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NATURAL HISTORY OF A POPULATION OF WOOD TURTLES (GLYPTEMYS INSCULPTA) IN WEST VIRGINIA

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NATURAL HISTORY OF A POPULATION OF
WOOD TURTLES (*GLYPTEMYS INSCULPTA*) IN WEST VIRGINIA

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Next, I'd like to thank all the field help that made long and sweaty days tromping through the woods more fun: Sara Davis, Sonny (the dog), Stephen Curtis, Jennifer Macdonald, Suzanne Curtis, Kaylin Curtis, and Christopher Curtis.

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I'd like to thank Dr. Pauley for kindly allowing me near his lab and person. He listened to me talk about nonsensical things and somehow didn’t kill himself or me (which is a commendable achievement). I’d also like to thank the other members of my committee Dr. Gilliam and Dr. May who, I’m sure, didn’t entirely know what they signed up for when they agreed to be on my committee.

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ABSTRACT

The Wood Turtle (*Glyptemys insculpta*) is listed as vulnerable in West Virginia and only occurs in the Eastern Panhandle. The study population is unique in West Virginia because it occurs at a much higher mean elevation than other Wood Turtle populations in the state. The primary objective of this study was to determine if, and to what extent, altitude affected this population's ecology. Turtles were located with opportunistic surveys and captured by hand.

I located 31 turtles: 18 males, and 13 females. Turtles were captured a total of 68 times. Ratio of males to females did not differ significantly from 1:1. Morphometric measurements were taken slightly differently than in other studies thus occluding results, but it appears this population may be slightly larger than other WV Wood Turtles. Growth after a conservative estimate of maturity was 1.00 ± 0.56 mm per year, but may occur at an older age. Total adult population was estimated to be 53 ± 14, and the density of turtles in occupied areas was 2.27 adult turtles per hectare. No juveniles were captured, which bodes poorly for the viability of the population. The population is reproducing, owing to the discovery of nests and a hatchling, but may not be recruiting hatchlings into older cohorts.

I found some evidence to support the notion that this population has natural history traits more typical of higher latitudes including larger body sizes, maturity at larger body sizes, and lower turtle density, but a lack of recruitment would mean an aging population that would mimic more northerly populations as individuals age. Additional research is needed on this population to determine if it is currently recruiting young turtles or is a ghost population and at risk of extirpation.

CHAPTER 1:
INTRODUCTION

Species Account

Glyptemys insculpta (Wood Turtle) is a moderately sized North American turtle. Adult size can range from 14 to 20 cm in carapace length (Collins and Conant 1998). Record carapace length is 238 mm (Saumure 1992). The carapace is grey or brown and appears patternless when dry (Fig. 1.1), but some individuals have a starburst pattern on the carapace that is most apparent when the turtle is wet (Fig. 1.2) (Harding & Bloomer, 1979). The carapace is rough with a "sculpted" appearance that develops as the turtle ages and new annuli are added to individual scutes, creating pyramids of keratin (Collins & Conant, 1998). The hingeless plastron is amber colored with a black blotch extending inward from the underside of the marginal scutes onto the plastral scutes (Fig. 1.3) (Harding & Bloomer, 1979).

The head and upper side of the legs and tail are black or dark grey, and the underside of the legs and the skin inside the shell adjoining to the legs is red, orange or dark yellow (Fig. 1.4) (Harding & Bloomer, 1979). During the early 20th century, when turtles from North America were being exported for consumption to Asian countries, this bright coloration on the legs earned the species the vernacular name "red leg" (Collins & Conant, 1998). Seasonal variations of the intensity of the bright coloration have been reported in a population in New Jersey (Harding & Bloomer, 1979).

Males are generally larger than females, with more robust heads and forelimbs relative to body size, longer tails with the cloaca positioned farther from the body, and larger scales on the front limbs (Harding & Bloomer, 1979). Males have concave plastrons to facilitate mating, while females and immature males have flat plastrons (Ernst, Barbour, & Lovich, 1994). Hatchling *G. insculpta* are uniformly brown or grey, and lack the distinct orange coloring and "sculpted" appearance of older individuals (Harding & Bloomer, 1979). Hatchlings have long tails relative to body size, typically as long as the carapace (Collins & Conant, 1998). The orange coloring and sculpted appearance develop within the first year (Harding & Bloomer, 1979), but the secondary sexual characteristics of males only develop at maturity(Brooks, Shilton, Brown, & Quinn, 1992).

Figure 1.1. Adult *Glyptemys insculpta* carapace (dry).

Photograph by Jessica Curtis 2013.

Figure 1.2. Adult *Glyptemys insculpta* carapace (wet).

Photograph by Jessica Curtis 2013.

Figure 1.3. Adult *Glyptemys insculpta* plastron (male).

Photograph by Jessica Curtis 2013.

Figure 1.4. Adult *Glyptemys insculpta* front view, note the orange on the limbs and on the flesh inside the shell.

Photograph by Jessica Curtis 2013.

Like most species of freshwater turtles, *G. insculpta* matures late and has relatively low fecundity and recruitment; thus, they rely on high adult survivorship to ensure population stability (Brooks, Brown, & Galbraith, 1991; Congdon, Dunham, & Sels, 1993, 1994; Dodd, Hyslop, & Oli, 2012). Age of sexual maturity is highly variable between and among populations, but typically occurs within nine to twenty years (Brooks et al., 1992; Ernst et al., 1994; Farrell & Graham, 1991; Ross, Brewster, Anderson, Ratner, & Brewster, 1991). Size appears to be a better determinant of sexual maturity than age with average size across most populations at maturity between 160 to 180 mm carapace length (Lovich, Ernst, and McBreen 1990; Walde et al. 2003). Maturity is achieved at a later age and at a larger body size at more northern latitudes than southern latitudes (Brooks et al. 1992; Walde et al. 2003). Smaller males, while sexually mature may be less likely to successfully compete for females due to their smaller size (Kaufmann, 1992b; Lovich et al., 1990). Thus, they may fail to father offspring until they've reached a more competitive size.

Mating has been recorded at all times during the active season (spring, summer, and fall) (Ernst et al., 1994). However, most courting and mating occur in the spring and fall (Brooks et al. 1992; Walde et al. 2003). Females can be courted and mated by multiple males in a season and cases of multiple paternities within clutches have been found (Kaufmann, 1992b). Clutch size ranges from three to twenty eggs, usually with an average clutch size of eight to ten (Harding and Bloomer 1979; Farrell and Graham 1991; Brooks et al. 1992; Hunsinger 2002; Walde et al. 2007). Clutches are laid from late May to early July; although, across the range most clutches are laid in June (Harding and Bloomer 1979; Quinn and Tate 1991; Tuttle 1996; Walde et al. 2007). Incubation duration is temperature dependent, ranging from 47 to 166 days (Farrell & Graham, 1991; Harding & Bloomer, 1979). Typically, hatchlings emerge from September to October (Harding & Bloomer, 1979; Lovich et al., 1990), and there is some evidence of overwintering of hatchlings within the nests in Vermont (Parren & Rice, 2004), but 100% mortality of eggs overwintering in Quebec (Walde et al. 2007), and no evidence of overwintering in Pennsylvania (Lovich et al., 1990) and Ontario (Brooks et al., 1992).

The range of *G. insculpta* extends from Nova Scotia in the North and East, west to Minnesota, and south to Virginia and West Virginia (Fig. 1.5) (Collins & Conant, 1998). In West Virginia, the species is restricted to the ridge and valley province in the Eastern Panhandle in just seven counties: Jefferson, Berkeley, Hampshire, Hardy, Morgan, Mineral, and Pendleton (Fig. 1.6) (Green & Pauley, 1987). During the last period of glaciation, *G. insculpta* occurred as far south as Georgia then moved northward following the glacial retreat (Ernst et al., 1994; Holman, 1967; Klippel & Parmalee, 1981).

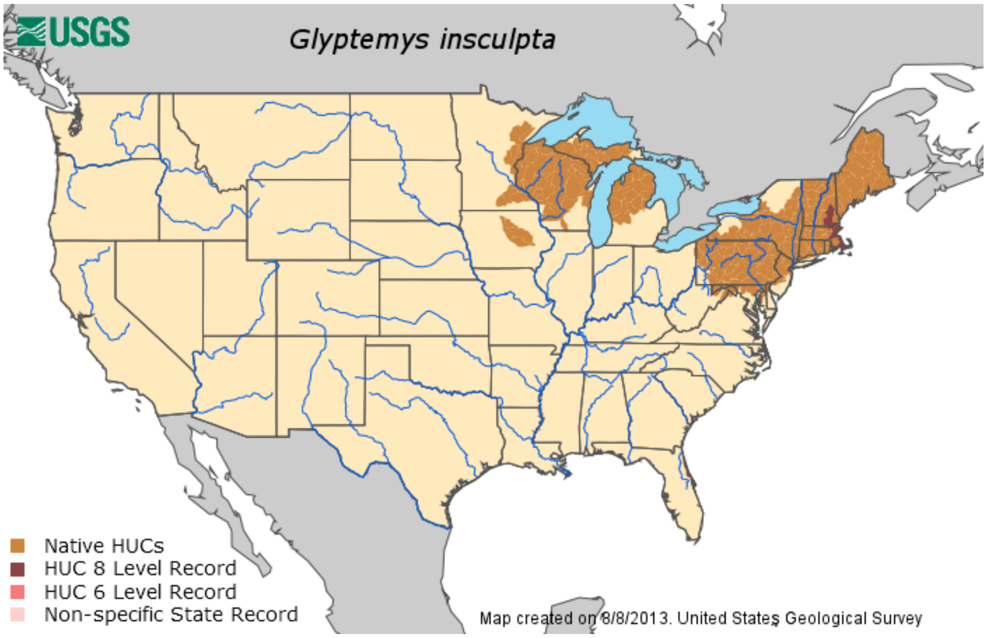

Figure 1.5. *Glyptemys insculpta* range within the US.

(McKercher & Fuller, 2014)

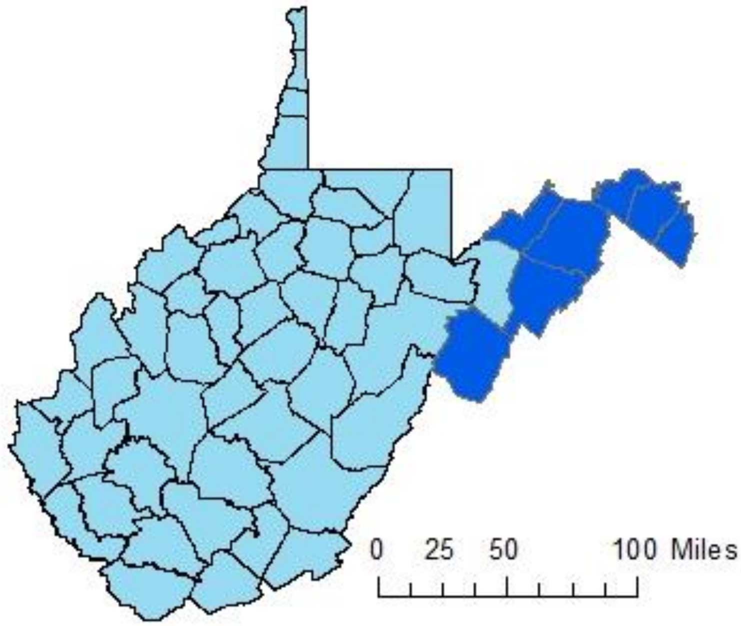

Figure 1.6. *Glyptemys insculpta* range within West Virginia.

Map created in ArcGIS by Jessica Curtis with data from Green and Pauley (1987).

Glyptemys insculpta prefers clear, moderate to fast moving streams that have year around hydroperiods (Ernst et al., 1994). Turtles select portions of the stream with gradients of less than 1% for their home ranges (Jones & Sievert, 2009). The stream channel should provide hibernacula sites, such as undercuts beneath the roots of trees, snags, beaver (*Castor canadensis*) dams, and muskrat (*Ondatra zibethicus*) burrows (Ernst et al., 1994). However, *G. insculpta* has been recorded overwintering exposed at the bottom of the stream channel (Greaves & Litzgus, 2007).

The stream habitat provides the cornerstone of a turtle's home range; home ranges are typically elongate, following the course of the primary stream (Kaufmann 1992b; Breisch 2006; Remsberg et al. 2006). Various natural and human impacted habitats around the stream will be also utilized including continuous forest, early successional forest, wetlands, and agricultural fields (Harding and Bloomer

1979; Ernst, Barbour, and Lovich 1994; Saumure and Bider 1998). Ideal habitat would be a mosaic of forest and open-canopy habitats adjacent to the stream (Ernst et al., 1994).

Habitat use can be roughly divided into four periods: (Ernst et al., 1994; Ernst, 1986; Niederberger & Seidel, 1999) winter brumation, spring aquatic, summer terrestrial and fall aquatic (Ernst et al., 1994; Ernst, 1986; Niederberger & Seidel, 1999). The first is a period of aquatic brumation during the winter months, where the turtles are primarily in hibernacula and underwater within the stream channel. Activity is typically limited; although movement has been observed during this period (Greaves & Litzgus, 2007). As water and air temperatures rise, turtles enter a spring aquatic period, which has them splitting their time equally between aquatic and terrestrial habitats. Females tend to bask more frequently during this time, which most likely benefits their developing eggs (Harding & Bloomer, 1979). Both genders return to the stream each evening. At the end of this period, typically late May or June, gravid females will migrate to nesting areas to lay their eggs (Walde et al. 2007).

During the summer terrestrial period, foraging leads turtles farther and farther away from the stream (Breisch, 2006; Tuttle, 1996). Full days can be spent on land with no return to the stream. True aestivation does not occur within a population of *G. insculpta* in Pennsylvania (Ernst, 1986). However, the deposition of multiple growth rings in a year (Harding & Bloomer, 1979) indicates abatement of growth during some portion of the active (growing) season, and aestivation remains one plausible explanation. The fall aquatic period is similar to the spring aquatic period with activity divided equally between terrestrial and aquatic habitats. Turtles prepare for brumation by congregating around their eventual hibernacula sites.

Glyptemys insculpta are opportunistic omnivores, consuming a wide variety of plant and animal matter. Many food sources are reported from wild populations including berries, leaves of various plants, fungi, agricultural products such as corn, mollusks, insects, worms, amphibians and carrion (Harding & Bloomer, 1979; Niederberger & Seidel, 1999). Notably, *G. insculpta* has been known to use a “worm stomping” behavior to force earthworms to exit their burrows; a turtle will stomp its feet and slam its plastron on the ground, mimicking the vibrations of rain (Ernst et al., 1994; Kaufmann, 1989). This behavior has been documented in captive and wild turtles, but not in most reported populations (Kaufmann, 1989; Kirkpatrick & Kirkpatrick, 1996).

All life stages of *G. insculpta* face at least some predation risk, but young turtles and eggs are at the greatest risk. Raccoons (*Procyon lotor*) and Striped Skunks (*Mephitis mephitis*) are dominate predators of nests, causing up to a 100% loss of eggs in one Michigan population (Harding & Bloomer, 1979), and even readily attack adult turtles (Harding, 1985). Other predators of adults include Fishers (*Martes pennant)* (Parren, 2013) and North American River Otters (*Lontra Canadensis*) (Carroll & Ultsch, 2006). Predator species of hatchlings and juveniles include racoons (*Procyon lotor*), Common Snapping Turtles (*Chelydra s. serpentina*), “various” birds including corvids, large fish, Virginia Opossums (*Didelphis virginiana*), Eastern Coyote (*Canis latrans*), feral cats (*Felis catus*), and feral dogs (*Canis lupus familiaris*) (Harding & Bloomer, 1979). There is some evidence that human impacted environments may increase predation risk to *G. insculpta* by artificially subsidizing mesopredators (Harding & Bloomer, 1979; Riley, Hadidian, & Manski, 1998; Smith & Engeman, 2002). Across many *G. insculpta* populations adult individuals show signs of predation attempts in the forms of scarring on limbs, damage to the carapace and plastron, and amputated limbs and tails (Breisch, 2006; Brooks et al., 1992; Farrell & Graham, 1991; Harding & Bloomer, 1979; Harding, 1985; Parren, 2013; Saumure & Bider, 1998; Tuttle, 1996; Walde et al., 2003).

Glyptemys insculpta appears to be declining in some portions of its range (Daigle & Jutras, 2005; Garber & Burger, 1995; Saumure, Herman, & Titman, 2007). Like many species of reptiles and amphibians, *G. insculpta* is threatened primarily by the destruction and alteration of preferred habitat (Garber & Burger, 1995; Gibbon et al., 2000). Additional threats include road mortalities, mortalities from agricultural machinery, excessive pressure from natural and exotic predators, mortality from floods, and collection for the pet industry (Garber & Burger, 1995; Harding & Bloomer, 1979; Jones & Sievert, 2009; Levell, 2000; Saumure & Bider, 1998; Saumure et al., 2007). The species has an IUCN Red List classification of "Endangered" due to range-wide declines and inherent fragility in life history traits (Van Dijk & Harding, 2011). *G. insculpta* has some degree of special status in multiple states and Canadian territories (Bowen & Gillingham, 2004; Green, 1996).

In West Virginia, the *G. insculpta* is ranked S3 or "vulnerable" (Sargent, 2014). Populations reported within the literature appear to be robust with large numbers of juveniles and the strong potential for recruitment into adulthood (Breisch, 2006; Niederberger & Seidel, 1999). The Eastern Panhandle has experienced rapid development and human population growth; in Berkeley County where the study takes place human population has increased 37.2% from the 2000 to 2010 censuses (U.S. Census Bureau, 2012). The increasing human pressures in the area warrant monitoring for vulnerable species, like *G. insculpta.*

Objectives

This study continued observations of a population of *G. insculpta* in the Eastern Panhandle of West Virginia that was previously studied in 2010 and 2011. The primary objective was to ascertain what, if any, effect higher elevation had on the natural history of this population. I collected aspects of natural history such as morphometrics, growth, estimations of total population, and demography and compared them to other *G. insculpta* populations reported in the literature.

This study also had two secondary objectives. The first was to attempt to see if commercially available trail cameras would confirm the presence of *G. insculpta* in a known location of occupancy. Camera traps could cost-effectively "survey" new watersheds for researchers hoping to find new *G. insculpta* populations. The last objective was to determine if Wild-ID, pattern recognition software, could accurately identify individual *G. insculpta*. Wild-ID has not been used on *G. insculpta* at this time and could provide a valuable supplement to traditional marking methods.

CHAPTER 2:
METHODS

Study Site

The study site was located on a 2.5 km stretch of stream located in Berkeley County in the Eastern Panhandle of West Virginia. The exact location of the study site is being withheld to protect the study animals from collection for the pet trade (Levell, 2000; Niederberger & Seidel, 1999). The elevation of the site was approximately 400 m. The stream was 1 to 3 m wide, and had a year-around hydroperiod, except for in very dry years. The 2013 active season was not sufficiently dry to prevent having flowing water in some portion of the channel.

The stream was impacted by beaver (*Castor canadensis*) activity to various degrees throughout the study area. In the southern portion of the study area, the creek was dammed in one location such that it backed up into first order tributaries. In other places dams only created slightly deeper pools than the channel would have normally afforded. The stream was primarily bordered by continuous deciduous forest, with some exceptions. In the Northern extent of the study area, wetland habitats bordered the stream (red polygon in Fig. 2.1), some portions with an overreaching tree canopy, some with only reeds as vegetative coverage. A grass field was also in the northern portion of the study area and was adjacent to both the primary stream and a nearby tributary (yellow polygon in Fig. 2.1). In the southern portion of the study area, beaver activity had dammed the stream and killed off the trees around the stream (green polygon in Fig. 2.1). The dam had long since broken and the riparian meadow ran for 1.2 km along the stream length. The beaver lodge (white X in Fig. 2.1) and current largest dam were just adjacent to this meadow and dammed a tributary to the stream but not the main stem of the stream.

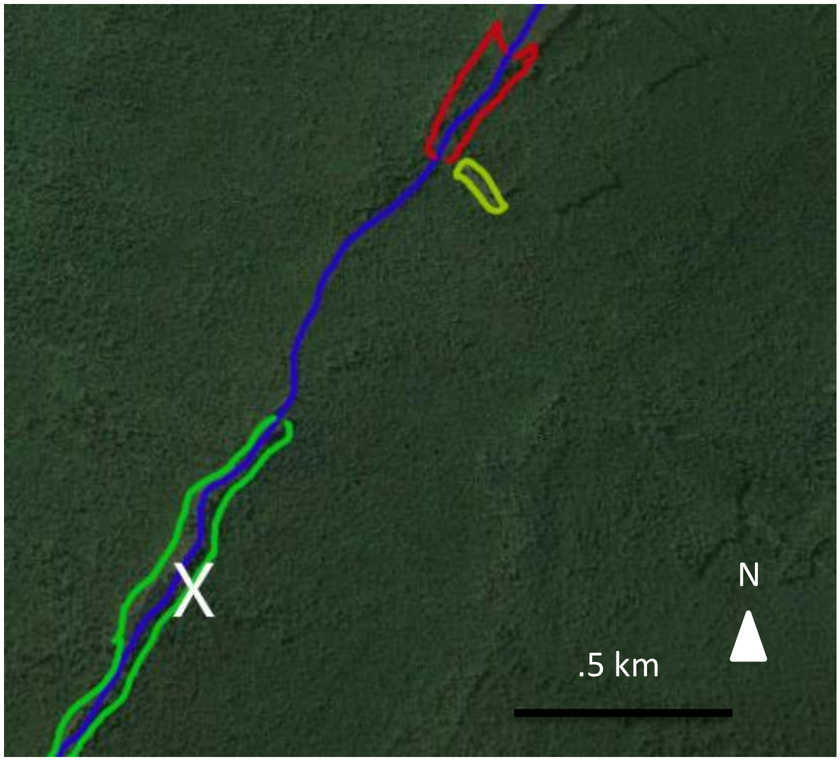

Figure 2.1. Study site. The blue line represents the approximate location of the main stem of the stream. The white X signifies the beaver lodge. The green polygon represents the tree die-off adjacent to the stream. The yellow polygon bounds the grass field. The red polygon contains the wetland area.

Modified from an aerial photograph available in GoogleEarth.

Capture and Treatment

Turtles were hand-captured in opportunistic visual encounter surveys. Field technicians walked both sides of the stream across the study area, typically 1 to 10 m from the main stem of the stream, and checked distances of up to 200 m from the stream randomly throughout the survey area (Flanagan, Roy-McDougall, & Forbes, 2013). In a radio telemetry survey conducted at the same site in 2010 and 2011, 150 m was the maximum distance turtles roamed from the stream (See Appendix D, Table D.1). Therefore, 200 m from the stream was determined to be sufficiently inclusive of all habitats used by turtles. Special effort was made to check terrestrial habitats that had not been surveyed in the 2010 and 2011 seasons like the tree die-off area (green polygon Fig. 2.1) and the northerly wetland habitat (red polygon Fig. 2.1).

Surveys were conducted from 05/05/2013 to 10/19/2013. There were 48 survey days in this study, with a mean number of survey days per month of eight (Fig. 2.2). Total number of person hours was 125.5, with a mean number of person hours per month of 20.9 hours (Fig. 2.3).

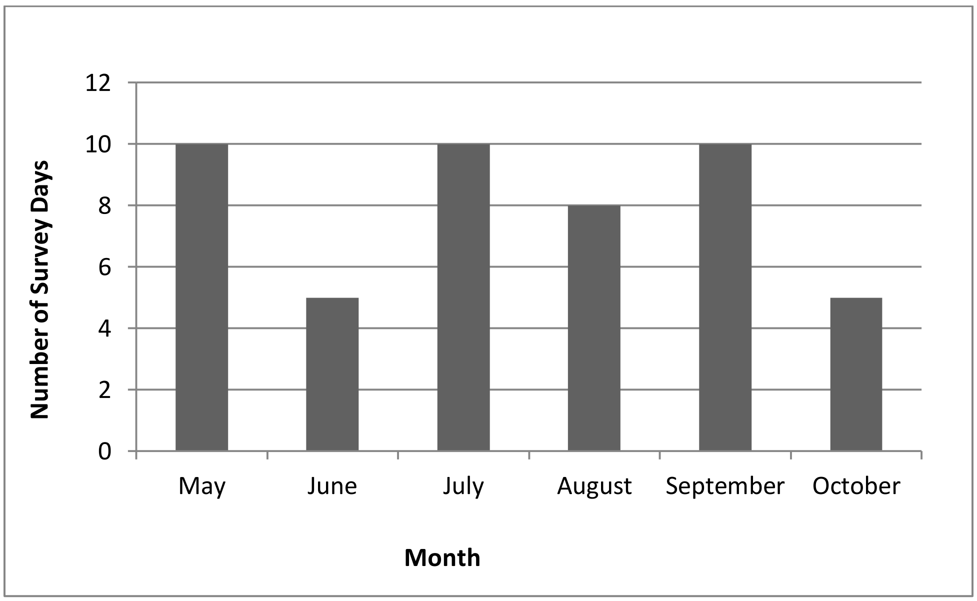

Figure 2.2. Number of survey days per month.

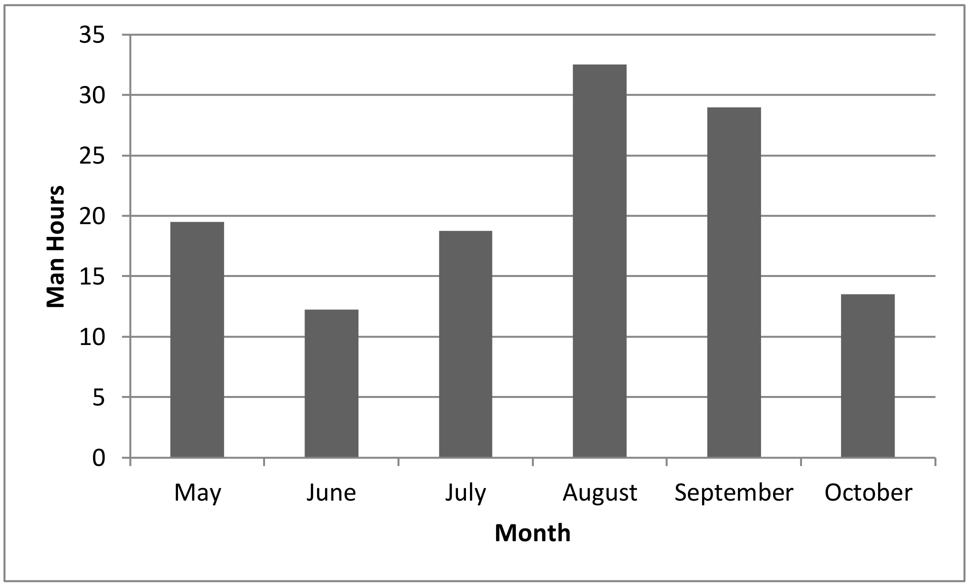

Figure 2.3. Number of person hours per month

In addition to visual encounter surveys, a baited trap (South Bend, Model # CD-2369) was placed in the main stem of the stream (Fig. 2.4). It was only of sufficient size to catch hatchlings and very young turtles. The trap was baited with sardines that had been packed in water and was deployed for six days at various times in June and July, and only on days when the trap could be checked the following day, to ensure that any animal captured would spend no more than 24 hours in the trap.

Figure 2.4. Baited trap in stream channel.

Photograph by Jessica Curtis 2013.

A trail camera (Tasco, Model # 119203C) was deployed at two points in an area that was known from a previous study to be frequented by *G. insculpta.* The trail camera was oriented initially along a game trail (Fig. 2.5). The camera was subsequently moved so that it pointed at the trap in the channel (Fig.2.6). The trail camera was active from 5/9/2013 to 7/29/2013 for 82 camera trap days.

Figure 2.5. First site for the trail camera. The trail camera is facing a game trail that runs perpendicular to the stream. Stream is located in the top left corner of the photograph.

Photograph by Jessica Curtis 2013.

Figure 2.6. Second site for the trail camera. The trail camera faced the channel and the baited trap. Photograph by Jessica Curtis 2013.

When a turtle was initially captured, it was marked with up to three notches in a modified Cagle marking system (Fig.2.7) (Cagle 1939). The notches were created in the marginal scutes with a triangular file. Turtles were then weighed with a 2 kg spring scale (Educational Innovations, Model# SP-730), and various morphometric lengths were measured with digital calipers (Neiko, Model # 01409A) (Fig.2.8): carapace length, carapace width, plastron length, plastron width, and height at bridge. For the carapace length, I used minimum straight-line distance from the crotch of the nuchal scute and a marginal scute to the crotch of the two most posterior marginal scutes. The plastron width measurement extended all the way to the terminal points of the pectoral scutes. Carapace width measurement was taken on the carapace but at the same point as the plastron width measurement. Plastron length measurement was the minimum straight-line distance between the gular and the anal scutes. I also noted other aspects of turtle condition such as: behavior, injuries, illness, deformities, and presence/absence of parasites. (See Appendix A for photographs of measurement locations.)

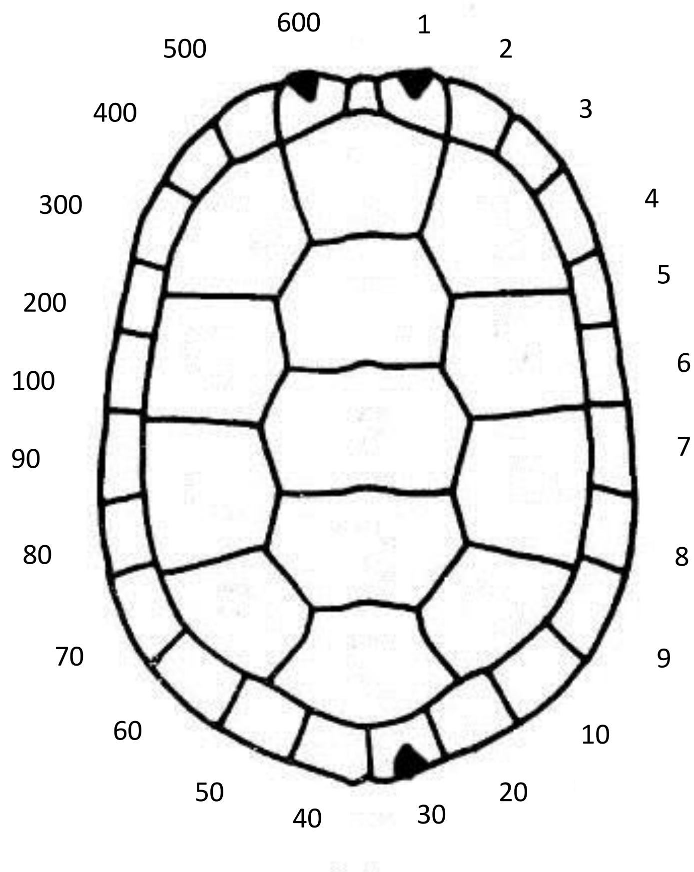

Figure 2.7. Modified Cagle (1939) marking system. The turtle marked in this example would be #631. Picture modified from http://www.bayramgocmen.com/herptiles_cyprus.html

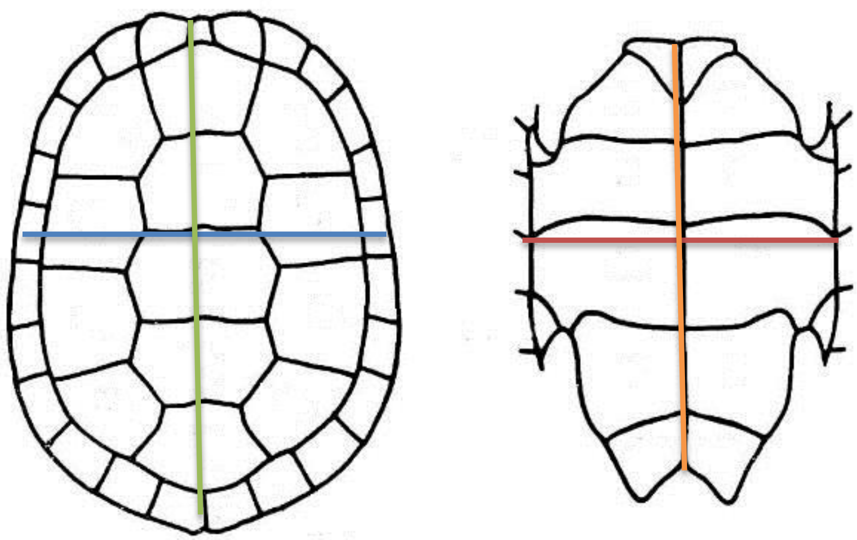

Figure 2.8. Morphometric measurements taken: carapace length (green), carapace width (blue), plastron length (orange), and plastron width (red). Not pictured is height at bridge which was measured vertically at the same point on the bridge as the two width measurements.

Picture modified from http://www.bayramgocmen.com/herptiles_cyprus.html

Attempts were made to accurately count the number of annuli, but any turtle with over 15 annuli was categorized simple as “15+,” owing to the difficulty of distinguishing individual annuli after that number (Harding & Bloomer, 1979). I photographed both the plastron and carapace of all turtles, and, if there were any, unusual characteristics of an individual (Nikon, Model# L110). Gender was determined in males by identifying secondary sexual characteristics described by Harding and Bloomer (1979) and in females by lack of male features and being larger than 160 mm in carapace length. Juveniles were all animals below 160 mm or less than 600 g (Harding & Bloomer, 1979; Lovich et al., 1990). Hatchlings were individuals with no annuli.

At the point of capture, I recorded coordinates in latitude/longitude with a hand held GPS receiver (Garmin, Model# 010-00631-00). I also recorded various habitat characteristics (See Appendix

A, Table A.1 for a description of habitat types), environmental conditions, and recent weather events.

Morphometric data were not taken at every capture of every turtle, but were recorded multiple times throughout the survey to determine the variability of measurement due to technician error. I also photographed individuals over multiple captures, to ensure sufficient replicates for the pattern recognition software test.

Software Assisted Identification

Photographs of the turtle plastrons were cropped to exclude background and other parts of the turtles shell (primarily the underside of the marginal scutes) and rotated so the anterior end faced the same direction on all photographs. Cropped photographs were compared and matched using pattern-recognition software, 'Wild-ID' (Bolger, Morrison, Vance, Lee, & Farid, 2012). Wild-ID is an open-source software that uses pattern-matching algorithms to determine most similar image pairs within a dataset (Bolger et al., 2012). The software matches one photograph to all photographs within the data set and then assigns the match a score of 0.0 to 1.0. Higher scores indicate a greater similarity and lower scores indicate less similarity. The software then ranks the photographs with the highest similarity scores first and allows the user to manually select a matching photograph. For my analysis, the highest ranked photographed was considered the software's "choice" and rates of accuracy were determined from that first choice.

Statistical Analysis

Differences between morphological characteristics were tested for using Student's t-test. Differences between categorical data (such as sex ratios) were tested with Fischer's exact test. Statistical significance was accepted at $p < 0.05$.

Ethics Statement and Permitting

The animal treatment protocol for this study was reviewed and approved by the Institutional Care and Use Committee of Marshall University (Permit#546). All care was taken to minimize handling time and subsequent stress to turtles. Turtles were not handled during especially critical times in their life history such as nesting and mating.

This study was conducted under a “Scientific Collecting Permit” (Permit# 2013.163) issued by West Virginia Department of Natural Resources, and all special provisions contingent upon that permit’s issuance were abided by.

CHAPTER 3:
CAPTURE SUCCESS

Results

Only visual encounter surveys were successful in capturing *G. insculpta.* The baited trap failed to catch anything, including non-target species. The trail camera failed to photograph turtles, but did photograph White-tailed Deer (*Odocoileus virginianus*), bobcat (*Lynx rufus)*, beaver (*Castor canadensis)*, and Eastern Towhee (*Pipilo erythrophthalmus*).

Turtles were captured 68 times (Table 3.1). I observed 31 turtles during this survey: 19 adult males, and 13 adult females. No juveniles or hatchlings were captured. Male turtles were captured more often than females, accounting for 55.9% of all captures. The difference was not statistically significant (p = 0.6065). An adult female (WT-50) was captured the most times (n = 8), and other individuals were seen only once. In the 2010-2011study, 21 turtles were marked in the study area. I recaptured 12 of those previously marked turtles and observed 19 new turtles.

Table 3.1. *Glyptemys insculpta* captures separated by gender.

Males (*n* =18)	Captures	Females (*n* = 13)	Captures
WT-2	2	**WT-3**	4
WT-4	4	**WT-10**	1
WT-5	1	**WT-11**	2
WT-7	4	**WT-14**	1
WT-12	3	**WT-15**	3
WT-13	2	**WT-17**	1
WT-16	2	**WT-21**	3
WT-18	3	**WT-23**	2
WT-19	3	**WT-24**	2
WT-22	1	**WT-26**	1
WT-25	1	**WT-28**	1
WT-27	2	**WT-50**	8
WT-32	2	**WT-402**	1
WT-40	1		
WT-90	1		
WT-200	3		
WT-300	2		
WT-602	1		
Total	38		30

The highest number of turtles was caught in the month of August, with 22 captures. The lowest number was caught in October with only three turtles. Average number of turtles caught per month was 13 (Fig. 3.1). Typically, temperate turtle capture rates have a bimodal distribution with a large peak in spring and a smaller peak in the fall (Breisch, 2006; Plummer, 1977). I did not see that distribution in my results for two reasons: (1) in August I began surveying a new area where turtles were frequently encountered, and (2) due to scheduling conflicts, survey days were restricted to weekends in the months of September and October; before this time, survey days occurred when the weather was most optimal for turtle movement, which likely increased the probability of turtles being located.

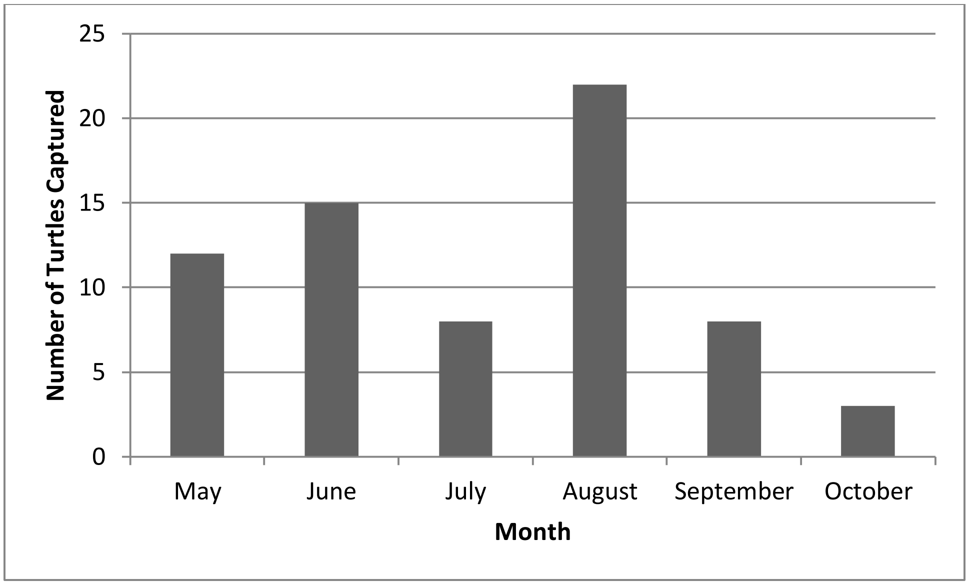

Figure 3.1. Number of turtles captured per month.

The average rate of turtle capture per person hour was 0.57 turtles per person hour. The highest rate was seen in the month of June with 1.22 turtles captured per person hour, and the lowest in October with 0.22 turtles per person hour. June's rate is likely artificially inflated for three reasons: (1) low number of search days in that month (5 days) (Fig. 3.2), (2) relatively high productivity of those days with 15 turtles captured, and (3) four of the five search days only had one technician, which reduces the total number of search hours.

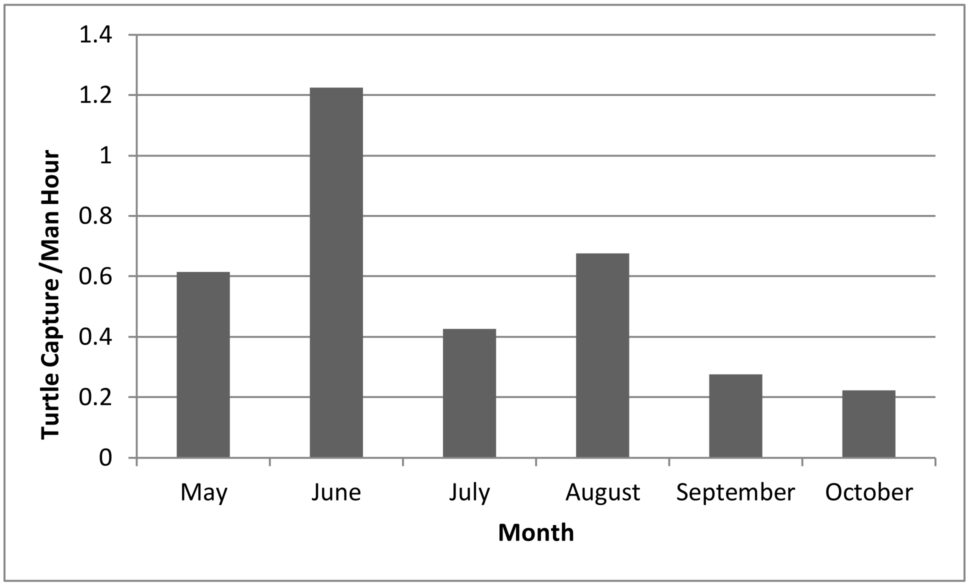

Figure 3.2. Rate of turtle captures per person hour.

Discussion

Visual encounter surveys with hand captures are typically used to catch *G. insculpta*. All turtles captured in this study were hand captures. Various trapping methodologies are frequently used with success for many species of turtles (Bluett, Schauber, Bloomquist, & Brown, 2012; Gamble, 2006). The closely related Bog Turtle (*Glyptemys muhlenbergii*) is often trapped during studies (Pittman & Dorcas, 2009; Somers & Mansfield-Jones, 2008). Trapping is infrequently used and has limited success for *G. insculpta*. Breisch (2006) deployed an array of traps in her study area and only captured one juvenile in a hoop trap. Parren (2013) utilized “modified” minnow traps, but does not report rate of trap success. Juvenile *G. insculpta* regularly avoid pitfalls associated with drift fences (Brewster and Brewster 1991). In the 2010 to 2011 seasons, drift fence with pitfall traps and basking traps were deployed in the area and neither was successful in capturing turtles.

Trap days were limited in this study and pulled from the field early because of constraints in checking traps on back to back days. There is probably some combination of trap form, baiting and deployment time that can successfully trap *G. insculpta*, particularly the more aquatic hatchlings and juveniles. So far, that combination has yet to be found.

Camera traps, using various styles of cameras including commercially available trail cameras, have been used to survey many species across taxa, but particularly large reclusive mammals like predatory cats (Rowcliffe & Carbone, 2008). Camera traps have been used to monitor crocodilians, sea turtles, and their nests (Charruau & Hénaut, 2012; Platt, Lynam, Temsiripong, & Kampanakngarn, 2002; Ratnaswamy, Warren, Kramer, & Adam, 1997; Somaweera, Webb, & Shine, 2011). Camera traps have been deployed around pitfall trap arrays to monitor predator influence on herpetofauna capture rates (Ferguson, Weckerly, Baccus, & Forstner, 2008; Fogarty & Jones, 2003), and to monitor use of road crossing tunnels by salamanders (Pagnucco, Paszkowski, & Scrimgeour, 2011). Among turtles, camera traps have been used to monitor nesting sites of the Ouachita Map Turtles (*Graptemys ouachitensis*) (Geller, 2012a, 2012b).

Despite these areas being within the known home ranges of multiple turtles, the trail camera deployed in this study failed to photograph *G. insculpta* at either location. The camera may have been oriented poorly and the IR beam was not broken, even though turtles passed near the camera. Additionally, the cameras were deployed at a time when *G. insculpta* are more terrestrially active and less likely to be near the stream corridor. Furthermore, density of turtles at this location may have been low enough to preclude a “capture” with only 82 camera trap days.

Camera traps are better suited at places where concentrations of individuals are naturally high as in this case with nesting areas, or are artificially high as in the case with baits and pitfall trap arrays. Camera traps would certainly be useful observation tools around *G. insculpta* nesting sites, but for the determination of occupancy in a given area the following three things are likely required: (1) camera deployment in the early spring and fall when *G. insculpta* are closest to the stream (Flanagan et al., 2013), (2) more cameras for more camera trap days, and (3) cameras that use motion detection interspersed with cameras that use preset intervals for photographs. Photographing at preset intervals will ensure that the turtles, which may be relatively small in the field of view and might not break the IR beam, could still be documented.

CHAPTER 4:
MORPHOMETRICS

Results

Adult male *G. insculpta* had a mean weight of 1165.56 ± 106 g (1032.5 -1400 g). Mean male carapace length was 197 ± 9 mm (184 – 210 mm). Mean male carapace width was 140 ± 7 mm (130 – 151 mm). Mean male height at bridge was 70 ± 4 mm (62 -77.5 mm). Mean male plastron length was 169 ± 6 mm (162 – 174 mm). Mean male plastron width was 113 ± 6 mm (103 – 120 mm) (Table 4.1).

Adult female *G. insculpta* had a mean weight of 1068.56 ± 125.9 g (810 – 1240 g) (Table 4.2). Mean female carapace length was 186 ± 10 mm (167 – 201 mm). Mean female carapace width was 136 ± 6 mm (131 – 146 mm). Mean female height at bridge was 71 ± 5 mm (64 – 77 mm). Mean female plastron length was 166 ± 9 mm (154 – 174 mm). Mean female plastron width was 117 ± 10 mm (104 – 125 mm) (Table 4.2)

Male *G. insculpta* were significantly heavier ($p = 0.0167$) and had significantly longer carapace lengths (p = 0.0013) than females turtles. However, the remaining four morphometric measurements were not significantly different between the sexes. There are a few possible explanations for the lack of equal growth among the measurements that could also account for the increased weight of the male turtles. Males had more robust heads and limbs; that certainly added to the weight. Additionally, the development of a concavity in the plastron of males results in reduced plastron length relative to carapace length (Fig. 4.1). The difference between male and female plastron length was not significant ($p = 0.9609$). However, the mean ratio of plastron length to carapace length (PL/CL) in males was significantly ($p = 0.0003$) smaller than in females. The ratio of bridge height to carapace length (HaB/CL) in males was also significantly ($p = 0.0019$) smaller than in females.

Table 4.1. Adult male *Glyptemys insculpta* weights and lengths. (*n* = 18)

Turtle ID#	Weight (g)	CL (mm)	CW (mm)	HaB (mm)	PL (mm)	PW (mm)	# of Measurements
WT-2	1105	184	136	73.5	164	110	2
WT-4	1180	203.33	145.67	72.33	171	118.33	3
WT-5	1200	194	143	65	173	112	1
WT-7	1032.5	194	131.33	63.5	167.33	111	3
WT-12	1200	202.5	145	77.5	173	116.5	2
WT-13	1100	190	138.5	68	165.5	112	2
WT-16	1150	196.25	141.75	72.75	169.25	114.25	2
WT-18	1125	193.13	140.13	70.38	167.375	113.13	2
WT-19	1137.5	194.69	140.94	71.56	168.31	113.69	2
WT-22	1160	202	132	70	167	108	1
WT-25	1200	204	150	62	173	120	1
WT-27	1240	193	137	74	168	115	2
WT-32	1250	206	141	72	172	114.5	2
WT-40	1040	188	138	66	162	103	1
WT-90	1240	210	151	70	174	118	1
WT-200	1140	199	144.5	68	168	110.5	2
WT-300	1080	188.5	130	65.5	164	103.5	2
WT-602	1400	210	140	71	181	113	1
Mean ± 1 SD	1165.56 ± 106	197 ± 9	140 ± 7	70 ± 4	169 ± 6	113 ± 6	
Range	1032.5 - 1400	184 – 210	130 – 151	62 -77.5	162 – 174	103 – 120	

Note: CL = Carapace Length, CW = Carapace Width, HaB = Height at Bridge, PL = Plastron Length, PW = Plastron Width.

Table 4.2. Adult female *Glyptemys insculpta* weights and lengths. (n = 13)

Turtle ID#	Weight (g)	CL (mm)	CW (mm)	HaB (mm)	PL (mm)	PW (mm)	# of Measurements
WT-3	973.33	186.33	134	66	171	112.33	3
WT-10	1200	201	146	77	174	118	1
WT-11	1100	189	140	80	164.5	142	2
WT-14	1060	185	131	69	164	118	1
WT-15	1120	191.67	139	75.33	167.5	126	3
WT-17	950	180	133	64	163	106	1
WT-21	900	172	124	67	156	107	1
WT-23	1110	191	138.5	72.5	176	120.5	2
WT-24	1180	189.5	136.5	70	170	113	2
WT-26	1100	183	137	70	158	115	1
WT-28	1240	201	143	70	185	125	1
WT-50	1148	185.6	139.4	74.8	159.8	116.8	5
WT-402	810	167	127	65	154	104	1
Mean ± 1 SD	1068.56 ± 125.9	186 ± 10	136 ± 6	71 ± 5	166 ± 9	117 ± 10	
Range	810 – 1240	167 – 201	131 – 146	64 – 77	154 – 174	104 – 125	

Note: CL = Carapace Length, CW = Carapace Width, HaB = Height at Bridge, PL = Plastron Length, PW = Plastron Width.

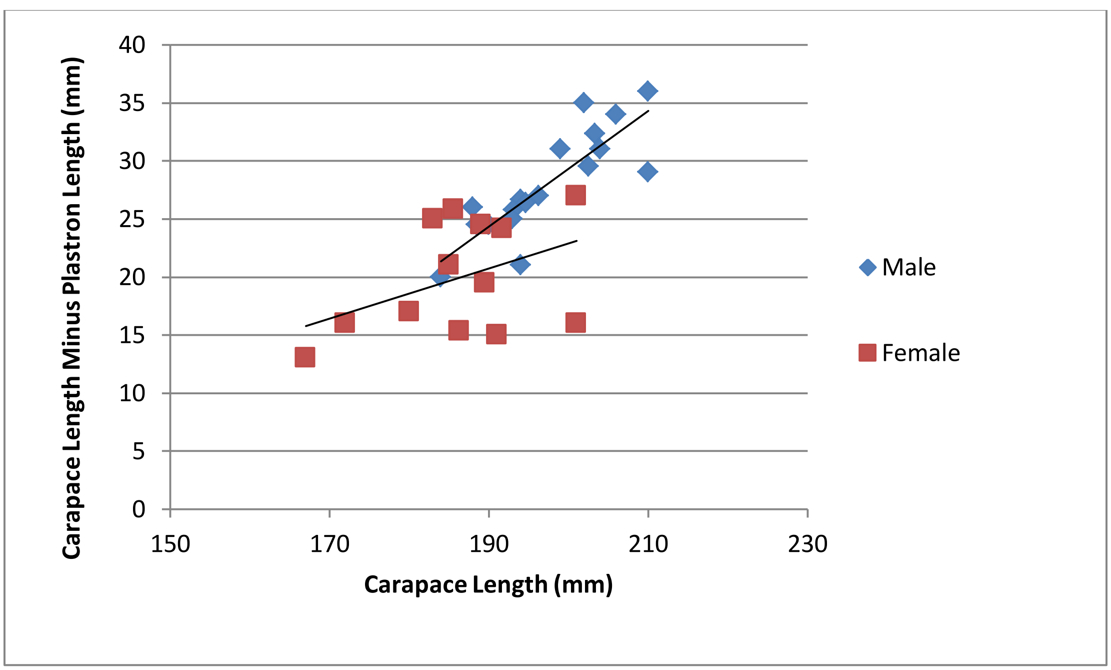

Figure 4.1. Relationship of carapace length to carapace minus plastron length in adult male and female *Glyptemys insculpta.* (p = 0.9609)

Discussion

As a brief caveat to the following discussion on morphometrics, different researchers choose to measure carapace length at one of two places: a straight line measurement from the crotch of the nuchal and a marginal scute on the anterior end to the crotch of the supracaudal marginal scutes, or maximum straight line distance from the edges of both the anterior and posterior marginal scutes. I'll refer to measurements of the former dimension as minimum carapace length and the later as maximum carapace length. Some authors explicitly state which measurement they chose, others do not. I believe minimum carapace length is a better measure of carapace length in *G. insculpta* due to the high rate of shell damage found in most turtles in most populations (Breisch, 2006; Brooks et al., 1992).

I estimate that maximum carapace length is ~5-10 mm larger than minimum carapace length in adult turtles. The implications of this disparity in measurement styles on associations between data sets are unclear, and I have no data to make an accurate correction. The following presents data "as is" from the primary source.

Adult *G. insculpta* tend to have longer mean carapace lengths with increasing latitude and concomitant decreasing frost free days (Brooks et al. 1992; Walde et al. 2003). It was expected that turtles from this study would have slightly larger morphometric characteristics than other turtles at the same latitude, due to this population living at a higher altitude and should experience slightly less frost free days.

This study found a mean male minimum carapace length of 197 ± 9 mm and a mean minimum female carapace length of 186 ± 10 mm. Another study conducted on West Virginia *G. insculpta* found mean male maximum carapace length of 190.6 ± 12.2 mm and mean female maximum carapace length of 179.9 ± 9.6 mm (Breisch, 2006). For both measurements the differences were nearly significant (p = 0.0714, p = 0.0911, respectively). Because Breisch (2006) and I used two different measurements for carapace length, the possibility exists that the differences in carapace length between the two populations would actually be significantly different if we were performing the test on the same measurement. This is especially true because the p values are already nearly significant.

Breisch (2006) found males weighed 932.3 ± 178.2 mm, and females weighed 846.7 ± 173.7 mm. This study found a mean male weight of 1165.56 ± 106 mm and a mean female weight of 1068.56 ± 125.9 mm. Both measurements were significantly different from Breisch's values ($p < 0.0001$, $p = 0.0008$, respectively).

I am skeptical of the validity of my own weight measurements. Breisch (2006) observed a mean carapace length/weight ratio for males of 0.20 and females of 0.21. Walde et al. (2003) observed a mean carapace length/weight ratio for males of 0.18 and females of 0.19. In this study the ratio was 0.17 for both males and females. During the 2010-2011 survey, the ratio was 0.19 for males and 0.2 for females. Either turtles in this study are heavier for their length in only this year, or more likely the spring scale was not functioning properly, and was giving an inappropriately large reading.

A study conducted in Virginia found males to have a maximum carapace length of 196 mm and females to have a maximum carapace length of 183 mm (Lovich et al., 1990). I found males had a minimum carapace length of 197 ± 9 mm and females had a minimum carapace length of 186 ± 10 mm. Because Lovich, Ernst and McBreen (1990) did not provide standard deviations for their means, I cannot determine if the populations are significantly different. As with the other West Virginia population (Breisch, 2006), carapace length was measured as the maximum length. Therefore, my population is likely slightly larger but whether that difference is significant is unclear.

The following frost free days are at best estimations based on the limited number of weather stations in the area ("Find the Freeze and Frost Dates for Your Area," 2014) and the elevations were taken from Google Earth. The elevation of my study area is 400 m and mean frost free days of 161. Breisch's (2006) study had an approximate elevation of 120 m and mean frost free days of 183, and Lovich, Ernst and McBreen (2003) an elevation of 90 m and mean frost free days of 186.

The largest male turtle in my study had a minimum carapace length of 210 mm and the largest female had a minimum carapace length of 201 mm. Breisch (2006) used maximum carapace length for her measurement: her largest male was 206.5 mm and her largest female was 199 mm. The study of Virginia *G. insculpta* does not report the range of carapace length.

I hypothesized that the increase in elevation at my study site would decrease the active season resulting in turtles that were later to mature and so larger than other turtles at the same latitude (39º). Because of issues with where carapace length is measured, it remains unclear to what extent the differences in frost free days estimated for the various populations significantly affects mean adult size. That being said, there is likely a modest difference in mean adult turtle size in this population versus other *G. insculpta* populations at the same latitude.

In my study, male *G. insculpta* had significantly longer carapaces and were significantly heavier than females. Male carapace length was also significantly longer than female carapace length in West Virginia (Breisch, 2006), New Jersey (Farrell & Graham, 1991; Harding & Bloomer, 1979), Michigan (Harding & Bloomer, 1979), New Hampshire (Tuttle and Carroll 1997), Ontario (Brooks et al., 1992), and Quebec (Walde et al. 2003).

Female *G. insculpta* maintain juvenile/sub-adult characteristics into adulthood (Harding & Bloomer, 1979), which includes a ratio of plastron to carapace of 0.89 and males have a lower ratio of 0.85. In males, the reduction of the growth of the plastron relative to the carapace is thought to be due to the development of concavity in the plastron, and has been documented in multiple studies (Breisch, 2006; Lovich et al., 1990).

CHAPTER 5:
GROWTH

Results

The carapaces of male *G. insculpta* on average grew 0.88% ± 0.7 per year (Table 5.1), and the carapaces of adult females on average grew 1.21% ± 1.3 per year (Table 5.2). Female carapaces grew more on average than male carapaces, but the difference was not significant (% Growth / Year $p = 0.6962$). The turtle designated WT-3 grew the most over three years with a 10.3% increase in size. She was one of the smallest turtles initially with a 169 mm carapace length. However, another turtle that started on the small end of the spectrum, WT-402, failed to grow at a rate that matched her smaller size. The cause of this stagnation in growth is unclear. The other two slowest growers, WT-7 and WT-50 are both turtles missing a single limb. I speculate that missing a limb has made them sufficiently less mobile such that they would have reduced effectiveness in foraging compared to other turtles, and would therefore grow more slowly. However, WT-300 is also missing a limb and still managed to achieve the second largest growth rate.

Table 5.1. Growth of the carapace in adult male *Glyptemys insculpta* that were caught in a previous study. (n = 8)

Turtle ID #	2010 CL (mm)	2013 CL (mm)	Growth (mm)	Growth (mm)/ Year	% Growth	% Growth / Year
WT-2	182	184	2	0.67	1.1	0.4
WT-4	196	203.33	7.33	2.44	3.7	1.2
WT-5	190	194	4	1.33	2.1	0.7
WT-7	193	194	1	0.33	0.5	0.2
WT-40	186	188	2	0.67	1.1	0.4
WT-90	205	210	5	1.67	2.4	0.8
WT-200	193	199	6	2	3.1	1.0
WT-300	176	188.5	12.5	4.17	7.1	2.4
Mean ± 1 SD			4.98 ± 3.5	1.66 ± 1.2	2.65 ± 2.0	0.88 ± 0.7
Range			1 – 12.5	0.33 – 4.17	0.5 – 7.1	0.2 – 2.4

Note: CL = Carapace Length.

Table 5.2. Growth of the carapace in adult female *Glyptemys insculpta* that were caught in a previous study. (n = 4)

Turtle ID #	2010 CL (mm)	2013 CL (mm)	Growth (mm)	Growth (mm)/ Year	% Growth	% Growth / Year
WT-3	169	186.33	17.33	5.78	10.3	3.4
WT-10	196	201	5	1.67	2.6	0.9
WT-50	184	185.6	1.6	0.53	0.9	0.3
WT-402*	166	167	1	0.5	0.6	0.3
Mean ±1 SD			6.23 ± 6.6	2.12 ± 2.2	3.57 ± 3.9	1.21 ± 1.3
Range			1 – 17.33	0.5 – 5.78	0.6 – 10.3	0.3 – 3.4

Note: CL = Carapace Length, *WT-402 was captured first in 2011 and not in 2010; her carapace length represents a change over two years.

Mean male plastron growth was 0.95% ± 1.0 mm per year (Table 5.3) and mean female plastron growth was 1.53% ± 1.4 mm per year (Table 5.4). Male plastrons grew more than female plastrons (% Growth / Year, p = 0.4771). Plastron length did not grow at rate significantly different than the carapace in either males or females (% Growth/ Year, males: p = 0.8617, females: p = 0.7868). The relationship of growth of carapace and plastron was not significantly different between the sexes (p =0.8317) (Fig. 5.1). It is likely that the shift in the ratio of plastron to carapace length occurs at maturation for males when secondary sexual characteristics develop. After that time both plastron and carapace grow at equal rates.

Table 5.3. Growth of the plastron in adult male *Glyptemys insculpta* that were caught in a previous study. (n = 8)

Turtle ID #	2010 PL (mm)	2013 PL (mm)	Growth (mm)	Growth (mm)/ Year	% Growth	% Growth / Year
WT-2	162	164	2	0.67	1.23	0.41
WT-4	167	171	4	1.33	2.40	0.80
WT-5	166	173	7	2.33	4.22	1.41
WT-7	165	167.33	2.33	0.78	1.41	0.47
WT-40	159	162	3	1.00	1.89	0.63
WT-90	172	174	2	0.67	1.16	0.39
WT-200	165	168	3	1.00	1.82	0.61
WT-300	151	164	13	4.33	8.61	2.87
Mean ±1 SD			4.54 ± 3.8	1.51 ± 1.2	2.84 ±2.5	0.95 ± 1.0
Range			2 – 13	0.67 – 4.33	1.16 – 8.61	0.39 – 2.87

Note: PL = Plastron Length.

Table 5.4. Growth of the plastron in adult female *Glyptemys insculpta* that were caught in a previous study. (n = 4)

Turtle ID #	2010 PL (mm)	2013 PL (mm)	Growth	Growth / Year	% Growth	% Growth / Year
WT-3	157	171	14	4.67	8.92	2.97
WT-10	171	174	3	1.00	1.75	0.58
WT-50	159	159.8	0.8	0.27	0.50	0.17
WT-402*	147	154	7	3.50	4.76	2.38
Mean			6.20 ± 5.8	2.36 ± 2.1	3.98 ± 3.7	1.53 ± 1.4
Range			0.8 – 14	0.27 – 4.67	0.50 – 8.92	0.17 – 2.97

Note: PL = Plastron Length. *WT-402 was captured first in 2011 and not in 2010; her carapace length represents a change over two years

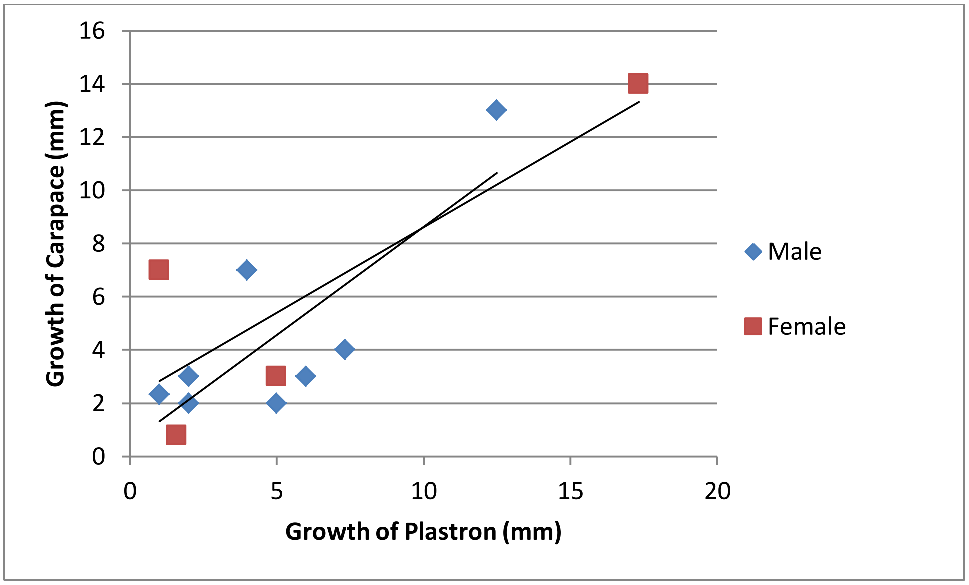

Figure 5.1. Relationship between the growth of carapace length and plastron length in male and female *Glyptemys insculpta.* (p =0.8317)

Discussion

Large rates of growth were recorded in my study for both male and female *G. insculpta*. Male *G. insculpta* plastrons on average grew 2.84% ± 2.5 per year (or 1.51 ± 1.2 mm per year) (Table 5.3), and adult females on average grew 3.98% ± 3.7 per year (or 2.36 ± 2.1 mm per year) (Table 5.4).

Different researchers choose to measure plastron length at different points on the plastron. Some researchers measure plastron length as the maximum straight-line distance not from the crotch of the gular scutes, but from the proximal portion of one gular scute to the distal end of one anal scute. Measuring the plastron in this way likely adds little length on the anterior end but can add a sizable amount to the length on the posterior end. This is especially the case for mature males. In males, the anal scutes are highly elongate and the gap between them more severe than in adult females. This likely increases the range of movement for the tail when mating.

I will refer to the measurement of plastron length from tip of one gular scute to the distal end of one anal scute as maximum plastron length and a measurement from the crotch of gular scutes to the crotch of the anal scutes as minimum plastron length. Like maximum carapace length and minimum carapace length, I estimate that there is a ~5-10 mm difference in the measurements of minimum and maximum plastron length.

Niederberger and Seidel (1999) also examined rates of growth in a West Virginia *G. insculpta* population, but used maximum plastron length. Niederberger and Seidel (1999) do not offer mean adult male and female growth but instead offer a table of the growth amounts, time interval between capture of various juvenile, and young adult turtles. I have taken the liberty of correcting their data for adults down to minimum plastron length so that it can be compared with the findings from my study site (See Appendix C, Table C.1). This correction is reliant on the assumption that growth of the maximum plastron measurement is equal to the growth of minimum plastron length. I have doubts about this due to the elongation of anal scutes in mature males, but I will proceed with this data for the sake of discussion.

Niederberger and Siedel (1999) also state that they found 24 turtles with a range of maximum plastron lengths of 175 to 222 mm that showed no change in length over some undisclosed lengths of time. The data from those turtles are not included in Table C.1, as those data are not explicitly stated in the paper. Those data, if included, would strongly affect the mean, both due to their number (24) and their value (0 mm of growth).

Niederberger and Seidel (1999) found an average minimum plastron length growth of 2.26 ± 2.8 mm per year for both male and female turtles (Table C.1). If I pool male and female minimum plastron length growth, I get a value of 1.80 ± 1.6 mm per year. The difference between the two means was not significant (p = 0.6763). However, since Niederberger and Seidel's (1999) mean does not include those 24 no growth encounters then it is probable that if those values were included, my growth rate would be higher. Niederberger and Seidel (1999) also have variable times between recaptures, and limited seasons over which growth was recorded (two seasons). Because turtles can have a compensatory growth response in the wake of limited food resources (Wang, Niu, Huang, Rummer, & Xie, 2011), which results in stochastic growth at the individual level, I believe the authors of this study would have found some growth in the 24 no growth individuals if the duration of their study had been increased.

Additionally based on data provided by Niederberger and Siedel (1999), growth stops or slows at ~12 annuli and plastron length ~170 mm in that population. All turtles in the present study were at least 15 annuli. Therefore, they took longer to reach the size of sexual maturity than was observed by Niederberger and Siedel (1999). Multiple annuli can be deposited within one growing season, due to abatement in growth, but can be confidently correlated with approximate age (Harding & Bloomer, 1979).

Lovich, Ernst and McBreen (1990) looked at the growth of *G. insculpta* in Pennsylvania. They found a mean growth rate of 0.8 ± 0.5 mm per year in adults (both sexes) with a maximum plastron length greater than 160 mm. A maximum plastron length of 160 mm was that study's very conservative cut off for sexual maturity; although, they did find numerous examples of smaller adults that were sexually mature. My findings for *G. insculpta* growth are higher than the Pennsylvania value, and are nearly significantly different ($p = 0.0716$). It is highly likely based on the minimum plastron lengths that all of my turtles meet the maximum plastron length threshold proposed by Lovich, Ernst and McBreen (1990). What is less clear is whether 160 mm maximum plastron length accurately splits all sexually mature individuals from individuals who show secondary sexual characteristics (males) or meet the established size threshold (females), but are not yet sexually mature, and thus might still grow at the increased rate of a young adult who are not yet diverting energy to reproduction.

The smallest and only female found mating and nesting was WT-50 with a minimum carapace length of 185.6 mm and a minimum plastron length of 159.8 mm. The smallest and only male found mating was WT-40 with a minimum carapace length of 188 mm and a minimum plastron length of 162 mm. I excluded adult turtles below the size of the two smallest turtles found to be sexually mature and examined their growth rates. Including only turtles above the minimum size to be sexually mature ensures that growth rate is indicative of turtles that are no longer growing rapidly as a sub-adult. Male minimum plastron length increased at a rate of 1.59 ± 0.6 mm per year (n = 7) and female minimum plastron length increased at a rate of 0.63 ± 0.52 mm per year (n = 2). The combined value for both genders was 1.00 ± 0.56 mm per year which brings it closer to the growth rate proposed by Lovich, Ernst, and McBreen (1990) of 0.8 ± 0.5 mm (p = 0.5612).

In conclusion, *G. insculpta* in this study site likely grow slower or perhaps more intermittently than turtles in another site in West Virginia (Niederberger & Seidel, 1999). Thus, the turtles at this study site reach the size of growth reduction and the diversion of energy resources to reproduction at a larger size (and perhaps an older age) than the population studied by Niederberger and Seidel (1999). Growth after this point continues at a rate similar to that seen in another *G. insculpta* population (Lovich et al., 1990). The exact magnitude of the difference between when growth slows is unclear without Niederberger and Seidel's (1999) full data set for comparison and a consensus in measurement styles.

CHAPTER 6:
INJURIES, DEFORMITIES, AND ECTOPARASITES

Results

Approximately 42% of *Glyptemys insculpta* observed in this study had some form of damage to their shell or limbs (Table 6.1). Six turtles had scarring or damaged marginal scutes, presumably from aborted predation attempts (19.4%). Plastron damage accounted for a large number of the injuries (19.4%). Two males and one female turtle captured were missing a limb (6.5%). Three male turtles were missing at least a third of their tail (9.7%). Two male turtles had abnormal carapacial scute arrangements (6.5%), where the central scutes were divided into two separate scutes instead of one larger scute (Fig. 6.1). There were no turtles with abnormal plastral scute arrangements.

One male turtle, WT-300 had an unusual pupil that was smaller and failed to contract or dilate (Fig. 6.2). The eye did not seem pustulent or diseased. This abnormality could have been a healed injury or a congenital condition.

An adult male, WT-602, had the most damage to the carapace (Fig. 6.3). One supracaudal marginal scute was missing, and there was damage to the other supracaudal scute, and the adjacent coastal and central scutes. The base of the tail where it adjoins the body was also injured, and the bottom third of the tail was missing. I suspect this injury was caused by the blade of a mower.

One female turtle had a drill hole in a marginal scute, and breakage on a marginal scute that suggest there was another hole in that scute. Drilling holes in the marginal scutes of turtles is a method used for marking turtles. Hole drilling as a means of marking were not used in the 2010 and 2011 seasons and according to the DNR no sanctioned research has been performed in this area (Larry Hines, personal communication, June 15, 2010). Niederberger and Seidel (1999) used drill holes to mark the scutes of *G. insculpta* in their study. This turtle may represent a turtle who emigrated from their population to this population (either of its own volition or with the assistance of humans), or the drill hole is the product of some budding, novice naturalist.

I found a leech (*Placobdella parasitica*) adhered to the top of a posterior marginal scute of a male turtle on 5/31/13 (3.2% of all turtles, 1.4% of all captures). The turtle was approximately 10 m from the main stem of the creek. This is the only occurrence of ectoparasitism observed in the study.

Table 6.1. *Glyptemys insculpta* injuries, markings, and abnormalities.

	Marginal Scute Chipping	Other Carapace Damage	Plastron Damage	Missing One Limb	Missing 1/3 of Tail or more	Drill Hole	Eye Injury	Atypical Scute Arrangement	Other
WT-2	X		X						
WT-4									
WT-5									
WT-7				X					
WT-12									
WT-13			X						
WT-16									
WT-18				X					
WT-19								X	
WT-22	X							X	
WT-25			X						
WT-27			X						
WT-32									
WT-40									
WT-90					X				
WT-200		X							
WT-300				X	X		X		
WT-602	X	X			X				X*
WT-3									
WT-10									
WT-11									
WT-14									
WT-15	X					X			
WT-17									
WT-21									
WT-23	X								
WT-24	X								
WT-26			X						
WT-28									
WT-50			X						
WT-402									
Total	6	2	6	3	3	1	1	2	1
% of Total	19.4%	6.5%	19.4%	9.7%	9.7%	3.2%	3.2%	6.5%	3.2%

Note: Males listed first then females. *WT-602 had an injury on the base of the tail (Fig. 6.3).

Figure 6.1. Male *Glyptemys insculpta* with atypical scute arrangement. The central scutes are divided.

Photograph by Jessica Curtis 2013.

Figure 6.2. Male *Glyptemys insculpta* with abnormal pupil.

Photograph by Jessica Curtis 2013.

Figure 6.3. Male *Glyptemys insculpta* with substantial injury to his posterior. One supracaudal marginal scute was missing, and there was damage to the other supracaudal scute, and the adjacent coastal and central scutes. The base of the tail where it adjoins the body was also injured.

Photograph by Jessica Curtis 2013.

Discussion

High rates of injuries are commonly reported in *G. insculpta* literature including damage to the marginal scutes, amputated limbs, and missing portions of the tail (Walde et al. 2003). Total percentages of turtles that suffered some injuries from predators in this study was 48.4% (n = 15) and was 47.6% in another West Virginia study (Breisch, 2006), 58.5% in Vermont (Parren, 2013), and 60% in Ontario (Brooks et al., 1992).

Marginal scutes damage affects 19.4% of turtles in this study (Table 6.1). This finding is substantially less than the 40% of turtles with damaged marginal scutes in another West Virginia study

(Breisch, 2006).

The number of individuals with a single limb amputation of 6.5% found in this study was similar to values found in other studies (Table 6.1). Percentage of individuals with at least a single limb amputation was 6% in West Virginia (Breisch, 2006), 8.6% in New Jersey (Farrell & Graham, 1991), 6.8% in Pennsylvania (Ernst, 2001), 4.5% in New York (Hunsinger, 2002), 9% in New Hampshire (Tuttle, 1996), 35.5% in Vermont (Parren, 2013), 9.7% in Michigan (Harding & Bloomer, 1979), then 12.5% in a later Michigan study (Harding, 1985), 9.6% in Quebec (Walde et al. 2003), and 15% and 32% at two different sites in Quebec (Saumure & Bider, 1998).

In my study, I found no double amputee turtles. Most studies fail to distinguish double amputees from single amputees. Of those studies that report it, double amputees accounted for 6.5% of all turtles in Vermont (Parren, 2013), 2% in Michigan (Harding & Bloomer, 1979) and 3.2% in Quebec (Walde et al., 2003).

Significant tail loss affected only 9.7% of turtles in the present study (Table 6.1). This number does not include more modest tail loss (the distal 5-10% of length), which was not documented in my study. It is unclear on some individuals if there was prior damage to the tail or if that was the natural length of the tail. Breisch (2006) reported that 20% of the turtles in her study area were missing the tail tip and 8% were missing half or more of the tail. Parren (2013) reported that 54.8% of all individuals had "obviously stubbed tail," 25.8% were missing their tail tips. Tail loss of any degree was reported as 16.8% in New Jersey (Farrell & Graham, 1991), 24.5% in Quebec (Walde et al. 2003) and 54.5% and 51.6% at two different sites in Quebec (Saumure and Bider 1998).

Direct observations and incidental evidence implicate raccoon (*Procyon lotor*) in the mutilation of adult *G. insculpta* (Harding 1985). Raccoons were never directly observed at the study site, but their footprints and partially eaten prey items were found. Fishers (*Martes pennanti*) (Parren, 2013) and otters (*Lontra canadensis*) (Carroll & Ultsch, 2006) are also implicated in turtle mutilation and death, but

I did not observe activity of either species in the study area.

Heavy machinery associated with agricultural activity has been found to cause high rates of turtle mutilation, both limb amputation and damage to the plastron and carapace (Saumure and Bider 1998). Heavy machinery is used rarely in the study area and only to mow the grass field (yellow polygon in Fig. 2.1). Only one of the turtles appeared to be injured by machinery in the present study, and the overall added risk because of mowing activities is likely modest.

Harding (1985) also observed gnaw marks on turtle shells which he attributed to either beaver (*Castor canadensis*) or porcupine (*Erethizon dorsatum*). None of the shell damage observed in this study could be characterized as damage from the incisors of a large rodent despite the fact that there was ample beaver activity at the study site.

The percentage of *G. insculpta* displaying abnormal scute arrangements in this study was 6.5% (Table 6.1). All abnormal scute arrangements were on the carapace. The percent of individuals displaying abnormal scute arrangements was 14% in West Virginia (Breisch, 2006), 4.5% in Pennsylvania (Ernst, 2001), and 2% in Michigan (Harding & Bloomer, 1979). Scute arrangement abnormalities do not appear to reduce fitness in affected turtles (Harding & Bloomer, 1979).

Leeches (*Placobdella parasitica* and/or *P. ornata*) are reported parasitizing *G. insculpta* juveniles and adults across the species' range: West Virginia (Breisch, 2006; Niederberger & Seidel, 1999), Pennsylvania (Ernst, 2001; Hulse & Routman, 1982), New York and New Jersey (Koffler, Seigel, & Mendonça, 1978), New Jersey (Farrell & Graham, 1991; Harding & Bloomer, 1979), Vermont (Parren, 2013), New Hampshire (Tuttle, 1996), Michigan (Harding & Bloomer, 1979), Wisconsin (Brewster & Brewster, 1986), Ontario (Siddall & Desser, 1992), and Quebec (Saumure and Bider 1996).

The one leech that was found in this study is the only leech I observed on a turtle in all field seasons (2010, 2011, and 2013). For the present study, parasitism was found on only 3.2% of all turtles (N = 31) and 1.4% of all captures (N = 68). Combining values for all three years, leech parasitism was found on only 2.5% of all juvenile and adult turtles (excluding hatchlings) (*n* = 40) and 0.31% of all captures (*N* = 318). That is an incredibly low level of leech parasitism compared to other studies.

Breisch (2006) found that 16% of turtles had leeches at least once, and that 3.9% of all captures were parasitized by leeches. Niederberger and Siedel (1999) reported that turtles in water were "often (>50%)" parasitized by leeches, although they did not provide the overall incidence of parasitism for all captures or the number of individuals parasitized. Infestation rates were much higher in Pennsylvania at 38.6% (Ernst, 2001) and almost 90% in New Jersey (Farrell & Graham, 1991).

The very low leech load in my study area could be explained by the fact that the stream is relatively small, and riverine habitats like the study area of Niederberger and Siedel (1999) are more suitable habitats for leeches. The stream habitat described by Breisch (2006) is similar to the habitat of the turtles in the present study, and yet there is still a large difference in the number of leeches observed in the two studies. It is likely that because leeches are often observed in the literature on turtles from October to May (Breisch, 2006; Hulse & Routman, 1982; Koffler et al., 1978; Tuttle & Carroll, 1997), and most of my captures from all three seasons fall into the period between May and October, I may have "missed" the reduced, but still likely present, number of leech parasitisms typical for this habitat type.

CHAPTER 7:
DEMOGRAPHY, POPULATION, AND DENSITY

Results

I captured more male than female *G. insculpta* in this study (18:13); however, the sex ratio was not significantly different from 1:1 (p = 0.789). Pooling all animals captured in 2013 with the animals captured in the 2010-2011 study, there were 21 adult males and 16 adult females in the study area. Again the ratio was male skewed, but did not differ significantly from 1:1 (p = 0.8158).

I captured no juveniles in 2013 and three juveniles in 2010-2011. All turtle captures had at least 15 annuli, and were classified as "15+" and certainly all adults despite having varied body sizes.

The size of the population of adults is estimated at 53 ± 14 using the Lincoln-Petersen Index (Krebs, 1999). Juveniles were excluded because of their lower capture probability versus adults, and the likelihood of higher mortality which would not meet the assumptions of the test.

Given a 200 m buffer on either side of the main stem of the stream, the area searched was approximately 100 ha, which would give a density of 0.53 adult turtles per ha. However, the distribution of captures was uneven across the study area. Turtles appeared to only utilize 23.35 ha of the study area. The density of the turtles in only utilized areas was 2.27 adult turtles per ha.

Discussion

Because *G. insculpta* have genetically based sex-determination (Bull, Legler, & Vogt, 1985), a 1:1 male: female sex ratio should occur in healthy populations. Deviations from 1:1 sex ratio could implicate excessive mortality of one gender. Typically, the impacted gender is female; female turtles make forays during nesting season and encounter increased mortality risk from anthropogenic sources, such as road mortalities (Brooks et al., 1992), and natural sources, including predators and disease. Skewed sex ratio can also be attributed to sampling bias, either attributing undistinguished sub-adult males to female counts or catching females at a higher rate than males due to nesting activity (Gibbons 1970; Harding and Bloomer 1979; Walde et al. 2003).

The present study found the ratio of adult males to females to be not significantly different from 1:1. This has also been found to be true in populations in West Virginia (Breisch, 2006; Niederberger & Seidel, 1999), New Jersey (Farrell & Graham, 1991), New Hampshire (Tuttle & Carroll, 1997), Vermont (Parren, 2013), Michigan (Harding & Bloomer, 1979), and Quebec (Walde et al. 2003).

Statistically significant female biased populations were documented in New Jersey (Harding & Bloomer, 1979), New York (Hunsinger, 2002), Michigan (Remsberg et al., 2006), Ontario (Quinn & Tate, 1991) and in a separate population in Ontario (Brooks et al., 1992). Some authors admit the skewed ratio was due to sampling bias; others claim no known reason to explain the bias.

I captured no hatchling or juvenile turtles in the present study. This is not typical of most studies. Various rates of juveniles have been captured in multiple studies: 36% in West Virginia (Breisch, 2006), 46% in another population in West Virginia (Niederberger & Seidel, 1999), 23.9% in Pennsylvania (Ernst, 2001), 63% in New Jersey (Farrell & Graham, 1991), 44% in New Hampshire (Tuttle & Carroll, 1997) 14.7% in Michigan (Remsberg et al., 2006), 12% in Ontario (Brooks et al., 1992), and 31.4% in Quebec (Walde et al. 2003).

Three juveniles and one hatchling (no annuli) were captured in this study area in the 2010-2011 study. Pooling data from all survey years, the percent of observed juveniles out of juveniles and adults in this population is only 7.5% (3/40) and the percent of juveniles and hatchlings out of all age classes is 9.8% (4/41). I separated these two values because high mortality of hatchlings makes counts that include them highly variable. This could indicate that the population in the present study may be failing to recruit new adults. Depredated nests were found once in 2010 and again in 2013, and the presence of a hatchling leads me to believe that the adults in this area are successfully breeding and hatching out some portion of the nests that are laid. This population may be a sink population persisting due to emigration from downstream populations. To what extent reproductive activity and emigration contribute to the number of juveniles and subsequent adults remains unclear.

Garber and Burger (1995) documented the declines of two *G. insculpta* populations in Connecticut after the inception of human recreational activities. Mean ages increased in the population, indicating a failure to recruit, and adult female mortality increased. Both populations eventually lost 100% of their individuals. Recreational activities (hiking, camping, hunting, etc.) are common occurrences in the study area. However, recreational activities have been occurring in the area for decades and are concentrated on a manmade lake 3 km north of the northernmost portion of the study site.

A low number of juveniles could bode poorly for this population of *G. insculpta.* A population of Blanding's Turtles (*Emydoidea blandingii*) required 72% survivorship of juveniles between 1 and 13 years old to maintain the population (Congdon et al., 1993). However, a 1:1 sex ratio likely indicates that mortality is equal between the adult sexes. Garber and Burger (1995) hypothesized that failure to recruit was not sufficient alone to cause the extirpation of a *G. insculpta* population; increased adult mortality was also key. I observed no incidences of adult mortality (either anthropogenic or natural), and it is likely that adult survivorship is high in this study area as is reported in other studies (Farrell and Graham 1991; Brooks et al. 1992; Garber and Burger 1995; Walde et al. 2003; Saumure, Herman, and Titman 2007).

It is possible that I and other technicians failed to locate juveniles at the same rate as adults. Capture probabilities are lower for juvenile and hatchling turtles than for adults (Langtimm, Dodd, Jr., & Franz, 1996). Most *G. insculpta* studies use visual encounter surveys as their primary method of capturing turtles. Therefore, variations in detection rate not caused by methodology are the cause of variations in capture rates of juvenile turtles. Detection probability is affected by both the effectiveness of the surveyor at locating juveniles and habitat characteristics or turtle behaviors that would occlude juveniles more often in one site versus another site. At this time, I do not have a way of quantifying the effects of surveyor efficacy, habitat characteristics, or turtle behavior on the juvenile turtle capture rate.

In conclusion, further study is warranted on this population of *G. insculpta* to determine if 1) the number of juveniles currently known in the area (7.5%) is accurate, and 2) the survivorship of both juveniles and adults. Additional work could indicate whether this population actually is a sink or ghost population, or if it is a viable population, but one with relatively modest population in size.

The density of adult of *G. insculpta* in this study was 2.27 turtles/ha. Density of *G. insculpta* in other studies was 19.1 turtles/ha in West Virginia (9.1 adult turtles/ha) (Niederberger & Seidel, 1999), 0.9 turtles/ha in another West Virginia study (Breisch, 2006), 12.4 turtles/ha in New Jersey (Harding & Bloomer, 1979), 10.7 turtles/ha in New Jersey (Farrell & Graham, 1991), 2.6 turtles/has in New Hampshire (Tuttle & Carroll, 1997), 0.24 adult turtles/ha in Ontario (Brooks et al., 1992), and 0.44 turtles/ha in Quebec (Walde et al. 2003).

Reports of *G. insculpta* density are confounded by the various determinations of area, the variability in the accuracy of estimating population, and what age cohorts are considered part of the population in the analysis. For area determination, some researchers utilize search area, others activity area and others use an amalgamation of home ranges determined through various methods. Estimates that include hatchlings and juveniles are likely inaccurate due to high mortality and low capture probability in those cohorts (Langtimm et al., 1996). Despite all the errors inherent in the various methods, *G. insculpta* populations tend to be less dense with increase in latitude, presumably to compensate for poorer habitat quality. Density in this study was modest at 2.27 adult turtles/ha and could indicate the habitat is suboptimal compared to other West Virginia study sites.

CHAPTER 8:
NOTES ON BEHAVIOR AND HABITAT USE

Behavior

There was a limited range of behavior observed in this study. Of the 68 captures, turtles were most often stationary (47.1%), walking (22.1%), or swimming (8.8%). Feeding was observed eight times (11.8%) and mushrooms of multiple, unidentified species were being consumed.

On 6/08/13, an adult female turtle WT-50 was seen digging in an exposed bank adjacent to the road into the study area (Fig. 8.1 and Fig. 8.2). This location was 100 m from the main stem of the stream and 50 m from a tributary. Cloud cover that day was 10% and the ambient air temperature was 23º C. She was presumed to be nesting and left undisturbed. I returned to the area after surveying for the day, WT-50 had departed from the area, so I examined the exposed slope more closely. I found eight false starts at nests, but couldn’t locate an area where eggs had been deposited (Fig. 8.3 and Fig. 8.4). The slope was south facing, but was more shale than soil and appeared not particularly suitable for egg laying.

Figure 8.1. A female turtle (WT-50) digging in exposed soil on a south facing slope.

Photograph by Jessica Curtis 2013.

Figure 8.2. A close-up of the female turtle WT-50 digging in exposed soil on a south facing slope.

Photograph by Jessica Curtis 2013.

Figure 8.3. False nesting starts.

Photograph by Jessica Curtis 2013.

Figure 8.4. Another set of false nesting starts.

Photograph by Jessica Curtis 2013.

On 7/23/2013, I found a predated nest adjacent to the stream ~1 m above the water line (Fig. 8.5 and Fig. 8.6). The nest faced the east and was 2 m away from a place farther up on the bank where turtles of both genders were frequently found basking, and 4 m away from the location of a predated nest found in 2010. Rain had pushed sand back into the nest cavity and washed away the tracks of whatever animal predated the nest. Egg shells were found on the bank and in the water immediately adjacent to the nest. An attempt was made to excavate the nest to determine if all eggs had been removed, and no additional eggs were found. Shell material was collected, and it appeared there were enough shells to account for 4-5 eggs. This is a relatively small clutch for a *G. insculpta* and it is likely that some of the shells were washed down stream or removed by the predator.

Figure 8.5. Predated nest. Filled in cavity is in the center of the shot.

Photograph by Jessica Curtis 2013.

Figure 8.6. Egg shells from the predated nest.

Photograph by Jessica Curtis 2013.

The only observation of mating or courtship occurred on 10/9/2013. Adult male WT-40 and adult female WT-50 were found mating 1 m from the main stem of the stream. Cloud cover that day was 100% and the ambient air temperature 15º C. Interestingly, the same pair was seen mating in almost the same spot on 10/7/2010.

Habitat Use

I captured turtles 68 times. Nine times in aquatic habitats and 59 times in terrestrial habitats. 'Forest' and 'Herbaceous with grasses' habitat types account for ~75% of all captures. These results are disproportionately skewed toward terrestrial habitat types because turtles were easier to locate in those habitat types than aquatic habitat types. Radio telemetry gives a better view of actual habitat utilized by turtles. A radio telemetry study was performed on this population in the 2010 and 2011 field seasons. For results, from that study see Appendix D (Table D.1 and Fig. D.1).

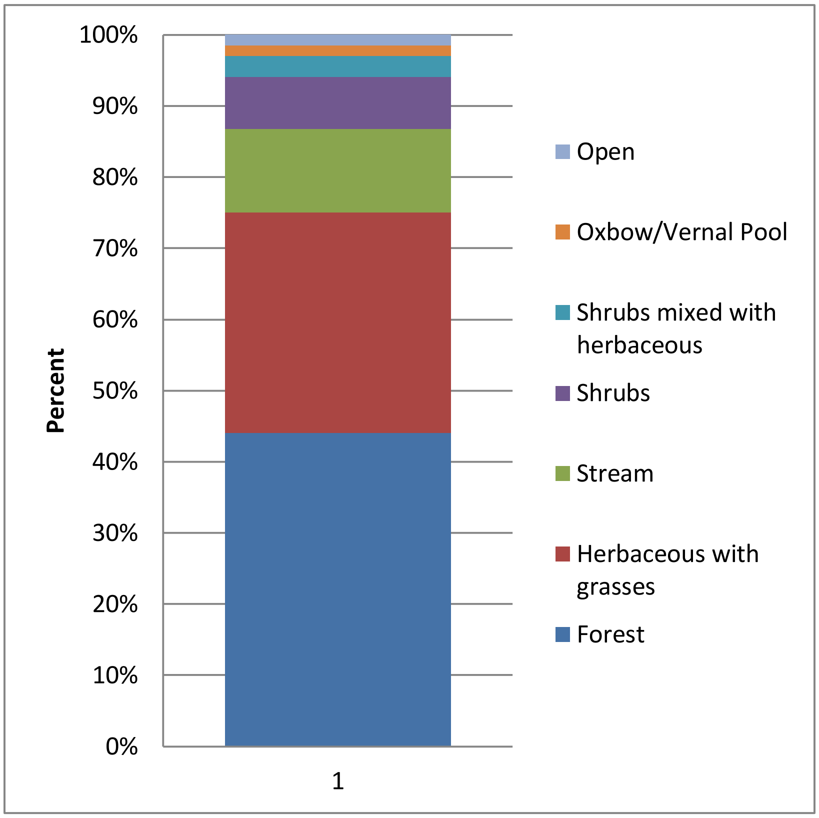

Figure 8.7. Percent of *Glyptemys insculpta* captures by habitat type across the entire study period.

CHAPTER 9:
SOFTWARE-ASSISTED IDENTIFICATION

Results

Wild-ID was highly successful in accurately identifying *Glyptemys insculpta*. I compared 29 pairs of photographs of the plastron, two photographs per turtle to determine the efficacy of the software for differentiating *G. insculpta* by pattern alone. Wild-ID chose the correct photograph as the most similar 28 of 29 times (97% accuracy). The pictures were taken under various conditions: variable light (full shade, full sun, mixed), plastron condition (wet, dry, dirty), variable object obstruction (blades of grass, small leaves), and some variation of angle of the plastron. These less than optimal conditions are likely typical of photographs of turtle plastrons taken in any similar study, and were considered a fair challenge for the software.

The highest similarity scores were seen between pictures with ideal conditions (Fig. 9.1): turtle plastrons were dry but not dusty or dirty, angle of the photograph is straight on with the plastron framed squarely, and lighting was best in continuous shade, which avoids glare. Scores above 0.1 are considered good and likely matches and require minimum manual confirmation (Bendik, Morrison, Gluesenkamp, Sanders, & O'Donnell, 2013). Ten of the pairs had a similarity score > 0.1.

Figure 9.1. The most similar pair of photographs by score. (Similarity score: 0.775198)

The one instance Wild-ID failed to pick the correct turtle, the plastron was tilted away from the camera in one photograph; the angle was likely too severe for the software to correctly gauge the pattern on the plastron (Fig. 9.2). Glare was also an issue in the pair. The software still matched the correct turtle as the third most similar out of all 47 photographs. All wet plastron photographs that had a large amount of glare had low similarity scores (<.01) with dry pictures.

Figure 9.2. The only pair of pictures where Wild ID failed to choose the correct turtle as the best match. (Similarity score: 0.000501)

Discussion

Photographic mark-recapture studies have been performed on a wide array of taxa (Bolger et al., 2012). Although, photographic mark-recapture studies are limited to species with variable patterns that are relatively stable over time, they are cheap and relatively easy to perform versus other more invasive marking protocols (Bendik et al., 2013). The photograph recognition software Wild-ID has been successfully used to identify giraffes (*Camelopardalis tippelskirchi*) (Bolger et al., 2012), wildebeests (*Connochaetes taurinus*) (Morrison & Bolger, 2012), and Jollyville Plateau Salamanders (*Eurycea tonkawae*) (Bendik et al., 2013), and has outperformed other photograph recognition software (Bolger et al., 2012).

Marking *G. insculpta and* other species of turtles using shell notching (Cagle, 1939) is an excellent method of identifying individuals: the notches persist, the notches are not injurious to the turtle, markings do not make turtles more susceptible to predation, and marking systems allow for up to thousands of individuals to be marked in a study area. While the notches do persist through time, injury or wear on the marginal scutes could occlude the presence of a notch, and young turtles may need notches to be refiled as new keratin is laid down on the scute. Photographs and photograph recognition software are valid supplements to shell notching. In *G. insculpta* the black marks on the plastral scutes do expand as an individual grows and injuries to the plastron would affect the pattern detected by the software. However, Bendik et al. (2013) found error rates were still low in matching individual salamanders even over years of growth and presumed color change and injury acquisition. It is likely that long term use of photograph recognition software on *G. insculpta* plastron patterns is efficacious and not particularly burdensome upon the researcher.

CHAPTER 10:
SUMMARY

The population of *Glyptemys insculpta* documented in this study exhibited slightly larger morphometric measurements than populations in West Virginia (Breisch, 2006) or Virginia (Lovich et al., 1990). Growth rates were fast until sexual maturity then slowed to modest levels as seen in Pennsylvania (Lovich et al., 1990). However, the annuli count (as an approximate surrogate for age) was higher in this population when growth slowed than in another West Virginia population (Niederberger & Seidel, 1999). Turtles in this population took longer to reach the size of sexual maturity than the population studied by Niederberger & Seidel (1999). Turtle density was lower than other West Virginia populations (Breisch, 2006; Niederberger & Seidel, 1999). These differences lead me to conclude that the study population is at least marginally different in natural history traits than other West Virginia and Virginia *G. insculpta* populations.

The low percentage of juvenile turtles found in the study could indicate this is a ghost population, or not actively recruiting. A non-recruiting population could explain the morphometric differences between this population and other similar latitude populations. As this population ages, indeterminate growth would make it increasingly larger as time passes. However, an aging population would not explain the later age of sexual maturity.

Rates of injuries were modest and no mortalities were observed. Pressure from predators and the impact of human use in the area does not appear to overly affect this population. The adult population of *G. insculpta* likely has high survival rate year over year, although it is not known to what extent removal or relocation of adult turtles by human recreationists is affecting the population. Ectoparasite load appears to be impressively low and may be an artifact of sampling bias.

The camera trap was ineffective in capturing *G. insculpta* presence in a known area of occupation, although it may still be a valid means for assessing occupation with greater trap effort. Wild-ID was effective at identifying individual turtles, and is proposed as a compliment to traditional shell notching methods (Cagle, 1939).

In conclusion, the adult population of *G. insculpta* is stable, but their overall number and density is relatively low. The amount of recruitment is unknown, but few juveniles in the population suggests problems for the long term survival of this population. This unique population of *G. insculpta* warrants further monitoring and investigation to better determine its risk of extirpation over the long term.

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APPENDICES:

APPENDIX A:
METHODS SUPPLEMENTS

Photographs of Morphometric Measurements

Figure A.1. Plastron width measurement. Measurement extends all the way to the terminal point of the pectoral scute.
Photograph by Jessica Curtis 2013.

Figure A.2. Carapace width measurement. Measurement taken at the same point on the shell has the plastron width.
Photograph by Jessica Curtis 2013.

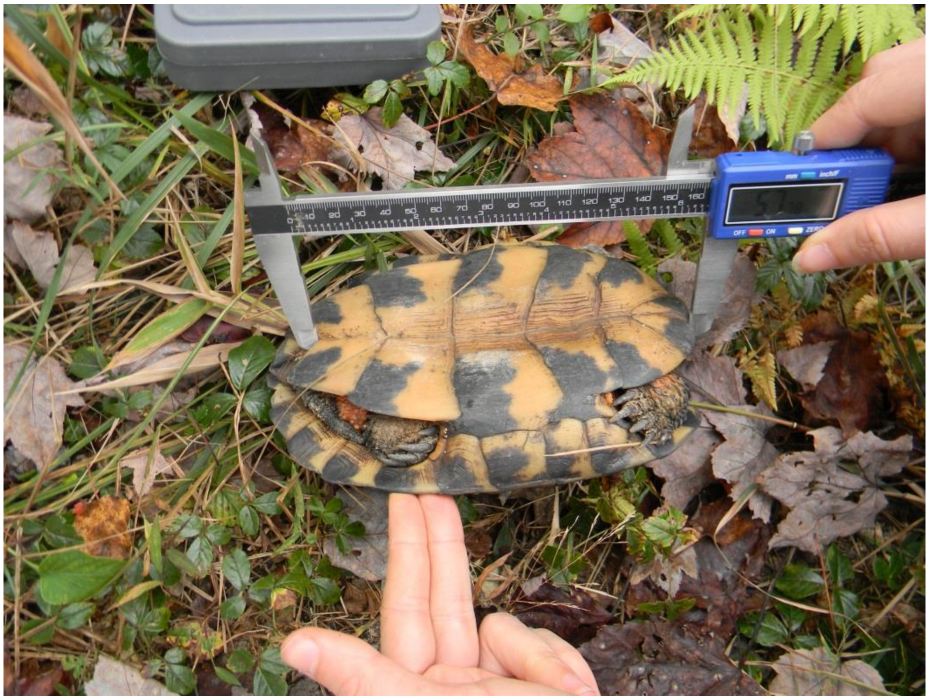

Figure A.3. Plastron length measurement. Measurement as the minimum straight-line length between the gular and the anal scutes.
Photograph by Jessica Curtis 2013.

Figure A.4. Height at bridge measurement. Measurement taken at the same point as the plastron width. Photograph by Jessica Curtis 2013.

Figure A.5. Carapace length measurements.
Photograph by Jessica Curtis 2013.

Description of Habitats

Table A.1. Habitat types and descriptions used in the present study and the previous study.

Habitat Type	Description
Aquatic	
Stream	Any flowing body of water, includes Meadow Branch and its tributaries.
Wetland	Any non-flowing, permanent body of water.
Oxbow/Vernal Pool/	Any non-flowing, seasonal body of water.
Terrestrial	
Forest	Dominate canopy over the capture location is trees of any age or species.
Shrubs	Dominate canopy over the capture location is woody vegetation of any age or species. Could contain a partial upper level tree canopy.
Shrubs Mixed with Herbaceous	Dominate canopy over the capture location is woody vegetation mixed with herbaceous vegetation, including grasses. Could contain a partial upper level tree canopy.
Herbaceous (including grasses)	Dominate canopy over the capture location is herbaceous vegetation, including grasses. Could contain a partial tree canopy but does not contain shrubs.
Open	Bare soil or leaf litter with no vegetation at any level.
Road	Open soil or gravel road.

APPENDIX B:
MORPHOMETRIC SUPPLEMENTS

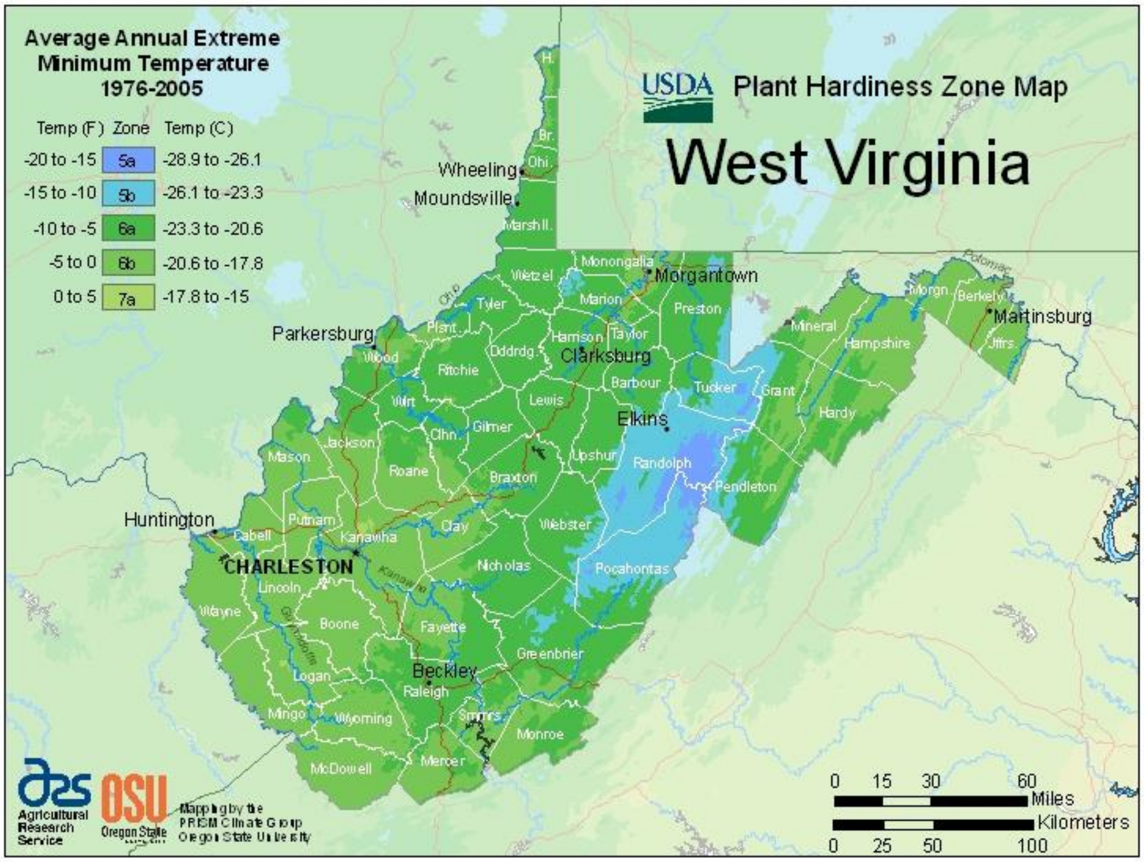

Figure B.1. Plant hardiness zones for West Virginia. Present study was conducted on the western edge of Berkeley County in zone 6b. Neiderberger and Seidel surveyed a population of *Glyptemys insculpta* in Morgan County (1999), also in zone 6b. Breisch worked with her population in the eastern portion of Jefferson County, and was in zone 7a (2006).
Photograph from USDA. 2014.
http://planthardiness.ars.usda.gov/PHZMWeb/Images/72DPI/wv.jpg

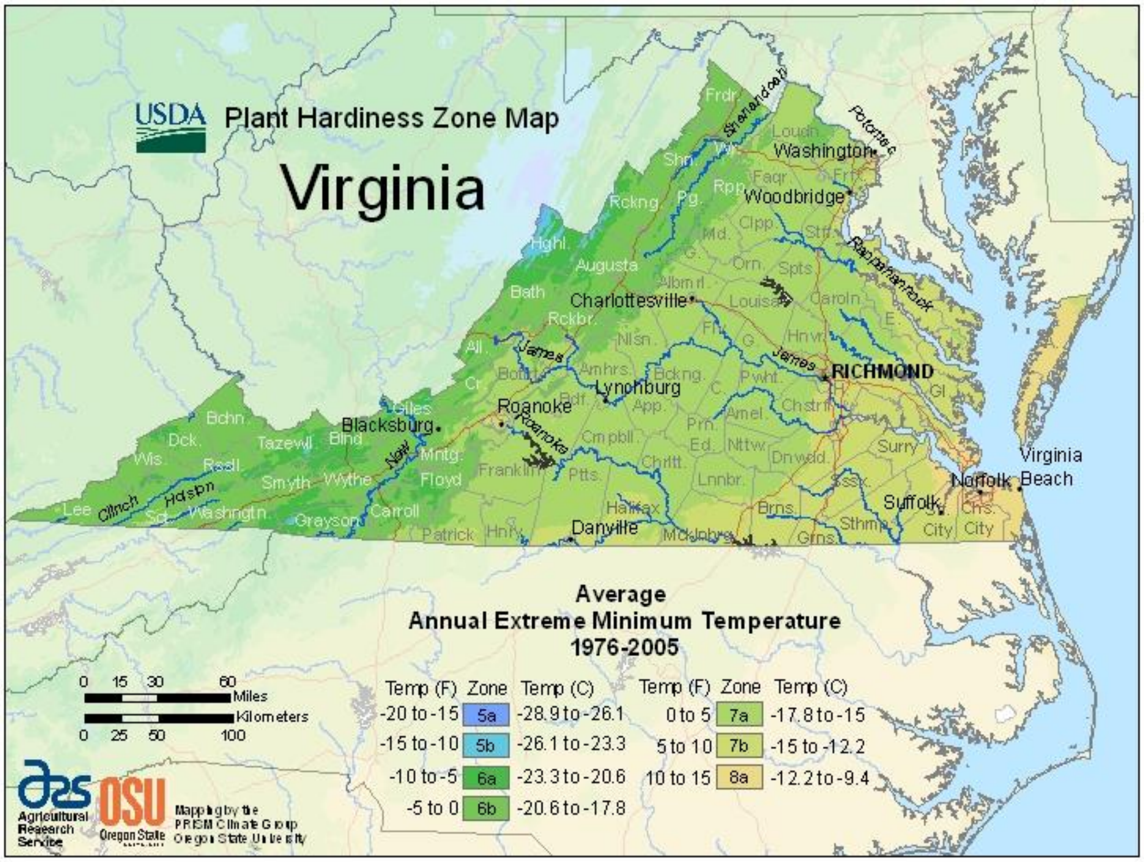

Figure B.2. Plant hardiness zones for Virginia. Fairfax County is the upper right hand corner of the state adjacent to Washington DC. The Virginia *Glypetemys insculpta* study was in zone 7a (Lovich et al., 1990).

Photograph from USDA. 2014. http://planthardiness.ars.usda.gov/PHZMWeb/Images/72DPI/va.jpg

APPENDIX C:
GROWTH SUPPLEMENTS

Table C.1. Growth in plastron length in a population of *G. insculpta* in West Virginia. Original data bound in black box from Niederberger and Seidel (1999). Graph doesn't include values for 24 captures of larger turtles which showed no growth.

	Months between recaptures	Original PL (mm)	Recapture PL (mm)	Corrected Original PL (mm)	Recapture PL (mm)	Total Growth (mm)	Growth (mm) per Month	Growth (mm) per year
	9	163	166	153	156	3	0.33	4
	8	170	175	160	165	5	0.63	7.5
	14	160	163	150	153	3	0.216	2.57
	3	170	170	160	160	0	0	0
	5	178	178	168	168	0	0	0
	14	165	165	155	155	0	0	0
	9	172	175	162	165	3	0.33	4
	14	165	165	155	155	0	0	0
Mean ±1 SD								2.26 ± 2.8

Note: PL = plastron length.

APPENDIX D:
HABITAT USE SUPPLEMENTS

Table D.1 Activity periods for *Glyptemys insculpta* in the study area. Taken from the 2010/2011 radio telemetry data.

Activity Periods	Months	Maximum Distance of Any Turtle from Water within Activity Period (m)	Percent Aquatic
Winter	Late October – mid-March	0	100%
Spring	Mid-March – mid-May	51.60	46%
Summer	Mid-May – mid-September	146.87	30%
Fall	Mid-September – Late October	39.88	54%

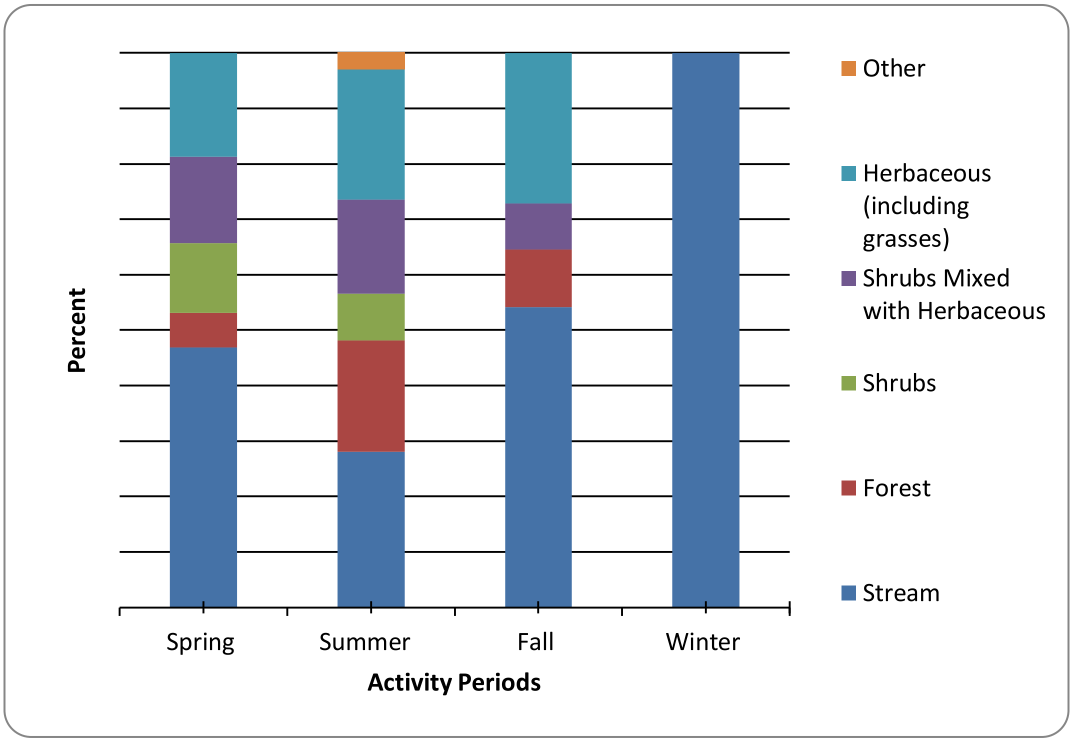

Figure D.1**.** Habitat use by *Glyptemys insculpta* across all four activity periods. Taken from the 2010/2011 radio telemetry data. “Other” includes: Wetland, Oxbow/Vernal Pool, Open, and Road.

APPENDIX E:
OTHER SPECIES FOUND

Eastern Painted Turtle	*Chrysemys p. picta*
Snapping Turtle	*Chelydra s. serpentina*
Eastern Box Turtle	*Terrapene c. carolina*
Five-Lined Skink	*Plestiodon fasciatus*
Northern Water Snake	*Nerodia s. sipedon*
Eastern Hognose Snake	*Heterodon platirhinos*
Eastern Ratsnake	*Pantherophis alleghaniensis*
Timber Rattlesnake	*Crotalus horridus*
Red-Spotted Newt	*Notophthalmus v. viridescens*
Red Back Salamander	*Plethodon cinereus*
Northern Dusky Salamander	*Desmognathus fuscus*
Northern Slimy Salamander	*Plethodon glutinosus*
Marbled Salamander	*Ambystoma opacum*
Jefferson Salamander	*Ambystoma jeffersonianum*
Spotted Salamander	*Ambystoma maculatum*
Northern Red Salamander	*Pseudotriton r. ruber*
Northern Two-Lined Salamander	*Eurycea bislineata*
American Toad	*Anaxyrus americanus*
Spring Peeper	*Pseudacris crucifer*
Eastern Cricket Frog	*Acris c. crepitans*
Grey Tree Frog	*Hyla versicolor*
Wood Frog	*Lithobates sylvaticus*
Pickerel Frog	*Lithobates palustris*
Green Frog	*Lithobates clamitans melanota*
Bullfrog	*Lithobates catesbeianus*

APPENDIX F:
IRB APPROVAL LETTER

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Office of Research Integrity

February 14, 2014

Jessica Curtis
384 Blairton Rd
Martinsburg WV 25404

Dear Ms. Curtis:

This letter is in response to the submitted thesis abstract entitled *"Ecology of Wood Turtles in the Eastern Panhandle of West Virginia."* After assessing the abstract it has been deemed not to be human subject research and therefore exempt from oversight of the Marshall University Institutional Review Board (IRB). The Institutional Animal Care and Use Committee (IACUC) has reviewed and approved the study under protocol #546. The applicable human and animal federal regulations have set forth the criteria utilized in making this determination. If there are any changes to the abstract you provided then you would need to resubmit that information to the Office of Research Integrity for review and a determination.

I appreciate your willingness to submit the abstract for determination. Please feel free to contact the Office of Research Integrity if you have any questions regarding future protocols that may require IRB review.

Sincerely,

Bruce F. Day, ThD, CIP
Director