SURVEY OF WOODLAND SALAMANDERS IN SOUTHERN GREENE COUNTY, TENNESSEE

Robert L. Morgan III*, and S. Conor Keitzer

Tusculum University, 60 Shiloh Road, Greeneville, TN 37745
**Corresponding Author e-mail: rmorga5@clemson.edu*

***Abstract.*—**Salamanders in northeast Tennessee face a number of potential threats, including climate and land use change. However, the current status and distribution of species in much of this area, which is important fundamental information for effective species management, are not well documented in the literature or public data sources. To help increase knowledge of salamander species in this area, we conducted salamander transect surveys (n = 246) from May 2017 to October 2019 across 70 transects within the Cherokee National Forest (CNF) of southern Greene County, Tennessee. Transects covered a wide range of elevations (500 – 965 m) and forest types and were located in five different publicly accessible areas. We observed 11 different species of salamanders, with an additional 10 species of herpetofauna documented. The Carolina Mountain Dusky Salamander (*Desmognathus carolinensis)*, Eastern Red-backed Salamander (*Plethodon cinereus*), and Northern Slimy Salamander (*P. glutinosus*) were most common species observed. We also found the Yonahlossee Salamander (*P. yonahlossee*) further west than it had previously been documented in Tennessee. From a standpoint of conservation planning, we found that higher elevation locations (> 700 m) were more diverse, highlighting the need for protection of high elevation forested ecosystems, which harbor much of the salamander diversity found in the southern Appalachian Mountains.

Key Words.—conservation, distribution, diversity, elevation effect, natural history, Yonahlossee salamander

The southern Appalachian Mountains are well known as a global hotspot for salamander diversity. Currently, there about 55 species of salamanders found in the southern Appalachians, with new species still being discovered (Mitchell et al 1999, Patton et al 2019). Abundant moisture and mild temperatures, coupled with a wide gradient of elevation and a long evolutionary history, has enabled a vast array of species to arise in this region (Petranka, 1998, Niemiller and Reynolds 2011). However, this unique diversity is currently under threat, with apparent population declines documented for many species in the region (Caruso and Lips 2012).

While apparent declines in salamander populations can be attributed to several factors, two of the greatest threats salamanders in the southern Appalachian Mountains face is the impact of land use and global climate change (Milanovich et al. 2010). Salamanders require temperate and moist environments to survive, but these habitat requirements and limited dispersal ability mean that salamanders are highly vulnerable to both of these threats. In recent decades, the southern Appalachian region has seen increased human population growth and associated land conversion. In fact, since 2010, the population of the south-central region of Appalachia (inclusive of Greene County, TN) has grown in population by about

4%, which is only 1.8% lower than the national average for the same duration (Appalachian Regional Commission 2020). As the southern Appalachian region continues to modernize, increasingly more demand will be placed on the region's forested ecosystems. While a sizable portion of the southern Appalachian Mountains are state or federally owned, the remaining "uninhabited" private land is being converted to accommodate the growing population and influx of visitors. This increases fragmentation, which has implication on genetic diversity and flow. As salamanders are less mobile than some taxonomic groups (i.e. *Avian*, *Canine*, or *Ungulates*), the barriers and loss of habitat that land development creates have huge implications on salamander populations.

In addition to changes in land use, global climate change has the potential to severely impact the salamander diversity of the region. There are multiple lines of evidences that suggest salamanders are already experiencing the effects of climate change. Past surveys within the Great Smokey Mountains National Park (GSMNP) found an approximately 39% decline in *Plethodon* salamander populations (Caruso and Lips 2012). These declines are troubling because they occurred in GSMNP, an area protected from most of the human disturbances that would affect salamanders. Despite this grim finding, some research suggests that salamanders have an increased ability to adapt to these future alterations. Recent findings suggest that extinction rates of salamanders likely could be reduced by about 72%, as a result of physiological adaptation and a change in behavioral patterns (Riddell et al. 2018). Additional evidence suggests that salamander diversity in the southern Appalachian Mountains has benefited from forest regrowth and modern management practices (Moskwik 2014). Forest regrowth has lowered the temperature of certain sites, therefore buffering salamanders from climate alterations. Thus, while climate change and land use change are potential threats, how salamanders have or will respond to those threats in the region is uncertain.

Outside of areas like Roan Mountain or Great Smoky Mountains National Park, relatively little information about the current distribution and status of salamanders is available for northeast Tennessee. This baseline data is greatly needed to help identify threatened populations and possible drivers of declines (Caruso and Lips 2012). To better understand the natural history and distribution of salamander species in northeast Tennessee, we conducted salamander surveys within the Cherokee National Forest (CNF) of Greene County, TN (Figure 1) over three summer field seasons from May 2017 to October 2019. These surveys are part of a long-term monitoring project of salamander populations in the region, but here we report on the first three field seasons.

METHODS AND MATERIALS

Survey Sites. – From May 2017 to October 2019, transect surveys (n = 246) were conducted on 70 established transects in 5 focal areas located in southern Greene County, TN. These included: Round Knob, Greene Mountain, Old Forge, Jennings Creek, and Squibb Creek (Table 1 and Figure 1). Survey elevations ranged from a low of 500 m at Squibb Creek to a high of 965 m at Round Knob. Most transects were in Cove Hardwoods (n = 52), but Oak-Conifer forests were also sampled (n = 18). All survey locations were within the Southern Sedimentary Ridges Ecoregion of the Blue Ridge Mountains of East Tennessee (See Figure 1). This ecoregion is best characterized by slopes with a steep elevation gradient, along with a combination of mixed and northern hardwood forest cover types dependent of elevation (Niemiller and Reynolds 2011).

TABLE 1. Survey locations with corresponding elevation, forest type, and transect totals.

Survey Site	Elevation Range (m)	Forest Type	Number of Transects
Round Knob	875-965	Cove Hardwood	29
Greene Mountain	740-770	Oak-Conifer	8
Old Forge	570-600	Oak-Conifer	10
Squibb Creek	530-670	Cove Hardwood	13
Jennings Creek	500-645	Cove Hardwood	10

Transects. – Transects measured 30 meters in length, and were established parallel to the slope contour to maintain a consistent elevation across the transect. Our team (2-6 surveyors) would turn over natural cover objects (i.e. rocks, logs, and leaf litter) within 1 meter of either side of the transect to capture salamanders. In addition to recording species capture totals, we collected total length, snout-vent length, and weight on every salamander before they were safely returned to their capture location. Transects were sampled randomly at various times (day & night) and climatic conditions (wet & dry) following a robust sample design (Pollock 1982). The number of sampling events was varied given logistical challenges, but transects were usually surveyed ≥ 3 times in a given field season (typically May – August). In August 2018, cover boards were added to several transects (n = 23). Our cover boards were locally sourced rough sawn pine lumber cut out into 30 x 30 cm squares, and about 2.5 cm thick. Cover boards were placed 1 meter apart along the length of the transect, with each transect having 30 boards deployed. Round Knob (n = 10), Greene Mountain (n = 7), and Old Forge (n = 6) are the only locations where cover board transects were added. These locations were selected for cover board inclusion due to their proximity to established trail systems, which made transport of supplies feasible for our small team. Cover board surveys began in May 2019, after winter acclimatization. We calculated both Species Richness and Simpson's Index of Diversity for each focal area.

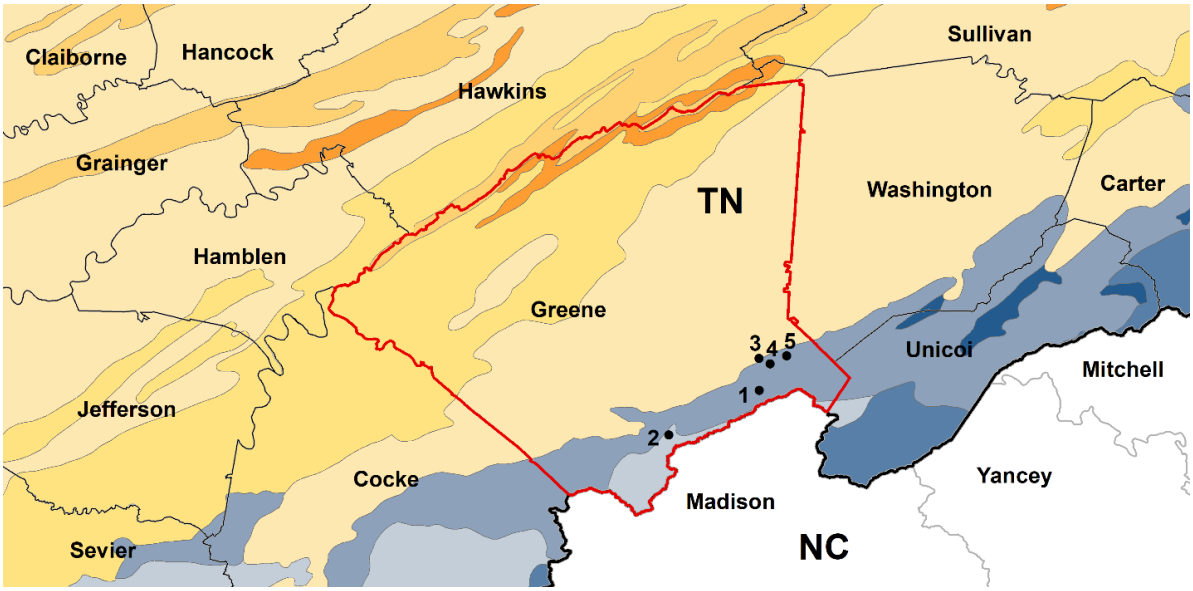

FIG. 1. Survey sites were within the Southern Sedimentary Ridges Ecoregion of Greene County, TN. (1) Round Knob, (2) Greene Mountain, (3) Old Forge, (4) Jennings Creek, and (5) Squibb Creek. Figure was adapted from Griffith et al. 1998.

RESULTS

Over the three field seasons from May 2017 to October 2019, 401 salamanders were encountered within the transects from 11 different species. Observed species varied based on elevation, with the Blue Ridge Two-lined Salamander (*Eurycea wilderae*), Eastern Red-backed Salamander (*Plethodon cinereus*), and Northern Slimy Salamander (*P. glutinosus*) being found over the widest range (> 375 m) in elevation (Table 2). Additionally, 10 other species of Herpetofauna were observed while sampling the transects (Table 3). The Round Knob survey sites had the highest species richness ($R = 8$), followed by Jennings Creek and Greene Mountain ($R = 5$). Simpson's Index of Diversity showed that 3 of the 5 survey sites were relatively diverse ($D > 0.60$), with Old Forge and Squibb Creek showing less diversity ($D < 0.60$) (Table 4). Across all survey sites, the Northern Slimy Salamander, Eastern Red-backed Salamander, and the Carolina Mountain Dusky Salamander (*Desmognathus carolinensis)* were encountered with the most frequency (Table 5).

TABLE 2. Elevation species were encountered during our surveys (Observed Range), and their suggested literature ranges (Niemiller and Reynolds 2011, Petranka 1998). Note that our surveys ranged from 500 to 965 m.

Common Name	Scientific Name	Min & Max Observed Elevation (m)	Literature Elevation (m)
Black Bellied Salamander	*Desmognathus quadramaculatus*	880 – 906	490 – 1680
Blue Ridge Two-lined Salamander	*Eurycea wilderae*	501 – 962	< 2000
Carolina Mountain Dusky Salamander	*Desmognathus carolinensis*	597 – 962	300 – 2000
Eastern Newt	*Notophthalmus viridescens*	583 – 758	no data
Eastern Red-backed Salamander	*Plethodon cinereus*	583 – 958	< 1500
Northern Gray-cheeked Salamander	*Plethodon montanus*	932 – 947	> 800
Red Salamander	*Pseudotriton ruber*	637 – 752	< 1500
Seal Salamander	*Desmognathus monticola*	606 – 906	< 1500
Spotted Salamander	*Ambystoma maculatum*	739 – 739	< 600
Northern Slimy Salamander	*Plethodon glutinosus*	577 – 958	< 1500
Yonahlossee Salamander	*Plethodon yonahlossee*	938 – 938	440 – 1740

TABLE 3. Additional herpetofauna observed within transects 2017-2019.

Common Name	Scientific Name
American Toad	*Anaxyrus americanus*
Eastern Box Turtle	*Terrapene carolina*
Fowler's Toad	*Anaxyrus fowleri*
Gray Ratsnake	*Pantherophis spiloides*
Green Frog	*Lithobates clamitans*
Racer	*Coluber constrictor*
Pickerel Frog	*Lithobates palustris*
Ring-necked Snake	*Diadophis punctatus*
Spring Peeper	*Pseudacris crucifer*
Wood Frog	*Lithobates sylvaticus*

TABLE 4. Species Richness and Simpson's Index of Diversity per site.

Survey Site	Elevation Range (m)	Species Richness	Simpson's Index of Diversity
Round Knob	875-965	R=8	D=0.67
Greene Mountain	740-770	R=5	D=0.70
Old Forge	570-600	R=2	D=0.50
Squibb Creek	530-670	R=3	D=0.53
Jennings Creek	500-645	R=5	D=0.62

TABLE 5. Species survey proportional data 2017-2019, with the number of survey areas observed.

Species	Observation (%)	Total Areas Observed
Northern Slimy Salamander	44.1	4
Carolina Mountain Dusky Salamander	26.9	2
Eastern Red-backed Salamander	10	3
Seal Salamander	7.7	2
Blue Ridge Two-lined Salamander	5.7	3
Northern Gray-cheeked Salamander	1.5	1
Red Salamander	1.2	2
Black Bellied Salamander	1	2
Eastern Newt	0.7	1
Yonahlossee Salamander	0.7	1
Spotted Salamander	0.2	1

Discussion

Our findings show that Greene County, which is part of the Bald Mountain Range, is home to a robust assortment of salamander species. Across our sites we documented

salamanders from four different Genera: *Plethodon, Desmognathus, Eurycea,* and *Ambystoma.* The most commonly encountered species were the Northern Slimy Salamander, Eastern Red-backed Salamander, and the Carolina Mountain Dusky Salamander. Combined, these three species represented 81% of our total captures. The least common species in these surveys were the Yonahlossee Salamander (*P. yonahlossee)* and the Spotted Salamander (*Ambystoma maculatum)*. Combined, these species accounted for about 1% of our total captures. These species were also apparently limited in their distribution, with each observed at only a single transect (Yonahlossee Salamander at Round Knob & Spotted Salamander at Greene Mountain).

We found the Yonahlossee Salamander (2 Adults, 1 Juvenile) in a Round Knob transect, at an elevation of 938 m, which as far as we are aware, is the first confirmed occurrence for the species in Greene County (Tennessee Natural History Program 2020). Within Tennessee, the Yonahlossee salamander is non-legally ranked as S2, or "very rare and imperiled within the state" (Tennessee Natural History Program 2020). Given its southwesterly location, this occurrence should be further assessed for protection and to determine if this is an isolated population or part of a larger population in nearby counties. A second interesting observation involved the Spotted Salamander. On 30 May 2018, we documented a Spotted Salamander within a short distance of a natural Fen wetland at one of our Greene Mountain transects. The salamander was found at an elevation of 739 m, which was higher than what has been previously suggested (< 600 m) for the species in Tennessee (Niemiller and Reynolds 2011). Currently, restoration work is being conducted on this Fen. Our observation further highlights the value of this project, and should inform management practices moving forward.

The most diverse public area we surveyed in regards to species richness was Round Knob (most species and 2nd highest diversity index). This cove-hardwood forest was one of the higher elevation areas we surveyed, which may partially explain its more diverse salamander assemblage. This is also the only area we found two of the rarer species, The Yonahlossee and the Northern Gray-cheeked Salamander (*P. montanus*). This suggests that Round Knob may be a particularly valuable area for salamander conservation and forest protection moving forward.

Collectively, these findings further highlight the conservation value of the southern Appalachians for salamander diversity. Much of these forested areas are part of protected state and federal lands, where more protection can be afforded compared to private land. In Greene County and the whole of northeast Tennessee continued protection of these lands, as well as increasing conservation acreage will be critical moving forward to ensure the long-term viability of salamanders and other amphibians in the face of uncertain global change.

Acknowledgements.—A number of Tusculum University students contributed to this research and we would like to thank Brandon Ball, Taylor Boles, Veronica Brown, Kelly Donnelly, John E. Durr, Tarah Helms, Kyler Johnson, Patrick Jones, Nathaniel Robinette, Megan Southerland, and Trevor Kahland for helping to establish transects and survey for salamanders. We would like to also thank the Tusculum University Department of Natural Sciences for access to their laboratory spaces and scientific instruments. Finally, we would like to thank the Appalachian College Association for providing financial support for a major portion of our research efforts. We greatly appreciate all who reviewed and provided valuable comments on this manuscript as well. These surveys were conducted under a Tennessee Wildlife Resources Agency scientific collection permit (#1673) with additional permission from the

Cherokee National Forest, Unaka Ranger District. We sincerely thank these agencies for their support and assistance.

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