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The Natural History and Distribution of the Mountain Earthsnake (Virginia valeriae pulchra) in West Virginia

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The Natural History and Distribution of the Mountain Earthsnake (*Virginia valeriae pulchra*) 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 in Biological Sciences

by

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ABSTRACT

The Natural History and Distribution of the Mountain Earthsnake (*Virginia valeriae pulchra*) in West Virginia.

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The Mountain Earthsnake, *Virginia valeriae pulchra*, has received little attention in the literature to date. It is imperiled in West Virginia with only 6 to 20 populations known throughout the Allegheny Mountain and Ridge and Valley Physiographic provinces. Eighty snakes were collected during the 2006 and 2007 summers. Typical habitat is open fields with short grass, flat to moderate slopes that have scattered fine sandstone rocks near a source of water and forest edge. Fine sandstone rocks were the primary cover objects used. Snakes were sexually dimorphic with males having longer tails expressed as a percent of total body lengths and females having longer total and snout-vent lengths. *Virginia v. pulchra* are active from April through September. Males were observed more in late spring and early summer while females were observed more in late summer and early fall. Snakes were diurnal and were found in higher numbers between 2:00-6:00 pm.

Acknowledgements

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Introduction

The genus *Virginia* is a small group of secretive, semi-fossorial snakes found in the unglaciated areas of middle to eastern United States. There are two species within this genus, the monotypic *Virginia striatula* and *V. valeriae*, which is comprised of three sub-species: *V. v. valeriae*, *V. v. elegans*, and *V. v. pulchra*. *Virginia v. pulchra* is the focus of this thesis.

Two subspecies of earthsnakes occur in West Virginia; *V. v. valeriae*, the Smooth Earthsnake and *V. v. pulchra*, the Mountain Earthsnake. *Virginia v. valeriae* are found in the lower elevations of the state west of the Allegheny Mountains in the Allegheny Plateau Physiographic Province and in the eastern panhandle in the Ridge and Valley Physiographic Province. *Virginia v. pulchra* are found in the higher elevations of the Allegheny Mountain and the Ridge and Valley Physiographic Provinces. The two major morphological differences between the two sub-species are the number of dorsal scales and the keeling of the scales. *Virginia v. valeriae* has smooth scales and a 15-15-15 scale count referring to the scale count at the head, mid-body and tail, respectively. *Virginia v. pulchra* has weakly keeled scales with the first two lateral rows being smooth and a scale count of 15-17-17.

Virginia v. pulchra distribution is endemic to and discontinuously distributed in the western parts of Pennsylvania and Maryland, southward along the Allegheny Mountains of West Virginia, and into Highland County, Virginia (Cervone 1983). They are probably most secure in Pennsylvania where *V. v. pulchra* is listed as vulnerable, while in Maryland and Virginia it is considered imperiled and critically imperiled, respectively. In West Virginia, which will be the area of focus in this study, they are listed as imperiled by the West Virginia Division of Natural Resources.

Although there have been studies and data collected on *Virginia v. pulchra* in Pennsylvania by Bothner and Moore (1964), Cervone (1983), Pisani (1971), Richmond (1954), and Maryland (Cooper 1958), there has been very little information for West Virginia (McCoy, 1965; Green and Pauley 1987), perhaps due to the secretive nature of the snake. Probably the most recent thorough study was by Dr. Thomas Cervone (1983), where most of the author's effort was concentrated in western Pennsylvania. The lack of attention in the past two decades in the literature and only small amounts of information coming from West Virginia warrants a study of *Virginia v. pulchra*.

Virginia v. pulchra was first described by Richmond (1954) as a subspecies of the *Virginia valeriae* complex. All snakes identified prior to this were classified as *Virginia v. valeriae*. Since its original description, the genus *Virginia* has gone through some changes in its nomenclature. *Haldea* and *Virginia* (Baird and Girard 1853) were combined in 1939 by Stejneger and Barbour so that *Haldea* was used for both *striatula* and *valeriae* until both species were later changed to *Virginia*. The name *Virginia* was in use for *valeriae* Baird and Girard from 1853 until 1938 and *Haldea* was the generic designation for *striatula* Linnaeus from 1853 to 1917 and again in 1938. Under the International Code of Zoological Nomenclature, *Virginia* Baird and Girard is the valid name of the genus (Zillig, 1958).

The overall range of *Virginia v. pulchra* has been extensively mapped out. For Pennsylvania, the distribution has been defined by Cervone (1983), McCoy (1980, 1982), and Richmond (1954). Other localities have been mentioned in articles and other literature by Bothner and Moore (1964) and Pisani (1971). The distribution in Maryland has been mapped by Cervone (1983) and localities presented in literature by Cooper (1958). For West Virginia, the range has been mapped by Green and Pauley (1987) and localities only briefly stated by Cervone

(1983) and McCoy (1965). The most thorough mapping of specific localities for *Virginia v. pulchra* throughout its entire range, with the exception of those for Highland County Virginia, was done by Cervone (1983).

Prior to Cervone's work in 1983, there had been very little habitat data published for *Virginia v. pulchra*. Cervone (1983) had reported typical habitat is clearings bordered by wooded areas with flat, fine sandstone rocks. Literature by Bothner and Moore (1964), Cooper (1958), Pisani (1971), and Richmond (1954) only had brief descriptions of physical habitat due in part to the small number of specimens caught before 1983. Although there have been descriptions of hibernating *Virginia v. valeriae* and *Virginia striatula*, there have been no hibernaculum studies published on *Virginia v. elegans* or *Virginia v. pulchra*.

The external morphology for *Virginia v. pulchra* in Pennsylvania was described by Richmond (1954), Bothner and Moore (1964), and Pisani (1971). Little published work describing the external morphology comes from the remainder of its range. McCoy (1965) and Cooper (1958) provided some description from West Virginia and Maryland, respectively, but these were only from a limited number of specimens. The largest contribution came from Cervone (1983) where morphological data was collected from over 300 preserved and live adult, juvenile, and young from Pennsylvania, Maryland, and West Virginia.

Because *Virginia v. pulchra* is secretive and has received little attention over the years, especially in West Virginia, the purpose of this study is to provide additional natural history data from West Virginia. My goals were, 1) to search historical population sites to determine their current status and to locate new populations throughout its range in West Virginia, 2) determine their preferred habitat, and 3) determine daily and seasonal activity. In doing so, I would develop habitat characters that could be used to assist in locating additional populations in the future. Another purpose of this study was to perform a mark- recapture study to contribute data on recapture rates and movement. Only minimal data has been published on mark-recapture or movement for *Virginia v. pulchra*.

Material and Methods

General

Field studies were conducted from May 29 to September 29 in 2006 and from May 28 to October 21 in 2007. In 2006, field studies were concentrated from June to August, while in 2007 most field data were collected from June through September. We surveyed sites in Greenbrier, Pendleton, Pocahontas, Preston, Randolph and Tucker counties in 2006. In 2007, all surveys were concentrated in Pocahontas County since all snakes from the previous summer were caught there. All snakes collected in this study were collected from Pocahontas County in May through September. Out of eleven collection sites, specimens were found in three.

Sites were chosen based on one of five criteria: (1) records of historical collection sites from specimens in the West Virginia Biological Survey Museum at Marshall University, (2) personal collection sites from Dr. Thomas K. Pauley, (3) areas from unconfirmed reports of *Virginia v. pulchra* by former Marshall University graduate students and the West Virginia DNR, (4) localities reported in previous literature, and (5) areas within the suspected range with suitable habitat. The following areas of natural history were studied for *Virginia v. pulchra*: (1) range, (2) habitat, (3) color and morphology, (4) time of appearance, (5) mark recapture, (6) population structure, and (7) competitors and predators.

Range

The range of *Virginia v. pulchra* in West Virginia was determined using historical records from the West Virginia biological Survey Museum at Marshall University, personal records from Dr. Thomas K. Pauley, areas where snakes were collected during this study, and records from literature. Localities for West Virginia can be found in literature from Cervone (1983), Green and Pauley (1987), and McCoy (1965).

Habitat

The habitat for *Virginia v. pulchra* was described in this study by using the following parameters: (1) percent type cover, (2) percent tree cover, (3) soil type and pH, (4) angle of slope, (5) aspect of slope, and (6) distance from water. The parameters used to describe the microhabitat were (1) type of cover object, (2) size of cover object, (3) soil temperature, (4) surface temperature of the cover object, and (5) underside temperature of the cover object.

Percent type cover was determined by creating a 1 m^2 grid that was flagged off around the area where each snake was captured. The type cover was recorded at every 0.25 m. Type cover was expressed as one of five types: (1) bare (no cover), (2) herbaceous cover, (3) rock, (4) leaf litter, and (5) woody cover. Within the grid, the height of the tallest plant was measured in centimeters. Canopy cover was measured with a densiometer. The percentage of canopy cover for each aspect was recorded and then averaged to determine total percent canopy cover.

Twenty-five soil samples were taken at random from Elleber Knob in Pocahontas County, where the majority of the snakes were collected. Soil samples were collected from the surface and placed in small plastic Ziploc bags. The bags were then sealed and placed in a freezer until the pH was measured. Prior to measuring the pH, soil samples were thawed out. Once thawed, 1.5 g of soil was placed in a 40ml glass beaker. Thirteen and a half milliliters of water was then added creating a 10% soil solution. The pH of the soil solution was measured using a calibrated Oakton Waterproof pHTestr 10 model. The type of soil was identified using GIS files from the United States Department of Agriculture-Natural Resources Conservation

Services. *Topo* topographic software was used to identify streams, rivers, and ponds. The same program was used to measure the distance from the nearest source of water to each collection site, slope, aspect, and altitude were all determined by using the same topographic software.

The width, length, and depth of cover rocks were measured (cm) to determine surface area and volume. *Virginia v. pulchra* were placed into the categories of mature males and mature females to determine if any difference existed in the selection of rocks based on surface area, volume, or thickness. All data that was statistically tested in this study was first tested for normal distribution using a proc univariate test. A *t*-test was done to determine if there was a statistical difference between rock surface area and volume selection by males and females. All statistical analysis was performed using SAS software.

During the second summer of my study, temperature of the surface and underside of each rock was taken. In addition, notes were taken on observations on the material underneath the rock. An Oakton digital pocket infrared laser thermometer was used to determine the temperature of the surface area and the underside of the rock. A digital thermometer was used to measure the temperature of the soil 2.5-5.0 cm below the surface where the snake was collected. No temperature was recorded if the soil was too rocky to insert the thermometer. A paired *t*-test was performed to determine whether there was a statistical difference in surface and underside temperature of rocks with the air temperature along with soil temperature selection by males and females.

Species Description

The color and morphology for *Virginia v. pulchra* was described using (1) color, (2) total length (mm), (3) snout-to-vent length (mm), (4) tail length (mm), (5) tail length expressed as a percent of total body length, (6) tail width, (7) tail depth, (8) dorsal scale counts, (9) degree of keel, and (10) weight (g). Sex was determined using the measurement for tail length expressed as a percent of total body length because *V. v. pulchra* is sexually dimorphic with males having longer tails expressed as a percent of total body length than females (Cervone, 1983; Richmond, 1954). A *t*-test was performed to determine whether there was a statistical difference between male and female total length (TL), snout-vent length (SVL), tail width, and tail depth.

Dorsal spots were recorded as either absent or present. The degree of keeling at mid-body was described as being weakly keeled or smooth. Dorsal scales were counted at three areas of the body: (1) posterior to the head, (2) mid-body, and (3) anterior to the anal plate. Scale counts were performed by starting on the first scale row on the lateral side of the snake and counting anterior at a 45° angle up to the center of the dorsal scales and then counting posterior at a 45° angle down to the last scale row of the opposite lateral side.

Time of Appearance

For this study, time of appearance is referred to as the time when *V. v. pulchra* can be found on the surface, usually under some type of cover. Both seasonal and daily time of appearance was evaluated. The following data were collected to evaluate the daily and seasonal phenologies for *V. v. pulchra*: (1) date, (2) time of day for each capture, (3) weather data one inch above ground, and (4) soil temperature. Weather data (air temperature, dew point, relative humidity, and barometric pressure) were collected with a Skymaster weather meter. Daily precipitation records, considered to be important by Cervone (1983) and Richmond (1954) for daily surface appearance, were obtained from the National Oceanic and Atmospheric Administration (NOAA) for the Bartow, WV weather station since it was the closest station to the Elleber Knob and Camp Allegheny sites. Regression analysis was performed to determine if there was any relationship between the number of monthly snake captures and monthly precipitation or if there was any relationship between the number of snakes caught in a day and total precipitation from the previous days.

Times in which snakes were captured were compiled for the first summer to determine best collection times during the day. Time periods were as follows: 10:00-12:00 hr, 12:01-14:00 hr, 14:01-16:00 hr, and 16:01-18:00 hr. Months in which snakes were caught were compared to determine peak activity as well as male and female activity.

Population Structure

Population structure was developed by looking at the SVL frequency of the snakes found in this study and labeling males and females as mature or immature. Maturity was determined using measurements reported by Cervone (1983). Live males reach sexual maturity between 158-168 mm SVL while live females reach sexual maturity between 214-227 mm SVL.

Mark Recapture and Movement

Snakes were marked individually to determine movement and mark-recapture rates. Since *V. v. pulchra* is a small snake, few marking options were available for such a study. I used ventral scale clipping to mark the snakes. Individuals over 170 mm in TL were scale clipped. Snakes that were shorter than 170 mm TL had ventral scales too small to safely clip

Once a snake was collected, environmental and morphological data were taken before clipping the scales. Ventral scales directly above the anal plate were clipped due to (1) the large size of the scales, (2) the distance from vital organs, and (3) proximity to a bodily landmark (i.e., anal plate) to make scale counting easier. The right side of the first 10 scales above the anal plate represented numbers one through 10. The left side of the same scales represented groups of 10 consecutive snakes. According to the number of the snake caught, the appropriate scales were clipped. If the snake was number seven, then the right side of the seventh scale above the anal plate was clipped. If the snake was number 24, then the left side of the second scale and right side of the fourth scale above the anal plate was clipped (Brown and Parker, 1976). Before each snake was marked, the first two-thirds of the snake were placed inside a small Ziploc bag to limit the snake's movement. With the last one-third of the snake outside the bag upside down, the tail was placed between the middle and index fingers while the thumb was used to put pressure on the dorsal side of the snake under the tail to expose the ventral side to make it easier to clip. With a small pair of fingernail clippers, small portions of the appropriate scale were clipped off, being careful not to cut too deep and harm the snake.

The location where the snake was caught was recorded with a Garmin 60 model GPS and the rock (cover object) was marked with a permanent marker with the corresponding scale clip number. The snake was then released under the same rock from which it was caught. If a snake was caught again, morphological and environmental data were collected and the rock was marked with the same number followed by an "R" for recapture with a number corresponding to the number of times it had been recaptured. In addition, the distance between the rock where the snake was originally caught and the rock where it was recaptured was measured in meters. If the original rock was not found, then the distance between the two collection sites was measured with a topographic software using the UTM coordinates from the GPS unit.

Results

Range

Using historic localities and those from this study, the range of *V. v. pulchra* appears to be found only in the higher elevations of the Allegheny Mountain and the Ridge and Valley Physiographic Provinces. *Virginia v. pulchra* is known from five counties in West Virginia: Hampshire, Pendleton, Pocahontas, Preston, and Randolph counties. Figure 1 shows the specific localities in West Virginia from this study as well as past studies.

Virginia v. pulchra is only found in the areas of the Allegheny Plateau that were unglaciated, and shows a discontinuous distribution throughout West Virginia. Their distribution appears to be associated with the tributaries of the Cheat River (Cervone 1983).

Camp Allegheny and Elleber Sods in Pocahontas County were the only areas where *V. v. pulchra* was found during this study. Over the course of this study, 80 snakes were caught from Elleber Sods (79) and Camp Allegheny (1). Elleber Sods represents the southern extent in West Virginia. No snakes were found at the historical site at Terra Alta, Preston County but a former graduate student from Marshall University, Zachary Loughman, caught a snake on June 08, 2006 a few miles north of Terra Alta near Flat Rock chapel in an area where no individuals have been caught before that he identified as *V. v. pulchra*. This record represents the northern extent known in West Virginia. No snakes were caught at the historical locations at Spruce Knob or Elk Mountain, Pocahontas County or potential sites at Dolly Sods, Canaan Valley, or Timberline in Tucker County. Historically, only four snakes have been captured between these two localities: one at Spruce Knob Lake in Randolph County, two on forest road 112 1.6 miles from the Rt. 28 and forest road 112 junction, and one near Romney in Hampshire County.

Figure 1: The geographic distribution of *Virginia v. pulchra* in West Virginia. Red circles represent collection sites where *V. v. pulchra* were caught in this study. Blue circles represent historical collections sites from museum records, and previous literature.

Habitat

All snakes caught in this study came from two collecting sites in Northeastern Pocahontas County. These include Locality 1: Camp Allegheny Range Allotment; and Locality 2: Elleber Knob Range Allotment. Both sites are cattle grazing range allotments on United States Forestry Service land. Both areas are at an elevation around 1,300 m. The vast majority of the snakes caught came from the latter of the two sites.

The angle of slope for both sites was slight to moderate ranging from 10-35 degrees (mean = 24). The aspect for Camp Allegheny and Elleber Knob was south and north-northwest, respectively. Cervone (1983) reported that *V. v. pulchra* avoids north-facing slopes due to lack of direct sunlight. With the majority of the snakes being caught at Elleber Knob which has a north-north west aspect *V. v. pulchra* apparently does not avoid north facing slopes in WV.

For this study, the distance of each capture from permanent water ranged from about 10 to 213m. The distance from permanent water for *V. v. pulchra* at Elleber Knob ranged from 122 to 146.3m. Although this was the distance measured using topographic maps, it was noticed from personal observations that in time of moderate rainfall snakes would have access to water at a much shorter distance in ruts and hoof impressions in the ground in cattle grazing in the areas. These areas do not allow water to permeate through the soil or run downhill. These places, in addition to nearby ditches and areas of runoff from higher elevations, help create multiple nearby water resources that last for some time during moderate rainfall.

For the 25 random soil samples taken from Elleber Knob, pH ranged from 3.9-7.3 ($\bar{x}$ = 5.9 pH). Three of the four current and historical localities as well as the area where most of the specimens were caught in this study, are classified as a silt loam. Soil in Pocahontas County where the largest number of *V. v. pulchra* were observed is classified as Calvin Channery silt

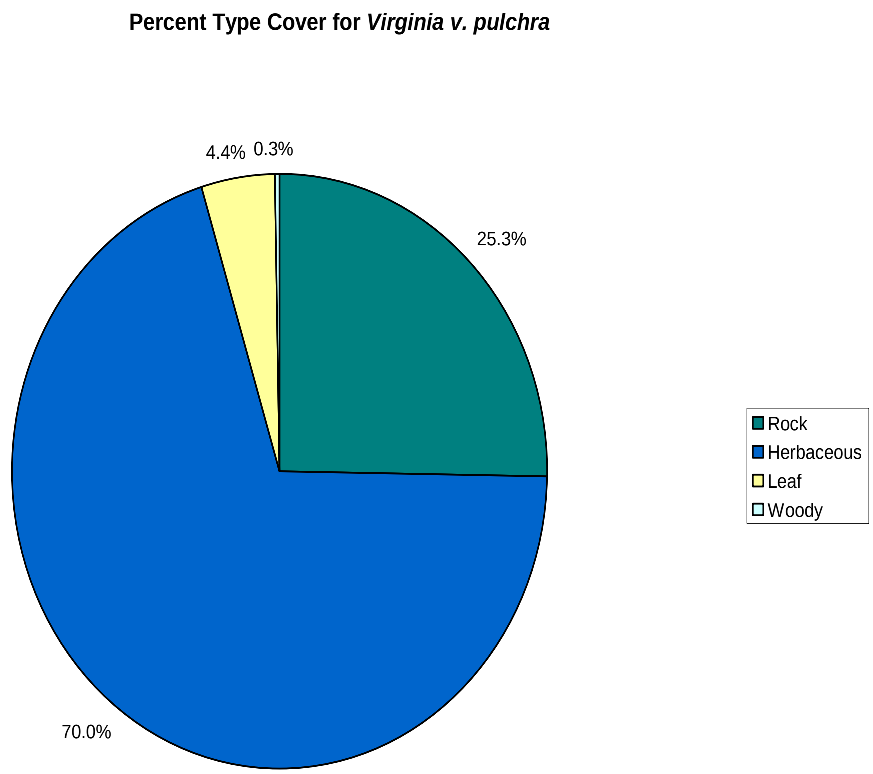

Figure 2: Percentage of cover type associated with the area around where *Virginia v. pulchra* were captured (n = 27).

loam with 15-30% slopes. This type of soil is very stony and considered not to be prime farmland. The soil where only a few snakes were captured is classified as a Shouns silt loam with 3-15% slopes that is extremely stony. The historical record in Preston County is considered a Dekalb very cobbly loam with 25-35% slopes and in Randolph County is classified as a Berks Channery silt loam with 15-25% slopes. The two areas counties are considered not to be prime farmland (Unpublished Data, USDA).

All 82 specimens caught were found under fine sandstone rocks of varying sizes, which were the dominant cover object at Elleber Knob and the only available source of cover at

Figure 3: Photograph showing typical habitat for *Virginia v. pulchra* at Elleber Knob in Pocahontas Co. Open area bordered by woods with flat to moderately slopes.

Figure 4: Photograph showing a group of rocks that *Virginia v. pulchra* is typically found under.

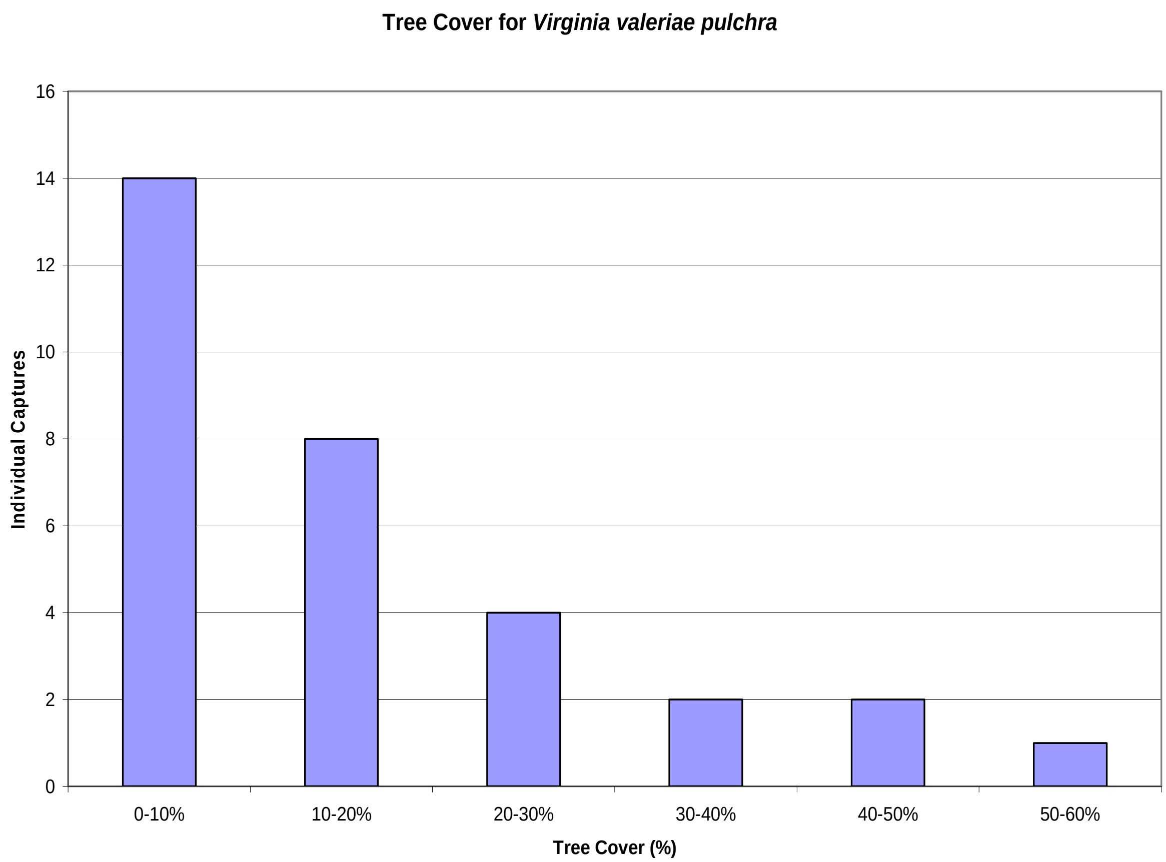

Figure 5: Number of individual *Virginia v. pulchra* (n = 30) captured under a specific range of tree cover.

Camp Allegheny (Figure 4). The surrounding cover around the area where each snake was caught was made up of mostly herbaceous (70%) and rock cover (25.3%). Surface area of the rocks ranged from 133.6 to 2,843.8 cm² ($\bar{x}$ = 848.9 cm²); rock volume ranged from 400.7-21,328.7 cm³ ($\bar{x}$ = 5,711.5 cm³); the thickness of the rocks ranged from 2-16.6 cm ($\bar{x}$ = 6.56 cm).

Virginia v. pulchra was placed into the categories of mature males and mature females to determine if any difference existed in the selection of rocks based on surface area, volume, or thickness. Both sexes were determined to be sexually mature by using the maximum snout-to-vent length measurement reported by Cervone (1983) for sexually mature male and female snakes. Rock surface area and volume data were not normally distributed and were log transformed. Females (n = 45, $\bar{x}$ = 912.4, SD = 624.7, range = 2,679) did not choose rocks with larger surface area (df = 86, *t* = 1.11, p = 0.27) than males (n = 43, $\bar{x}$ = 785.8, SD = 466.6, range 1,760). There was no difference in rock volume selection (df = 85, *t* = 0.36, p = 0.71) between females (n = 44, $\bar{x}$ = 6,013, SD = 4,757.8, range = 20,774) and males (n= 43, $\bar{x}$ = 5,464.3, SD = 4,061.3, range = 19,015).

During the second summer of my study, temperature of the surface and underside of each rock was taken. In addition, notes were taken on observations on the material underneath the rock. The underside temperature (n = 27, $\bar{x}$ = 31.7, SD = 5.5, range = 19.6) and surface temperature (n = 28, $\bar{x}$ = 32.9, SD = 6.2, range = 23.1) were higher than the surrounding air temperatures (n = 28, $\bar{x}$ = 25.9, SD = 3.84, range = 13.1). Both the underside surface (df = 26, *t* = -6.17, p < 0.001) and surface temperatures (df = 27, *t* = -7.24, p < 0.0001) differed from the surrounding air temperatures. The primary substrate snakes were observed on top of when captured was dry, dead plant material with some rocks. The dead plant material was found to be a few degrees warmer than the rocks. The type of cover, plant height ($\bar{x}$ =114.5 cm), and tree cover ($\bar{x}$ =16.5%) show that the habitat is short, grassy, open areas with scattered sandstone rocks.

Records were kept on all amphibians and reptiles caught in the vicinity of *V. v. pulchra*, particularly at Elleber Sods where they were abundant. This data was intended to be used to compare the relative abundance of these species to *V. v. pulchra* as well as determine what species share the same habitat, which may offer more insight into potential habitat for this species. The two most dominant species at Elleber Knob were *Storeria o. occipitomaculata* (Northern-red Bellied Snake) and *V. v. pulchra* (Figure 6). The most common species found

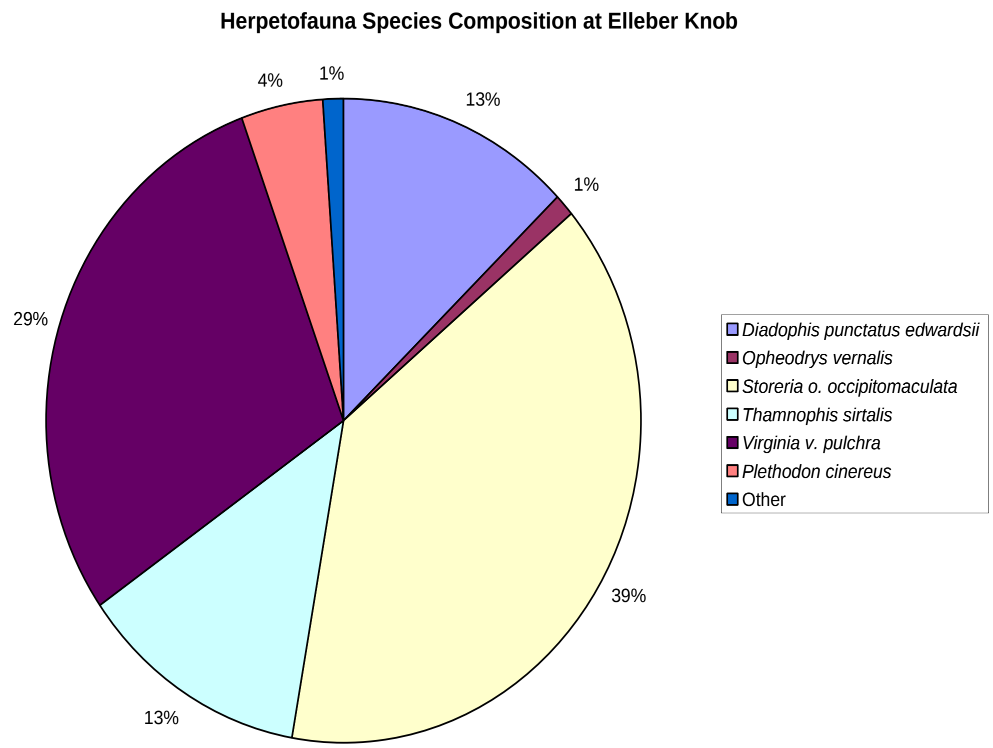

Figure 6: Percent of herpetofauna species found at Elleber Knob in Pocahontas Co. West Virginia. *Elaphe o. obsoleta* and *Lampropeltis t. triangulum* were labeled as "other" since both were caught in small numbers.

along with *V. v. pulchra* were *Storeria o. occipitomaculata*, *Diadophis punctatus edwardsii* (Northern Ring-necked Snake) and *Thamnophis s. sirtalis* (Common Garter Snake).

Cervone (1983) reported that ant colonies were very common throughout the range of *V. v. pulchra* and there was a high correlation between signs of ant activity and snake presence. All sites where specimens were collected in his study showed large numbers of galleries and tunnels under the same type of cover rocks for *Virginia v. pulchra*. This was not the case in my study. From observations in field, there was little or no significant ant activity. Most of the ants that were seen were too small to create tunnels that would be of significant size for *V. v. pulchra* to use. Most specimens that were caught were found under rocks with no ant tunnels or galleries.

One large female was found several times under the same rock that had large ant tunnels that were used in an attempt to escape.

One site that was searched extensively in this study that yielded no specimens was Dolly Sods, Tucker County. Dolly Sods had a very high amount of ant activity. One species that was seen was the Allegheny Mound Ant, *Formica exsectoides*, which was found to be highly aggressive toward *Virginia v. pulchra* and never found together under the same rock (Cervone, 1983).

Species Description

Color

The dorsal color for a living *V. v. pulchra* specimen ranges from dark gray to dark brown. The most common color is olive drab brown. Some specimens had a mid-dorsal stripe going the length of the body that was lighter in color than the surrounding dorsum. Most specimens also had rows of black spots on the dorsum that were usually more concentrated toward the anterior part of the snake. Most snakes that lacked black spots on the dorsal side were preparing to shed their skin. The most common ventral color ranged from cream to tan with light red lateral edges (58.6%). Some adult specimens (20.8%) had a shade of light red throughout the ventral scales. All neonates had white venter and a dark gray dorsum without spots.

Size and Weight

Because TL, SVL, and tail depth data were not normally distributed (Shapiro-Wilk $p < 0.05$), data were transformed by squaring the values. Females ($n = 45$, $\bar{x} = 262.8$, SD = 42.7, range = 177.0) were significantly longer ($df = 86$, $t = 3.07$, $p = 0.003$) in TL than males ($n = 43$, $\bar{x} = 239.9$, SD = 35.4, range = 155). Females ($n = 45$, $\bar{x} = 223.5$, SD = 36.2, range = 156.3)

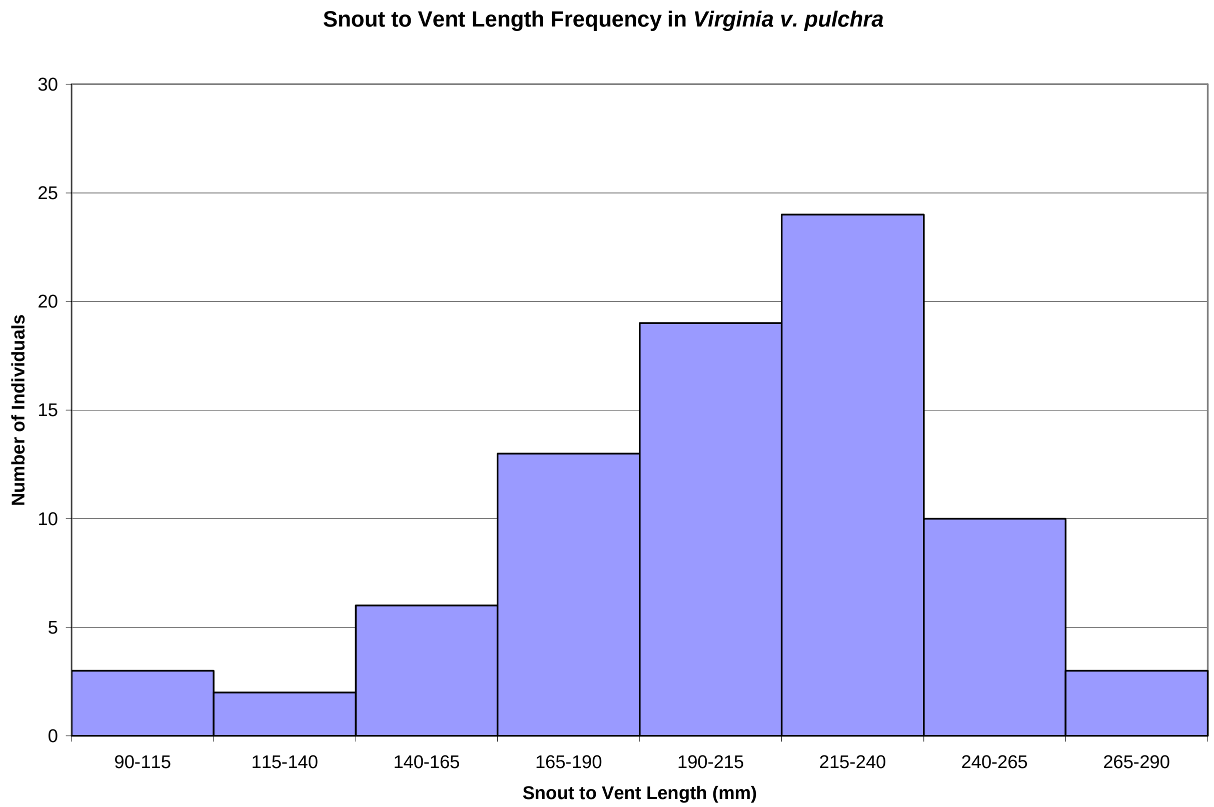

Figure 7: Size frequency distribution of *Virginia v. pulchra* (n = 80)

were also significantly longer (df = 77.1, t = 5.09, p < 0.0001) in SVL than males (n = 43, $\bar{x}$ =191.4, SD = 28.6, range =133.0).

Females (n = 43, $\bar{x}$ =3.95, SD = 0.78, range = 4.25) were not significantly bigger (df = 80, t = 1.85, p = 0.07) in tail width than males (n = 39, $\bar{x}$ = 3.65, SD = 0.63, range = 2.9). There was no difference in tail depth (df = 70.1, t = 1.77, p = 0.08) between females (n = 43, $\bar{x}$ = 4.14, SD = 0.87, range = 3.9) and male (n = 39, $\bar{x}$ = 3.9, SD = 0.61, range = 2.85). Adult males ranged from 18.2% to 26.6% ($\bar{x}$ = 20.2%) in tail length expressed as a percentage of total body length while adult females ranged from 10.3% to 16.8% ($\bar{x}$ = 14.9%).

Figure 8: ***Virginia v. pulchra*** **with the most common color observed in the field.**

Figure 9: Two ***Virginia v. pulchra*** **specimens with different dorsal colors and one specimen (above) has the black spots commonly found on** ***Virginia v. pulchra*** **while the other (below) does not.**

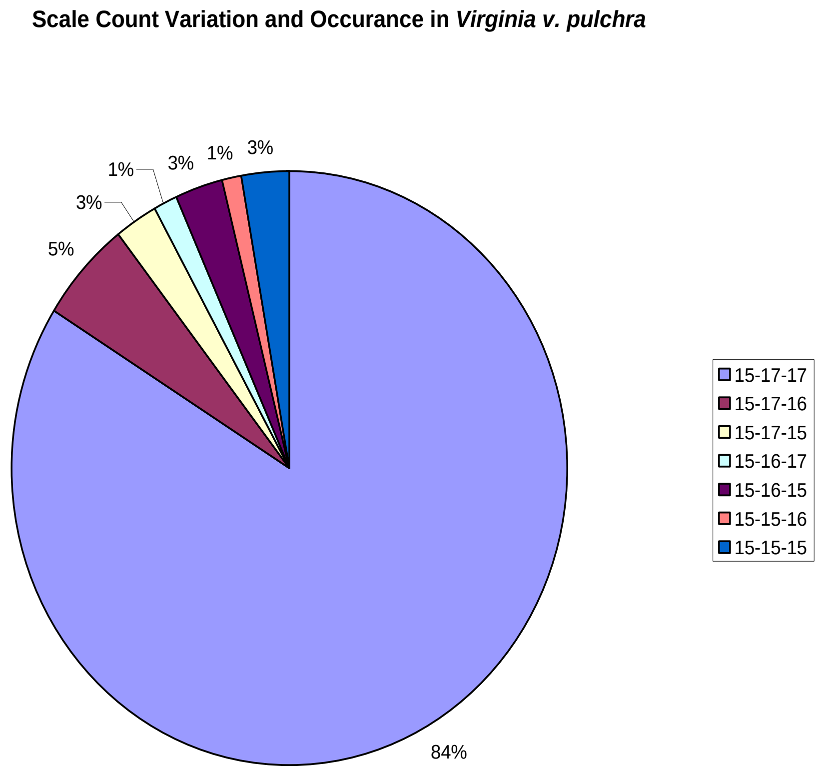

Figure 10: Percent of *Virginia v. pulchra* specimens displaying certain scale count patterns.

Scale Count and Keeling

Of 76 snakes, 84% displayed the typical 15-17-17 scale count. The remaining snakes displayed different variations of atypical scale counts. Figure 10 shows the total number and percentage for each dorsal scale pattern that was observed in the field. Of 77 snakes, 96% had weakly keeled scales while the remaining did not appear to show any keeling. Those that were keeled showed varying degrees of keeling. The keel of some snakes was obvious while the keel in other snake was very difficult to see. However, the keel was difficult to see were when snakes were in ecdysis.

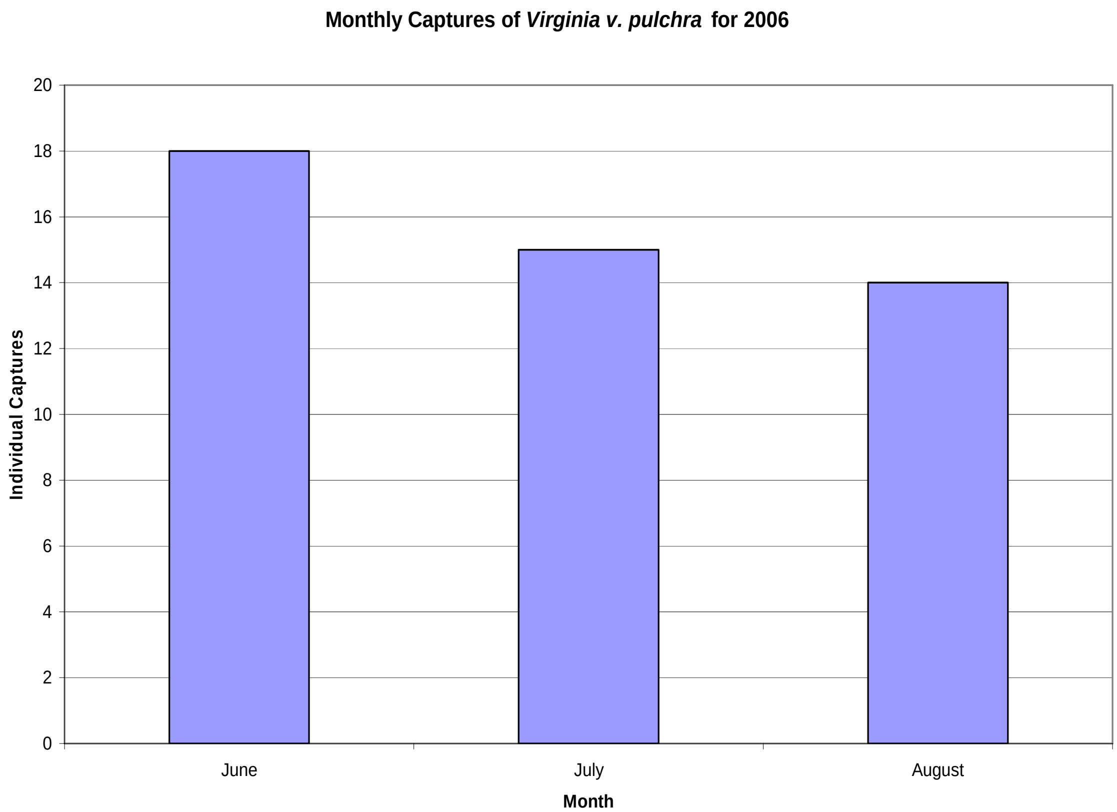

Figure 11: Number *Virginia v. pulchra* (n = 47) caught each month during the 2006 field season at Camp Allegheny and Elleber Knob.

Time of Appearance

Seasonal

The earliest record during this study was May 28 and the latest record was September 22. Seasonal occurrence during the 2006 summer is shown in Figure 11. *Virginia v. pulchra* was found in higher numbers during June.

In figure 11, the number of captures peaked in June and decreased through July and August. Although snakes were caught during September, it is not represented in Figure 11 since less time was spent searching during this month because I was unable to make trips to the

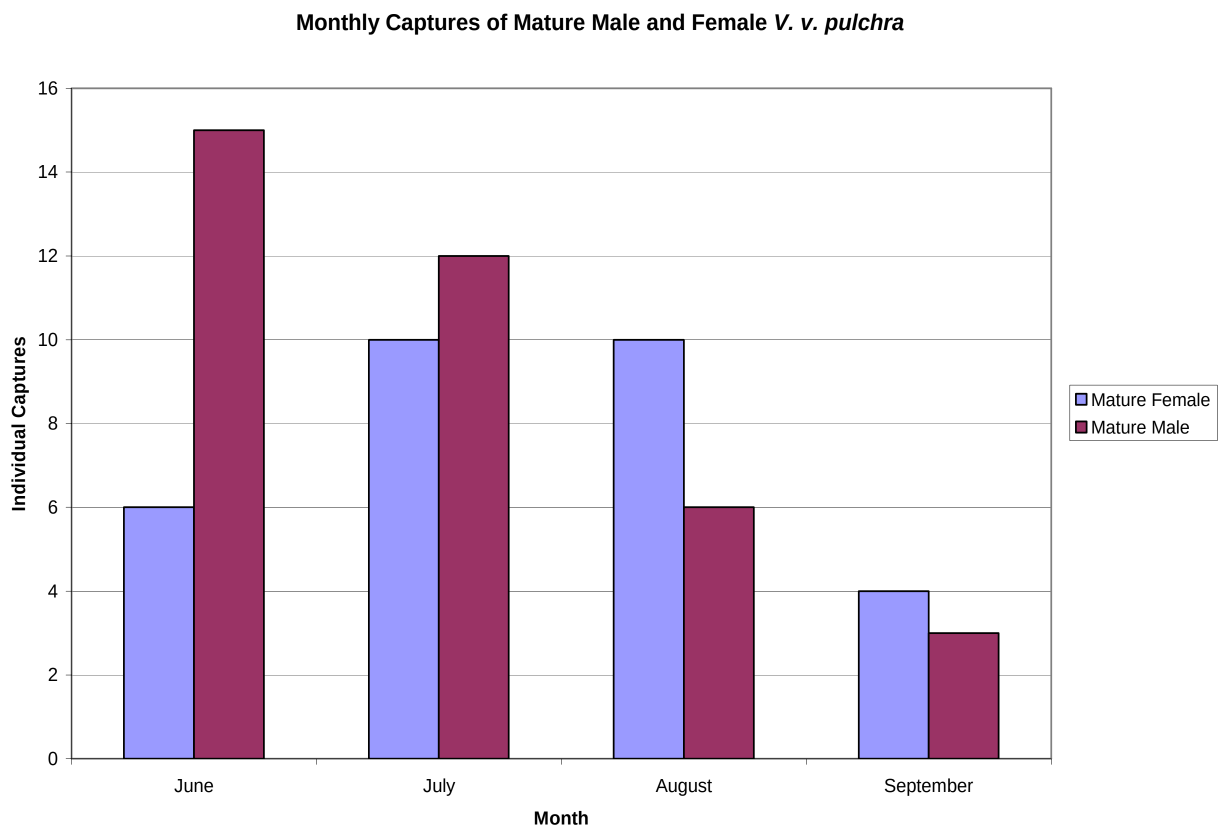

Figure 12: Number of individual mature male (n = 36) and mature female (n = 30) *Virginia v. pulchra* caught during two field seasons from June through September in 2006 and 2007 at Camp Allegheny and Spruce Knob.

collection sites due to schedule conflicts. Monthly occurrences for mature males and females are shown in Figure 12. Males were more readily found during June and July while more females were found in August and September. There was no difference in soil temperature selection (df = 80, t = 1.21, p =0.23) between females (n = 43, $\bar{x}$ = 19.73, SD = 3.1, range = 12.7) and males (n = 39, $\bar{x}$ = 18.98, SD = 2.4, range = 9.5).

Daily

During the summer of 2006, searches were conducted between 10:00 am and 8:00 pm. *Virginia v. pulchra* were most active on the surface between 1400 and 1800 hours (Figure 13). There was no relationship between the number of snakes captured on a particular day with the

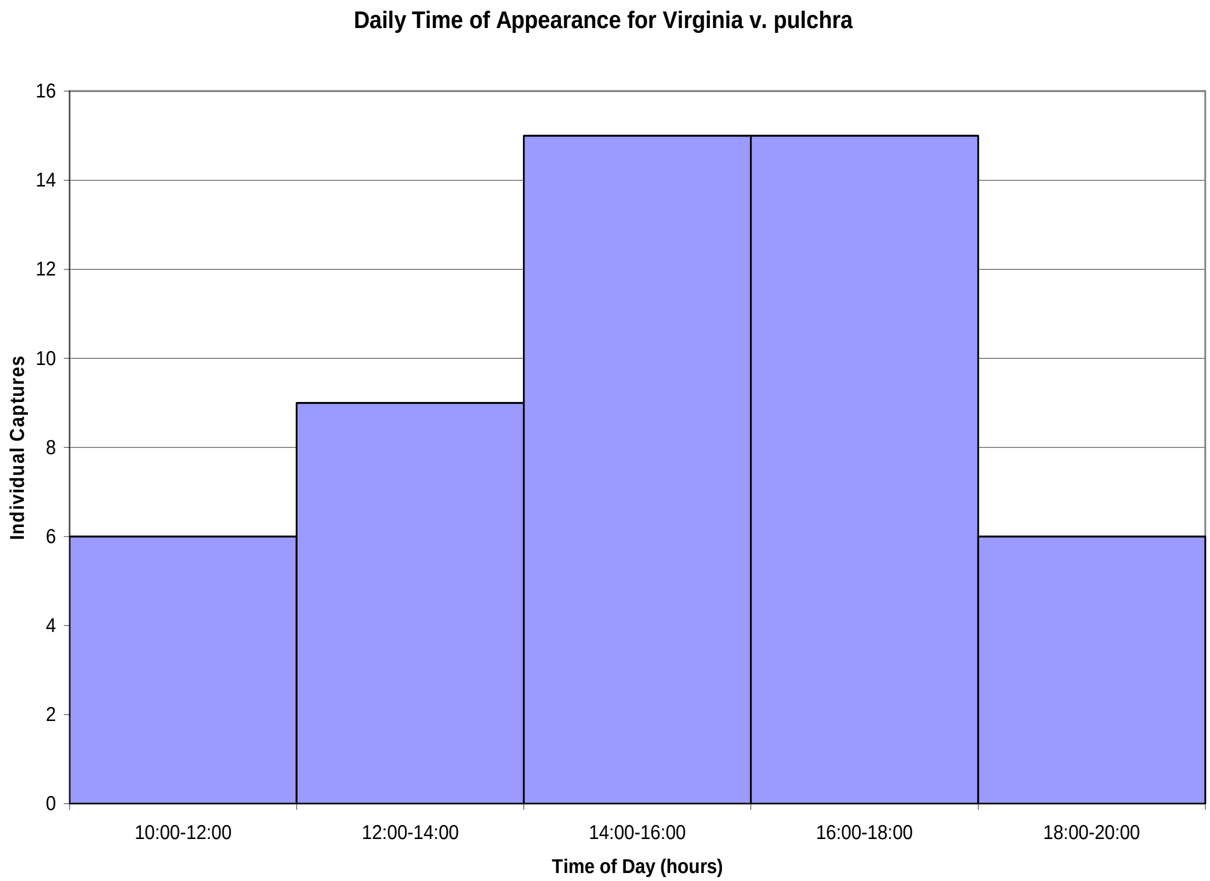

Figure 13: Number of *Virginia v. pulchra* captured per time of day for 2006.

amount of precipitation for the previous three days leading up to and including the day of the capture (p = .5). Although the relationship with the total number of snakes caught during one month and the monthly precipitation was not significant by typical standards (p = .06), there appears to be some degree of relationship between the two. More snakes were captured during months with higher amounts of rainfall.

Population Structure

The majority (70%) of the snakes were between 165-240 mm in SVL. Larger adults that were longer than 240 mm SVL (16.3%) and sexually immature snakes that were under 165

Collection Date	Day 1 Rainfall (inches)	Day 2 Rainfall (inches)	Day 3 Rainfall (inches)	Capture Date Rainfall (inches)	Total	Monthly Total	Number of Snakes Caught
6/9/2006	0.05	0.55	0	0.01	0.61	7	6
6/16/2006	0	0.01	0.01	0	0.02		3
6/23/2006	0.12	0	0	0	0.12		6
6/30/2006	0.30	0.02	0.22	0.41	0.95		3
7/14/2006	0.41	0.44	0.67	0.05	1.57	4.88	7
7/20/2006	0	0.96	0.87	0	1.83		1
7/21/2006	0.96	0.87	0	.10	1.93		7
8/3/2006	0	0	0	0	0	1.98	3
8/11/2006	0	0.01	0.10	0	0.11		7
8/16/2006	0	0.01	0.01	0	0.02		2
9/22/2006	0	0	0	0.25	0.25	3.6	8
5/28/2007	0	0	.70	0	0.70	2.94	3
5/29/2007	0	.70	0	0	0.70		1
6/5/2007	0.01	0.51	0.02	0.05	0.59	5.56	6
6/10/2007	0	0.18	0	0	0.18		2
6/24/2007	0	0	0	0.11	0.11		1
7/2/2007	0.27	0	0	0	0.27	4.66	1
7/18/2007	0.15	0	0.17	0	0.32		3
7/20/2007	0.17	0	0.41	0	0.58		2
7/22/2007	0.41	0	0	0	0.41		3
7/31/2007	0	0.21	0.37	0.44	1.02		1
8/5/2007	0	0	0	0.44	0.44	3.27	4
8/6/2007	0	0	0.44	0	0.44		1
8/19/2007	0.44	0	0.03	0.37	0.84		2
9/9/2007	0.04	0	0	0	0.04	3.33	3
9/12/2007	0	0	0.98	0	0.98		2
9/19/2007	0	0	0	0	0		1

Table 1: Dates when *Virginia v. pulchra* were collected with the number of snakes caught each day. For each day, total rainfall with amounts of the previous three days along with monthly totals is shown.

mm (13.8%) SVL were more uncommon. The sex ratio for V. *v*. pulchra was approximately 1:1.

Mark Recapture and Movement

We marked 74 snakes, including 39 females and 35 males. We recaptured five males and two females (9.46%). Of the seven snakes recaptured, there was a combine total of 10 recaptures. None of the snakes caught in the summer of 2007 were identified as snakes caught from the previous summer. Snake movement ranged from 0-16.9 m ($\bar{x}$ =6.8 m). Two recaptures, one male and one female, did not move at all from the previous capture after 5 and 4 days, respectively. The longest time elapse between captures was 42 days for a large, gravid female that had only moved 15.7 m. Another large, gravid female, specimen #55, seemed to favor a particular rock. The female was originally found under a rock with rocks and loose soil with a couple of large ant tunnels big enough for the snake to enter. The first time she was recaptured she had moved 3.3 m. The second time she was recaptured she had moved back to the original rock she was captured under and was found under the same rock the third time she was recaptured. Thus, from May 29th to July 22nd, specimen #55 was found three out of four times under the same rock.

Discussion

Range

In West Virginia, *V. v. pulchra* are confined to the Allegheny Mountain and Ridge and Valley Physiographic Provinces (Figure 1). Since 1964, 80 snakes from this study, 8 from the West Virginia Biological Survey, and areas presented in previous literature were used to determine its known distribution.

The distribution for *V. v. pulchra* can be broken into four regions based on the location of each site and its distance from other areas where snakes were found (Figure 1). Region A is in Preston County, near the town of Terra Alta and the Flat Rock area; Region B is near Romney in Hampshire County; Region C is in Randolph County at Spruce knob and on the Pendleton and Pocahontas County line near the Elk Mountain range allotment; and Region D is in Pocahontas County at the Elleber Knob and Camp Allegheny range allotments. Cervone (1983) had divided up the overall range into five areas. Two of these (Area IV and V) found in West Virginia represent the southern most areas of the range. Regions A and B are associated with Area IV which encompasses the area of Terra Alta in Preston County, Hampshire County and Swallow Falls State Park in Garrett County, Maryland. Regions C and D are associated with Area V, which was only associated with Spruce Knob. With Elleber Knob and Camp Allegheny being around 27.4 km south-southwest from Spruce Knob, I decided to place it in Area V in regard to the overall geographical distribution for *Virginia v. pulchra* due to Elleber Knob's close proximity to Spruce Knob.

Areas IV and V in West Virginia seem to be associated with particular river drainages. The river drainages associated with Area IV are the Cheat and Youghiogheny Rivers, while Area V is associated with the Cheat, Greenbrier, and Potomac River (Cervone, 1983).

Throughout its range, *V.v. pulchra* is only found in unglaciated locations. Areas IV and V are the two farthest away from any glaciated areas. Cervone (1983) made several attempts to find *V. v. pulchra* in the glaciated sections of northwestern Pennsylvania and southwestern New York but did not have any success.

The soil in Areas I, II, III was described by Cervone (1983) as loamy sand to clay type soil and sandy-loam soil appear to be important in their distribution. Cervone had only sampled one site from Area IV and none from Area V. Baker (1936) described Areas IV and V as being rough and stony (from Cervone 1983). GIS files from the U.S. Department of Agriculture describe the localities in Pocahontas County as a Calvin channery silt loam with 15 to 30% slopes and a Shouns silt loam with 3 to 15% slopes, which are very stony and considered not to be prime farmland. Both the Preston County site, a Dekalb very cobbly loam with 25 to 35% slopes, and the Randolph County site, a Berks channery silt loam with 15 to 25% slopes, are considered not prime farmland. No soil information is available for the record near Romney in Hampshire County since a specific location was never given. Areas with silt loam soils that are stony and are considered not prime farmland seem to be important for the geographic range in West Virginia.

One area believed to be a potential site for *V. v. pulchra* was at Dolly Sods in Tucker County, West Virginia. Significant time was spent there during the summer of 2006. Although all snakes that are associated with *V. v. pulchra* at Elleber Knob were present, no *V.v. pulchra* were caught. Given my results and those of Dr. Thomas Pauley who has searched this area for 30 years, we believe *Virginia v. pulchra* is absent at Dolly Sods.

Virginia v. pulchra will utilize the galleries and tunnels of several ant species when they are abandoned so it is not surprising there is a high correlation between snake presence and ant activity (Cervone, 1983). There was a very high ant presence at Dolly Sods, including the highly aggressive *Formica exsectoides*. Many rocks have large tunnels and galleries with hundreds of ants. With *V. v. pulchra* being subterranean and using abandoned tunnels, this high ant presence may be one reason why *V. v. pulchra* is not found at Dolly Sods.

Dolly Sods is a unique area of West Virginia, because of cold weather and altitude Dolly Sods resembles places that are similar to more northern places in the U.S. and Canada (Venable, 1996) were *V. v. pulchra* is not found. Although cool, wet weather prevails throughout the year, several other species of snakes including *Thamnophis s. sirtalis*, *Storeria o. occipitomaculata*, *Diadophis punctatus edwardsii*, *Opheodrys vernalis*, and *Lampropeltis t. triangulum* are found in large numbers so it is unlikely that the cooler temperatures associated with Dolly Sods would be the reason why *V. v. pulchra* is absent.

From the 1880's to the 1920's, Dolly Sods was extensively logged and during that time fires repeatedly swept through the area. In some areas of Dolly Sods, fires were so intense that 2 to 4 feet of accumulated humus soil was burned down to the rock (Venable, 1996). Several studies have shown that fire has little effect on herpetofauna species (Ford et al, 1999; Langford et al, 2007; and Lyon et al, 2000), however, a fire of this intensity would have killed all of the snakes. The habitat of a subterraneous species like *V. v. pulchra* would have been strongly affected by the burning of so much soil, unlike the species that are currently found at Dolly Sods that are surface snakes and would not have had their habitat affected so strongly.

Although there were some areas where cattle grazed, Dolly Sods may not have originally been ideal habitat for *Virginia v. pulchra*. Before Dolly Sods was logged in the late 1880's, it was covered by Red Spruce (Venable, 1996). Since the time when it was logged, *Virginia v. pulchra* may not have been able to immigrate to Dolly Sods. This may be due to short movements seen with *V. v. pulchra* or some biological barrier preventing them from entering Dolly Sods. With populations being sporadic throughout its range, until some are found in Tucker County, it is hard to say whether or not there are populations close enough to Dolly Sods where immigration is a possibility.

Of all the historical sites searched in this study that did not yield any captures, the hillside near the boat ramp and parking lot at Spruce Knob Lake was the only site where *V. v. pulchra* could be absent. The area where the specimen was captured has several small trees and shrubs that would block out important sunlight and limited rocks to be used as cover, and may have forced snakes to move to more suitable habitat surrounding the lake.

I believe that the range depicted in Figure 1 does not represent the entire range for West Virginia. Three areas where *V.v. pulchra* are found — Elleber Knob, Camp Allegheny, and the area near Elk Mountain — are all range allotments owned by the U.S. Forestry Service in the Greenbrier Ranger District. All three allotments are grazed by cattle, have light to moderate slopes, not suitable farmland, open, near a forest edge, and contain some amount of sandstone rocks. There are several other range allotments within district along with other districts that could contain populations of *V. v. pulchra*. There are several other areas throughout Tucker, Pendleton, Pocahontas, and Greenbrier counties that meet this description that are privately owned. To completely understand the range of *V. v. pulchra*, all range allotments owned by the

U.S. Forestry Service should be searched and attempts should be made to reach out to private land owners in an attempt to search their property.

Habitat

Virginia v. pulchra is found in open areas scattered throughout the forests of the Allegheny Mountain Physiographic Province(Figure 2). Of the two subspecies found in West Virginia, *V. v. pulchra* is the more montane form, while *V. v. valeriae* is found in lower elevations. *Virginia v. pulchra* has been found from 275 m above sea level in Hampshire County, West Virginia (Cervone, 1983) to about 1,300 m above sea level at Elleber Knob in Pocahontas County, West Virginia. The elevation range for *V. v. valeriae* using records from the West Virginia Biological Survey Museum is 188 m above sea level to 365 m above sea level.

Virginia v. pulchra can be found on slopes that are flat to moderate. The nature of the slope is a more suitable habitat than steeper slopes due to the fact that rocks are much more stable in their placement. These slopes must be available to sunlight; snakes were previously reported to avoid north-facing slopes (Cervone, 1983). The area at Elleber Knob where most snakes were caught in this study was on a north-northwest slope. Typically north facing slopes receive less sunlight but, the area in which they were caught was a field open enough to receive an adequate amount of sunlight.

Virginia v. pulchra were found in close proximity to water. All snakes that were caught in this study were found no further than 210 m away from permanent water. This is very similar to the 250 m that Cervone reported (1983) for *V. v. pulchra*. The main difference between my data and Cervone's was that he caught the majority of snakes next to roads that typically followed the same paths of smaller brooks whereas I found snakes in fields that were near small streams or had areas where rain water collected in ruts and hoof impressions. These places, in addition to nearby ditches and areas of runoff from higher elevations, help create multiple nearby water resources that last for some time during moderate rainfall. Although *V. v. pulchra* were found in close proximity to a permanent water source, I did not find any connection between the two. Several searches were made to find *V. v. pulchra* on rocky slopes that were next to a road but no snakes were ever captured.

The main topographic barrier of the Eastern Allegheny Plateau and Mountains that runs through the center of the county is the divide of the Allegheny Mountains which creates a “rain shadow” on the eastern half of the county. It is because of this “rain shadow” that the eastern half of Pocahontas County has higher average temperatures and lower average precipitation (Flegel, 1992).

Since the majority of the snakes (99%) were caught at Elleber Knob, this area will be the focus of the soil discussion. The soil at Elleber Knob is a Calvin channery silt loam. Calvin soils are moderately deep and well drained with moderate permeability at 2.0-6.0 in/hr. Calvin soils are weathered from shale, siltstone, or fine sandstone and the depth of the bedrock ranges from 20 to 40 in. The amount of clay in the first four inches ranges from 10-25% while the amount ranges from 15 to 30% in the remaining 35 inches. Soils are typically acidic ranging from 4.5-5.5 pH (Flegel, 1992). Soil samples taken from Elleber Knob during this study had an average of 5.8 pH. The content of shale, siltstone, and fine grained sandstone fragments ranges by volume from 5-25% in the A and Ba horizons, from 25-55% in the Bw and Bc horizons, and from 55-70% in the C horizon. The soil texture below the A horizon is loam to silt loam (Flegel, 1992).

The silt loam soils from this study differ from the majority (84.7%) of soil samples previously found by Cervone (1983), which were loamy sand. Sand is an important component for the snake since sandy loam soils have a shallower frost line than clay soils (Cervone, 1983). Calvin soils have a moderate potential frost action (Flegel, 1992). Despite clay soil having a deeper frost line, clay is still important because it allows underground tunnels to persist that would otherwise collapse without a clay component. Sandy or loamy soils would facilitate an earlier spring emergence compared to clay soils (Cervone, 1983). Although sandy loam soils have a lower potential for frost action than silt loam soils, silt loam soils are still suitable for *V. v. pulchra* because the combination of having moderate permeability and well drained soils while containing only small amounts of clay to allow tunnels to persist allows for a moderate potential for frost action.

V. v. pulchra is found typically under fine sandstone rocks (Figure 3). All of the snakes in my study and 96.8% of the snakes in Cervone's study were found under fine sandstone rocks. One of the most important functions of these rocks is keeping open tunnels under them warm and to be a heat sink during the day, helping reradiate heat during the night (Cervone, 1983). These rocks also provide a heat source for *V. v. pulchra* via conduction and protect the snake from predation. Without these rocks the snake would be exposed to lower temperatures and would be more exposed to predators. Lower temperatures would prolong the gestation period reducing the amount of time young have to build fat reserves for hibernation (Cervone, 1983). *V. v. pulchra* have been reported under other kinds of cover objects such as corrugated iron, board, trash, dried leaves, and a piece of carpet (Cervone, 1983), small rocks and boards (Richmond, 1954).

Gravid females prefer larger rocks. Since thicker and more voluminous rocks are slower to heat and cool, this offers gravid females more stability allowing the female to remain in one area, also reducing the risk of predation (Cervone, 1983).

Typical habitat for *V. v. pulchra* is a field with short grass, flat to moderate slopes that have scattered fine sandstone rocks near a source of water and a forest edge. Ideal habitat is open areas that are grazed by cattle and not suitable for farmland. Cattle grazing can be beneficial because they maintain the height of grass, keeping cover objects exposed to sunlight, and create ruts and hoof impressions in the ground that collect water keeping the soil moist, which favors earthworms activity. Other authors have found them in different habitats such as along the cleared sides of the road (Cervone, 1983), timbered areas with dense undergrowth of ferns and bryophytes, and in a bog where ferns, sphagnum and other mosses are abundant (Cooper, 1958).

The most common species found with *V. v. pulchra* are *Storeria o. occipitomaculata*, *Diadophis punctatus edwardsii*, *Thamnophis s. sirtalis*. *Diadophis punctatus edwardsii* are found in or near moist woodlands (Green and Pauley, 1987). *Thamnophis s. sirtalis* can be found in a variety of habitats which includes grassy areas primarily in open or semi-open lowlands while *S. o. occipitomaculata* can be found in wet, sedgy meadows and the edges of forest clearings. All are found under a different variety of cover objects which includes rocks (Green and Pauley, 1987; Tennant, 2003). Even though all three species are associated with *V. v. pulchra*, finding them in a particular area does not necessarily mean *V. v. pulchra* will be present.

Ant and ant mounds were not very common where *V. v. pulchra* were found. Ants make tunnels, which *V. v. pulchra* are incapable of making (Cervone, 1983). If *V. v. pulchra* requires the use of ant tunnels to maneuver through the soil where ants are not obvious, then there are either more ant tunnels than visible or *V. v. pulchra* is using some other means of travel. Snakes were observed to attempt to push through the soil or attempt to escape by moving in the spaces between rocks under the soil. If neither attempt was successful then snakes would escape by moving on the surface through the grass to the nearest rocks. Several small mammals, one of which was identified by Dr. M. H. Hight of Marshall University as *Cleithrionomys gapperi*, Northern Red-backed Vole, were seen in the field along with several small tunnels they used to move around. With few signs of ant activity and ant tunnels, *V. v. pulchra* may be using tunnels made by small mammals or moving on the surface from rock to rock concealed by the tall grass.

Species Description

The dorsal color of live *V. v. pulchra* ranges from reddish brown to smoke gray. Cervone described the majority of snakes he observed as brownish olive to fuscous brown dorsum suffused with a vivacious pink color especially towards the ventrals (Cervone, 1983). Others have described the dorsum as reddish brown (Richmond, 1954) or a russet tan (Cooper, 1958). Specimens I encountered ranged from olive brown to dark gray with the majority being olive brown. Majority of these snakes had black spots on the dorsum usually more concentrated toward the anterior portion of the snake. In addition to spots, some snakes had a mid-dorsal stripe that was lighter than the rest of the dorsum with a hint of yellow. Most snakes that had a dark gray color or did not have any visible spots were preparing to molt. A few times the loose skin was removed by hand revealing the typical olive brown color and black spots on the dorsum.

The ventral color varies from cream to greenish-sulfur color (Cervone, 1983) to off-white to grayish white or a yellow color (Cooper, 1958; Richmond, 1954). I encountered some snakes that the ventral color was off white to cream but they were either preparing to molt or were neonates. The typical ventral color I observed was a yellow to tan with a reddish pink on the lateral edges or throughout the ventral scales.

Virginia v. pulchra is one of the smallest snakes found in West Virginia. They can obtain a maximum length around 320 mm but this size is not entirely common. Females are longer than males and thus the only ones that can reach 320 mm. One female that was caught measured a total of 324 mm, which is 4 mm longer than the longest one previously reported by Richmond (1954). Tail length expressed as a percent of total body length is longer in males than females. Similar findings were reported by Cervone (1983) and Richmond (1954), while Cooper (1958) only published raw data on tail length expressed as a percent of total body length.

Virginia v. pulchra is sexually dimorphic in the number of sub-caudal, ventral scales, and tail length expressed as a percent of total body length. (Cervone, 1983; Richmond, 1954). Males have longer tails expressed as a percent of total body length and more sub-caudal scales to provide space for the hemipenes. Females have a higher number of ventral scales because they have longer bodies to accommodate for developing young (Cervone, 1983). Sexual dimorphism lengths have been reported by Cervone (1983) and Richmond (1954). Similar sexual dimorphism has been reported for other small snake like *Carphophis amoenus*, *Diadophis punctatus edwardsii*, and *Storeria dekayi* (Willson and Dorcas, 2004).

Cervone (1983) evaluated the coefficient of divergence (CD) compared by Clark (1966) for the *V. valeriae* group. A higher CD indicates a greater degree of subterranean activity. Of the three subspecies, *V. v. pulchra* had the lowest CD suggesting it is the least subterranean of the three thus spending more time on the surface. *Virginia v. pulchra* is found in higher elevations where soil and air temperatures are cooler. To adjust to this, they spend longer periods on the surface under rocks warmed by the sun. This reinforces the importance of rocks as a cover object for *V. v. pulchra*.

Typical dorsal scale count for *V. v. pulchra* is 15-17-17. There are variations in the typical dorsal scale count but they only accounted for a small number of the total number of snakes caught. Cervone (1983) noticed a 20.2% variation in the typical scale count for *V. v. pulchra*. Some of these variations are the same as the typical dorsal scale counts for *V. v. valeriae* (15-15-15) and *V. v. elegans* (17-17-17). Variation in typical dorsal scale count is higher in *V. v. pulchra* than *V. v. valeriae* (6.3%) and *V. v. elegans* (4.8%) (Cervone, 1983).

Virginia v. pulchra typically has weakly keeled scales. Over 96% of the snakes captured were weakly keeled while the remaining did not appear to have any keels. Individuals that did not appear to have keels were dark gray in color and believed to be in the process of molting. Many snakes that were similar in color appeared to have a very weak keel that was difficult to see. When *V. v. pulchra* is in the process of shedding, it may make keels more difficult to see. A portion (15.1%) of snakes caught by Cervone (1983) was smooth at the anterior portion of the body. Of the three subspecies, *V. v. pulchra* shows more keeling throughout the body than the other two. *Virginia v. valeriae*, the other subspecies found in West Virginia, is primarily smooth throughout the body (Cervone, 1983).

The evolutionary trend for *V. valeriae* appears to be moving away from keeled scales to smooth ones (Cervone, 1983) because keeled scales are considered more primitive than smooth ones (Richmond, 1954). Jackson and Reno (1975) stated that smooth scales would be more advantageous for snakes that were subterranean (From Cervone 1983). This primitive trait together with a low CD compared to the other two subspecies, makes it the least subterranean of the three (Cervone, 1983).

Time of Appearance

The active season for *V. v. pulchra* at the collection sites in Pocahontas County is May through September. Activity in April is probably minimal since temperatures are still low and snowfall occasionally occurs. I personally observed snowfall at collection sites in late May of 2006. Activity is more likely to be higher at the northern extent of its range in West Virginia at Terra Alta, Preston County. Terra Alta is about 600 m lower in elevation than the sites in Pocahontas County and activity probably begins in April and may extend through October. I was unable to make any searches in April due to schedule conflicts so I am unable to confirm activity during this month. The earliest collection date in the year reported previously was March 28th (Cervone, 1983). It might be possible for activity in March during warmer years at Terra Alta. In Pocahontas County activity is highest during June and July. Cervone (1983) showed a higher activity during May and June in northwestern Pennsylvania near the areas of Sizerville State Park, Slabtown Hollow Field, and Warren, PA. Studies by Bothner and Moore (1964); Cooper (1958); Pisani (1971); and Richmond (1954) report observing *Virginia v. pulchra* from May to August.

The appearance of *V. v. pulchra* during late spring is most likely due to elevated temperatures and the presence of earthworms (Cervone, 1983). Earthworm activity differs between seasons in temperate climates. Earthworms are most active during autumn and especially during the spring when warmer and wetter soil conditions are more favorable. Moisture is lost through the earthworm’s cuticles so soil moisture is critical to their survival. It is therefore not surprising that activities are linked with rainfall patterns (Edwards, 2004).

With each passing month from June to September, the total number of *V. v. pulchra* decreased. This decrease throughout the summer is most likely due to drier soil, decrease in earthworm activity, and warmer substrate temperatures (Cervone, 1983). During drier periods in the summer, earthworms will burrow deep into the soil and will sometimes construct cells lined with mucus where they coil up and enter a dormant state until conditions become more favorable (Edwards, 2004).

Virginia v. pulchra can be found on the surface during the active season when air temperatures are above 10.5°C. Since *V. v. pulchra* spend the majority of their time using underside of rocks as a means of thermal regulation, they are not directly exposed to air temperatures and may be found when air temperatures are lower. Snakes were found several times on top of dead vegetation under rocks and in some instances were found to be coiled up creating a small “pocket” in the dead vegetation. Bogert (1959) found that lizards basked on mats of dead grass that insulated them from the cold ground. This strategy would prove useful for *V. v. pulchra*, helping them to stay above the colder soil preventing the loss of body heat. This strategy in combination with remaining underneath sandstone rocks would help explain why *V. v. pulchra* can still be found on the surface when temperatures are low.

Cervone (1983) and Richmond (1954) stated the best time to collect *V. v. pulchra* is immediately after a rainfall. This was not the case in my study as there was no relationship between the number of snakes caught and the total amount of rainfall on the date the snake was captured along with the previous three days. For 45% of the snakes captured (36) during the study, the total rainfall for the three previous days leading up to and including the capture date was equal to or less than 0.25 in. The relationship between the total number of snakes caught in one month with the monthly precipitation was marginally significant suggesting that monthly rainfall is more important in determining presence of *V. v. pulchra* than isolated rain events during a particular period of time. The best time to collect snakes is during months with high monthly precipitation in late spring and early summer on clear days between 2:00-6:00 pm. During months with very low monthly precipitation, searches should be made after a rain shower.

The relationship between monthly rainfall and the activity of *V. v. pulchra* is most likely due to the availability of earthworms during months of greater precipitation. As monthly precipitation decreases, so does the presence of *V. v. pulchra* since conditions are not as favorable for earthworms. The site where the majority of specimens were captured was on a north-northwest aspect. Typically north-facing aspects are cooler and wetter than most other aspects since it does not receive as much sunlight. Cooler and wetter conditions may explain why there was not strong relationship between snake presence and small rain events. With the site facing north, moisture in the soil would persist for longer periods of time, favoring the availability of earthworms making them less dependent on rainfall events. During years and months with little rainfall, there would probably be a stronger relationship between snake presence and rainfall events.

Mature male *V. v. pulchra* were found in slightly higher numbers than females during the June and July, while mature females were found in higher numbers during August and September. Mature males were probably actively searching for mates during at the beginning of the season and activity decreased as the mating season progressed. The reason why females are found in higher numbers during August and July is that gravid females seek out higher temperatures, which can reduce gestation time (Deeming and Ferguson, 1994). Gregory (2001) and Lourdais et al. (2004) found that higher temperatures hastened development, and decrease parturition date and frequency of stillborn neonates in *Thamnophis s. sirtalis* and *Vipera aspis,* respectively.

Although I did not search for snakes at night, *V. v. pulchra* has been previously caught during the night (Cervone, 1983). I found snakes to be most active between the hours of 2:00-6:00 pm, which is similar to the hours of 3:00-6:00 pm reported by Cervone (1983). Typically, most snakes are found during the cooler hours of the early morning and late evening, avoiding hotter temperatures during the afternoon. *Virginia. v. pulchra* are more active during the mid-afternoon when they are seeking warmer temperature since the early morning and late evening are much cooler in higher elevations.. Peak surface activity during the day depends on the difference in temperature between the substrate and ground temperatures. *Virginia v. pulchra* is found in higher numbers when substrate temperature is higher than ground temperature compared to when the ground temperature is higher than the substrate temperature (Cervone, 1983).

Population Structure

Adult *V. v. pulchra* were found in higher numbers than juveniles and neonates. Occasionally finding juvenile and neonates compared to higher numbers of adults is common in many studies (Cervone, 1983; Larson and Gregory, 1989; and Willson and Dorcas, 2004). Juveniles are probably encountered less frequently because they move less than adults and spend more time in concealment (Cervone, 1983). Neonates are encountered less often since they are born months after the beginning of the active season. Studies on the reproductive biology show the gestation period for *V. v. pulchra* is from August 16th to September 20th (Cervone, 1983).

Sex ratio for male (37) and female (42) *V. v. pulchra* is 1:1.3. This is almost identical for the 1:1.6 ratio found by Cervone (1983). Depending on the time of year, there is a bias toward males or females. Searches in the early part of the active season are potentially biased toward males because they are actively looking for mates, while later in the active season is potentially biased toward females because gravid females spend more time on the surface seeking warmer temperatures to reduce the gestation period.

Mark Recapture and Movement

Of 74 snakes, only 7 (9.46%) were recaptured 10 times. The only other mark-recapture study known was a daily mark recapture done by Cervone (1983) where 8 of 28 (28.6%) were recaptured with daily movements ranging from 0-6.4 m. Other studies have reported low recapture rates as well (Blanchard et al, 1979; Russel and Hanlin, 1999; and Willson and Dorcas, 2004). The longest movement recorded during this study was only 16.97m. Unfortunately, with so few snake recaptured during this study, the data supports no conclusions.

Regardless of how far *V. v. pulchra* moves, one thing that most likely limits snake movement is roads. Smaller snakes typically show a greater tendency to avoid roads then larger snakes because they move at a slower rate than larger snakes exposing them to predators and vehicles (Andrews and Gibbons, 2005). Another reason they avoid roads may be due to elevated road temperatures during the late morning through early evening hours. Smaller snakes would move slower across the road exposing them to high surface temperatures for a prolonged time. Where *V. v. pulchra* is so small, it would not take as much thermal energy to raise the temperature of the snake risking it to overheating compared to larger snakes. This is not to say that *V. v. pulchra* does not cross roads, one specimen collected by Cooper (1958), which was a DOR (Dead on Road) shows that they do, but it is probably a rarity.

At a glance, it may appear that *V. v. pulchra* only moves short distances with the short, maximum movements found in this study and reported previously, but this may not be the case. One of the largest movements recorded for *V. v. pulchra* was a gravid female that moved

15.74m. Parker and Anderson (2007) found that *Crotalus oreganos concolor* gravid females moved much less than non-gravid females and males. If this is true for *V. v. pulchra* then non-gravid females and males could potentially move a much greater distance. In addition, few snakes were recaptured in a small study area because they may have been secluded beneath the soil surface or could have moved greater distances out of the search area. *Storeria o. occipitomaculata* (Blanchard, 1937) and *Diadophis punctatus edwardsii* (Blanchard et al, 1979) have been recorded to move long distances; up to a quarter mile and one mile, respectively. So movements for *V. v. pulchra* may be much farther than anticipated and warrants further study.

Summary

Virginia v. pulchra are discontinuously distributed throughout the unglaciated areas of western Pennsylvania, western Maryland, eastern West Virginia, and Highland County, Virginia. In West Virginia, snakes are found in the higher elevations of the Allegheny Mountain and Ridge and Valley Physiographic Province. Records exist from Hampshire, Pendleton, Pocahontas, Preston, and Randolph counties. This most likely does not represent the entire range because many populations are probably yet to be discovered. *Virginia v. pulchra* are absent from Dolly Sods in Tucker County and any further attempts to find populations there should concentrate their searches in other parts of the county.

Typical habitat for *V. v. pulchra* is short, grassy fields with flat to moderate slopes that have scattered fine sandstone rocks near a source of water or forest edge regardless of aspect. Fine sandstone rocks are the primary cover object used. Snakes are found in loamy soils that are well drained and have a low to moderate potential for frost action. The most common species found in association with *V. v. pulchra* are *Storeria o. occipitomaculata*, *Diadophis punctatus edwardsii*, and *Thamnophis s. sirtalis*.

Virginia v. pulchra are sexually dimorphic with males having more sub-caudal scales and longer tail expressed as a percent of total body length while females have a longer average snout-to-vent and total length. Females obtain a maximum total length between 320-330mm while males reach a maximum total length between 290-300mm. The most common dorsal color is an olive brown with black spots scattered throughout the dorsum usually concentrated on the anterior portion of the body. The most common ventral color is cream with reddish brown edges. *Virginia v. pulchra* are weakly keeled and shows variation in scale counts at the head, mid-body, and tail portions of the body, but the typical scale county is 15-17-17.

Virginia v. pulchra are active from April through September with more snakes being observed in late spring and early summer. Males are observed more in late spring and early summer while females are observed more in late summer and early fall. Activity appears to be more associated with monthly rainfall rather then short term rain events. *Virginia v. pulchra* are diurnal and are found in higher numbers between 2:00-6:00 pm.

The sex ratio is approximately 1:1 with adult snakes observed more than immature ones. Individuals between 165-240 mm in SVL represent the majority of the population.

Virginia v. pulchra are very secretive and have very low recapture rates. For the few snakes recaptured, movements appear to be made over short distance.

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Appendix I

Collection Sites for *Virginia valeriae pulchra* throughout the state of West Virginia

Hampshire County:

1. Near Romney at an elevation of 900ft. (TC and CMNH)

Pendleton County:

1. Beside forest road 112(103), 1.6 miles north of state route 28 and forest road 112 junction (WVBS).

Pocahontas County:

1. Elleber Sods Road (FR 1681), 4.3 miles from U.S. 250.

2. Elleber Knob Range Allotment at the end of Elleber Sods Road (FR 1681)

3. Camp Allegheny Range Allotment.

4. Area around the Elk Mountain Range Allotment near Pocahontas/Pendleton County border (TKP).

Preston County:

1. Terra Alta Biological Station, northeast shore of Terra Alta Lake (WVBS)

2. Two miles north of Terra Alta Lake in clearing across from Flat Rock Chapel (ZL).

Randolph County:

1. Grassy hillside between Spruce Knob Lake and parking lot (WVBS).

WVBS = West Virginia Biological Survey
TKP = Dr. Thomas K. Pauley
TC = Dr. Thomas Cervone
CMNH = Carnegie Museum of Natural History
ZL = Zachary Loughman

Appendix II

Notes and Observations on Competitors and Predators

Competitors and Predators

Competitors and predators were determined by analyzing natural history information from literature for species that were caught in the same area as *V. v. pulchra*. Diets of sympatric species were studied to determine if any snakes would potentially prey on *V. v. pulchra* and those that would compete for the same prey. Competition for space was evaluated by looking at the number of cover objects versus the amount of snakes caught along with the number of times *V. v. pulchra* was caught under the same rock with another species.

Competitors

Any interspecific and intraspecific competition that could happen would occur over space and food (Cervone, 1983). The species that occur in the same area as *V. v. pulchra* from most abundant to least abundant were *Storeria o. occipitomaculata* (Northern Red-bellied Snake), *Diadophis punctatus edwardsii* (Northern Ring-necked Snake), *Thamnophis s. sirtalis* (Eastern Garter Snake), *Opheodrys vernalis* (Eastern Smooth Green Snake), *Elaphe o. obsolete* (Black Rat Snake), and *Lampropeltis t. triangulum* (Eastern Milk Snake) (Figure 6).

Areas where *V. v. pulchra* were caught had a high number of fine sandstone rocks. Occurrences where *V. v. pulchra* were observed under the same rock with another snake of the same or different species were rare. For *V. v. pulchra*, only 7.5% of the snakes observed were found together under the same rock with the same species, while occurrences with finding *V. v. pulchra* under the same rocks with a snake of a different species were only observed 5% of the time.

Virginia v. pulchra preys exclusively on earthworms (Cervone 1983). Of snakes found in association with *V. v. pulchra*, *Storeria o. occipitomaculata*, *Diadophis punctatus edwardsii*, and *Thamnophis s. sirtalis* have been reported to eat earthworms but it does not constitute a major part of the diet (Green and Pauley 1987; Tennant 2003). The United States Department of Agriculture Natural Resources Conservation Service states that the majority of temperate soils support significant populations of earthworms. A square yard of cropland can contain 50-300 earthworms and grasslands can have 100 to 500 earthworms. With V. *v. pulchra* being the only snake to feed solely on earthworms (Cervone, 1983) and the population density of earthworms ranging from 100-500 per square yard, it is unlikely that much competition would occur. Especially during the spring when soils are moist and earthworms are more abundant. Times of the highest competition for food would be during the summer when the surface of the soil is higher in temperature and drier compared to the spring, thus making earthworms less available.

Interspecific competition would be limited since other sympatric species consume other prey as a part of their diet. *Diadophis punctatus edwardsii* seem to prefer salamanders, especially *Plethodon cinereus* (Blanchard et al, 1979). *Storeria o. occipitomaculata* consume slugs as their primary source of prey, while *Thamnophis s. sirtalis* consume a variety of prey including frogs, toads, salamanders, and fish (Green and Pauley, 1987).

Intraspecific competition would probably be the main source of competition for *V. v. pulchra*, especially during the summer when earthworms are less accessible. It would seem that there would not be any real significant threat to other snakes from intraspecific competition from gravid females since they feed less during the gestation, which is when earthworms are less abundant on the surface. This would leave males and non-gravid females to compete for food but because earthworm population density is so high, it would most likely be minimal. Neonate and juvenile *V. v. pulchra* would be most at risk from competition since they would be restricted to consuming smaller earthworms while larger snakes would not (Cervone, 1983).

Predators

There is most likely very little predation on *V. v. pulchra*. These snakes are small and secretive, spending the majority of their time beneath the soil or under rocks. The only time *V. v. pulchra* was observed to move on the surface out in the open was when an individual was released after being captured. Out in the open, the dorsal color of *V. v. pulchra* would blend in well with the ground and the tall grass in the open field would help seclude the snake from predators.

Lampropeltis t. triangulum and *Diadophis punctatus edwardsii* will both consume snakes if available (Green and Pauley, 1987; Tennant, 2003). Since *Lampropeltis t. triangulum* were rarely encountered during the study, it is unlikely that they would be a major predator on *V. v. pulchra*. *Plethodon cinereus,* the preferred food of *Diadophis punctatus edwardsii,* was found in the same area as *V. v. pulchra*. During times of rainfall when the ground is moist, *Diadophis punctatus edwardsii* will most likely prey mainly upon *Plethodon cinereus*. When *P. cinereus* are not available during dry conditions, *Diadophis punctatus edwardsii* could prey upon snakes as an alternative source of food. One *V. v. elegans* specimen was found in the stomach of *Diadophis punctatus arnyi* (Christiansen, 1973). One juvenile *Elaphe o. obsoleta* was caught and regurgitated a small *Storeria o. occipitomaculata* showing that juvenile *E. o. obsoleta* prey upon small snakes that would include *V. v. pulchra*. Several hawks were seen in the area and might prey on *V. v. pulchra* but predation is probably minimal since *V. v. pulchra* is so secretive. There were a couple of specimens that had significant scarring on the lateral sides of the mid-body that appeared to be from an attack of some sort, most likely from a small mammal.