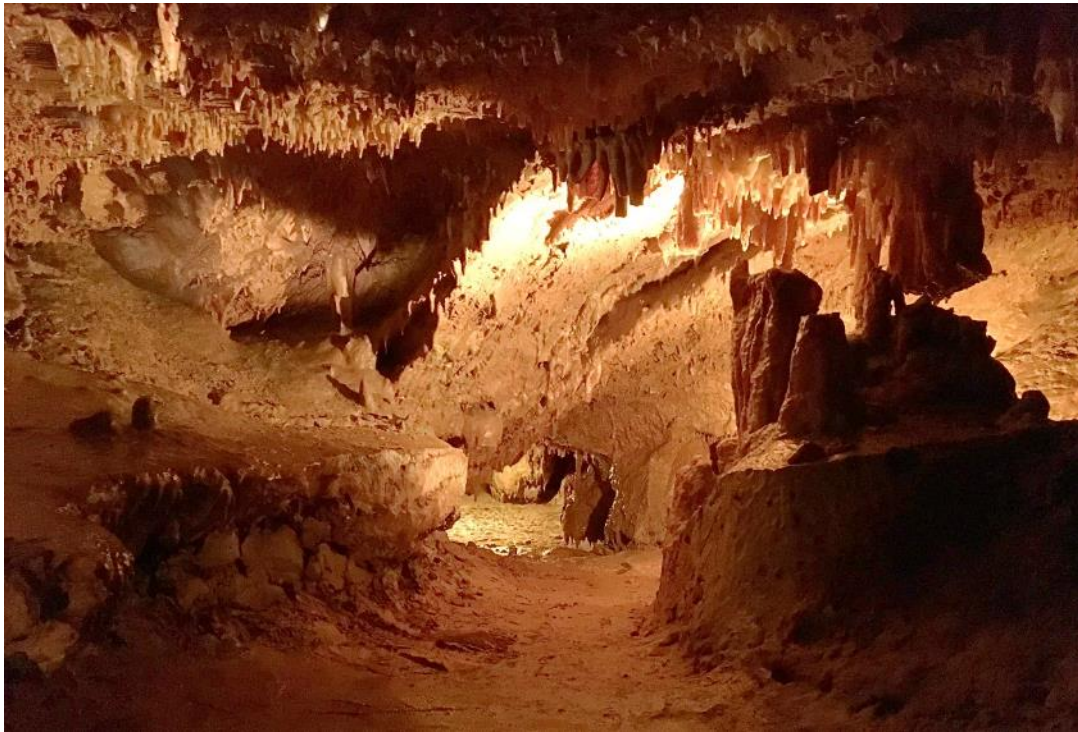


A Herpetological Survey of Dixie Caverns and Explore Park in Roanoke, Virginia and the Wehrle's Salamander



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Introduction

The Virginia Herpetological Society (VHS) Dixie Caverns Survey was held at Dixie Caverns and Explore Park in Roanoke County, Virginia on 24 September 2016. According to legend, Dixie Caverns was discovered in 1920 by two young men after their dog Dixie fell through a hole that led to the caves. In honor of their dog's discovery, they decided to name the caverns Dixie. One of those boys was Bill "Shorty" McDaniel who would later go on to work at the caverns for more than 50 years and was known fondly for his sometimes embellished stories (Berrier, 2014). In actuality, the presence of Dixie Caverns, according to The Roanoke Times, was known as early as 1860 and had been mapped in the early 1900's (Berrier, 2014). Guided tours of the caverns began in 1923 and still occur today with about 30,000 people visiting annually (Berrier, 2014).

Dixie Caverns is located in Roanoke County which is in the Valley and Ridge and Blue Ridge provinces (Mitchell, 1999). A key feature of the Valley and Ridge is karst topography with soluble rocks such as limestone which create caves and caverns when weathered (Tobey, 1985). Over millions of years the caverns were formed as water dissolved the limestone that created

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holes and even larger passageways. Many of the rock formations in Dixie Caverns are made of calcite which was formed by dripping water that evaporated leaving behind tiny particles which eventually created stalactites (Berrier, 2014). The cave stays close to 11.5°C year-round with high humidity (Fowler, 1951).

Dixie Caverns was selected as a survey site to see a rare form of *Plethodon wehrlei* (Wehrle's Salamander). *Plethodon wehrlei* was discovered in 1917 by naturalist RW Wehrle in Indiana, Pennsylvania (Fowler and Dunn, 1917). They are a medium-sized woodland salamander attaining a length of 66 mm SVL (Hulse et al, 2001) with 17 costal grooves and webbed hind-feet (Petranka, 1998). They are a brownish-purple salamander with white to cream-colored spots that fuse to form irregular blotches on their flanks (Conant and Collins, 1998). Hatchlings and young *P. wehrlei* often have paired reddish spots on their back that disappear as they age (Mitchell and Gibbons, 2010). Although *P. wehrlei* is pretty widespread throughout northern Appalachia, their habitat is confined to rocks and logs on forested hillsides, especially north facing slopes, and cave entrances (Martof et al, 1980) from elevations as low as 180 m to as high as 1400 m (Petranka, 1998).

In 1949, a new species of salamander was described living only in Dixie Caverns and was named *Plethodon dixi* (Pope and Fowler, 1949) also known as the Roanoke Salamander (Burger, 1958). A paper in 1946 first noted the presence of *P. wehrlei* in Dixie Caverns, which extended their range into the Valley and Ridge Province of Virginia, but didn't mention coloration of the specimens found (Netting et al, 1946). This salamander was described as being similar to *P. wehrlei*, but smaller in size and coloration. Adult males averaged 55 mm snout-vent length (SVL) and this salamander's coloration was a deep purplish-black with bronzy mottling on its back (Pope and Fowler, 1949). Juveniles of this new species lack the paired reddish dorsal spots seen in young *P. wehrlei* (Pope and Fowler, 1949). This new species was only found in the immediate area around the caverns (Pope and Fowler, 1949). A few years later, *P. dixi* was also described as far as 3.86 kilometers (km) east of Dixie Caverns in Blankenship Cave, Roanoke County, Virginia (Fowler, 1951). In 2015, a specimen was seen 18.35 km southeast of Dixie Caverns in Franklin County, Virginia (Figures 1 and 2) out during the day on exposed rocky outcroppings (Alex Bentley, pers. comm.). A few decades after their discovery, *P. dixi* was reduced to a variant of *P. wehrlei* based on pattern variability across the range (Highton, 1962) and later by modal number of trunk vertebrae (Highton, 1972).

Figure 1. Dorsum of a Dixie Cavern variant of *P. wehrlei*



Figure 2. Diurnal activity and habitat of Dixie Cavern variant of *P. wehrlei*



Explore Park is a 450 ha park in the eastern part of Roanoke County that opened in October 2013. There are over 22.5 km of trails that wind through sloping wooded forests and numerous streams. Explore Park is also right off the Blue Ridge Parkway. This park is owned and maintained by the County of Roanoke.

Study Sites

There were three study sites. Site 1 was at Dixie Caverns and Sites 2 and 3 were at Explore Park (Figure 3).

Site 1 – Dixie Caverns (37°15'9"N, 80°10'34"W)

This site was Dixie Caverns. There were rocky outcroppings, cave formations, seeps, and small pools.

Site 2 – Forrester's Trail, Explore Park (37°14'13"N, 79°51'7"W)

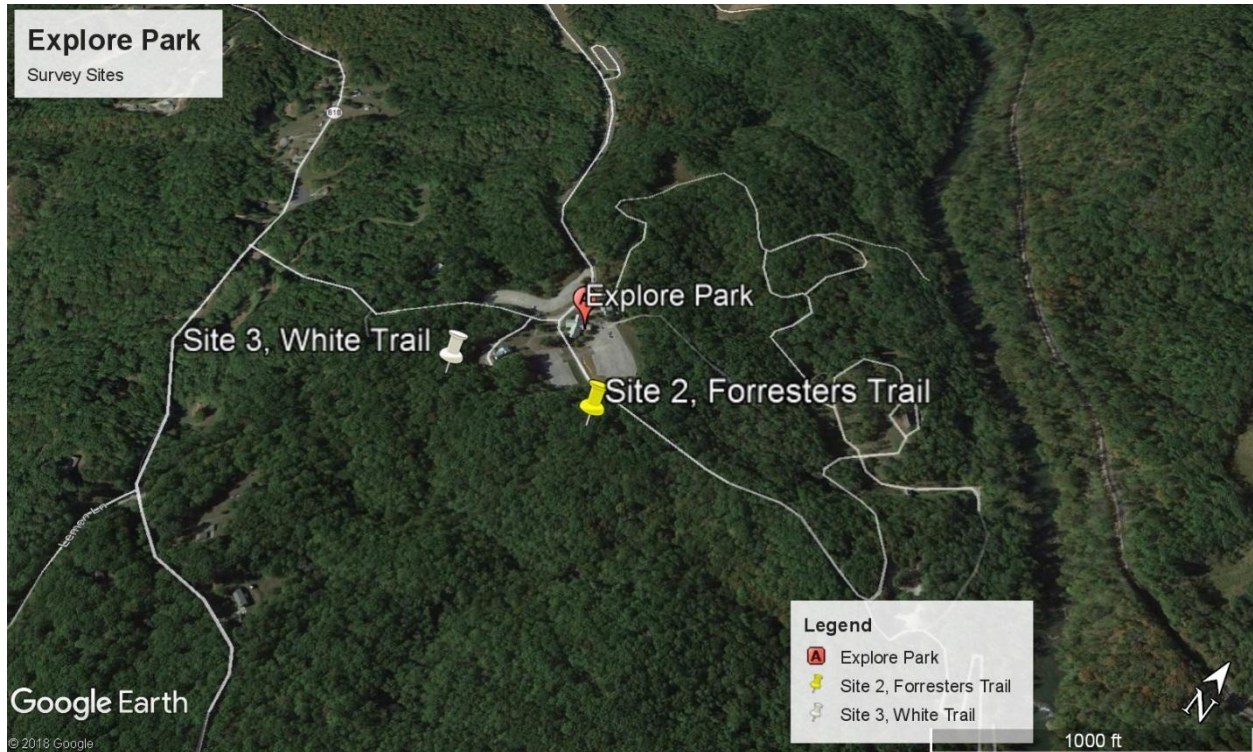
This site was an upland forest that went down a ravine and had small streams, rocky outcroppings, and a small spring house.

Site 3 – White Trail, Explore Park (37°14'18"N, 79°51'12"W)

This site was an upland forest that went down a ravine and had small streams and a pond.

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Figure 3. Map showing the survey area of Explore Park



Materials and Methods

On Saturday 24 September 2016, 15 participants were together as one group during the morning survey conducted at Dixie Caverns. For the afternoon portion of the survey at Explore Park, participants were divided into two groups of seven persons each. Once at the survey sites, methods used to find animals included hand capture, visual observation, listening for calling frogs, and flipping over cover objects. Each species was photographed as a voucher specimen and animals with abnormal patterning, signs of disease, or injury were especially noted. Group leaders were tasked with recording all observations on standardized recording sheets which included information on: the physical environment, weather, animal health, and microhabitat. Other data collected included morphometric measurements of rare species, age, and sex. Site 1 was surveyed in the morning from 0930hr – 1040hr. Sites 2 and 3 were surveyed in the afternoon from 1230hr – 1530hr (see Table 1 for amount of survey effort expended at each site).

Table 1. The amount of survey effort per site for the Dixie Caverns and Explore Park Survey.

	Site 1	Site 2	Site 3	Total
No. Surveyors	15	7	7	-
Hours Surveyed	1.0	3.0	3.0	-
Person Hrs of Survey effort	15.0	21.0	21.0	57.0

Results

There were 15 participants in attendance for the Dixie Caverns portion of the survey and 14 participants for the survey at Explore Park. Over 300 individual animals of 19 species of herpetofauna were documented on 24 September 2016, as noted in Table 2.

Table 2. Summary of the number of amphibians and reptiles observed at each site.

Sites	1	2	3	Total
<u>Amphibians</u>				
<i>Anaxyrus americanus</i>		1		1
<i>Desmognathus fuscus</i>		5		5
<i>Desmognathus monticola</i>		5	7	12
<i>Eurycea cirrigera</i>		4, 2 [†]	2	8
<i>Lithobates clamitans</i>		1	6, 200 [†]	207
<i>Lithobates sylvaticus</i>			3	3
<i>Notophthalmus viridescens viridescens</i>			1	1
<i>Plethodon cylindraceus</i>		1		1
<i>Plethodon glutinosus</i>		3		3
<i>Plethodon wehrlei</i>	60			60
<i>Pseudacris crucifer</i>		1*		1
<i>Pseudotriton ruber ruber</i>		4 [†]	1	5
<u>Reptiles</u>				
<i>Carphophis amoenus</i>		2	1	3
<i>Nerodia sipedon</i>		2		2
<i>Pantherophis alleghaniensis</i>	1			1
<i>Plestiodon spp.</i>		1	2	3
<i>Sceloperus undulatus</i>		1		1
<i>Terrapene carolina</i>			2	2
Total:	61	33	224	319

[†]larvae, *auditory

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Amphibians

1. *Anaxyrus americanus* (American Toad) An adult *A. americanus* was found in the open, foraging in a ravine leading to a small stream.



2. *Desmognathus fuscus* (Northern Dusky Salamander) Five *D. fuscus* were found at site 2 in a stream under small rocks.

3. *Desmognathus monticola* (Seal Salamander) Twelve *D. monticola* were found at sites 2 (5) and 3 (7) respectively. All individuals were found in a small stream under rocks.

4. *Eurycea cirrigera* (Southern Two-lined Salamander) Six adult *E. cirrigera* were noted at sites 2 and 3 under rocks in a stream and under logs approximately 30 m from a stream, respectively. One individual at site 3 was missing its entire tail. Two larval specimens were noted in a stream at site 2.

5. *Lithobates clamitans* (Green Frog) Seven adult *L. clamitans* were noted at both sites 2 and 3 under a rock in a headwater stream and at the edge of a pond, respectively. Approximately 200 tadpoles were noted at site 3 in a pond as well.



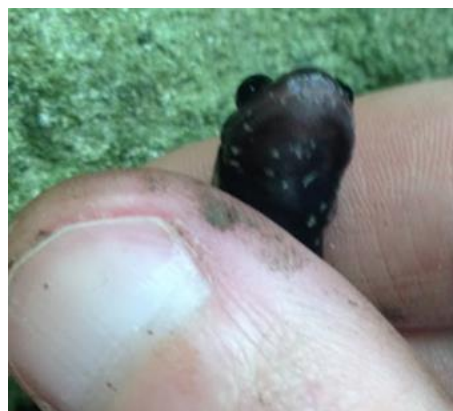
6. *Lithobates sylvaticus* (Wood Frog) Three adult *L. sylvaticus* were observed at site 3 in a ravine approximately 20 m from the bottom.

7. *Notophthalmus viridescens viridescens* (Red-spotted Newt) A juvenile *N. v. viridescens* was noted under a log at site 3. This individual was the terrestrial eft form under 2.5 cm total length.

8. *Plethodon cylindraceus* (White-spotted Slimy Salamander) Three adult *P. cylindraceus* were noted under logs on NE and SW facing slopes leading to a stream. One adult had a prominent mental gland. Another individual was in the process of regenerating its tail. Note the light gray/white chin.



9. *Plethodon glutinosus* (Northern Slimy Salamander) An individual adult female *P. glutinosus* was noted at site 2 under a log on a slope leading to a stream on a NE facing slope. Note the black chin.



10. *Plethodon wehrlei* (Wehrle's Salamander) 60 *P. wehrlei* were observed at site 1 in the "Cascades" formation and the "Bat Room" areas of Dixie Caverns. Salamanders of varying age classes were observed out and in the rock formations of the cave. Most of the area that the

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salamanders were observed was fairly wet, but lacked standing water.



11. *Pseudacris crucifer* (Spring Peeper) One *P. crucifer* was heard calling at the end of the trail at site 2. The call was heard several times by the whole group at approximately 1500 hrs. The frog was calling from the canopy of the forest; no water was nearby.

12. *Pseudotriton ruber ruber* (Northern Red Salamander)

One adult and 4 larval *P. r. ruber* were noted at sites 3 and 2 respectively. The 5 cm adult was found under a log approximately 25 m from a ravine stream. The four larval *P. r. ruber* were found under rocks in a stream.



Reptiles

13. *Carphophis amoenus* (Eastern Wormsnake) Three *C. amoenus* were noted at both sites 2 and 3. At site 2 two were found under cover objects in a ravine, and at site 3 one was found under a rock with termites.

14. *Nerodia sipedon* (Northern Watersnake) Two juvenile *N. sipedon* were noted at site 2. One individual was found under a rock in a small stream and the other was seen under an embankment further upstream.



15. *Pantherophis alleghaniensis* (Eastern Ratsnake) One juvenile *P. alleghaniensis* was noted at the entrance of the cavern at site 1. It was active and climbing on the rock formations.



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16. *Plestiodon* spp. (Common Five-lined Skink, Southeastern Five-lined Skink) Two *Plestiodon* spp. were noted at sites 2 and 3. At site 2, an adult individual was seen sunning on a log and scampered away when the group approached. At site 3, a juvenile was seen basking on a log. Neither individual was apprehended for a closer inspection of scalation.

17. *Sceloporus undulatus* (Eastern Fence Lizard) An adult *S. undulatus* was observed basking on a tree towards the end of the trail at site 2.

18. *Terrapene carolina* (Eastern Box Turtle) Two adult males were seen on the forest floor at site 3.

Discussion

Dixie Caverns in Roanoke County, Virginia was a neat place to do a herpetological survey due to its unique location and its rare variation of *P. wehrlei* found within the cavern. Explore Park, also in Roanoke County, was the second location of this survey. This park was chosen due to its proximity to Dixie Caverns as well as the potential for cave dwelling species being found above ground around rocky outcroppings within the park. Explore Park had a number of habitats such as upland forests, rocky outcroppings, streams, ponds, and an open field. The Virginia Herpetological Society's database for Roanoke County shows that there are 40 species of herpetofauna documented, 20 species of amphibians and 20 species of reptiles (VHS Herp Database).

The Dixie Caverns Survey was the second herpetological survey to occur in Roanoke County, Virginia. The first time was at the Haven's Wildlife Management Area (HWMA) in March 2010 - October 2011 (Bentley, 2012). The HWMA is located in the north central part of Roanoke County, 8 km northeast of Dixie Caverns. The HWMA survey was conducted over a period of several months and documented 10 species of amphibians and 16 species of reptiles (Bentley, 2012).

Dixie Caverns is located in the northwestern part of Roanoke County. During the first portion of the survey, the only amphibians that were encountered were *P. wehrlei*. Salamanders were found on the rock formations of the "Cascades", the same area where they were found by James A. Fowler back in 1946; although *P. wehrlei* did not occur in densities as high - Fowler described seeing as many as 322 individuals in this area (Fowler, 1951). Salamanders were also found in decent numbers in the "Bat Room" (Tyler Hall, pers. comm.), but they were found more sporadically than around the "Cascades" formation. Although other species of salamanders have not been documented in Dixie Caverns (Fowler, 1951), it was surprising not to see normal cave-dwelling species such as *Gyrinophilus porphyriticus porphyriticus* (Spring Salamander), *Eurycea longicauda* (Long-tailed Salamander), and *Eurycea lucifuga* (Cave Salamander), especially since several pools seen within the cave would have been suitable for larvae.

Explore Park is located in the southeastern part of Roanoke County at 330 m elevation. Explore Park is on the opposite side of Roanoke County from Dixie Caverns and HWMA. Seventeen species of reptiles (5) and amphibians (12) were found at Explore Park, however many more species were expected. According to the VHS Database there are 17 herp species (2 lizards, 4

snakes, 3 frogs, and 8 salamanders) that have not been verified in Roanoke County and are common elsewhere in the state.

There are two species of lizard suspected in Roanoke County. One of them, *Scincella lateralis* (Little Brown Skink) has not been documented in Roanoke County, although it is expected (VHS database). It is found in neighboring Bedford County to the east and Franklin County to the south (VHS database). *Aspidoscelis sexlineata sexlineata* (Eastern Six-lined Racerunner) is found in neighboring Bedford County to the east and Botetourt County to the northeast (VHS database). There was ample habitat for both of these lizards in the western part of site 2, leaf litter and detritus for foraging and basking areas (Conant and Collins, 1998).

There were four snakes that have been found in counties surrounding Roanoke, but have not been documented in Roanoke County yet. *Lampropeltis getula* (Eastern Kingsnake) is in nearby Bedford County to the east and Floyd County to the south (VHS database). The habitat for *L. getula* is the edges of wooded areas under cover objects such as logs and boards. They can also be found in moist areas near marshes and swamps (Linzey and Clifford, 1981). Open fields close to wooded areas were seen at the end of the Forresters Trail at site 2. *Storeria dekayi dekayi* (Northern Brownsnake) is found to the north in Botetourt County and to the east in Bedford County (VHS database). *Storeria occipitomaculata occipitomaculata* (Northern Red-bellied Snake) is found in Franklin County to the south and Botetourt County to the north (VHS database), but has not been documented in Roanoke County. The habitat for both *S. d. dekayi* and *S. o. occipitomaculata* is damp cover objects such as logs, boards, and rocks in wooded areas (Linzey and Clifford, 1981) which is similar to habitat seen at sites 2 and 3. *Thamnophis sauritus sauritus* (Common Ribbonsnake) is found in nearby Botetourt County to the north and Montgomery County to the southwest (VHS database), but hasn't been documented yet in Roanoke County. *Thamnophis s. sauritus* can be found in grasses and branches close to the water's edge of ponds and boggy areas (Linzey and Clifford, 1981) which is present at site 3 and other trails within Explore Park that were not surveyed.

Three species of frogs were expected to be encountered and haven't been documented in Roanoke County; they are: *Acris crepitans* (Eastern Cricket Frog), *Anaxyrus fowleri* (Fowler's Toad), and *Hyla versicolor* (Gray Treefrog). *Acris crepitans* has been found in Botetourt County to the north and is expected to be found in Montgomery County to the southwest (VHS database). There is suitable habitat at sites 2 and 3 and the many creeks around Explore Park. Other sites that were not surveyed have vegetation surrounding wetlands which is ideal habitat for this species (Martof et al, 1980). *Anaxyrus fowleri* has also been found in Botetourt to the north and Montgomery to the southwest (VHS database). Moist woodland and vernal pool areas that this species prefers (Conant and Collins, 1998) were found at site 3 and also expected in other areas within Explore Park. *Hyla versicolor* has been found in the neighboring counties of Montgomery, Franklin, Bedford, Botetourt, and Craig (VHS database), but has not been documented in Roanoke County. Their preferred habitat is shrubs or small trees near a shallow body of water (Conant and Collins, 1998) which was seen in site 3 and other parts of the park that were not surveyed.

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There were eight species of salamanders that were expected to be found at both sites 2 and 3, but were not documented. *Hemidactylium scutatum* (Four-toed Salamander) is a woodland species that breeds in boggy vernal pools, usually associated with sphagnum (Conant and Collins, 1998). Although breeding areas for this species was not documented at sites 2 or 3, Explore Park had appropriate woodland habitat to uncover this species. *Hemidactylium scutatum* is found in five counties neighboring Roanoke: Montgomery, Floyd, Franklin, Botetourt and Bedford (VHS database).

The next two species of salamanders that have not been documented in Roanoke County belong to the family Ambystomatidae that are hard to document outside of their breeding season (Conant and Collins, 1998). *Ambystoma jeffersonianum* (Jefferson Salamander) breeds in the early spring and *Ambystoma opacum* (Marbled Salamander) breeds in the early fall (Conant and Collins, 1998). Both of these species occur in wooded forests and are seen during their breeding seasons in and near vernal pools or slow moving bodies of water (Mitchell and Gibbons, 2010). Both *A. jeffersonianum* and *A. opacum* are found in counties surrounding Roanoke County: Craig, Botetourt, and Montgomery (VHS database).

The next five species that are thought to be found in Roanoke County are stream-dwelling salamanders in the genera *Desmognathus* and *Eurycea*. Four of these species, *Desmognathus ochrophaeus* (Allegheny Mountain Dusky Salamander), *Desmognathus orestes* (Blue Ridge Dusky Salamander), *Desmognathus quadramaculatus* (Black-bellied Salamander), and *Eurycea guttolineata* (Three-lined Salamander), can be found under logs and rocks near and in streams (Petranka, 1998) which are present at sites 2 and 3. Another species within *Eurycea* thought to be found in Roanoke County is *Eurycea lucifuga* (Cave Salamander) which is found in cave entrances and deep within caves (Petranka, 1998) found at sites 1 and 2. *Desmognathus ochrophaeus* and *D. orestes* are species that closely resemble one another (Mitchell and Gibbons, 2010). *Desmognathus ochrophaeus* is found in two counties that surround Roanoke County, Craig to the north and Montgomery to the west (VHS database), while *D. orestes* is found in Floyd County to the south (VHS database). It is likely that an individual encountered would be *D. ochrophaeus* since Roanoke County is in the middle of its range, while for *D. orestes*, Roanoke would be the northernmost county of its range in Virginia (VHS database). It would not be a stretch to find *D. quadramaculatus* in future surveys as five counties that surround Roanoke have reported sightings: Craig, Montgomery, Floyd, Franklin, and Bedford (VHS database). *Eurycea guttolineata* is found in neighboring counties to the east: Floyd, Franklin, and Bedford (VHS database), a sighting in Roanoke County would not be surprising, but would be a range extension west. *Eurycea lucifuga* is found in neighboring Craig and Botetourt Counties (VHS database) to the west; the sighting in Botetourt County is very close to the border shared with Roanoke County, a county record would not be out of the realm of possibility. Additional surveys of Roanoke County could uncover these 17 undocumented species.

Other Variations and Future of *Plethodon wehrlei*

Plethodon dixi (Roanoke Salamander) is not the only variation of *P. wehrlei*. Two other forms of *P. wehrlei* have been found since the description of *P. dixi*. Newman (1954) found a similar type of salamander resembling *P. wehrlei* that was bluish-black with orange-red spots on its back in its adult form; this new species was named *Plethodon jacksoni* (Figure 4). This color-form was

only found around the Blacksburg area of Virginia and was also known as the Blacksburg Salamander (Burger, 1958). This species was also small like *P. dixi* with an average SVL of 57 mm (Newman, 1954). Similar to the fate of *P. dixi*, *P. jacksoni* was reduced to *P. wehrlei* based on variable coloration throughout the range of Wehrle's Salamander (Highton, 1962) and later separated from *P. punctatus* by the number of trunk vertebrae (Highton, 1972). It should be noted that genetic work has not been done to confirm this.

Figure 4. *Plethodon wehrlei* from Southwestern Virginia showcasing the red spots on its back similar to the *P. jacksoni* form Newman described.



Additionally, in 1983 another color form of *P. wehrlei* was discovered. This variant was described as brown with two rows of irregular, yellow spots down its back (Figure 5). It was a smaller size, like the Dixie Caverns variant, with adults measuring 55 mm SVL (Cupp and Towles, 1983). Its habitat is shale-rock cliffs in West Virginia and Kentucky. Since then additional disjunct populations have been discovered in other parts of West Virginia (Highton, 1987)(Waldron et al, 2001), Tennessee (Redmond and Jones, 1985) and North Carolina (Beane and Somers, 1994)(Beane et al, 2001).

Figure 5. *Plethodon wehrlei* from Kentucky showcasing paired yellow spots.



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These different types of *P. wehrlei* have been lumped together via number of trunk vertebrae (Highton, 1972), but the difference in habitat, coloration, and size show stark differences.

Habitat: *Plethodon wehrlei* is found in forested hillsides and caves (Martof et al, 1980), *P. "dixi"* in and around limestone caves near Roanoke County (Pope and Fowler, 1949), *P. "jacksoni"* around cave entrances near Montgomery County (Newman, 1954), and the yellow-spotted variant in shale-rock cliffs and outcroppings (Cupp and Towles, 1983).

Coloration: *Plethodon wehrlei* is brownish-purple with white to cream-colored flecks on its sides that usually fuse together to form continuous blotches (Petranka, 1998), *P. "dixi"* is a purplish-black salamander with profuse bonzey mottling on its back (Pope and Fowler, 1949), *P. "jacksoni"* is bluish-black with orange-red spots on its back (Newman, 1954), and the yellow-spotted variant is a brown salamander with two rows of yellow spots (Cupp and Towles, 1983).

Size: *Plethodon wehrlei* averages 66 mm SVL (Hulse et al, 2001), *P. "dixi"* averages 52 mm SVL (Pope and Fowler, 1949), *P. "jacksoni"* averages 57 mm SVL (Newman, 1954), and the yellow-spotted variant averages 52 mm SVL (Cupp and Towles, 1983).

These numerous differences should warrant a second look at speciation within *P. wehrlei*. Highton et al. (2012) looked at the genetic differences between five populations of the *P. wehrlei* group: four *P. wehrlei* from different locales and *P. punctatus*. The DNA sequencing from that study indicated that *P. wehrlei* from Southwestern Virginia (formerly *P. "dixi"* and *P. "jacksoni"*) were different from other populations of *P. wehrlei* and cluster more closely with *P. punctatus* (Highton et al, 2012). It was suggested that an allozyme study be completed for this group to determine if unrecognized species exist (Highton et al, 2012). At the time of press a larger study was published analyzing the taxonomy of *P. wehrlei*. This study suggested a modest split of *P. wehrlei* would be to recognize *P. dixi* as a separate species and suggested further work be completed looking at the distinction of the southern population of *P. wehrlei* from the northern population (Kuchta et al, 2018). It should read: It is a neat time to be interested in a species that has had little taxonomic interest since *P. punctatus* was split from *P. wehrlei* in 1972.

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