Marshall University
Marshall Digital Scholar

Theses, Dissertations and Capstones

1-1-2008

Ecology, Reproduction and Morphometrics of the Common Ribbonsnake (Thamnophis sauritus) and Eastern Gartersnake (Thamnophis sirtalis) in West Virginia

Noah McCoard
nsmccoard@yahoo.com

Follow this and additional works at: http://mds.marshall.edu/etd

Part of the Animal Sciences Commons

Recommended Citation
McCoard, Noah, "Ecology, Reproduction and Morphometrics of the Common Ribbonsnake (Thamnophis sauritus) and Eastern Gartersnake (Thamnophis sirtalis) in West Virginia" (2008). *Theses, Dissertations and Capstones.* Paper 310.

This Thesis is brought to you for free and open access by Marshall Digital Scholar. It has been accepted for inclusion in Theses, Dissertations and Capstones by an authorized administrator of Marshall Digital Scholar. For more information, please contact zhangj@marshall.edu.

Ecology, Reproduction and Morphometrics of the Common Ribbonsnake (*Thamnophis sauritus*) and Eastern Gartersnake (*Thamnophis sirtalis*) in West Virginia

Thesis submitted to the Graduate College of Marshall University
In partial fulfillment of the Requirements for the Degree of
Master of Science
Biological Sciences

By

Noah McCoard

Thomas K. Pauley, Committee Chair
Dan K. Evans
Frank Gilliam
Jessica Wooten

Copyright

Keywords: ***Thamnophis sauritus, Thamnophis sirtalis,*** **Habitat, Reproduction, Morphology**

Abstract

Two species of gartersnakes, *Thamnophis*, are found in West Virginia. *Thamnophis sauritus* , a semi-arboreal and semi-aquatic species, is listed as very rare and imperiled (S2) by the West Virginia Division of Natural Resources (WVDNR) while the other *Thamnophis sirtalis sirtalis*, a terrestrial species, is secure (S5). During the summer of 2007, I traveled to 53 counties in West Virginia searching for habitat and these two species. Several *Thamnophis sirtalis* were found in a variety of habitats throughout the state, but only three *Thamnophis sauritus* were found. Reproductive aspects were compared between the two species by holding gravid females in captivity until they had given birth, as well as dissection of museum specimens. *Thamnophis sauritus* has a significantly smaller clutch size than *Thamnophis sirtalis.* Dietary analysis was conducted by nonlethal stomach flushing, experimental feeding trails, and dissection of museum specimens. Both species consume most amphibians and to lesser degree fish. Because morphology can have a significant impact on the ecological habits of a species, various morphological measurements were taken and compared among four snake species that are found in different habitats. *Thamnophis sauritus* shows very little morphometric variation, sharing traits of both arboreal and aquatic species and is the most limited in habitat and diet of the four species compared. *Thamnophis sirtalis* shows much variation in diet, habitat and has the most morphometric variation. Comparison of habitat and morphology of these two species provides insight on the cause for the difference in ranking of these two species.

Acknowledgments

I would first like to thank my parents Jean and Doug McCoard. Thanks for assisting me financially when I was waiting for grant money to come through. You have always supported my decisions and put up with all the new critters I would bring home as a child. I would like to thank God for bringing me to this place in my life. Thank you for helping me find my path in life and helping me accomplish my goals. I would like to thank Katy Pawlik for spending countless hours in the field helping search for the snakes. You became much more than a field assistant; you became the best friend I could ever have. I would like to thank Dr. Thomas Pauley for being a great advisor. You helped organize this project with your immeasurable knowledge in herpetology. You offered many suggestions which helped shape my thesis into what it has become. Thanks Dr. Dan Evans for showing me how to conduct vegetation analyses. Your help in teaching me how to set up plots to measure vegetation is greatly appreciated. Thanks for spending hours with me trying to identify the variety of plant species and for serving on my committee. Thank you, Dr. Frank Gilliam, for conducting the statistical analysis on the vegetation data and for serving on my committee. Your help in understanding the statistics of plant communities is greatly appreciated. Your editing techniques were very helpful in pulling this thesis together. I would like to thank Jessica Wooten for running additional statistical analyses on morphology and for your help in editing this thesis. Lastly I would like to thank members of the herpetology lab for all of your support and assistance over the last two years.

Table of Contents

List of Tables

List of Figures

Chapter One: Literature Review

Several species of *Thamnophis* (Gartersnakes) occur throughout North America and two subspecies, the Common Ribbonsnake, *T.s sauritus* (Figure 1) and the Eastern Gartersnake, *T.s sirtalis* (Figure 2) are found in West Virginia. *Thamnophis s. sauritus* is among one of the rarest snake species in West Virginia. *Thamnophis s. sirtalis* is among the most common subspecies found in this state and can be found in every county in the state. There are numerous subspecies of *Thamnophis sauritus* and *Thamnophis sirtalis* throughout North America; however, I will be referring to these two snakes at the species level for the remainder of this paper as they are the only subspecies of these two species occurring in West Virginia.

Thamnophis sauritus is a slender snake which measures 45-66cm in total length (TL) (Conant and Collins 1991) with stripes on scales rows 3 and 4 and one solid dorsal stripe. These stripes are usually yellow or orange on a dark brown to black dorsum; younger snakes have a much lighter brown dorsum than adults (Rossman 1963). Two rows of black spots may be present between the stripes. The venter is yellow or greenish. Faint parental spots may be present and do not touch each other when present (Rossman 1963). On each ocular scale a white or yellow vertical bar is present (Rossman 1963). Scales are keeled and occur in rows of 19-19-17 (Ernst 1989, Rossman 1963) and the anal plate is single. The tail is long, making up one-third to two thirds of total body length.

Thamnophis s. sauritus species complex was split into 4 subspecies including *T. s. sauritus, T. s. sackenii, T. s. nitae* and *T. s. septentrionalis* based on morphological differences (Rossman1963). He described the subspecies *T. s. sauritus* as being more specialized than the other subspecies and is characterized by 7 supralabials, brown dorsum, a golden yellow vertebral strip and a long tail. *Thamnophis s. sauritus* individuals also exhibit sexual dimorphism in the number of ventral and subcaudal scales where the males have more ventral and subcaudal scales

(Rossman 1963). Female *T. s. sauritus* tend to be longer in total body length than males but have shorter tails.

Considered semi-aquatic because of their tendency to stay near water, the primary food item of *T. sauritus* is amphibians. Rossman (1963) described that this species' narrow muzzle reflects inhabiting semi-aquatic habitats. *Thamnophis sauritus* can be found along the banks or in the water searching for prey. Amphibians, mostly anurans, are preferred prey items and very rarely eat earthworms which other members of *Thamnophis* have been shown to commonly consume (Carpenter 1952). Diets also include salamanders, fish, caterpillars (Carpenter 1952) and spiders (Hamilton & Pollack 1956). *Thamnophis sauritus* is diurnal during most of the active season, although when frogs are actively breeding *T. sauritus* may forage at night (Ernst and Barbour 1989).

Mating of *Thamnophis sauritus* begins in March or April and continues through May (Mitchell 1994). Gravid females have been documented from early April and through July (Tinkle 1957). Young snakes are typically born from July to August (Rossman 1963). Litter size can range from 3 to 26 (Rossman 1963) with a typical litter size of 8 to 13. Clutch size is often correlated with female size (Rossman 1963), where larger females posses larger clutch sizes.

Carpenter (1952) demonstrated that females reach maturity at 2 to3 years with minimum snout-vent length of 42.1cm; however, McCauley (1945) and Rossman (1963) found gravid females ranging from 34.1cm to 41cm. Females ordinarily have one clutch a year although there is some evidence that suggests some specimens may have a second clutch. Although Carpenter had no evidence, he postulated that males reached maturity at the same age as females.

Hibernation has been documented in ant mounds, vole tunnels, crayfish burrows, rock crevices and in beds of railroads (Carpenter 1953; Klemens 1993). Both *T. sauritus* and *T.*

sirtalis typically enter hibernation in November, but some specimens have been observed as late as November 20 in North Carolina (William 1995). Emergence occurs as early as late February but individuals have been observed outside of their hibernacula on unusually warm days on February 2 and February 8(William 1995).

The geographical range of *Thamnophis sauritus* extends from southern half of New England to South Carolina; southwest to extreme southeast Illinois, Louisiana and the Florida panhandle, absent from large areas in Pennsylvania, West Virginia, Ohio, Indiana, Kentucky, Tennessee, Alabama, Georgia, North Carolina, and Virginia(Conant and Collins 1991). In West Virginia, this species is classified as S2, very rare and imperiled making it vulnerable to extirpation by the West Virginia Division of Natural Resources (WVDNR). The distribution of *T. sauritus* in West Virginia is very restricted and, to date, individuals may be found in the eastern part of the state, north from Preston County and south to Monroe County and also includes Randolph, Hardy, and Greenbrier counties (Green and Pauley 1986).

Thamnophis sirtalis is genetically closely related to *T. sauritus* (Baker 1972); however, *T. sirtalis* is more common and the WVDNR considers this species to be an S5, very common and secure. *Thamnophis sirtalis* individuals exhibit a wider variation in morphology, habitat, and diet than *T. sauritus*. For example, *T sirtalis* is more robust and posses a longer total length than *T. sauritus. Thamnophis sirtalis* measures 45.7-66cm TL (Conant and Collins 1991). This species may or may not have stripes, but when stripes are present they occur on scale rows 2 and 3. Stripes are usually yellow but may be brownish, greenish, or even bluish. The background color is usually back, but may also occur in brown, green or olive (Contant and Collins 1991) some individuals have be reported to melanistic, especially in the Lake Erie region(Rossman 1996).

Thamnophis sirtalis occupy a wider variety of habitats including meadows, marshes, wetlands, woodlands, hillsides, and are even found in cities (Fitch 1965). This species prefers variety of mesic habitats (Rossman 1996) but can also be found in drier grassland disturbed fields.

The diet of *T. sirtalis* has been shown to be more variable than *Thamnophis sauritus* (Rossman 1996) and includes mostly earthworms and amphibians but small mammals, birds, leeches, fish, and insects are also eaten.

Breeding begins in the spring, for *T. sirtalis*, although fall breeding periods have been reported (Rossman 1996). The young are born from midsummer to early fall. Clutch size is highly variable depending on geographic location, and adult female body size. Clutch size on average for *T. sirtalis* is 10-15 individuals. Gestation lasts from 87 days during hot summers (Ernst and Barbour 1989) but up to 121 days during cooler periods (Blanchard and Blanchard 1936), which may be correlated with their endothermic physiology. Research has shown that the gestation period is highly dependent on temperature, for every 0.5^{o} C variation there is a difference of 4.5 days in time of birth (Blanchard and Blanchard 1936).

Females reach maturity at two years with at a snout-vent length (SVL) of at least 42.6cm (Carpenter 1952b). Similar to *T. sauritus*, this species could possibly also have a fall breeding season although there is little evidence to support this. Males could possibly reach maturity at two years as well; the smallest mature male was 38cm SVL (Carpenter 1952).

Studies have shown that spermatogenesis of *T. sirtalis* occurs in the summer and lasts until fall(Clesson et al. 2002) More research is needed to confirm if this spermatogenesis is completed in time for fall breeding or if sperm is stored until the next season (Clesson et al.2002). Spermatogenesis has been observed in *T. s. sirtalis* during the snakes second active season in a central Wisconsin population. If sperm is stored until spring then this suggests that breeding would not take place until the third year.

The range of *Thamnophis sirtalis* comprises most of the eastern half of the United States and adjacent Canada. They are found as far south as Florida and continue up into southern Canada. The northern most limit of their range is found in the Northwest Territories of Canada (Larsen and Gregory 1992). They are found west into to Minnesota and Eastern Texas (Conant and Collins 1991).

Figure 1: Female Common Ribbonsnake (*Thamnophis sauritus*) from Mason County, West Virginia

Figure 2: Female Eastern Gartersnake (*Thamnophis sirtalis*) from Mason County, West Virginia

Chapter Two: Habitat and Distribution of the Common Ribbonsnake (*Thamnophis sauritus*) and the Eastern Gartersnake (*Thamnophis sirtalis*) in West Virginia

Introduction:

Habitat selection among all species can be a very complex process. Different factors such as canopy cover, herbaceous cover, thermal sites, prey availability (Rossman et al. 1996), and predator avoidance (Burger and Jeitner 2004) may determine how species select habitats. Habitat choice of a generalist species may show much variation while a specialist species will be very selective. Habitat can greatly influence the distribution a species, especially a specialist species. Land configurations such as mountains or bodies of water, as well soil types, vegetation, and climate, can affect the habitat availability and the distribution of species.

Habitat selection of Common Ribbonsnakes has not been well studied throughout most of its range, and has never been studied in West Virginia. Carpenter (1952) found this species has a preference for wetland habitats. Thick grasses, shrubs and trees such as buttonbush, alder, blackberry and sumac are considered to be present in ideal habitats for *T. sauritus* and are often used for basking (Carpenter 1952).

Habitat of Eastern Gartersnakes has been well documented in literature (Fitch 1965, Rossman et al 1996, Carpenter 1952). This snake seems to be present in nearly all habitat types. Fitch (1965) described it habitat as vegetation around water, woodland edges, prairies with native grasses, meadows with non-native grasses, bottomlands, thick woodlands, uplands, and even in disturbed areas such as gravel roads, rock quarries and lawns. While some habitats may be more preferential, this species is found in such a variety of habitats that it is considered a generalist.

Moisture appears to be factor in predicting the presence of both *T. sirtalis* and *T. sauritus* (Carpenter 1952, Fitch 1965). Areas with moisture are more favorable, possibly due to presence of amphibians (Matthews et al.2002) which both species prey upon (Carpenter 1952, Rossman et al. 1996,Fitch 1965).

Habitats of 2 species of Gartersnakes, *T. sauritus*, and *T. sirtalis*, were examined to characterize their habitats and to determine if these species are generalists or specialists. An additional objective of this study was to determine locations of where *T. sauritus* is present in West Virginia. *Thamnophis sirtalis* was included in this search because of the close relationship of these species.

Methods:

Throughout the active season of these two species, (May through October) of 2007, 53counties in West Virginia were searched for *T. sauritus, T. sirtalis*. Suitable habitat that was searched was characterized by the presence of marshes, wetlands, ponds, streams, or rivers with very thick vegetation and the presence of frogs. Frog species and abundance were noted when frogs were found or heard. Location and GPS coordinates were recorded at each site where either snake species was found or potential habitat was observed. Other species of snakes found with *T. sauritus* or found at potential habitat sites were documented.

Distribution and Habitat:

Determination of the distribution of *T. sauritus* was conducted using records from the West Virginia Biological Survey (WVBS) at Marshall University, Carnegie Museum of Natural History (CMNH), and the West Virginia Division of Natural Resources (WVDNR). Specimens found in the field were used as well. Unconfirmed records reported from the general public were also recorded as possible occurrences of this species in those areas; however, no positive identification was made and therefore can only be included as possible populations. Potential habitats were included in the distribution as well but are not as reliable as documented populations.

Several distribution maps of these two species in West Virginia were prepared with ArcMap 9.2 using the data collected from historic, current, unconfirmed, and potential habitat records. Historic records were considered to be records from more than 20 years ago and current records were within the past 20 years. Several historic records did not have detailed location information, therefore GPS coordinates had to be estimated.

Distribution maps were created to define the total distribution for both species. Additional maps were created to link wetlands and major rivers to populations of *T. sauritus*. Maps which relate land use to populations were not created for *T. sirtalis* because of the variety of habitats which this species has been documented to inhabit.

Vegetation Analysis:

Typical vegetation of these habitats consists of, but not limited to, various grass species, poison ivy (*Rhus radicans*), jewel weed (*Impatiens capensis),* and various species of the Rosaceae family (Carpenter 1952). Some plants, such as sedges (*Carex* spp.), smartweeds (*Polygonum* spp.) and some species of the Asteracea family, are listed as being associated with wetlands (Harmon et al. 1996) and were noted if present or absent. These species were used as indicators for potential *T. sauritus* habitat.

Plants were identified following the nomenclature of Strausbaugh and Core (1977). Codes consisting of 4 letters were created to describe each species and all species and, if indicated, were labeled as wetland indicator species or upland habitat indicators (Table 1). The indicator type was determined from Harmon et al. (1996) and from PLANTS database (USDA, NRCS 2004). Codes will be used for the remainder of the paper.

At sites where *T. sauritus* had been found, a description of the area was recorded and photographs of the site were taken. To efficiently survey the vegetation at these sites, 3 plots were set up and the vegetation was documented. Each plot measured 10 m^2 (Figure 3). The first plot was placed where the snake was found (or as close to location as possible) with additional plots 100 meters apart. This separation was done to reflect the common vegetation throughout the habitat.

The overstory, shrub layer, and herbaceous layer were all surveyed and analyzed in the plots. The overstory was surveyed by measuring diameter at breast height (DBH) on all trees which were greater than 5 cm in diameter, and were within the plot. The shrub layer, which consists mostly of small trees, shrubs, and young overstory trees measuring over 1m tall and less than 5 cm in diameter, was surveyed by counting the number of stems within the plot. The herbaceous layer was surveyed by measuring 1-m^2 subplots in each corner and estimating percentage cover of each species present. The herbaceous layer consisted of young overstory and shrub species, as well as small vascular plants such as flowering plants and ferns. Non-vascular plants were not surveyed.

Statistical analysis was conducted on the data collected from the vegetation using Canoco 4.1 software (Gilliam and Saunders 2002). Detrended correspondence analysis (DCA) was used to determine differences and similarities among sites. Each species was assigned a species score which indicates the importance of that species within the sites surveyed. Variation among the sites and presence of wetland plants were described to characterize the habitat which *T. sauritus* prefers and how this may relate to wetland habitats.

When *T. sirtalis* was found, I recorded a description of the area and took photographs of the site.

Diet Analysis:

Diet was considered to be an important aspect for habitat selection of *T. sirtalis* and *T. sauritus*. Prey items of these two species were evaluated by dissecting specimens from WVBS. Stomach contents were removed to identify items; however, some items were nearly digested and could not be identified accurately. Live specimens of *T. sauritus* and *T. sirtalis* were held in captivity and were put through feeding trials. These feeding trails consisted of offering a variety of food items to determine food preference for both species.

Results:

Distribution and Habitat:

Historically, only 25 records exist for *T sauritus* in West Virginia. These locations were in Mason, Monroe, Greenbrier, Randolph, Hardy and Preston counties (Figure 4). During the summer of 2007 only 3 Common Ribbonsnakes were found including a gravid female. These 3 were located in McClintic WMA in Mason County (Figure 5), Tygart Valley River in Randolph County, and at Mill Creek WMA in Cabell County (Figure 6). Five current unconfirmed records exist for other areas in the state (Figure 7). Additionally several areas of potential habitat were observed around the state (Figure 8). *Thamnophis sauritus* were observed only near wetlands (Figure 9) and, in some cases, major rivers. The location of the most occurrences historically was in Tygart Valley River in Randolph County. This area consisted of a large river surrounded by thick vegetation species typical of wetland habitats. Total possible distribution is presented in figure 10.

Areas where fewer wetlands exist did not have populations or areas of potential habitat. Two large areas in the state did not appear to have *T. sauritus* populations or potential habitat which could support populations (Figure 11 and Figure 12). One of these areas is along the northwestern side of the state including at least part of Wetzel, Tyler, Doddridge, Gilmer, Lewis, Harrison, Calhoun, Braxton, Clay, Roane, Wirt, Kanawha, Fayette and Ritchie counties. The other area was the southern portion of the state including at least part of Wayne, Mingo, Lincoln, Logan, Boone, Raleigh, Wyoming, McDowell and Mercer counties. *Thamnophis sauritus* was not found in habitats away from water sources or in areas without thick vegetation. Wooded hillsides, roadsides, lakes and ponds without sufficient vegetation were searched for this species, yet none was found.

Abundant amphibian populations were also present with *T. sauritus.* Tygart Valley River, McClintic WMA, and Mill Creek WMA all had large populations of various frog species such as *Rana* spp. and Hylid species. *Thamnophis sauritus* was not present in areas that did not appear to have an abundance of frogs.

The DCA analysis suggests there are vegetation differences among the sites (Figure 13). Tygart Valley River was the most different than all other sites which is presented in a single small group on the right side of the DCA. There is overlap among all other sites with the largest sites being McClintic WMA. The DCA was driven by species scores which indicate the importance of each species within the system (Table 2). The species with the largest species scores are PHAR, PACL, CASP, DIFI, and POAC, with scores of 300, 238.75, 207.08, 127.5, and 90 respectively.

Nearly every county in the state has records for *T. sirtalis*, the 2 two which do not have records are Tyler and Wetzel County (Figure 14). This species was found in many different habitats. There did not appear to be habitat in which this species was not present and they did not seem to have a preference for a specific type of habitat. Twenty- two *T. sirtalis* were found in several counties in a variety of habitats. Open fields were the most common habitat followed by wooded hillsides, forest edges, along rivers and streams, roadsides, rock crevices, wetlands, and trash piles (Figure15).

Listed below are descriptions for sites of confirmed populations of *T. sirtalis* and *T. sauritus*, as well as site descriptions of potential habitat and unsuitable habitat that I surveyed during this study.

<u>Burnsville Lake Wildlife Management Area</u>- Braxton County

This site did not have potential habitat. The lake was large and was surrounded by little vegetation which was mowed up to the edge of the water. No other nearby areas had potential habitat. *T. sauritus* were observed.

<u>Cedar Creek State Park</u>- Gilmer County

This site did not appear to have potential habitat. The area was mostly hilly without wetlands. A few ponds were observed in which vegetation had been mowed up to the water's edge. One *T. sirtalis* was observed but no *T. sauritus* was discovered.

<u>Stumptown Wildlife Management Area</u>- Gilmer County

At this site, wetlands were observed and it did not appear to have suitable habitat. No indicator species were observed and *T .sauritus* were observed.

<u>Holly River State Park</u>- Webster County

This area had several creeks and small wetlands, yet suitable habitat was not observed. Two *T. sirtalis* were found, but no other snake species were found. Vegetation was mostly woody species; herbaceous species were not dense enough to support *T. sauritus*.

<u>Big Ditch Wildlife Management Area</u>- Webster County

This site had a small area along the lake edge which could possibly support *T. sauritus*. A marshy area in front of the lake was also surveyed and appeared to have potential habitat.

Vegetation was thick and had several shrubby species. One Common Watersnake, *Nerodia sipedon* was observed, but no amphibian species were seen or heard. In spite of lack of amphibians, this site does appear suitable for *T. sauritus*.

Sleepy Creek Wildlife Management Area- Berkeley and Morgan Counties

This area had a large wetland in front of a lake which appeared to be potential habitat. This area had sufficient vegetation and cover objects. Frog species such as Green frogs, *Rana clamitans melanota*, Spring Peepers, *Pseudacris crucifer*, and Gray Tree Frog *Hyla chrysoscelis*, were heard. Indicator species were present. One current unconfirmed record of *T. sauritus* exists for this area.

Blackwater Falls State Park- Tucker County

No potential habitat was observed at this site. No indicator species were found and no frogs were observed or heard calling. *T. sauritus* were not observed.

Audra State Park-Barbour County

No suitable habitat was observed at this site. No aquatic habitats or areas with thick vegetation which could support *T. sauritus* were observed.

Twin Falls State Park -Wyoming County

No wetlands were observed at this site, and it did not appear to have suitable habitat. No indicator species were observed and no *T. sauritus* were observed.

Berwind Lake Wildlife Management Area-McDowell County

No wetlands were observed at this site and it did not appear to have suitable habitat. There was very little vegetation around the lake which was mowed up to edge of bank. No indicator species were observed and no *T. sauritus* specimens observed.

Teter Creek Wildlife Management Area-Barbour County

No potential habitat was observed at this site. There was a small lake, but there were no wetlands present and no thick vegetation around the aquatic area. No *T. sauritus* were observed.

Stonewall Jackson Lake State Park-Lewis County

This site consisted of a very large lake where vegetation was mowed up to the edge of the water. No thick vegetation was observed and no indicator species. No potential habitat was observed.

Moncove Lake State Park –Monroe County

No wetlands were observed at this site and it did not appear to have suitable habitat. No indicator species were observed and no *T. sauritus* were observed.

Meadow River Wildlife Management Area- Greenbrier County

This site was comprised of large wetland areas with thick vegetation around water consisting of various grasses, cattails, jewelweed, and poison ivy that appeared to be potential habitat as indicator species were present, as well as amphibians. One *T. sirtalis* was observed but no *T. sauritus*. One current record for *T. sauritus* exists for this site.

Droop Mountain State Park- Pocahontas County

No wetlands were observed at this site and it did not appear to have suitable habitat. No indicator species were observed and I did not observe any *T. sauritus* specimens.

Watoga State Park-Pocahontas County

Potential habitat was observed along Jesse Coves Trail, and beside the road leading into the park beside Greenbrier River. There was thick vegetation consisting of various grasses, jewel weed, multiflora rose, and other herbaceous and shrub species. *Thamnophis sirtalis,* Long-tailed Salamander, *Eurycea longicauda,* Northern Ring-neck Snake *,Diadophis punctatus,* and

Northern Red-bellied Snake, *Storeria occipitomaculata* were observed, but no *T. sauritus* were found.

Cranberry Glades Botanical Area-Pocahontas County

Very good potential habitat was observed at this area. There were many species comprising a thick herbaceous layer and woody vegetation. Some frogs were observed, but I could not survey sufficiently due to restrictions of remaining on the boardwalk.

I conducted an addition search on state RT 102 about 2/10 of one mile from junction with state RT 150, 2 miles south of Cranberry Glades Botanical Area. There was good potential habitat consisting of many species of grasses and other herbaceous species and shrubs which continued up to the forest edge. A beaver pond created a large aquatic area suitable for *T. sauritus* and amphibian species. No *T. sauritus* were observed, but other species including *D. punctatus* and *S. occipitomaculata* were captured.

Tea Creek Interpretive Trail –Pocahontas County

Potential habitat was observed at this site consisting of one small wetland at the beginning of the trail with a much larger wetland at the end of the trail. Thick grasses and other herbaceous species were present along the water's edge. Unknown anurans were observed jumping into the water around the wetland. One Smooth Greensnake, *Opheodrys vernalis* and *S. occipitomaculata* were captured, but no *T. sauritus* were observed.

Monongahela National Forest-Pocahontas County

I surveyed a wetland along state RT 39 which had good potential habitat. There were various species of herbaceous and woody plants as well as dead trees which could provide cover. A beaver pond created good aquatic habitat. Salamanders and frogs, including Eastern Redbacked Salamander, *Plethodon cinereus, R.c. melanota,* and Red-spotted Newt,*Notophthalmus viridescens*, were observed, but no *T. sauritus* were observed.

McClintic Wildlife Management Area-Mason County

This site had very good habitat of multiple large wetland areas with many species of herbaceous and woody plants present. Many species of frogs were observed and heard calling, including Mountain Chorus frog, *Pseudacris brachyphona, P. crucifer, H. chrysoscelis, R. c. melanota,* and Bullfrogs *Rana catesbeiana*. Several *T. sirtalis* were observed as well as one gravid *T. sauritus*.

Moose Lodge, Point Pleasant- Mason County

This area was dry, due to recent lack of rain, when surveyed. An employee of Moose Lodge stated that he had not mowed the area in five weeks due to drought. One section appeared to be a dried-up wetland. Vegetation was thick and seemed to be sufficient for supporting semi-aquatic species. One unconfirmed record of *T. sauritus* exists for this site.

Summersville Lake Wildlife Management Area –Nicholas County

This site consisted of a lake where vegetation was mowed up to the edge of the water. No thick vegetation or indicator species were observed. No potential habitat or *T. sauritus* s were observed.

Greenbottom Wildlife Management Area-Cabell County

This site consists of a large wetland and has thick vegetation, including tall grasses, shrubs and trees. Many frogs were observed, including Pickerel Frog *Rana palustris, R. catesbeiana,* Northern Leopard Frog,*Rana pipiens,* and *P. crucifer*. This area appears to have suitable habitat although no *T. sauritus* were observed.

Big Ugly Wildlife Management Area- Lincoln County

This area did not have suitable habitat. This consisted of a very dry, hilly, forested area with no aquatic habitats observed. No indicator species were identified and no frog species were observed or heard. No *T. sauritus* were found.

Kanawha State Forest- Kanawha County

This state forest has a small wetland across from Polly Hollow trail for which one unconfirmed record exists. This wetland consists of a small marsh with abundant vegetation. When the area was surveyed, a drought had lead to most of the aquatic area being dried-up. Species observed include *N. sipedon*, *R. c. melanota,* and *R. catesbeiana.* No *T. sauritus* were observed although the habitat appeared suitable, but only in the small wetland area. Many *H. chrysoscelis* were heard during the night.

Chief Cornstalk Wildlife Management Area-Mason County

I surveyed areas along state RT 40 at Upper Ninemile Creek and this area has potential habitat. Indicator species were present as thick vegetation and shrubs, as well as rocks and logs which would be suitable for cover or basking. The area was experiencing drought when surveyed and no *Thamnophis* or frog species were observed.

East Lynn Wildlife Management Area-Wayne County

This site did not have potential habitat. The area was a dry, rocky hillside that overlooked the lake. No suitable vegetation was observed and no *T. sauritus* were discovered.

Kumbrabow State Forest-Randolph County

This was a forested area with small streams running through it. No wetlands or suitable habitat were observed and no *T.sauritus* were observed.

Woodrum Wildlife Management Area-Mason County

No potential habitat was observed. No indicator species were identified and no amphibian species were observed or heard calling. No specimens of *T. sauritus* were observed.

<u>Frozen Camp Wildlife Management Area</u>-Jackson County

This area, which was along Right Fork, has potential habitat. There was thick vegetation consisting of *Salix* spp., grasses, and other small woody and herbaceous plants which could allow for basking. *Rana pipiens* was observed at this site, but no *T. sauritus*.

<u>Hughes River Wildlife Management Area</u>- Wirt County

There was no potential habitat at this dry site. No wetland habitat was observed; it was a hilly, wooded area without any indicator species. Salamanders including Dusky Salamnder, *Desmognathus fucus*, and Northern Red Salamander, *Pseudtrition ruber* were observed but no frogs or *T. sauritus* were found.

<u>North Bend State Park</u>-Ritchie County

This area did not appear to have suitable habitat. There was one small marshy area which appeared to have been experiencing effects of drought. Cattails were present, but no other thick vegetation or indicator species were observed.

<u>Mill Creek Wildlife Management Area</u>- Cabell County

This site has a small creek running through an area with thick vegetation, including grasses and sedges. Several shrub species, including spice bush and redbud, were observed. Salamanders including the Southern Two-lined Salamander, *Eurycea cirrigra*, and *D. fucus* were found. Although this was not the typical characteristic wetland, one *T. sauritus* specimen was observed along this creek. This was a county record.

<u>Beech Fork State Park</u>-Wayne County

No wetlands were observed in this area. No indicator species or areas with thick vegetation around water were found. This site consisted mostly of hilly, forested area through the state park. No *T. sauritus* were observed.

<u>Lance Farm and Nature Preserve</u>- Wetzel County

No suitable habitat was found in this area. The only aquatic habitats were a few small ponds without thick vegetation surrounding them. The area appeared to have been mowed often and cover objects had been removed. No frog species were observed or heard. No indicator species were observed anywhere around the water. One employee from told me that there were few wetland areas, and most of those had been drained in previous years.

<u>Conway Lake Wildlife Management Area</u>- Tyler County

No suitable habitat was observed at this site. There was only one small marshy area observed at one end of a lake next to a busy campground. No indicator species were found. Vegetation had been mowed up to the water's edge, eliminating thick herbaceous cover. The only frog observed was a single *R. c. melanota*.

<u>The Jug Wildlife Management Area</u>-Tyler County

I surveyed area along CR-46 on top of a ridge and did not find wetlands, streams, rivers, or ponds. No suitable habitat or specimens were observed.

Middle Island Creek was also surveyed. This area had a very large river with very dry, sandy banks. Little vegetation was observed and no frog species were observed indicating that this area did not have suitable habitat.

<u>Burches Run Lake Wildlife Management Area</u>- Marshall County

This area appeared to have suitable habitat and there may have been a lake which was drained. This "drained" lake had large marshy areas with thick vegetation that consisted of cattails, various grasses, jewelweed, and a mixture of other herbaceous plants. There were large piles of dead trees which looked like the remains of a beaver den. *R. c. melanota, N. sipedon,* American Toad, *Bufo americanus* and Queen Snake, *Regina septemvittata* were observed at this site; however, no *T.s sauritus* were observed.

Right Buffalo Run- Tyler County

This area along CR-10, North of Adonis, along Right Buffalo Run, was surveyed for possible habitat, yet none was found. No indicator species were observed in this forested area. One open field had few shrubs or cover objects and was dry during the survey. No frog species were observed or heard in this area.

Bear Rock Lakes Wildlife Management Area- Ohio County

This site along CR-41/6 had potential habitat. There was a large wetland around a pond which had thick vegetation throughout it which could potentially support *T. sauritus*. A few amphibian species, *P. cinereus* and *R. c. melanota* were observed. No *T. sauritus* were observed at this site.

Tygart Valley River-Randolph County

This large river is surrounded by thick vegetation of wetland species. Vegetation consisted mostly of thick grasses as well as several shrubs, including alder, silky cornel, and smartweeds. This appeared to be good habitat as indicator species were present. One *T. sauritus* was captured swimming across the river.

Castleman Run Lake Wildlife Management Area- Brooke County

This site did not appear to have suitable habitat. There was a large stream with an open field adjacent to it. The field did not have indicator species, bushes, or many cover objects. No frog species were observed or heard at this site.

Tomlinson Run State Park- Hancock County

I surveyed fishing ponds around Poe Trail and found some areas of potential habitat. There were several ponds at this area. Many of them had thick vegetation surrounding them consisting of herbaceous and woody species. *R. c. melanota*, *R.catesbeiana,* and *P. crucifer* were heard calling. No *T. sauritus* were observed.

Pricketts Fort State Park- Marion County

This site had an area of potential habitat along Prickett Creek. This site had thick vegetation consisting of several herbaceous and shrubby species with a wooded area adjacent. In spite of few cover objects, a lack of frogs, and no *T. sauritus* observed, the vegetation looked suitable.

Valley Falls State Park- Marion County

This site had no suitable habitat. No wetlands were observed within the park. Valley River appeared to be too large and fast-moving to support amphibians or *T. sauritus*. Other areas of the park consisted of hilly, forested areas without any aquatic habitats.

Curtisville Lake- Marion County

This area does not appear to have suitable habitat. No wetland or swampy areas were observed. No indicator species or thick vegetation was along the stream. No *T. sauritus* or species of frogs were observed.

Cooper's Rock State Forest- Monongalia County

No suitable habitat was observed at this site. The area consisted of rocky upland habitat. No aquatic habitats or areas with vegetation which support *T. sauritus* were observed.

Tygart Lake State Park- Taylor County

This state park did not appear to have suitable habitat. No wetlands or areas with thick vegetation or shrubs available for cover or basking needed by *T. sauritus* were found.

Monongahela National Forest- Pocahontas County

The area surveyed was across from Falls at Hills Creek, at junction of state RT-39 and road which leads into Falls at Hills Creek, had a large area of potential habitat. This area consisted of a large wetland area with a forested area adjacent. Large amounts of thick vegetation surrounded the water and continued up to the forest edge. Lots of shrubs and downed trees could provide suitable area for basking and cover. Amphibian species observed included *N. viridescens, R.c. melanota,* and Allegheny Mountain Dusky Salamander, *Desmognathus ochrophaeus*. No *T. sauritus* were observed; however, a slender snake, possibly *T. sauritus,* was seen crossing the road, but was not captured for identification.

Point Pleasant Launch Ramp- Mason County

Potential habitat was observed along the boat launch area on Kanawha River. The edge of the water had thick vegetation and several downed trees and rock which could have been used for cover. No frogs were observed in this area and no *T. sauritus* were observed.

Babcock State Park- Fayette County

No suitable habitat was observed at this site. No wetlands or aquatic habitat with sufficient vegetation were observed. No *T. sauritus* were observed.

Wallback Wildlife Management Area- Kanawha County

No suitable habitat was observed at this site. No wetlands were observed and no sufficient vegetation was found. No frog species were observed or heard calling. No specimens of *T. sauritus* were observed.

Allegheny Trail Head 701- Randolph County

This area along Glady Fork had an area of potential habitat. The area consisted of thick vegetation around a creek and marshy area. Lots of fallen trees and rocks for providing sufficient cover, as well as shrubs for basking, made this area appear suitable. One *N. sipedon* was observed but no *T. sauritus* were seen.

Canaan Valley Wildlife Refuge-Tucker County

This site had large wetlands, which provided potential habitat. Thick vegetation surrounded the aquatic areas providing areas for individuals to hide and for basking. Several frogs were observed, including *R. pipiens, R. c.s melanota*, and *R. catesbeiana*. In spite of extensive searching, no *T. sauritus* were observed.

Camp Creek State Park-Mercer County

This area did not appear to have any suitable habitat. When surveyed, this creek was dry with only small pools of water and no wetlands or suitable vegetation present. No indicator species were present at this site and no *T. sauritus* were found.

Pinnacle Rock- Mercer County

This site was dry and with a steep grade. It looked like there was no area where a wetland could exist. No indicator species were present and no specimens were observed.

Plum Orchard Lake Wildlife Management Area- Fayette County

No suitable habitat was observed at this site. No wetlands were observed and no sufficient vegetation was found. No frogs or *T. sauritus* were seen.

Little Beaver State Park- Raleigh County

I surveyed a tributary of Laurel Run and did not find suitable habitat. Vegetation did not appear to be thick enough and no shrubs were present to support *T. sauritus*.

Bluestone State Park- Summers County

This park was dry and hilly. At the time of survey, it appeared as though it had not rained in several weeks. No wetlands were found and no area with sufficient vegetation around water was observed. One *T. sirtalis* was found dead on the road, but no *T. sauritus* were observed.

Diet analysis

Specimens of *T. sirtalis* that were dissected had similar stomach contents (Table 3). Salamanders were the most common item found in *T. sirtalis* stomachs such as the Northern Slimy Salamander, *Plethodon glutinosus* and *Desmognathus ochrophaeus* . Earthworms were the second most common food item observed *T. sirtalis* stomach contents. Only one specimen of *T. sauritus* had stomach contents, an unidentified *Pseudacris* species.

Feeding trail results were similar between both *T. sauritus* and *T. sirtalis* (Table 3). Salamanders were accepted more often than any other food type. Fish were offered but not accepted as quickly as amphibians. When fish and amphibians were offered together, amphibians were chosen over fish. No arthropods were accepted by either species and earthworms were accepted by only *T. sirtalis*. All food items had to have been living, dead specimens were ignored.

Size was factor in prey selection. Smaller items were accepted more readily than larger items. *Thamnophis sauritus* would not accept adult Mole salamanders, genus *Ambystoma,* or large frogs. Tadpoles, salamander larvae, and small salamanders were accepted by *T. sauritus*. *Thamnophis sirtalis* accepted large frogs, adult salamanders, and amphibian larvae.

Discussion

Distribution and habitat

The distribution of *T. sauritus* was found to be restricted to areas where specific habitat was present. This is consistent with studies by Carpenter (1952) and Bell et al. (2007). Only three specimens were found during the summer of 2007 making 27 occurrences from 1936 to 2007. This information suggests that this species is rare and is in need of conservation. Habitat is likely a factor influencing the status of this species as extensive wetlands are relatively uncommon in the state.

Frog populations may be a significant factor that determines habitat selection for *T. sauritus*. Matthews et al. (2002) observed a strong association between amphibian presence and *T. elegans* presence in the high elevations of Sierra Nevada. At sites with *T. sauritus* frogs were abundant. This suggests that frogs may be an important factor in habitat selection.

Thamnophis sirtalis is found statewide. There are no known geographical limitations and *T. sirtalis* were found in every habitat. The lack of records from counties without *T. sirtalis* is most likely due to lack of voucher specimens, not due to this species not occurring there.

The association of *T. sauritus* with wetlands suggests that *T. sauritus* is dependent on wetland habitats. Approximately 50% of the plant species found in each site were associated with wetlands. Some of the plant species, which had high species scores, are PHAR and CASP which are considered to be wetland plants, whereas PACL can be found in either wetland or upland habitats. POAC is often found in upland habitats while DIFI does not have any information to indicate whether it is a wetland or upland species (PLANTS database, USDA, NRCS 2004). This data suggests that wetlands plants may play an important role in habitat selection for *T. sauritus*.

Thamnophis sauritus appeared to be selecting wetland habitats. The total known distribution of this species, which includes historic, current, and unconfirmed records as well as potential habitat indicate that *T. sauritus* is found in the eastern, northern and part of the western portions of the state (Figure 10). When compared to wetlands and major rivers, it appears that *T.*

sauritus is only found in areas around the state where wetlands are large and abundant (Figure 12). This suggests that extensive wetlands are important for this species which has been found to occur only where extensive wetlands are present.

Habitat of *T. sirtalis* was extremely variable, including woodland hillsides, open fields, roadsides, streamsides, rock crevices, and wetlands. Carpenter (1952), Fitch (1965) and Larsen et al. (1992) have described similar habitats including wooded hillsides, open fields, marshes, and wetlands.

My data suggest that *T. sauritus* is specific in habitat selection, preferring wetlands to any other habitat type whereas *T. sirtalis* others a habitat generalist. Bell et al. (2007) described *T. s. septentrionalis* has being found in wetlands along the edges of water and appears to prefer wetlands above other types of habitat. *Thamnophis sirtalis* may have been found in wetland habitats, but are also found in a variety of other places (Fitch 1965, Carpenter 1952).

Diet Analysis

Food items of both species most commonly consisted of amphibians. Earthworms are also an additional prey item eaten by *T.sirtalis*. Carpenter (1952) found in Michigan populations of *T. sirtalis* that the diet mostly consisted of earthworms followed by amphibians, and other small invertebrates. He found *T. sauritus* ate mostly amphibians followed by fish and caterpillars. My stomach analysis data showed that amphibians were the most preferred prey items for both species.

Feeding trials resulted in both species accepting many amphibian species, with *T. sauritus* accepting fewer species than *T. sirtalis*. My data was similar to other studies. Carpenter (1952) and Rowe et al. (2000) showed that *T. sauritus* preyed primarily on amphibians, while earthworms and insects were refused. Size of prey and of the snake itself is likely to be a factor resulting in prey selection of the two species. For example, I found that that *T.sauritus* would not eat adult *Ambystomid* salamanders or large frogs, but *T. sirtalis* would. Small amphibians such as juvenile *Ranids, Ambystomid* larvae, and *Pseudacris* spp. were quickly accepted which is consistent with the study done by Rowe et al.(2000) Although Carpenter (1952) suggested that *Thamnophis sauritus* will eat insects, my data indicated that this species will not accept insects, or any type of arthropod.

Thamnophis sirtalis eats almost anything small enough to be swallowed (Carpenter 1952). My data showed that they prefer amphibians as the primary prey item, followed by earthworms, then fish. This is similar to Fitch (1965) who found numerous frogs and few earthworms eaten by T. *sirtalis*. Carpenter (1952) found that *Thamnophis sirtalis* would eat small mammals in the field and in laboratory trials. Fitch (1965) found that *T. sirtalis* would feed on mammals such as mice and voles, birds, even other snakes. I did not find any small mammal species in any stomach analysis and mammal trials in the laboratory were refused.

The West Virginia Division of Natural Resources classifies *T. sauritus* as an S2 species. This status is defined as “six to twenty documented occurrences, or few individuals remaining within the state. Very rare and imperiled; or because of factor(s) making it vulnerable to extinction” (www.wvndr.org). Twenty-seven occurrences over a 71 year period (average of 1 occurrence every three years) indicate that this species is much rarer than once thought. To assist the conservation of this species I recommend the status of *T. sauritus* be lowered from S2 to S1. *Thamnophis sirtalis*, which is ranked as an S5, or secure in the state, is at a status that I believe should remain due to the number of individuals that were recorded during my study.

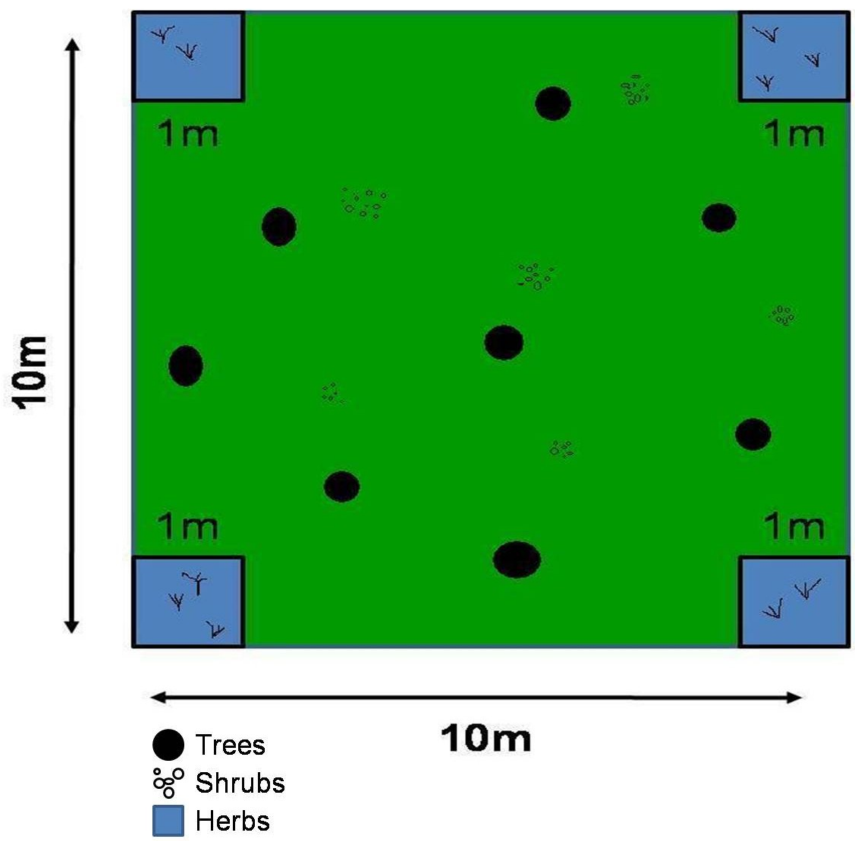


Figure 3: Ten meter squared plots were measured and surveyed for vegetation. Trees and shrubs were measured throughout the plot while herbaceous species were only measured in the 1 meter squared plots at each corner.

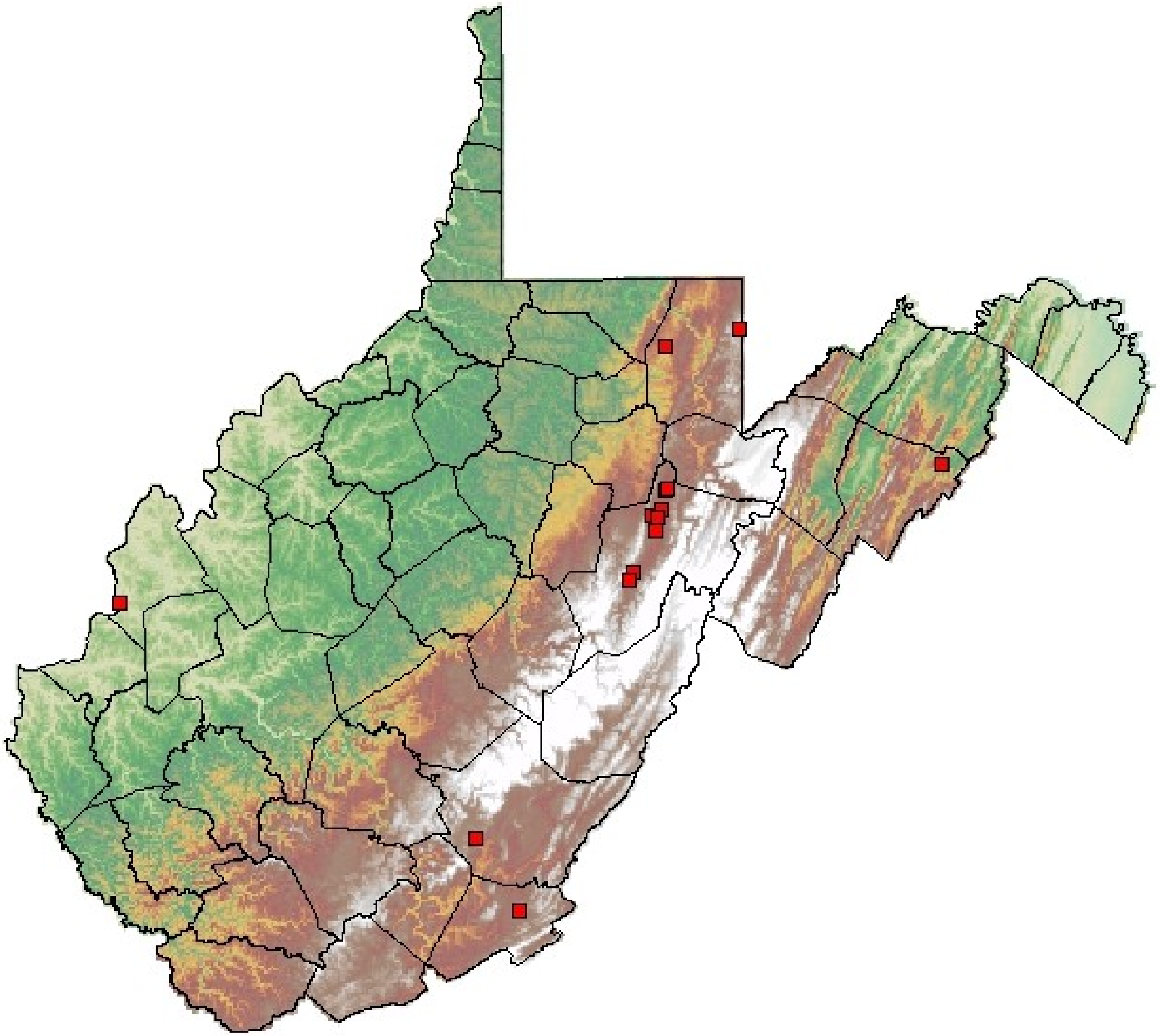


Figure 4: Historic records of Common Ribbonsnakes (*Thamnophis sauritus*). These records were obtained from WVBS, CMNH and WVDNR.

Figure 5: Wood pile where *Thamnophis sauritus* and *Thamnophis sirtalis* were found. This site is located at McClintic Wildlife Management Area in Mason County, West Virginia.

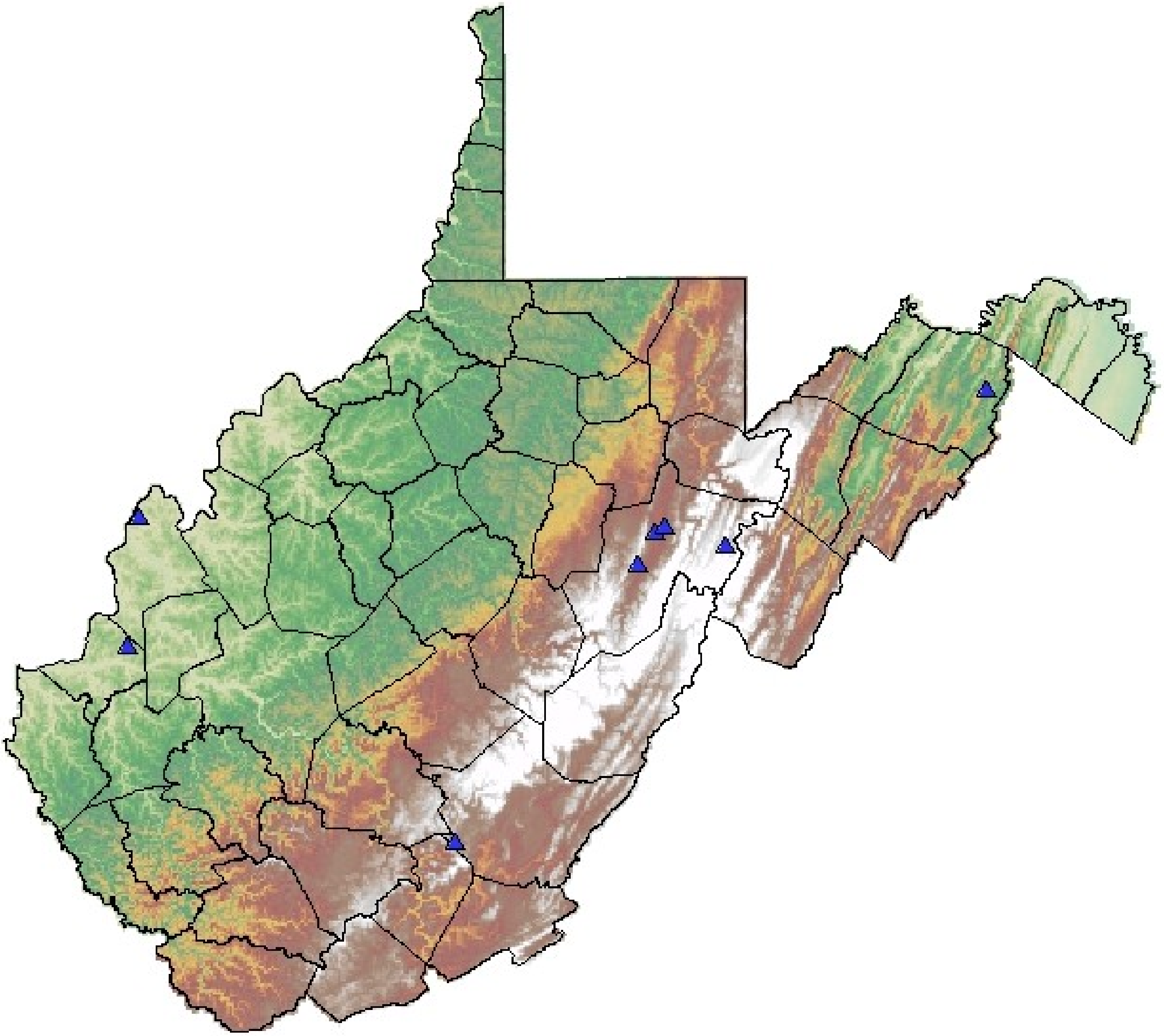


Figure 6: Current Records of Common Ribbonsnakes (*Thamnophis sauritus*). These sites were determined by records of WVBS, WVDNR and population I encountered during my study.

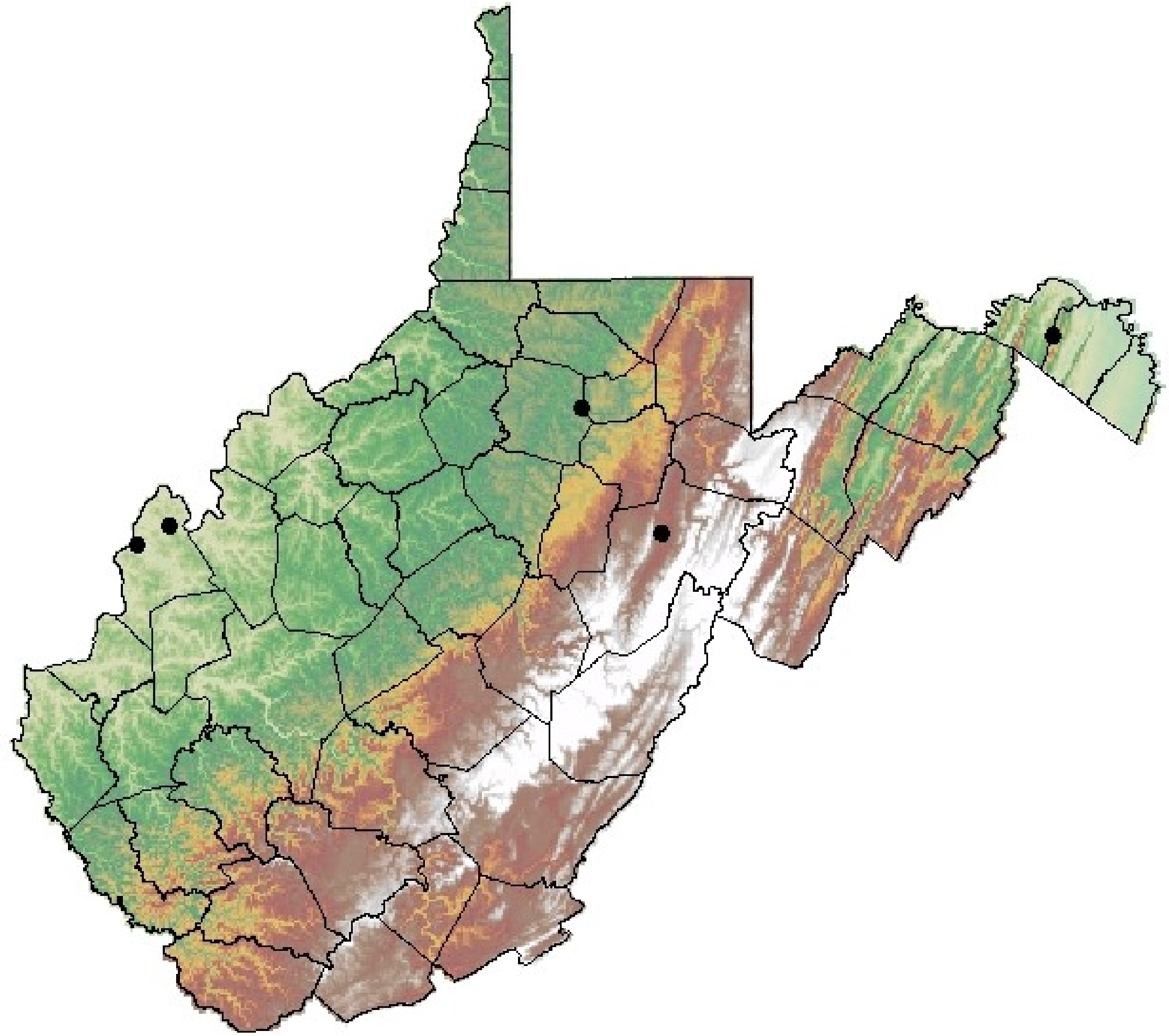


Figure 7: Unconfirmed records for Common Ribbonsnakes (*Thamnophis sauritus*). These records were obtained by personal communication from various people.

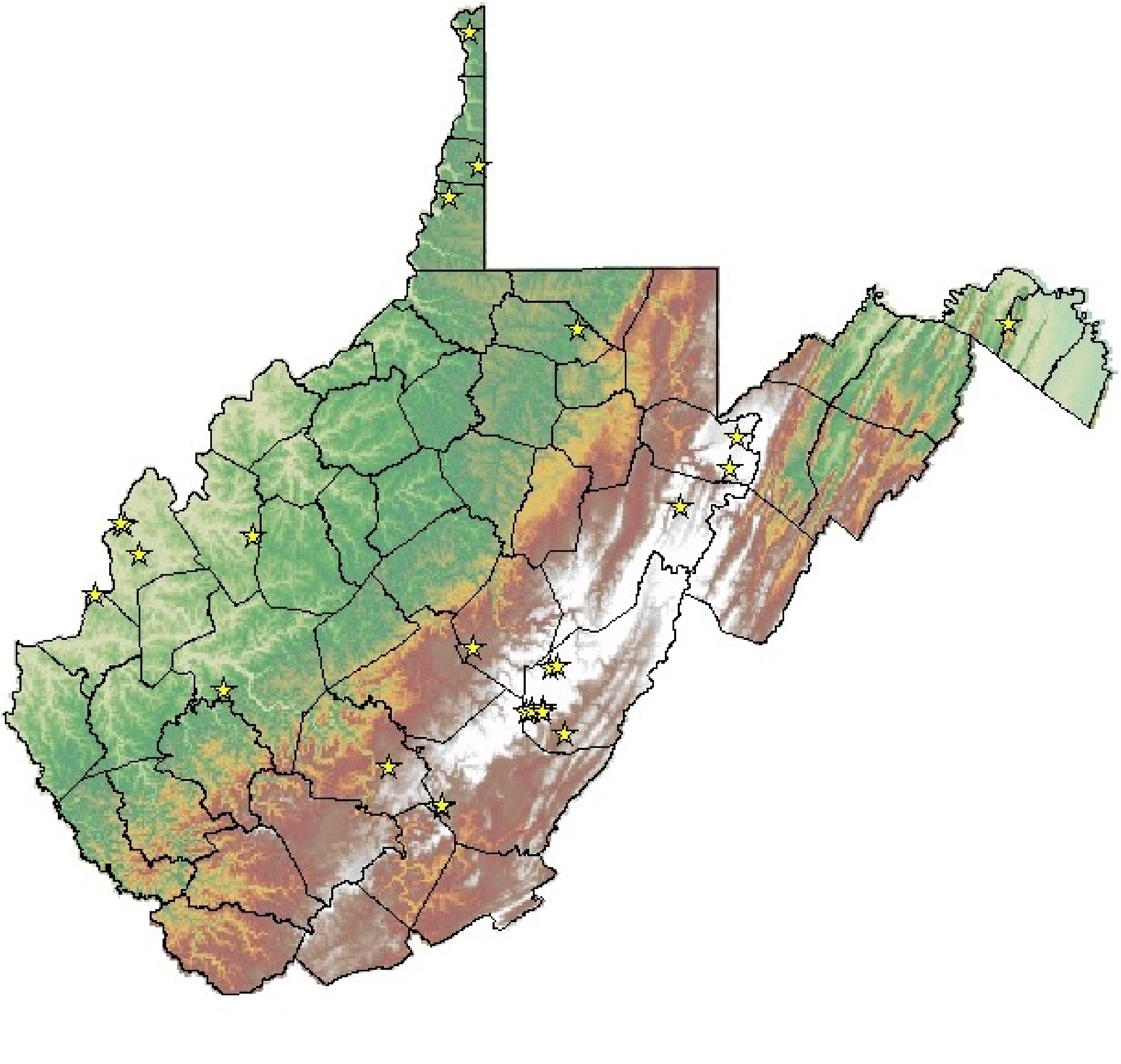


Figure 8: Potential habitat for Common Ribbonsnakes (*Thamnophis sauritus*). These sites were determined to be suitable during my surveys.

Figure 9: Wetland adjacent to location where *Thamnophis sauritus* was found.

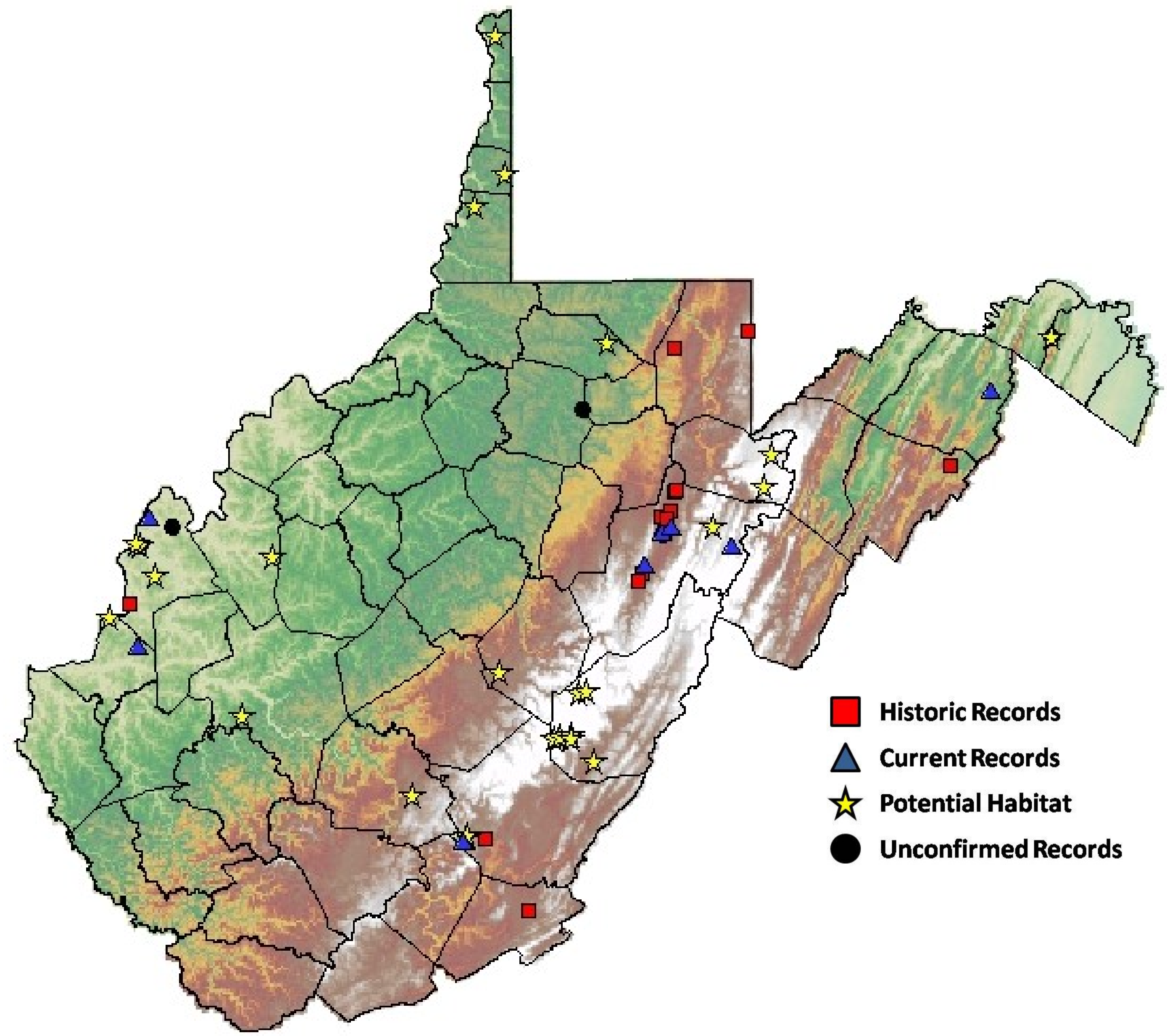


Figure 10: Total possible distribution for the Common Ribbonsnakes (*Thamnophis sauritus*).

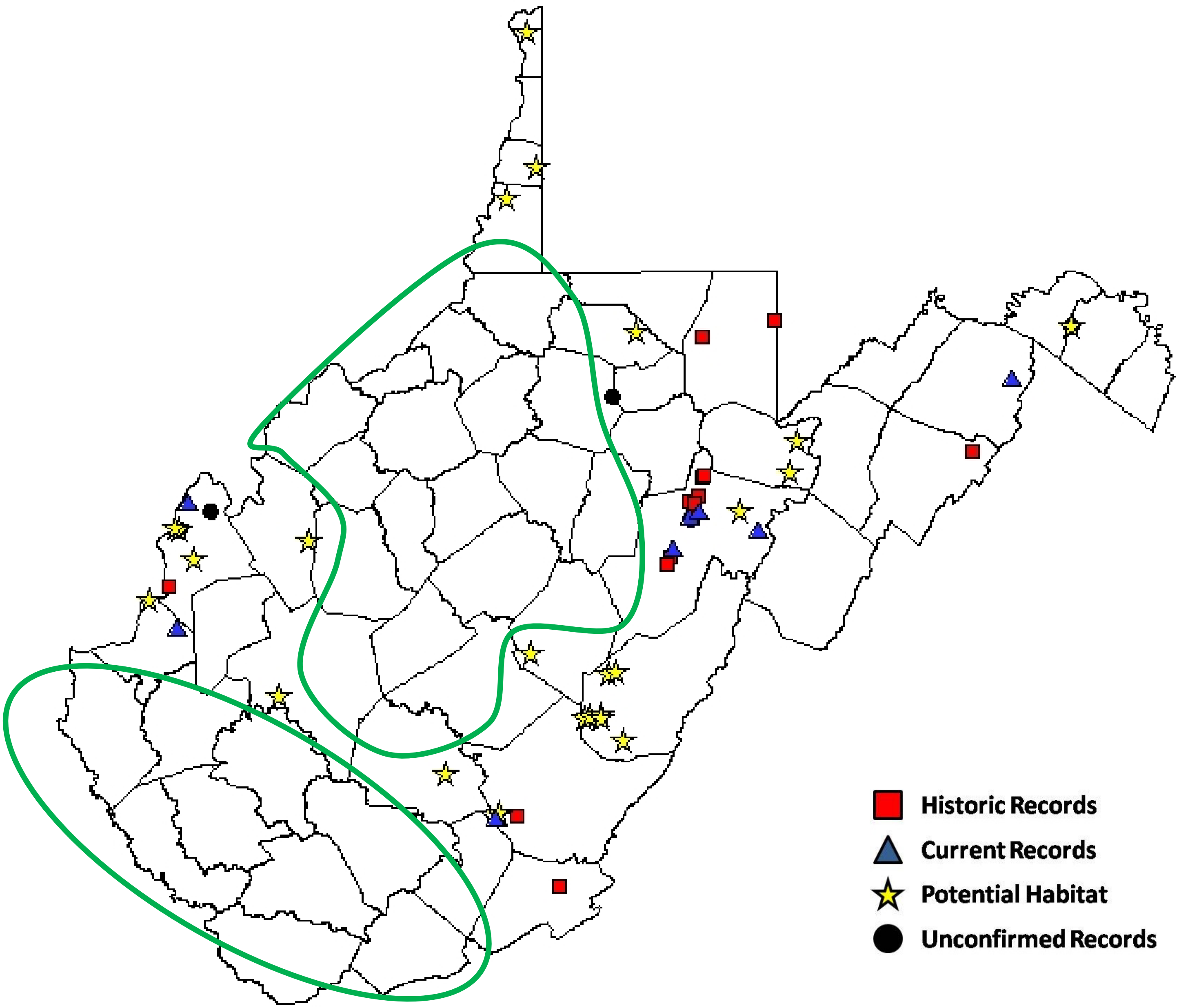


Figure 11: Total possible distribution indicating areas without *Thamnophis sauritus* populations (outlined in green).

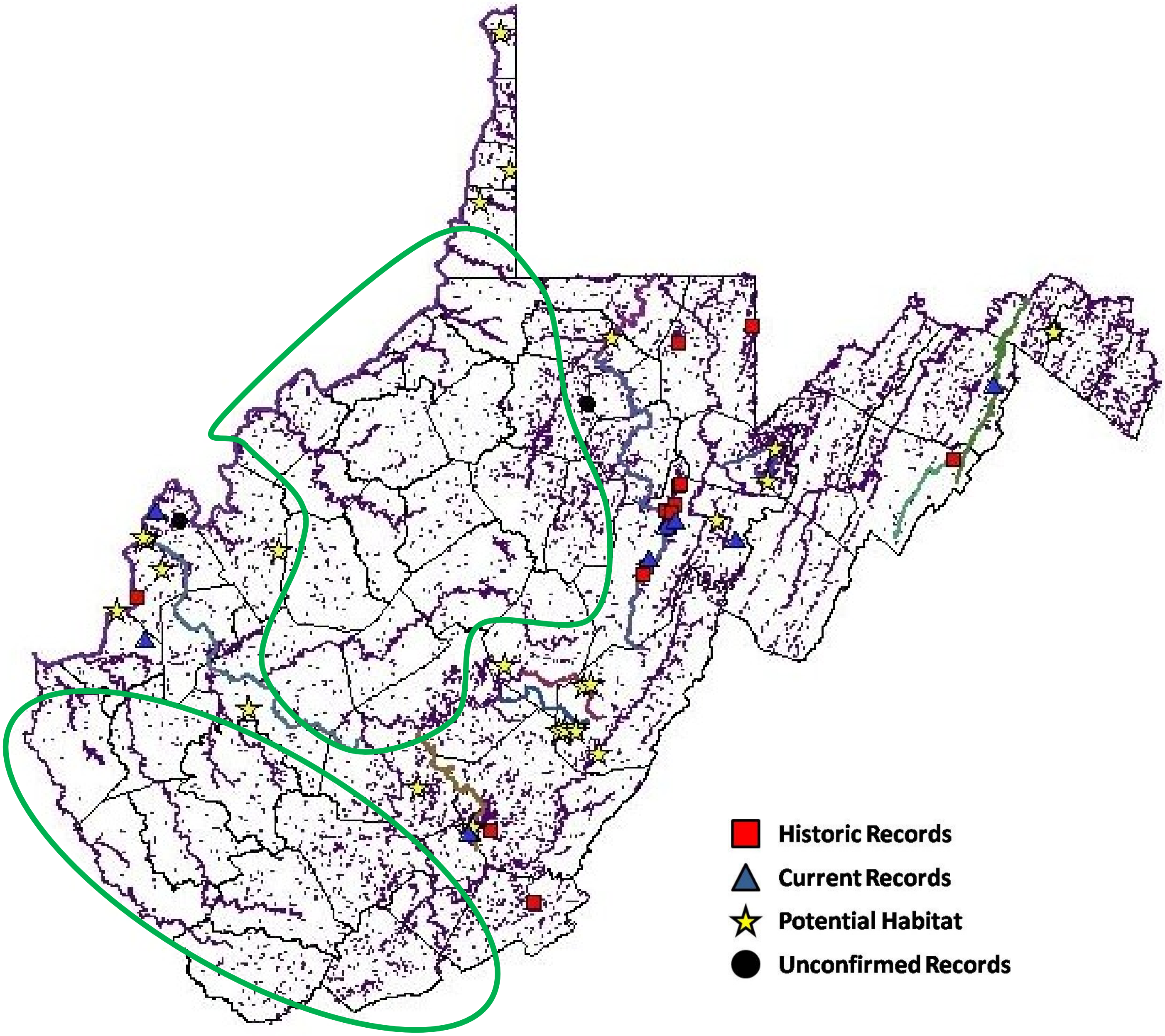


Figure 12: Distribution of *Thamnophis sauritus* in relation to wetlands and major rivers.

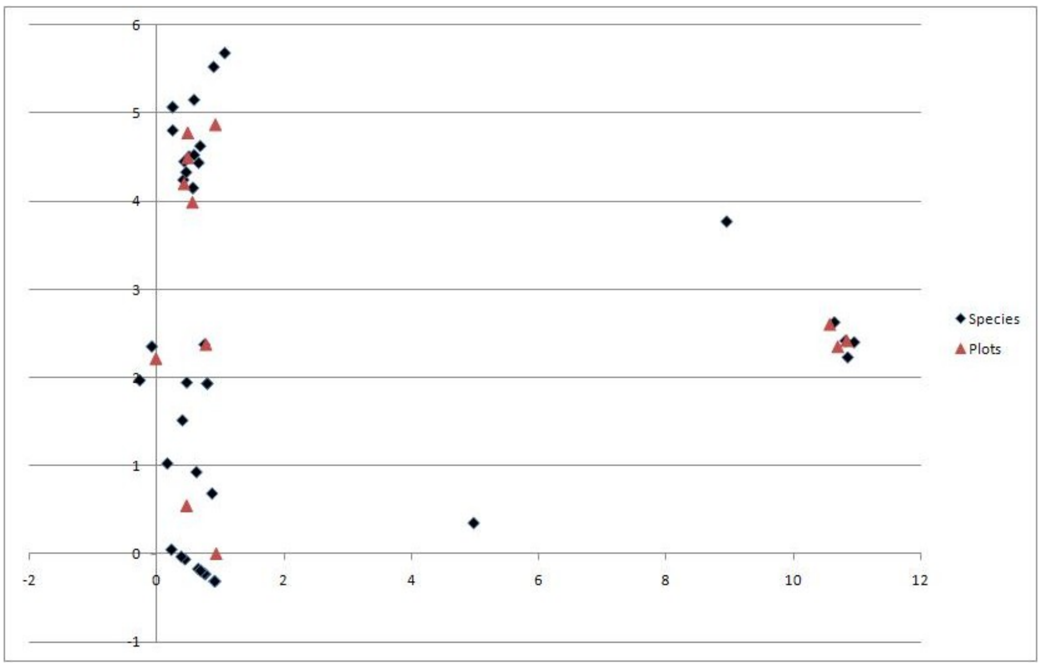


Figure 13: DCA vegetation analysis for sites surveyed.

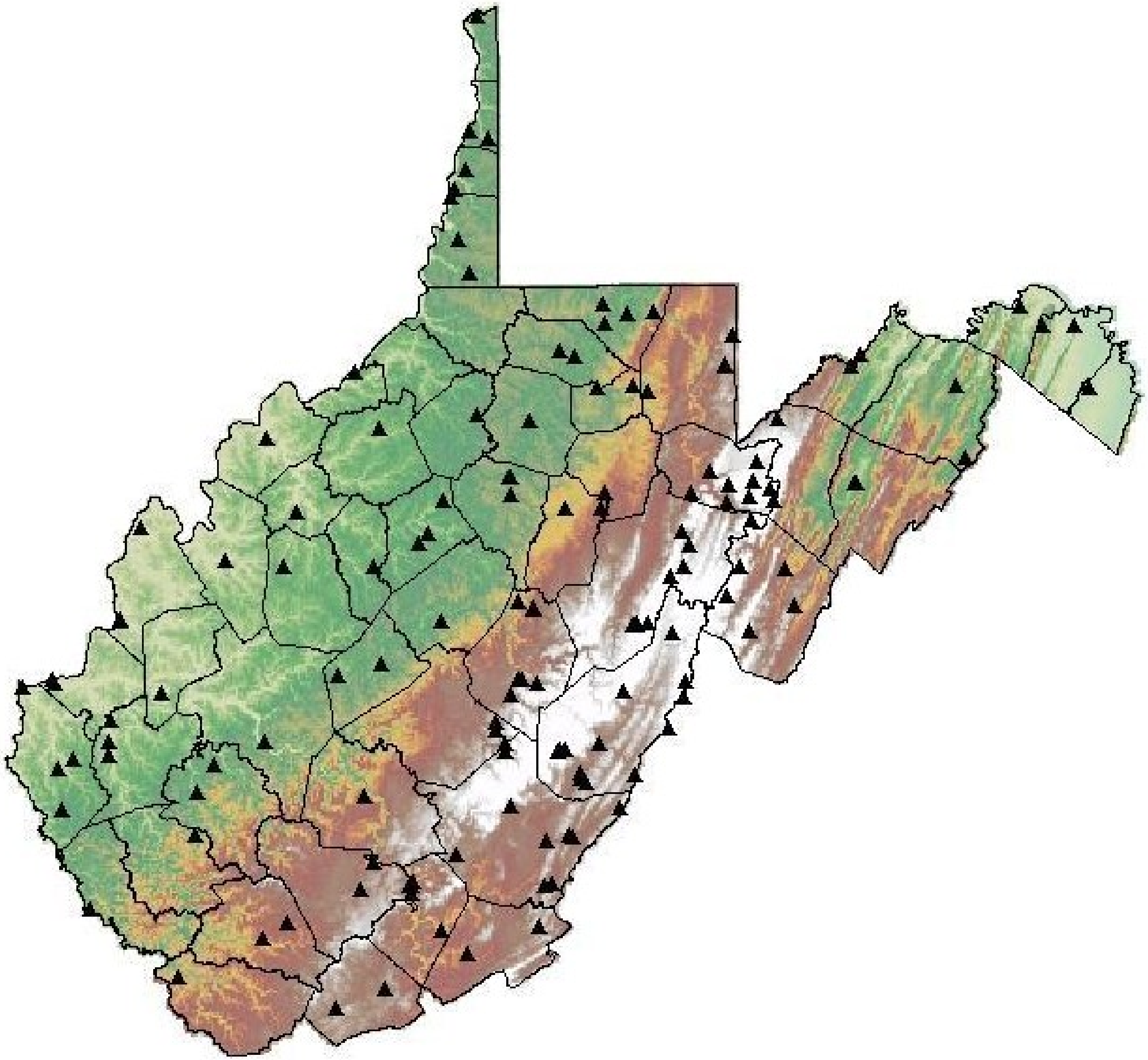


Figure 14: Distribution of the Eastern Gartersnake (*Thamnophis sirtalis*). This distribution was determined from personal collections, records from WVBS and records from CMNH.

Figure 15: Locations where *Thamnophis sirtalis* were found. Habitats are variable for this species: A) Woodland hillside B) Grassy field C) Wetland and D) River bank

Table 5: Total species found at all sites surveyed for vegetation analysis. Obligate Wetland (OBL) Occurs almost always (estimated probability 99%) under natural conditions in wetlands. Facultative Wetland (FACW) Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands. Facultative (FAC) Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%). Facultative Upland (FACU) Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%). Obligate Upland (UPL) Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. No indicator (NI) Insufficient information was available to determine an indicator status(Harmon et al.1996).

Species	Code	Common Name	Indicator
Acer negundo L.	ACNE	Box Elder	FAC
Acer rubrum L.	ACRU	Red Maple	FACW+
Acer saccharum Marsh.	ACSA	Sugar Maple	FACU-
Alnus serrulata (Ait.) Willd	ALSE	Hazel Alder	OBL
Asimina triloba L.	ASTR	Pawpaw	FACU+
Aster prenanthoides (Muhl. ex Willd.) G.L. Nesom	ASPR	Crookedstem Aster	FAC
Aster sp	ASSP	----	---
Avena sativa L.	AVSA	Common Oat	NI
Bidens cernua L.	BICE	Nodding Beggartick	OBL
Boehmeria cylindrical (L.) Sw.	BOCY	False Nettle	FACW+
Carex frankii Kunth	CAFR	Frank's Sedge	OBL
Carex lupulina Muhl. ex Willd	CALU	Sedge	OBL
Carex sp	CAsp	Sedge	---
Cephalanthus occidentalis L.	CEOC	Buttonbush	OBL
Cercis Canadensis L.	CECA	Redbud	FACU-
Cornus amomum Mill.	COMM	Silky Dogwood	FACW+
Corylus Americana Walter	COAM	American Hazelnut	FACU-
Cyperus erythrorhizos Muhl.	CYER	Redroot Flatsedge	FACW+
Dactylis glomerata L.	DAGL	Orchardgrass	FACU
Daucus carota L.	DACU	Queen Anne's Lace	NI
Digitaria filiformis (L.) Koeler	DIFI	Slender Crabgrass	NI
Elaeagnus umbellata Thunb.	ELUM	Autum Olive	NI
Eleocharis obtusa (Willd.) Schult	ELOB	Blunt Spikerush	OBL
Elymus riparius Weigand	ELRI	Riverbank Wildrye	FACW
Elymus L.	ELVI	Virginia Wildrye	FACW
Eupatorium perfoliatum L.	EUPE	Common Boneset	FACW+
Fagopyrum sagittatum Mill.	FASA	Buckwheat	NI
Fagus grandifolia Ehrh.	FAGR	American Beech	FACU

Table 1 Cont.

Galium asprellum Michx.	GAAS	Rough Bedstraw	OBL
Galium sp	GASP	Bedstraw	---
Geum sp	GESP	----	---
Glechoma hederacea L.	GLHE	Ground Ivy	FACU
Hamamelis virginiana L.	HAVI	Witchhazel	FAC-
Hibiscus moscheutos L.	HIMO	Swamp Rose Mallow	OBL
Hypercium muitlum L.	HYMU	Small Flowered St.John's Wort	FACW
Juncus effusus L.	JUEF	Common Rush	FACW+
Leersia oryzoides (L.) Sw.	LEOR	Rice Cutgrass	OBL
Ligustrum vulgare L.	LIVU	European Privet	FACU
Lindera benzoin (L.) Blume	LIBE	Spice Bush	FACW-
Lonicera japonica Thunb.	LOJA	Japanese Honeysuckle	
Lonicera tatarica L.	LOTA	Bush Honeysuckle	FACU
Ludwigia palustris (L.) Elliot	LUPA	Marsh Seedbox	OBL
Lysimachia nummularia L.	LYNU	Creeping Jenny	OBL
Myriophyllum heterophyllum Michx.	MYHE	Twoleaf Watermilfoil	OBL
Oxalis sp	OXSP	Woodsorrel	---
Oxydendrum arboreum L. DC	OXAR	Sourwood	NI
Panicum clandestinum (L.) Gould	PACL	Deertongue Grass	FAC+
Phalaris arundinacea L.	PHAR	Reed Canary Grass	FACW+
Plantago lanceolata L.	PLLA	Narrowlead Plantain	UPL
Plantago rugelii Decne.	PLRU	Blackseed Plantain	FACU
Platanus occidentalis L.	PLOC	Sycamore	FACW+
Polygonum hydropiperoides Michx.	POHY	Swamp Smartweed	OBL
Polygonum persicaria L.	POPE	Lady's Thumb	FACW
Polygonum sagittatum L	POSA	Arrowleaf Tearthumb	OBL
Polystichum acrostichoides (Michx.) Schott	POAC	Christmas Fern	FACU-
Potentilla sp	POSP	----	---
Prunus serotina Ehrh.	PRSE	Wild Black Cherry	FACU
Quercus rubra L.	QURU	Red Oak	FACU-
Rhus radicans L. Kuntze	RHRA	Poison Ivy	FAC
Rosa multiflora Thunb.	ROMU	Mutliflora Rose	FACU
Rubus sp	RUSP	Blackberry	---
Salix caroliniana Michx.	SACA	Coastal Plain Willow	OBL
Salix nigra Marsh	SANI	Black Willow	FACW+
Scirpus cyperinus Fernald	SCCY	Blackgridle Bulrush	FACW
Secale cereal L.	SECE	Cereal Rye	NI
Sedum ternatum Michx.	SETE	Wild Stonecrop	NI
Setaria geniculata (Poir.) Kerguélen	SEGA	Marsh Bristlegrass	FAC
Smilax sp	SMsp	Greenbrier	---

Table 1 Cont.

Solanum carolinense L.	SOCA	Horsenettle	UPL
Solidago graminifolia Salisb.	SOGR	Flat-top Goldentop	FAC
Stellaria media (L.) Mill	STME	Common Chickweed	UPL
Triodia flava(L.) Hitchc. var. flavus	TRFL	Purple Top Tridens	FACU
Typha latifolia L.	TYLA	Cattail	OBL
Verbesina alternifolia L.) Britton ex Kearney	VEAL	Wingstem	NI
Viburnum dentatum L.	VIDE	Southern Arrowwood	FACW
Viola sp	VIOSP	Violet	---
Viola striata Aiton	VIST	Strioed Cream Violet	FACW
Vitis sp	VISP	Grape	---

Table 6: Results from DCA analysis. All species found in all plots with species scores and axis scores.

N	Species	AX1	AX2	AX3	AX4	Species Score
	EIG	0.9718	0.8111	0.4467	0.1752	
1	ACRU	0.2504	5.0736	3.7047	-0.5039	2.5
2	ACSA	0.4331	0.7506	3.4229	1.4674	6.25
3	ASPR	0.2504	5.0736	3.7047	-0.5039	17.5
4	ASSP	1.1966	5.8512	2.4485	1.799	2.5
5	AVSA	0.5695	4.1554	3.7944	0.5947	20
6	BICE	0.2318	0.0508	3.5843	1.2867	10
7	BOCY	0.1667	1.0275	4.0657	0.4702	35
8	CAFR	0.7942	1.9354	-0.6124	0.8013	10
9	CALU	-0.2657	1.9725	4.46	0.7504	18.75
10	CASP	0.5865	5.155	3.4588	0.4413	207.08
11	CEOC	0.9112	-0.309	2.9731	-0.1149	1.25
12	COMM	10.9454	2.4041	3.0148	3.9277	7.5
13	CYER	0.9112	-0.309	2.9731	-0.1149	16.25
14	DAGL	0.1895	4.3855	1.2058	1.2024	5
15	DACU	0.7942	1.9354	-0.6124	0.8013	5
16	DIFI	-0.0754	2.3557	4.1224	0.7249	127.5
17	ELUM	0.5695	4.1554	3.7944	0.5947	2.5
18	ELOB	0.8691	0.688	-0.1136	0.1845	31.25
19	ELRI	0.2504	5.0736	3.7047	-0.5039	20
20	ELVI	1.068	5.6865	2.6775	1.7118	17.5
21	EUPE	0.9112	-0.309	2.9731	-0.1149	15
22	FASA	0.4726	1.9468	-0.319	0.7855	36.25
23	GAAS	0.5695	4.1554	3.7944	0.5947	17.5
24	GASP	4.9759	0.3526	2.9796	-1.3689	15
25	GESP	0.2318	0.0508	3.5843	1.2867	6.25

26	GLHE	0.2509	4.8089	3.6719	-0.2556	42.5
27	HIMO	0.2318	0.0508	3.5843	1.2867	5
28	HYMU	0.9112	-0.309	2.9731	-0.1149	20
29	JUEF	0.7942	1.9354	-0.6124	0.8013	8.75
30	LEOR	0.6517	-0.1682	3.2586	0.4156	57.5
31	LOJA	0.5111	4.512	3.4612	0.3112	75
32	LUPA	0.7644	-0.229	3.1383	0.1689	11.25
33	LYNU	10.845	2.2325	3.0122	-2.8413	20
34	MYHE	0.4456	-0.0599	3.4327	0.8668	65
35	OXSP	0.4961	3.3099	-0.2828	1.0067	2.5
36	OXAR	0.9112	-0.309	2.9731	-0.1149	12.5
37	PACL	0.4335	4.4551	1.4147	0.6506	238.75
38	PHAR	10.8085	2.4195	2.2688	0.6025	300
39	PLLA	0.7942	1.9354	-0.6124	0.8013	2.5
40	PLRU	0.7942	1.9354	-0.6124	0.8013	5
41	POHY	0.7459	-0.219	3.1584	0.2071	40
42	POPE	0.6243	0.9301	3.3402	-0.0876	22.5
43	POSA	10.9454	2.4041	3.0148	3.9277	12.5
44	POAC	0.894	5.5295	2.9717	1.4647	90
45	POSP	8.9463	3.7741	0.5228	1.0517	27.5
46	PRSE	0.6904	-0.189	3.2188	0.3295	11.25
47	RHRA	0.2318	0.0508	3.5843	1.2867	2.5
48	ROMU	0.4049	1.5182	3.2735	0.9994	62.5
49	RUSP	0.4187	4.247	3.1068	0.8457	12.5
50	SANI	0.7942	1.9354	-0.6124	0.8013	10
51	SCCY	10.6356	2.6304	0.6898	0.3583	10
52	SECE	0.5695	4.1554	3.7944	0.5947	8.75
53	SETE	0.2504	5.0736	3.7047	-0.5039	2.5
54	SEGA	0.7942	1.9354	-0.6124	0.8013	5
55	SMSP	0.6826	4.6317	3.2759	0.8422	22.5
56	SOCA	0.7496	2.3782	-0.4458	0.76	12.5
57	SOGR	10.9454	2.4041	3.0148	3.9277	2.5
58	STME	0.2511	4.6986	3.657	-0.0465	7.5
59	TRFL	0.7942	1.9354	-0.6124	0.8013	40
60	TYLA	0.6904	-0.189	3.2188	0.3295	22.5
61	VEAL	0.6584	4.441	1.9193	1.177	53.75
62	VIDE	0.3867	-0.0291	3.4802	0.9912	11.25
63	VIOS P	0.5877	4.531	3.4481	0.7525	33.75
64	VISP	0.464	4.3335	3.7536	0.372	22.5

Table 7: Food items removed from dissected specimens.

X=item observed, 0=item not observed.

	T. sirtalis	T. sauritus
Desmognathus ochrophaeus	x	0
Earthworm	x	0
Pseudacris spp	0	x
Bufo americanus	x	0
Plethodon glutinosus	x	0
Plethodon electromorphus	x	0

Table 8: Food items offered during feeding trials. X=accepted O=not accepted n.o.=not offered

	T. sirtalis	T. sauritus
Desmognathus fuscus	x	x
Desmognathus monticola	x	x
Desmognathus ochrophaeus	x	x
Rana catesbeiana	x	x
Rana clamitans melanota	x	x
slug	0	0
earthworm	x	0
grasshopper	0	0
Pseudacris crucifer	x	x
crayfish	0	0
minnow/goldfish	x	x
Bufo americanus	x	x
Rana palustris	x	0
Notophthalmus viridescens	x	n.o.
Rana pipiens	x	0
Rana sylvatica	n.o.	x
caterpillar	0	0
Thamnophis sauritus (juvenile)	0	n.o.
Eurycea bislineata	x	x
Hyla chrysoscelis	x	n.o.
***Ambystoma* jeffersonianum**	x	0
***Ambystoma opacum* (Larvae)**	n.o.	x

Chapter Three: Reproduction of the Common Ribbonsnake (*Thamnophis sauritus*) and the Eastern Gartersnake (*Thamnophis sirtalis*) in West Virginia

Introduction:

Reproduction is an important factor when considering the conservation of a species (Seigel and Fitch 1985). Reproduction and survivorship can have a significant impact on the status of a given species. *Thamnophis sirtalis* is one the most common snake species in West Virginia and *Thamnophis sauritus* is one of the rarest (Green and Pauley 1987). Understanding the reproduction of this species could provide insight to the vulnerability of these two snakes.

Much work has been done on the reproduction on the *Thamnophis* genus; however most of data available are from studies on *T. sirtalis* (Rossman 1996). Few studies have examined the reproduction of *T. sauritus* and the data are very limited due to small sample sizes in each study. These studies have been conducted mostly in the northern portion of the ranges of these species because these snakes are more abundant in the northern regions of their range (Rossman 1996). Information regarding reproduction in the southern ranges is insufficient because most of the studies have data on only one or very few specimens.(Rossman et al. 1996) Reproduction on either *T. sauritus* or *T.sirtalis* has never been studied in West Virginia.

Mating has been assumed to be similar for *T. sauritus* and *T. sirtalis* (Carpenter 1952. Mating has been shown to begin in early spring usually just after emerging from hibernation (Ernst and Barbour 1989). Mating usually takes place in second-year females that are minimum snout-vent length of 34.1cm (Rossman 1963) and after the second or third year for males (Clesson et al.2002) at a minimum snout-vent length of 38.0cm. Although minimum lengths have been reported, Clesson et al.(2002) has shown evidence that length does not accurately show age for many species of snakes.

Mating time varies with different populations and numerous factors account for this variation. Factors such as hibernation time, weather and elevation can influence time of mating (Blanchard and Blanchard 1937; Larsen et al. 1992). For example, snakes in northern populations mating do not mate until mid-April (Larsen et al. 1992). Southern populations might mate as early as March (Blanchard and Blanchard 1937; Ernst and Barbour 1989). Gestation period has been estimated to last from 84 to 117 days (Blanchard and Blanchard 1937). Using these estimations, time of mating and date of birth can be predicted (Blanchard and Blanchard 1937). Several factors can influence gestation. Temperature is the most influential factor, and variation of approximately 0.5^{o} C causes a difference of 4.5 days in gestation period (Blanchard and Blanchard 1937).

Clutch size varies as well and tends to increase with increasing size of the mother (Gregory and Larsen 1993). Other factors such as prey availability and environmental condition can also have an impact on clutch size (Seigel and Fitch 1985). During such times females may reabsorb follicles, reducing the size of the clutch (Seigel and Fitch 1985).

Thamnophis sauritus is considered a semi-arboreal and semi-aquatic species and is therefore restricted to wetland habitats (Carpenter 1952; Bell et al.2007, Rossman 1996). *Thamnophis sirtalis* is more terrestrial and lives in more variable habitats (Carpenter 1952). Juveniles are small versions of adults and exhibit the same morphological traits as the adults which make them adapted to the habitats in which they are found.

The objectives of this study were to determine mating time, time of birth, and clutch size of *T. sauritus* and *T. sirtalis* populations in West Virginia. Morphometric analysis of the neonates was also conducted to determine any differences which are present at birth which could partially account for the differences in habitat selection (Chapter 2).

Methods:

During the active season (May-August) of 2007, *T. sauritus and T. sirtalis* were collected in Mason County, West Virginia. Gravid females were placed into captivity and water was given *ad libitum* during this time. Food was occasionally offered but was always refused. Specimens were held until they had given birth and offspring were counted and measured (Table 5). As soon as possible (usually within a few days) the young and the female were released at the location from which they were captured. Further monitoring of the released animals was not conducted after they were released.

Specimens from the West Virginia Biological Museum (WVBS) at Marshall University and Carnegie Museum of Natural History (CMNH) were measured and dissected to determine the number of embryos (i.e. clutch size) (Seigel and Fitch 1985). Embryos were measured to estimate the development which could then be used to estimate parturition.

Time of mating was estimated using the date of neonate deposition and previously documented gestation length. The gestation period for *T. sauritus* has not been well documented however, it is assumed to be similar to *T. sirtalis* (87-116days) because of other members of the genus (Minton 1972).Mating time was assumed to be just after emergence from hibernation and gestation was estimated to be the same as *T.s sirtalis*, based on studies that have shown similar life history traits of *T. sauritus* and *T. sirtalis*(Rossman 1963, Carpenter 1952).

The summer of 2007 was very warm and gestation could be assumed to have taken a shorter amount of time. Both 87 and 117 days were used to estimate mating season in spite of high temperatures recorded. Records of temperature for the preserved snakes had considerable variation for the years in which the snakes were collected; therefore both minimum and maximum temperature estimations were used to estimate gestation period.

Some museum specimens were captured when they were gravid and for these specimens, the time of collection and how far the embryos were developed was noted to estimate time of mating. This method is not as accurate as calculating mating from parturition; however, this does provide insight on time in which mating occurs.

The earliest time of mating was determined by searching records for the earliest month of occurrence from hibernation for both species. Collection dates of females were used as well to estimate time of mating by noting when they were captured and if they were gravid. From this the earliest record of a gravid female can be used to estimate when mating occurs. Monthly activity patterns, which show the time of year of when the snakes have been encountered (therefore are active), were prepared from records. Determining when snakes are encountered and not encountered can be used to determine when emergence from hibernation occurs and when the species is most active. From this, an estimation can be made to determine when hibernation, mating, time of most activity, and reemergence into hibernation occur for *T. sauritus* and *T. sirtalis*.

Statistics:

Statistica 6.0 (StatSoft) software was used to statistically analyze possible differences in clutch sizes, SVLs, and tail lengths of the offspring of both species, and to determine any correlations between SVL and clutch size. Differences in SVL and tail length were compared within species and between species of neonates. Samples sizes were different for *T.sauritus* and *T. sirtalis*. To account for this difference Shapiro-Wilk W test was conducted to determine if the two samples met normality. Differences in clutch size were determined between the two species using Mann-Whitney U test. Neonate morphometrics were compared using Bonferroni post hoc test.

Results:

Thamnophis sauritus emerge from hibernation in late March. The earliest time of emergence was March 27 in Randolph County. Emergence from hibernation occurs as early as mid-March for *T. sirtalis*. Their earliest recorded time of occurrence was March 15, also in Randolph County. Emergence from hibernation continues through April and into May. Summer activity begins in March to April for *T. sirtalis* (Figure 20). Due to the small sample size of *T. sauritus*, initiation of activity could not be determined. I found activity to increase in the later months of May through June and reach a peak in June. July and August have a decrease in activity followed by a slight increase from September to October.

Mating occurs from mid-April to mid-May for *T. sauritus* and early April to early May for *T. sirtalis* (Table 6). Mating is likely to occur shortly after hibernation. Gravid females were recorded from May through July for both species. The earliest recorded gravid female for *T. sauritus* was on April 27 and on April 15 for *T. sirtalis*.

Parturition occurs in early August for *T sauritus* and late July in *T.sirtalis.* I observed the latest day of birth for captured *T. sirtalis* to be July 30, which occurred before captured *T. sauritus* was observed to give birth on August 3.

Clutch size was significantly different between the two species (Figure 16). *T. sauritus* had a smaller clutch size than *T. sirtalis (*Table 7). The clutch size for *T. sauritus* was 9.75(SD=2.6049, n=8) with a range of 7-15 neonates. Neonate size in *T. sauritus* averaged 11.93 (SD=.7196, n=15) with a range of 10.1 to 12.9. There was not a significant difference in SVL of neonates within *T. sauritus*. The neonates of *T. sauritus* ranged in weight from ½ gram to 1 ½ grams, sex ratios were 1:1. Clutch size was not significantly correlated with SVL in this species (P=0.105, Figure 17).

Thamnophis sirtalis had a much larger clutch size than *T. sauritus* (Table 7). *Thamnophis sirtalis* had an average clutch size of 15.8 (SD=8.064, n=15) with a range of 7-40 neonates. There was not a significant difference in SVL of the neonates within *T. sirtalis*. Weight ranged from ½ gram to 1 ½ grams and sex ratios were also 1:1. SVL and clutch were weakly correlated (P=0.051) in *T. sirtalis* (Figure 18).

Size of offspring of both species was similar in body size, but not for tail and head size. Snout-vent length, eye diameter, and head width did not show any significant differences. Tail length and head length did show differences. Tail length was longer in *T. sauritus* than for *T. sirtalis (*Figure 19*)*. *T. sauritus* had a shorter head than for *T.s sirtalis* (Table 8).

Discussion:

The reproductive biology of *T. sauritus* and *T. sirtalis* in West Virginia is similar to that of other regions such as Michigan, Maryland, Ontario, Northwest Territories, and North Carolina

(Table 9) which have conducted similar studies. I found hibernation to end in March to April for both species, occurring slightly earlier for *Thamnophis sirtalis*. Studies from other regions including Michigan, Maryland, Ontario, Northwest Territories, and North Carolina have found that T. sirtalis emerges from hibernation from mid march through April and May (Palmer, 1995, Larsen et al. 1992, Minton, 1972).

After hibernation, I found peak activity to occur during in June (Figure 20), after individuals left the proximity of the hibernacula to feed which is similar to Larsen et al. (1992). During July and August activity decreases possibly due to less movement by gravid females or the tendency to remain hidden to escape heat which was first observed by Carpenter (1952). September and October indicate a slight increase as the snakes return to the hibernacula, similar to the findings of Larsen et al. (1992). This increase in activity could indicate a fall mating period as suggested by Gregory (1974) and Rossman et al. (1996).

From museum records and personal observation I determined that mating takes place shortly after emergence from April to May and females show signs of pregnancy in March through July with birth occurring in late July for *T.sirtalis* and early August for *T. sauritus*. Time of mating is very similar to that of other regions(Table 10).Time of parturition is consistent with other studies (Carpenter 1952, Bell et al. 2007) conducted in Michigan and Canada which found parturition in early August for *T. sauritus*. Parturition occurring from late July to early August is consistent with populations of *T. sirtalis* in Kansas (Fitch 1965); however, studies on more northern populations such as, Michigan and the Northwest Territories of, *T. sirtalis* have reported that birth occurs from late July through late August (Blanchard and Blanchard 1936, Carpenter 1952, Larsen et al. 1992).

As previously stated, *T. sauritus* is a rare species whereas *T. sirtalis* is among the most common of snakes in West Virginia (Green and Pauley. 1987). Factor such as habitat, diet and reproduction might account for the difference in their occurrences (Seigel and Fitch 1985, Carpenter 1952). Clutch size is significantly different between species (Carpenter1952), in that *T. sauritus* has a smaller average litter size than *T. sirtalis*. Clutch size can linked to reproductive success (Seigela and Fitch 1985) which can ultimately reflect the success of the species.

Variation of clutch size between individuals was observed in my study within both species, but much more variation was observed for *Thamnophis sirtalis*. Food supply often accounts for variation in cutch size and size of neonates (Seigel and Fitch. 1985). During times of drought or a decrease in the availability of food females may reabsorb underdeveloped embryos (Seigal and Fitch 1985). This greater variation in clutch size in *T. sirtalis* may be a result of this species occupying a greater variety of habitats (Chapter 2) and thus possibly a greater fluctuation in food availability within each habitat.

My data showed that tail length was much longer in neonates of *T. sauritus* than in *T. sirtalis* (Figure 19). Longer tails are a trait often found in arboreal species (Pizzato et al. 2007). I observed that *T. sauritus*, even at a very young age, to displayed traits of semi-arboreal behavior by using their long tails as a support when climbing on limbs.

Increased head length is usually found in arboreal species (Lillywhite and Henderson 1993) suggesting that *T. sauritus* should have longer head length. However, this was not the case in the neonates that I measured. Head length was shorter in *T. sauritus* than in *T. sirtalis*. Carpenter (1952) and Rossman (1963) showed that the primary prey items for *T. sauritus* are amphibians and amphibian larvae, whereas *T. sirtalis* consumes a variety of prey including amphibians, mammals, earthworms, snails, and leeches as primary prey (Carpenter 1952). Larger head size in *T. sirtalis*, even displayed at this young age, could be explained by the large variety of prey items.

My study has indicated that mating and reproduction of *T. sauritus* and *T. sirtalis* are very similar to reports from other regions including Michigan, Maryland, Nova Scotia, Northwest Territories, and North Carolina (Carpenter 1952, Larsen et al. 1992, Bell at al. 2007, McCauley, 1945, Palmer, 1995). *Thamnophis sauritus* mates slightly later and has a much smaller clutch size than *T. sirtalis*. Clutch size is a likely one factor which influences the success of these two species. From my results, I believe that the smaller clutch size of *T. sauritus* may be a leading factor as to why this species is less common in West Virginia.

Figure 16 : Clutch size of *Thamnophis sauritus* and *Thamnophis sirtalis*. Clutch size is significantly higher in *Thamnophis sirtalis* than in *Thamnophis sauritus*(P=0.020). Error bars show standard error 0.921 (*T. sauritus*) and 2.082 (*T. sirtalis*).

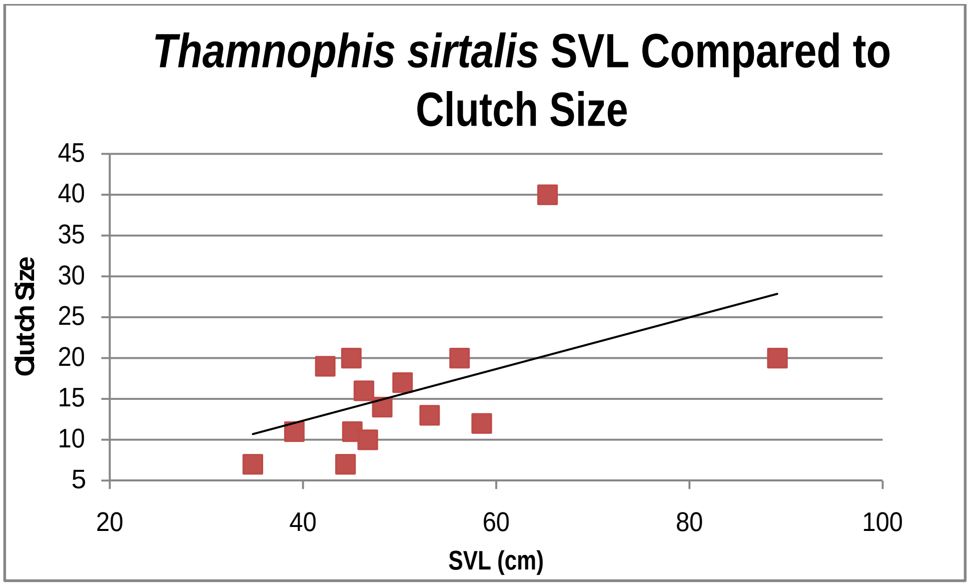


Figure 17: SVL compared to clutch size in *Thamnophis sirtalis*. This weakly correlated with clutch size(P=0.051).

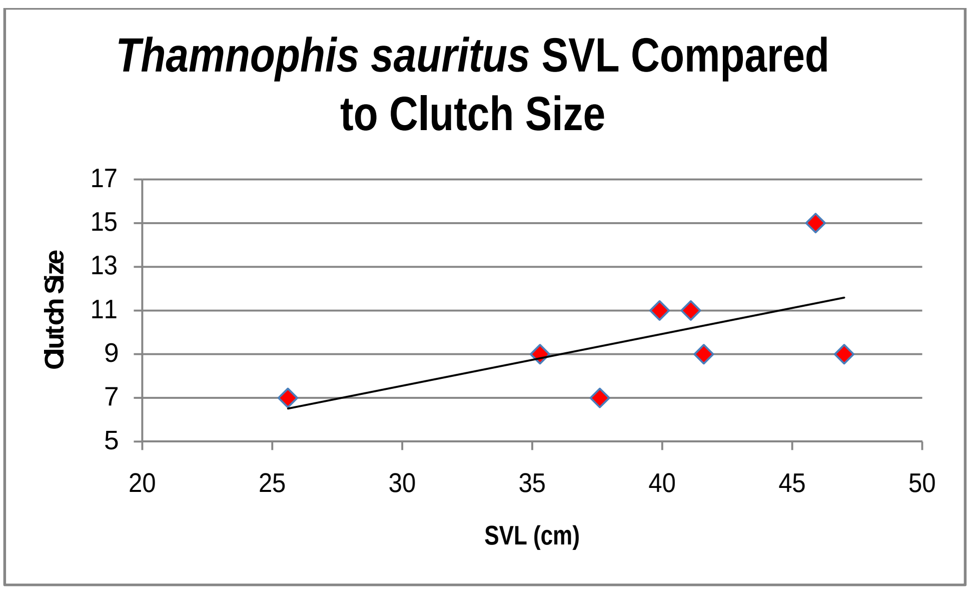


Figure 18: SVL compared to clutch size for *Thamnophis sauritus*. This not correlated with clutch size (P=0.105)

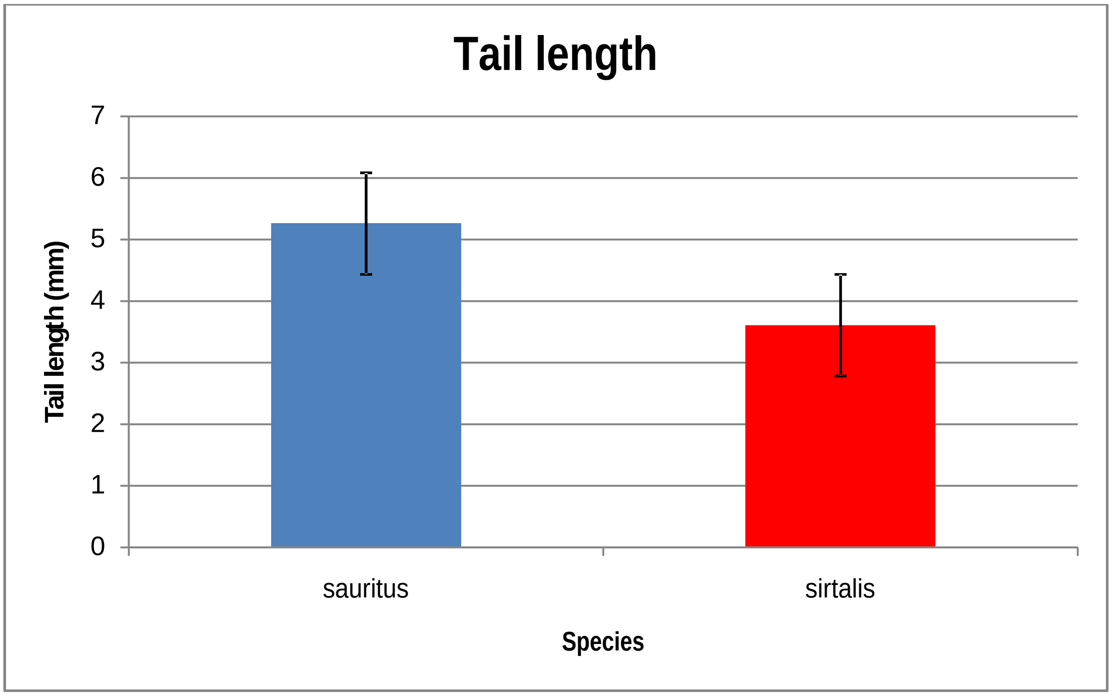


Figure 19: Comparison of tail length for *Thamnophis sauritus* and *Thamnophis sirtalis* newborns in West Virginia. This is a significant difference between species.

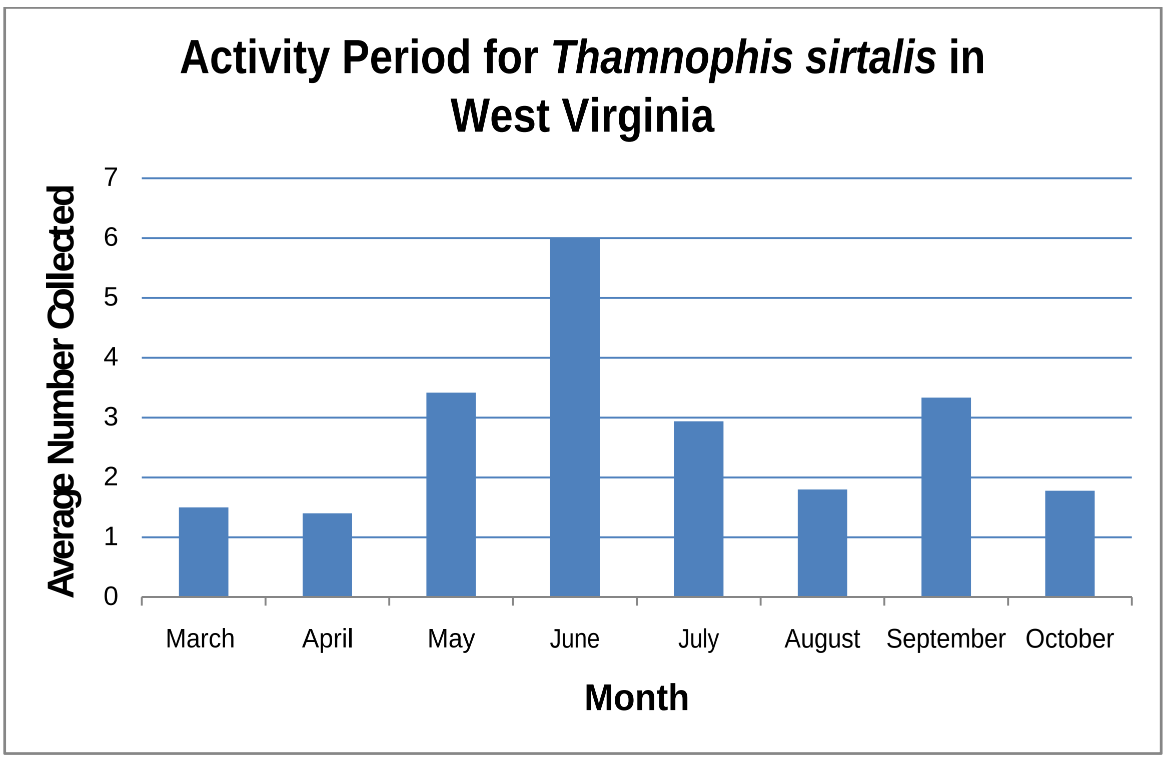


Figure 20: Activity period for *Thamnophis sirtalis*. Number collected were standardized by dividing the number of snakes recorded in each month by the number of times that month was surveyed in West Virginia from 1936-2008.

Table 5: Morphometrics collected from neonates of *Thamnophis sauritus* and *Thamnophis sirtalis*.

Characteristic	Description
Weight	Measured total weight to nearest half-gram
Snout-vent Length	Measured from tip of rostrum to anal vent
Tail Length	Measured from anal vent to tip of tail
Eye Diameter	Measured eye between preocular and postocular scales
Cranial Length	Measured from tip of rostrum to angle of jaw
Cranial Width	Measured across width of head at angle of jaw
Sex	Determined by palpating tail for presence of hemipenes

Table 6: Estimated time of mating for *Thamnophis sauritus* and *Thamnophis sirtalis* in West Virginia. These periods were estimated from dates of birth I observed for captured animals.

Species	Time of Mating
T. sauritus	1st week of April – 2nd week of May
T. sirtalis	Last week of March – 1st week of May

Table 7: Comparison of reproductive characteristics for *Thamnophis sauritus* and *Thamnophis sirtalis* in West Virginia. Statistics are mean(top row), number of individuals (middle row) and range (bottom row). * indicates statistical significance

Species	SVL	Clutch Size	Neonate SVL	Sex Ratio
T. sauritus	395mm	9.75*	119mm	1:1
	(8)	(8)	(15)	
	(25.6-47.0)	(7-15)	(4.3-5.8)	
T. sirtalis	509.6mm	15.8*	123.7mm	1:1
	(15)	(15)	(67)	
	(34.8-89.1)	(7-40)	(10.1-13.7)	
		(P=0.020)		

Table 8: Comparison of head morphometrics between neonate *Thamnophis sauritus* and *Thamnophis sirtalis* in West Virginia. Statistics are mean(top row), number of individuals (middle row) and range (bottom row). * indicates statistical significance

Species	Head Length	Head Width	Eye Diameter	Weight
Thamnophis sauritus	9.64mm*	4.77mm	3.19mm	0.833grams
	15	15	15	15
	(8.2-10.8)	(4.0-5.6)	(2.8-3.5)	(0.5-1.0)
Thamnophis sirtalis	10.12mm*	4.96mm	3.26mm	0.835grams
	67	67	67	67
	(8.3-11.3)	(4.1-6.4)	(2.7-3.6)	(0.5-1.5)
	(P=0.0096)			

Table 9: Reproduction characteristics from other regions.

Species	Region	Clutch Size	Offspring size	Source
T. sauritus	Maryland	10.7		McCauley, 1945
T. sauritus	Michigan	6		Burt, 1928
T. sauritus	Michigan	10		Carpenter, 1952
T. sauritus	Ontario	12.2	141.1-165.3mm	Rossman, 1963
T. sauritus	Pennsylvania	11.3		Hulse et al., 2001
T. sauritus	North Carolina	8.3	195-208mm	Palmer, 1995
T. sauritus	Indiana	6.3		Minton, 1972
T. sirtlais	Kansas	14.5	168mm	Fitch 1965, Seigel and Fitch 1985
T. sirtlais	Maryland	32.5		McCauley, 1945
T. sirtlais	Michigan	16.9		Burt, 1928
T. sirtlais	Michigan	18		Carpenter, 1952
T. sirtlais	Ontario	18.3		Gregory and Larsen, 1993
T. sirtlais	Alberta	12.5		Larsen et al., 1993
T. sirtlais	Pennsylvania	22.4		Hulse et al., 2001
T. sirtlais	North Carolina	33.3	141-193.3mm	Palmer, 1995

Table 10: Time of mating from other regions.

Species	Region	Time of mating	Source
T. sauritus	North Carolina	2nd week of April- Last week of June	Palmer, 1995
T. sauritus	Indiana	Last week of March- 2nd week of May	Minton, 1972
T. sirtalis	North Carolina	last week of March – 2nd week of June	Palmer, 1995
T. sirtalis	Indiana	1st week of April- 1st week of July	Minton, 1972
T. sirtalis	Michigan	1st week of April- 2nd week of May	Blanchard and Blanchard, 1937
T. sirtalis	Northwest Territories	3rd week of April-2nd week of June	Larsen et al., 1992

Chapter Four: Morphological Comparison of the Common Ribbonsnake (*Thamnophis sauritus*) with Terrestrial, Aquatic, and Arboreal Snake Species

Introduction

The morphology of a given species is relevant to its ecological relationships. Morphological traits often have an association with habitat preference. Arboreal snakes have slender bodies, and long tails (Pizzatto et al. 2007) for climbing on tree branches. Aquatic snakes tend to have narrow heads to enable them to reduce hydrodynamic drag (Hibbits and Fitzgerald1993), and shorter tails (Pizzato et al. 2007). Terrestrial species tend to have more blunt heads and thicker bodies.

Adaptations in morphological characteristics enable a species to inhabit a certain area. Prey selection can be an additional factor influencing morphological characteristics, such as head size and shape (Hibbitts and Fitzgerald 2005). Four species in the family *colubridea*, among the three different genera, *Thamnophis*, *Opedodrys* and *Regina* represent species which inhabit four separate microhabitats and have different prey selections. Investigation into the morphometrics of four different species may reflect differences and similarities in ecology and prey selection.

Common Ribbonsnakes, *Thamnophis sauritus*, (Figure 21) are considered semi-arboreal and semi-aquatic and they inhabit aquatic areas such as wetlands, ponds, and streams with thick vegetation. They are frequently found along the edge of water basking in trees and shrubs (Carpenter 1952, Bell et al. 2007, Scribner et al. 1995). *Thamnophis sauritus* preys mostly on amphibians and amphibian larvae, and to a lesser extent fish (Carpenter 1952, Rossman 1963).

Eastern Gartersnakes, *Thamnophis sirtalis*, (Figure 22) are a very closely related species but more terrestrial than *T. sauritus*. They are habitat generalists and are commonly found on the ground basking on rocks or under trees (Carpenter 1952). *T. sirtalis* eats mostly worms, amphibians and fish although small mammals, birds and invertebrates(Carpenter 1952; Fitch 1963;Rossman 1965).

Rough Green Snakes, *Opheodrys aestivus*, (Figure 23) are an arboreal species which inhabit open sunny areas with shrubs and trees (Green and Pauley 1987). Rough Green Snakes have thin bodies and narrow heads indicating an adaptation to an arboreal habitat and are found primarily up in trees and shrubs, rarely found along the ground. This species feeds mostly on insects and spiders (Hamilton and Pollack 1956).

Queen Snakes, *Regina septemvittata*,(figure 24) are aquatic snakes which inhabit streams and creeks. Queen snakes are often found basking along the water's edge, under rocks or swimming within the water current. This species is a medium-bodied snake which eats primarily crayfish (Green and Pauley1987).

Forces in nature often result in species selecting characteristics which adapt them for the specific habitat in which they live. Links between morphological features can provide clues to habitat and prey selection (Dwyer and Kraiser1997). Long tails and slender bodies enable snakes to forage in trees and shrubs for insects (Lillywhite and Henderson 1993). Larger bodies and narrow heads allow foraging within the water current (Hibbits and Fitzgerald 2005).

The primary objective of this study was to determine differences between these species and to determine characteristics unique to arboreal, aquatic, and terrestrial habits. Comparing the morphometrics of species which inhabit different habitats can provide insight on what morphological characteristics are significant for adaptation to different habitats. These adaptations to habitats may be able to limit restrict a species to a specific area or habitat. Four species, *Thamnophis sauritus, Thamnophis sirtalis, Opheodrys aestivus, and Regina septemvittata* were used to represent terrestrial, aquatic and arboreal habitats. I hypothesized that *T. sirtalis* will have the most variation among morphological characteristics because it has the most variable diet and habitat, and *T. sirtalis* will morphometrics characteristics shared with both *O. aestivus* and *R. septemvittata* because *O. aestivus* is an arboreal species, *R. septemvittata* is an aquatic species and *T. sauritus* is a semi-arboreal and semi-aquatic species.

Methods:

Specimens of each species were obtained from the West Virginia Biological Survey (WVBS) and the Carnegie Museum of Natural History (CMNH) for morphometric analysis. Twenty-two of *T. sauritus* and *T.s sirtalis,* 23 *Regina septemvittata*, and 25 *Opheodrys aestivus* were analyzed for morphological characteristics. Twenty-six measurements(Table 11) were collected from each specimen (Figure 25 and Figure 26) with a measuring tape and dial calipers. This method was modified from Rossman et al. (1996) by using significant characteristics which can be applied to all species among three different genera.

To adjust for variation within the same species and between species some measurements were converted into ratios (Pizzato et al. 2007, Rossman et al. 1996). This would allow for measurements to be relative to other measurements (Table 12).

Statistical analysis was done to compare morphological features between species. Normality (Shapiro-Wilk's Test) and variance of each morphological variable were tested in Statistica version 6.0 (StatSoft). If the morphological variables did not meet the assumption of normality, then the data were $\log_{10}$ transformed. Morphological variables that were highly correlated (Pearson's correlation coefficient, r=95%) were removed from further analysis. Principle-components analysis (PCA) was conducted on the remaining morphological variables.

Using the factor scores derived from the PCA, a one-way ANOVA was used to compare differences of means of the morphometric data collected from the four snake species. The Bonferroni post-hoc test was used to determine which variables were significantly different among species. A P-value greater than or equal to 0.05 was indicated as a statistically significant difference.

Results:

The first three PCA factors were plotted to show differences in morphology which comprised 71.92 % of the total variance, with Factor 1, Factor 2, and Factor 3 explaining 38.23%, 24.80%, and 8.88% of the total variance respectively. Factor 1 was driven by head length, head width and subcaudal scale count. Factor 2 was driven primarily by dorsal scale counts and tail length, and factor 3 by eye diameter and circumference at midbody.

Results from the ANOVA indicated that there is a significant difference in the means of the morphological measurements across all four species (Table 13). The morphological characteristics which showed the most differences were the head width, head length, eye diameter, circumference at midbody, subcaudal scale counts, and dorsal scale counts.

Overall the PCA analysis (Figures27 Figure 28, and Figure 29) presented much overlap in the 4 species, but each species could be distinguished. In spite of the overlap between groups, the PCA analysis indicates that *T. sauritus* dorsal scale count, head length and head width were between the values of *R. septemvittata and O. aestivus.* However, *T. sirtalis* has a larger head length and head width, but a shorter tail length than *T. sauritus*. The circumference at midbody, eye diameter and tail length sizes for *T. sauritus* were between the sizes of all four species. *T. sauritus* had the least variation of all characteristics measured.

Regina septemvittata had the second smallest variation of dorsal scale counts, tail length, subcaudal scale counts, eye diameter, circumference and head size. Dorsal scales counts, head size and eye diameter were imilar to *O. aestivus*, but bigger than *T. sauritus*. Tail length was smaller than that of *O.aestivus*, but it had a larger circumference. Tail length was also shorter *T. sauritus* and *T. sirtalis.* Head size was smaller than that of *Thamnophis sirtalis*.

Opheodrys aestivus had the third smallest variation of dorsal scale counts, tail length, subcaudal scale counts, eye diameter, circumference and head size. This snake has the smallest circumference at midbody of the four species and tail length was longer than the other species. Eye diameter was smaller than *T. sauritus* and *T. sirtalis* species but larger than *Regina septemvittata*.

The PCA analysis indicates that *T. sirtalis* hadthe largest variation of dorsal scale counts, tail length, subcaudal scale counts, eye diameter, circumference and head size than all other species. Although there was overlap, this species has the largest head width, head length and eye diameter. Overall tail length was smaller than *T. sauritus,* and *O. aestivus*, but larger than that of *Regina septemvittata*.

Thamnophis sauritus in West Virginia are characterized by an average SVL of 391mm and an average tail length of 199mm. The maximum SVL was 564mm and the minimum was 294mm and the tail length ranged from 153mm to 255mm. Scutellation consisted of ventral scale counts equaling 146-167 (average 154); subcaudal scales counts 97-126(average 113) combined ventrals and subcaudal scales 252-285(average 267); dorsal scales are keeled and occur in rows of 19-19-17; anal plate is single; infralabials 9-11 (mode 10); supralabials 7 (did not find any other variations); postoculars 1 (did not find any other variations); temporal 1(did not find any other variations).

Thamnophis sirtalis in West Virginia have an average of 389mm SVL with a range from 538-254mm and an average tail length of 111mm with a range from 65-148mm. Scutellation consists of ventral scale counts equaling 131-152 (average 143); subcaudals 38-74 (average 63); combined ventrals and subcaudals 145-222 (average 204); dorsal scales are keeled and occurring in rows of 19-19-17; anal plate is single; infralabials 9-11 (mode 10); supralabials 7-8 (mode 7); postoculars 1(did not find any other variations); temporal 1 (did not find any other variations).

Opheodrys aestivus in West Virginia are characterized by an average SVL of 424mm and ranging from 319-510mm. The average tail length for *O. aestivus* is 275mm, ranging from 197-319mm. Scutellation consists of ventral scales equaling 144-156 (average 151); subcaudals 114-146 (average 128); combined ventrals and subcaudals 260-295 (average 279); dorsal scales weakly keeled occurring in rows of 17-17-15; anal plate is divided; infralabials 7-9 (mode 8); supralabials 7-8 (mode 7); postoculars 1 (did not find any other variations); temporal 1 (did not find any other variations).

Regina septemvittata in West Virginia have an average SVL of 429mm with a range of 338-544 and an average tail length 132mm, ranging from 15-167mm. Scutellation consists of ventral scale counts equaling 134-152 (average 142); subcaudals 31-82 (average 69); combined ventrals and subcaudals 169-225 (average 212); dorsal scales are keeled and occur in rows of 19 at midbody; anal plate is divided; infralabials 9-10 (mode 10); supralabials 7-8 (mode 7); postoculars 2 (did not find any other variations); temporal scales 1 (did not have any other variations).

Discussion:

Mitchell (1994) conducted a similar morphological analysis of *T. sirtalis* in Virginia. He found that SVL of *T. sirtalis* reached a maximum of 898mm which is longer than specimens I found from West Virginia (Table 15). Scutellation from Virginia specimens was similar to West Virginia specimens. Average ventral scale counts were nearly equal (average 142.8) in specimens between the two states, but subcaudal scale counts were larger in Virginia (average 66.5). Combinations of infralabials and supralabials were greater in *T. sirtalis* found in West Virginia than in Virginia. Preocular scales were identical between the two states. Temporal scales had more variation in Virginia than in West Virginia (Table 16).

The wide-ranging *T. sirtalis* is a species variable both in habitat and prey selection. In contrast to the other species, *T. sirtalis* had the largest head size. A large head could benefit this species by enabling it to consume a large variety of prey species (Carpenter 1952, Rossman 1963). There was a large range in overall morphometric details for this species suggesting that it is not only variable ecologically, but morphologically as well.

Opheodrys aestivus in Virginia had a greater maximum length than those from West Virginia; the largest recorded specimen reached 600mm in Virginia (Table 15) (Mitchell 1994). Ventral scale counts were similar (average 151.9) as well as subcaudal scale counts (average 126) to that of specimens in West Virginia. Preoculars were identical, but supralabials and temporal scales showed variation between *O. aestivus* of Virginia and West Virginia (Table 16).

Opheodrys aestivus is an arboreal species specific to low elevations and open habitats (Green and Pauley 1987). This species had the longest tail of all four species and the smallest circumference indicating an adaptation to an arboreal environment. Lillywhite and Henderson (1993) described that arboreal species tend to have light bodies, large eyes, and long tails. My data showed that body size and tail length of this species support this. However, eye size was smaller than for *T. sauritus* and *T sirtalis*. Eye size is an arboreal adaption due to visual hunting strategies (Lillywhite and Henderson 1993). Along with *O. aestivus*, both *T. sauritus* and *T. sirtalis* had large eyes as well suggesting that they hunt with visual cues also.

Compared to specimens in Virginia, *R. septemvittata* in West Virginia had smaller SVL and total lengths (Table 15) (Mitchell 1994). West Virginia specimens averaged more ventral scales than Virginia specimens, and fewer subcaudal scales. Temporal and supralabial scales varied between individuals from the two states. Postoculars were consistent in both Virginia and West Virginia specimens (Table 16).

Species of the genus *Regina* have head sizes which are correlated with prey selection (Dwyer and Kaiser 1997). Soft-bodied crayfish are the most common prey items (Dwyer and Kaiser 1997). The PCA showed this species had little variation morphologically; however, their characteristics were similar to that of *Opheodrys aestivus*. Comparing this analysis with *O. aestivus* suggests that a larger circumference and a shorter tail are important for adaptation to an aquatic habitat verses an arboreal habitat.

Thamnophis sauritus from Virginia had longer SVL, maximum of 685mm, than those found in West Virginia (Table 15) (Mitchell 1994). Ventral and subcauldal scale counts were similar in Virginia and West Virginia, averaging 153.9 ventrals and 111.9 subcaudal scales. West

Virginia individuals had more variation in infralabials than Virginia individuals. Preoculars were identical, but temporal scales and supralabials had variation between the two states (Table 16).

The PCA results provided evidence that morphology of *T. sauritus* is consistent with the ecological characteristic that this species is semi-arboreal and semi-aquatic (Carpenter 1952, Scribner 1995, Rossman et al. 1996). Morphology results show that tail size, head size and dorsal scale counts are between that of the arboreal and aquatic species. This species is very limited in habitat and prey selection (Carpenter 1952, Scribner 1995, Rossman et al. 1996) and my data suggests that this species had very little morphological variation as well.

Of the four species analyzed, I found *T. sirtalis* to be the most variable in morphology and one of the most common species ecologically (Green and Pauley1987, Rossman 1996). *Thamnophis sauritus* is an uncommon species restricted in habitat and prey selection (Chapter 2). This species showed the least amount of morphometric variation. *Opheodrys aestivus* and *R. septemvittata* were shown by my data to have characteristics that are consistent with arboreal and aquatic snake species (Pizzato et al. 2007, Hibbits and Fitzgerald 2005). Morphology is related to ecological success (Koehl 1996). This is supported by data I obtained in this study.

Figure 21: Common Ribbonsnake (*Thamnophis sauritus*)


Figure 22: Eastern Gartersnake (*Thamnophis sirtalis*)


Figure 23: Rough Greensnake (*Opheodrys aestivus*)

Figure 24: Queensnake (*Regina septemvittata)*

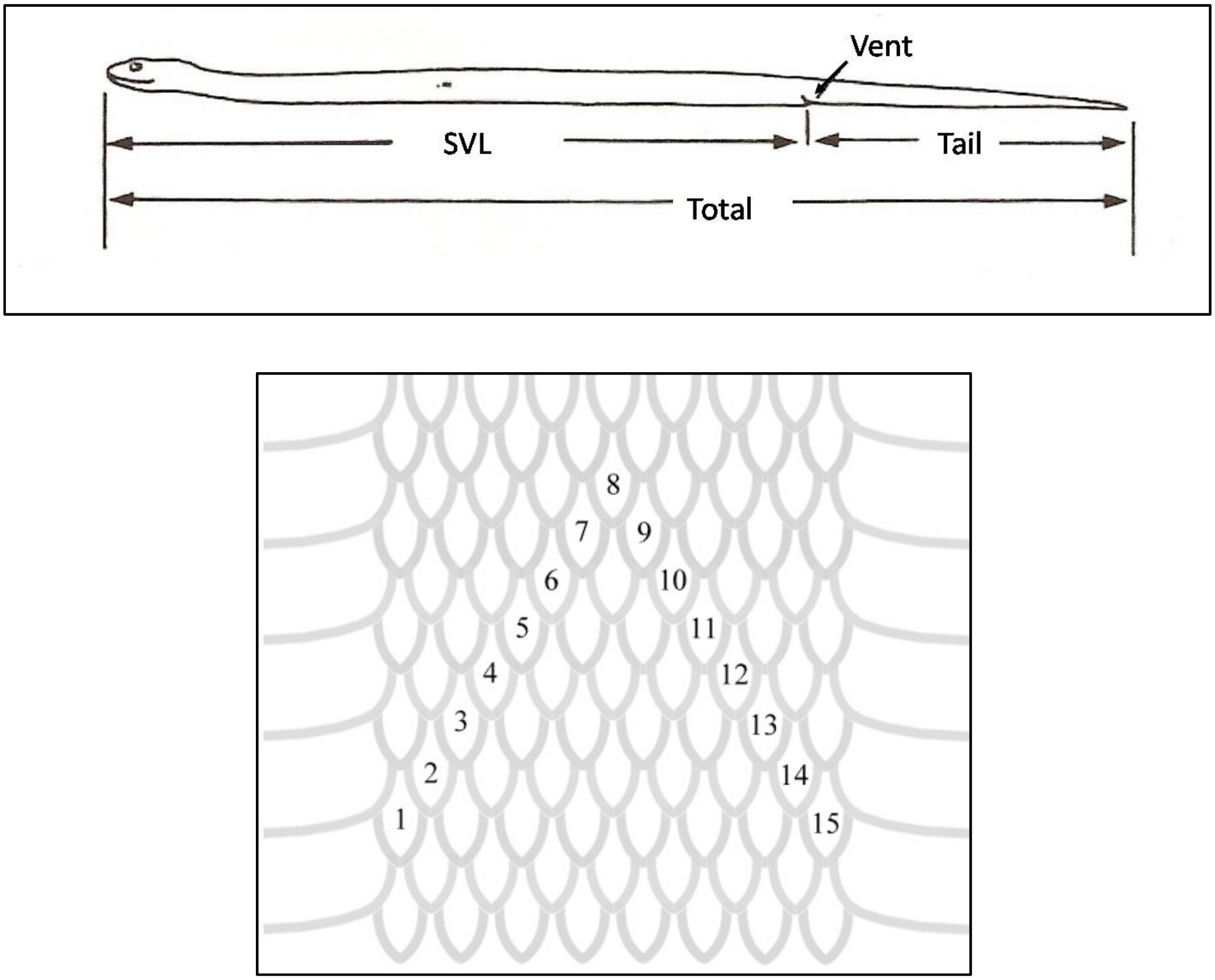
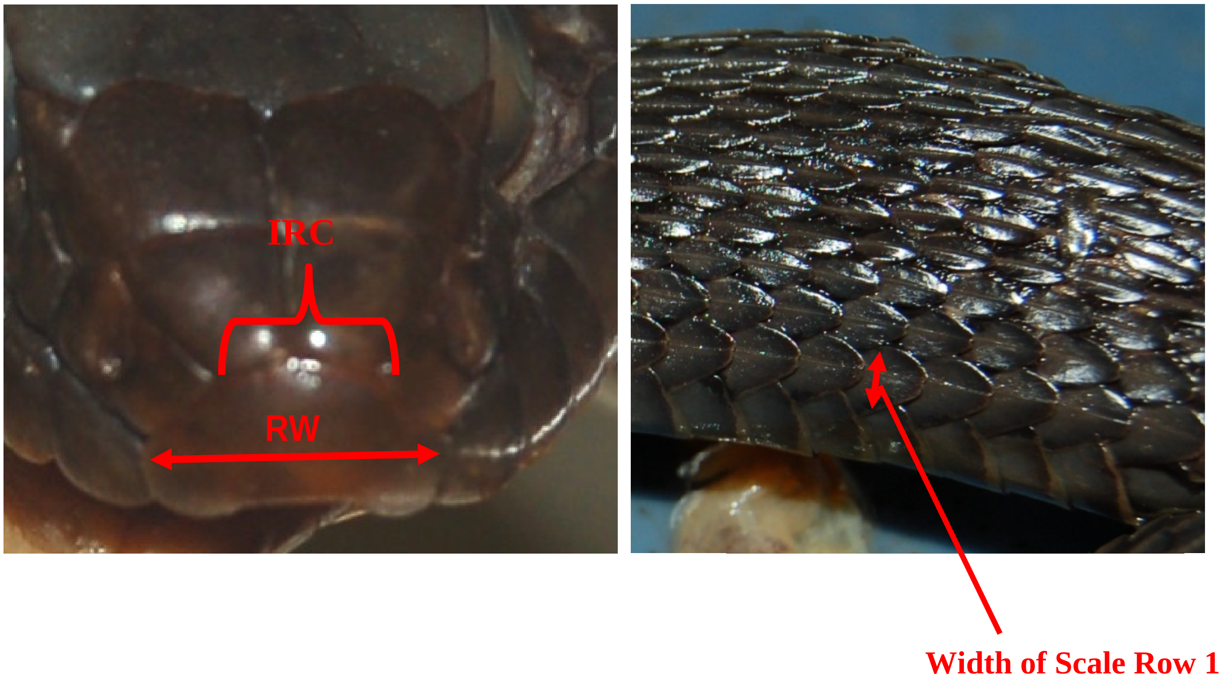
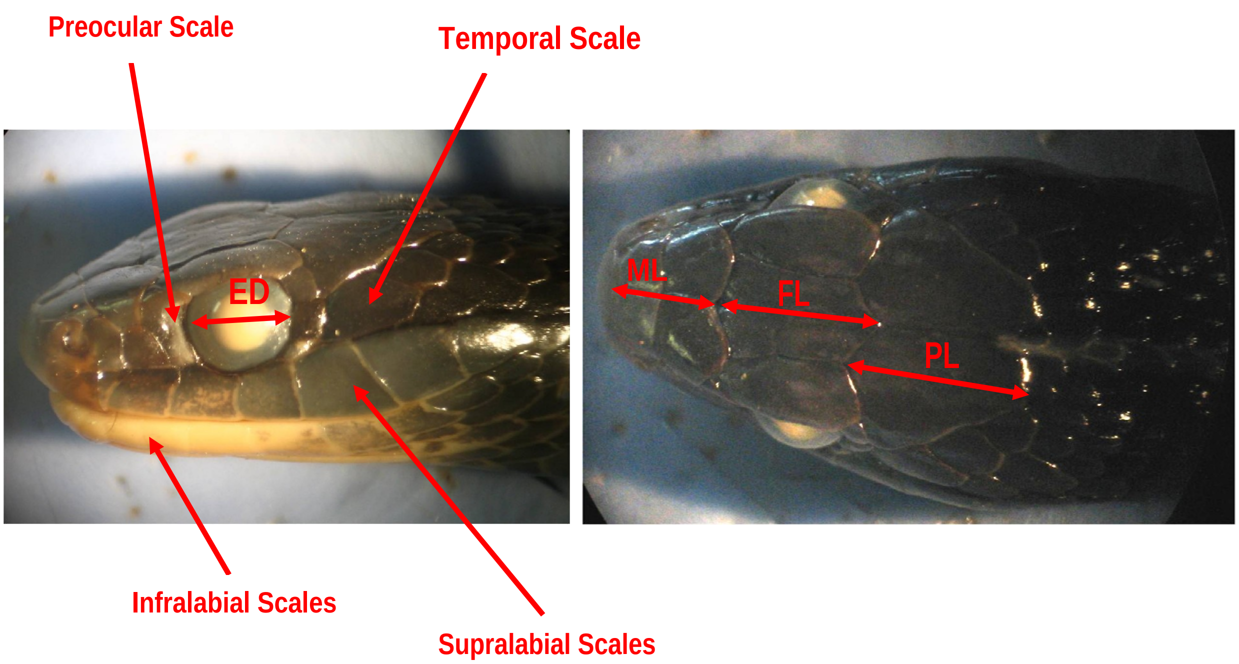


Figure 25: Snout-vent and tail length measurements and scale counts. Modified from Conant and Collins (1991) and Wynn and Moody (2006).


IRC
RW
Width of Scale Row 1


Preocular Scale
Temporal Scale
ED
ML
FL
PL
Infralabial Scales
Supralabial Scales

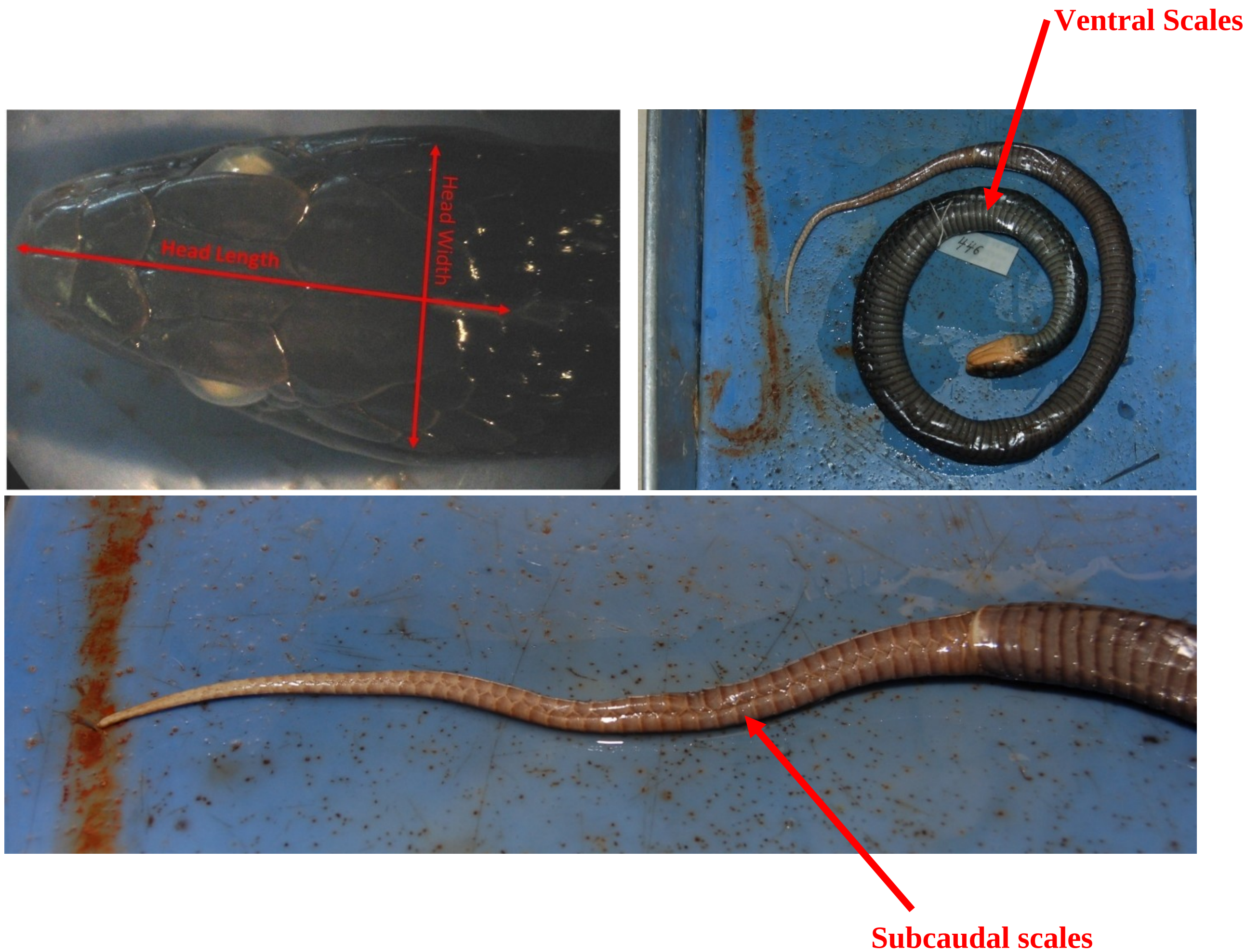


Figure 26: Morphometrics collected on preserved specimens.

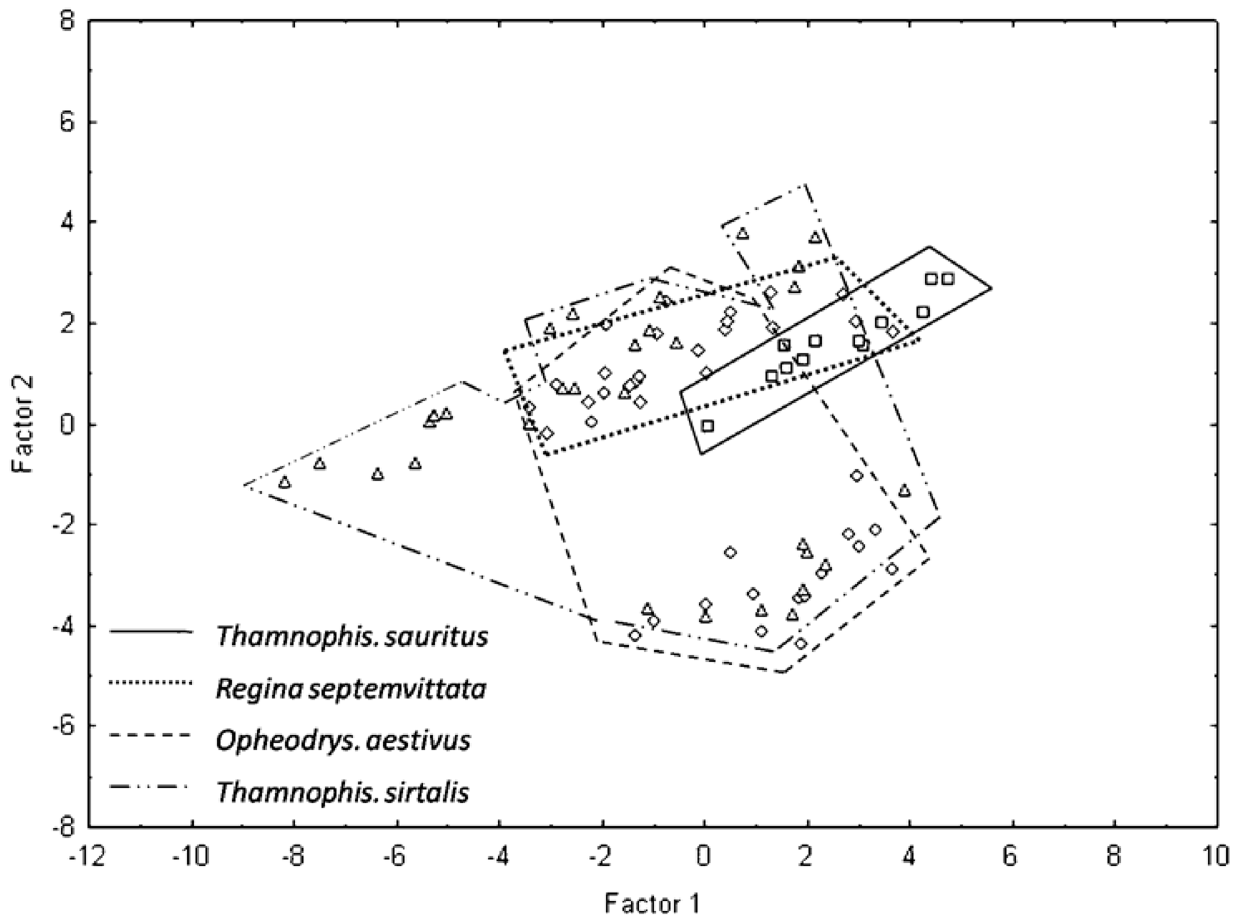


Figure 27: Scatter plot analysis of PCA factors 1 and 2

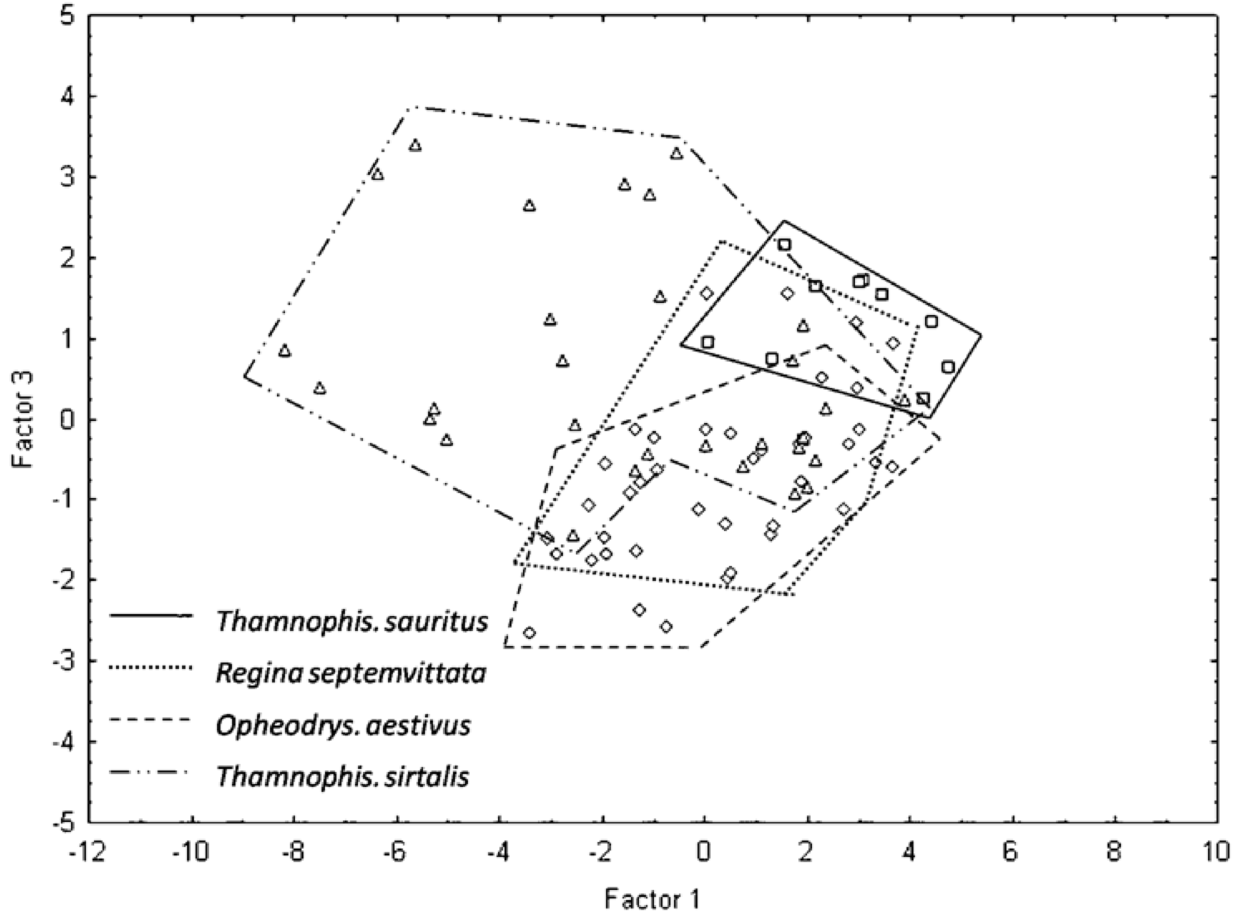


Figure 28: Scatter plot analysis of PCA Factors 1 and 3

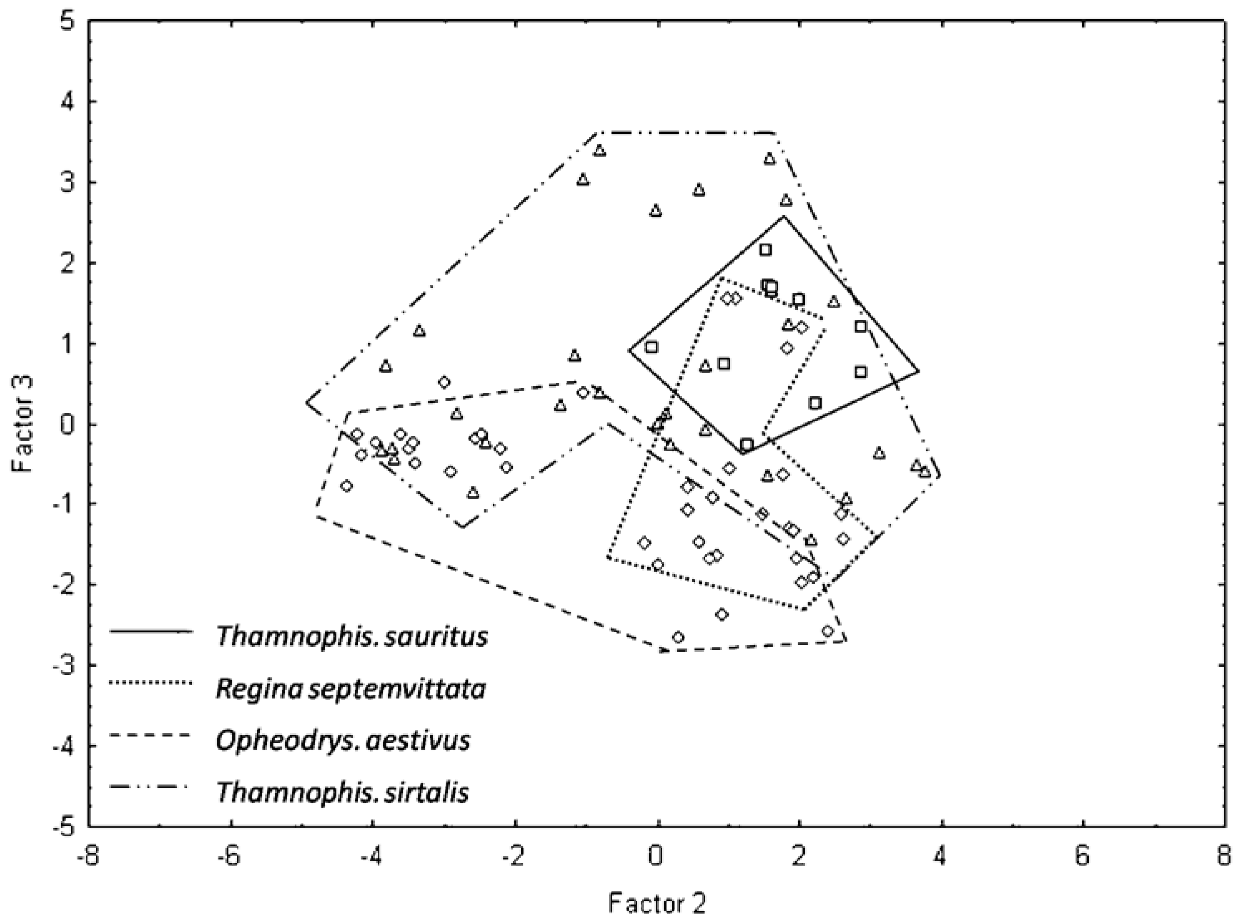


Figure 29: Scatter plot analysis of PCA factors and 2 and 3

Table 11: Morphometrical characteristics collected from museum specimens. Modified from Rossman et al. (1996)

Characteristic	Description
Snout-Vent Length (SVL)	Measurement from tip of rostrum to cloaca
Tail Length (TL)	Measurement from cloaca to tip of tail
Eye diameter (ED)	Measurement of eye between preocular and post ocular scales
Head width (HW)	Measurement of head width at widest point
Head Length (HL)	Measurement of head from tip of rostrum to angle of jaw
Circumference-head (CH)	Measurement of circumference right behind head
Circumference-midbody (CM)	Measurement of circumference at midbody
Circumference-tail (CT)	Measurement of circumference right in front of tail
Ventral Scale Count (VSC)	Total count of ventral scales
Subcaudal Scales (SSC)	Total count of subcaudal scales
Supralabial Length (SL)	Measurement of all supralabial scales combined
Supralabial Scales Count (SLSC)	Total count of supralabial scales
Intranasal Rostral Contact (IRC)	Measurement of width of rostral scale at contact with internasal scales
Rostral Width(RW)	Total width of rostral scale between the supralabial scales
Dorsal Scale Count-Head (DSCH)	Total number of scale rows right behind head
Dorsal Scale Count-Midbody (DSCM)	Total number of scale rows at midbody
Dorsal Scale Count-Tail (DSCT)	Total number of scale rows right in front of tail
Width of Scale Row 1 (SR1)	Measurement of width of first scale row at midbody
Width of Vertebral Scales Row(VSR)	Measurement of width of vertebral scale row at midbody
Infralabial Scale Count (ILSC)	Total number of infralabial scales
Preocular Scale Count(PSC)	Total number of preocular scales
Temperal Scale Count(TSC)	Total number of temporal scales
Frontal Length (FL)	Measurement of length of frontal scales measured along the midline of the scale
Muzzle Length (ML)	Measurement of combined lengths of prefrontal and internasal scales
Parietal Length (PL)	Measurement of parietal scale from posterior tip to junction with frontal and supraocular scale

Table 12: Ratios obtained from converting morphometrics. Motifed from Rossman et al. (1996)

Characteristic	Ratio
Relative Tail Length	Ratio of tail length divided by snout-vent length (TL/SVL) expressed as percentage
Relative Head Length	Ratio of head length divided by SVL (HL/SVL) expressed as percentage
Relative Eye Size	Ratio of eye diameter divided by frontal length (ED/FL) expressed as percentage
Relative Parietal Length	Ratio of frontal length divided by parietal length (FL/PL) expressed as percentage
Relative muzzle length	Ratio of muzzle length divided by frontal length (ML/FL) expressed as percentage
Relative Dorsal Scale Row	Ratio of width of dorsal scale row 1 divided by width of vertebral scale row
Relative Circumference-head	Ratio of circumference at head divided by snout-vent length (CH/SVL) expressed as percentage
Relative Circumference-midbody	Ratio of circumference at midbody divided by snout-vent length (CH/SVL) expressed as percentage
Relative Circumference-tail	Ratio of circumference at tail divided by snout-vent length (CH/SVL) expressed as percentage

Table 13: ANOVA results for all characteristics.

	Multivariate Tests of Significance sigma Sigma-restricted parameterization Effective hypothesis decomposition					
Effect	Test	Value	F	Effect df	Error	p
Intercept	Wilks	0.722544	1.04228	21	57.000	0.4324
"Var22"	Wilks	=0.001	30.73003	63	170.98	=0.001

Table 14: ANOVA results for significant variables.

	Bonferroni test; Variable 1 Probabilities for Post Hoc Tests Error: Between MS=.50932, df=77.0000

Cell No.	Var22	{1}	{2}	{3}	{4}
		0.90032	-3375	0.55901	-0.9445
1	sauritus		=0.001	0.9016	=0.001
2	regina	=0.001		=0.001	0.0438
3	opheodrys	0.9016	=0.001		=0.001
4	sirtalis	=0.001	=0.001	=0.001	

	Bonferroni test; Variable 2 Probabilities for Post Hoc Tests Error: Between MS=.21815, df=77.000				
Cell No.	Var22	{1}	{2}	{3}	{4}
		0.7114	0.55704	-1.356	0.48519
1	sauritus		1.0000	=0.001	0.93887
2	regina	1.0000			1.0000
3	opheodrys	=0.001	=0.001	=0.001	=0.001
4	sirtalis	0.93887	1.0000	=0.001	

	Bonferroni test; Variable 3 Probabilities for Post Hoc Tests Error: Between MS=.46101, df=77.000				
Cell No.	Var22	{1}	{2}	{3}	{4}
		0.84906	-1.097	-0.1146	0.6214
1	sauritus		=0.001	=0.001	1.0000
2	regina	=0.001		=0.001	=0.001
3	opheodrys	=0.001	=0.001		=0.001
4	sirtalis	1.0000	=0.001	=0.001	

	Bonferroni test; Variable 3 Probabilities for Post Hoc Tests Error: Between MS=.55345, df=77.000				
Cell No.	Var22	{1}	{2}	{3}	{4}
		0.84906	-1.097	-0.1146	0.6214
1	sauritus		0.06081	=0.001	=0.001
2	regina	0.06081		=0.001	=0.001
3	opheodrys	=0.001	=0.001		0.097841
4	sirtalis	=0.001	=0.001	0.09784	

Table 15: Comparison of average, minimum and maximum morphological characteristics. Snout-Vent Length (SVL), ventral scale count (VSC) and subcaudal scale counts (SSC).

West Virginia	*T. sauritus*	SVL	VSC	SSC
	Average	391.50	154.82	113.00
	MIN	294.00	146.00	97.00
	MAX	564.00	167.00	126.00
Virginia	***T.sauritus***			
	Average		153.90	111.90
	MIN		123.00	94.00
	MAX	685.00	168.00	132.00
West Virginia	***R. septemvittata***			
	Average	429.04	142.87	69.52
	MIN	338.00	134.00	31.00
	MAX	544.00	152.00	82.00
Virginia	***R. septemvittata***			
	Average		138.10	71.90
	MIN		124.00	47.00
	MAX	555.00	151.00	87.00
West Virginia	***O. aestivus***			
	Average	424.68	151.00	128.20
	MIN	319.00	144.00	114.00
	MAX	510.00	156.00	146.00
Virginia	***O. aestivus***			
	Average		151.90	126.90
	MIN		142.00	105.00
	MAX	600.00	163.00	147.00
West Virginia	***T. sirtalis***			
	average	389.23	143.50	63.86
	MIN	254.00	131.00	38.00
	MAX	538.00	152.00	74.00
Virginia	***T. sirtalis***			
	average		142.80	66.50
	MIN		128.00	52.00
	MAX	898	155.00	81.00

Table 16: Comparisons of mode, minimum and maximum morphological characteristics. Supralabial Scale Count (SLSC), Infralabial Scale Count (ILSC), Preocular Scale Count (PSC) and temporal Scale Count (TSC).

West Virginia	*T. sauritus*	SLSC	ILSC	PSC	TSC
	Mode	7	10	1	1
	MIN	7	9	1	1
	MAX	7	11	1	1
Virginia	***T. sauritus***				
	Mode	7	10	1	1
	MIN	7	10	1	1
	MAX	7	10	1	3
West Virginia	***R. septemvittata***				
	Mode	7	10	2	1
	MIN	7	9	2	1
	MAX	8	11	2	1
Virginia	***R. septemvittata***				
	Mode	7	10	2	1
	MIN	6	10	2	1
	MAX	8	10	2	3
West Virginia	***O. aestivus***				
	MODE	7	7	1	1
	MIN	7	7	1	1
	MAX	8	9	1	1
Virginia	***O. aestivus***			1	1
	MODE	7	7	1	1
	MIN	6	7	1	1
	MAX	8	7	1	3
West Virginia	***T. sirtalis***				
	Mode	7	10	1	1
	MIN	7	9	1	1
	MAX	8	11	1	1
	T. sirtalis				
	Mode	7	10	1	1
	MIN	6	8	1	1
	MAX	8	11	1	4

Appendix

Table 17: Correlation Matrix

	SVL	TL	ED	HW	HL	CH	CM	CT	VSC	SSC	SL
SVL	1.00	0.38	0.23	0.39	0.51	0.08	0.10	0.14	0.10	0.04	0.63
TL	0.38	1.00	-0.15	-0.41	-0.33	0.03	0.01	0.12	0.62	0.91	-0.12
ED	0.23	-0.15	1.00	0.55	0.64	-0.30	-0.26	-0.33	-0.04	-0.26	0.68
HW	0.39	-0.41	0.55	1.00	0.86	-0.03	-0.01	-0.10	-0.48	-0.57	0.83
HL	0.51	-0.33	0.64	0.86	1.00	-0.16	-0.12	-0.20	-0.37	-0.55	0.87
CH	0.08	0.03	-0.30	-0.03	-0.16	1.00	0.97	0.96	-0.17	-0.03	-0.10
CM	0.10	0.01	-0.26	-0.01	-0.12	0.97	1.00	0.97	-0.18	-0.07	-0.05
CT	0.14	0.12	-0.33	-0.10	-0.20	0.96	0.97	1.00	-0.12	0.03	-0.12
VSC	0.10	0.62	-0.04	-0.48	-0.37	-0.17	-0.18	-0.12	1.00	0.70	-0.34
SSC	0.04	0.91	-0.26	-0.57	-0.55	-0.03	-0.07	0.03	0.70	1.00	-0.38
SL	0.63	-0.12	0.68	0.83	0.87	-0.10	-0.05	-0.12	-0.34	-0.38	1.00
SLSC	0.23	-0.11	0.28	0.43	0.43	0.07	0.08	0.03	-0.29	-0.21	0.48
IRC	0.42	0.39	0.25	0.29	0.25	-0.11	-0.11	-0.08	-0.10	0.22	0.48
RW	0.46	-0.29	0.43	0.70	0.70	0.18	0.21	0.13	-0.45	-0.51	0.74
DSCH	-0.16	-0.70	0.11	0.29	0.27	0.04	0.06	-0.02	-0.30	-0.63	0.06
DSCM	-0.19	-0.72	0.07	0.25	0.26	0.02	0.04	-0.07	-0.25	-0.64	0.02
DSCT	-0.14	-0.72	0.12	0.28	0.32	0.04	0.05	-0.02	-0.29	-0.68	0.09
SR1	0.55	-0.11	0.41	0.72	0.66	0.13	0.18	0.14	-0.48	-0.38	0.74
VSR	0.55	-0.03	0.15	0.47	0.43	0.26	0.29	0.28	-0.33	-0.26	0.51
ILSC	-0.12	-0.63	0.17	0.27	0.32	-0.07	-0.04	-0.12	-0.18	-0.57	0.10
FL	0.55	-0.13	0.65	0.69	0.74	-0.16	-0.13	-0.16	-0.24	-0.36	0.83
ML	0.31	0.06	0.59	0.54	0.54	-0.19	-0.17	-0.23	-0.06	-0.07	0.61
PL	0.66	-0.10	0.48	0.66	0.79	-0.05	-0.03	-0.03	-0.40	-0.41	0.80

	SLSC	IRC	RW	DSCH	DSCM	DSCT	SR1	VSR	ILSC	FL	ML	PL
SVL	0.23	0.42	0.46	-0.16	-0.19	-0.14	0.55	0.55	-0.12	0.55	0.31	0.66
TL	-0.11	0.39	-0.29	-0.70	-0.72	-0.72	-0.11	-0.03	-0.63	-0.13	0.06	-0.10
ED	0.28	0.25	0.43	0.11	0.07	0.12	0.41	0.15	0.17	0.65	0.59	0.48
HW	0.43	0.29	0.70	0.29	0.25	0.28	0.72	0.47	0.27	0.69	0.54	0.66
HL	0.43	0.25	0.70	0.27	0.26	0.32	0.66	0.43	0.32	0.74	0.54	0.79
CH	0.07	-0.11	0.18	0.04	0.02	0.04	0.13	0.26	-0.07	-0.16	-0.19	-0.05
CM	0.08	-0.11	0.21	0.06	0.04	0.05	0.18	0.29	-0.04	-0.13	-0.17	-0.03
CT	0.03	-0.08	0.13	-0.02	-0.07	-0.02	0.14	0.28	-0.12	-0.16	-0.23	-0.03
VSC	-0.29	-0.10	-0.45	-0.30	-0.25	-0.29	-0.48	-0.33	-0.18	-0.24	-0.06	-0.40
SSC	-0.21	0.22	-0.51	-0.63	-0.64	-0.68	-0.38	-0.26	-0.57	-0.36	-0.07	-0.41
SL	0.48	0.48	0.74	0.06	0.02	0.09	0.74	0.51	0.10	0.83	0.61	0.80
SLSC	1.00	0.17	0.38	0.10	0.12	0.09	0.37	0.28	0.14	0.41	0.20	0.34
IRC	0.17	1.00	0.32	-0.48	-0.51	-0.47	0.50	0.33	-0.47	0.36	0.43	0.40
RW	0.38	0.32	1.00	0.34	0.32	0.36	0.61	0.45	0.29	0.73	0.30	0.67
DSCH	0.10	-0.48	0.34	1.00	0.78	0.88	-0.11	-0.02	0.80	0.15	-0.06	-0.03
DSCM	0.12	-0.51	0.32	0.78	1.00	0.85	-0.12	-0.12	0.81	0.15	-0.15	-0.03
DSCT	0.09	-0.47	0.36	0.88	0.85	1.00	-0.12	-0.05	0.86	0.20	-0.08	0.05
SR1	0.37	0.50	0.61	-0.11	-0.12	-0.12	1.00	0.71	-0.15	0.54	0.39	0.75
VSR	0.28	0.33	0.45	-0.02	-0.12	-0.05	0.71	1.00	-0.13	0.36	0.15	0.60

ILSC	0.14	-0.47	0.29	0.80	0.81	0.86	-0.15	-0.13	1.00	0.24	-0.04	-0.01
FL	0.41	0.36	0.73	0.15	0.15	0.20	0.54	0.36	0.24	1.00	0.33	0.71
ML	0.20	0.43	0.30	-0.06	-0.15	-0.08	0.39	0.15	-0.04	0.33	1.00	0.36
PL	0.34	0.40	0.67	-0.03	-0.03	0.05	0.75	0.60	-0.01	0.71	0.36	1.00

Literature Cited:

Aubret, A., R. Shine. 2007. The origin of evolutionary innovations: locomotor consequences of tail shape in aquatics snakes. Functional Ecology 1-6

Baker, Robert J., Greg A. Mengden, James J. Bull. 1972. Karyotypic Studies of Thirty-Eight Species of North American Snakes. Copeia.2: 257-265

Blanchard, Frank N., Frieda Cobb Blanchard. 1936. Mating of the Garter Snake Thamnophis sirtalis sirtalis (Linnaeus). Papers Michigan Acad. Sci.

Blanchard, Frank N. Frieda Cobb Blanchard.1937. Factors Determining Time of Birth in the Garter Snake Thamnophis sirtalis sirtalis (Linneaus). Papers Michigan Acad. Sci.

Burt, M.D. 1928. The relationship of size to maturity in the garter snakes, Thamnophis sirtalis sirtalis (L.) and T. sauritus sauritus . Copeia 1928:8-12

Carpenter, Charles C. 1952. Comparative ecology of the Common Gartersnake (*Thamnophis s. sirtalis*), the Ribbonsnake (*Thamnophis s. sauritus*) and Butler's Gartersnake (*Thamnophis bulteri*) in Mixed Populations. Ecological Monographs. 22(4)235-258.

Carpenter, Charles C. 1952. Growth and Maturity of Three Species of *Thamnophis* in Michigan. Copeia 4:237-243

Carpenter, Charles C. 1953. A Study of Hibernacula and Hibernating Associations of Snakes and Amphibians in Michigan. Ecology 34(1) 74-80

Clesson, Dawn, Bautista, Alma, Baleckaitis, Daniel, Krohmer, Randolph. 2002. Reproductive Biology of the Male Eastern Garter Snakes (Thamnophis sirtalis sirtalis) from a Denning Population in Central Wisconsin. Am. Midl. Nat. 147: 376-386

Contant, Roger and Joseph Collins. 199. Reptiles and Amphibians Eastern/Central North America. Houghton Mifflin Company, Boston

Dwyer, Christine M., Hinrich Kaiser. 1997. Relationship between Skull Form and Prey Selection in the Thamnophiine Snake Genera *Nerodia* and *Regina*. Journal of Herpetology 31(4):463-475

Ernst, Carl. H., Roger W. Barbour. 1989. Snakes of Eastern North America, George Mason University Press, Fairfax,

Fitch, Henry. 1965.An Ecological Study of the Garter Snake, Thamnophis sirtalis University of Kansas, Museum of Natural History 15(10):493-564

Green, N. B. and T. K. Pauley. 1987. Amphibians and Reptiles in West Virginia. University of Pittsburgh Press. 241 pp.

Gregory, Patrick T., Karl W. Larsen. 1993. Geographic Variation in Reproductive Characteristics o the Common Garter Snake (Thamnophis sirtalis). Copeia 4:946-958

Hamilton, W.J. Jr., Joseph A. Pollack 1956 The food of some Colubrid snakes from Fort Benning, Georgia Ecology 37(3): 519-526.

Harmon, Paul J., John T. Kartesz, Christopher M. Jessee, Brian R. McDonald, Barbara D. Sargent. 1996. Checklist of Wetland Vascular Plants of West Virginia. West Virginia Division of Natural Resources, Wildlife Resources Section, Nongame ad Natural Heritage Programs.

Hibbits, Tony J., Lee A. Fitzgerald. 2005. Morphological and ecological convergence in two natricine snakes. Biological Journal of Linnean Society. 85: 363-371

Hulse, Arthur C., C.J. McCoy, Ellen Censky. 2001. Amphibians and Reptiles of the Nortwest. Cornell University Press, Ithaca.

Klemens, M.K. 1993. Amphibians and reptiles of Connecticut and adjacent regions. State ecological and Natural History Survey of Connecticut, Bulletin No. 112

Koehl, M.A.R.1996. When does Morphology Matter?Annual Review of Ecology and Systematics 27:501-542

Krohmer, Randolph W.; Mark Grassman, David Crews. 1987. Annual Reproductive Cycle in the Male Red-Sided Gartersnake, Thamnophis sirtalis parietalis: Field and Laboratory Stuides. General and Comparative Endocrinology 68: 64-75

Larsen, Karl W., Patrick T. Gregory. 1992. Reproductive Ecology of the Common Garter Snake Thamnophis sirtalis at the Northern Limit of Its Range. Am. Mid.Nat. 129: 336-345

Lillywhite H. and R.W. Henderson. 1993. Behavioral and Functional ecology of Arboreal Snakes . Snakes: Ecology and Behavior. Cadwell: The Blackburn Press 1: 1-38

Matthews, Kathleen R., Ronald A. Knapp, Karsen L. Pope. 2002. Gartersnake Distributions in High-Elevation Aquatic Ecosystems: Is There a Link with Declining Amphibian Populations and Nonnative Trout Introductions. Journal Of Herpetology. 36(1): 16-22

McCauley, R. H. Jr. 1945. The Reptiles of Maryland. Privately printed , Hagerstown, Maryland.

Milton, Sherman A. Jr. 1972. Amphibians and Reptiles of Indiana. The Indiana Academy of Science, Indianapolis.

Mitchell, J.C. 1994. *The Reptiles of Virginia*. Smithsonian Institution Press, Washington, DC

Palmer, William M. 1995. Reptiles of North Carolina. The North Carolina Press.

Pizzato, Ligia, Selma M. Almeida-Santos, Richard Shine. 2007. Life-history adaptations to arboreality in snakes. Ecology 88(2):359-366

Rossman, Douglas. A.1963. The Colubrid snake genus Thamnophis: A revision of the Sauritus group. Bull. Florida State Mus., 7(3) 99-178

Rossman, Douglas A., Neil B. Ford, Richard A. Seigel. 1996 The Garter Snakes Evolution and Ecology. University of Oklahoma Press, Norman

Scribner, Stephen J., Patrick J. Weatherhead. 1995. Locomotion and antipredator behaviour in three species of semi-aquatic snakes. Can. J. Zool. 73: 321-329

Seigel, R.A., H.S. Fitch. 1985. Annual Variation in the Reproduction of Snakes in a Fluctuating Environment. The Journal of Animal Ecology 54(2): 497-505

Strausbaugh, P.D., E.L. Core. 1977. Flora of West Virginia, 2nd Edition Seneca Books Inc. Grantsville.

Tinkle, Donald W. 1957. Ecology, Maturation and Reproduction of Thamnophis sauritus proximus. Ecology 38(1): 69-77

West Virginia Department of Natural Resources. 2008. Rare, Threatened and Endangered Species In West Virginia. Retrieved 3/13/2007 http://www.wvdnr.gov/wildlife/endangered.shtm

Vita
Noah McCoard
539 Loys Run Rd
Lucasville, Oh 45648

740-222-3439 Mobile
nsmccoard@yahoo.com
mccoard@marshall.edu

Education:

2006 – Present	Marshall University, Huntington, West Virginia M.S. in Biological Science Expected graduation date: May 2008 Advisor: Dr. Thomas K. Pauley
2001-2005	Shawnee State University, Portsmouth Ohio B.S. in Biological Science GPA 3.3/4.00 Graduation date: June 2005 Advisor: Dr. D. Robert Deal, Dr. Jon C. Bedick

Honors and Awards:

BBB - John C. Johnson Award for Outstanding Research

Deans List- Shawnee State University

Grants:

West Virginia Division of Natural Resources 2007. Distribution and Natural History of the Common Ribbonsnake in West Virginia

Manuscripts in Preparation:

McCoard, N.S., K.R. Pawlik, T.K. Pauley. Distribution of the Common Ribbonsnake and Eastern Gartersnake in West Virginia. Proceedings of the West Virginia Academy of Science. In preparation.

McCoard, N.S., K.R. Pawlik, T.K. Pauley. Reproduction of the Common Ribbonsnake in West Virginia. Proceedings of the West Virginia Academy of Science. In preparation.

Pawlik, K.R., N.S. McCoard, and T.K. Pauley. Distribution of the Northern Red Salamander, Pseudotriton ruber ruber, in West Virginia. Proceedings of the West Virginia Academy of Science. In preparation.

Publications:

McCoard, N.S. 2007. Wildlife Diversity Notebook: Eastern Ribbon Snake. West Virginia Wildlife Magazine. Spring/Summer :19.

Contributed Scientific Presentations:
McCoard, N.S., K. Y. Corley, T. K. Pauley. Effects of water pH and ultraviolet radiation on the reproductive success of Wood Frogs (*Rana sylvatica*) in high elevations of West Virginia. Association of Southeastern Biologists 54 (3) :294.

Thesis:
Marshall University Huntington, WV
Master of Science
2006-Present
Ecological and Morphometric Comparison between Common Ribbonsnakes (*Thamnophis sauritus sauritus*) and Eastern Gartersnakes (*Thamnophis sirtalis sirtalis*) in West Virginia

- Surveyed West Virginia for habitat and presence of the Common Ribbonsnake and Eastern Gartersnake.
- Conducted morphometrical analysis on Common Ribbonsnake
- Compared morphometrics of Common Ribbonsnake with Eastern Gartersnake
- Compared morphometrics of Common Ribbonsnake with an aquatic snake: Queen Snake (*Regina septumvittata*)
- Compared morphometrics of Common Ribbonsnake with an arboreal snake: Rough Green Snake (*Opheodrys aestivus)*
- Analyzed habitat of Common Ribbonsnake through vegetation surveys
- Analyzed habitat of Eastern Gartersnake through vegetation surveys
- Compared habitats of Common Ribbonsnake and Eastern Gartersnake
- Analyzed diet of Common ribbonsnake and Eastern Gartersnake
- Characterized reproduction of Common Ribbonsnake and Eastern Gartersnake
- Compared reproduction characteristics of Common Ribbonsnake to literature
- Compared reproduction characteristics of Common Ribbonsnake to Eastern Gartersnake

Professional Experience:

2006-2008
Teaching Assistant-Marshall University- Introduction to Biology

- Taught introduction to biology labs
- Held office hours
- Tutored biology students
- Assisted in teaching Herpetology
- Assisted setting up herpetology exams

2006-2008
Research Assistant-Marshall University

- Surveyed Rivers in West Virginia for the Eastern Hellbender (*Cryptobranchus a. alleganiensis)*
- Surveyed West Virginia for the Northern Red Salamander (*Pseudotriton r. ruber*)
- Surveyed West Virginia for Eastern Wormsnake (*Carphophis a. amoenus)*

- Constructed drift fence and pitfall traps for Amybistomid salamanders

2006-2008
Journal Club-Marshall University

- Reviewed and discussed journal articles from professional journals

2007-2008
Master Naturalist-WVDNR

- Taught herpetology class for Master Naturalist Program with West Virginia Department of Natural Resources

2006-2008
North American Amphibian Monitoring Program-USGS

- Conducted frog calling survey in West Virginia as part for NAAMP (North American Amphibian Monitoring Program -United States Geological Survey)

2006
Teaching Assistant-Introduction to Biology-Shawnee State University

- Assisted in teaching introduction to biology labs
- Supervisor: Dr. Jon Bedick

2006
Teaching Assistant- Animal Behavior -Shawnee State University

- Assisted in teaching and setting up animal behavior labs
- Supervisor: Dr. Scott Oliver

2005-2006
Animal Caretaker-Shawnee State University

- Cleaned animal cages and fed iguana, Boa constrictor, Lorikeets, Tarantula, Green Anoles, Cockroaches, crickets, and mice.
- Conducted educational tours about animals for 6^{th} and 8^{th} grade students
- Supervisor: Dr. Larry Lonney

2005-2006
Tour Guide-Shawnee State University

- Conducted tours of Shawnee State University for 6^{th} and 8^{th} grade students
- Set up and assisted with education workshops for 6^{th} and 8^{th} grade students
- Supervisor: Louis Rase

2005
Vegetation Survey-Shawnee State University Undergraduate Research

- Conducted vegetation surveys at seven research sites in Pike County, Scioto County, Athens County and Franklin County Ohio.
- Analyzed soil through testing levels of macronutrients, pH, and organic matter
- Compared plant diversity and soil characteristics
- Supervisor: Dr. Bob Deal

2005
Northern Water Snake Movement Study-Shawnee State University Undergraduate Research

- Radio tracked Northern Water Snakes at Shawnee State Park, Scioto County Ohio
- Monitored daily movements for one month during fall of 2005
- Surveyed habitat where Northern Water Snakes were located
- Supervisor: Dr. Jon Bedick

2005-2007
Naturalist Assistant

- Presented wildlife programs to the general public
- Caretaker of native reptiles and amphibians
- Maintained nature trails
- Supervisors: Jenny Richards, Kevin Bradbury

Professional Memberships

Beta Beta Beta- Biological Honors Society, Shawnee State University

Phi Eta Sigma- National Honor Society

SSAR –Society for the Study of Amphibian and Reptiles

ASB-Association of Southeastern Biologist

OBS-Ohio Biological Survey

References:

Thomas Pauley, Professor
Department of Biological Science
Marshall University
One John Marshall Dr.
Huntington, WV 25755
(304)696-2376
pauley@marshall.edu

Frank Gilliam, Professor
Department of Biological Science
Marshall University
One John Marshall Dr.
Huntington, WV 25755
(304) 696-3636
gilliam@marshall.edu

Jon Bedick, Assistant Professor
Department of Natural Science
Shawnee State University
940 Second St
Portsmouth, OH 45662
(740) 351-3469
jbedick@shawnee.edu

D. Robert Deal, Professor
Department of Natural Science
Shawnee State University
940 Second St
Portsmouth, OH 45662
(740) 351-3486
bdea@shawnee.edu

Larry Lonney, Professor
Department of Natural Science
Shawnee State University
940 Second St
Portsmouth, OH 45662
(740) 351-3426

lonney@shawnee.edu

Scott Oliver, Professor
Department of Natural Science
Shawnee State University
940 Second St
Portsmouth, OH 45662
(740) 351-3336
soliver@shawnee.edu

Julie Basham, Professor
Department of Natural Science
Shawnee State University
940 Second St
Portsmouth, OH 45662
(740) 351-3343
Jbasham@shawnee.edu

Kevin E. Bradbury, Regional Manager
Shawnee/Adams Lake State Parks
4404 State Route 125
West Portsmouth, Ohio 45663
(740) 858-6652
Kevin.bradbury@dnr.state.oh.us

Jenny Richards, Naturalist
Shawnee/Adams Lake State Parks
4404 State Route 125
West Portsmouth, Ohio 45663
(740)858-6652
jenny.richards@dnr.state.oh.us