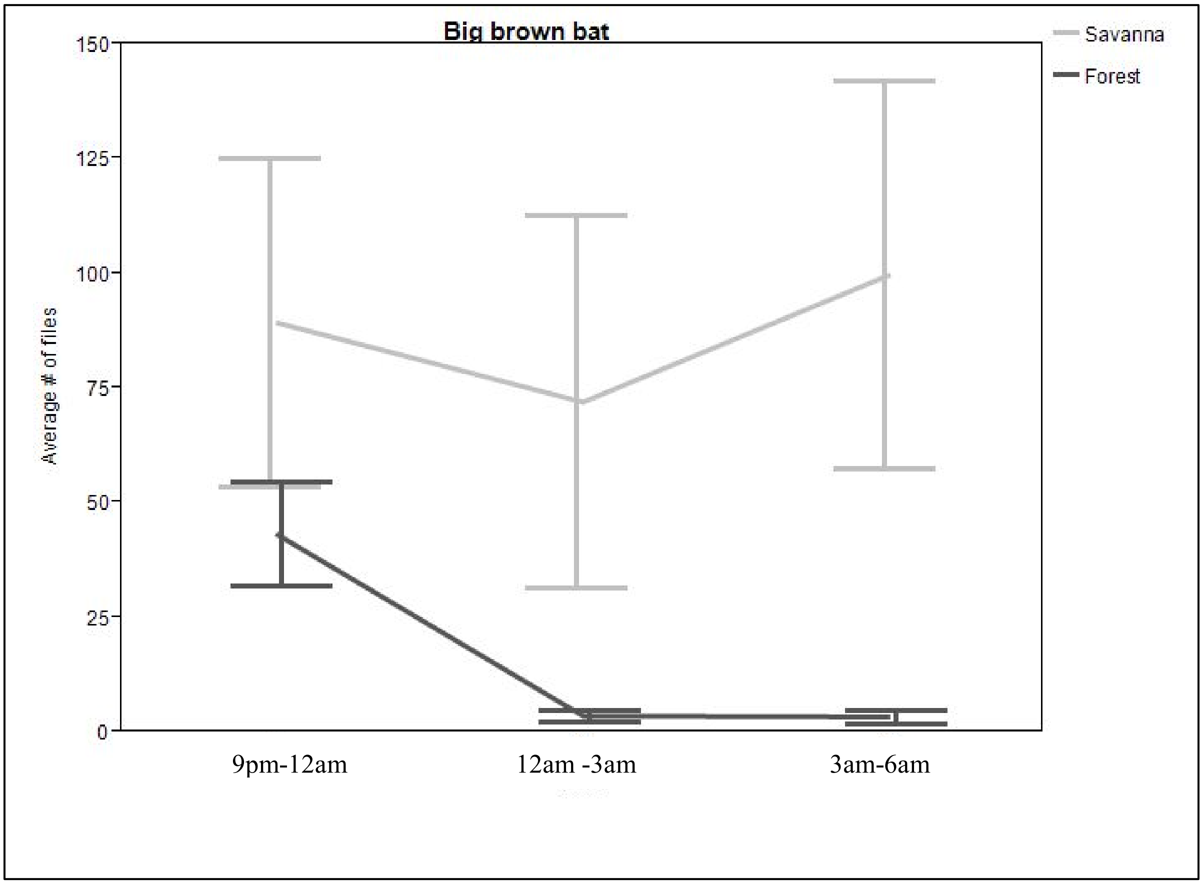
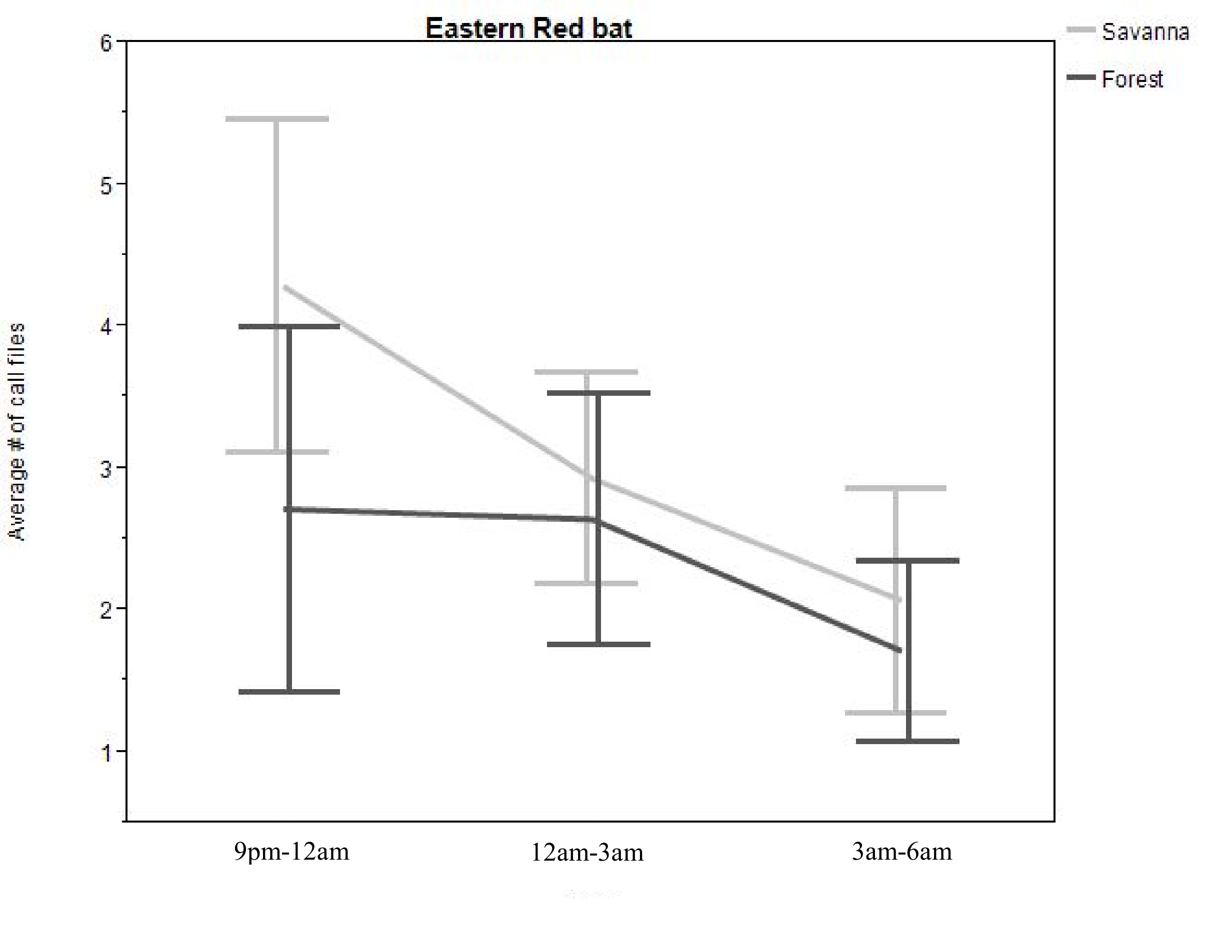


Figure 3. Principal components analysis including eight species of bats acoustically surveyed within savanna and forest sites in the Oak Openings Region of Northwest Ohio between June and August of 2010 and 2011. Stand and macrohabitat variables included are those that differed between savanna and forest sites.



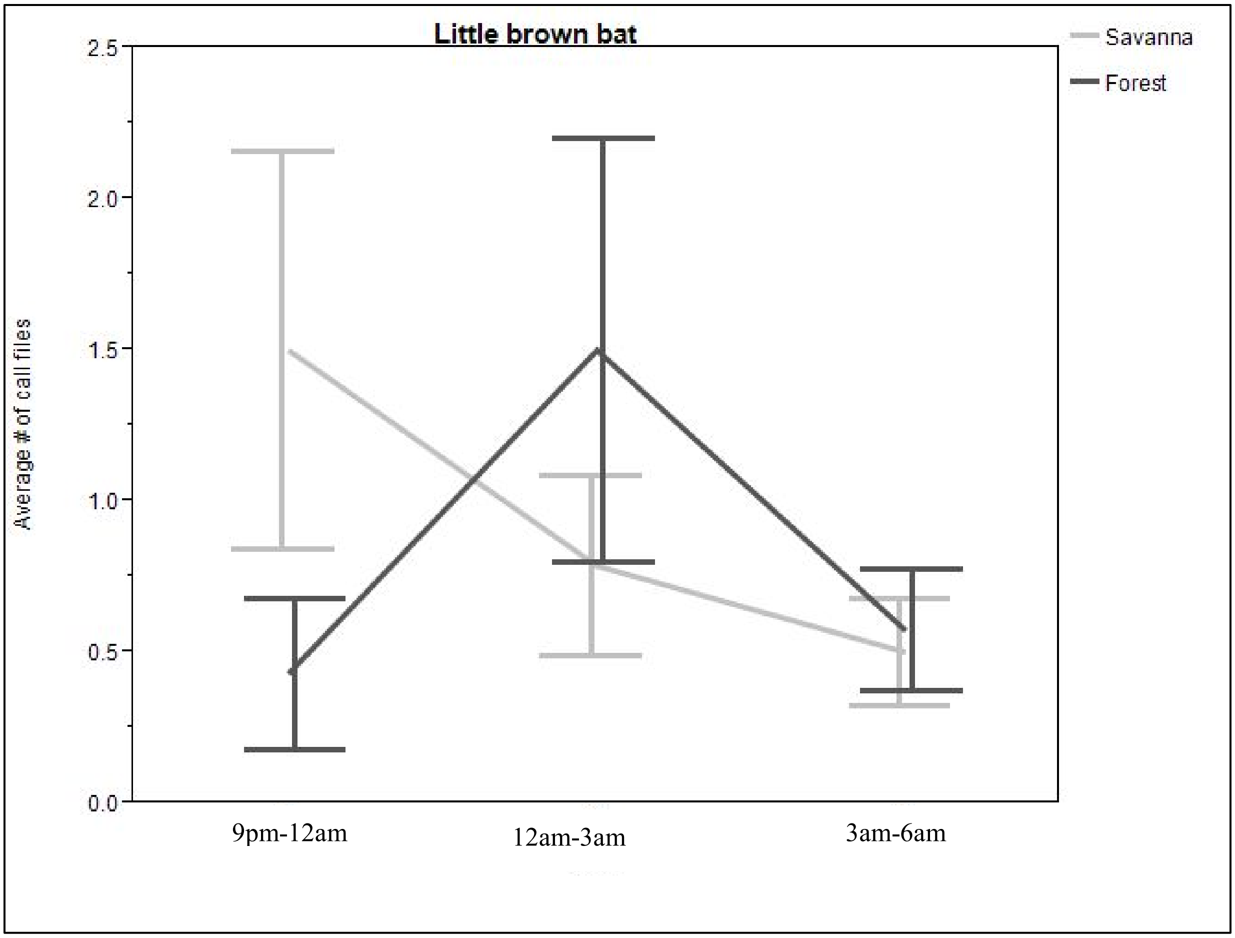
There was no interaction between the type of habitat and time of night for big brown bats $F(2,81) = 2.39$, $p=0.09$ and no main effect for time $F(3,80) = 2.79$, $p= 0.06$, but a significant main effect difference between savanna and forest sites $F(1,82)=13.68$, $p=0.0004$

Figure 4a. Graph of the average number of calls for big brown bats in forest and savanna sites during the early (9pm-midnight) mid (midnighy-3am) and late (3am-6am) time of night.



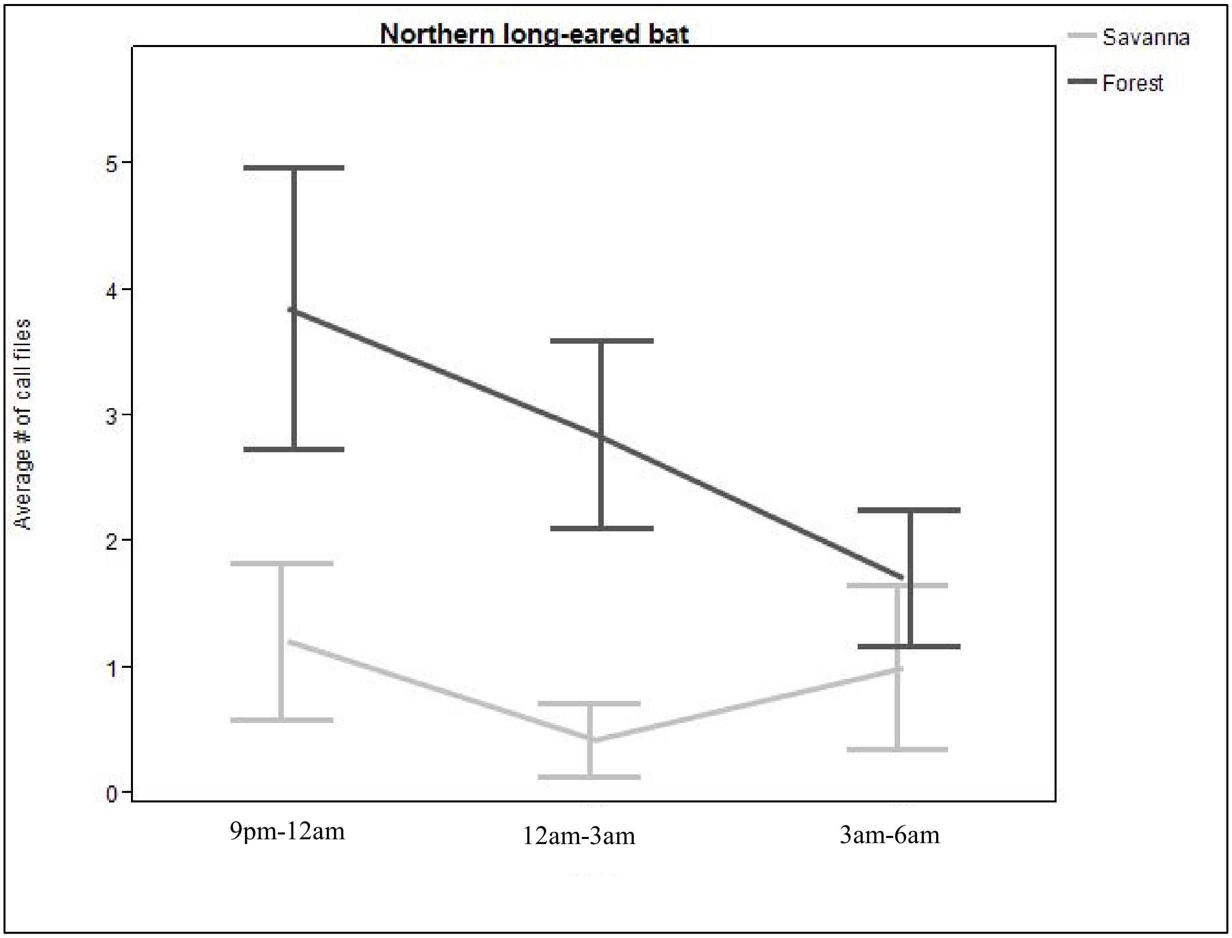
There was no interaction between type of habitat and time for eastern red bats F(2,81)=0.91, p=0.41 and no main effect for time F(3,80)=1.24, p=0.29 but a significant difference between savanna and forest F(1,82)=2.12, p=0.04.

Figure 4b. Graph of the average number of calls for eastern red bats in forest and savanna sites during the early (9pm-midnight) mid (midnighy-3am) and late (3am-6am) time of night.



There was no significant interaction between type of habitat and time F(2,81)=0.54, p=0.59 for little brown bats and no significant main effects for time F(3,80)=0.13, p=0.58 or type of habitat F(1,82)=0.93, p=0.34

Figure 4c. Graph of the average number of calls for little brown bats in forest and savanna sites during the early (9pm-midnight) mid (midnighy-3am) and late (3am-6am) time of night.



There was no significant interaction between type of habitat and time $F(2,81)=1.77$, $p=0.12$ for northern long-eared bats and no main effect of time $F(3,80)=2.32$, $p=0.1$ but a significant difference between type of habitat $F(2,81)=21.33$, $p=0.0001$

Figure 4d. Graph of the average number of calls for big brown bats in forest and savanna sites during the early (9pm-midnight) mid (midnighy-3am) and late (3am-6am) time of night.

CHAPTER III

REBRANDING BATS: STRATEGIES FOR ASSESSING AND ADJUSTING HUMAN PERCEPTIONS

ABSTRACT

The authors studied the link between knowledge of and attitudes towards bats, a historically disliked group of animals. A baseline survey was administered to homeowners, college students and participants of classes at local organizations. When possible a follow-up survey was also administered after exposure to educational outreach. A strong and positive link was found between knowledge and attitudes across all groups and education was successful for increasing some measures of attitudes, but not necessarily knowledge. These results demonstrate that knowledge regarding bats is still lacking and the authors give recommendations for educators.

INTRODUCTION

Species in the order Chiroptera, or bats, make up a large portion of the mammal world (Wilson and Reeder 2005). They are considered keystone (Bohm, Wells and Kalko 2011) and indicator species (Fenton 2003; Jones et al. 2009), are the main predators of night flying insects (Williams-Guillen, Perfecto and Vandermeer 2008), and are important in the regeneration of forests (Pierson 1998). The importance of North American bats to agriculture has recently been estimated in the billions of dollars (Boyles et al. 2011). Yet, in spite of these benefits, bats confront numerous threats on several fronts.

Most animals are negatively affected by habitat loss and bats are no exception. Bats now also face the devastation of White Nose Syndrome (WNS; Frick et al. 2010), a fungus that attacks the skin of hibernating bats (Gargas et al. 2010). This infection causes increased arousal from torpor which leads to a number of issues, from starvation during the winter months when food is unavailable, to a decrease in ability to gather food and reproduce in the summer months (Francl et al. 2011). Since the initial discovery of WNS in New York in 2007, mortality at some caves has been as high as 99% (Blehert et al. 2009; Frick et al. 2010), which translates into millions of bats. Although WNS has thus far impacted only those bats that hibernate in caves and mines, migratory bats that spend the summer months in warmer climates face the challenges emanating from wind energy development. Bats have been found colliding directly with rotating blades, or have suffered barotrauma from the pressure changes caused by these blades (Cryan and Barclay 2009).

If these assaults were not enough, worldwide historical threats continue, including the effects of bioaccumulation of pesticides (Fenton and Rautenbach 1996), and hunting pressure (Mickleburgh, Waylen and Racey 2009). The challenge that bat conservationists are faced with, however, are the widespread misconceptions and misunderstandings regarding bats that people often hold (Morton and Murphy 1995). These misconceptions can lead to a variety of behaviors, such as direct eradication (Hart 2009). It has become crucial that we mediate these misconceptions and misunderstandings and the impacts they may have on bats. It is ultimately the human inhabitants of an area that will make decisions regarding the protection or changes in important habitat, funding for research and support for non-governmental organizations (Jacobson, McDuff and Monroe 2006).

Conservation education is an integral part of the conservation of native species (Jacobson, McDuff and Monroe 2006) and has been successfully shown to change people’s knowledge of, and attitude towards, a host of different organisms (Zimmerman 1996).

Knowledge regarding manatees was positively correlated with conservation support for the species (Aipanjiguly et al. 2003). Knowledge regarding wildlife is also a predictor of attitudes towards them for both adults (Tarrant et al. 1997) and children (Gutierrez de White and Jacobson 1994). This relationship is also not unique to animals, but also overall environmental knowledge and attitudes (Arcury 1990). It is hoped that these increases in positive attitudes then result in changes in behavior, and, when studied, this is often the case. For instance, Steel (1996) found that those individuals that scored higher on an environmental attitudes questionnaire were more likely to participate in pro-environmental behaviors.

It may be, however, that those who hold more positive attitudes have more motivation and willingness to learn new information (Tobias 1994). Pooley and O'Connor (2000) propose that the more positive your attitudes towards a concept, the more willing you are to learn about it. How the cognitive (knowledge) and affective (emotion) domains interact or whether one leads to the other is still unclear (Zimmerman 1996), but regardless of the relationship, it does appear that increases occur together.

This relationship between knowledge and attitudes has also been found for bats. In a survey of college students Prokop, Fancovicova and Kubiatko (2009) found that over half of the students surveyed held incorrect myths about bats, but the more the students knew more about the biology of bats the more positive attitudes they also had. In other places (such as Latin America and Asia) where education about bats has been initiated, the views of people about those bats have improved (Trewhella et al. 2005; Morton and Murphy 1995). It remains to be seen if these misconceptions persist in North America, or in an adult demographic a groups for which little research has been done (Zimmerman 1996).

In the current study it is our goal to further the work of Prokop, Fancovicova and Kubiatko (2009) who found a link between knowledge of and attitudes towards bats for college students in Slovakia. We have utilized their research methodology to determine if this link exists for not only college students in the United States, but also other groups. Our surveyed groups include: 1)participants in different types of educational outreach; 2) homeowners in the Toledo Metropolitan area; and 3) biology majors and 4) non-majors in introductory biology classes at Bowling Green State University, Bowling Green OH, USA. From information gathered on the baseline survey we could better understand what is already known about bats, where gaps in knowledge might be, and what types of attitudes are the most persistent. We also wanted to know whether there was a relationship between knowledge of and attitudes towards bats and attitudes towards the environment in general.

Our second aim was to determine if education increases both knowledge and attitudes, and if there was a difference in this increase if hands-on experiences were included in the educational unit. By conducting education for a wide range of audiences with various types of educational outreach we can better understand what type of education is critical in increasing knowledge and changing attitudes, and potentially behaviors. This study is unique due to its integration with ongoing ecological work. It is important to understand whether education has had an impact so that resources, in terms of time and money, are effectively utilized (Padua and Jacobson 1993; Jacobson, McDuff and Monroe 2006).

METHODS

Baseline survey

We developed a 5 point Likert scale survey that is an adaptation from two previously used and validated surveys. The first was from Prokop, Fancovicova and Kubiatko (2009), which was originally designed to test the knowledge, beliefs and attitudes regarding bats held by high school students. The second survey was developed and implemented by Stern et al. (2008). This survey was designed to test the effects of an environmental education program on four indices: environmental stewardship, connection with nature, interest in learning, and knowledge and awareness of biodiversity. We used items from 2 of the 4 indices, those from environmental stewardship and connection with nature. These indices were used to establish participant's overall understanding and awareness of the environment.

After combining questions from the two surveys and adding seven demographic questions, the result was a final survey of 43 questions. These included 19 questions relating to attitudes about bats, 9 relating to knowledge about bats, and eight regarding the environment. In addition, we broke the attitudes questions into three subsets also originally used by Prokop, Fancovicova and Kubiatko (2009): Scientistic, which is reported behavior towards bats and interest in their overall biology (e.g., I want to take part in activities that help bats); Ecologistic, the overall concern for the species (e.g., I am not interested in whether bats in the United States are endangered); Negativistic, the comfort with bats in personal space (e.g., I would rather avoid places where bats are present). The three subsets of attitudes were originally developed by Kellert (1996) to describe the differences in types of values that people hold regarding the living world.

In some situations it was necessary for us to utilize a shorter survey. For these situations we took representative questions from the two bat measures, attitudes and knowledge, and created a six question 5 point Likert scale survey. We created the short survey after we had used the full version on 130 undergraduate freshman and chose questions that were highly correlated to the overall measure (i.e., those questions highly correlated to average bat knowledge and average attitudes from the original survey). This survey was used for a majority of the outreach classes as the classes were of limited time and taking the entire survey became a hindrance to the educational efforts. Surveys were considered confidential and participants were asked only to supply a unique identifier at the top of each survey so that baseline and follow-up surveys could be matched.

Follow-up survey

A follow up survey was also created that included the original questions about knowledge regarding and attitudes towards bats. Questions related to environmental attitudes were not included as they would likely not change over the course of a short-term class. This full length follow-up survey was administered to participants in three Toledo Zoo classes and one class at the Metroparks of the Toledo Area. An identical shortened version of the short baseline survey was used for all remaining outreach classes; therefore all comparisons between outreach classes are based on this shortened survey.

Participants

The baseline survey was given to four distinct groups of people. We obtained a list of 500 homeowners (Kaczala 2005) that resided within the Oak Openings Region of northwest Ohio (as defined by the borders of Brewer and Vankat (2004) and that lived within 10 miles of three of the larger protected areas within the region. We chose this area because it is also where a concurrent ecological study regarding bats was being conducted by the authors. In this way we were able to directly link ecological research with education.

To increase the sample and probability of residents filling out surveys, we followed the methods developed by Salant and Dillman (1994). We sent a paper copy of the survey out to 500 randomly selected homeowners within the Oak Openings Region. The mailing included a return envelope as well as a website in which participants could choose to fill out the survey online if they preferred not to send it back. A week after the initial mailing we also sent a follow-up postcard reminding participants of the survey.

The second and third groups were non-biology and biology majors that were students in introductory biology courses offered at Bowling Green State University. The non-biology students were enrolled in an introductory environmental science course and the majors were enrolled in an introduction to organismal biology course. The baseline surveys were given within the first three weeks of the course.

The last group comprised citizen science volunteers and participants of classes offered to families at no fee at various community organizations. These classes were informal educational classes in which the basic biology and importance of bats were discussed. Before the class began adult participants were asked to fill out the survey. The primary author taught all classes and used knowledge gained during a concurrent study focusing on the local ecology of these animals to augment general information about bats.

In addition, different types of experiences were given to each of the classes. At three classes held at the Toledo Zoo, participants were able to “meet” a resident bat of the zoo, while “bat walks” occurred at the Metroparks of the Toledo Area and in association with a local science center. Participants were able to visit a bat foraging area and listen to them with an Anabat acoustic monitor (Titley Electronic, Ballina New South Wales, Australia). A third type of class was not able to engage in these types of activities due to time or location constraints and we termed these classes “basic classes”.

A final type of education outreach was a citizen science volunteer program that was initiated in conjunction with the Metroparks of the Toledo Area. At the beginning of the volunteer experience participants were surveyed and then given the same information as the other outreach classes, as well as training on the acoustic devices. Participants were able to participate in data collection using the acoustic monitor from June-August of 2011 and at the conclusion of this they were given the follow-up survey. The acoustic data collected was used for a spatially-explicit habitat model of bat presence (Chapter 1).

RESULTS

Baseline Survey

We received full baseline surveys from 126 homeowners, 135 from non-biology majors, 395 from biology majors, and 57 class participants. Questions that were worded in the negative were re-coded so that higher values reflected more knowledge/more positive attitudes. We then averaged the responses for each of the five measures (attitudes towards the environment, overall attitudes towards bats, negativistic attitudes, scientistic attitudes, ecologistic attitudes, and knowledge regarding bats) to obtain one score for each respondent per measure.

General attitudes and knowledge on baseline surveys

Our findings regarding general attitudes and knowledge were similar to the findings of Prokop, Fancovicova and Kubiatko (2009). Overall, 40% of respondents indicated an average score of neutral or unknown on knowledge questions, while 60% indicated positive scores (indicating a high level of knowledge). However, certain knowledge questions were answered better than others. Those questions that were specifically asked about bats in Ohio were answered poorly while what was thought to be a common misunderstanding about bats (that they mostly feed on blood) was generally answered correctly (Table 1).

For overall attitudes 36% were, on average, neutral, 56% positive, and 8% had a negative score. In terms of the submeasures, respondents were concerned about bats in nature (ecologistic sub measure: 80% average positive response, 18% neutral and 3% negative) but less positive scores were obtained for scientistic (41% positive, 47% neutral, and 11% negative) and negativistic (56% positive, 33% neutral, and 11% negative) sub measures. Prokop, Fancovicova and Kubiatko (2009) found a similar pattern with respondents scoring the highest on ecologistic and the lowest on negativistic.

Relationship between knowledge and attitudes

Results indicate that, when all groups are considered together, there is a significant and positive correlation between average attitudes towards bats (average score from all measures of negativistic, ecologistic and scientistic) and knowledge regarding them. In general the more someone knew about bats the more positive their attitude (or, conversely, the more positive their attitude, the more they knew). There was also a significant and positive correlation between knowledge about bats and each submeasure of attitudes (Table 2). This correlation was strongest between the ecologistic submeasure and knowledge.

Differences between groups

The correlation between attitudes towards bats and knowledge regarding them was significant even when we analyzed each group separately (Table 3), but the correlation between attitudes and knowledge was strongest for outreach participants and weakest for both groups of college students. Results indicated a significant difference between the groups on the measure of knowledge, $F_{(3,709)} = 10.4513$, $p. < 0.0001$. Tukey HSD pairwise comparisons revealed that the outreach participants (M=3.82) and homeowners (M=3.69) scored higher than both the college non-biology majors (M=3.51) and the college biology majors (M=3.57). There was also a significant difference for overall attitudes $F (3,709) = 4.7071$, $p. = 0.0029$, but the outreach participants scored higher (M=3.6) on this measure than the homeowners (M=3.2) and non-majors, (M=3.2) but not the biology majors (M=3.4) (Figure 1).

There were also significant differences between the groups on each of the submeasures of attitudes (ecologistic, $F(3,709) = 3.6313$, $p.=0.0127$; scientistic, $F(3,709) = 10.7830$, $p. < 0.0001$ and negativistic $F(3,709) = 5.1845$, $p.=0.0011$) (Figure 2). Tukey HSD pairwise comparisons revealed that outreach participants scored the highest on all three submeasures of attitudes. They scored significantly higher (M=3.7) than all three other groups on the scientistic measure (biology majors, M=3.09; non-majors, M=2.988; homeowners, M=3.135). They also scored significantly higher (M=4.06) on the ecologistic measure in relation to the two groups of biology students (non-majors, M=3.72; majors, M=3.82), but were not different from the homeowners (M=3.86). On the negativistic measure, however, the outreach participants (M=3.43) and the biology majors (M=3.44) scored significantly higher than both the non-majors (3.3) and the homeowners, who scored the lowest on this measure (M=3.098).

The role of attitudes towards the environment

Results also indicated that the more positive a respondent's attitudes towards the environment in general, the more positive their attitudes towards bats, Pearson's $r(712) = 0.4640$, $p. < 0.001$ and the more they knew about bats, Pearson's $r(712) = 0.4451$, $p. < 0.4451$. These correlations were significant across the four groups as well, but the strongest correlations were for the outreach participants, while the weakest correlations were for homeowners (Table 3).

Differences in baseline and follow-up survey

A total of 155 people participated in outreach classes. Seventy of these participants were given both a baseline and follow-up survey (14 in the "basic class", 12 citizen scientists, 15 in the "bat walk" and 29 in the "meet a bat"). Due to time constraints, many of these participants were given the shortened version of the survey. This six question survey contained three negativistic questions, one ecologistic question, one scientistic question and one knowledge question. These questions were highly correlated with each of the respective measures and considered proxies for those measures. Although some respondents were given the full survey, results regarding these classes are taken only from the questions that were given to all respondents.

We conducted, for each of the three submeasures and the measure of knowledge, univariate 4(class type) x 2 (survey) between groups ANOVA's to determine if baseline and follow-up surveys differed and if that difference depended on the class type. Although we attempted to match all pre and post surveys, many were returned in a way that we were unable to match each individual's baseline and follow-up survey, therefore we conducted between subjects ANOVA's rather than the more robust within subjects.

We found that there was no interaction between the different types of classes and the different measures of attitudes and knowledge (Table 5). The difference between baseline and follow-up did not differ across groups, nor did groups differ between the baseline and follow-up surveys. The only measures that increased between baseline and follow-up surveys was that of the negativistic (baseline $M = 3.5$, follow-up $M = 3.9$) while there was no significant difference in scientistic (baseline $M = 4.0$, follow-up $M = 4.6$), ecologistic (baseline $M = 4.6$, follow-up $M = 4.8$) attitudes or knowledge (baseline $M = 4.2$, follow-up $M = 4.4$).

The four class types differed regardless of survey point (baseline vs follow-up) for all but the scientistic sub-measure. Tukey HSD was conducted to determine which classes differed. The meet a bat class had a higher score on knowledge ($M=4.5$) than both the volunteers ($M=4.0$)

and the participants in traditional classes (M=4.0), while the volunteers had a higher score on the negativistic submeasure (M=4.16) than did the meet a bat (M=3.6) and traditional class (M=3.5) participants. On the ecologistic submeasure, however, the volunteers again had the highest score (M=4.95), but the traditional class participants (M=4.82) also scored higher than the meet a bat participants (M=4.55).

DISCUSSION

This work demonstrates that there are still knowledge gaps that remain about bats, but that these gaps may not be as widespread and common as originally thought, at least within the population that was surveyed. We did find, however, that there was a lack of knowledge about the bats that ranged within this area of Ohio. Outreach classes not only increased overall positive attitudes and knowledge, but the baseline survey suggested that we needed to focus the classes on the particular Ohio species. This demonstrates the importance of gathering baseline data to know where education should be targeted.

The results of our baseline surveys were in line with the research of Prokop, Fancovicova and Kubiatko (2009) who originally developed the survey we used, pointing out the comparisons across cultures. There were notable differences, however, mainly due to our survey of additional groups. Homeowners had high knowledge regarding bats, but this did not necessarily reflect in positive attitudes towards them, especially in terms of willingness to be around bats or in areas with bats; whereas the biology majors did not have high levels of knowledge regarding bats, but their attitudes were favorable. We see that overall there may be a correlation between knowledge and attitudes, but it does depend on the group. Based on our results with the outreach participants, the correlation between knowledge and attitudes may be driven by attitudes, and not knowledge as there were gains in attitudes and not knowledge. Hands on experience may drive a personal desire for knowledge, or make knowledge more pertinent and memorable.

Attitudes towards an animal can also be multi-faceted. Homeowners may have been interested in ecology of bats (ecologistic sub-measure) but were not interested in being near bats or having bats near them. Outreach participants scored the highest on the scientistic measure, they were, not surprisingly, more interested in learning about bats. The role these measures play in a person's awareness or desire to conserve a species remains to be understood. Is it necessary to be willing to be around bats, to want to save them or be interested in their conservation?

This is further exemplified with the correlation between attitudes towards the environment and attitudes towards and knowledge regarding bats. Although significant, the weakest correlation was between the negativistic attitudes towards bats and attitudes towards the environment. Positive attitudes towards the environment did not necessarily reflect a willingness or desire to be around bats. Again, perhaps the only important criterion is an appreciation of an animal rather than a desire to be around that animal. Kotchen and Reiling (2000) found that those respondents with higher environmental attitudes placed higher economic value on peregrine falcons and shortnose sturgeons. An economic evaluation of bats in relation to attitudes towards them would be an interesting follow-up to the current study especially in light of the realized economic importance of bats (Boyles et al. 2011).

Throughout this process educational units were delivered by the primary author, a person also studying the ecology of bats in the area. It has been pointed out by others (Fox-Parrish and Jurin 2008) that perhaps a subject matter expert may have more impact when delivering the education. This should be further investigated, but this is an intriguing idea and one that biologists that are interested in conservation should perhaps consider. In the current study local and relevant knowledge was important for increasing knowledge and local engagement. Concurrent ecological research coupled with educational outreach creates the most holistic approach to overall conservation of imperiled species (Walsh and Morton 2009).

Outreach groups did have pre-existing positive views toward bats, even before participation in the class, and although there was an increase in both attitudes and knowledge (although only significant for attitudes), these measures were mostly positive in the beginning. This may have been an audience that did not necessarily need education regarding bats, but it is important to continue to positively reinforce and affirm favorable attitudes (Storksdieck, Ellenbogen and Heimlich 2005) to influence the process of behavior change (Jacobson, McDuff and Monroe et al. 2006). Results with a larger sample size or the full version of the survey might have had different results. The short survey, however, was essential for the time constrained classes. Our methods of testing a full survey on a large sample of respondents and then using that to create the short version gave us confidence in the measure. This is a potentially useful tool for conservationists as improvement of conservation programs is needed (Kleiman et al. 2000) and often lacking.

It is, of course, difficult to educate people that are not actively seeking out education. The question still remains as to how we increase the knowledge and attitudes of those that were not involved in classes, such as homeowners and undergraduate students. The materials that we used in the classroom and for homeowners was passive, such as lectures, newsletter mailings and community events where we had an exhibit with information about bats, but it is still unclear what impact these measures might have had. We do know, however, what knowledge is lacking within the greater population and can continue to use that information for targeted passive education.

We also do not know if our education will have long term impacts on knowledge retention or attitude changes and of course, changing behavior can be a much more complicated process. Although there may be an increase in knowledge, behavior changes many not surface due to the constraints of social or economic stressors (Trewhella et al. 2005) and, in some cases, these may be the culprit for a lack of attitude and knowledge changes as well (Struhsaker, Struhsaker and Siex 2005; Zimmermann 1996). The specific attitudes questions that we analyzed indicated that people left the outreach classes thinking that studying bats is beneficial and that greater attention should be dedicated to bat protection.

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Table 1. Percentage of correct answers of a few key questions in regards overall knowledge of bats and the knowledge of bats in Ohio for all respondents (n= 713)

Knowledge Question	% of respondents scoring answers correctly (either 4 or 5 on Likert scale)
Most bats in the United States feed on insects	81%
Most bats feed on blood	76%
Bats can get tangled in your hair	35%
Bats in Ohio over winter in abandoned caves and tunnels	38%
Bats in Ohio sleep through winter and do not feed	18%
Protection of old buildings and trees contribute to bat protection	46%

Table 2. Pearson correlation between knowledge regarding bats and overall attitudes towards them, as well as three sub-measure of attitudes (scientistic, ecologistic and negativistic) obtained from a baseline measure given to non-biology and biology majors, homeowners and participants in outreach classes (n= 713). All correlations significant at p. < 0.0001

	Scientistic	**Ecologistic**	**Knowledge**
Negativistic	0.6651	0.5571	0.4628
Scientistic	--	0.6610	0.4470
Ecologistic	--	--	0.5516
Overall attitudes	--	--	0.5228

Table 3. Pearson correlations between each submeasure of attitudes regarding bats and knowledge bats for each of four groups of respondents, biology majors, non-majors, homeowners and participants in outreach (all correlations significant at p. < 0.0001)

	Scientistic	**Ecologistic**	**Knowledge**
Negativistic			
Biology majors	0.6853	0.5580	0.4615
Biology non-majors	0.6532	0.5644	0.4590
Homeowners	0.7124	0.6130	0.5674
Outreach participants	0.6777	0.5323	0.5553
Scientistic			
Biology majors		0.6371	0.4044
Biology non-majors		0.7044	0.4590
Homeowners		0.6838	0.4759
Outreach participants		0.6065	0.6164
Ecologistic			
Biology majors			0.5352
Biology non-majors			0.6010
Homeowners			0.4955
Outreach participants			0.5793
Overall attitudes			
Biology majors			0.4992
Biology non-majors			0.5028
Homeowners			0.5816
Outreach participants			0.6561

Table 4. Pearson correlation between knowledge about bats, overall attitudes regarding bats and the three submeasures of attitudes, scientistic, negativistic and ecologistic with overall attitudes towards the environment for four groups of respondents. All correlations significant at $p < 0.0001$

	Attitudes towards the environment
Knowledge about bats	
Biology majors	0.3962
Biology non-majors	0.5042
Homeowners	0.3277
Outreach participants	0.6227
Overall attitudes	
Biology majors	0.4893
Biology non-majors	0.4290
Homeowners	0.4100
Outreach participants	0.5493
Scientistic	
Biology majors	0.4976
Biology non-majors	0.4313
Homeowners	0.4320
Outreach participants	0.5064
Negativistic	
Biology majors	0.3584
Biology non-majors	0.2996
Homeowners	0.2918
Outreach participants	0.4660
Ecologistic	
Biology majors	0.5827
Biology non-majors	0.5596
Homeowners	0.4764
Outreach participants	0.5686

Table 5. Results of 4x2 between subjects ANOVA for three submeasures of attitudes towards bats and knowledge regarding bats for baseline and follow-up surveys given to participants in four types of classes about bats (volunteers, bat walks, meet a bat and traditional class).

Measure		**df**	**SS**	**F**	**P**
Negativistic	Class type	3	6.901148	3.4784	0.0178*
	Survey point	1	4.126202	6.2392	0.0137*
	Class type* survey point	3	1.722602	0.8682	0.4593
Scientistic	Class type	3	4.424998	1.5007	0.2179
	Survey point	1	5.727396	5.8271	0.0173*
	Class type* survey point	3	4.566787	1.5488	0.2055
Ecologistic	Class type	3	3.338036	5.6486	0.0011*
	Survey point	1	0.636498	3.2312	0.0745
	Class type* survey point	3	0.260964	0.4416	0.7236
Knowledge	Class type	3	7.759541	3.8705	0.0108*
	Survey point	1	1.447997	2.1668	0.1433
	Class type* survey point	3	0.80581	0.4019	0.7518

*significant at < 0.05

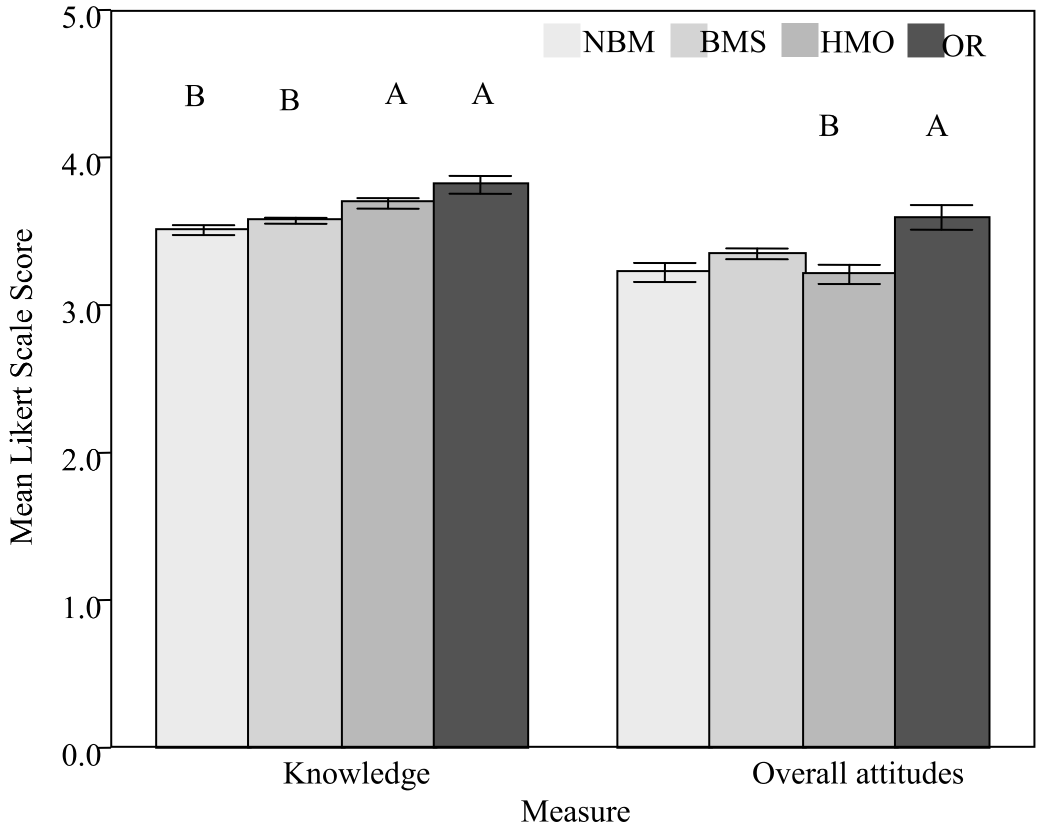

Figure 1. Mean Likert scale score for knowledge regarding bats and overall attitudes towards bats for each of four groups, biology non-majors (NBM), biology majors (BMS), homeowners (HMO) and outreach participants (OR). Different letters indicate significant differences between groups

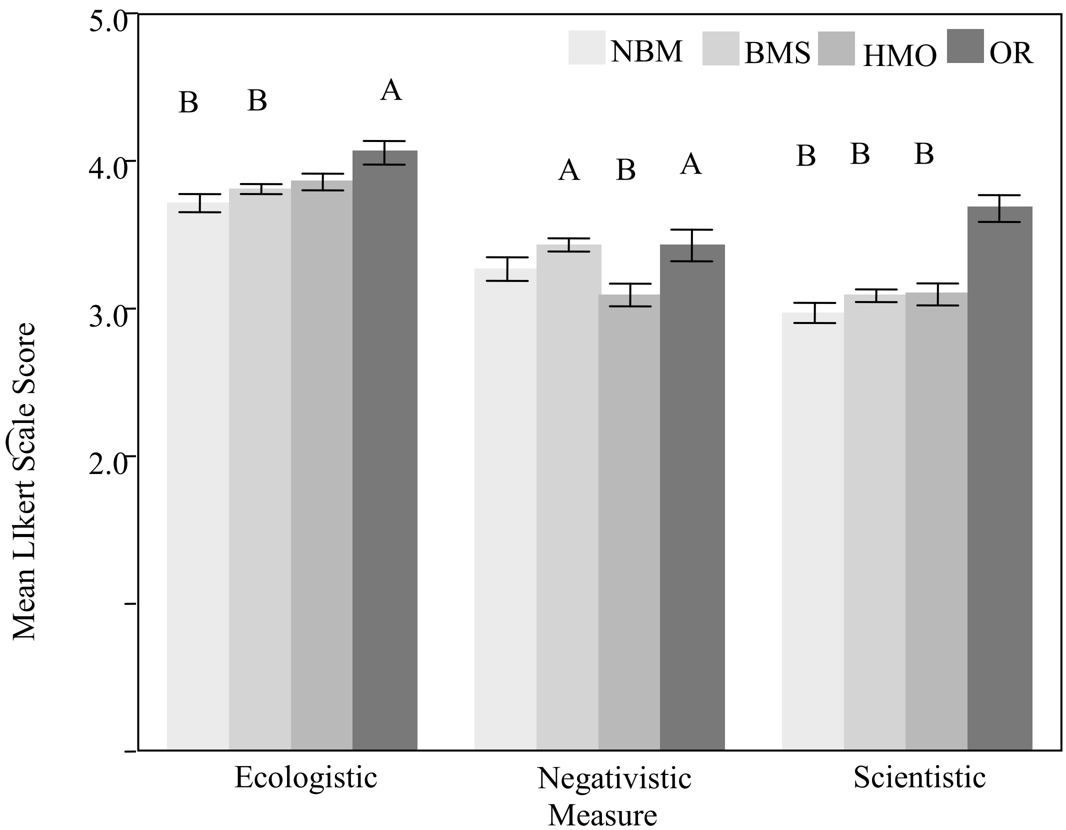

Figure 2. Mean Likert Scale Score for each of the three sub-measures of attitudes for the four groups surveyed, non-biology majors (NBS), biology majors (BMS), homeowners (HMO) andoutreach participants (OR). Different letters indicate groups significantly different at p. < 0.05

CHAPTER IV

CONCLUSIONS

In Chapter I, I used a novel approach to modeling bat species distribution. Maxent modeling has not been applied to species in the Midwestern United States and I demonstrated its utility at the intermediate macrohabitat scale. I also tested these models with an independent data set, a task which is seldom completed in spatially explicit modeling. To gather this independent data set, I utilized data gathered from citizen science volunteers, demonstrating that citizen science data can be used both to increase stakeholders interest in a species (in this case bats) but can also be used for scientific purposes.

Results indicate that there are at least eight species of bats present in protected areas of the Oak Openings Region, big brown, eastern red, hoary, silver-haired, little brown, northern long-eared, evening bat and tri-colored bat, with the possible presence of the endangered Indiana bat. The big brown bat was found in all areas and appears to be ubiquitous, potentially due to its flight ability and generalist nature. The eastern red bat, little brown and northern long-eared were also relatively common, while the remaining species were rare.

The results from Chapter I can be used for land managers as they determine areas for priority conservation, especially in light of the finding that bats were present in different types of habitat. Overall, forest and open areas near water are where bats are likely to be found, and for some species, including little brown and eastern red bats, edges between forest and agricultural areas are also potentially important.

The Metroparks of the Toledo Area and personnel in the lab of Dr. Karen Root continue to engage citizen science volunteers. This continued and long-term data set can be used to test the developed models in different areas as well as across time. These citizen scientists continue to engage other people and have become bat “champions”.

In Chapter II I investigated the relative activity and presence of bats in savanna and forest areas within the Oak Openings Region, which has not been investigated before in regards to bats. Savannas were not greater in species richness in regards to bats, but were being utilized in varied ways by different species. The more open adapted bats, Hoary, eastern red and tri-colored bats were more likely in savanna areas, but eastern red and tri-colored were also present in some forest areas, depending on the structure and insect availability. The bat that appears to be the most forest adapted is the northern-long eared bat which was rarely present in savanna areas and more likely present in any type of forest. Savanna areas within forest may be used as foraging, roosting or commuting, but further investigation into this question is necessary.

In Chapter III I investigated the knowledge and attitudes that people living within the Oak Openings have towards bats. I adapted previously used and validated surveys to determine overall knowledge and attitudes about bats in undergraduate biology and non-biology majors at Bowling Green State University, participants in outreach classes at the Toledo Zoo and the Toledo Metroparks, and also homeowners.

Findings indicated a relationship between knowledge and attitudes, and that certain myths, such as all bats drink blood, were not as prevalent as I had originally thought, while others, such as bats get tangled in your hair, were still quite common. Homeowners and outreach participants did have greater knowledge regarding bats, but not necessarily more positive attitudes (at least for homeowners). I used the knowledge I gained from these surveys regarding what people did and did not know, in combination with the knowledge gained about bats during the ecological portion of this work to create and initiate outreach opportunities, including the citizen science program mentioned in Chapter I. These classes resulted in decreasing the negative views of bats that people held.

Overall, this research shows synthesis between multiple disciplines, including conservation biology, basic ecological research, and behavioral ecology, to address critical questions relating to the ecology of bats in human-dominated systems. This work contributes to the larger and local knowledge base of bats in protected areas, and their presence in oak savannas. Managing for species diversity with a diversity of habitat types and structures is important within this system. This work also contributes to the work of conservation biologists and educators in demonstrating that assessment of this kind can and should occur, especially in conjunction with ecological work.

APPENDIX I

BASELINE SURVEY

The answers to the following questions will not be identified to you, but to compare surveys taken at multiple time points, I ask that you create a unique identifier. This identifier should start with your birthday (month and day) and your middle initial (example 0721v) and be placed in the space provided.

UNIQUE IDENTIFIER ________________

Demographic questions: please check the appropriate box for questions 1-7 below.

1. My county of residence is

   - Lucas ☐
   - Wood ☐
   - Other ☐

2. My age is

   - under 18 ☐
   - 18 or older ☐

3. I am

   - Male ☐
   - Female ☐

4. I have the following educational background

   - High school diploma or less ☐
   - Undergraduate degree ☐
   - Graduate degree ☐

5. I have visited a zoo or metropark in the

   - Last 6 months ☐
   - Last year ☐
   - Last 5 years ☐
   - Never ☐

6. I volunteer at a zoo, metropark or nature based organization

   - Yes ☐
   - No ☐

7. I have taken a class at a metropark or zoo in the

   - Last 6 months ☐
   - Last year ☐
   - Last 5 years ☐
   - Never ☐

		Strongly Disagree	Disagree	Not applicable/ Neutral	Agree	Strongly Agree
1**	Bats are likeable animals					
2	I'd rather spend time outside than inside					
3	If I am told that a bat is near me, I get nervous					
4	I would like to read a book about bats					
5	I would like to watch bats at night using night vision binoculars					
6	Bats in Ohio over winter in abandoned caves and tunnels					
7	Bats scare me more than any other animal					
8	I'd rather visit a national park than see a movie					
9	When I'm outside, I pay close attention to different plants and animals					
10**	I would like to know how scientists investigate bats					
11**	I would rather avoid places where bats are present					
12	I would rather watch a TV program about bats than encounter them in nature					
13	We should learn more about bats					
14	Most bats feed on blood					
15	I talk to my friends and family about bats					
16	It is important to protect as many animals and plants as we can					
17	Bats can suck out blood from humans					
18	I am not interested in whether bats in the United States are endangered					
19	Bats can get tangled in your hair					
20	Protection of old buildings and trees contributes to bat protection					
21	I want to take part in activities that help bats					
22	Bats in Ohio sleep through winter and do not feed					

		Strongly Disagree	Disagree	Not applicable/ Neutral	Agree	Strongly Agree
23	Most bats in the United States feed on insects					
24	I feel it is important to take good care of the environment					
25	I dislike looking at pictures of bats					
26	I talk to my friends and family about the environment					
27	Bats can be quite interesting animals					
28	I would avoid places in my house if bats were there					
29	I would like to participate in trips that investigate bats					
30**	The thought of a bat in my hand scares me					
31	Humans are a part of nature, not separate					
32	Greater attention should be dedicated to bat protection					
33	Some tropical bats feed on fruit					
34**	Bats have great importance in nature					
35	I would like to have bats in my yard					
36	I feel comfortable in the outdoors					
37	If I see a bat, I feel nervous					

Thank you for completing this survey. Your input is a valuable part of my research project and I appreciate your time.

** indicates that questions that were used in the shortened version of the survey

APPENDIX II

FOLLOW-UP SURVEY

The answers to the following questions will not be identified to you, but to compare surveys taken at multiple time points, I ask that you create a unique identifier. This identifier should include your birth month and birth date and the first initial of your middle name (example 0721v) and be placed in the space provided.Please answer the following questions by checking the box that best corresponds to your attitudes regarding the question.
UNIQUE IDENTIFIER __________________

		Strongly Disagree	Disagree	N/A or Neutral	Agree	Strongly Agree
1	I better understand the importance of bats in nature					
2	I have a better understanding of the bats in Ohio					
3	I am less fearful of bats					
4	I have a better understanding of the diversity of bats in the world					
5	I would like to read a book about bats					
6	The thought of touching a bat scares me less than it did					
7	I plan on talking to my friends and family about bats					
8	Don't think that bats can get tangled in your hair					
9	Understand that bats in Ohio sleep through winter and do not feed					
10	If I was told there was a bat near me, I would not be nervous					
11	I want to take part in activities that help bats					
12**	I would be comfortable if I encountered a bat in nature					
13**	I would like to know more about how scientists investigate bats					
14**	Know that most bats in the United States feed on insects					
15	I would like to participate in trips that investigate bats					
16	Think we should learn more about bats					
17	Bats can be quite interesting animals					
18	I would like to see pictures of bats					

		Strongly Disagree	Disagree	N/A or Neutral	Agree	Strongly Agree
19	When I'm outside, I will pay closer attention to different plants and animals					
20	Think that most bats feed on blood					
21	Some tropical bats feed on fruit					
22	Protection of old buildings and trees contributes to bat protection					
23**	Bats have great importance in nature					
24	If I see a bat, I will feel less nervous than I did before					
25	I would like to watch bats at night using night vision binoculars					
26	Greater attention should be dedicated to bat protection					
27**	Bats are likeable animals					
28	Bats can suck blood out from humans					

AS A RESULT OF THIS CLASS
If I had the resources, I would be willing to do the following

☐ Put up a bat house in my yard or near my home
  ☐ Already have a bat house

☐ Decrease my use of pesticides
  ☐ I Don't currently use pesticides

☐ Educate others about bats
  ☐ I already do this

☐ I Would donate to a conservation organization that helps bats
  ☐ I already donate to an organization

☐ I Would donate to any conservation organization
  ☐ I already donate to conservation organizations

☐ I Would vote to protect land that bats require for survival

☐ I Would like to be contacted regarding local upcoming activities that will help bats,

If you checked the above box, please fill out the sheet below, detach and hand in with the survey. Don't worry, I will keep them separate from your survey.

** Indicates that questions that were used in the shortened version of the survey

APPENDIX III

HUMAN SUBJECTS REVIEW BOARD APPROVAL

BGSU
Bowling Green State University

Office of Research Compliance
309A University Hall
Bowling Green, OH 43403-0183
Phone: (419) 372-7716
E-mail: hsrb@bgsu.edu

November 16, 2010

TO: Jessica Sewald
Biological Sciences

FROM: Hillary Harms, Ph.D.
HSRB Administrator

RE: Continuing HSRB Review for Project H10D142GE7

TITLE: *Assessing Peoples Attitudes and Behavior Towards Bats*

This is to inform you that your research study indicated above has received continuing Human Subjects Review Board (HSRB) review and approval. This approval is effective November 18, 2010 for a period of 12 months and will expire on November 17, 2011. You may continue with the project.

The final approved version of the consent document(s) is attached. Consistent with federal OHRP guidance to IRBs, **the consent document(s) bearing the HSRB approval/expiration date stamp is the only valid version and, on November 18, 2010, supercedes all previously approved versions. You must use copies of the date-stamped document(s) in obtaining consent from research subjects.**

Please communicate any proposed changes in your project procedures or activities involving human subjects, including consent form changes or increases in the number of participants, to the HSRB via this office. Please notify me, at 372-7716 or hsrb@bgsu.edu, upon completion of your project.

Good luck with your work. Let me know if this office or the HSRB can be of assistance as your project proceeds.

Comments:
Stamped consent form is coming to you via campus mail.

C: Dr. Karen Root

BGSU
Bowling Green State University

Office of Research Compliance
309A University Hall
Bowling Green, OH 43403-0183
Phone: (419) 372-7716
E-mail: hsrb@bgsu.edu

November 16, 2010

TO: Jessica Sewald
Biological Sciences

FROM: Hillary Harms, Ph.D.
HSRB Administrator

RE: Continuing HSRB Review for Project H10D142GE7

TITLE: *Assessing Peoples Attitudes and Behavior Towards Bats*

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Good luck with your work. Let me know if this office or the HSRB can be of assistance as your project proceeds.

Comments:
Stamped consent form is coming to you via campus mail.

C: Dr. Karen Root

APPENDIX IV

INSITUTIONAL ANIMAL CARE AND USE COMMITTEE APPROVAL

BGSU
Bowling Green State University

Office of Research Compliance
309A University Hall
Bowling Green, OH 43403-0183
Phone: (419) 372-7716
Fax: (419) 372-6916
E-mail: hsrb@bgnet.bgsu.edu

May 11, 2010

Dr. Karen Root
Biological Sciences
Bowling Green State University

Re: IACUC Protocol 10-006

Title:
Assessing bat species deiversity in the Oak Openings Region of Northwest Ohio

Dear Dr. Root:

On **May 11, 2010** the above referenced protocol received **final approval** after review of the requested clarifications by the IACUC. The clarifications have been incorporated into the official copy of your protocol (see attached).

This approval expires on May 10, 2011, by which time renewal must be requested if you wish to continue work on the protocol. The Office of Research Compliance will send notification reminding you of the need for renewal in advance of that date.

Please have all members of your research team read the approved version of the protocol.

Good luck with your project.

Sincerely,

Hillary Harms
IACUC Administrator

Comments:

BGSU
Bowling Green State University

Office of Research Compliance
309A University Hall
Bowling Green, OH 43403-0183
Phone: (419) 372-7716
Fax: (419) 372-6916
E-mail: hsrb@bgnet.bgsu.edu

April 5, 2011

Dr. Karen Root
Biological Sciences
Bowling Green State University

Re: Annual Renewal of IACUC Protocol 10-006

Title:
A multidisciplinary approach to the conservation of bat species in the Oak Openings Region

Dear Dr. Root:

On April 4, 2011 the annual renewal for the above referenced protocol was **approved** after review by the IACUC. This renewal is in effect for one calendar year and expires on April 3, 2012. Please consult with the staff of the Animal Facility about any special needs you might have to continue with this project.

Comment(s):
Please submit a copy of your 2011 Metroparks of the Toledo Area permit.

Sincerely,
Hillary Harms
Hillary Harms, Ph.D.
IACUC Administrator