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A Little Bat and a Big City: Nocturnal Behavior of the Tricolored Bat (Perimyotis subflavus) Near Indianapolis Airport

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ABSTRACT

I captured 16 *Perimyotis subflavus* on property owned by the Indianapolis International Airport, of those 16 animals I obtained roosting data on all 16 and foraging data on 11 individuals. The goal of this project was to see if a short broad winged bat's foraging and roosting habits were affected by the fragmentation of habitat due to rapid urbanization. Using radio telemetry to find roosts and to create multi-azimuth triangulation I was able to create data points and place them onto a habitat map inside ArcGIS software. Sampling the size of woodlots available to the bats I was able to see that the bats only roosted in larger woodlots on the property. Using Euclidian distance analysis I was able to compare the distance of data points both with roosting and foraging from habitat classes to see that this species roosts in woodlots next to old fields and maintained habitats, does not roost in woodlots near commercial areas, and prefers foraging in forests, agricultural fields, maintained habitats, and old fields.

PREFACE

Introduction

Chiroptera has the second highest species diversity in the order Mammalia, and 25% of bat species worldwide are listed as critically endangered, endangered, or vulnerable by the IUCN red list (IUCN 2006). Three highly correlated ecological variables associated with the extinction risks of bats are small geographic range, low wing aspect ratios, and dietary specialization (Jones et al. 2003, Boyles and Storm 2007). While the tricolored bat (*Perimyotis subflavus*) occupies much of eastern North America and has low dietary specialization, the aspect ratio of a tricolored bat's wing is slightly larger (6.2 *A*) than that of the endangered Indiana myotis (*Myotis sodalis*) (5.4 *A*) which only occupies a range which is a fraction of that occupied by *Perimyotis subflavus* (Norberg and Rayner 1987, Whitaker and Hamilton 1998, Whitaker 2004). Bats such as these, with short, broad wings are relatively inefficient fliers, have high flight costs, have smaller foraging ranges, and are poor dispersers/migraters (Norberg and Rayner 1987; Jones et al. 1995; Arita et al. 1997; Lockwood et al. 1998; Entwistle et al. 2000). All of this suggests that a bat with the wing morphology of *Perimyotis subflavus* should face challenges in a highly fragmented landscape that contains patches of unsuitable habitat, such as areas where substantial suburban development is occurring. In fact, Gehrt and Chelsvig (2004) suggested this species was particularly sensitive to development in the Chicago, Illinois Metropolitan Area, although some, if not all, of this impact is due to historical absence of suitable hibernacula in the region (Brack and Mumford 1984). Although this species is abundant in the eastern United States, little is known about its nocturnal behavior (Whitaker and Hamilton 1998, Carter et al. 1999). In order to begin understanding what challenges these bats face in a fragmented environment, a further grasp of these bats' foraging and roosting habitat will be needed.

Recent work in our lab supports the contention that foraging habitat is a major conservation concern for a number of bat species, including the evening bat (*Nycticeius humeralis*) (Duchamp et al. 2004), Indiana myotis (*Myotis sodalis*) (Sparks et al. 2005), and the eastern red bat (*Lasiurus borealis*) (Walters et al 2007). Currently, little is known about the tricolored bat's foraging habitat. Therefore, chapter one will include an analysis of the tricolored bats' foraging habitats along the edge of a rapidly developing metroplex Indianapolis, Indiana.

While Jones et al. (2003) correlated wing morphology with conservation status, most bat conservationists have traditionally managed bats by managing roosts (Sparks et al. 2009). Roosts are a critical element in determining the distribution and abundance of bats (Humphrey 1975). In fact, tricolored bats invaded the Great Plains (Benedict et al. 2004, Sparks and Choate 1995) and subsequently the intermountain West (Geluso et al. 2005), following the spread of trees and development of anthropogenic roosts. Because this species is primarily associated with larger woodlots (Mumford and Whitaker 1982; Davis and Mumford 1962; Carter et al. 1999), and has short, broad wings, I predict that tricolored bats occurring near the Indianapolis International Airport will forage (Chapter 1) and roost (Chapter 2) primarily in larger woodlots in a series of properties managed for Indiana bats by the Indianapolis Airport Authority (described below).

I conducted this study on properties owned and managed for conservation by the Indianapolis International Airport where a long-term study of how bats respond to urbanization has been underway since 1997 (Whitaker et al. 2004, Sparks et al. 2009). This community is composed of 10 species, including *Perimyotis subflavus* which, despite its hypothesized inability to tolerate highly fragmented landscapes, is relatively common at this site and throughout most of Indiana (Mumford and Whitaker 1982, Whitaker et al. 2004).

Study Animal

Perimyotis subflavus is a small bat, with tri-colored hair, and reddish forearms that contrast with dark wing membranes (Whitaker and Hamilton 1998). *Perimyotis subflavus* ranges from as far north as southern Quebec, South to northern Honduras, and east to the Atlantic Ocean, and west to New Mexico, (Fujita and Kunz 1984, Geluso et al. 2005). In summer, these bats mostly roost in clusters of dead leaves (Veilleux et al. 2003), although anthropogenic structures are also used (Mumford and Whitaker 1982, Whitaker and Hamilton 1998, Whitaker 1998). In summer it appears that these bats are most abundant in well-wooded regions that contain water, streams or ponds, but they have also been seen over farm lands (Mumford and Whitaker 1982, Davis and Mumford 1962). A single *Perimyotis subflavus*, tracked on the Savannah River Ecology Lab in South Carolina, spent most of its time in bottomland hardwood and made use of pine stands and upland hardwoods while foraging (Carter 1999).

The diet of *Perimyotis subflavus* is strictly insectivorous with its food consisting mainly of Cicadellidae, Coleoptera, and Diptera. Other insects found in their diet consisted of Hymenoptera, Lepidoptera, Formicidae, Cercopidae, and several other types of insects (Mumford and Whitaker 1982, Whitaker et al. 2004).

Perimyotis subflavus is an obligate hibernator, hibernating even in Florida during winter months (McNab 1974). *Perimyotis subflavus* begins arriving at hibernacula in August, but continues to reach the hibernacula through early November (Whitaker and Hamilton 1998). The bats emerge from hibernation in April and May, and move to summer locations which are not far from their hibernacula (Whitaker and Hamilton 1998). The furthest known distance between a summer roost and hibernacula was only 52.8 km (Griffin 1940).

Study Area

This study of foraging and roosting habitat selection of the tricolored bat was conducted at a long term study site adjacent to the Indianapolis International Airport. Much of the property is owned and was protected by the airport to offset lands lost to development, and the rest consists of areas of privately owned lands. The property extends south and west along US highway 40 from the airport to Indiana State Highway 267 in the west and Indiana State Highway 67 in the south. Interstate Highway 70 bisects the study area, which includes parts of Marion, Hendricks, and Morgan counties (figure 3). The area includes several different land classes consisting of wetlands and forest fragments of various ages enclosed in a matrix of subdivisions in the north and a variety of agriculture in the south (Sparks et al. 1998). The study site is unusual in that natural habitat is being restored, and the remaining habitat is being conserved, but it is surrounded by a fast growing urban-suburban environment.

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CHAPTER 1

HABITAT SELECTION OF THE TRICOLORED BAT (*PERIMYOTIS SUBFLAVUS*) WHILE FORAGING.

Introduction

Little is known about the tricolored bat's (*Perimyotis subflavus*) foraging range or nocturnal behavior, although this species is abundant in the eastern United States (Whitaker and Hamilton 1998, Carter et al. 1999). In the summer it appears that these bats are most abundant in well-wooded regions that contain water, either streams or ponds, and they have also been seen over farm lands (Mumford and Whitaker 1982, Davis and Mumford 1962). A single *Perimyotis subflavus* tracked on the Savannah River Ecology Lab in South Carolina spent most of its time in bottomland hardwood and made use of pine stands and upland hardwoods while foraging (Carter 1999). However, these bats have a low wing aspect ratio, which suggests that they are relatively inefficient fliers, have high flight costs, have smaller foraging ranges and are poor dispersers/migraters (Norberg and Rayner 1987; Jones et al. 1995; Arita et al. 1997; Lockwood et al. 1998; Entwistle et al. 2000).

The objectives of this study were: (1) to determine the foraging area characteristics of *Perimyotis subflavus* (e.g., home range size, maximum distance flown), (2) to determine habitat use of *Perimyotis subflavus*, (3) to compare the foraging habitat of *Perimyotis subflavus* to that of other species studied in this same area, and (4) to further explore the relationship between selection of foraging habitat and conservation status by examining a short broad-winged bat that is abundant locally. I predict that the short, broad-wings of *Perimyotis subflavus* will restrict the bat to foraging in areas of relatively contiguous natural habitats near the roost, as opposed to occupying large foraging ranges scattered through the area.

Methods

I captured *Perimyotis subflavus* in 50-denier, 6 and 9 m mistnets set throughout the study area, but especially along the East Fork of White Lick Creek. Captured bats were identified, weighed, sexed, reproductive status determined, and a uniquely numbered aluminum wing band was attached to one wing. Sixteen individuals of *Perimyotis subflavus* weighing 6 g or more, received 0.37 g radio transmitters (model Holohill LB-2) attached to the mid-scapular area using a surgical adhesive (Skin-Bond, Smith & Nephew, Largo, Florida).

To locate these animals while roosting I followed the signal to the area the bat was roosting, and used in-field triangulations to determine the tree the animal was using. Each bat was tracked to its roost every day. That same day, at dusk, a team of 3-6 trackers would surround the roost and begin taking multi-azimuth triangulations using a 3 or 5-element yagi antenna and a radio receiver (model TRX2000S, Wildlife materials Inc, Carbondale IL) as soon as the bat emerged. Communication among trackers was maintained using two-way radios and cellular telephones which allowed them to take synchronized azimuths every 3-12 min and reposition to follow the bat as needed. Each bat was tracked each night from emergence until it roosted for the night. This was done for multiple days until that bat occupied a stable home range which allowed analyses of the bat's nocturnal behavior.

Transmitter life was as long as 30 days, but the surgical glue would last approximately 6 days. At this field site a radio-tagged bat could typically be detected as far as 2 km away, and occasionally as far as 4 km away. As a measure of average error, I compared the position generated by azimuths obtained before the bat began moving to the mapped location of the roost (Walters *et al*., 2007).

Azimuths were converted to point data using the computer program Locate III (Nams 2005), and overlaid on both a photographic map (Indiana Geological Survey 2005) and a site-specific habitat map (updated from those used in Duchamp et al. 2004, Sparks et al. 2005, and Walters et al. 2007) in a Geographic Information System (ArcGIS 9.2). The habitat map included 10 different types of land classes: (1) low density residential, which consisted of scattered houses and buildings often associated with agriculture; (2) high density residential, which consisted of subdivisions; (3) commercial, which consisted primarily of warehouses and stores; (4) forest, which consists of wooded areas with canopies; (5) agriculture, which consisted of fields of corn, soybeans, wheat, alfalfa, and milo; (6) maintained lands, which consisted of areas of mowed grassland including public parks; (7) old field lands, which consisted of unmaintained grasslands, recently planted tree fields, and a few pastures; (8) open water, which consisted mostly of storm water retention basins and agricultural ponds; (9) transportation, which consist of highways, railroads, and the airport; (10) and industrial, which consisted of a gravel quarry.

Within Arc GIS, I calculated two nocturnal home ranges for each bat, one a 95% minimum convex polygon (MCP) and the other an adaptive kernel (including a 50% use core area). I report MCP, kernel, and 50% core area analysis to ensure comparability with previous studies. I also used the GIS to measure the maximum distance flown by each bat.

I used a Euclidean distance analysis (Conner and Plowman 2001; Conner et al. 2003) to compare the average distance from land classes between known foraging points and random points within the same landscape in an effort to quantify habitat selection by this species. A 3.05

km buffer (farthest distance flown by any bat in the study) was placed around all roosts and then these areas were overlaid to provide an estimate of habitat available to the bats. Within this available habitat I used the GIS to generate as many random points for each bat as were obtained during the foraging study. Distances between points (whether random or triangulated) and surrounding habitats were measured in the GIS. A multivariate analysis of variance (MANOVA) was used to determine if non-random habitat preference occurred across all land classes, while a series of paired sample t-tests were used to separately examine each land class (Walters *et al*., 2007). All statistical analyses were performed in SPSS 16.0.

Results

I captured and tracked 11 adult *Perimyotis subflavus* (1 male, 10 females) to stable home ranges. Limited data were obtained on five additional bats (4 females and 1 male) before their radio-tags ceased to function or fell off. The male bat had descended testes, and the females included five bats that were lactating, four that were gravid, and one that was post-lactating. We tracked bats for an average of 4 (range 3-7) nights and obtained an average of 81 (range 44-115) data points per bat (Table 1). Bats were monitored after the 3-7 nights to make sure a home range had been established. Telemetry error was estimated at 132.71 m. An average home range size of 321.57 ha (range 67.90-613.14 ha, Figure 1) was obtained using MCPs and an average home range size of 199.02 ha (range 62.58-306.51 ha, Figure 2), was obtained using adaptive Kernal technique. An average core home range size of 22.41 ha (range 11.10-52.62 ha, Table 1) using the adaptive Kernal technique. On average these bats flew 1.92 km (range 0.69-3.05 km, Table 1) from their roosts. A buffer of this radius around all known roosts produced 75.84 km^2 of available habitat, of which bats were tracked to 18.16 km^2 (23.95%). First foraging flights lasted just over two hours and most bats made only occasional flights after they began night roosting.

The most extensively utilized habitat class was forest (32.27% of data points), but the bats were also tracked to agriculture (31.36%), unmaintained (12.61%), maintained (6.14%), high density residential (5.45%), transportation corridors (4.32%), low density residential (3.98%), open water (1.82%), commercial (1.59%), and industrial (0.46%) (Table 2). *Perimyotis subflavus* did not make random use of habitat (F= 67.96; d.f. = 10; Wilks' Lambda= .720; P < .001). This shows that some habitat classes were used above their availability.

Preferred habitats were significantly used more often than random and included forest (t= -4.97, d.f.= 10, P < .001), old field (t= -8.04, d.f.= 10, P < .001), maintained grasslands (t= -3.72 , d.f.=10 , P < .001), and agriculture (t= -3.15 , d.f.=10 , P=.010). Use of other habitats including: transportation corridors (t= -1.47, d.f.=10 , P = .173), low density residential (t= -1.20, d.f.= 10, P = .258), high density residential (t= 1.35, d.f.= 10, P = .208), commercial (t= 1.25, d.f.= 10, P = .241), industrial (t= -.816, d.f.= 10, P = .434), and water (t= .826, d.f.= 10, P = .428) were used similarly to the availability of these land classes, or similar to random and considered neutral habitats (Figure 3).

Discussion

This study represents the first comprehensive study of the nocturnal foraging behavior of *Perimyotis subflavus*. Prior to this study capture records suggested they frequently foraged in well-wooded regions that contained water, and they had been seen over farm-lands (Mumford and Whitaker 1982, Davis and Mumford 1962). However, echolocations of this species were detected across many types of forest including newly regenerating stands (Loeb and O'Keefe 2006). One individual in South Carolina spent most of its time in forests including bottomland hardwood, pine stands, and upland hardwoods while foraging (Carter 1999). In this study, however, we found a nearly equal use of forested (32% of the time) and agricultural lands (31%

of the time) (table 2), with the balance spent in a wide variety of habitat types. The fact that this bat showed no aversion to highly developed land classes suggests that while the species mostly uses rural habitats, it also is capable of using fragments of these habitats within a matrix of more urban types. This pattern is contrary to the hypothesis that this species is especially challenged by developed habitats because of its low wing aspect ratio.

It is thought that because of low wing aspect ratio and small size, *Perimyotis subflavus* is a relatively inefficient flier with high flight costs, and correspondingly smaller foraging ranges and limited ability to disperse/migrate (Norberg and Rayner 1987; Jones et al. 1995; Arita et al. 1997; Lockwood et al. 1998; Entwistle et al. 2000). Based on wing morphology, I predicted that foraging range of *Perimyotis subflavus* would be most similar to that of *Myotis sodalis* which had an average foraging range of 335 ha (MCP) (Sparks *et al*. 2005a), than that of the other bats tracked at this field site. These included the big brown bat (*Eptesicus fuscus*) with an average foraging range size of 1086 ha (MCP), the evening bat (*Nycticeius humeralis*) with an average foraging range size of 325 ha (MCP) (Duchamp *et al*., 2004), the red bat (*Lasiurus borealis*) with an average foraging range size of 67.96 ha (MCP) (Walters *et al*., 2007), and one juvenile hoary bat (*Lasiurus cinereus*) with an average foraging range size of 21.5 ha (MCP) (Sparks *et al*, 2005c). Instead, *Perimyotis subflavus* occupied foraging ranges most similar to those of *Nycticeius humeralis*. While *Perimyotis subflavus* is willing to fly in developed areas, it appears that wing morphology plays less of a roll than that of other factors. Other factors could include low insect abundance in urban area (Faeth and Kane 1978: Blair and Launer 1997) or increased bat mortality (Lode 2000). Another factor that could be causing avoidance of urban areas is the over abundant light and sound.

This study was conducted as part of a long term study of how bats and other wildlife are reacting to the rapid urbanization occurring around this field site located near Indianapolis International Airport. In the past it was thought that the focus of chiropteran conservation should be targeted on roosting sites (Humphrey, 1975). However development within foraging areas could have a negative impact on chiropteran species by making foraging areas inaccessible or removing them altogether (Jones *et. al*. 2003, Duchamp *et al*. 2004, Sparks *et al*. 2005a, 2005b). Previous studies at this field site have shown that development has a negative impact on foraging behavior of *Eptesicus fuscus*, *Nycticeius humeralis*, *Lasiurus cinereus*, and *Myotis sodalis* (Duchamp *et al*., 2004, Walters *et al*., 2007, Sparks *et al*. 2005a). In this study *Perimyotis subflavus* spent significantly more time in forest, parks, agriculture field, and over grown fields. While the other areas were not significantly avoided, this species did spend considerably less time in developed than undeveloped areas (table 2). This shows *Perimyotis subflavus* is affected negatively by development by making some habitat undesirable. However, it also indicates that the current conservation measures are providing appropriate habitat.

CHAPTER 2

ROOSTING HABITAT SELECTION OF THE EASTERN PIPISTRELLE (*PERIMYOTIS SUBFLAVUS*)

Introduction

The tricolored bat (*Perimyotis subflavus*) is a small bat with tri-colored hair. In summer it typically roosts using leaf clusters (Veilleux et al. 2003), although anthropogenic structures are also used (Mumford and Whitaker 1982, Whitaker and Hamilton 1998). There is evidence that anthropogenic structures are used as pre-maternity roosts during late spring and early summer by bats using leaf clusters (Whitaker et. al. 1998).

Most bat conservationists have traditionally managed bat populations by managing roosts, although there is evidence that foraging habitat is also important particularly in areas of rapid habitat conversion (Duchamp et al. 2004, Sparks et al. 2005, Walters et al 2007, Sparks et al. 2009). Roosts remain a critical habitat as indicated by the impact roost availability has on community diversity (Humphrey 1975). In the case of *Perimyotis subflavus,* extensive growth of riparian forests and availability of buildings associated with settlement allowed the species to invade the Great Plains (Benedict et al. 2001, Sparks and Choate 2000) and subsequently the intermountain West (Geluso et al. 2005).

Perimyotis subflavus has a small wing aspect ratio, which makes this bat a relatively slow and inefficient flier, with high flight costs. This characteristic also relegates it to having smaller foraging ranges, and being a poor disperser/migrater (Norberg and Rayner 1987; Jones et al. 1995; Arita et al. 1997; Lockwood et al. 1998; Entwistle et al. 2000). These characteristics suggest that *Perimyotis subflavus* should face challenges in a highly fragmented landscape that contains patches of unsuitable habitat such as areas where substantial suburban development is occurring.

This evidence suggests that *Perimyotis subflavus* would have difficulty traversing a highly fragmented landscape. Because it is primarily associated with larger woodlots (Mumford and Whitaker 1982; Davis and Mumford 1962; Carter et al. 1999), the objective of this study will be to determine if habitat fragmentation, due to urban landscapes, affects roosting patterns of *Perimyotis subflavus* by looking at the size of woodlots used and not used for roosting, and the landscapes around used woodlots. I predict that *Perimyotis subflavus* living at the edge of suburbia would roost primarily in large intact woodlot landscapes instead of roosting in fragmented woodlots surrounded by developed landscapes.

Methods

I captured *Perimyotis subflavus* in 50-denier, 6 and 9 meter mistnets set throughout the study area, but especially along the east fork of White Lick Creek. Once an individual was captured it was identified, weighed, sexed, reproductive status determined, and an aluminum wing band was attached giving each bat an individual number. Bats weighing more than 6 g, received 0.37 g radio transmitters (model Holohill LB-2) which were attached to the mid-scapular area using a surgical adhesive (Skin-Bond, Smith & Nephew, Largo, Florida in 2005-2006).

Once the animal was fitted with a radio transmitter, it was released to return to its roost. The next day I located the bat using a 3 or 5-element yagi antenna and a radio receiver (model

TRX2000S, Wildlife materials Inc, Carbondale IL). To locate the roosts I followed the radio signal to the area of the roost, then performed in-field triangulations to determine which tree or structure was being used as the roost (close approach telemetry techniques) (Sparks et al. 2005a, Sparks et al. 2005b). This was done every day that the animal carried a transmitter. At the roost an attempt was made to visually locate the bat in the roost, but if the bat was not located its location was estimated using telemetry. The roost was then mapped using a GPS and the point data transferred to a Geographic Information System (GIS, ArcGIS 9.2). In GIS, these points were plotted on a habitat map originally created by Duchamp et al (2004) that has been continuously updated using both aerial photos and ground truthing to include recent changes in the landscape.

The habitat map included 10 different types of land classes: (1) low density residential, which consisted of scattered houses and building which most of were associated with agriculture; (2) high density residential, which consisted of block housing like subdivisions; (3) commercial, which consists of areas like warehouses and strip malls; (4) forest, which consists of wooded areas with canopies; (5) agriculture, which consists of active farm lands such as corn, soybean, wheat, alfalfa, and milo; (6) maintained lands, which consist of areas of mowed grasses such as parks; (7) old field lands, which consist of areas like pastures and unmaintained grasslands; (8) water, which consists of areas of open water including farm and storm-water retention ponds; (9) transportation, which included highways, railroads, and the airport; (10) and gravel quarries.

To determine the size of available wootlots I used ArcGIS to sample the size (ha) of all wootlots within a 3.05 km buffer (farthest distance flown by one of the foraging bats) around all roosts. This included sampling the size of each woodlot that contained roosts.

To determine if this species selected certain land classes over others while roosting I used a Euclidean distance analysis (Conner and Plowman 2001; Conner et al. 2003) to compare the average distance from land classes between known roosting points and random points within the same landscape. A 3.05 km buffer was placed around each roost, and this area was considered as available habitat (Chapter 1). Within this area, a random point was generated (using ArcGIS) for each real data point within that buffer. For each point a Euclidean distance was taken to each habitat, and a number of 0 was assigned for the habitat class in which the point fell. A multivariate analysis of variance (MANOVA) was used to indicate whether non-random habitat selection occurred across all landscape classes. The MANOVA was followed by a paired samples t-test that was used to determine if a particular habitat was closer to or farther from roosts than what was expected by chance. All statistical analyses were performed in SPSS 16.0.

Results

A total of 16 bats was successfully tracked to 26 roosting locations, some of which were used more than once. Bats were tracked for a mean of 7.06 days (3-13 days), and used an average of 2.13 roosts per bat (1-3 roosts per bat). I found these bats roosting in a wide variety of forest types including 3 bats roosting in woodlands dominated by pole timber, 10 bats roosting in woodlands dominated by saw timber, 2 bats roosting in a covered bridge within a city park, and 1 bat roosting in a brushy fence row dominated by bush honeysuckle (*Lonicera mackii*). Woodlots within the bats available habitat ranged in size from .069 ha to 94.85 ha, the average size of woodlots which had *Perimyotis subflavus* roosting in them was 50.28 ha (range 7.42 ha to 94.85 ha), and woodlots which had no roosts averaged 5.02 ha (range .069 ha to 71.96). Landscape context ranged from large contiguous woodlots surrounded by conservation plantings to small woodland fragments surrounded by suburbia. Two bats were tracked to a covered footbridge in a city park, which follow-up surveys have indicated is used by up to 13 *Perimyotis subflavus* every year until early June. There is evidence that anthropogenic structures are used as pre-maternity roosts during late spring and early summer by this species (Whitaker et. al. 1998). A northern myotis (*Myotis septentrionalis*) and a big brown bat (*Eptesicus fuscus*) were also found roosting in this bridge, but after the *Perimyotis subflavus* had left for the year.

Perimyotis subflavus made selective use of habitat while roosting (F= 67.961; d.f.= 10; Wilks' Lambda= .720; P<.001). While roosting this species made exclusive use of forest (t= -4.483; d.f. = 25; P<.001), including roosts in both trees and the covered bridge mentioned above. Associated habitats are those that occurred significantly nearer to roosts than random points included maintained (i.e. mowed) lands (t= -4.141; d.f. = 25; P<.001), and old-fields (i.e. unmanaged fields and unmanaged corridors) (t= -3.867; d.f. = 25; P=.001). These habitats were roosted nearer to more often than their availability and considered favorable. The habitat that was significantly farther from woodlots containing roosts, and thus was avoided, was commercial (t= 3.020; d.f. = 25; P=.006). All other habitats are considered neutral and were no nearer to roosts than random points. These included: low density residential (t= -2.754; d.f.= 25; P= .011); high density residential (t= 1.905; d.f.= 25; P=.068); industrial (t= .041; d.f.= 25; P= .968); agriculture (t= -1.010; d.f.= 25; P= .322); water (t= .037; d.f.= 25; P= .971); and transportation (t= -.324; d.f.= 25; P= .749)(Figure 4).

Discussion

This study was initiated to determine if a small broad winged bat's roosting patterns are affected by habitat fragmentation due to urbanization. To do this, I compared the size of woodlots available to *Perimyotis subflavus* with those used for roosting by that species. I also looked at habitat selection while roosting on a landscape scale. Other studies have shown that this species roosts in the foliage of trees and anthropogenic structures during summer roosting (Veilleux et al. 2003, Mumford and Whitaker 1982, Whitaker 1998). Capture records suggested they frequently are present in well-wooded regions that contain water, and they have been seen over farm-lands (Mumford and Whitaker 1982, Davis and Mumford 1962). Echolocations of this species were detected across many types of forest including newly regenerated stand, and one individual in South Carolina spent most of its time foraging in forests including bottomland hardwood, pine stands, and upland hardwoods (Loeb and O'Keefe 2006, Carter 1999).

In this study I found *Perimyotis subflavus* roosting exclusively in forested areas, and these bats favored larger intact woodlots, over smaller fragmented woodlots with the average size of a woodlot with a bat roost being 50.28 ha and the average size of a woodlot without roosts being 5.02 ha. This study also showed that these animals selectively roosted in woodlots nearer to old farm lands (t= -3.867; d.f. = 25; P=.001) and maintained lands (t= -4.141; d.f. = 25; P<.001) such as unplanted fields and parks, and that they avoided roosting in woodlots nearer to commercial landscapes (t= 3.020; d.f. = 25; P=.006). These results suggest that while *Perimyotis subflavus* does use larger woodlots, it does not avoid roosting in woodlots near many common components of urban landscapes (low/high density residential, industrial, and transportation). In this landscape only commercial developments (primarily shopping centers) appear to negatively impact the value of surrounding woodlots as roosting habitat for tricolored bats.

Table 1

Characteristics of Tircolored Bats (*Perimyotis subflavus*) Tracked Near the Indianapolis Airport in Summers 2005-2007.

		Home Range (ha)					
Bat	Reproductive Status	MCP 95%	KDE 95%	KDE 50%	Maximum Distansts Flown (km)	# of Locations	Days Tracked
1	Male	545.87	306.41	25.71	3.05	101	4
2	Lact	292.33	286.36	19.65	2.21	92	5
3	Gravid	430.89	192.03	24.98	2.55	77	5
4	P-Lact	206.35	178.87	35.97	1.19	115	4
5	Gravid	613.14	271.84	15.61	2.44	44	4
6	Gravid	108.07	72.60	13.32	0.98	61	7
7	Gravid	539.09	280.47	52.62	2.90	51	4
8	Lact	67.90	62.58	11.10	0.69	56	3
9	Lact	370.05	217.37	13.33	2.25	101	5
10	Lact	150.28	150.86	21.55	1.31	101	4
11	Lact	213.30	169.83	12.72	1.60	90	5
Avg		321.57	199.02	22.41	1.92	81	4.5

Table 2

Percent Use of Each Land Class by Each Bat, and the Total Percent Used By All Bats on Each Land Class.

Bat	Low Density Res	High Density Res	Comm-ercial	Indu-strial	Maint-ained	Agricu-lture	Unmain-tained	Forest	Water	Transpo-rtation
1	4.76	0.00	0.00	0.00	0.00	15.87	7.94	60.32	11.11	0.00
2	10.99	6.59	5.49	3.30	9.89	20.88	5.49	37.36	0.00	0.00
3	0.00	25.74	0.00	0.00	1.98	28.71	8.91	32.67	0.00	1.98
4	0.00	0.00	5.77	0.00	0.00	53.85	3.85	34.62	0.00	1.92
5	0.00	7.14	2.38	2.38	4.76	47.62	7.14	23.81	4.76	0.00
6	11.34	0.00	0.00	0.00	1.03	47.42	14.43	25.77	0.00	0.00
7	3.19	2.13	1.06	0.00	3.19	34.04	21.28	29.79	5.32	0.00
8	0.98	0.00	0.98	0.00	0.00	22.55	24.51	16.67	1.96	32.35
9	3.33	1.67	0.00	0.00	35.00	5.00	6.67	48.33	0.00	0.00
10	0.99	5.94	1.98	0.00	0.00	41.58	15.84	32.67	0.00	0.99
11	5.19	5.19	1.30	0.00	20.78	31.17	10.39	24.68	0.00	1.30
T %'s	3.98	5.45	1.59	0.45	6.14	31.36	12.61	32.27	1.82	4.32

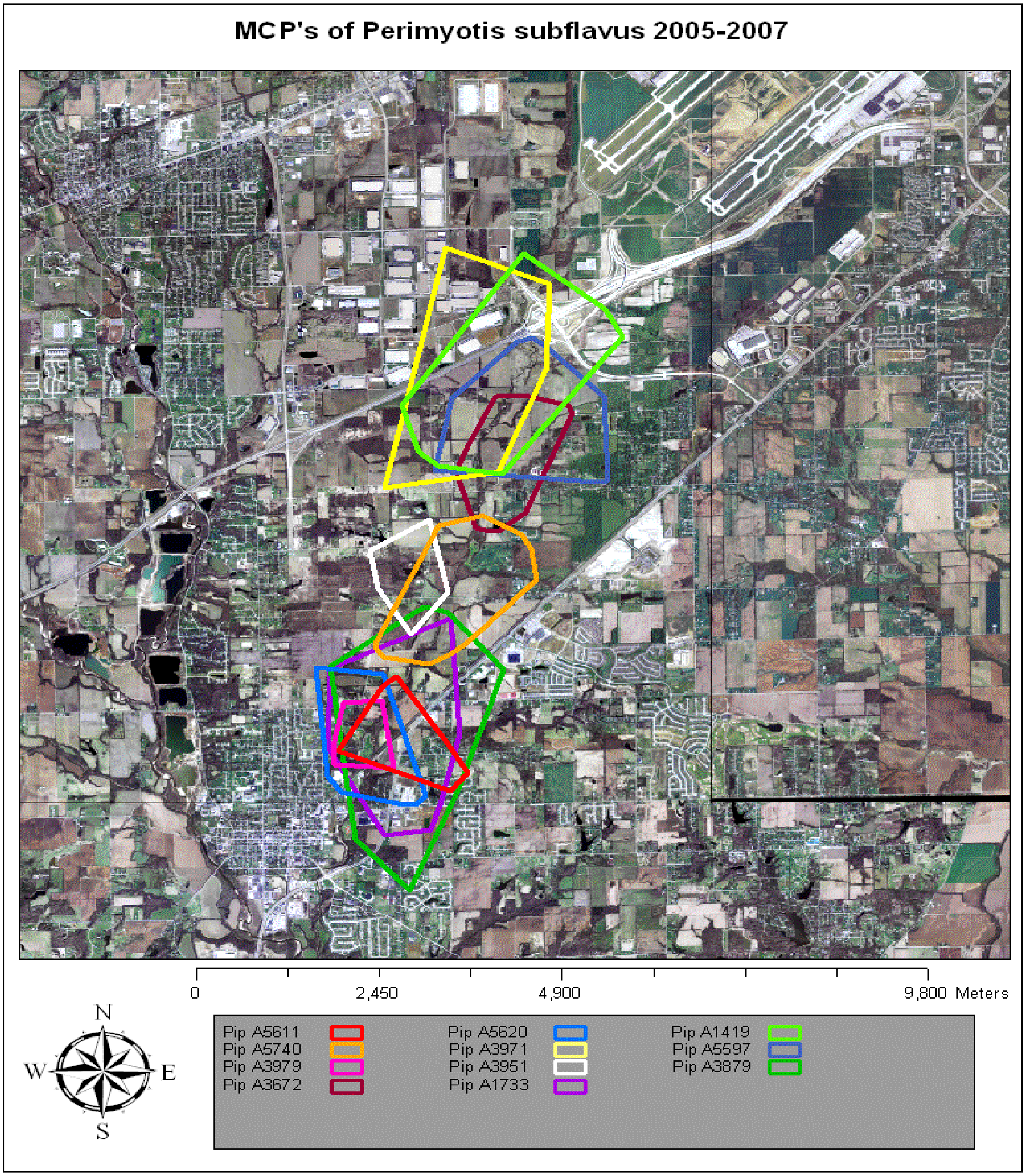

Figure 1. MCP's of all *Perimyotis subflavus* tracked from 2005-2007.

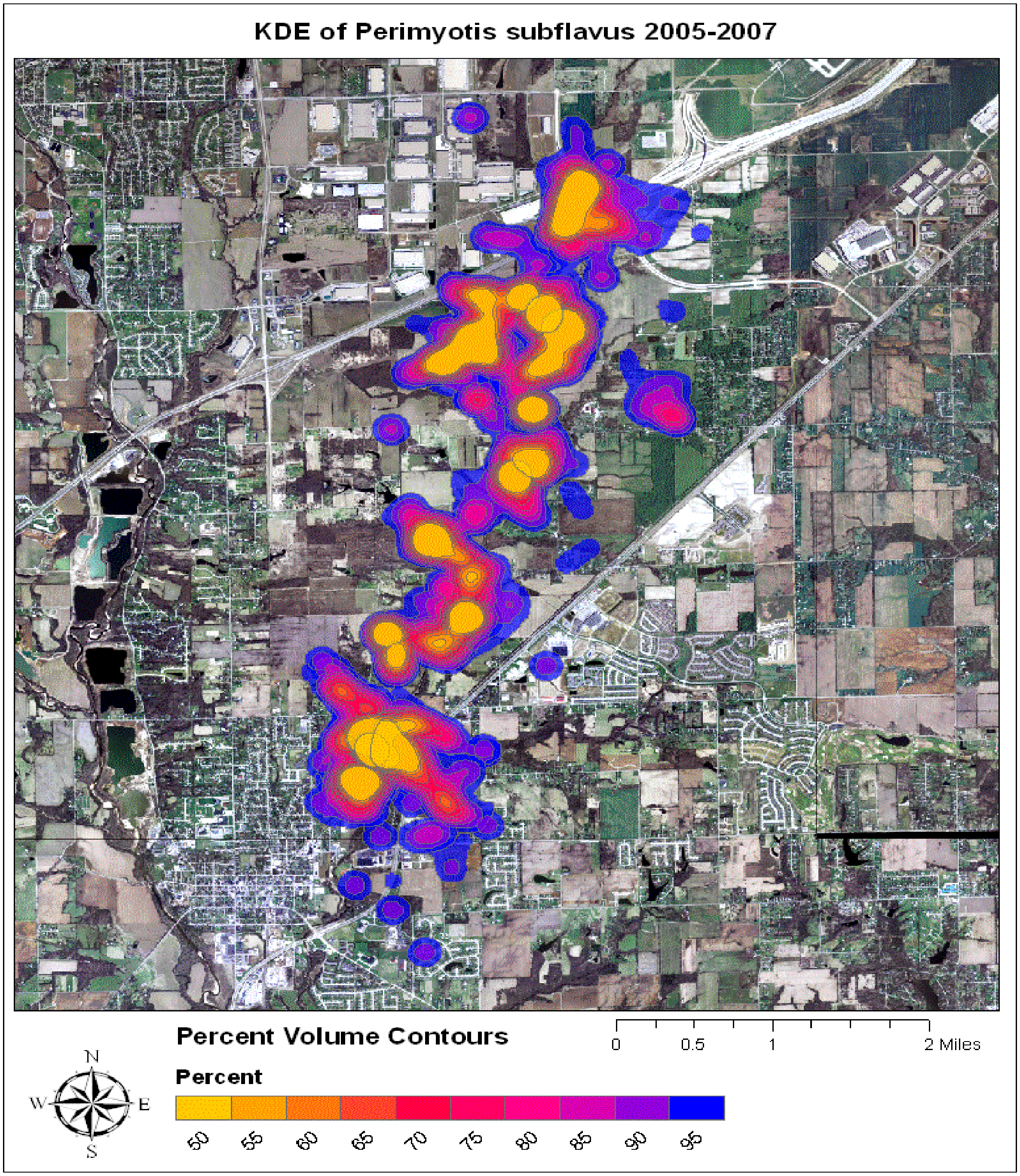

Figure 2. KDE's of all *Perimyotis subflavus* tracked from 2005-2007.

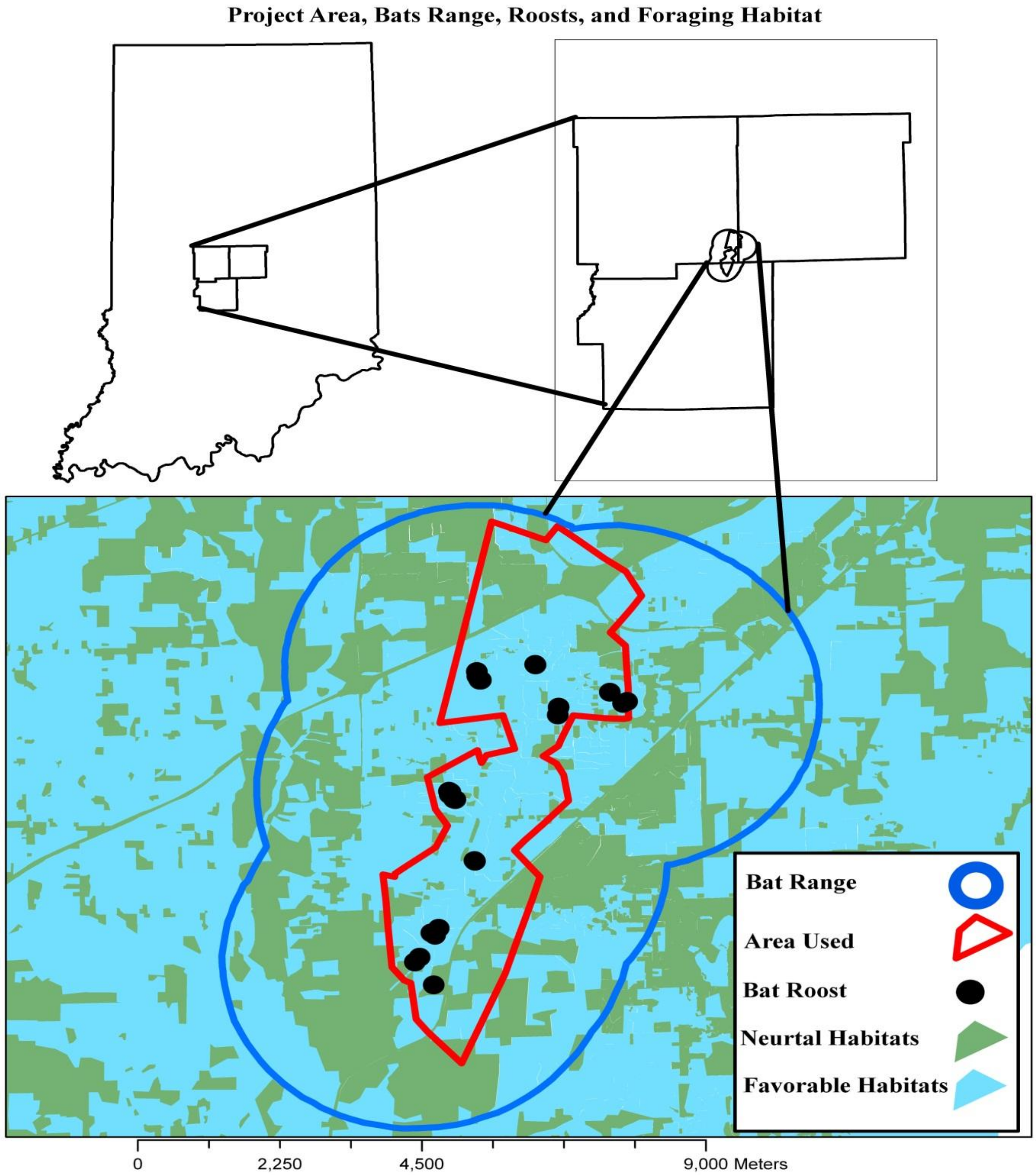

Figure 3. Project Area, Bats Range, Roost Locations, and Habitat Selection While Foraging.

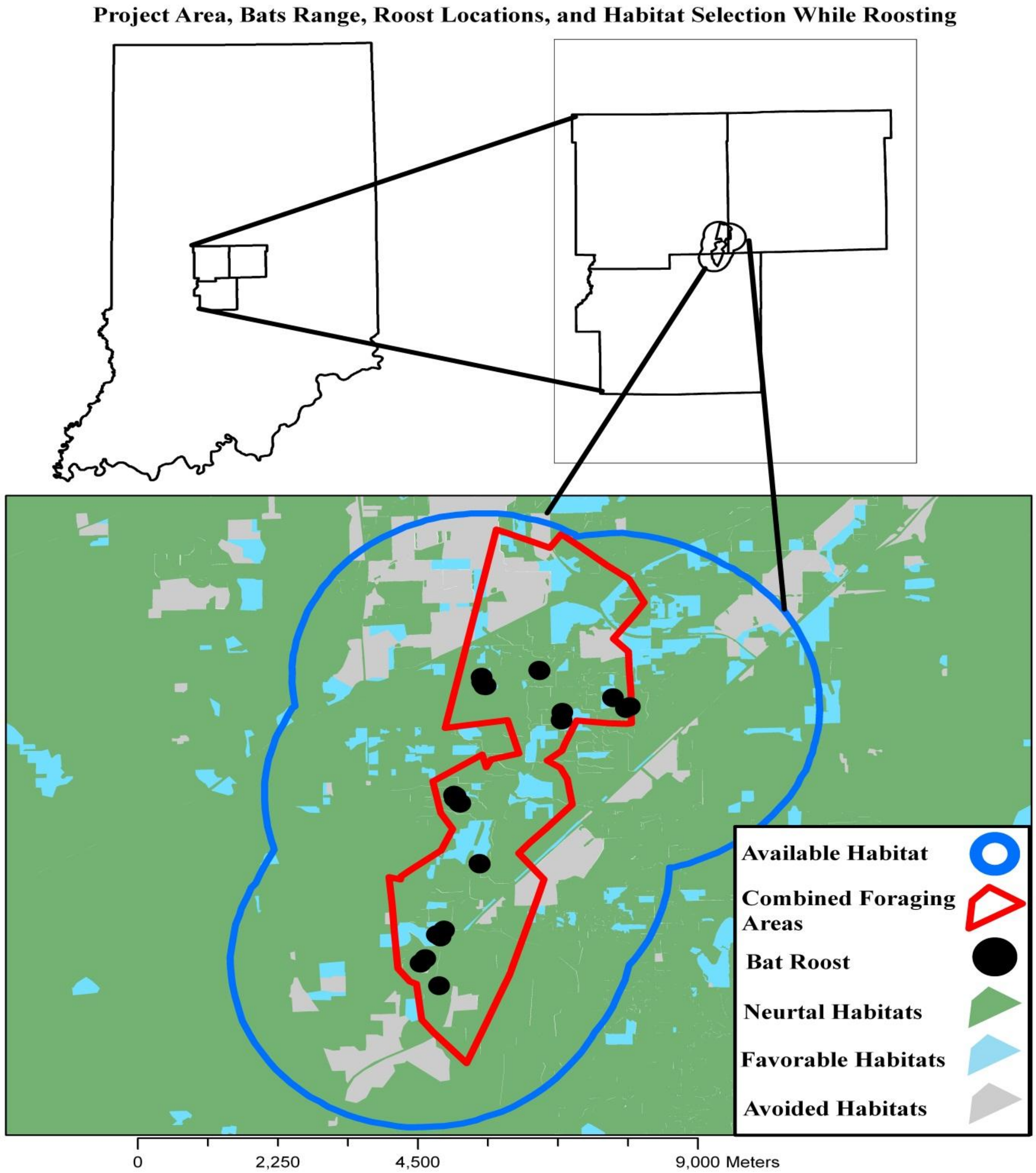

Figure 4. Project Area, Bats Range, Roost Locations, and Habitat Selection While Roosting.

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