MOVEMENT AND ECOLOGY OF THE EASTERN BOX TURTLE (*Terrapene carolina carolina*) IN A HETEROGENEOUS LANDSCAPE

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ABSTRACT

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The Eastern Box Turtle (EBT) (*Terrapene carolina carolina*) is a land turtle which is native to much of Eastern North America. Despite its large range, populations appear to be in an overall state of decline and the small, highly fragmented population within the Oak Openings Region of Northwest Ohio attests to this. Suitable, intact habitat is becoming increasingly rare outside of reserves and conservation action is warranted in order to determine how to best manage remaining populations of this species. I conducted a radio-telemetry survey in a study site which was located within Oak Openings Preserve Metropark, which is one of the largest blocks of intact habitat currently remaining within the Oak Openings Region. I used the data from this field study to look at the land cover composition of the home ranges of individuals, as well as which land cover types all of the turtles together had used throughout the year. I also looked at the importance that vegetation played as an indicator of box turtle site selection. Wilcoxon tests were used to compare the home ranges of five study turtles to ten similarly sized, randomly selected buffered points which were also found within the preserve. Although not statistically significant, EBT home ranges did seem to be composed largely of floodplain forest habitat. Open canopy habitat use was restricted to the month of June, which also coincided with the EBT nesting season. Understory forest plants, such as Pennsylvania sedge (*Carex pensylvanica*), were identified near the turtles in a large portion of the capture/recapture events. These results indicate that temporal changes in habitat use should be the focus of future studies for this species across its range. Further study on EBT use of floodplain forest should also be

pursued. Local land management regimes should avoid high-intensity disturbance of open canopy sites during the month of June and reintroduction of native forest sedges and shrubs should be considered in post-managed, woody stands.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Background Information

Most land turtle species are experiencing large-scale, global declines and the Eastern Box Turtle (EBT) (*Terrapene carolina carolina*) is no exception (Dodd, 1997). Their increasing rarity can probably be attributed to a variety of demographic-related issues. Their relatively low fecundity rates, high juvenile mortality rates, and slow growth rates all contribute to the several decades of time needed for EBT populations to recover from any sort of natural or human-made disturbance events (Hall et al., 1999). Few nests seem to go unnoticed by predators, and Flitz and Mullin (2006) recorded a nest depredation rate of 87.5% within the first 72 hours. Nuisance species such as raccoons, skunks, and ants are often to blame. Mortality rates are also likely very high for juvenile box turtles. Nazdrowicz, Bowman, and Roth (2005) recorded juvenile proportions ranging anywhere from 0-31%. Similarly, Hall, Henry and Bunck (1999) recorded the proportion of young turtles (i.e. juveniles) in a population in Maryland as ranging from just 4.2%-15.7%. They seem to be ideal prey for any terrestrial carnivore and the known predators include, but are not limited to: skunks, raccoons, foxes, coyotes, feral cats, domestic dogs, predatory birds, snakes, and even shrews. Because of their potentially long life spans, it is possible for a single population of EBTs to go decades without producing viable offspring but few demographic changes are noticed until the population spirals into extinction (Dodd, 2001).

Dodd, Enge and Stuart (1989) found that motor vehicle collisions are another important source of mortality in areas with heavily traversed roads cutting through them. Additionally, they are attractive pets and there is little doubt that the exotic animal trade has claimed a heavy toll on populations. It is believed that at least 100,000 box turtles have been removed from the wild over the years and sold in foreign markets (Dodd, 2001). Land management practices, which include mowing and controlled burning, are also large sources of mortality, even on reserves (Nazdrowicz et al., 2005; Platt et al, 2010). All of these factors may be significant when looking at the small, increasingly isolated box turtle population which lies within the Oak Openings Region. Taking into account that the remaining intact habitat within this region is often subjected to many of these same threats, further study of this population is essential for its long-term sustainability.

The EBT ranges over much of the continental United States East of the Mississippi River (Figure 1). It is listed as a “Species of Concern” in Ohio and was recently downgraded from being “Near Threatened” to “Vulnerable” federally (IUCN, 2011). It is considered uncommon to rare throughout much of the Great Lakes Region and the Oak Openings Region is thought to be the only place in Northwest Ohio where this species naturally occurred in recent history (Lipps, 2004).

Breeding typically occurs in the fall and early spring just after the winter dormancy period. Females may travel up to 774 m from their normal home range to the nesting site (Stickel, 1950). The nesting season in northern latitudes typically starts in early June and ends during the first week or two of July (Stickel, 1950); periods of high rainfall during this same time period have been found to be a potential trigger for females to leave their home ranges in pursuit of adequate nesting sites (Congello, 1978). Four to six eggs are laid in a shallow nest, often in clearings which receive sufficient sunlight and are free of debris (Messinger and Patton, 1995). The incubation period generally lasts from 69-136 days. The sex of the young is temperature dependent with cooler temperatures (<27°C) hatching mostly males and warmer temperatures (≥27°F) hatching mostly females. Heavily shaded nesting sites have the potential of producing more males, which can lead to skewed sex ratios (Dodd, 1997), which in turn would lead to declines on local populations. Sexual maturity isn't reached until 6-8 years but beyond this age, annual survival rates are often greater than 90% (Nazdrowicz et al., 2005). Box turtles are quite long-lived animals and ages of 70+ years have been attained for some wild specimens (Hall et al., 1999).

The EBT uses different habitats at different times of the year with movements heavily dependent on local temperature and humidity levels (Stickel, 1950; Reagan, 1974; Congello, 1978). During the spring, when it is generally cooler and wetter, they are often located in open canopy habitats where they can bask freely in the sun (Reagan, 1974; Dodd et al., 1994). As the summer season progresses and the landscape becomes much hotter and drier, they tend to move toward adjacent mesic forests and bottomlands where the heat may be less intense and the humidity levels are higher (Reagan, 1974; Doroff and Keith, 1990). EBTs typically use areas with multiple habitats lying in close proximity as well as "ecotones" in between habitats (Madden, 1975). Gibson (2007) found 40% of the EBTs captured in forest habitats to be within 15 m of the forest's edge and 75% of the turtles in open prairie/grasslands to be within 15 m of some sort of stand of trees as well. Madden (1975) also found woodlands to be very important for overwintering during the dormancy period. In general, however, seasonal habitat use by box turtles is still poorly understood and there is still much to learn about how adults use the different parts of their home range throughout the year.

Box Turtles do not seem to persist well in urbanized landscapes' (Budischak et al., 2006). Movements in general are often severely inhibited in highly fragmented habitats and it has been found that the EBT will rarely, if ever, utilize narrow corridors which might link suitable patches (Iglay et al., 2007). Nazdrowicz, Bowman and Roth (2005) found that human disturbances, isolation, and habitat composition appear to have the greatest influences on some populations.

The daily activities of box turtles seem to be highly driven by the weather and in general they tend to favor warm temperatures, especially in temperate climates (Dodd, 2001). Reagan (1974) suggested that box turtles exist within a very limited range of microclimatic variables throughout their active season. The most favorable conditions include warm temperatures, high humidity, as well as frequent rains (Stickel, 1950), conditions which are generally highest in early summer.

Very little is known about dispersal in box turtle populations. It could be assumed that, similar to sea turtles (*Cheloniidae*), Blanding Turtles (*Emydoidea blandingi*), and Wood Turtles (*Glyptemys insculpta*), these nesting sites may be the same natal areas where those particular females hatched. Therefore dispersal, at least for females of this species, would be around 700-800 m. There is also evidence that a certain portion of each population is made up of transients that, for whatever reason, don't settle into a permanent territory. Williams and Parker (1987) noted that transients from their population in Indiana made up 29-56% of their population at times but there was no pattern amongst these individuals with regard to sex. These transients show up in population surveys and then suddenly disappear, sometimes reoccurring several years later. Most of the transients seemed to be younger, growing individuals. Very little is known, though, concerning how long turtles go through this "transient phase" before establishing permanent home ranges, if some turtles in each population remain permanent transients for life or, if in fact, there really is any link for sure between transient turtles and dispersal.

Home range sizes typically vary by both sex and habitat quality. Stickel (1989) recorded ranges of 1.2 ha for males and 1.13 ha for females on optimal habitat in Maryland while Gibson (2007) recorded mean areas of 1.66 ha for juveniles, 4.52 ha for adult males, and 16.18 ha for adult females on Fort Custer Training Center, MI. Box Turtle densities tend to vary widely as well and also seem to depend largely on the suitability of a habitat as well as the availability of resources. Nazdrowicz, Bowman and Roth (2005) recorded densities which ranged from 0.81-3.62 turtles/ha in four different populations in Maryland while Wilson and Ernst (2005) recorded up to 16 turtles/ha in Central Virginia. Williams and Parker (1987) recorded 2.7-5.7 turtles/ha in Indiana. Though these numbers fluctuate heavily based on the study location, it does seem evident that a population's density has a negative correlation with the latitude.

Much of the literature about box turtles derives from studies where radio-telemetry as well as mark/recapture surveys have been conducted on wild populations. Radio-telemetry has become the more common method of choice when studying movements of wild animals (Samuel and Fuller, 1996; Iglay et al., 2006; Gibson, 2007). Although the technique does not add much knowledge to the current pool of demographic information available on box turtles, it can potentially allow for the collection of data relating to how box turtles move on a seasonal basis as well as use the habitat around them.

Very little research has been done regarding the population of EBTs in Northwest Ohio. Through the work of Lipps (2010) we now know that their range is limited strictly to the Oak Openings Region and that this isolated population appears to be highly fragmented. There is a need for research, however, on these turtles in terms of their general ecology as well as their habitat needs on a landscape level scale. This need is especially strong when looking at an area as heterogeneous in its land cover types as the Oak Openings Region. In addition, there is little information about the status of this population and its likelihood of persistence in the face of future land use changes and increasing management activities.

My research helped address these needs by determining which habitats EBTs include in their home ranges and use with the highest frequencies as the seasons change. My research also attempted to determine the importance of any specific plant species within each turtle's home range and also determined the rates of movement for individual turtles as they traversed these home ranges. These data should help determine the most appropriate course of action in conserving this isolated, increasingly fragmented population within the Oak Openings Region.

The Oak Openings Region

The Oak Openings Region (Figure 2) is a globally rare ecosystem which has recently been designated by the Nature Conservancy as "One of America's Last Great Places." This unique ecological unit is located in Lucas, Henry, and Fulton counties of Northwest Ohio and stretches from the Maumee River, across the state line at least as far North as Monroe County, Michigan (EPA, 2006). It is approximately 40,000 ha in size (Abella et al., 2007) though it may have been as large as 78,000 ha in pre-settlement times (Gordon, 1969).

The ecosystem is very heterogeneous in its habitat types; pre-settlement vegetation would have been dominated by White Oak (*Quercus alba*) and Black Oak (*Quercus velutina*) savannas and woodlands mixed with wet prairies and oak barrens (Brewer and Vankat, 2004). The region has been viewed as a "hotspot" for biodiversity and seems to serve as a last haven for a rich variety of threatened and declining indigenous plant and animal species (EPA, 2006). Nearly 1,200 different vascular plant species have been identified there with 165 of them considered to be potentially threatened, threatened, or endangered throughout the state of Ohio (Walters, 2004). With plant diversity and abundance being such a contributing factor to the overall high ecological value and importance of the Oak Openings Region, this research also addressed the question of whether there are any specific plant species, within EBT habitat, that they tend to be associated with.

Today, the Oak Openings Region is located in a land matrix of post-developed, urban/suburban land in the northern portion (The Greater Toledo Metropolitan Area) and cleared agricultural farmland, used primarily for corn and soybean production, in the southern end of the region. Only about 10% of this landscape (≈3,800 ha) is currently under any form of protection (Abella et al., 2007). Many of the higher quality tracts of habitat became severely altered and fragmented starting in the 19th Century as a result of agricultural land expansion, fire suppression, large scale ditching to intentionally lower the water tables, and urban development (Mayfield, 1969). As a result, only about 20% of the total land area is still thought to exist in a semi-natural state (Schetter and Root, 2011). A large network of paved streets also run through much of the region and systematically sub-divides the land into 1 mile^2 patches. Through the work of Dodd, Enge, and Stuart (1989), we know that losses attributed to moderate to heavy vehicular traffic can extract heavy tolls on herp populations, which includes box turtles.

Management, usually through prescribed burning, is necessary in maintaining the structure and composition of upland oak savanna habitat (Peterson and Reich, 2001; Brawn, 2006) and as a result has become a commonly used tool within the Oak Openings Region. However, the impacts of fire use on box turtles, and many reptile species in general, can potentially be quite devastating (Babbitt and Babbitt, 1951; Cavitt, 2000; Wilgers et al., 2006; Platt et al., 2010). Hence, being able to determine which times of the year box turtles use these open-canopy plots could be quite valuable when planning for the timing of future management activities.

METHODS

I utilized radio-telemetry of a selected group of individual turtles to answer the questions regarding local box turtle ecology and habitat use. The study site used was an area located within the boundaries of Oak Openings Preserve Metropark (Figure 3) in Swanton, Ohio, within the periphery of the grid coordinates of 41.555341 (latitude) and -83.860167 (longitude). The land area was approximately 200 ha in size and was a very heterogeneous landscape. Swan Creek bisected the site, which contained a mixture of upland deciduous forest, upland coniferous forest, floodplain forest, swamp forest, sand dune barrens, as well as upland prairie and Eurasian meadow (Schetter and Root, 2011). Weekly mowing occurred along an approximate 10-15 ft berm along the edge of all three roads that bordered the study site, as well as along both sides of the Wabash-Cannonball Bike Trail. Controlled burns were conducted within the Eurasian meadow, which was located along the west side of Girdham Rd., as well as the prairie which was located along the east side of Girdham Rd., on a rotational basis that occurred approximately every 2-3 years.

Radio Telemetry

I utilized radio-telemetry of five turtles to test my hypotheses regarding local box turtle ecology and habitat use. The first two box turtles that I obtained for the study were rehabilitated individuals that had been released back into Oak Opening Preserve Metropark by Nature's Nursery (a licensed, local wildlife rehabilitator). I attached Holohil SB-2T radio transmitters to both of these turtles a day or two prior to their release (see Table 1). The other three turtles were randomly encountered and captured within the study site between 20 May 2010 and 13 August 2011. I used Devcon 5-Minute Epoxy to attach the transmitter to the carapace of each of the turtles, similar to Gibson (2007). The epoxy allowed each turtle to be released within approximately 30-40 minutes of being captured and fitted with the transmitter. Transmitters were placed on the back of the carapace, just above the tail for males. In order to mitigate the impact they might potentially have had in preventing copulation, on females it was placed more off to the side of the carapace just above the right rear leg. Once the epoxy had adequately cured, the turtle was then released back at the original capture site. Each turtle was then tracked and located approximately two times each week by using a TRX-1000s receiving unit. A Garmin Etrex Legend global positioning system (GPS) was used to record each turtle's location. Passive integrated transponders (PIT tags) were implanted into all captured turtles (see Table 1). An AVID Mini Tracker Reader was then used to identify the nine digit identification code of the tag within each implanted turtle. The following data was collected for each turtle:

- Mass (g)
- Carapace length (mm)
- Overall health status (any noticeable injuries, burns, or signs of illness)
- Sex
- Behavior prior to capture (e.g. feeding, sleeping, walking, etc.)

A tubular spring scale was used to weigh each turtle at each capture to monitor for any sudden fluctuations in body mass, and electronic digital calipers were used to measure overall carapace length approximately once per month. Sex was estimated by using the turtle's plastron shape (concave and round in males and flatter in females) as well as tail length. Behavior was also recorded and was categorized as: feeding, sleeping, basking, hiding, walking, or hibernating.

Several different environmental variables were recorded during the capture/recapture events:

- Air temperature (C°)
- Relative humidity (%)

- O Estimated cloud cover (%)
- O Barometric pressure (psi)
- O Wind direction and speed (mph)
- O Overall weather condition (e.g. clear, rainy, snowing etc.)

The different habitat variables that were measured at each location (see Table 2) included:

- O Surrounding plant species (<1 m from capture/recapture point)
- O Water depth (cm) if submerged
- O Leaf litter depth (cm)
- O Height of the tallest plant located in close proximity (cm)
- O Depth of turtle if buried (cm)

A meter stick and ruler were used for the linear measurements. The meter stick was used to determine the height, in centimeters, of any plants which were found within a 1 m radius of the turtles during each capture/recapture event. In instances where multiple plants of varying heights were observed near the turtles, I recorded only the height of the highest reaching plant. Use of leaf litter was also regularly noted, especially in the small number of open woodland sites where nearby vegetation was in fact absent. The metric ruler was used to measure the depth of the litter just off to the side (<5 cm) of the location where each turtle was initially encountered during each event.

The field manual, Woody Plants of Ohio: Trees, Shrubs, and Woody Climbers Native, Naturalized, and Escaped by Lucy Braun (1989), was used to identify plants found near each turtle. To address what, if any, importance each species had on box turtle presence, I recorded the species of all identified plants if they were found within 1 m of the capture/recapture location (see Table 3). The total number of sightings for each plant species was counted at the end of the study and compared (Figure 4). Air temperature, humidity, barometric pressure, wind temperature, and wind speed were each obtained from the NOAA National Weather Service.

Location Data

Additional spatial data which was obtained included:

- Land cover image (Schetter and Root, 2011)
- Rivers (Brewer and Vankat, 2004)
- Roads (US Census Bureau, 2009)
- Current boundaries for preserves managed by Metroparks of the Toledo Area (Zeigler, 2010)
- Current boundaries for preserves managed by all three agencies (Metroparks of the Toledo Area, Ohio Department of Natural Resources, and The Nature Conservancy) (Zeigler, 2010)
- A satellite picture image of Lucas and Fulton counties (Kaczala, 2005)

For each capture location, the land cover type was identified based on the land cover categories developed by Schetter and Root (2011) (Figure 5). Minimum convex polygons were developed for each individual turtle's movements. To create these polygons, each of the capture/recapture points (Figure 6) was classified by the identification number of the turtle that corresponded to each point. The 'Minimum Convex Polygon' tool, within ArcView GIS, was then used to create a polygon for each of the five turtles. I intersected these newly created minimum convex polygons with the land cover image developed by Schetter and Root (2011) (Figure 7). These polygons were then analyzed for the proportion of each land cover type (see Table 4). The distance of each capture/recapture point to the nearest road/hard edge was also measured and assessed. Analyses focused on the relationship between the environmental/habitat variables and the capture locations.

The land cover types, in which turtle home ranges occurred, were tested against a randomly generated set of ten circular shaped, buffered points within Oak Openings Preserve Metropark (Figure 8). Sites were set at a minimum of 500 m apart. The size of each random point was selected by using the mean area from the five minimum convex polygons, which was 64,370 m^2. Thus, each point was given a 142.4 m radius in order to be proportionate in size to this determined home range mean. The points were then intersected with the land cover map developed by Schetter and Root (2011) before being analyzed for land cover proportion. To test for any statistical significance between either of the land cover types within the home range polygons, the proportions for each polygon and each random buffered point were uploaded into JMP 9 once they had been calculated. I then tested the proportion for the polygon land cover types against the proportion of the buffered points by performing Wilcoxon tests for each land cover type.

While the land cover proportions were based upon the analysis of the minimum convex polygons, for seasonal habitat use I looked at the land cover type that each of the individual 101 capture/recapture points occupied and then sorted the data based upon the month that the point had been recorded (see Table 5). I calculated these proportions for the months of April, May, June, July, and August (Figure 9) since these were the months when I saw the most box turtle activity. I excluded October, November, December, January, February, and March as the turtles were mostly in the dormancy period during these months.

I also wanted to determine the importance of edge habitat in relation to box turtle habitat use. To do this, the distance was measured on the ArcView GIS land cover image from each box turtle's capture/recapture point to the nearest anthropogenic hard edge surface (essentially either of the roads or the bike trail).

The last parameter I wanted to assess was the distance traveled by individual turtles, throughout the study, between capture/recapture events. To do this, I measured the straight line distance between each point on ArcView GIS based on the sequential date that each capture/recapture point was recorded as well as by the identification number of the turtle that had made the point.

RESULTS

Turtle Movements

Distances travelled by individual turtles (see Table 1) tended to vary widely throughout the duration of the study with the maximum distances being recorded in the month of June. The maximum distance on a daily time span was achieved by turtle 002 (n=751 m) on 17 June 2011. This same turtle also had the maximum distance traveled for the monthly time span (n=1,469 m) for the entire month of June. Mean daily distances traveled were much lower (x=93 m) with monthly distances being approximately four times this amount (x=424 m) for each of the study turtles. The distance traveled by all five turtles by the end of the study was 8,896 m total.

In April, floodplain forest (50%) and residential/trail (50%) were the primary habitats occupied (Figure 9). In May, floodplain forest made up nearly a third of the used habitat (34%) while upland coniferous forest (22%), residential/trail (22%), upland deciduous forest (11%), and swamp forest (11%) made up smaller proportions. For June, floodplain forest (70%) made up the majority of the occupied habitat while upland coniferous forest (10%), prairie (10%), and Eurasian meadow (10%) were also occupied, though each to a much lesser extent. In July, floodplain forest made up nearly half of the occupied habitat (47%), swamp forest was approximately one third (33%) with upland coniferous forest (10%), residential/trail (5%), and shrub/scrub (5%) used much less frequently. For August, upland deciduous forest (33%), floodplain forest (27%), and swamp forest (22%) made up the majority with upland coniferous forest (13%) and residential/trail (5%) being used much less frequently.

When I analyzed the distances to the nearest hard edge, I found that box turtles in this study rarely ventured near any of the hard edge areas (e.g. roads and/or paved bike trails) and their occupied habitat seemed to consist of more interior habitat as opposed to exterior habitat. The distance from each of the capture points to the nearest hard edge surface for all of the capture/recapture points (x=128 m) ranged widely when looking at means for each individual turtle (see Table 1). Turtle 001 had the smallest mean distance (x=68 m) while turtle 004 held the maximum distance (x=297 m).

Vegetation and other Environmental Variables

Pennsylvania sedge (*Carex pensylvanica*) was identified near the turtles in a large portion (n=31) of the capture/recapture events (see Table 3). Japanese barberry (*Berberis thunbergii*), cinnamon fern (*Osmundastrum cinnamomeum*), and eastern skunk cabbage (*Symplocarpus foetidus*), though to a slightly lesser extent, were also seen regularly near the turtles (n=8-20). Smooth sawgrass (*Cladium mariscoides*), various types of oak (*Quercus*) saplings, black raspberry (*Rubus occidentalis*), and water smartweed (*Polygonum coccineum*) were seen more rarely near the turtles (n=3-6). Multiflora rose (*Rosa multiflora*), poison ivy (*Toxicodendron radicans*), grape vine (*Vitis riparia*), blue lupine (*Lupinus perennis*), and big blue stem (*Andropogon gerardii*) were each only seen near the turtles a couple of times each (n=1-2). In all, 97 plants had been identified in close proximity to the turtles throughout the course of this study.

Vegetation height around capture/recapture sites' (see Table 2) was relatively high (x=45) with a range of 0 to 150 cm and only on a small number of occasions (n=16) were study turtles ever found to occupy sites where ground vegetation was completely absent. Leaf litter was also abundant in the capture/recapture sites (x=1.74 cm) and ranged from 0 to 9.5 cm.

Home Range Analysis

I only analyzed data from the original 119 capture/recapture locations where no data was duplicated and repeat captures in the same grid coordinates (i.e. hibernation sites) were eliminated. Using these remaining 101 grid points, I was able to determine the land cover composition of each turtle's home range.

Floodplain forest made up the majority of the habitat area (x=31%) proportions for all five of the minimum convex polygon home ranges (Figure 10). Upland deciduous forest was the next most abundant (x=23%) land cover area; upland coniferous forest (x=21%) and swamp forest (x=13%) were each slightly less abundant. Other land cover types which comprised a smaller proportion of the home range areas were residential/trail (x=5%) as well as prairie and savanna (x=2%). Shrub/scrub, turf, and Eurasian meadow (x≤1%) each made up a very small proportion of the total mean polygon area as well.

The proportion of habitats used for the home ranges of the male turtles (001, 003, and 004) were very similar in composition and had large proportions of floodplain forest (51-54%) and upland deciduous forest (11-27%) (Figure 11). Upland coniferous forest, swamp forest, residential/trail, and shrub/scrub were present in male home ranges but made up much smaller proportions (1-14%). Female turtle (002 and 005) home range polygons were composed primarily of upland coniferous forest and upland deciduous forest (29-47%). Residential/trail, swamp forest, floodplain forest, turf, savanna, prairie, and Eurasian meadow each made up much smaller proportions (<1-10%), though it is important to note that the latter three habitats were only found within turtle 002's home range.

When I analyzed the means of the 10 random buffered points (Figure 10), upland deciduous forest made up the largest majority of the land cover type (x=33%). Upland coniferous forest and floodplain forest each made up the next highest proportions (x=17%) with swamp forest slightly less (x=13%). However, it is important to note that the proportion of floodplain forest in the random points was still much smaller than the proportion it made up in the minimum convex polygons. Eurasian meadow, prairie, and residential/trail each made up much smaller proportions of the random point areas (x≤10%).

To compare the total proportion of land cover for the entirety of Oak Openings Preserve Metropark to the home range polygons of the study turtles (Figure 7), as well as the 10 random buffered points (Figure 8), an outline was made along the boundaries of the park which was also intersected with the land cover map developed by Schetter and Root (2011) (Figure 12). Upon analysis, upland deciduous forest (27%) made up the majority land cover type within the preserve while floodplain forest was just slightly less abundant (22%). Upland coniferous forest (18%) was the next most abundant land cover with swamp forest (13%) and residential/trail (9%) being slightly less. Knowing the proportions that each land cover type made up for the entirety of the preserve gave me an additional means of comparison for the home range polygons. However, I did not statistically compare any of these proportions amongst one another.

After running the statistical tests wherein I compared the land cover types between the home range polygons and the random buffered points (Figure 13), I determined that out of all 15 of the land cover types which had originally been identified by Schetter and Root (2011) that none of the proportions were statistically different between the two data sets.

DISCUSSION

Turtle Movements

When looking at land cover use on a seasonal basis (see Table 5), I found that the study turtles used the non-forested land cover types (Eurasian meadow and prairie) only during the early summer, specifically within the month of June. The rest of the activity period was characterized by heavy use of floodplain forest, swamp forest, upland deciduous forest, and upland coniferous forest. This was somewhat contrary to the findings of Reagan (1974) who found box turtles to use both forested and non-forested sites during late spring, summer, and early fall with a peak in non-forested habitat use occurring in late spring and early fall. However, it is important to note that this study was performed on the Three-Toed Box Turtle (*Terrapene carolina triunguis*) which is a different subspecies from the population native to the Oak Openings Region. The study site was also located much further to the south within the Ozark Mountain Range on a farm where much of the native temperate forest habitat had been cleared. Given these contrasts from my study, it is expected that differences would occur in the habitat use shown by both populations when being compared to one another.

When I looked at the overall distances traveled by individual turtles throughout the duration of this study, the straight line distances measured between subsequent capture/recapture points tended to vary quite widely. The distances started off at 0 meters for each turtle in the early spring when cool weather kept them dormant. The largest travel distances occurred during the months of June and July. During June, mean distances traveled in between capture events were highest (x=182 m); by July, however, this number had more than halved (x=72 m). This was similar to the findings of Strang (1983) who measured overall mean distances of 40 m ± 50 in 24 hour time periods for EBTs in Pennsylvania with means being affected most greatly by days of rain (75 m ± 65, n=12) and days of dry weather (19 m ± 20, n=21). It is important to note that these distances were probably much further in reality, as I only measured straight line distances between capture/recapture points at a frequency which only occurred about two times per week.

Despite the fact that hard edge seemed to present no barrier to the study turtles (I documented crossings of paved surfaces between captures on several occasions [n=5]), the results suggest that overall, the turtles avoided hard edge habitat throughout the study (see Table 5). When looking at the distance from hard edge for each capture/recapture point, the mean distance was 127.95 m. The minimum distance of any turtle to edge was 5 m and the maximum was 564 m. It is important to note, though, that 93% (n=94) of these points occurred at a distance which was greater than 25 m from the edge and only 7% (n=7) were at a distance less than 25 m. These findings are counter to the habitat use shown by E. Box Turtles from other populations, which actually seemed to show a preference for varying sorts of edge habitat (Madden, 1975; Gibson, 2007). It is difficult to determine why turtles in the Oak Openings Region appeared to have a higher usage of non-edge sites. Differences may be attributed to the small sample size involved with this study (n=5) or in a difference in the types of edge. Had we monitored a larger number of turtles, it is possible that the results of our findings involving edge habitat use by box turtles may have been more similar to the findings of these other studies. It is also possible that because of the high value of Oak Openings Preserve to local recreationists, that turtles which had a higher propensity to use non-interior and edge sites may have been selectively removed by park visitors over the years.

Vegetation and other Environmental Variables

As stated earlier, EBTs occurred most often in forested sites that had an herbaceous understory that included species of sedges and shrubs. The vast majority of the plants within the most heavily used sites were native, forest dwelling species, with the exception of the non-native Japanese barberry (*Berberis thunbergii*). We know from Surface (1908) that grass leaves can make up a large portion of a mature box turtle's diet. It may, therefore, not be entirely coincidental that Pennsylvania sedge (*Carex pensylvanica*), a native forest grass, was identified in 31 of the 101 capture/recapture events and was found near the turtles in by far the highest frequency. The fact that the invasive Japanese barberry (*Berberis thunbergii*) was identified in 20 of these events may be related to its presence in dense, protective stands within the forest which were difficult for humans to travel. Stickel (1950) documented a thorny, mixed thicket composed of *Rubus*, *Smilax*, and *Viburnum* species to be very heavily used by box turtles in her study in Maryland. Cinnamon fern (*Osmundastrum cinnamomeum*) and eastern skunk cabbage (*Symplocarpus foetidus*) were each identified 13 and 8 times within these events. Reagan (1974) regularly found ferns belonging to the class *Polypodiopsida* throughout portions of his study site in Arkansas, which were commonly used by box turtles. *Monocots* and other sorts of flowering forbs, belonging to the same class as skunk cabbage (*Symplocarpus foetidus*), were found there as well.

Grasses within the genus Andropogon, which includes big blue stem (*Andropogon gerardii*), were also common throughout the heavily used study site of Stickel (1950). These findings differed from my study; I only found the turtles near the prairie/savanna dwelling plant species (*Andropogon geradii* & *Lupinus perennis*) on two occasions despite the fact that each appeared to be relatively common throughout large portions of the study site. This was also the case for poison ivy (*Toxicodendron radicans*) and grape vine (*Vitis riparia*) which, overall, rarely occurred near turtle locations.

The presence of ground vegetation, (e.g. Pennsylvania sedge, Japanese barberry, and cinnamon fern) in general, was found to be a relatively frequent occurrence in each of the recapture events. During the hibernation period, from November to mid April, most understory vegetation had all but died off for the season. However, as the active season progressed from late April to the end of August, the presence and height of all understory vegetation within close proximity to each study turtle's location increased. For the 101 capture/recapture events, vegetation heights had a mean of 44.99 cm. It seemed that understory vegetation was utilized by the turtles, most likely as a potential food source. This is supported by the work of Surface (1908) who found plant material in the digestive tracts of 62.5% of the turtles sampled in a study done in the neighboring state of Pennsylvania. The presence of native and non-native shrubs also may serve as a form of cover for the turtles to hide amongst as well even when they were not foraging. Similarly, Stickel (1950) found a high frequency of box turtles in brush piles, heaps of debris, and tangles of vines and briars when they were not actively moving. Rarely in the entirety of the study, with the exception of the dormancy period, did I ever find box turtles utilizing sites where ground vegetation was completely absent. In the 101 capture/recapture events, most of the sites (n=85) had some sort of vegetation present which was found within a 1 m radius of the turtles. Of the remaining captures where no vegetation was found in close proximity to the turtles, nearly a third of those captures (n=6) had occurred from October to April when turtle activity and plant productivity both seemed to be at their lowest.

It was also very common to find turtles hiding in and amongst leaf litter during capture/recapture events, especially when they were occupying sites where live vegetation was absent. Depths had a mean of 1.74 cm. Further analysis of leaf litter use by box turtles is a topic that hasn't been studied to any great extent in any similar studies regarding this species.

Home Range Analysis

Swan Creek bisected the study site and ranged from a couple of centimeters to 1-2 ft. in depth during the summer months. It did not appear to present any sort of barrier to individual turtle movement as three out of the five turtles had crossed this stream at some point during the study. Floodplain forest bordering the creek was by far the most heavily used land cover type by the sample turtles throughout the study (see Table 2). Approximately 31% of the mean of the home range polygons were composed of this sort of habitat. This was much larger than the 17% which composed the random buffered points or the 22% proportion that floodplain forest made up of the land cover composition for Oak Openings Preserve Metropark. Donaldson and Echternacht (2005) found wetlands and other areas of standing water to be a vital part of EBT habitat, and Stickel (1950) found box turtles in Maryland to congregate primarily in and around bottomlands and floodplains. While the data is suggestive of a high usage of floodplain forest, there was no statistically significant difference between the proportions of floodplain forest in random locations versus the proportions found within the home range polygons in this study. It is very possible that this, again, is attributable to the small sample size of turtles (n=5) that were monitored.

By studying a local population in a landscape as diverse and complex as the Oak Openings Region, I gained insight into the ecology of this species on many different scales. By assessing radio-telemetry data of five mature study specimens over the course of a single field season, I learned that these turtles use closed canopy sites at a high frequency throughout the majority of the year with many of these sites occurring in and around floodplain forest habitat.

Open canopy site use was restricted to the nesting season (June-early July) and, in my study, only involved a single female specimen. Insights were also gained on the use of woodland sites with understory vegetation as well as the specific plant species that occupied the habitats utilized by box turtles. A majority of the capture/recapture events did have a large quantity of understory vegetation present with Pennsylvania sedge (*Carex pensylvanica*) being the most abundant plant. These data should aid in making the intelligent management decisions that will result in persistence of the EBT in the Oak Openings Region.

Management Implications

As the floodplain forest which bordered Swan Creek was the dominant land cover type within the combined home range area of all of the turtles, I recommend the continued preservation of floodplain forest habitat within the Oak Openings Region. I also advise the strong use of caution for any land management which may occur in any of the floodplain forest dominated sites as outlined by the Oak Openings Region land cover image established by Schetter and Root (2011).

Land management practices focused on oak savanna and prairies (e.g. mowing and controlled burning), within the Oak Openings Region, might negatively affect box turtles. The only time any of the turtles in my study used any of the open canopy land cover types within the study site was during the month of June. This was also when I recorded the highest rates of travel for EBTs. This timeframe coincides with the box turtle nesting season, as documented in similar studies (Stickel, 1950), which typically commences in early June and ends approximately mid-way through July. During the rest of the field season, the turtles remained in closed canopy sites and therefore would be less vulnerable to potential land management activities conducted within open canopy sites.

Although much emphasis has been on restoration of native plant communities within many of the open canopy sites throughout the Oak Openings Region (Abella et al., 2004), it should be noted that understory woodland plants also have a valuable niche within this ecosystem as well. Pennsylvania sedge (*Carex pensylvanica*), Japanese barberry (*Berberis thunbergii*), cinnamon fern (*Osmundastrum cinnamomeum*), and eastern skunk cabbage (*Symplocarpus foetidus*) were each found in close proximity to the box turtles of my study relatively frequently and each seemed to be well established throughout various portions of the study site. Although I do not recommend the preservation of any exotic plant species (e.g. Japanese barberry), replanting closed canopy plots with native forest sedges and shrubs could be beneficial to local box turtles.

There is a need for continued research on the EBT population within the Oak Openings Region. The information we have on this population is very limited as few other studies have been performed within the area. The sample size for this study was small (n=5) and as a result there were many limitations to the conclusions that can be drawn. I believe that continued study of habitat usage by a larger sample of locally captured EBTs, over a wider geographic area within the region, would give us much greater understanding of the seasonal movements and habitat usage of this population. Given the relatively large size of Oak Openings Preserve Metropark, and the fact that box turtles do not occur anywhere else outside of the Oak Openings Region in Northwest Ohio, there is much potential within the preserve to maintain a large, robust

EBT population. It will, however, be critical to gain further insight on the ability of this species to utilize specific habitats in this heterogeneous landscape.

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TABLES

Table 1: Capture data for the E. Box Turtles which were used in this study.

Turtle ID	Sex	Date of Capture	Pit Tag Number	Home Range Size (m^2)	Mean Distance Traveled Between Captures (m)	Mean Distance from Captures to Nearest Hard Edge (m)
001	Male	10/11/2010	016-269-571	38,933	62	68
002	Female	10/11/2010	016-110-600	144,756	119	103
003	Male	05/20/2011	016-259-281	66,074	92	102
004	Male	07/23/2011	016-122-319	69,108	95	297
005	Female	08/13/2011	016-262-549	2,979	98	230

Table 2: Results of the analysis of leaf litter depth, vegetation height, temperature, humidity, and distance from edge.

	Mean	S.D.	Minimum	Maximum
Leaf Litter Depth (cm)	1.9	1.91	0	9.5
Vegetation Height (cm)	45	36.2	0	150
Temperature (F°)	75	10.75	36	91
Humidity (%)	61	15.59	30	100
Dist. From Edge (m)	127.95	97.34	5	564

Table 3: Frequency of plant sightings, found within close proximity to box turtle capture/recapture points, by species.

Plant Species	**No. Sightings**	**Proportion**
Andropogon gerardii	1	0.01
Berberis thunbergii	20	0.21
Carex pensylvanica	31	0.32
Cladium mariscoides	6	0.06
Lupinus perennis	1	0.01
Osmundastrum cinnamomeum	13	0.13
Parthenocissus quinquefolia	1	0.01
Polygonum coccineum	3	0.03
Quercus	5	0.05
Rosa multiflora	2	0.02
Rubus occidentalis	4	0.04
Symplocarpus foetidus	8	0.08
Toxicodendron radicans	1	0.01
Vitis riparia	1	0.01
Total	**97**	**1.0**

Table 4: The area, in meters², of each land cover type. Note that 'Home Range Total' may include overlapping land cover area between home ranges.

Land Cover Type	Turtle 001	Turtle 002	Turtle 003	Turtle 004	Turtle 005	Home Range Total	Preserve Total	Random Points Total
	Area(m²)							
Turf	0	2,750	0	0	0	2,750	2,105,952	5,413
Wet Prairie	0	0	0	0	0	0	0	0
Residential/Trail	2,220	14,037	0	1,124	300	17,681	14,834,692	46,114
Asphalt	0	0	0	0	0	0	7,629	0
Pond	0	0	0	0	0	0	184,243	0
Savanna	0	7,764	0	0	0	7,764	4,295,293	14,812
Shrub/Scrub	243	0	900	0	0	1,143	480,648	4,500
Swamp Forest	2,700	7,512	15,465	15,613	250	41,540	21,700,214	60,389
Upland Coniferous	3,607	54,382	0	9,806	865	68,660	29,615,765	79,763
Upland Deciduous	10,356	42,613	13,767	7,474	1,395	75,605	43,552,941	155,770
Floodplain Forest	19,806	7,859	35,942	35,090	168	98,865	35,839,321	81,531
Barrens	0	0	0	0	0	0	1,366,401	912
Eurasian Meadow	0	688	0	0	0	688	5,074,146	8,303
Prairie	0	7,170	0	0	0	7,170	4,940,084	19,423
Cropland	0	0	0	0	0	0	68,773	0
Total	**38,933**	**144,756**	**66,074**	**69,108**	**2,979**	**321,866**	**164,066,102**	**3,531,378**

Table 5: Habitat use for the study turtles by month.

Land Cover Type	April	May	June	July	August
	No. of Captures				
Upland Deciduous Forest	0	1	0	0	15
Floodplain Forest	1	3	7	10	12
Upland Coniferous Forest	0	2	1	2	6
Swamp Forest	0	1	0	7	10
Residential/Trail	1	2	0	1	2
Shrub/Scrub	0	0	0	1	0
Prairie	0	0	1	0	0
Eurasian Meadow	0	0	1	0	0
Total	**2**	**9**	**10**	**21**	**45**
	Proportion				
Upland Deciduous Forest	0	0.11	0	0	0.33
Floodplain Forest	0.50	0.34	0.70	0.47	0.27
Upland Coniferous Forest	0	0.22	0.10	0.10	0.13
Swamp Forest	0	0.11	0	0.33	0.22
Residential/Trail	0.50	0.22	0	0.05	0.05
Shrub/Scrub	0	0	0	0.05	0
Prairie	0	0	0.10	0	0
Eurasian Meadow	0	0	0.10	0	0
Total	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**

FIGURES

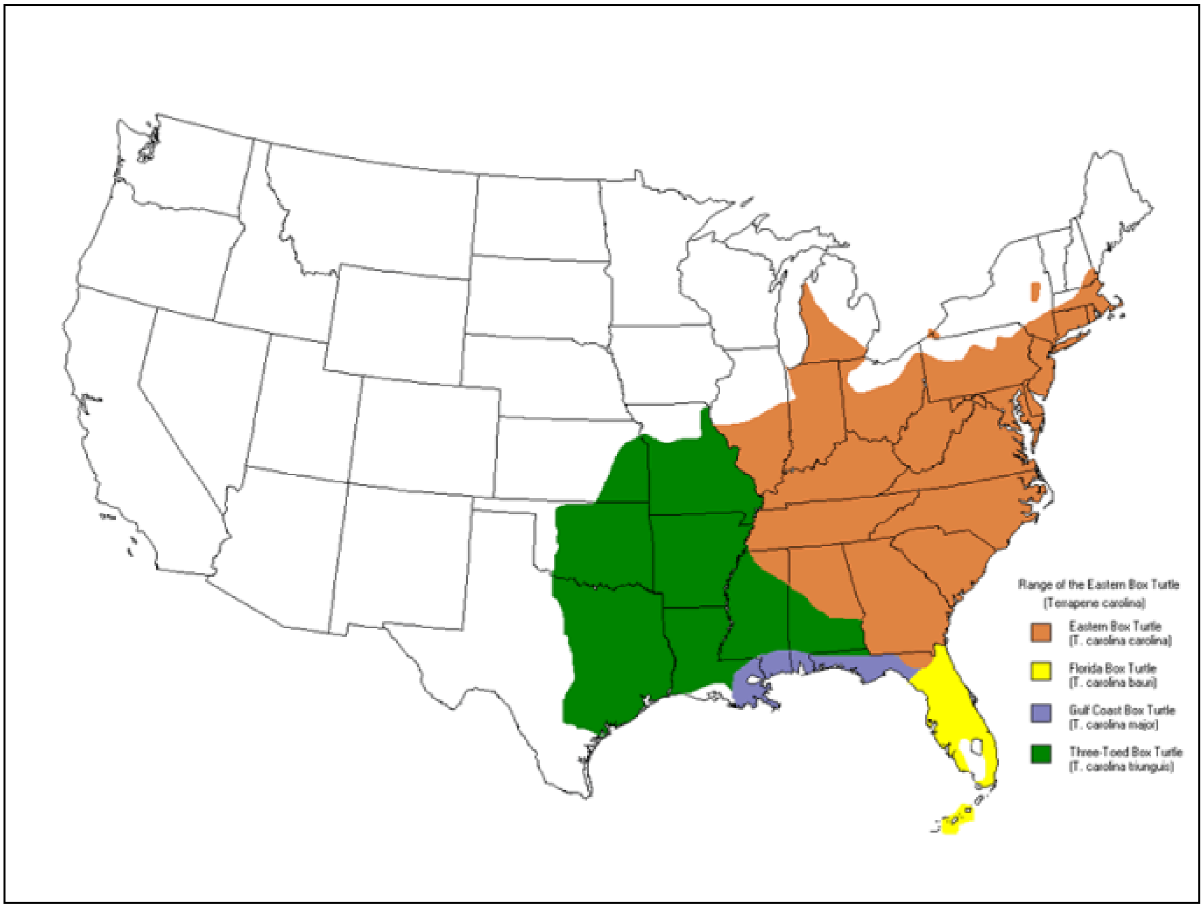

Figure 1: Range map of E. Box Turtle, as well as its various subspecies, in North America; based on the Davidson College Herpetology Lab Webpage (http://www.bio.davidson.edu/people/midorcas/dorcas_home.htm).

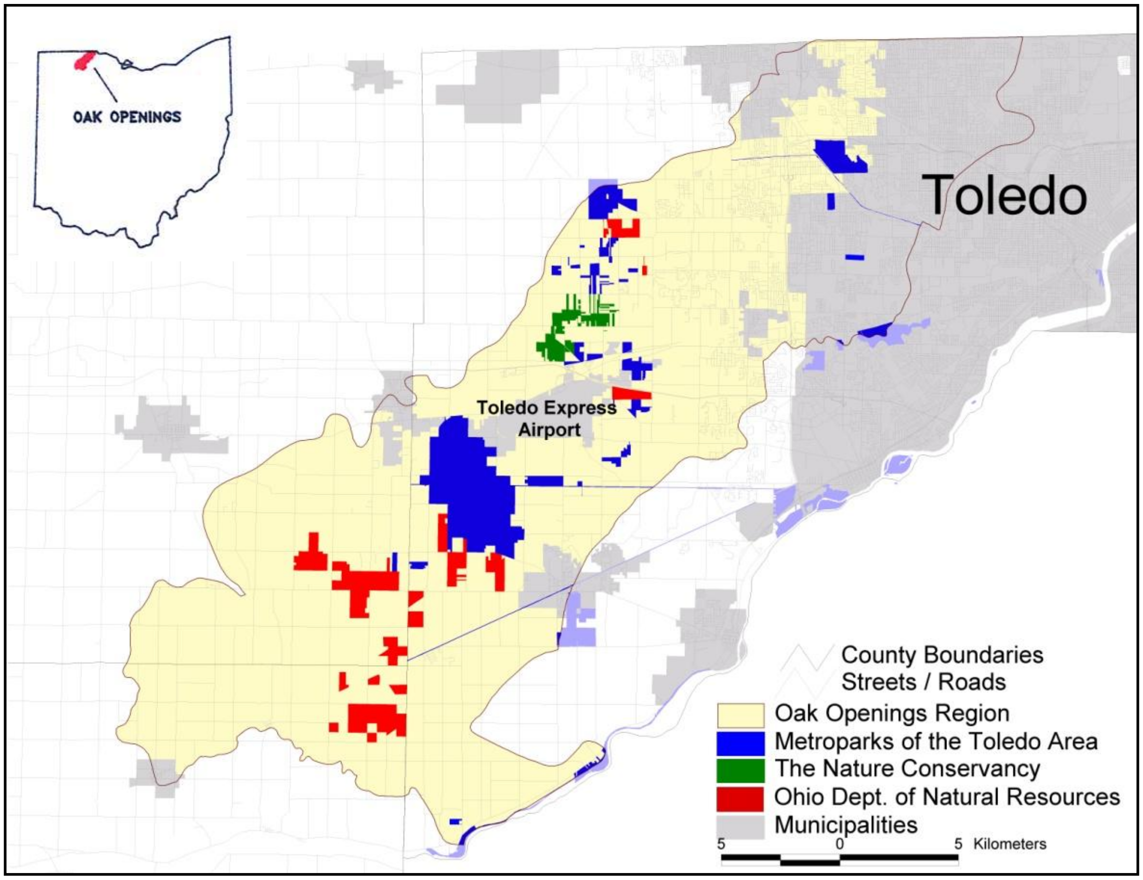

Figure 2: Map of the existing reserve system within the Oak Openings Region; image from Schetter and Root (2011).

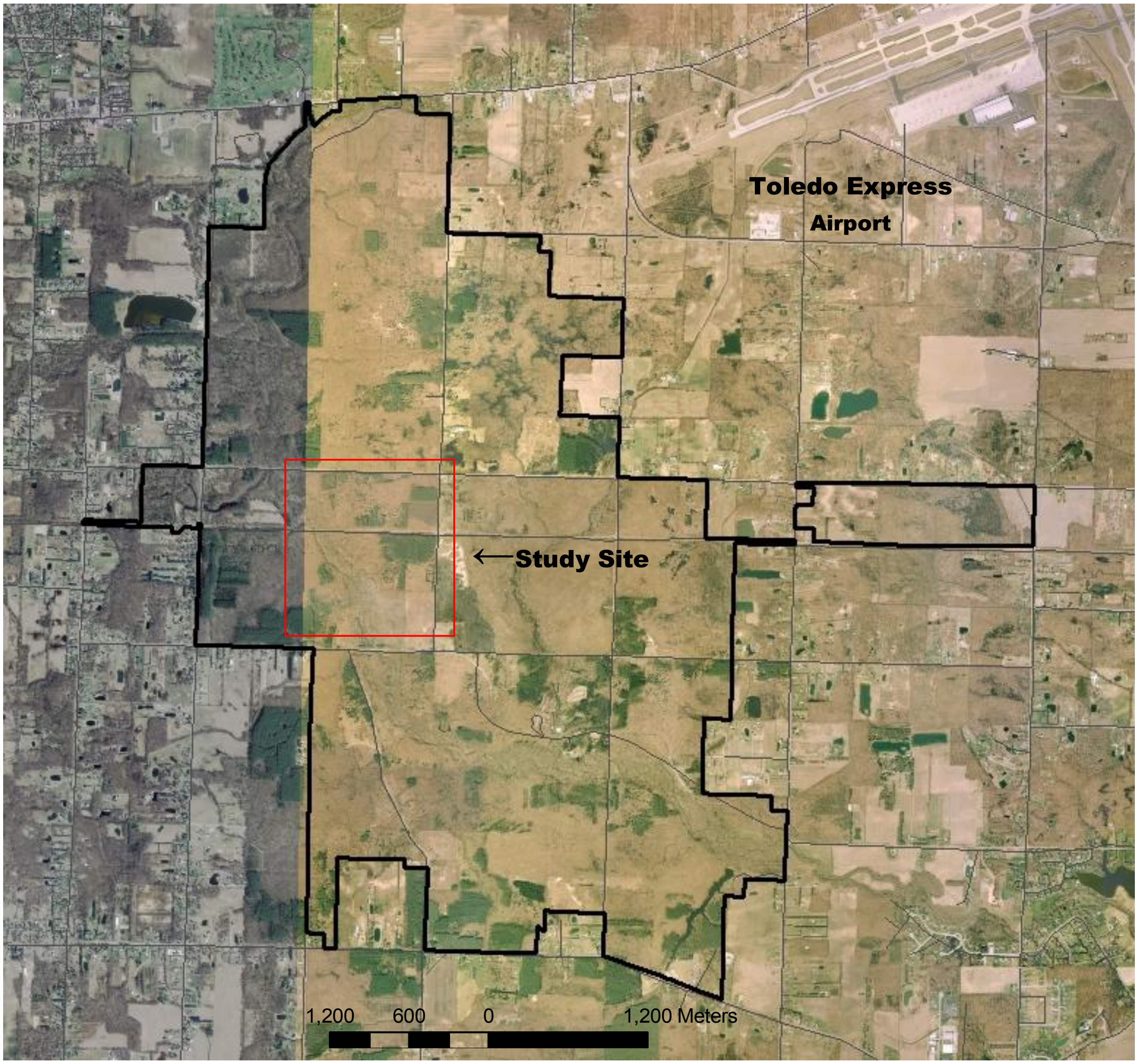

Figure 3: Landsat satellite image of Oak Openings Preserve Metropark including the location of the study site (2005).

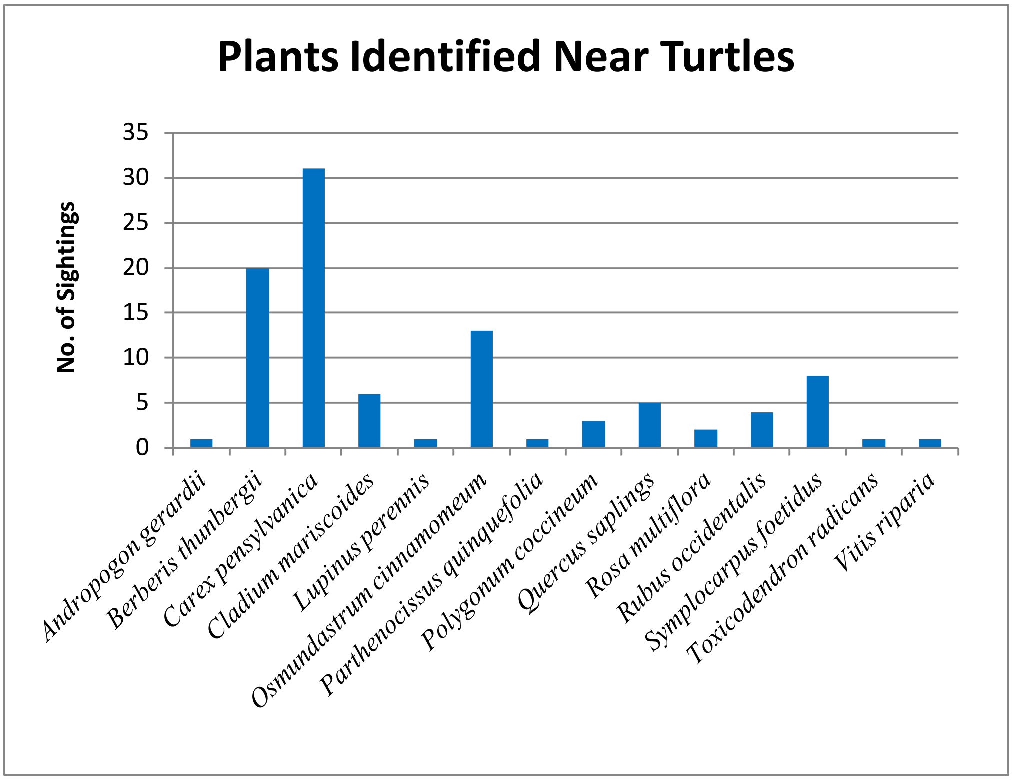

Figure 4: Frequency of sightings of all understory plant species identified within a 1 m radius of the study turtles during each capture/recapture event.

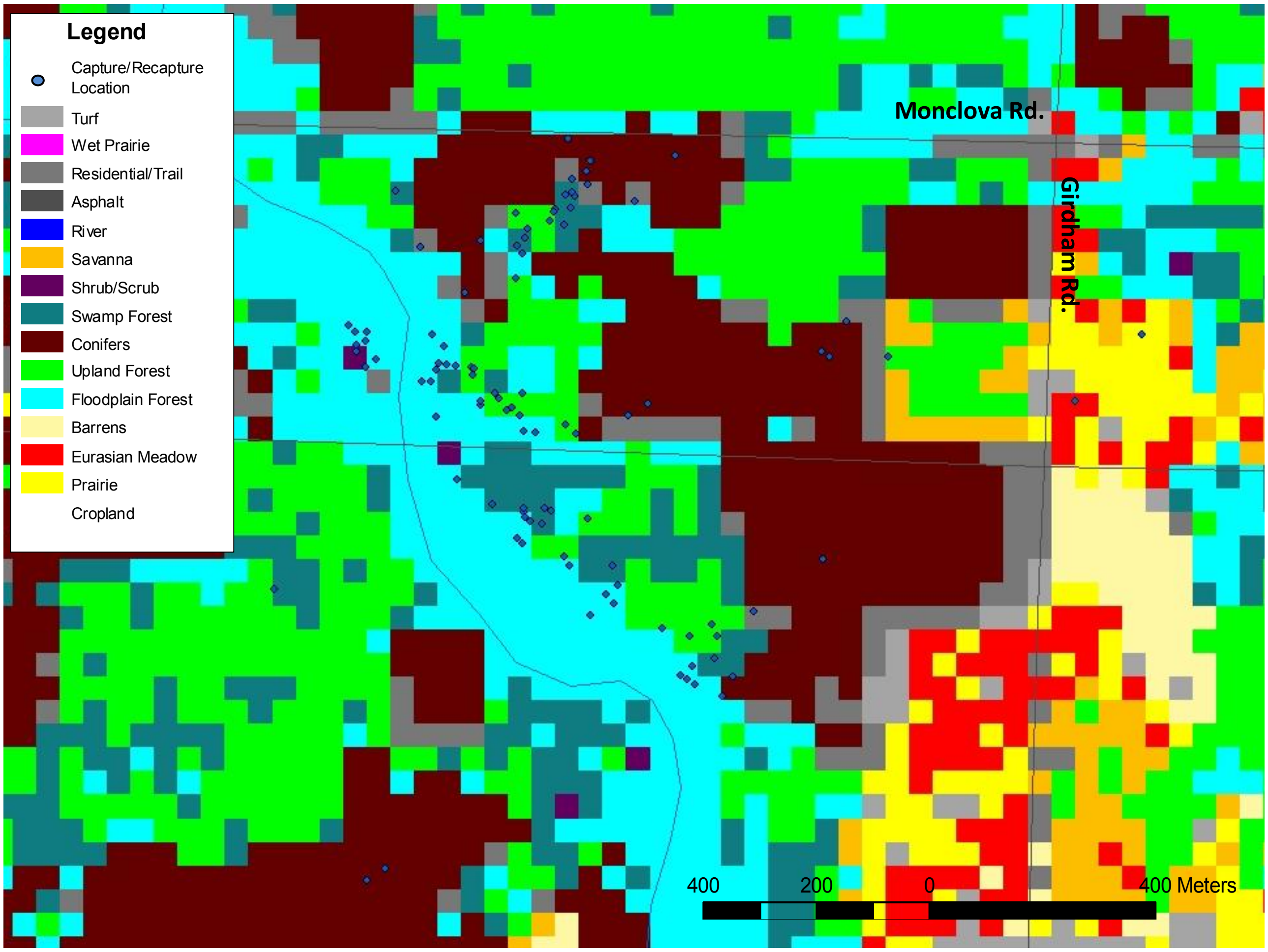

Figure 5: Image of the study site with each capture/recapture location using a land cover image layer as a background to highlight the composition of the habitat matrix of the study site.

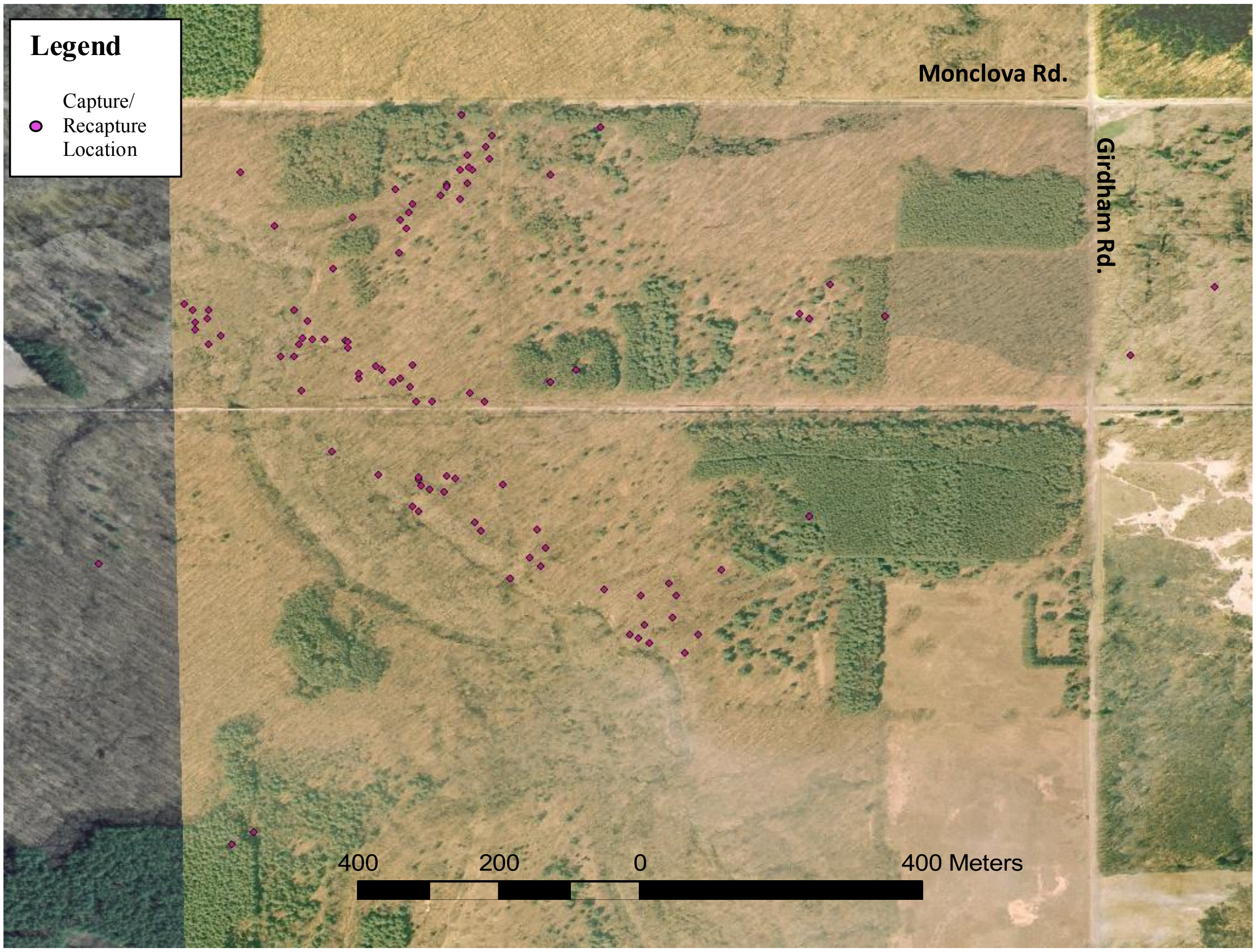

Figure 6: The locations of each EBT capture/recapture event which took place during the study.

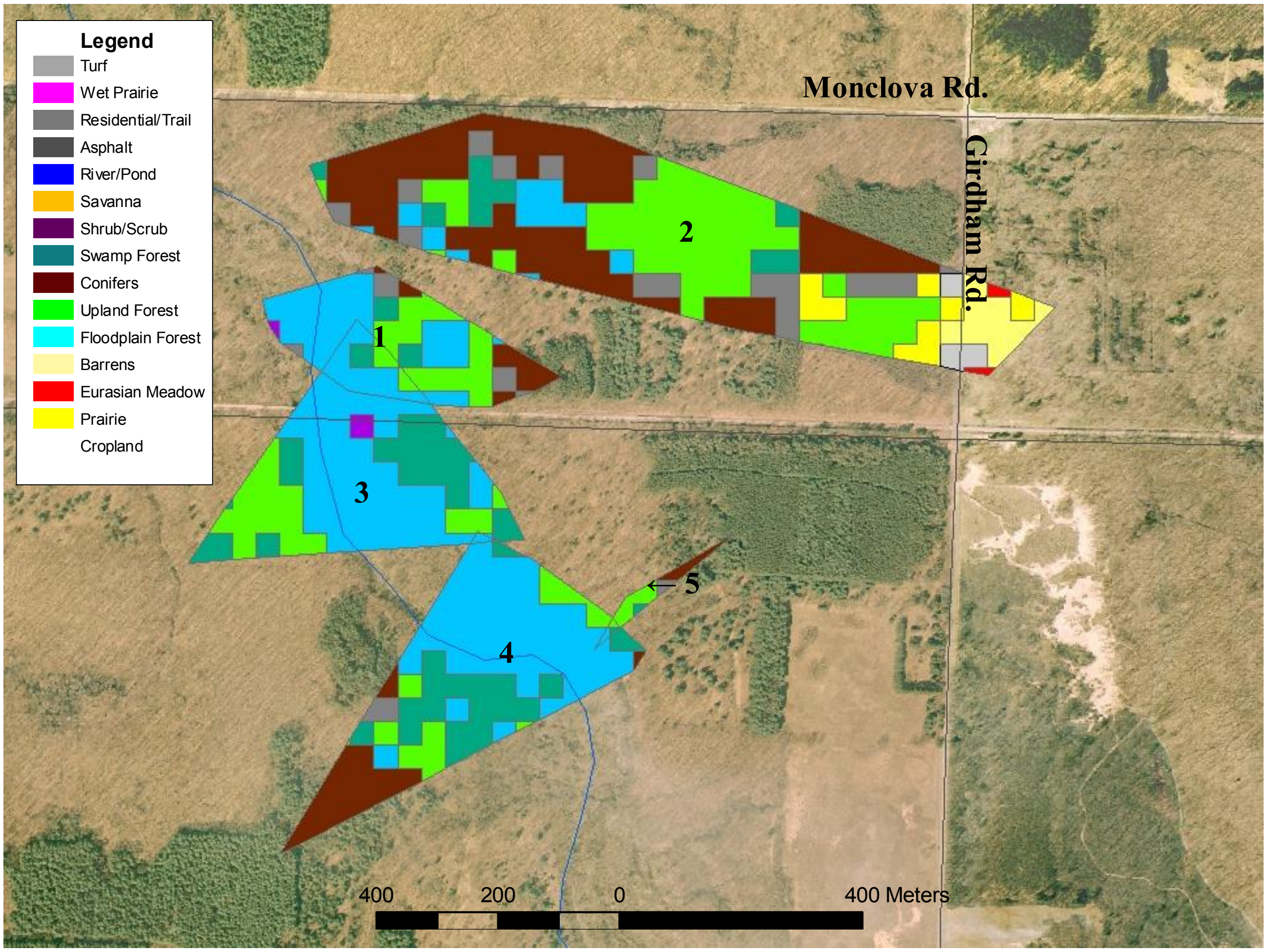

Figure 7: The minimum convex polygons of the five tracked turtles with the land cover (based on Schetter and Root, 2011), as a home range; the number that corresponds to each turtle's identification number is given within each polygon.

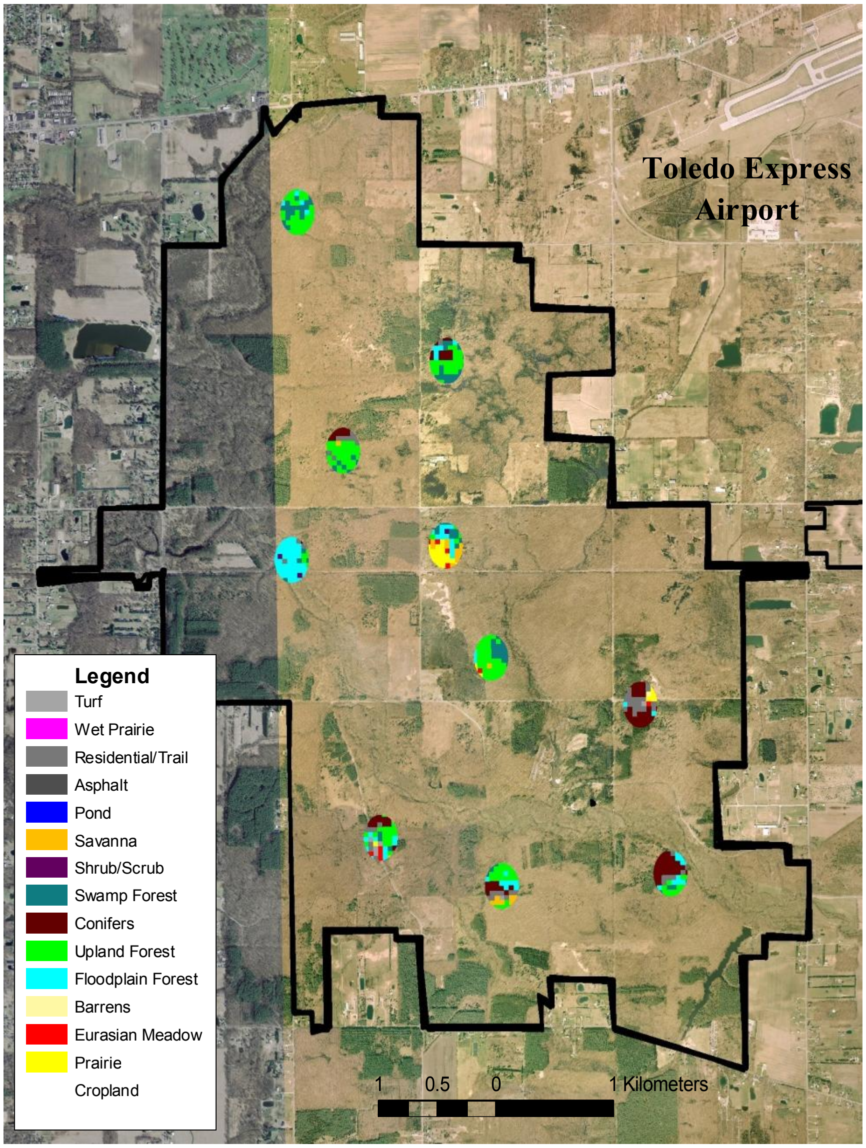

Figure 8: Map of the random buffered points, within the boundaries of Oak Openings Preserve Metropark, once they had been intersected with the land cover map.

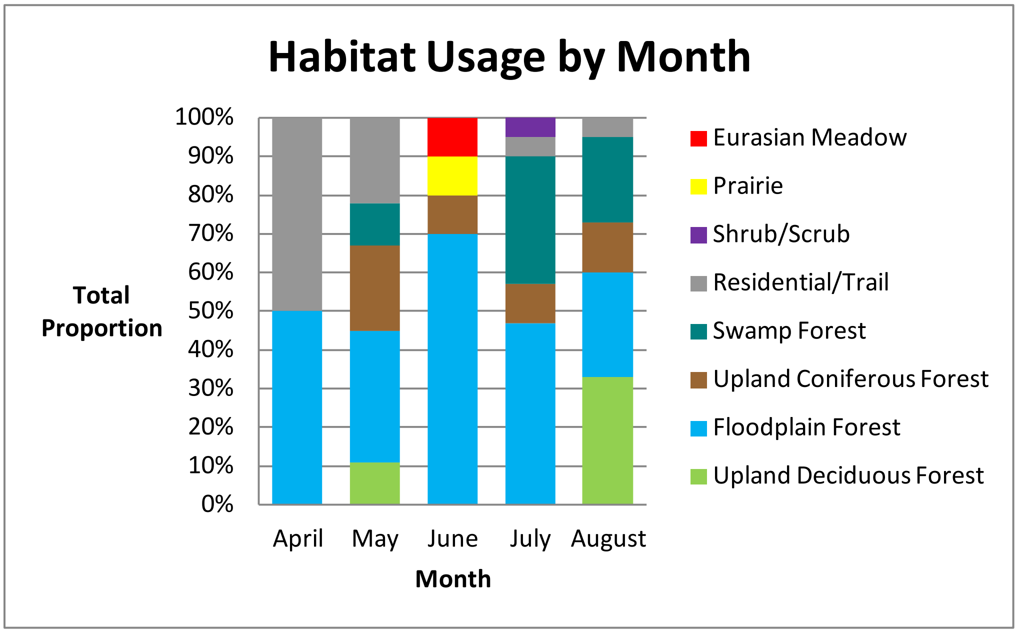

Figure 9: Habitat composition for the study turtles by month.

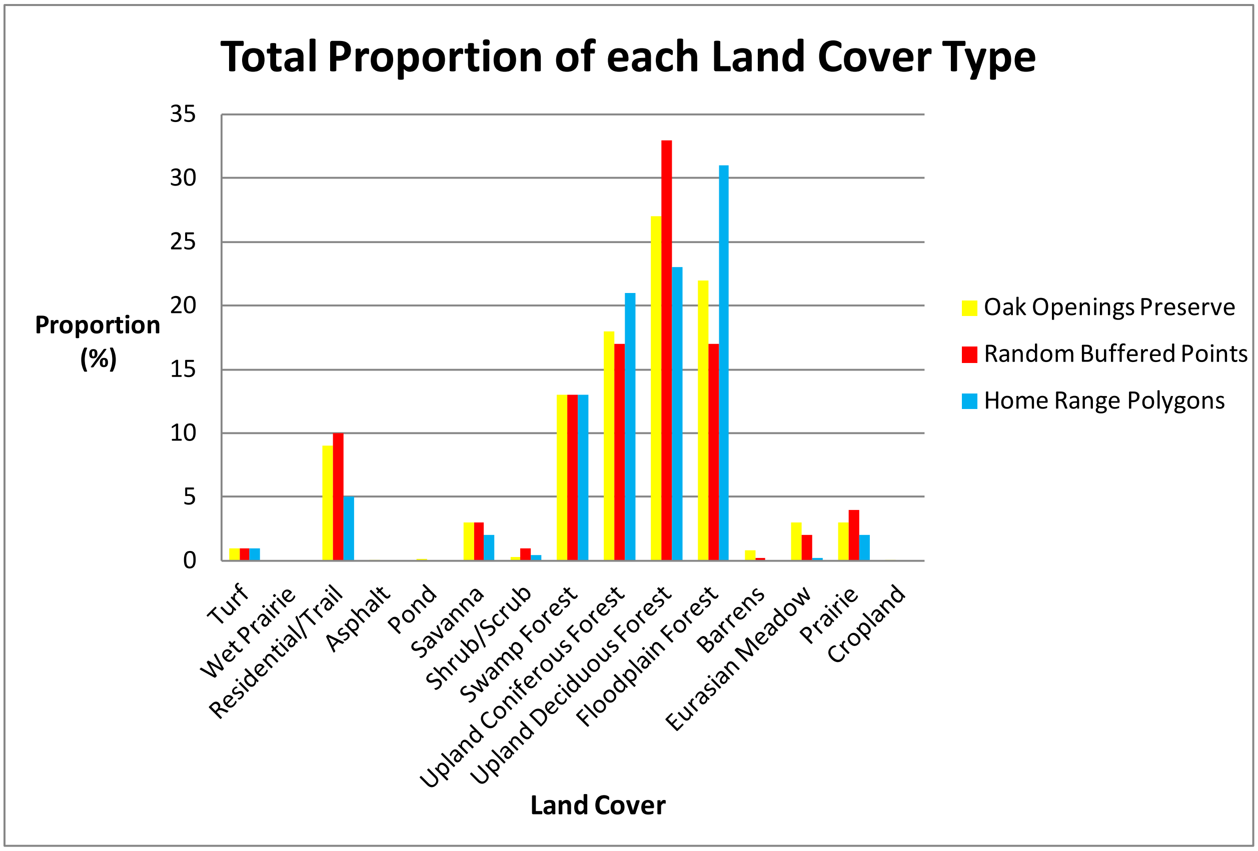

Figure 10: Land cover proportions for the total range area of the study turtles when compared with the total composition for both Oak Openings Preserve as well as the random, buffered points.

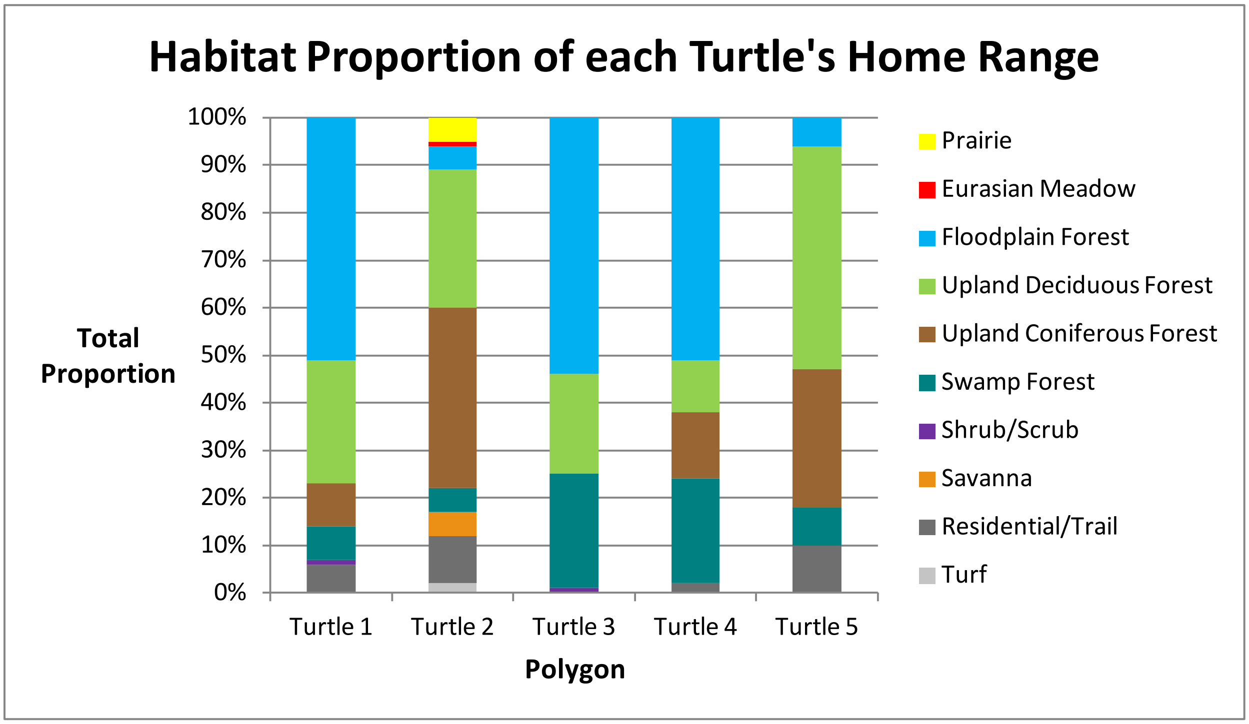

Figure 11: Habitat composition of each polygon that was used to depict the home range of each turtle.

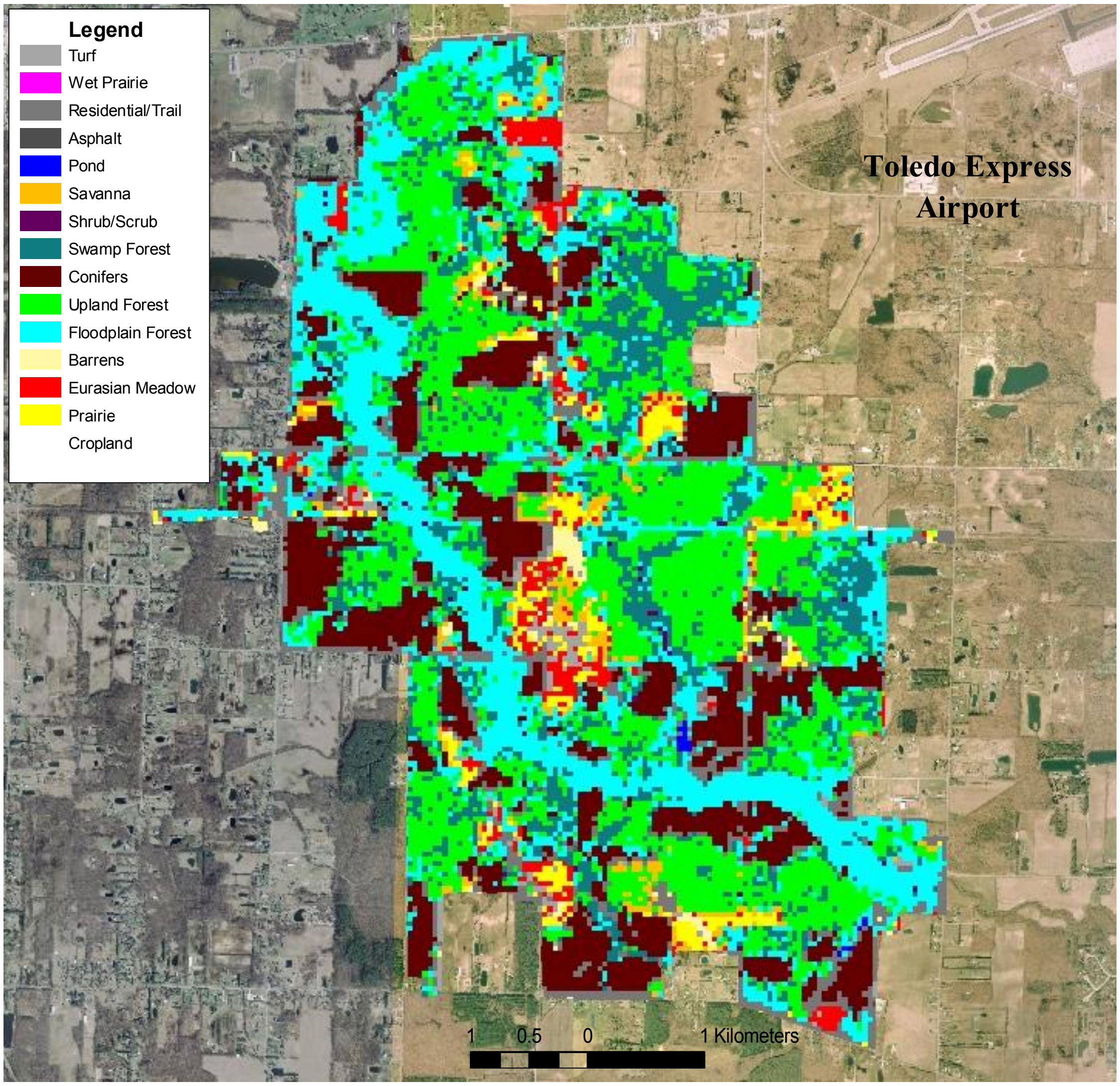

Figure 12: Map of the land cover layer (Schetter and Root, 2011) within the boundaries of Oak Openings Preserve Metropark.

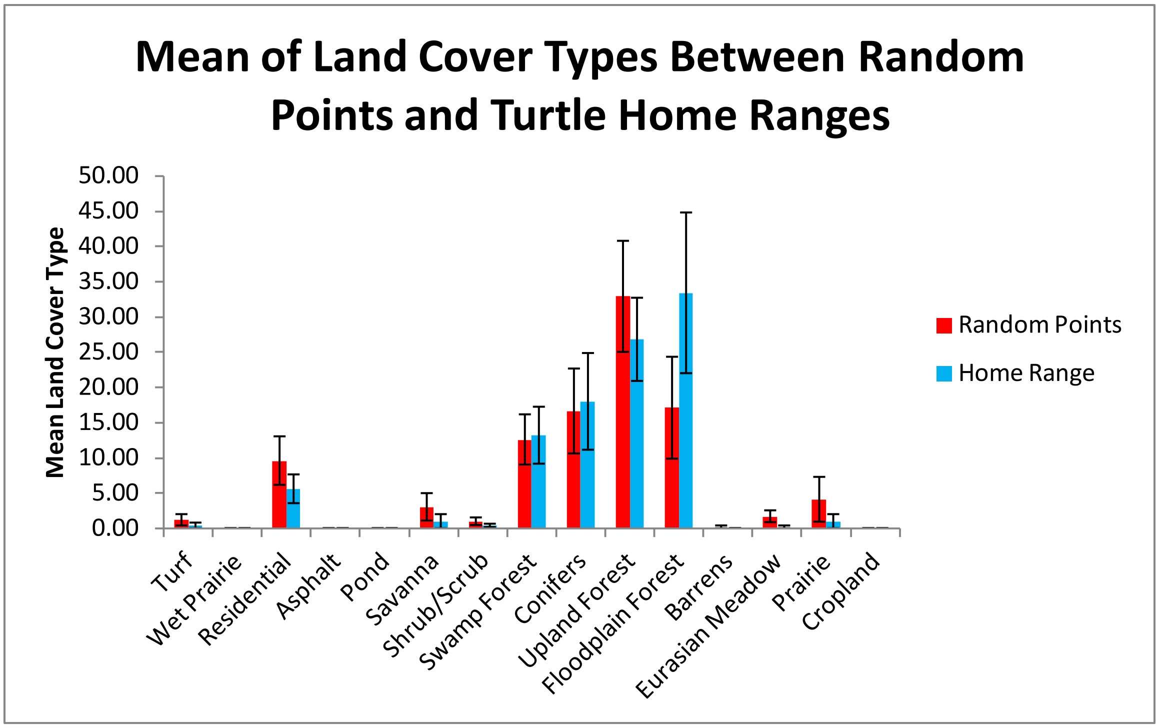

Figure 13: Mean proportion of each land cover type, within the given standard error margin, found in the random points versus the home ranges.

APPENDICES

Appendix A

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

FAXED 5/26/09

May 26, 2009

Dr. Karen Root
Biological Sciences
Bowling Green State University

Re: IACUC Protocol 09-002

Title:
The Effects of Varying Intensities of Land Management on Individual Eastern Box Turtles (*Terrapene carolina carolina*) within the Oak Opening's Region

Dear Dr. Root:

On **May 22, 2009** the above referenced protocol received **final approval** after review of the requested modifications by the IACUC. The modifications have been incorporated into the official copy of your protocol (see attached).

This approval expires on May 21, 2010, 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. Please also remember to keep a copy of the approved protocol in the animal facility room(s) in which your animals are housed and in any associated procedure rooms (contact the UAF staff for assistance in this regard).

Please consult with the staff of the Animal Facility about your requirements to get started on this project. Good luck with your project.

Sincerely,

Hillary Harms

Hillary Harms
IACUC Administrator

Comments:
1. In item 12, please provide the units when describing the transmitter weight (6 grams).
2. Don't handle animals until the proper permits have been obtained.
3. Please provide a copy of the permits to the Office of Research Compliance as soon as they are obtained.