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Demographics, Activity, and Habitat Selection of the Eastern Box Turtle (Terrapene c. carolina) in West Virginia

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By

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ABSTRACT

Demographics, Activity, and Habitat Selection of the Eastern Box Turtle (*Terrapene c. carolina*) in West Virginia

By Justin Adam Weiss

Little is known about the eastern box turtle, *Terrapene c. carolina,* in West Virginia. The purpose of this study was to compare demographic data between two populations of box turtles, to determine which environmental parameter(s) influence activity patterns, and to describe the optimal habitat of the box turtles at two study sites (Lake and State Park) at Beech Fork Wildlife Management Area. I observed male-skewed sex ratios and low numbers of juveniles in both populations. Male turtles were larger than females in carapace length, but females were larger in carapace height. Turtles at the Lake site exhibited greater body mass and carapace height due to more food and shelter availability. Turtles were most likely found active in the morning hours due to cooler air temperatures, but warmer substrate temperatures. Optimal box turtle habitat conditions at the study site were mixed hardwood forests with nearby fields and 1st order streams.

ACKNOWLEDGEMENTS

I thank Dr. Thomas K. Pauley for helping me develop a better understanding of the natural world. This thesis could not have been completed without his assistance, guidance, and support. I also thank Dr. Jayme Waldron for helping develop a better understanding of statistics and experimental analysis by serving on my committee. Thanks go to Dr. Adkins for helping me with statistical programming. This will undoubtly assist me in future endeavors. Committee members Drs. Evans and Gilliam deserve my thanks for helping develop an appreciation for the plant kingdom and expanding my knowledge of their works in the natural world. I thank the Army Corps of Engineers, Huntington District and the West Virginia Division of Natural Resources for the use of Beech Fork Wildlife Management area for field studies. Funding was provided by the Marshall University Graduate College Advisory Board, which was necessary in order to partake in this study. Thanks go to the members of the Marshall University Herpetology Lab for their suggestions and assistance in the field. My wife, Beth Weiss, and our families deserve thanks for their support and love while I took upon the challenge of graduate school. I do not know how life would be without them. Finally, I thank God for giving me the capacity to learn about the natural world and hopefully to teach the importance of conserving His creation to future generations to come.

I dedicate this thesis in loving memory of my grandmother,

Adell Elizabeth Woolwine

April 3rd 1931 – March 5th 2008

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CHAPTER ONE: INTRODUCTION TO THE EASTERN BOX TURTLE IN WEST VIRGINIA

Taxonomy

Terrapene c. carolina or the eastern box turtle is in the family Emydidae, the pond, basking, and box turtle family. The genus *Terrapene* consists of 4 species in North America: *Terrapene carolina, T. ornata, T. coahuila, and T. nelsoni*. The former two are native to the United States. *Terrapene ornata* is divided into two subspecies: *T. o. ornata* (ornate box turtle) and *T. o. luteola* (desert box turtle). *Terrapene carolina* is divided into four subspecies: *T. c. triunguis* (three-toed box turtle), *T. c. major* (Gulf Coast box turtle), *T. c. bauri* (Florida box turtle), and *T. c. carolina* (eastern box turtle) (Dodd, 2001). All members of *T. carolina* species intergrade where their ranges overlap (Minx, 1996), however, *Terrapene c. carolina* is the only subspecies found in West Virginia. *Terrapene* comes from the Algonquin Indian word for turtle and *carolina* is named from the Carolinas (Green and Pauley, 1987). The full nomenclature of the eastern box turtle is listed in Figure 1.1.

Taxon	Scientific Name
Kingdom	Animalia
Phylum	Chordata
Subphylum	Vertebrata
Superclass	Tetrapoda
Class	Reptilia
Subclass	Anapsida
Order	Testudines
Suborder	Cryptodira
Family	Emydidae
Genus	*Terrapene*
Species	*T. carolina*
Subspecies	*T. c. carolina*

Figure 1.1 Full nomenclature of the eastern box turtle.

Identification

Terrapene c. carolina is the only fully terrestrial turtle in West Virginia. Box turtles possess a high dome shell with keels running down the vertebral scutes and a hinge on the plastron situated between the pectoral and abdominal scutes. Colors vary from yellow, orange, brown, and olive (Conant and Collins, 1998). Males typically have red eyes (Figure 1.2) and a concavity in the plastron, whereas females have brown eyes and a flattened plastron (Figure 1.3) (Ernst *et al*., 1994). Concavity of the shell in males helps them to mount females during mating (Evans, 1951). Hindclaw curvature in turtles is another method of determining sex externally, where females have slight curvature and males have distinct curvature (Figure 1.4). This feature assists males to clamp onto the female's plastron during mating (Cahn and Conder, 1932; Evans, 1951).

Study Area

I selected two study sites at the Beech Fork Lake Project near Lavalette, WV in Wayne County (38^{o}16-18'N, 82^{o}24-25W) and Beech Fork State Park near Huntington, WV shared by Wayne and Cabell Counties (38^{o}18-19"N, 82^{o}20-21W) (Figure 1.5). Elevations range between 166-303m and both sites were located in the Allegheny Plateau Physiographic province of West Virginia.

Beech Fork Lake Project is operated by the United States Army Corps of Engineers, Huntington District and encompasses the western end of the lake. Habitat is characterized by open fields, recreational areas, and forests with oaks (*Quercus* spp.), maples (*Acer* spp.), hickories (*Carya* spp.), American beech (*Fagus grandifolia*), and tulip poplar (*Liriodendron tulipifera*).

Beech Fork State Park is operated by the West Virginia Division of Natural Resources on lease from the United States Army Corps of Engineers and is situated on the eastern end of the lake. Area consists of open fields, a cemetery, campgrounds, other recreational areas and forests characterized by oaks, maples, hickories, Virginia pine (*Pinus virginiana*), and tulip poplar.

I selected these sites at opposite ends of the management area to ensure two separate populations and to compare demographic, habitat, and environmental data between the two populations. Beech Fork State Park will be referred to as State Park and Beech Fork Lake will be referred to as Lake throughout the remainder of the thesis. When referring to both sites, Beech Fork Wildlife Management Area will be used.

Turtle Collection

I surveyed turtles between 20 March and 15 November 2008 by searching both sites. Turtle were collected systematically by investigating specific locations at both sites (woodlands, fields, or along hiking trails). I located turtles by scanning the forest floor, searching brushy areas, or under large logs. Few specimens were located accidentally by stepping on the carapace in deep leaf litter.

Figure 1.2 Eye color of box turtles as a method for determining sex externally. Males (above) typically have red eyes and females (below) typically have brown eyes.

Figure 1.3 Plastron concavity as a method for determining sex in box turtles. Males (above) typically have obvious plastron concavity, whereas females (below) have flattened to slightly convex shell concavity.

Figure 1.4 Hindclaw curvature as a method for determining sex in box turtles. Females (above) have straighter hindclaws, whereas males (below) have more curved hindclaws. Curved hindclaws on males help to attach themselves to females during mating.

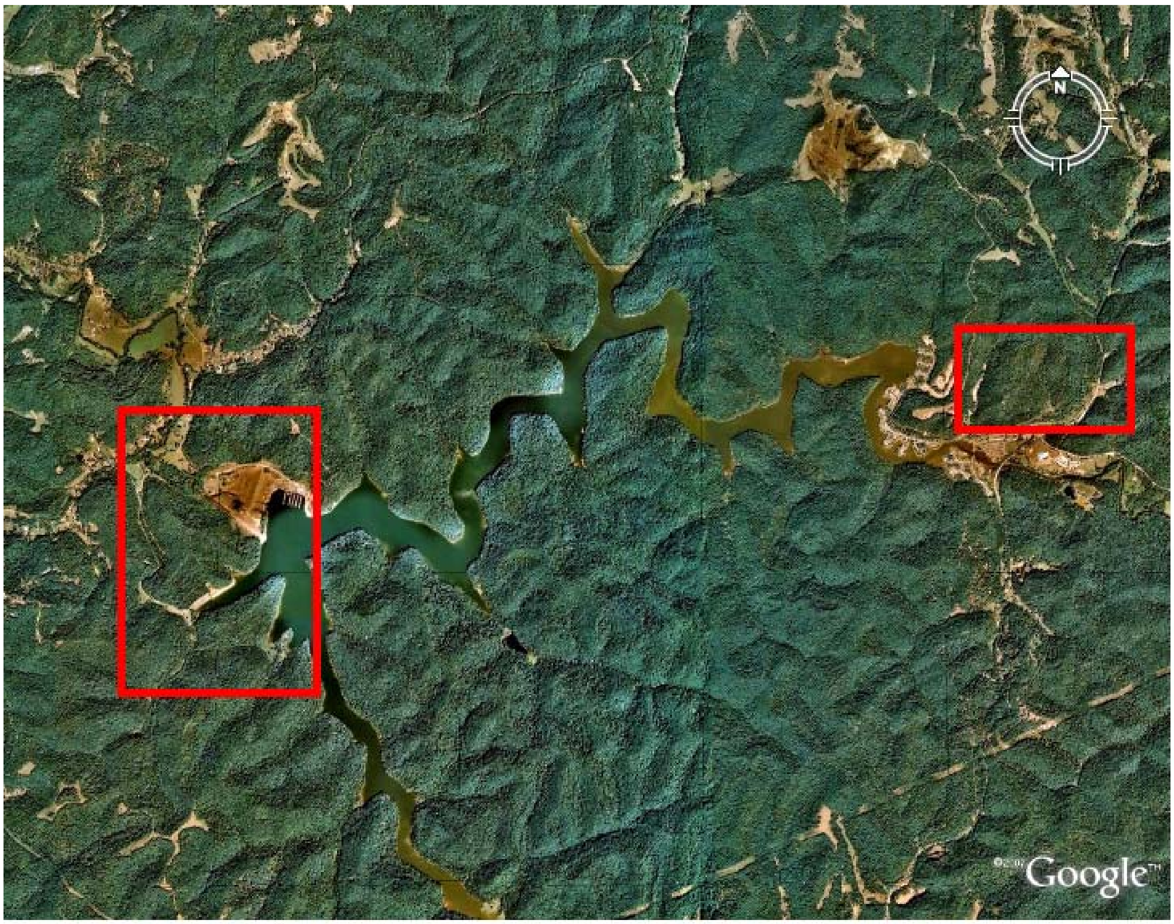


Figure 1.5 Beech Fork Wildlife Management Area in Cabell and Wayne Counties, West Virginia (Latitude 38°16-19'N, Longitude 82°20-25'W). Two sites were used within the management area Beech Fork Lake (Left) and Beech Fork State Park (Right) to ensure two separate populations. Scale 1km = 2.1 cm approximately, Eye Altitude = 8.23 km. Image by Google Earth™.

CHAPTER TWO: STATEWIDE DISTRIBUTION AND DEMOGRAPHICS OF TWO EASTERN BOX TURTLE POPULATIONS IN WEST VIRGINIA

Abstract

Demographic data can assess the status of turtle populations and provide additional morphology information to a species across its geographic range. Previous literature suggests that males have a larger and wider carapace, but females show greater carapace heights. I measured 126 turtles (57 females and 68 males) for morphometrics at two study sites named Lake and State Park. I collected data on carapace length, carapace width, carapace height, plastron length, and hinge length and used ANOVA to test for differences in sizes between sex, study site, and interaction between site and sex. Males were significantly longer than females in carapace length while females were significantly taller than males in carapace height. Carapace height and body mass differed between study sites. There was no statistically significant interaction between site and sex on the given measurements occurred. Vegetation structure might have accounted for weight and morphometric differences between sites. The lack of plant diversity at the state park site may cause turtles to expend more energy searching for sources of food instead of using that energy for growth.

Introduction

Measuring demographic data on populations of box turtles is important to assess the status of populations and to provide additional morphology information in a species over its geographic range. Natural selection may favor certain body sizes and masses in populations of box turtles to assist in male-to-male combat or storage of more eggs within female turtles (St. Clair, 1998). Morphometric data of box turtle populations in West Virginia are lacking thus baseline data are needed to make comparisons with turtles in other parts of the state and across the box turtle's range in North America. Lack of accurate baseline range and distribution data of box turtles within the state of West Virginia poses a problem. Wildlife management techniques and preservation cannot be possible without such necessary data. Many studies report differences in straight line carapace length and carapace height between sexes. Males have greater straight line carapace lengths, but females have greater carapace height (Stickel and Bunck, 1989; Dodd, 1997; Pilgrim *et al*., 1997; Ernst *et al*., 1998). Weight differences in a *Terrapene c. bauri* population in Florida were not significant between sexes (Dodd, 1997). Typically sex ratios have been male-biased in numerous populations (Stickel and Bunck, 1989; Dodd, 1997; Hall *et al*., 1999). However, with the exception of two years in Williams and Parker's (1987) long term study of turtle populations in Indiana, a close 1:1 male to female ratio was common.

Many authors reported few juveniles in population and demographic studies (>25%) (Stickel, 1950; Williams and Parker, 1987; Langtimm *et al.*, 1996). This trend could be attributed to low detection probabilities (Ernst *et al.*, 1994) and variation in researchers' definition of juveniles (Budischak *et al.*, 2006).

In the United States, the eastern box turtle ranges from northeastern Massachusetts south to Georgia, west to Michigan, Illinois, and Mississippi (Conant and Collins, 1998). Records of *Terrapene c. carolina* in West Virginia were mapped in Greene and Pauley (1987). While *Terrapene c. carolina* can be found in every county in West Virginia, they are devoid at higher elevations (Pauley and Seidel, 2002).

In this study, I collected data on morphometrics, weight, age, and sex in two populations of box turtles found at Beech Fork Wildlife Management Area. Comparisons of morphometrics and weight were compared among sex, study site, and we tested for a sex and site interaction. I compared age class structure and sex ratios between both study sites. I also developed eastern box turtle range and distribution maps from the West Virginia Herpetological Atlas to provide baseline data for future study.

Methods

Demographics

I collected data on age and sex on all box turtles at both sites. I recorded age by counting and averaging annuli on the costal scutes of turtles (Ewing, 1939). Scute annuli tend to wear with age making counts of scutes difficult to interpret, especially when turtles reach 15-20+ years (Stickel, 1978). For this reason, I placed turtles in age classes similar to Budischak *et al*. (2006) to place turtles in. Class one contained turtles with 0-4 annuli, class two with 5-9, class three with 10-14, class four with 15-19, and class five with 20 or more annuli. In this study, number of annuli was assumed to be relative to turtle age in years.

I recorded turtle sex as male, female, or juvenile. Juveniles usually lack sexually dimorphic characters and well-developed hinges (Ernst *et al*., 1994). I assumed turtles with straight-line carapace length <110mm to be juvenile. I then calculated male-to- female sex ratios for both sites.

Data on straight line carapace length (SLCL), carapace width (CW), carapace height (CH), plastron length (PL), hinge length (HL), and body mass (BM) were taken. Morphometric variables were measured using a 150.0 mm analog caliper and body mass was recorded using a 600 g scale and plastic bag which was calibrated before each measurement.

For statistical analysis, I used Analysis of Variance (ANOVA) (PROC: GLM, SAS Institute, 2003) to test for differences in weight and morphometrics between sexes, study sites, and we tested for a sex and site interaction. Then, I arranged turtles into four classifications: males of Lake (M/L), females of Lake (F/L), males of State Park (M/S), or females of State Park (F/S). Juveniles were not included in the analysis. See Table 2.1 for descriptive and inferential statistics of males/females and both sites.

Distribution

An analysis of historical distribution of box turtles using the West Virginia Biological Survey Herpetology Atlas was prepared using 63 entries for *Terrapene c. carolina* from 1935-1997. I developed two West Virginia county maps: one for statewide range and one for statewide distribution. Range is the geographical area where turtles can be located and distribution is the specific location where a turtle was found. If a turtle was recorded for a specific county, the county became shaded on the range map (Figure 2.6). If the record had a specific location, then location was marked on the distribution map (Figure 2.7). I used red dots to represent areas where one turtle record exists and blue dots for areas where two or more turtle records exist. Green dots represent records with county information only, but no specific location within the county. Finally, the black dot represents Beech Fork Wildlife Management Area on the border of Cabell and Wayne counties, the location of our study sites. The red dot serves the same purpose for the range map.

Results

Distribution

Forty-one out of 55 counties in West Virginia have records of box turtles. They are more concentrated in the central part of the Allegheny Plateau physiographic province of West Virginia, less common in the Ridge and Valley Province, and absent along the Allegheny Mountain Province.

Demographics

There was a 1.20:1 male to female sex ratio at Lake and a 1.19:1 ratio at State Park. Ratio for finding turtles on either site was 2.468:1 Lake to State Park. The 20+ age class contained the highest proportion of turtles at both sites (L=68.3% and S=56.7%). The 5-9 age class had the lowest proportion of turtles at Lake (1.0%) and 0-4 had the lowest proportion at State Park (2.7%) (Figure 2.1).

There was a significant difference between the straight line carapace lengths ($P < 0.001$; $F = 19.65$) and carapace heights ($P = 0.0063$; $F = 7.74$) between sexes with males having longer carapace lengths than females and females having greater carapace height than males (Figures 2.2 and 2.3). A significant difference was also found in the carapace heights ($P = 0.0084$; $F = 7.14$) and body masses ($P = 0.0091$; $F = 6.99$) of turtles between the two study sites with Lake turtles having both greater carapace height and body mass (Figures 2.4 and 2.5). We failed to detect an interaction between site and sex occurred ($P > 0.05$).

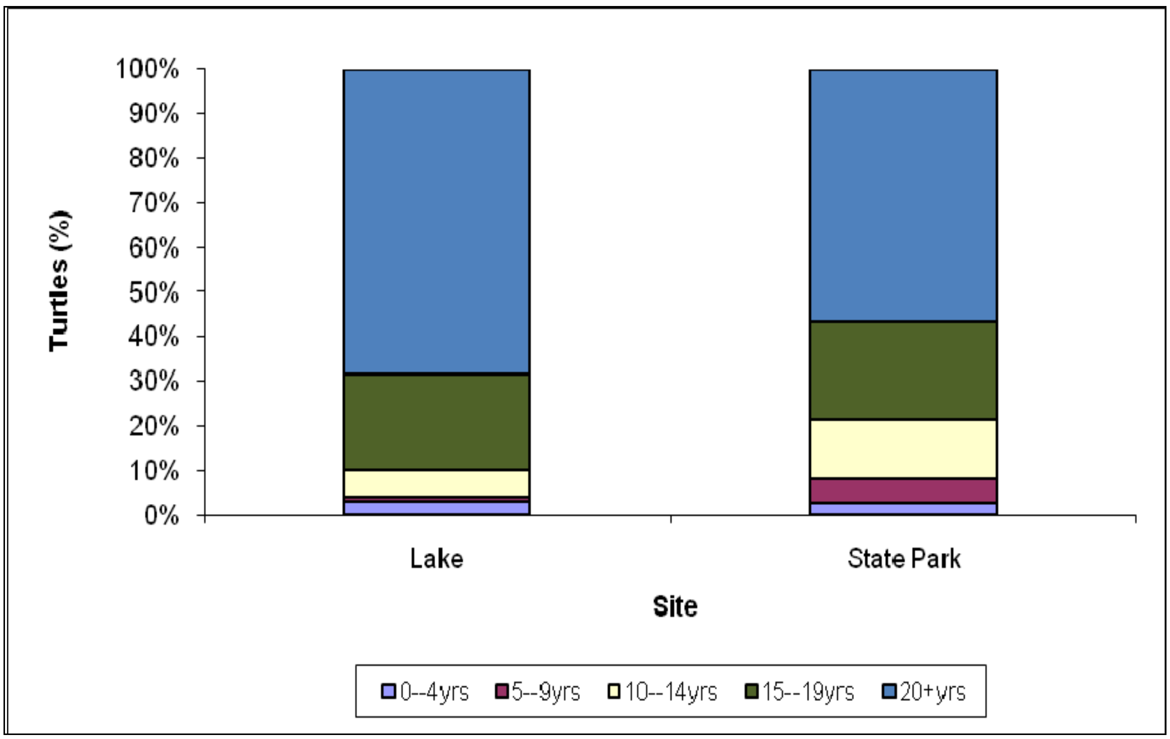


Figure 2.1 Percentage of individuals found in each age class (years) at both sites of Beech Fork Wildlife Management Area.

Table 2.1 Comparison of means, standard deviations, sample size, and ANOVA results of *Terrapene c. carolina* analysis of sexes and turtles of both sites. SLCL (straight line carapace length), CW (carapace width), CH (carapace height), PL (plastron length), HL (hinge length), and BM (body mass). All measurements were in millimeters with the exception of BM which is in grams.

Sex		**SLCL**	**CW**	**CH**	**PL**	**HL**	**BM**
	Mean	128.1	97.4	57.6	122.2	71.5	383.9
	SD	6.7	5.0	3.0	5.6	3.7	50.9
M	**N**	68	68	68	68	68	68
	Mean	122.5	96.5	59.3	121.2	70.7	388.5
	SD	6.5	5.4	3.8	6.5	4.6	62.3
F	**N**	57	57	57	57	57	56
	P	<0.0001	0.1867	0.0063	0.4408	0.6081	0.498
	F	19.65	1.76	7.74	0.60	0.26	0.46

Site		**SLCL**	**CW**	**CH**	**PL**	**HL**	**BM**
	Mean	124.6	95.2	57.0	121.0	70.6	369.7
	SD	7.4	4.1	3.9	5.6	3.3	62.4
S	**N**	35	35	35	35	35	35
	Mean	125.9	97.0	59.0	122.0	71.3	392.3
	SD	7.2	5.7	3.2	6.3	4.5	54.0
L	**N**	90	90	90	90	90	89
	P	0.3673	0.1954	0.0084	0.5479	0.5230	0.0091
	F	0.82	1.70	7.18	0.36	0.41	6.99

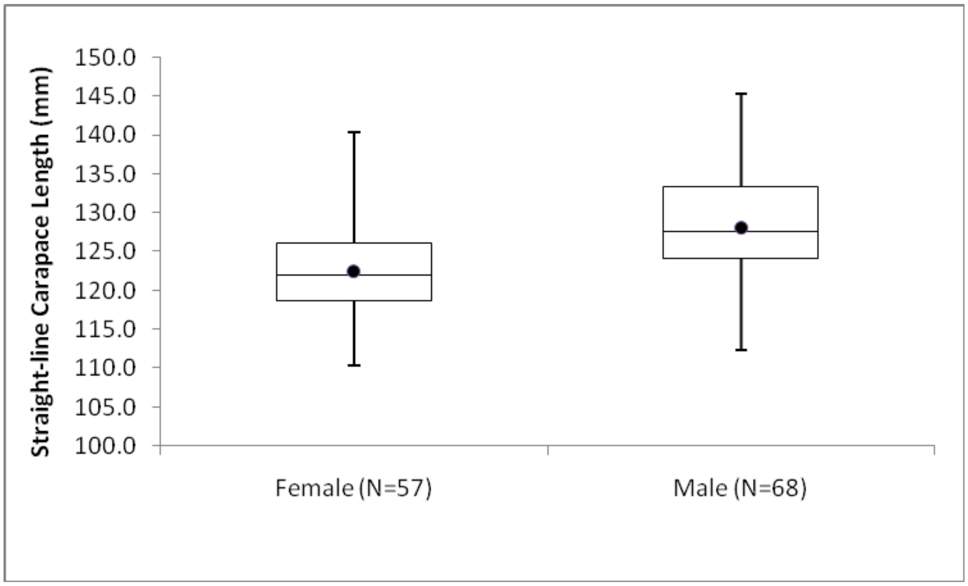


Figure 2.2 Box and whisker plot of straight line carapace lengths (in mm) between female and male *Terrapene c. carolina* at Beech Fork Wildlife Management Area. Black dots represent means.

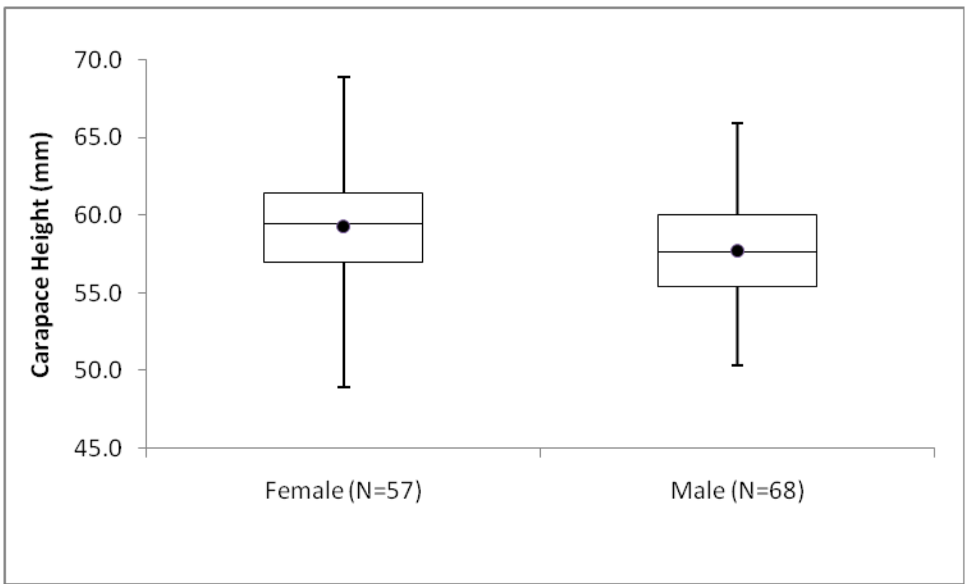


Figure 2.3 Box and whisker plot of carapace heights (in mm) between female and male *Terrapene c. carolina* at Beech Fork Wildlife Management Area.

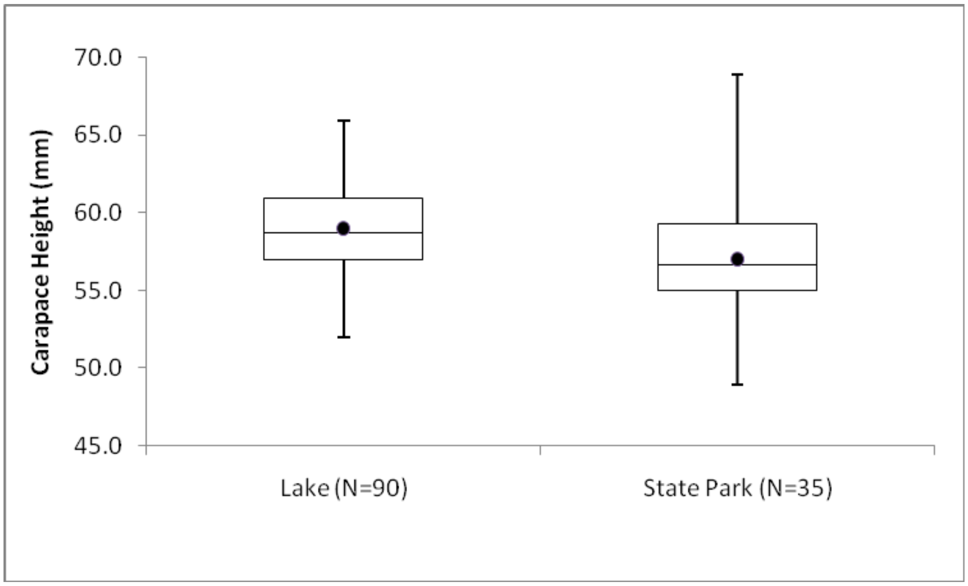


Figure 2.4 Box and whisker plot of carapace heights (in mm) between lake and state park site in *Terrapene c. carolina* at Beech Fork Wildlife Management Area.

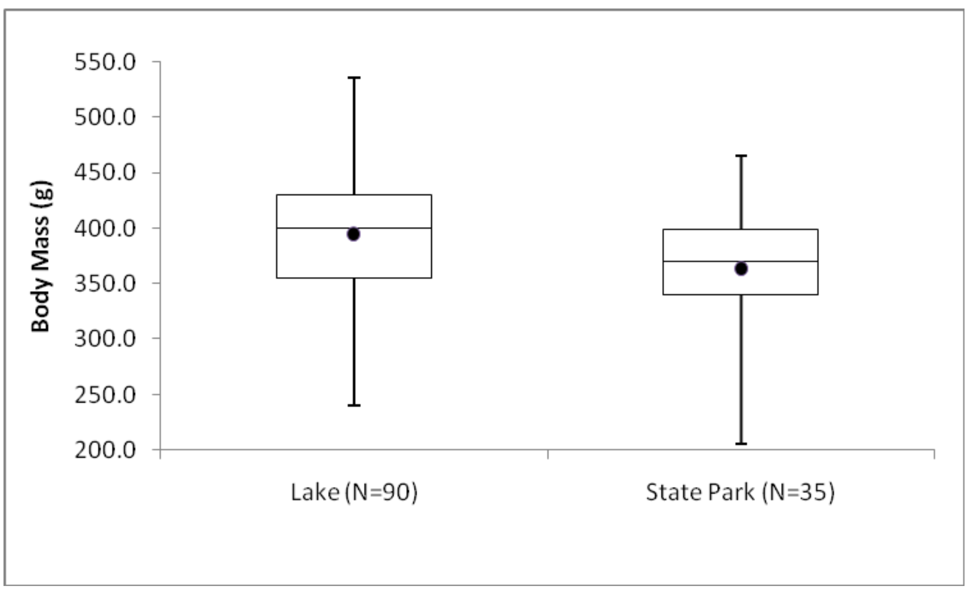


Figure 2.5 Box and whisker plot of body mass (g) between lake and state park *Terrapene c. carolina* at Beech Fork Wildlife Management Area.

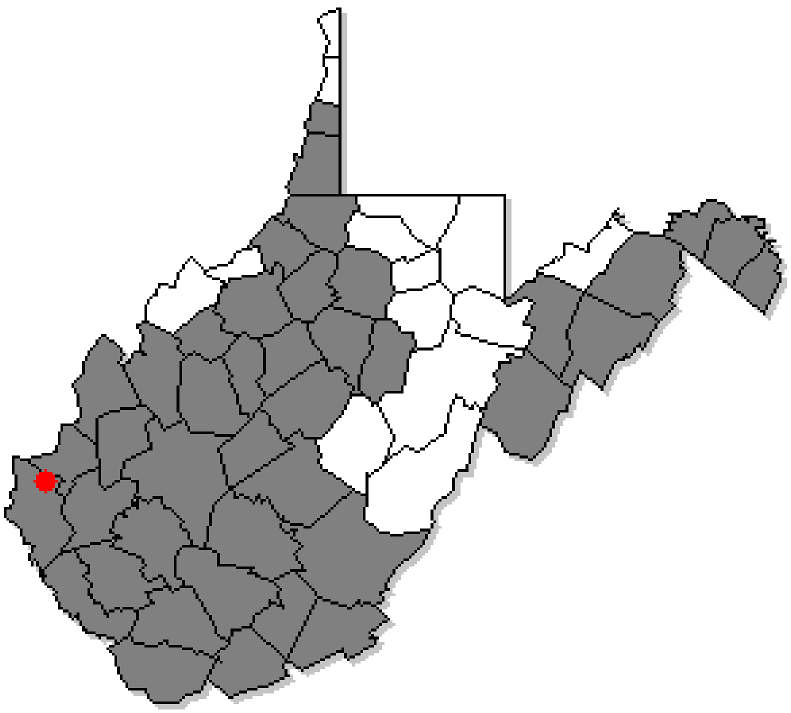


Figure 2.6 Range of *Terrapene c. carolina* in West Virginia by county. Shaded areas are records of turtles found in each county. The red dot represents Beech Fork Wildlife Management Area where live specimens were measured in the morphometric analysis.

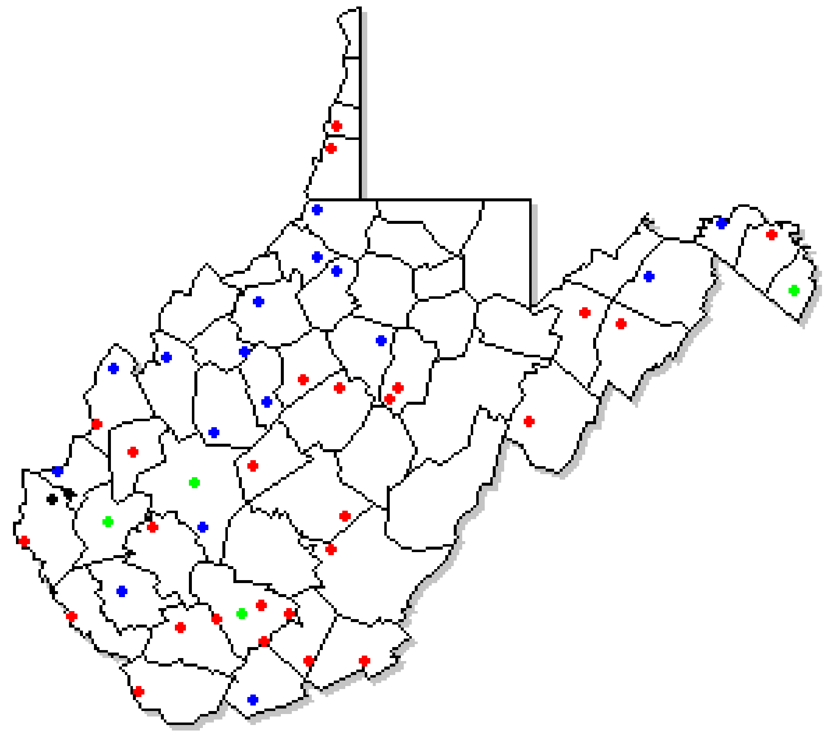


Figure 2.7 Distribution of *Terrapene c. carolina* in West Virginia. 63 records were located in the West Virginia Biological Survey Herpetology Atlas. Red dots represent one turtle sighting, blue dots represent two or more turtle sightings, green dots represent turtle sighting in the county but no specific location, and the black dots represent both sites at Beech Fork Wildlife Management Area.

Discussion

Distribution

Forty-one out of 55 counties in West Virginia have historic records of box turtles. The majority of turtle records were located in the Allegheny Plateau physiographic province, the largest province in the state, with fewer records found in the Ridge and Valley Province No records were located in the Allegheny Mountain Province probably due to high montane elevations (>600 m) (Greene and Pauley, 1987). However, Martof *et al*. (1980) reported box turtles at elevations as high as 1,220 m in North Carolina and Virginia means turtles could be found in every county in the state. However, montane regions are typically cold for box turtles, which prefer moderate temperatures (13-25°C) (Reagan, 1974; Stuart and Miller, 1987). Hancock and Brooke counties located at the top of the northern panhandle were devoid of turtle records, as were Wood and Pleasants counties along the Ohio River. Anecdotal evidence suggests that box turtles are located in every county of the state (Thomas Pauley, *pers. comm.* and Jayme Waldron, *pers. comm.*); however, entries in the West Virginia Herpetological Atlas do not exist

Demographics

The majority of all turtles were found in the 20+ year age category, which results in an unbalanced age class distribution of older turtles. While turtles are amongst the longest lived animals (Gibbons, 1987), Stickel (1978) reported that the older turtles make a small proportion of the population at Patuxent Wildlife Management Area in Maryland with 15% of males and 11% of females aged 20+ years. This unbalanced trend appears in many box turtle demographic studies (Stickel, 1950; Legler, 1960; Pilgrim *et al*., 1997). The shortage of juveniles in my two populations probably might be attributed to low recruitment (Pilgrim *et al*., 1997) and issues with the annuli-count method of aging. Juveniles are prone to predation due to their soft carapaces and a lack of a well developed hinges (Dodd, 2001) making them difficult to find (Jennings, 2007).

While many people employ the method of counting scute annuli, the validity of this method has been challenged (Wilson *et al*., 2003). Wilson *et al.* (2003) stated that more than 67% of all papers published did not have reliable data from the annuli count aging technique. The only reliable method to determine turtle age is by long term mark-recapture (Dodd, 2001). Stickel (1978) studied Maryland box turtles for thirty years at the Patuxent National Wildlife Refuge and Hall *et al* (1999) extended the study for another twenty years. Both studies have accurate aging data from the use of mark-recapture. Another method of aging turtles is by skeletochronology a method proposed by Zug (1991), which uses cross-sections of the limb bones to determine age via counting annuli in the bones. However, the turtle would need to be dead, which might account for lack of skeletochronology in box turtle studies (Dodd, 2001). Deplorably, the annuli count aging technique was the only method I could employ. The research was carried out during one field season, which did not leave enough time to collect sufficient mark-recapture data for modeling age. Further, I could not use skeletochronology, due to insufficient collections in the West Virginia Biological Survey.

Sex ratios were slightly male skewed at both sites (Lake = 1.20:1, State Park = 1.19:1), although the male to female ratio differed only slightly between sites. Male biased sex ratios are quite common in many box turtle populations (Stickel and Bunck, 1989; Dodd, 1997; Hall *et al.* 1999). One instance of a female-biased population occurred in an Illinois study where the ratio for male to female was 1:3.4 (Elghammer *et al.*, 1979). The majority of my study sites were woodlands providing plentiful shade. Many turtle species are dependent on nesting temperature to determine sex (Bull and Vogt, 1979). They also found 73% of hatchling *Terrapene c. carolina* at 22.5˚C, 95% at 25.0˚C, and 81% at 27.0˚C to be male. He found no male hatchlings when temperatures exceeded 30.0˚C or higher indicating that females require warmer temperatures than males. In this study, turtles at both sites might have hatched in woodlands in which the cooler substrate temperatures produced more male hatchlings.

Box turtle morphometrics at both sites revealed no significant interaction between site and sex. Males had greater carapace lengths than females, but females have greater carapace height. Reports in the literature are similar to these with regards to sex (Stickel and Bunck, 1989; Dodd, 1997; Pilgrim *et al*., 1997; Ernst *et al*., 1998). Dodd (1997) stated that the differences box turtle size were purely mechanical. It is easier for larger males to copulate with smaller females due to the larger surface area of concavity fitting into the high dome shape of female carapaces.

There was a statistical significance between the body masses and carapace heights of turtles between sites with both body masses and carapace heights being greater in turtles at Lake. Habitat quality probably attributes to the difference in the body masses of turtles between both sites. The State Park site was characterized by scrub pine (*Pinus virginiana*), a species that often overtakes abandoned farmland during secondary succession (Orwig and Abrams, 1994). State Park was largely farmland prior to the 1970s when it was founded (Dan Evans, pers. comm.). The dry soil of this site is optimal for *Pinus virginiana* in West Virginia (Strausbaugh and Core, 1973) and the addition of pine needles to the soil prevent the growth of several shrub, herbaceous, and mushroom species (Odom, 1953). Even though box turtles have an omnivorous diet (Klimstra and Newsome, 1960), lack of biodiversity at state park causes turtles to expend more energy in search of food sources, contributing to a decreased mass and carapace height

(Figure 2.8). Lake on the other hand is characterized by various hardwoods (oaks, maples, hickories, beech, and yellow poplar) which are considered indicators of a post climax community (Oosting, 1956) and require rich moist soil in West Virginia (Strausbaugh and Core, 1973). Greater biodiversity at Lake creates more food sources for turtles (Figure 2.8).

Reproductive isolation is one possible explanation for differences in carapace heights at both sites. To assume two separate populations, I placed the sites on opposite sides of the lake over 5 km apart. Box turtle home ranges typically measure 1-5 ha (Dodd, 2001), so it would be highly improbable for integration between populations to occur. However, genetic studies need to be conducted to confirm the possibility of reproductive isolation between the species. Reeves and Litzgus (2008) had a similar situation between an island and mainland population of spotted turtles. Island turtles exhibited many smaller morphometric variables then the mainland populations. They concluded the cause was possibly genetic due to reproductive isolation and the founder effect. In our study, carapace height was the only morphometric variable that was statistically significant between the sites. One advantage to having a greater carapace height, especially in females, is to assist males in mounting females when mating (Dodd, 1997). An advantage to having a smaller carapace height could help turtles wedge themselves under cover objects easier when escaping unfavorable climatic conditions.

It would be interesting to find accurate population counts using mark-recapture or radio telemetry for both populations of box turtles. I assumed that all turtles were present and above ground. This study provides baseline data to carry out a long term demographic surveys on box turtle populations. Genetic testing will need to be performed in order to confirm two separate populations. To further this study, taking demographic data on "intermediate" populations could provide more insight of a possible growth gradient for the differences in carapace heights between both sites. With the rise in development and depletion of natural lands, it is becoming important to know the current status and distribution of box turtles in West Virginia. Although this distribution analysis is mostly historical, dating as far back as 1935, it will provide the West Virginia Herpetology Atlas with baseline information to begin a current distribution analysis.

Figure 2.8 General vegetation at State Park (Top) and Lake (Bottom). State Park was characterized by *Pinus virginiana*, which indicates poor soil conditions. Lake had more plant diversity and thicker leaf litter layers which makes Lake more optimal habitat.

CHAPTER THREE: THE EFFECTS OF ENVIRONMENTAL PARAMETERS ON THE ACTIVIY OF EASTERN BOX TURTLES (*TERRAPENE C. CAROLINA*) IN WEST VIRGINIA

Abstract

Terrapene c. carolina activity has been widely studied throughout the species' range. Environmental parameters, such as air temperature, substrate temperature, relative humidity, and percent canopy cover influence activity. However, many reports in the literature place moderate temperatures (13-25°C) and high humidity (>50%) as the top parameters that control activity levels in turtles. The objective of this study was to determine which environmental parameter had the greatest influence on turtle activity. I captured 136 box turtles at two study sites in Cabell and Wayne counties. I recorded turtle activity and measured environmental parameters (i.e., air temperature, substrate temperature, relative humidity, and percent canopy cover) upon each turtle capture. I used logistic regression and Akaike's Information Criterion corrected for small sample size (AIC_c) for model selection to determine the top environmental parameter model and test for significance on the influence of box turtle activity. Inactive turtles were encountered more frequently then active turtles. The top model included air temperature, substrate temperature, and canopy cover model. Air temperature and substrate temperature significantly influenced activity levels in box turtles. As air temperature decreased and substrate temperature increased, box turtles were more likely to be active. Activity increases in the morning probably due to the ambient substrate temperature conducting heat onto the turtle, thereby allowing them to forage before air temperatures become too unfavorable later in the day.

Introduction

Terrapene c. carolina is an inhabitant of eastern deciduous forests of the United States (Stickel, 1950) and are encountered between the months of April and November in many parts of its range (Ernst *et al*., 1994). Turtles emerge from hibernation when substrate temperature rises above 7°C for a week or more or by frequent warm precipitation (Grobman, 1990). Morning frosts in the autumn months influence box turtles to go into hibernation (Stuart and Miller, 1987).

Morning hours, specifically 0800-1000, are peak times of activity for box turtles (Dodd, 1994) since ambient humidity and temperatures are favorable (Dodd, 2001). During summer months, activity lessens as midday approaches and temperature and moisture conditions become unfavorable as stated by Schwartz and Schwartz (1974) in Dodd (2001). Box turtles usually take cover under leaf litter, under rocks, or develop shallow depressions in the ground called forms (Stickel, 1950). Even during periods of favorable conditions, turtles may still remain inactive (Stickel, 1950). To date, few records of night activity in box turtles exist in the literature (Dodd, 2001), however nesting and egg deposition in females is common on rainy or cloudy evenings and can continue into the night (Congello, 1978).

Environmental variables significantly influence the activity of box turtles (Penick *et al*., 2002). Turtles select habitats during different seasons of the year due to levels of relative humidity, air temperature, and canopy cover (Reagan, 1974) and are more active in open grassy areas in late spring due to warmer temperatures and higher humidity then in adjacent woodlands. Turtles shift to a mesic woodland habitat with the rise in air temperatures and fall of humidity in the open grassy areas.

The objective of this study was to define which environmental parameter(s) have the greatest influence on turtle activity. I hypothesized that high humidity (>50%) and moderate temperatures (13-25°C) would drive activity in box turtles in West Virginia.

Methods

Microclimate and Activity Measurements

I conducted turtle surveys between 6 April and 1 November 2008. Because box turtles are diurnal (Dodd, 2001), I conducted surveys between 0600 and 2100 during the summer months. I did most of our surveys during morning hours because box turtles are most active before 1200 (Dodd, 1994). All searches were systematic and limited to incidental turtle sightings above ground.

Activity categories and definitions were similar to Niewolt (1996). I defined turtle activity based on resting behavior. Activity was determined by observing each turtle for twenty minutes. I categorized behavior as inactive (i.e. resting, basking, or resting in water) and active (i.e. foraging, walking, mating). I compared behavior based on percentages of the population.

I measured microenvironmental parameters upon each turtle capture. These parameters were: air temperature, substrate temperature, relative humidity and canopy cover. Air temperature and relative humidity were recorded using a digital thermohygrometer (Forestry Suppliers: Model# 1555) placed directly in front of the turtle. I used two Reotemp analog soil thermometers placed on both sides of the turtle to measure substrate temperature and percent canopy cover using a spherical densiometer placed on the turtle's carapace.

Statistical Analyses

I used logistic regression, Akaike's Information Criterion corrected for small sample sizes (AIC_c; Burnham and Anderson, 1998) and Akaike weights (w_i; Burnham and Anderson, 1998) to compare models of turtle activity using SAS (SAS Institute, 2003). Prior to data analysis I developed a set of candidate models (Table 3.2) that were based on published accounts of the influence of microenvironmental parameters on turtle activity and on our field observations of study animals. We considered models with ΔAIC <2.00 to have empirical support. I calculated correlation analyses on a substrate/air temperature ratio versus average number of active or inactive turtles found per month.

Results

I captured 133 turtles at Beech Fork Wildlife Management Area between 17 April 2008 and 25 October 2008. Table 3.1 includes descriptive statistics for each environmental parameter recorded for active and inactive turtles. Sample size for each parameter varied due to lack of data in some parameter measurements. For example, I could not record substrate temperature on impenetrable surfaces such as concrete or asphalt. Resting/basking was the most common behavior encountered (51.3%). The most common type of active behavior in box turtles was walking (24.4%) with swimming and mating being most uncommon (both 1.3%).

Two models (Tables 3.3 and 3.4) received empirical support ($\Delta AIC_c < 2.00$). The top logistic regression model ($\chi^2 = 16.13$, df = 3, $P < 0.01$) included air temperature, substrate temperature, and canopy cover as predictor variables. Parameter estimates Table 3.5 derived from the top model indicated that box turtle activity was negatively associated with air temperature and positively associated with soil temperature. There was no significant association with canopy cover Table 3.4. In the global model, which also received empirical support, box turtle activity was also positively associated with substrate temperature (Table 3.3) The parameter estimates for the other variables in the global model were not significantly associated with box turtle activity.

There was a strong correlation between number of active turtles found per month and the average substrate/air temperature ratio per month (R^2=0.959, P<0.001), indicating that as the substrate and air temperature approach similar temperatures, turtles were more likely to be active (Figures 4.1 and 4.2). No correlation was found between number of inactive turtles and the substrate/air temperature ratio (R^2=0.20277, P=0.6628).

Table 3.1 Means, standard errors, and ranges of environmental parameters tested on active versus inactive turtles found at Beech Fork Wildlife Management Area during the 2008 season. AT = air temperature, ST = substrate temperature, RH = relative humidity, and C = % Canopy Cover

Active Turtles

Parameter	N	Mean ± SE	Range
AT (°C)	46	24.8 ± 0.8	14.4 – 42.6
ST (°C)	41	21.7 ± 0.5	13.0 – 28.0
RH (%)	46	55.5 ± 3.3	8.0 – 95.0
C (%)	48	65.8 ± 4.6	0.0 – 95.8

Inactive Turtles

Parameter	N	Mean ± SE	Range
AT (°C)	98	25.1 ± 0.6	11.4 – 40.2
ST (°C)	100	20.9 ± 0.4	11.0 – 28.0
RH (%)	97	47.9 ± 2.2	10.0 – 88.0
C (%)	102	77.2 ± 2.4	0.0 – 100.0

Table 3.2 Models selected for the AIC_c procedure. Global contains all four parameters. K = number of parameters in a given model + 1. w_i represents the model weights out of 1.

Model	**K**	**N**	**AIC_c**	**ΔAIC_c**	**w_i**
Global	5	133	156.86	1.86	0.28
AT	2	133	165.81	11.19	0.01
RH	2	133	161.38	6.76	0.01
ST	2	133	159.58	3.96	0.01
AT/RH	3	133	163.40	8.69	0.02
AT/C	3	133	163.92	9.30	0.02
AT/ST/C	4	133	154.84	0.00	0.63
AT/RH/C	4	133	163.8	8.97	0.02

Table 3.3 Global Model (χ^2=16.27, df = 4, P <0.01) with maximum likelihood estimates from logistic regression comparing all environmental parameters measured in *Terrapene c. carolina* habitat.

Parameter	**Parameter Estimate ± SE**	**df**	**X^2**	***P***	**Odds Ratio (CI)**
AT	-0.1870 ± 0.0986	1	3.5987	0.0578	0.829 (0.684-1.006)
ST	0.2650 ± 0.1300	1	4.1561	0.0415	1.303 (1.010-1.682)
RH	0.00464 ± 0.0126	1	0.1358	0.7125	1.005 (0.980-1.030)
C	-0.00917 ± 0.00889	1	1.0651	0.3021	0.991 (0.974-1.008)

Table 3.4 Air Temperature/Substrate Temperature/Canopy Cover Model ($\chi^2 = 16.13$, df = 3, $P < 0.01$) with maximum likelihood estimates from logistic regression comparing air temperature, substrate temperature, and cover in *Terrapene c. carolina* habitat.

Parameter	**Parameter Estimate ± SE**	**df**	X^2	***P***	**Odds Ratio (CI)**
AT	-0.2081 ± 0.0810	1	6.5954	0.0102	0.812 (0.693-0.952
ST	0.2845 ± 0.1189	1	5.7270	0.0167	1.329 (1.053-1.678)
C	-0.00918 ± 0.00890	1	1.0659	0.3019	0.991 (0.974-1.008)

Table 3.5 Parameter weights for microclimate variables measured upon *Terrapene c. carolina* captures at Beech Fork Wildlife Management Area, WV (2008).

Parameter	w_i
AT	0.27
ST	0.25
RH	0.28
C	0.26

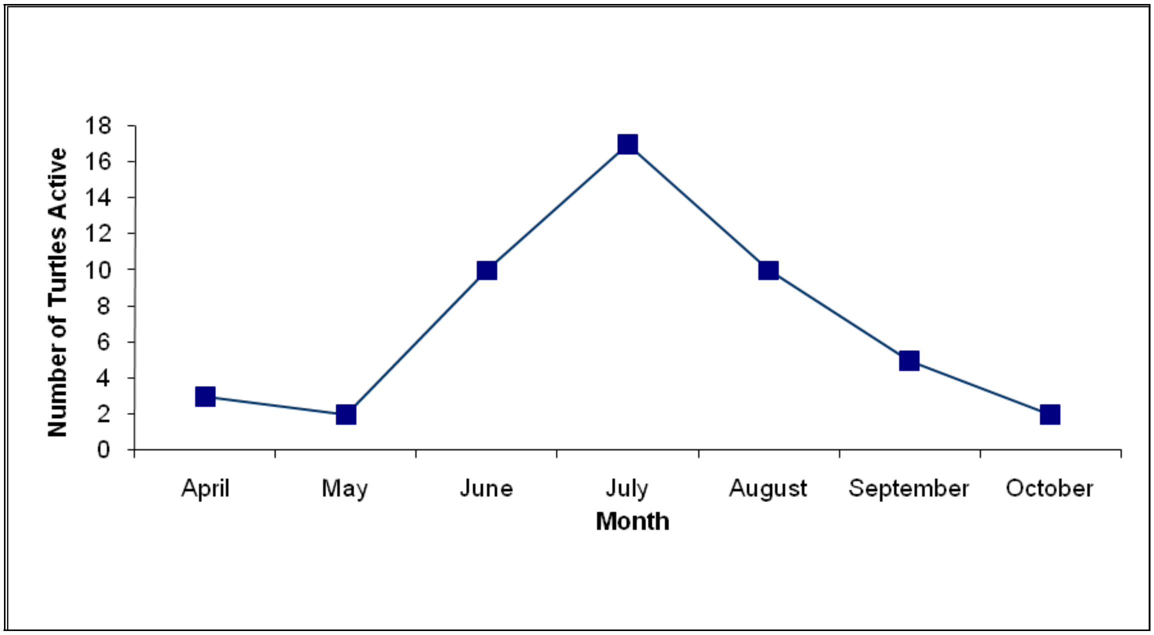


Figure 3.1 Number of active turtles found per month. Close consideration of figure (#) below shows that the closer the two variables are, the more active turtles present per month. Review graphs on next page, which show correlation of the substrate air temperature ratio vs. number turtles found per month for both inactive and active turtles.

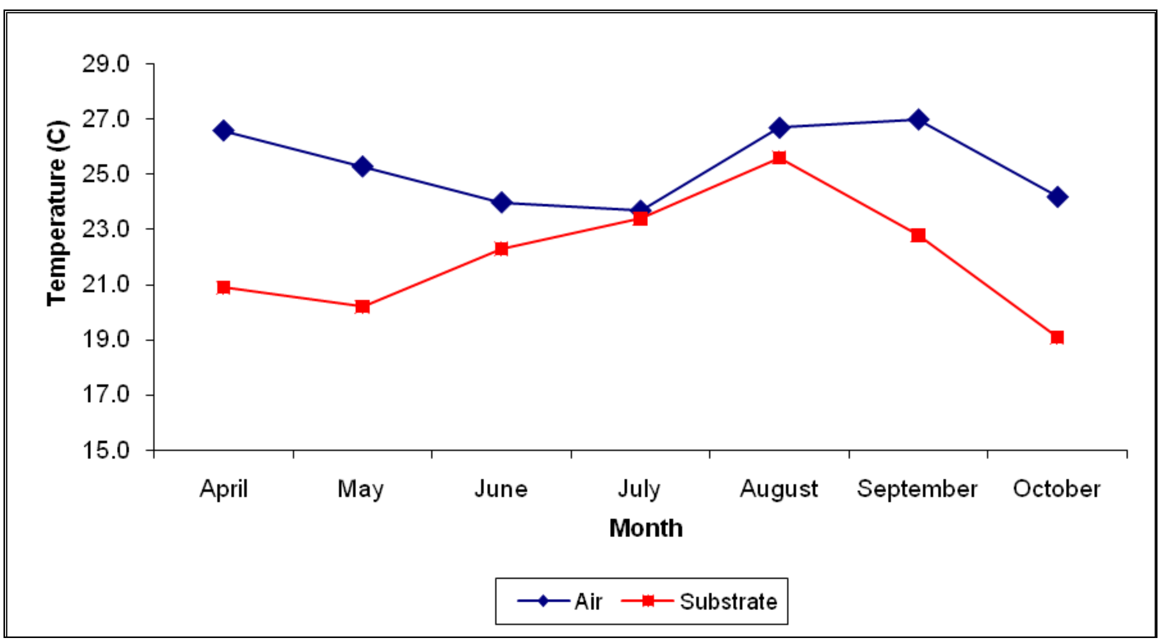


Figure 3.2 Average air and substrate temperatures (in °C) of microenvironments of active turtles per month at Beech Fork Wildlife Management Area. Air and substrate were considered the two parameters that influence box turtle activity ($P<0.05$).

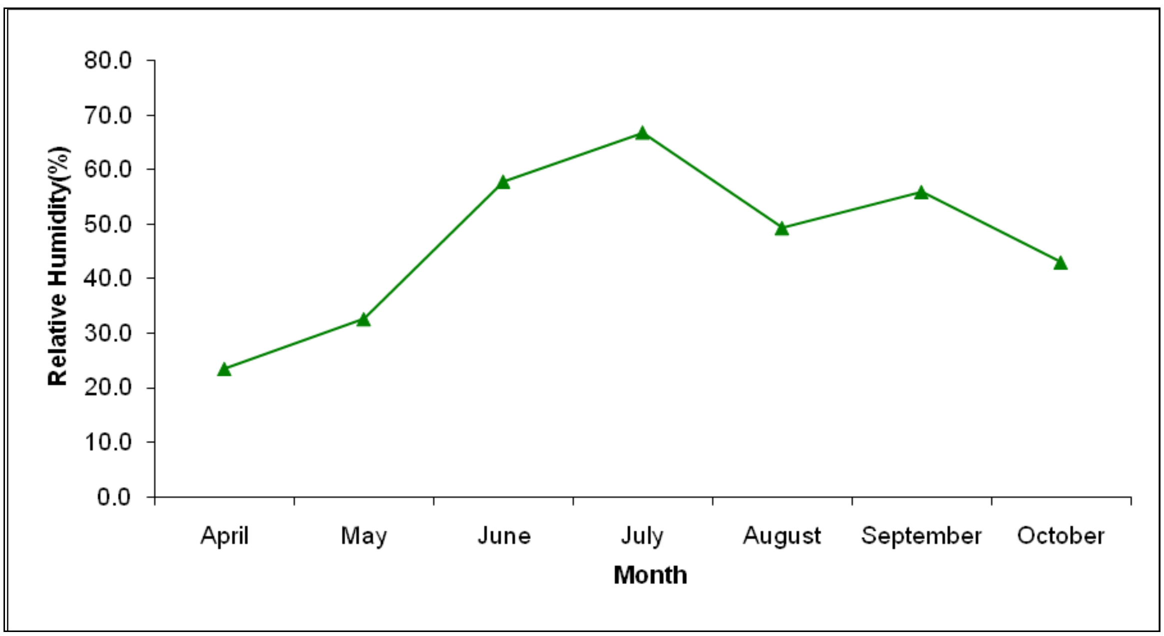


Figure 3.3 Average relative humidity per month at Beech Fork Wildlife Management Area. This variable was found to be insignificant ($P>0.05$) to turtle activity. However relative humidity is considered a significant parameter that influences turtles in other studies (Reagan, 1974; Dodd 1994; Penick, 2002).

Discussion

The majority of turtles captured were inactive which coincides with previous work on box turtle activity (e.g. Converse and Sadvige 2003: Dodd *et al*. 1994; Niewolt 1996). I found more inactive turtles than active turtles during every month but June. Turtles appeared to be most active in July, which might be due to their nesting behavior in June and July in many parts of their range (Ewing, 1933; Congello, 1978; Palmer and Braswell, 1995). Females travel long distances when selecting nest sites (Stickel, 1950) which could explain why there is a peak in activity levels of females during June and July. Males were more active than females during other months as they were likely searching for mates.

I encountered only 10 juveniles throughout the entire field season, and only one juvenile was active. In many box turtle studies, juveniles are underrepresented (Ernst *et al*., 1994), probably due their secretive behavior and low recruitment (Pilgrim *et al*, 1997), which most likely contributes to the presumed inactivity of many juvenile box turtles. According to our observations, I found most juveniles under vegetation.

Soaking behavior was more common from late July to mid-October due to high temperatures and drought (Allard, 1948; Stickel, 1950). Donaldson and Echternacht (2005) noted that box turtles make linear movements to bodies of water in June and July in Tennessee as drought and high temperatures occurred. A drought affected both study sites during late summer 2008 and many turtles started to congregate in 1st order streams.

Walking was the most common type of active behavior. Typically, I observed turtles walking early in the morning before 1000 hours. This behavior was observed by Dodd *et al*. (1994) and Jennings (2003) who both stated that *Terrapene c. bauri* are more active between 0800-1000 hours, when turtles locate and consume the dew on plants and mushrooms (Dodd, 2001). I observed more ground invertebrates during the morning hours, which could increase activity in box turtles since they are "opportunistic omnivores" (Stuart and Miller, 1987).

Model selection revealed that air temperature and substrate temperature were important microclimatic parameters. Converse and Savidge (2003) reported that box turtles were more likely to be active if there was a decrease in air temperature. Turtles in this study also followed the same trend, but there was a significant increase in active turtles when substrate temperatures increased.

Percent canopy cover was not significant, which contrasted with previous studies (Reagan, 1974; Penick *et al*., 2002). When canopy cover is high (70-100%) it could reduce turtle activity due to providing optimal conditions of high humidity, moderate temperatures, protection from predators, and abundant resources in their microhabitat (Reagan, 1974). Turtles can become inactive for days, even under optimal conditions of moderate temperatures and high humidity (Stickel, 1950). Areas with low canopy cover (0-30%), such as roadways, lawns, and old fields, might make turtles more disposed to activity in order to travel to a more favorable habitat (Iglay *et al*. 2007).

There was a significant correlation between the number of active box turtles per month and the average substrate to air temperature ratio. As air and substrate temperature converged, box turtles were more likely to be active. I did not detect any correlation between average number of inactive turtles per month and average substrate to air temperature ratio. Substrate temperatures probably conducted heat on the turtle from the plastron dorsally. Low to moderate temperatures of the morning hours could explain why turtles are most active during this part of the day since turtles become inactive in higher temperatures (Reagan, 1974). However, high humidity in the morning is optimal for activity in box turtles (Reagan, 1974; Stickel 1950; Dodd *et al*. 1994; Jennings 2003). My analysis revealed that relative humidity did not have a significant effect on the activity levels of box turtles at my study site, but air temperature coincided with the above literature. Dodd (2001) stated that he observed few box turtles when relative humidity fell below 50%, however, 36.2% of turtles in my study were captured when humidity was below 50%.

Turtles may have detected my presence before I could locate them, impeding activity. This behavior could have obscured my determination of activity types on some turtles and could have contributed to the insignificance of relative humidity on activity. If the turtle were walking before detecting my presence, the legs would usually cease in an alternating manner. To reduce bias, I determined activity levels of all turtles in the field and am confident of all observations.

It is important to understand activity patterns in box turtles in order to assess wildlife management implications. Since environmental parameters influence activity in box turtles, it is important that environmental conditions are maintained. Mesic forests with nearby open fields, or patches of basking sites are important in thermoregulation. With the destruction of box turtles habitat, namely mesic forests, alterations in air and substrate temperature out of optimal zones may decrease activity in turtles. Forests are important to maintain optimal air and substrate temperatures, canopy cover, and humidity conditions for box turtles.

CHAPTER FOUR: HABITAT SELECTION OF EASTERN BOX TURTLES (*TERRAPENE C. CAROLINA*) IN WEST VIRGINIA

Abstract

Habitat preference in many reptile and amphibian species is largely dictated on thermoregulatory needs. *Terrapene c. carolina* are inhabitants of the eastern United States with habitat descriptions ranging from mesic forests, pastures, and marshy meadows. I collected data on habitat type, substrate type, aspect, and dominant vegetation in *Terrapene c. carolina* habitat at two study sites (Lake and State Park). I performed chi-square tests on categorical habitat variables and plant species given importance values. Box turtles preferred mixed hardwoods and mixed pine hardwoods at both sites. Softer substrates such as leaf litter, herbaceous species, and mud were preferred and turtles did not appear to favor a specific aspect. Dominant woody plant species of State Park were *Pinus virginiana*, *Elaeagnus umbellata*, and *Lonicera japonica*. *Quercus* spp., *Acer* spp., *Liriodendron tulipifera*, *Ulmus rubra*, *E. umbellata*, and *Lindera benzoin* were the dominant tree and shrub species of Lake. Turtles are probably more dependent on the shrub species due to their fleshy fruits and low-lying branches. While *E. umbellata* is considered an invasive species, it appears to be an important shrub species to box turtles at both sites. Optimal habitat conditions are mixed hardwood or hardwood-pine forests with nearby fields and creeks with plentiful soft substrate types. Shrubs that have low-lying branches and produce fleshy fruits also optimize box turtle habitat.

Introduction

Habitat selection is an important ecological aspect of many terrestrial vertebrates. Unlike endotherms, reptiles and amphibians largely select habitat based on thermoregulatory needs (Huey, 1991). The function of a box turtle's habitat is to provide food and to provide shelter from unfavorable environmental conditions (Nieuwolt, 1996; Reagan, 1974). Habitat descriptions of eastern box turtles range from forests, pastures and marshy meadows (Ernst *et al*. 1994).

Reagan (1974) suggested habitat use was a function of temperature, relative humidity, and cover. Turtles preferred habitats that provided moderate temperatures, high humidity, and high cover. Mesic forests are optimum habitats of box turtles because they provide sufficient shade but have patches of sunlight for basking and forests also provide a thick layer of leaf litter to escape unfavorable climatic conditions or predators (Dodd, 2001).

During late spring and early fall, Reagan (1974) noted that habitat preference shifted to open fields and pastures due to cooler ambient temperatures, and high humidity. Turtles then choose mesic forests in the summer since forests provide cooler temperatures, high humidity, and higher cover during hot, dry periods in the summer.

Water use in small creeks and stagnant pools becomes prevalent during periods of drought and higher temperatures (Allard, 1948). Turtles are often seen along banks or submerged in pools of water in or near creeks (Stickel, 1950). Straight-line movements to bodies of water have been observed during periods of drought and high temperature during June and July (Donaldson and Echternacht, 2005).

There are two objectives to my study: 1) to ascertain preferred habitat parameters (i.e. habitat type, substrate type, distance to water, and aspect), and 2) to list important plant species in box turtle habitat. I hypothesize that mesic forests of mixed hardwoods and mixed pine-hardwoods with abundant leaf litter on northern slopes would be preferred by eastern box turtle at my study sites. Dominant vegetation will include plants that produce fleshy fruits, which are a good source of food for box turtles (Klimstra and Newsome, 1960).

Methods

Habitat

I recorded habitat type upon each turtle capture as: mixed hardwood forest (Forests without *Pinus* spp.), mixed pine/hardwood forest (Forests that include *Pinus* spp.), field, roadside, or 1st order streams. Substrate was recorded as: leaf litter, soil/mud, herbaceous, gravel, or pavement. Herbaceous referred to herbaceous plants, grass, or moss. Pavement refers to either concrete or asphalt. Aspect of each turtle capture was recorded in degrees with an analog magnetic north compass. All habitat and environmental data were segregated by study sites, Lake and State Park and later compared in the analysis to note any differences in habitat parameters between study sites.

Vegetation Survey

I conducted vegetation surveys to describe the plant diversity within a box turtles habitat. Surveys were conducted in 10 x 10 m square plots situated 50 m from each other on transects. Transects were selected in areas where at least five turtles, dead or alive, had been found. Transect length varied depending on how clumped turtle populations were. For example, if turtles occupied a small area (1 ha), two plots were used, if turtles occupied a large area (4 ha), eight plots were used. No fewer than two and no more than eight plots were used within a transect.

Seven transects (four in Lake and three in State Park) were used in seven different habitat types where turtle captures were common. These included: mixed pine/hardwood (MPH) hillside and lower forest (State Park), mixed hardwood (MH) hillside and upper forest (Lake), MH upper forest (Lake), MH lower hardwood forest (Lake), MPH lower forest (State Park), MH lower forest bordering a 1st order stream (Lake), and mixed pine/hardwood hillside and upper forest (State Park). Dominant vegetation types were compared by habitat type and between sites. See Figure 4.2 for typical vegetation structure of the State Park transects and Figure 4.3 for typical vegetation of the Lake transects.

Vegetation plots were formed in 10 x 10 m square plots (Figure 4.1**)**. Woody plants were categorized as either tree or shrub. Woody plants that exceed 5 cm in diameter at breast height (dbh) were considered trees, and woody plants that are taller than 1m but less than 5cm in dbh were considered shrubs. All plants less than 1m tall were not included in the analysis. I measured cover for each species using diameter of breast height for trees and stem count for shrubs. Diameter at breast height was measured in cm, then converted to relative basal area ($BA = \pi\left(\frac{DBH}{2}\right)^2$). Units were in cm^2 and basal area for a given species was calculated by adding all basal areas of all individuals of the same tree species. All trees and shrubs were sampled inside the 10 x 10 m plot. Strausbaugh and Core (1973) and Petrides (1972) were the field guides used to identify local flora. To prevent biasing my sample to late summer vegetation, herbaceous plants and non-vascular plants were not surveyed. Red oak species could not be identified accurately due to the heights of the trees' branches and the uncertainty of matching acorns on the forest floor with the proper parent tree; therefore, I classified them as *Quercus* (red) spp. I recorded any vertebrates observed in the field in Appendix II and all tree and shrub species encountered in Appendix III.

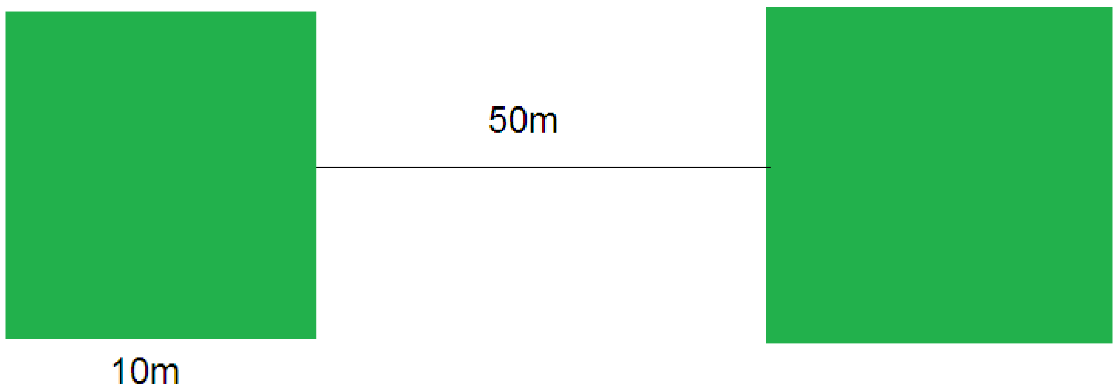


Figure 4.1. Plant transect used for sampling of trees in shrubs. Square plots 10x10m were placed 50m apart on transects ranged from two-eight plots.

Statistical Analyses

Importance values were designed to determine dominant vegetation per each plot and transect. Importance values were calculated by dividing total basal area of all individuals of species A divided by total basal area of all individual trees of all species within the plot (Relative Basal Area). Importance values of shrubs were calculated by counting stems for each individual. Stems per species were divided by stems of all species to calculate a relative stem count per plot per species.

Chi-square tests were used to test for uniformity in habitat variable selection (i.e. habitat type, substrate type). Proportions among the differing classes in each of the categorical habitat variables were compared using a 95% confidence interval. Confidence intervals that did not overlap were considered statistically significant.

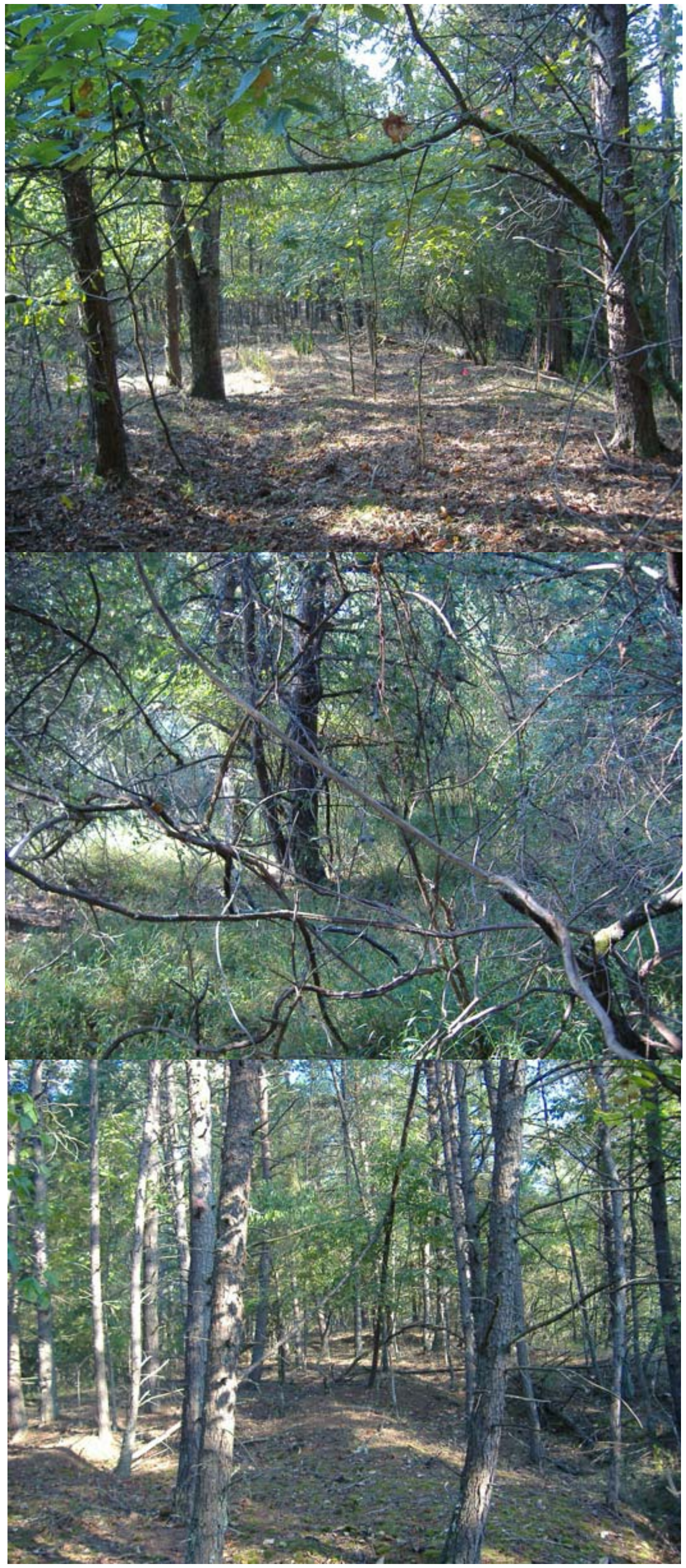


Figure 4.2 Typical vegetation of transects 1 (top), 5 (middle), and 7 (bottom) at State Park site.

Figure 4.3 Typical vegetation structure of transects 2 (top left), 3 (top right), 4 (bottom left), and 6 (bottom right), at Lake site.

Results

Habitat

There was strong evidence for habitat selection for both sites ($\chi^2 = 61.3706$, df = 4, $P < 0.0001$). Box turtles at Lake were typically found in mixed hardwood forests (58.4% ± 9.1%). Box turtles at State Park typically found either mixed pine/hardwood forests (46.3% ± 15.3%) or mixed hardwood forests (34.1% ± 14.5%). Lake was devoid of the mixed pine/hardwood forest (Figure 4.4).

Box turtles were found more in hardwoods of both sites throughout the 2008 field season (40.9-80.0%) than any other habitat type. Use of fields was more prevalent in April and October (25.0% and 15.4%, respectively). Mixed pine-hardwoods were more common in May (50.0%). Box turtles were found in 1st order streams from July through early September with August being the most prevalent time (40.0%). Turtles on or beside roads was most widespread in July with 14.6% of all turtles being found here (Figure 4.5).

There was evidence of substrate selection for both sites ($\chi^2 = 9.9172$, df = 4, $P < 0.0418$). Box turtles at Lake were typically located on softer substrates such as leaf litter (33.3% ± 8.8%) and soil/mud (27.5% ± 8.4%), or herbaceous (23.9% ± 8.0%). Box turtles at State Park were generally found on either herbaceous (46.3% ± 15.3%) or leaf litter (34.1% ± 14.5%) (Figure 4.6).

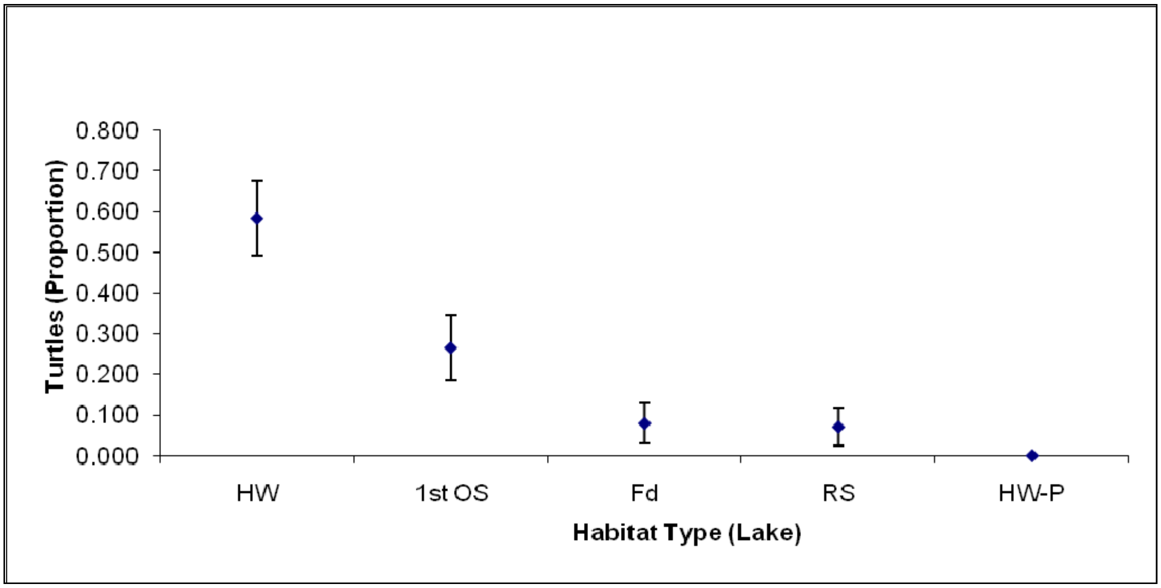
Most turtles were located on hilltops or valleys (57.5%) where aspect could not be directly measured. Turtles with true aspect measurements did not appear to have a favorable location ($\chi^2 = 4.75$, df = 3, $P > 0.10$) at both sites (Figure 4.7).

Vegetation Survey

Dominant vegetation of each plot with importance values are listed in Table 4.1. *Pinus virginiana* (Scrub Pine) was the most common tree species encountered at the wildlife management area, especially at State Park where three transects were used. Dominant trees of Lake were *Quercus* spp. (Oaks) which characterized the upper and hillside forests, and *Liriodendron tulipifera* (Tulip Poplar) and *Ulmus rubra* (Slippery Elm) which were widespread in the lower forests near creeks. *Elaeagnus umbellata* (Autumn-Olive), *Lonicera japonica* (Japanese Honeysuckle), and snags were the most common shrub species of State Park. *Elaeagnus umbellata* and *Acer saccharum* (Sugar Maple) were dominant shrubs in the upper and hillside forests of Lake, with *Acer negundo* (Boxelder) and *Lindera benzoin* (Spicebush) being prevalent in the lower forests.

Table 4.1 Importance values of top tree and shrub species per plot.

Habitat	Plot	Tree Species	Importance Value (%)	Shrub Species	Importance Value (%)
Hillside Mixed Pine/Hardwood Forest	1.1	*Pinus virginiana*	59.7	*Cornus florida*	31.6
	1.2	*Quercus marilandica*	37.4	*Fraxinus americana* *Vitis spp.*	30.0 (Each)
	1.3	*Pinus virginiana*	86.1	*Lonicera japonica*	65.9
	1.4	*Pinus virginiana*	95.0	*Rhus radicans*	41.7
	1.5	*Pinus virginiana*	76.9	*Parthenocissus quinquefolia*	28.6
	1.6	*Pinus virginana*	69.4	NO SHRUBS	N/A
	1.7	*Pinus virginiana*	92.2	*Elaeagnus umbellate*	42.9
Upper and Hillside Hardwood Forest	2.1	*Quercus (red)* spp.	83.0	*Ostrya virginica*	30.0
	2.2	*Quercus alba*	38.0	*Acer rubrum*	40.0
	2.3	*Quercus alba*	47.1	*Acer saccharum*	100.0
	2.4	*Quercus (red)* spp.	78.7	*Acer saccharum*	100.0
	2.5	*Quercus alba*	90.8	*Acer saccharum*	100.0
	2.6	*Carya ovata*	43.8	*Acer saccharum*	81.5
Upper Hardwood Forest	3.1	*Quercus alba*	83.6	*Elaeagnus umbellate*	60.8
	3.2	*Quercus alba*	86.0	*Elaeagnus umbellate*	93.3
	3.3	*Quercus alba*	100.0	*Quercus stellata*	42.9
	3.4	*Quercus alba*	97.9	*Acer rubrum*	37.0
Lower Hardwood Forest	4.1	*Acer saccharinum*	42.4	*Acer negundo*	100.0
	4.2	*Pinus virginiana*	43.1	*Elaeagnus umbellate*	61.1
Lower Mixed Pine/Hardwood Forest	5.1	*Prunus serotina*	55.3	*Lonicera japonica*	42.9
	5.2	*Pinus virginiana*	97.2	*Elaeagnus umbellate*	57.9
	5.3	*Pinus virginiana*	92.8	*Elaeagnus umbellata* *Lonicera japonica*	41.2 (Each)
	5.4	*Pinus virginiana*	86.5	*Elaeagnus umbellate*	45.3
	5.5	*Pinus virginiana*	100.0	*Lonicera japonica*	44.0
	5.6	*Pinus virginiana*	56.0	*Lonicera japonica*	54.7
	5.7	*Pinus virginiana*	90.9	*Elaeagnus umbellate*	73.5
	5.8	*Pinus virginiana*	83.5	*Lonicera japonica*	69.8
Lower Hardwood Forest along Creek	6.1	*Prunus serotina*	39.8	*Menispermum canadense*	43.8
	6.2	*Liriodendron tulipifera*	85.3	*Lindera benzoin*	82.9
	6.3	*Ulmus rubra*	44.3	*Lindera benzoin*	69.8
	6.4	*Liriodendron tulipifera*	79.4	*Lindera benzoin*	44.4
	6.5	*Ulmus rubra*	58.9	*Lindera benzoin*	37.5
Upper Mixed Pine/Hardwood Forest	7.1	*Quercus marilandica*	28.9	*Snag*	45.0
	7.2	*Pinus virginiana*	87.9	*Ostrya virginica*	60.9
	7.3	*Pinus virginiana*	88.3	*Smilax rotundifolia*	47.8
	7.4	*Quercus marilandica*	81.9	*Smilax rotundifolia*	47.8
	7.5	*Quercus stellata*	42.5	*Snag*	66.7
	7.6	*Pinus virginiana*	25.2	*Cornus florida*	42.9
	7.7	*Quercus (red)* spp.	76.0	*Acer rubrum*	45.5



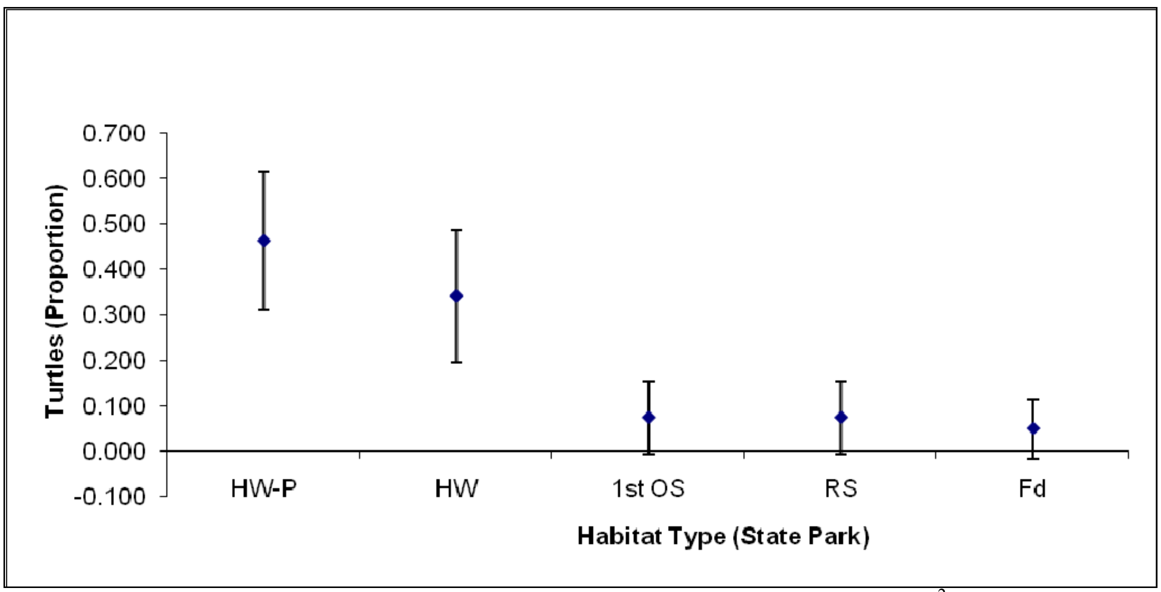


Figure 4.4 Proportion of turtles found in each habitat type with 95% confidence intervals ($\chi^2 = 61.3706$, df = 4, P < 0.0001). Non-overlapping intervals are considered statistically significant. Habitat selection is non-uniform with turtles selecting hardwoods or mixed pine-hardwoods habitats. Mixed pine-hardwood habitat type was non-existent at Lake. Mixed hardwoods (HW), mixed pine-hardwoods (HW-P), Field (Fd), first order stream (1^{st} OS) and roadside (RS).

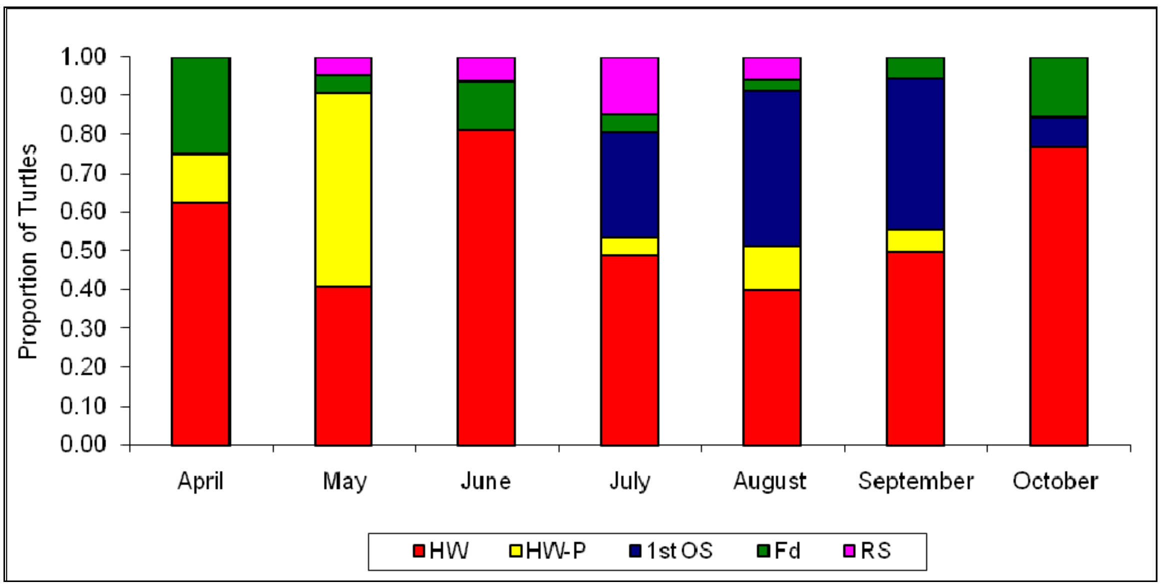


Figure 4.5 Proportional habitat selection per given month for eastern box turtles at Beech Fork Wildlife Management Area.

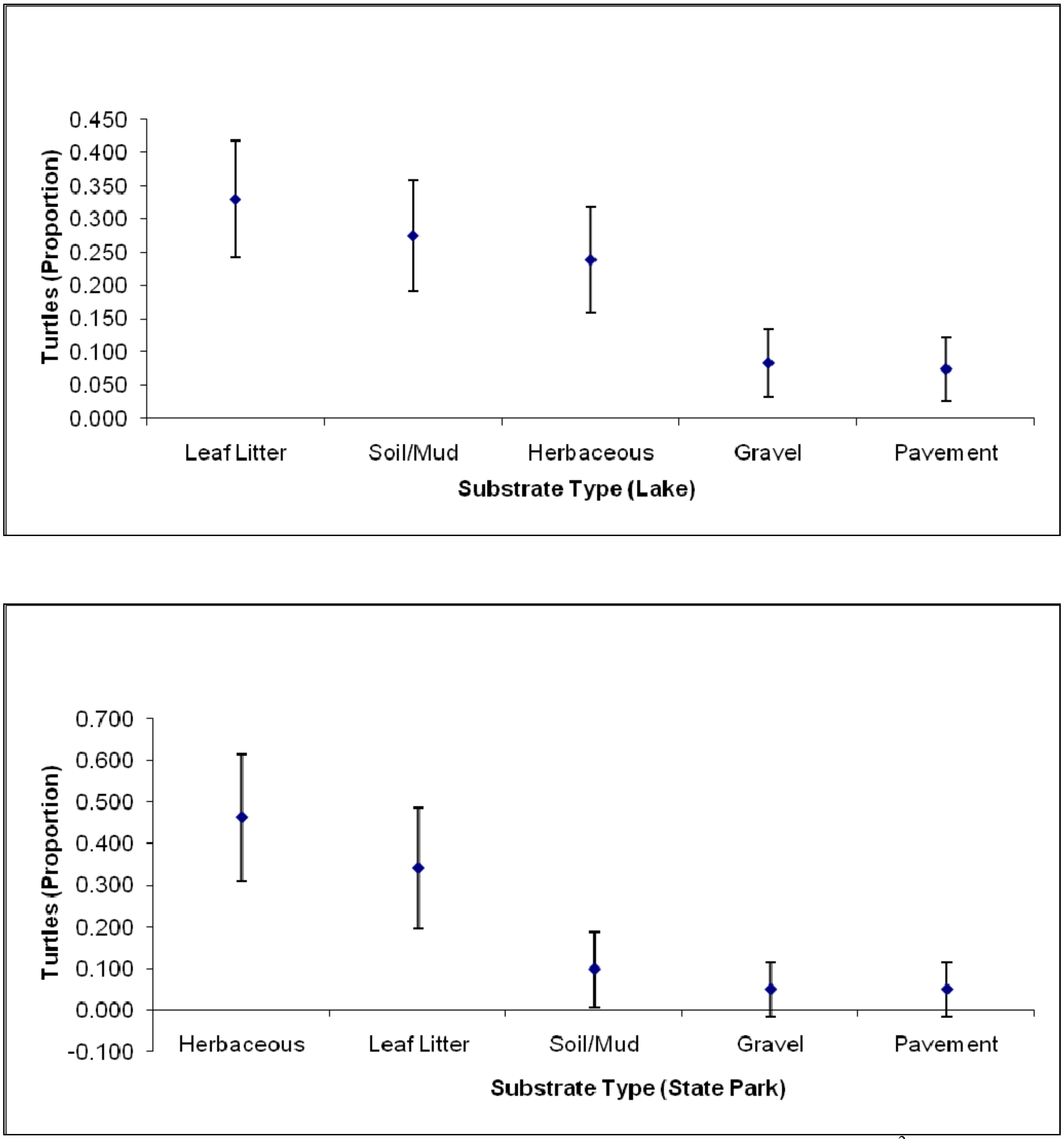


Figure 4.6 Substrate use in eastern box turtles at Beech Fork Wildlife Management Area ($\chi^2 = 9.9172$, df = 4, P = 0.0418). Substrate use was non-uniform with box turtles at Lake selecting leaf litter, soil/mud, and herbaceous substrate and State Park selecting herbaceous and leaf litter. Herbaceous refers to any substrate where live vegetation occurs such as herbaceous plants, grass, or moss. Pavement refers to areas of man-made pavement.

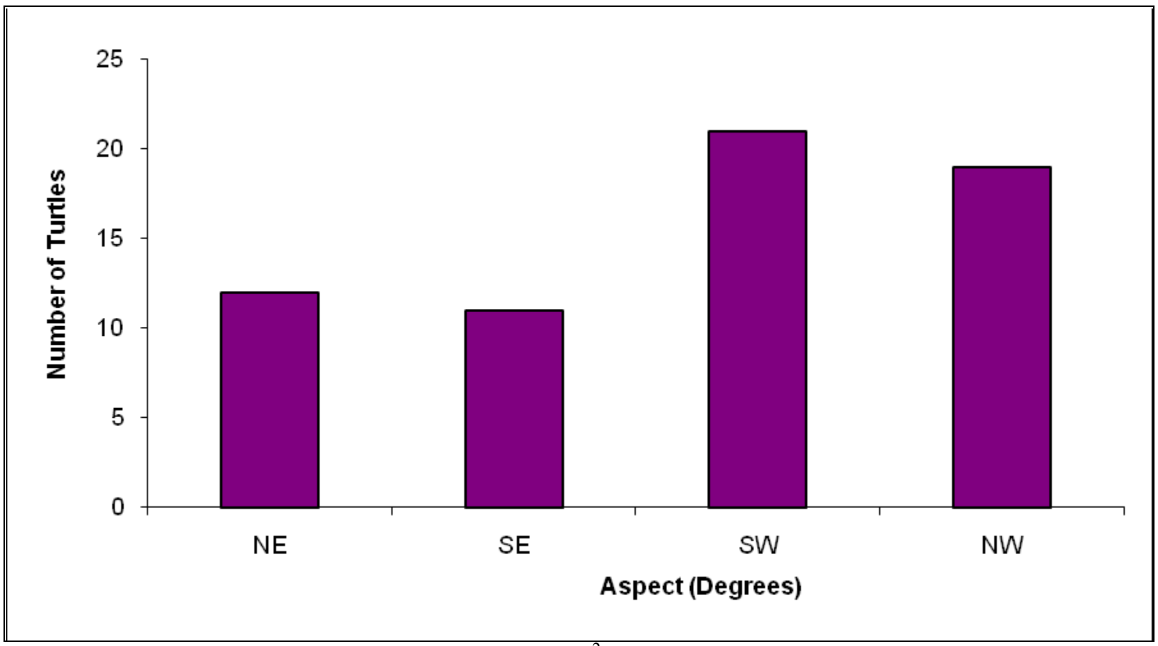


Figure 4.7 Aspect of eastern box turtles at both sites ($\chi^2 = 4.75$, df = 3, $P > 0.10$). Turtles did not have an optimal aspect. Aspect was not measured for turtles found in valleys or flattened hilltops.

Discussion

Turtles at both sites exhibited habitat preference for mixed hardwood forests or mixed-pine hardwood forests which is typical of *Terrapene c. carolina* being a species of eastern deciduous forests (Dodd, 2001). Use of open areas such as fields became prevalent during April and October, the first and last months of their active season. Turtles might have moved to these sites due to optimal temperatures and high humidity in fields before summer and winter arrives (Reagan, 1974). Madden (1975) suggested that forest shrub and forest field ecotones also serve as favorable habitats.

Water use became prevalent between 24 July and 5 September. High temperatures and a drought had affected my study site during this part of the 2008 field season. Turtles would congregate in pools of water with 25 observations recorded between 24 July and 19 October. Anecdotal evidence by E. Knizley in Dodd (2001) states that large number of turtles were observed assembling at mountain streams in low elevations in West Virginia. Turtles enter water during periods of drought and high heat, sometimes staying there for days, with only their head propping out of the water (Allard, 1948; Donaldson and Echternacht, 2005). Donaldson and Echternacht (2005) have noted that turtles make linear trips to water during June and July due to drought and high temperatures.

During hot afternoons, turtles were more likely to be found in water to escape unfavorable heat and humidity conditions. However, turtles can sometimes be 0.5 km or more from a water source, thus they will utilize mud puddles that collect water to prevent dehydration (Stickel, 1950; Strang, 1983). Not only did these puddles help to cool turtles, but it probably provided concealment from predators.

Movements across roads were most common in July with the majority of turtles being female. June and July is considered nesting season in box turtles across its range (Ewing, 1933; Congello, 1978; Palmer and Braswell, 1995). Females travel far distances to lay eggs (Stickel, 1950) which could explain why more females were seen on roads than males.

Soft substrates such as leaf litter, soil/mud, and herbaceous were typical for box turtles at Lake and leaf litter and herbaceous were typical substrate choices at State Park. Leaf litter was the most common substrate used by *Terrapene c. bauri* (Dodd, 1994), probably because these substrates used by box turtles at my sites and others probably provide refugia from unfavorable environmental conditions and possible predators (Stickel, 1950; Reagan, 1974; Strang, 1983; Penick *et al*. 2002). Dodd (2001) suggests that the preference for substrate has probably more to do with food searching or presence of optimal environmental conditions. Leaf litter contains numerous invertebrate food sources for box turtles, retains moisture, and remains relatively cooler than the surface temperature, which could explain why turtles are found on or near leaf litter.

Turtles do not appear to select a specific aspect on a hillside. Most turtles were located on hilltops or valleys, areas where aspect could not be measured directly. It was expected that more turtles would be found on north-facing slopes due to high humidity and cooler temperatures and avoid south-facing slopes with lower humidity and warmer temperatures (Smith and Smith, 2001). Stickel (1950) stated that box turtles had a preference for floodplains; however, Strang (1983) noted that turtles were evenly distributed at different elevations. In my study, turtles were more likely to be found in valleys probably due to being in close proximity to water and opportunities for more cover from objects and lower plants.

State Park was represented by transects 1, 5, and 7. *Pinus virginiana* (Scrub Pine) was the dominant tree species of State Park. This is probably due to the nutrient poor soil type that scrub pine use in West Virginia (Strausbaugh and Core, 1974). Orwig and Abrams (1994) noted that scrub pine overtake abandoned farmland during secondary succession. Prior to the 1970s, Beech Fork State Park was largely farmland (Dan Evans, pers. comm.) which could explain the abundance of this species at State Park. Japanese honeysuckle (*Lonicera japonica*) and autumn-olive (*Elaeagnus umbellata*) were the most common shrub species at State Park. Japanese honeysuckle and autumn-olive produce fleshy fruits and they probably provide box turtles with another food source. Both species are considered invasive, yet autumn-olive was introduced as a wildlife food in the 70s in West Virginia (Strausbaugh and Core, 1974).

Lake was represented by transects 2, 3, 4, and 6. Dominant tree species of hilltop and hillside forests were white oak (*Quercus alba*) and various red oak species (*Quercus* (red) spp.) with common shrubs being red maple (*Acer rubrum*), sugar maple *(Acer saccharum*), and autumn-olive (*E. umbellata*). Yellow poplar (*Liriodendron tulipifera*) and slippery elm (*Ulmus rubra*) were the most common tree species in valley forests with common spicebush (*Lindera benzoin*) being the most prevalent shrub species.

Turtles are known to be seed dispersers of many species of plants (Braun and Brooks, 1987). The turtles at my study site may have contributed to the overwhelming numbers of Japanese honeysuckle and autumn-olive at State Park and autumn-olive and spicebush at Lake. Though invasive, autumn-olive could provide box turtles with food with its fleshy fruits and shelter with its low-lying branches, making this shrub a possible important species in box turtle habitat.

Williams and Parker (1987) reported that box turtles avoid upland oak habitat, but favor habitats with maples (*Acer* spp.). In this study, oak species were quite common in box turtle habitat and appeared to have no influence on their selection; however, many oak habitats contained maples and autumn-olive in the shrub layer. While Williams and Parker (1987) did not elaborate the importance of maples, it is highly likely that dominant shrub species with fleshy fruits and low-lying branches are a necessary component for box turtle life history because they could provide food and shelter from unfavorable conditions or predators. Further research needs to be conducted in the relationships between box turtles and seed dispersal at both study sites.

Wildlife Management Implications

Owing to the significant proportion of turtles found soaking in mud puddles and 1^{st} and 2^{nd} order streams, water is apparently an important component of box turtle life-history (Donaldson and Echternacht, 2005). Suggestions for box turtle habitat selection in the Allegheny Plateau region of West Virginia would be mixed forests, with a shrub layer that produces fleshy fruits. Though invasive, native shrubs similar to *Elaeagnus umbellata* could provide box turtles with a source of food and a source of shelter. Substrate types such as leaf litter, mud, and herbaceous provide box turtles with numerous invertebrate food sources and another source of shelter.

CHAPTER FIVE: DIGITAL PHOTOGRAPHY AS A MEANS OF FUTURE RECOGNITION IN INDIVIDUAL *TERRAPENE C. CAROLINA*

Abstract

The mark-recapture technique is one of the most common methods of formulating population size estimates and other demographic parameters. Digital photography is a useful technique for identifying species that display individual colors or patterns on their external surface, but this method has largely been used on large mammals. Traditionally, box turtles were marked by shell notching or painting numbers on the carapace. With the variation in carapace and plastron colors and patterns of turtles, digital photography can successfully differentiate between two similar individuals. Turtles were photographed from the carapace, plastron, and side angles. Photos were analyzed in the laboratory by making comparisons and looking for matches. I captured 136 individual turtles and recaptured 20 individuals at Beech Fork Wildlife Management Area, Wayne County, WV. This method was shown to be a useful noninvasive technique for future recognition because notching can cause open wounds leading to infection. Infectious diseases can also be spread by failure to clean equipment between notching different turtles. Painting numbers wears off with rain and objects brushing up against the shell. Box turtle populations are declining over their range and the use of digital photography could be used as a non-invasive means for future recognition

Introduction

Mark-recapture methods have been useful in determining population sizes, survivorship, and other demographic data for wildlife life history. Mark-recapture assumes that all individuals in a given area have an equal chance for recapture and organisms do not enter or leave the study area (Heilbrun, *et al*. 2003). When marking an animal, the mark must be unique to a particular individual and easily observable by the researcher. Traditionally individual recognition methods in turtles have followed the method by Cagle (1939) (Figure 5.1), in which marginal scutes are notched using a file and combinations of these notches are used to identify individuals. Notching is effective because it is usually permanent and researchers can quickly identify individual turtles in a population.

Other forms of marking turtles include painting a number on the carapace using either wall paint or fingernail polish (Ewing, 1933; Nieuwolt, 1996; Donaldson and Echternacht, 2005), which is temporary. Shell notching is more commonly used due to permanence; however, there are two problems with shell notching. First, notching cannot be used on hatchlings or young turtles because their carapaces are too soft and malleable. Second, notching could also lead to open wounds, therefore subjecting the specimen to further infection by local pathogens (Fisher, 2007).

Several researchers have proposed the use of digital photography for mark-recapture studies, but it has largely been used with large mammals (Heilbrun *et al*, 2003; Kelly, 2001; Karanth and Nichols, 1998). Fisher (2007) showed that many species of aquatic turtles have variable patterns and colors, enough to distinguish individuals. Moon (2004) suggested that the tail patterns of western diamondback rattlesnakes (*Crotalus atrox*) were enough to differentiate between individuals. Kelly (2001) devised a computer program that matches similar photographs in Serengeti cheetahs (*Acinonyx jubatus*). Budischack *et al*., (2006) mentioned digital photography as a way of future identification in eastern box turtles, but used it as a backup to shell notching.

Box turtles have distinctive shell patterns, making them ideal candidates for photographic recognition. From my observations of over 136 turtles in 2008, turtles have displayed solid colors, stripes, blotches, spots, etc. I propose that variations in colors and patterns of turtles will make it easy to identify individuals in a given population with the use of digital photography.

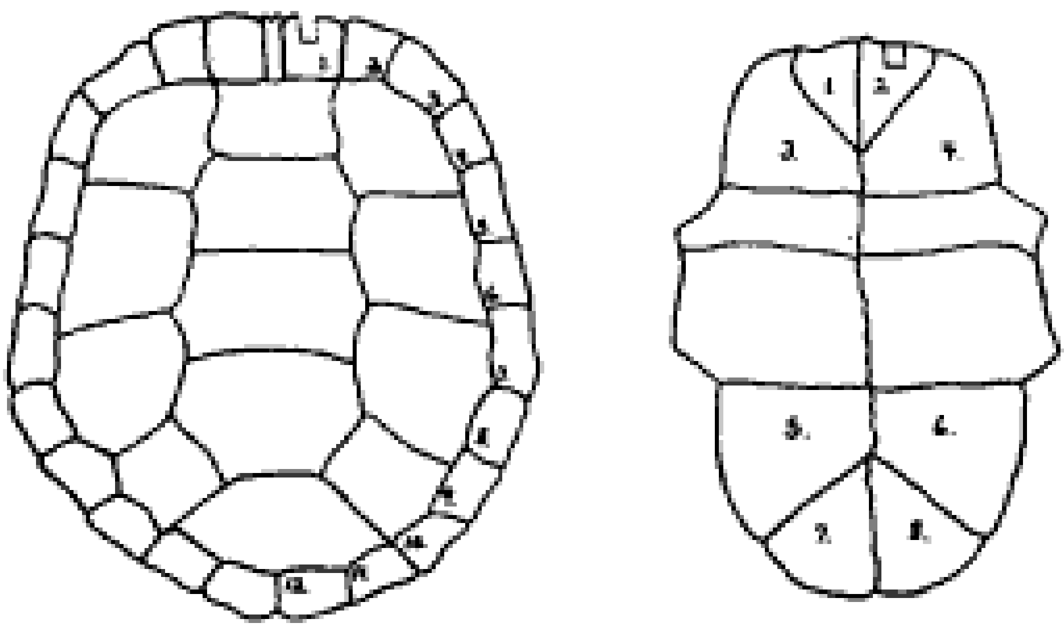


Figure 5.1 Diagram of the shell notching technique most commonly used in box turtle studies. Figure from Cagle (1939).

Figure 5.2 Plastrons of six individual turtles collected at Beech Fork Lake. Notice the different patterns of colors and shapes of the plastrons. Plastron photos were the most accurate to match similar turtles due to more conspicuous colors or patterns.

Methods

Photography

Upon capture each turtle was photographed from three different angles: dorsal (carapace), ventral (plastron) and left side view with a four megapixel Fugifilm™ digital camera in order to provide us with an extensive view of the turtle's shell (Figure 5.3). Photographs were encoded by the turtle number and the angle the photograph was taken. For example, L41C stands for the 41st turtle found on Beech Fork Lake side and the "C" represents a photograph taken at the carapace angle. At the end of each field day, photos were downloaded into a personal computer, encoded, and reviewed for matches. Recaptures were noted and photo names changed to the proper turtle identification. For example, if L41C were found to be the same as L9C, L41C was changed to L9IIC, indicating the second time that L9 was captured. To reduce bias I reviewed all photography and comparisons and confirmed them with second opinions of colleagues.

Rules for recapture were similar to Heilbrun *et al.,* (2003). First, a new individual has never been photographed. Second, three features on the turtle (i.e. patterns, colors, anatomical abnormalities) had to be identified in order to justify a recapture. Last, in the case of individuals that appeared identical, one feature was enough to confirm two individuals. Low-quality photographs were not analyzed.

Results

I captured 136 individual turtles 156 times between 17 April and 25 Oct 2008. Four individual turtles were not photographed due to camera technical difficulties (lens unfocused, dead batteries) or poor imagery. Twenty recaptures were confirmed using the digital camera method. One turtle, L9 (Figure 5.4), was captured four times using this method (16 May 2008, 29 July 2008, 20 Sept 2008, and 19 Oct 2008). The latter three captures were all within a 2 m radius whereas the first capture was 165m away. Similarly, L89 was captured four times (12 Sept 2008, 20 Sept 2008, 21 Sept 2008, and 25 Oct 2008). One juvenile (specimens <110mm in straight-line carapace length) was effectively recaptured approximately 8 m from its original capture site. All other recaptures were within a 10 m radius of the initial capture indicating that this area is within the turtle's home range.

Figure 5.3 Left column photos represent SP16 and right column photos represent SP16II. Each turtle capture consisted of turtles photographed at the carapace, plastron, and side view with anterior end facing left. SP16 was captured 18 July and 30 August 2008. Photos from all three angles provide further confirmation when matching possible recaptures.

Figure 5.4 L9P and L9PII were photographed on two different dates (16 May 2008 and 29 July 2008, resp.). Close comparison of the patterns and colors show that these photos are of the same turtle.

Discussion

Whereas 20 turtle recaptures were successfully identified by this technique, time consumption and a few low-quality photos were problematic. I recommend that photos be reviewed at the end of each field trip by the same investigator to prevent bias and provide early confirmation before the photographs accumulate. Low-quality photos were rare, and even then the ability to locate matches was not as difficult.

While it is more time efficient to simply notch turtles and recognize notches on recapture, it may not be the safest method for the specimen (Fisher, 2007). Notching cannot be used on juvenile turtles, because the exponential growth of the shell will cause notches to regenerate. In addition, the shell is not well ossified (Dodd, 2001). Notching can sometimes leave adult turtles with open wounds making them more susceptible to infection. Naturally, turtles can lose marginal scutes by injuries, but in order to reduce impact on local populations, digital photography should be an accurate method.

Chronic upper respiratory tract disease caused by bacterium *Mycoplasma aggasizii*, which affects gopher tortoises in the southeastern United States (Smith *et al.*, 1998) and desert tortoises in the southwestern United States (Jacobson *et al.*, 1991), has been found in wild populations of box turtles (Calle *et al.*, 1996; Siefkas *et al.*, 1998; Feldman *et al.*, 2006). This condition is considered infectious (Brown *et al.*, 1994) and is spread by direct contact (Dodd, 2001). This disease originated from captive desert tortoises released into the wild, thus affecting wild turtles (Jacobson *et al.*, 1991). Upper respiratory tract disease and other diseases could be spread by filing equipment used on infected turtles and spread to uninfected turtles. If unclean equipment contacts the carapace, or worse, bloodstream, the spread of disease is possible in natural populations.

Shell notching may also lead to unnecessary stress in box turtles. Corticosterone, which maintains water and electrolyte balance in animals, increases during stress and can lead to a reduction of steroid hormones, thus interfering with mating behavior in several reptile species (Lance *et al*., 2003; Moore *et al*., 2000; Cash *et al*., 1997).

Photography can also be used to display details of external morphology for turtles in a given population or aspects of their natural history (Figure 5.6). Researchers can also review photos to assess anatomical abnormalities in individuals (Figure 5.5). This might help in assessing the health of the microenvironment and microhabitat selection of a population of turtles for implications of wildlife management

Digital photography is a simple procedure for small samples (Kelley, 2001) although larger samples need the assistance of a computer matching program similar to Kelly (2001) who used over 10,000 photos of Serengeti cheetahs. If a program can be developed similar to Kelley (2001), digital photography could be the ideal method to identify individual turtles in a given population.

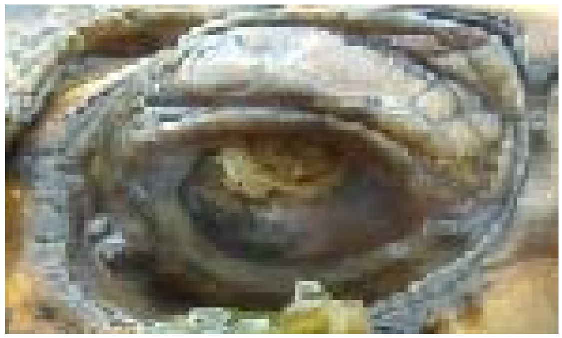


Figure 5.5 Box turtle with an abnormality of the eye. An example of unusual findings in the field that can be photographed and later researched for possible diseases or genetic defects.

Figure 5.6 Box turtle preparing to enter a creek. Another advantage of digital photography in the wild is to provide more concrete evidence of an animal's natural history.

Wildlife Management Implications

Digital photography should be used on all species of the genus *Terrapene* as it would reduce stress and possible infection or spread of disease by notching, is inexpensive, and simple to do. Eastern box turtles are a species of concern in Massachusetts, Michigan, and Ohio, threatened in Iowa, and endangered in Indiana, Maine, and Wisconsin (Dodd, 2001; ohiodnr.gov) so it may be appropriate to revaluate our methods of individual recognition. With the decline of box turtles throughout many northern parts of its range, it is recommended that researchers apply this recognition technique to prevent further decline in the entire range of these species.

CONCLUSIONS

Optimal habitat conditions for turtles in my study included mixed hardwood forests or mixed pine hardwood forests bordering first-order streams and open areas, such as fields. Turtle activity levels depended on decreased air temperatures and increased substrate temperature that forest cover maintains. The presence of low-lying, fleshy fruit shrubs provide box turtles with a source of food and shelter. A thick leaf litter layer is necessary to allow the turtle to escape possible predation or unfavorable climatic conditions.

My demographic data appear to agree with reports in current literature. Males had greater straight-line carapace lengths and females had greater carapace heights. Differences in the carapace heights and body masses between populations of both sites were likely attributed to genetic isolation and/or habitual differences. In my study, male-biased sex ratios occurred more often and can be attributed to nests in cool forest soil, which resulted in more male hatchlings. Age-class structure was biased towards older turtles and may be the result of poor aging methodology.

Terrapene c. carolina is considered a common species in West Virginia (Green and Pauley, 1987), but have had substantial declines across its geographic range (Dodd, 2001). West Virginia legislation allows for a collection limit on *Terrapene c. carolina* (Levell, 1997). Pennsylvania, Kentucky, and Virginia, West Virginia bordering states, have similar legislation, but Ohio and Maryland have listed *Terrapene c. carolina* as a species of concern (ohdnr.gov; mddnr.gov). Box turtles are listed as endangered in the nearby state of Indiana (Levell, 1997).

Further study of *Terrapene c. carolina* in West Virginia is important because little is known about the species' natural history and habitat requirements. Many would argue that a political border should make no difference on our overall knowledge of a species, but I say it should, especially if the entire state of West Virginia falls within the species' geographic range. That in itself is a large portion of unknown information that needs to be researched in order to secure the box turtle's future in West Virginia.

Dodd and Franz (1993) mentioned that many "common" reptiles are ignored in field studies. More funding is provided for threatened, endangered, and sensitive species due to the species survival and it should be a top priority, but if researchers procrastinate on the opportunity to investigate and manage organisms that are well known to many, the fate of these organisms could become similar to many species listed on the Endangered Species Act. As biologists, or even as humans, we should take advantage of this golden opportunity to collect as much data as possible on "common" species if we are to preserve the knowledge and appreciation of all life.

APPENDIX ONE: NATURAL HISTORY NOTES OF *TERRAPENE C. CAROLINA* AT BEECH FORK WILDLIFE MANAGEMENT AREA

Active Season

The first sighting of a turtle was on 11 April 2008 by one of my colleagues, at Beech Fork State Park; however, the first recorded sighting for my study was on 17 April 2008 at the same location. The last recorded sighting for the season was 25 October 2008 following three morning frosts at Beech Fork Lake. Any turtles seen after this date were deceased, probably from the drop in temperature.

Swimming Behavior

Box turtles swim well and will enter the water when threatened (Overton, 1916). I have observed two cases of box turtles swimming and they appeared to float with little trouble. While being along shallow stream banks is typical, I have witnessed a turtle swim across a creek to avoid me. Tyler (1979) witnessed a three-toed box turtle (*Terrapene c. triunguis*) swimming across a stream 15 m wide and over 1 m deep. He estimated that it took the turtle approximately 12 minutes at 1.25 m/min to cross the stream.

Two Cases of Mating

On 26 April, two turtles were observed mating. Mating occurs in three phases; phase one the male circles and bites the female; phase two the male climbs onto the female's carapace, the female relaxes her plastron allowing the male to attach his hindclaws inside; phase three the female begins to grasp the hindclaws and the male will fall onto his back where the two tails will join, allowing copulation between cloacas (Evans, 1953). The mating I observed was in phase two as the male had just mounted the female (Figure AI.1). Dwight Robinson (*pers. comm.*) located two box turtles mating in Putnam County, near Scott Depot on 28 April in phase three (Figure AI.1). While mating can occur any time during the active season, it is most common before or after hibernation (Iglay *et al*., 2007; Ewing, 1933). No turtles were observed mating before the end of the active season.

Figure AI.1 Eastern box turtles mating behavior in West Virginia. Evans (1953) phase 2 (above) and phase 3 (below, photo by: Dwight Robinson).

Food Observations

On 15 June, I observed 2 turtles eating. One turtle was found in an upland habitat eating a mushroom (*Russula* sp.), a food source that makes up a large portion of a box turtle's diet (Klimstra and Newsome, 1960). On 6 July and 8 July, 2 different turtles were observed eating mushrooms of the *Russula* genus on a hillside forest. Mushrooms were present in this habitat between May to August, but were abundant between June and mid-July.

On 15 June another turtle was found in an upland habitat eating a cicada (*Magicada sp.*). May and June of 2008 was brood XIV of cicadas. Cicadas will mate and then die off within a matter of weeks, providing the forest with a superabundance of resources for the forest ecosystem, increasing soil microflora and soil nitrogen (Yang, 2004), thus box turtles benefit with an additional food source.

On 17 July, in a concrete drainage area near a Corps of Engineers dam, another turtle was examined eating an earthworm (Class: Oligochaeta; Order: Haplotaxida) that had been dried by the sun. This observation confirms that box turtles have omnivorous diets (Stickel, 1950; Klimstra and Newsome, 1960; Stuart and Miller, 1987).

Road Crossing Behavior

On 2 August, I observed a box turtle crossing the north entrance road to Beech Fork State Park 1007 hours. On one side of the road there was a ditch leading to a creek and the other side of the road was a hillside leading to a wooded area. The turtle walked in a diagonal direction towards the wooded hillside. One vehicle did pass the turtle during its trek and the turtle responded by retracting into its shell. As soon as the car passed, the turtle immediately came out of its shell and increased its speed to cross the road. Roads have a detrimental effect on nearby reptile populations (Dodd *et al*., 1989), and Dodd (2001) suggested that research on box turtle populations near and far away from roadways should be considered to see the direct affect on roadways on turtle populations.

APPENDIX TWO: INCIDENTAL VERTEBRATES FOUND IN *TERRAPENE C. CAROLINA* HABITAT

Class Mammalia

Order	Family	Species
Artiodactyla	Cervidae (Deer)	*Odocoileus virginiana* (White-tailed Deer)
Carnivora	Procyonidae (Raccoon)	*Procyon lotor* (Raccoon)
	Mustelidae (Weasel)	*Mephitis mephitis* (Striped Skunk)
Lagomorpha	Leporidae (Rabbits)	*Sylvilagus floridana* (Eastern Cottontail)
Marsupialia	Diadelphidae (Possum)	*Diadelphis virginiana* (Opossum)
Rodentia	Cricetidae (New World Mice)	*Microtus pennsylvanicus* (Meadow Vole)
	Sciuridae (Squirrel)	*Sciurus caroliniensis* (Eastern Gray Squirrel)
		Tamias striatus (Chipmunk)

Class Aves

Order	Family	Species
Anseriformes	Anatidae (Swans, Geese, and Ducks)	*Anas platyrhynchos* (Mallard)
		Branta canadensis (Canada Goose)
Ciconiiformes	Ardeidae (Herons, Egrets, and Bitterns	*Ardea herodius* (Great Blue Heron)
	Cathartidae (New World Vultures)	*Cathartes aura* (Turkey Vulture)
Galliformes	Phasianidae (Turkey and Grouse)	*Meleagris gallopavo* (Wild Turkey)
Passeriformes	Cardinalidae (Cardinals)	*Cardinalis cardinalis* (Northern Cardinal)
	Corvidae (Crows, Jays, and Magpies)	*Corvus brachyrhyncos* (American Crow)
		Cyanocitta cristata (Blue Jay)
	Troglodytidae (Wrens)	*Thryothorus ludovicianus* (Carolina Wren)
Piciformes	Picidae (Woodpeckers)	*Picoides villosus* (Hairy Woodpecker

Class Reptilia

Order	Family	*Species*
Squamata	Colubridae (Non-Venomous Snakes)	*Carphophis amoenus* (Eastern Worm Snake)
		Coluber constrictor (Northern Black Racer)
		Elaphe alleghaniensis (Black Ratsnake)
		Lampropeltis getula niger (Eastern Black Kingsnake)
		Opheodrys aestivus (Northern Rough Green Snake)
		Thamnophis sirtalis (Eastern Garter Snake)
	Phrynosomatidae (Fence Lizards)	*Sceloporus undulatus* (Northern Fence Lizard)
	Scincidae (Skinks)	*Eumeces fasciatus* (Common Five-lined Skink)
Testudines	Chelydridae (Snapping Turtles)	*Chelydra serpentina* (Eastern Snapping Turtle)
	Emydidae (Basking Turtles)	*Terrapene carolina* (Eastern Box Turtle)

Class Amphibia

Order	Family	*Species*
Anura	Bufonidae (True Toads)	*Bufo americanus* (Eastern American Toad)
	Hylidae (Tree Frogs)	*Pseudacris crucifer* (Northern Spring Peeper)
	Ranidae (True Frogs)	*Rana catesbeiana* (Bullfrog)
		Rana clamitans melanota (Northern Green Frog)
Caudata	Plethodontidae (Lungless Salamanders)	*Desmognathus fuscus* (Northern Dusky Salamander)
		Eurycea cirrigera (Southern Two-lined Salamander)
		Plethodon kentucki (Cumberland Plateau Salamander)
		Plethodon richmondi (Southern Ravine Salamander)

Class Osteichthyes

Order	Family	Species
Cypriniformes	Cyprinidae (Minnow)	*Notropis sp.* (Minnow Species)
Perciformes	Centrarchidae (Sunfish)	*Lepomis sp.* (Sunfish Species)

APPENDIX THREE: OBSERVED WOODY VEGETATION IN *TERRAPENE C. CAROLINA* HABITAT

Class Pinopsida (Conifers)

Order	**Family**	**Species**
Pinales	Cupressiaceae (Cypress)	*Juniperus virginica* (Red Cedar)
	Pinaceae (Pine)	*Pinus strobus* (White Pine)
		Pinus virginiana (Virginia Pine)

Class Liliopsida (Monocots)

Order	**Family**	***Species***
Liliales	Liliaceae (Lily)	*Smilax rotundifolia* (Common Greenbrier)

Class Magnoliopsida (Dicots)

Order	**Family**	***Species***
Aquifoliales	Aquifoliaceae (Holly)	*Ilex opaca* (American Holly)
Cornales	Cornaceae (Dogwood)	*Cornus florida* (Flowering Dogwood)
	Nyssaceae (Sour Gum)	*Nyssa sylvatica* (Sour Gum)
Dipsacales	Caprifoliaceae (Honeysuckle)	*Lonicera japonica* (Japanese Honeysuckle)
		Lonicera tatarica (Tartarian Honeysuckle)
Fabales	Fabaceae (Pulse)	*Cercis canadensis* (Redbud)
		Robinia pseudoacacia (Black Locust)
Fagales	Betulaceae (Birch)	*Ostrya virginica* (Eastern Hop Hornbeam)
	Fagaceace (Beech)	*Fagus grandifolia* (American Beech)
		Quercus alba (White Oak)
		Quercus marilandicada (Blackjack Oak)
		Quercus muehlenbergii (Yellow Oak)

Fagales	Fagaceae (Beech)	*Quercus (red) spp.* (Red Oak Species)*
		Quercus stellata (Post Oak)
	Juglandaceae (Walnut)	*Carya glabra* (Pignut Hickory)
		Carya laciniosa (Shellbark Hickory)
		Carya ovata (Shagbark Hickory)
		Carya tomentosa (Mockernut Hickory)
		Juglans nigra (Black Walnut)
Lamiales	Oleaceae (Olive)	*Fraxinus americana* (White Ash)
		Fraxinus pennsylvanica (Green Ash)
	Scrophulariaceae (Figwort)	*Paulownia tomentosa* (Empress Tree)
Laurales	Lauraceae (Laurel)	*Lindera benzoin* (Spicebush)
		Sassafras albidum (White Sassafras)
Magnoliales	Annonaceae (Custard Apple)	*Asimina triloba* (Pawpaw)
	Magnoliaceae (Magnolia)	*Liriodendron tulipifera* (Tulip Poplar)
Malpighiales	Salicaceae (Willow)	*Salix nigra* (Black Willow)
Malvales	Tiliaceae (Basswood)	*Tilia heterophylla* (White Basswood)
Proteales	Platanaceae (Plane Tree)	*Plantanus occidentalis* (Sycamore)
Ranunculales	Menispermaceae (Moonseed)	*Menispermum canadense* (Canadian Moonseed)
Rosales	Elaeagnaceae (Oleaster)	*Elaeagnus umbellata* (Autumn Olive)
	Roseaceae (Rose)	*Crataegus sp.* (Hawthorn Species)
		Prunus serotina (Black Cherry)
		Rosa multiflora (Multifloral Rose)
	Ulmaceae (Elm)	*Ulmus rubra* (Slippery Elm)

Rosales	Ulmaceae (Elm)	*Celtis occidentalis* (Hackberry)
Sapindales	Aceraceae (Maple)	*Acer negundo* (Box Elder)
		Acer rubrum (Red Maple)
		Acer saccharinum (Silver Maple)
		Acer saccharum (Sugar Maple)
	Anacardiaceae (Cashew)	*Rhus copallina* (Winged Sumac)
		Toxicodendron radicans (Poison Ivy)
	Hippocastanaceae (Horse-Chestnut)	*Aesculus glabra* (Sweet Buckeye)
	Simaroubaceae (Tree-of-Heaven)	*Ailanthus altissma* (Tree-of-Heaven)
Saxifragales	Hamamelidaceae (Witch-Hazel)	*Hamamelis virginiana* (Witch-Hazel)
		Liquidambar styraciflua (Sweetgum)
Vitales	Vitaceae (Vine)	*Parthenocissus quinquifolia* (Virginia Creeper)
		Vitis spp. (Grape Species)

*Due to difficulty in field identification and heights of branches and leaves of these tree species for identification, the following oaks were grouped together as *Quercus* (red) spp. and could be any one of the following since they are native to this region of West Virginia: *Q. coccinea* (Scarlet Oak), *Q. palustris* (Pin Oak), *Q. shumardii* (Shumard Oak), *Q. velutina* (Black Oak), *Q. rubra* (Red Oak), or *Q. falcata* (Spanish Oak) (Straugborough and Core, 1973).

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