Herpetological Conservation and Biology 20(1):158–166.
Submitted: 23 May 2023; Accepted 18 March 2025; Published: 30 April 2025.

Herpetofauna of Catoosa Wildlife Management Area and Species-Area Relationships of Reptiles and Amphibians Across Tennessee, USA

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***Abstract.*—Catoosa Wildlife Management Area (CWMA) is a 33,184-ha expanse owned and operated by the Tennessee Wildlife Resources Agency (TWRA), USA. The area is located within the Cumberland Plateau, a physiographic subregion of the southwestern Appalachians of the southeastern U.S. Despite extensive research throughout Tennessee, limited information exists on the herpetofaunal community within the Cumberland Plateau. Our goals were: (1) to inventory herpetofauna species richness and relative abundance within CWMA; (2) to compare our study with studies conducted in adjacent ecoregions and across the state; and (3) to assess species-area relationships of herpetofauna across Tennessee. We conducted at a minimum twice monthly inventories from 2017 to 2020 using a variety of surveying techniques focused on both terrestrial and aquatic habitats. Of the 42 species (20 amphibians and 22 reptiles) we documented, 40 were previously recorded in Morgan and Cumberland counties, representing 67.8% of the 59 herpetofauna known to occur in the region. Comparative analysis of species numbers and survey area size among CWMA and included studies produced a significant positive correlation, indicating a strong relationship between species diversity and survey area size.**

Key Words.—abundance; conservation; diversity; occupancy; southeastern U.S.; species-area; squamates

Introduction

Global decline in herpetofaunal populations has garnered attention from scientific communities and conservation groups worldwide. The International Union for Conservation of Nature (IUCN) estimates that 35.9% of amphibian species and 18.0% of reptile species worldwide are threatened with extinction (IUCN 2022). Additionally, ambiguity around the status of data-deficient species indicates that the actual proportion of herpetofauna threatened with extinction may be much higher. Thus, major gaps in knowledge concerning herpetofaunal species occurrence and how occurrences may change temporally makes it difficult to track population declines. Efforts to document current patterns of species abundance and distribution are vital for understanding patterns that drive diversity and geographic distributions as well as for maintaining and managing populations of herpetofauna globally.

The southeastern U.S., which we define as including the states of Alabama, Florida, Georgia, Kentucky, Maryland, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia (based on the American Association of Geographers) has greater diversity of amphibian and reptile species than any other region in the U.S. or Canada (Tuberville et al. 2005). Approximately 450 species of amphibians and reptiles occur within the U.S.; of these, almost half occur in the Southeast and many species are endemic to the area (Gibbons and Buhlmann 2001). Negative changes in population demographics and in local occurrences are likely to be indicative of declining habitat conditions and may serve as early warning signs for other at-risk organisms and overall ecosystem stability. While regionally varied, causes of herpetofaunal decline have been tied to habitat degradation and destruction, often in the form of agricultural land conversion, water contamination, and introduction of invasive species (Cox et al. 2022; Gibbons et al. 2000; Hopkins et al. 1999).

Tennessee is located in the southeastern U.S. and encompasses eight ecoregions, all of which extend into its eight neighboring states. These ecoregions and the geographic orientation of Tennessee along with its climatic and physiographic heterogeneity provides habitat for a variety of herpetofaunal species.

The abundance and distribution of herpetofaunal species varies significantly among ecoregions because of their corresponding topographic, hydrologic, and vegetative characteristics (Niemiller and Reynolds 2011; Niemiller et al. 2013). The frequency with which new county records are published (e.g., Grisnik and Hanscom 2020; Limon 2022; Hanscom et al. 2023), however, indicates that our understanding of the distribution of species of amphibians and reptiles in Tennessee is still incomplete.

Although the distribution of species of herpetofauna have been examined statewide (https://www.apsubiology.org/tnamphibiansatlas/index.html; https://apsubiology.org/tnreptilesatlas.index.htm; Niemiller and Reynolds 2011; Niemiller et al. 2013), limited information exists for herpetofauna within the Cumberland Plateau region of the state. Meade (2005) surveyed the Obed Wild and Scenic River Park and found 29 of the 41 herpetofaunal species known to occur within the Cumberland Plateau; however, they surveyed only sections of the park surrounding the Obed River, limiting potential inferences on diversity within the region. To our knowledge, there have been no subsequent surveys of the herpetofaunal community composition in the Cumberland Plateau. Additionally, there are 20 herpetofaunal species within Tennessee considered to be endangered, threatened, or in need of management (https://publications.tnsosfiles.com/rules/1660/1660-01/1660-01-32.20241225.pdf). Of these, six species are known to occur in Morgan and Cumberland counties: the Hellbender Salamander (*Cryptobranchus alleganiensis*); Eastern Pinesnake (*Pituophis melanoleucus*); Cumberland Dusky Salamander (*Desmognathus abditus*); Black Mountain Salamander (*Desmognathus welteri*); Four-toed Salamander (*Hemidactylium scutatum*); and Slender Glass Lizard (*Ophisaurus attenuatus*).

Our study assesses the herpetofauna of the Catoosa Wildlife Management Area (CWMA) within the Cumberland Plateau, a physiographic subregion of the southwestern Appalachians in Tennessee. By using several inventory techniques, we provide baseline data on herpetofaunal species richness and relative abundance throughout CWMA. We compare the diversity of species present at CWMA with: (1) that reported by Meade (2005) for the Obed Wild and Scenic River Park; (2) to other studies in different ecoregions in Tennessee; and (3) the species expected to be present based on documented county occurrences. We excluded Fentress County records in this effort as only a small portion of CWMA lies within county borders and cannot offer a reliable depiction of countywide herpetofauna. Additionally, we generated species-area curves for all herpetofauna, amphibians only, reptiles only, and all herpetofauna considered of greatest conservation need across the state. Overall, we provide essential data and discussion of the herpetofauna in the Cumberland Plateau Region in Tennessee that can be used to develop effective management practices and monitoring programs for the species present in this area.

Materials and Methods

Study area.—The CWMA covers 33,184 ha of land and spans parts of Morgan, Cumberland, and Fentress counties (Fig. 1). It lies entirely within the Cumberland Plateau in the southwestern portion of the Appalachians which spans Kentucky, Tennessee, and Alabama. The Cumberland Plateau subregion is characterized by rolling hills, valleys, and ridges with elevations ranging from 360–610 m. The area remains relatively cooler and receives more precipitation than surrounding subregions (Niemiller and Reynolds 2011). Underlying much of the Cumberland Plateau is Pennsylvanian conglomerate, siltstone, sandstone, shale, and coal. The subregion is characterized by low to moderate streams, broad floodplains, riparian wetlands, and two large river systems (Niemiller et al. 2013). The Catoosa WMA sits within the Emory Creek watershed and includes several drainages, including Daddys Creek, Clear Creek, Otter Creek, and the Obed River. Approximately 95% of CWMA is forested, with a mosaic of pine, hardwood, and fire-maintained oak savanna (Cantrell 2012).

The Tennessee Wildlife Resources Agency (TWRA) owns and manages CWMA. At the time of this study and in subsequent months, concerted efforts to restore patches of oak (*Quercus* spp.)-pine (*Pinus* ssp.) savanna within CWMA and the adjacent Lone Mountain State Forest have been ongoing. Prescribed fires have been used by TWRA in forest diversification and active habitat management (Vander Yacht et al. 2017).

Sampling efforts.—We visited CWMA at least twice monthly from March to October from 2017 to 2020. More specifically, during the summer of 2018, we visited CWMA at least twice weekly. During 2017, 2018, and 2019, we conducted Visual Encounter Surveys (Crump 1994) via hiking or road cruising (at night and during the day) to document

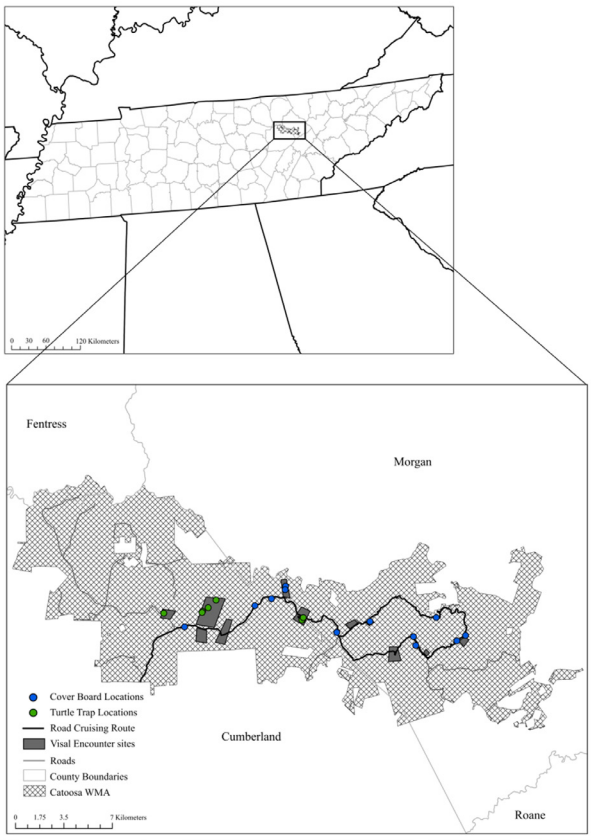

Figure 1. Location of Catoosa Wildlife Management Area (CWMA) in the Cumberland Plateau ecoregion of middle Tennessee, USA. The CWMA is located in Cumberland, Morgan, and Fentress counties, and the Obed River passes through it from west to east. Location and sampling effort types used throughout the study area shown throughout CWMA.

herpetofauna diversity and abundance throughout the park (Fig. 1). We focused on specific habitats (e.g., open oak savanna, mature and young hardwoods forest, riparian areas, and recently burned areas) to increase the likelihood of species detection in these efforts and each survey typically lasted from early afternoon to several hours after dusk. In 2020, we used fyke net and minnow traps in three ponds and in both the Obed River and Daddys Creek within CWMA to document aquatic turtle and amphibian diversity (Fig. 1). We placed 12 cover boards throughout the area in different habitat types during the early spring of 2020 and checked them in the fall (Fig. 1). Additionally, we placed PVC pipes around wetlands to document anuran species not typically seen during Visual Encounter Surveys. Lastly, we used Niemiller and Reynolds (2011) and Niemiller et al. (2013) for species identification efforts and Crother (2017) for species nomenclature.

Data analysis.—We compared our list of herpetofaunal species in this study to historical records in Morgan and Cumberland counties and from several sources (Niemiller and Reynolds 2011; Niemiller et al. 2013; https://www.apsubiology.org/tnamphibiansatlas/index.html; https://apsubiology.org/tnreptilesatlas.index.htm). Survey inventories from the adjacent Interior Plateau ecoregion were taken from results published in Davenport and Scott (2009). Additionally, we included more recent studies conducted within the Southwestern Appalachians and Ridge and Valley ecoregions. We also compiled data from herpetofaunal inventories from Tennessee to determine if there was a correlation between species richness and size of the survey area separately for all herpetofauna, reptiles, and amphibians (Table 1). We first log-transformed these data to improve linearity and to meet parametric assumptions. Then, we tested for correlation of species richness and study size area using Pearson's Product-moment Correlation (Rodgers and Nicewander 1988). We tested for correlation across four groups: (1) all herpetofaunal species; (2) amphibians only; (3) reptiles only; and (4) only amphibian and reptile species determined to be of greatest conservation need by the TWRA. We used the ggpubr, tidyverse, and corrr packages in R (R

Table 1. List of areas surveyed along with author(s) of each study, publication date, area size in ha, and number of reptile and amphibian species documented.

Area surveyed	Reference	Size of area (ha)	No. species documented
Catoosa Wildlife Management Area	Strebler et al. (2025)	33,184	42
Obed Wild and Scenic River	Meade (2005)	2,023	33
Seven sites in Rutherford and Wilson counties	Niemiller et al. (2011)	5,071	49
Fort Donelson National Battlefield	Davenport and Scott (2009)	234	37
Upper Duck River Watershed	Niemiller (2005)	1,307	51
Arnold Air Force Base	Miller et al. (2005)	15,800	60
Oak Ridge Reservation	Giffen et al. (2009)	13,619	32
Montgomery County	Scott and Snyder (1968)	140,634	60
Land Between the Lakes	Snyder (1972)	68,799	66
Fort Campbell Military Reservation	Zirkle (1993)	42,699	48
Haynes Bottom Wildlife Management Area	Scott and Williamson (1999)	393	35
Shelton Ferry Wetland	https://www.apsubiology.org/tnamphibiansatlas/index.html	176	34
Dunbar Cave State Natural Area	Fitch (1998)	44	33
Barnett Woods Natural Area	Scott (1991)	28	25
Steele Creek Park	Jessee et al. (2022)	926	41

Core Team 2022) for all analyses and visualizations.

Results

Species richness and relative abundance.—We found 633 amphibian and reptile individuals from which we identified 42 species, including 20 species of amphibians (10 species each of caudates and anurans), and 22 species of reptiles (13 species of snakes, five species of turtles, and four species lizards). We documented 67.8% of the herpetofaunal species known to occur in Morgan or Cumberland counties while, again, excluding Fentress County to avoid misrepresenting county-wide occurrences here (Supplemental Information Table S2). We found more Northern Dusky Salamanders (*Desmognathus fuscus*) than any other species of salamander, followed by Southern Two-lined Salamanders (*Eurycea cirrigera*). We found Northern Slimy Salamanders (*Plethodon glutinosus*), Northern Zigzag Salamanders (*Plethodon dorsalis*), and Eastern Newts (*Notophthalmus viridescens*) far less frequently. Lastly, we found only one Red Salamander (*Pseudotriton ruber*; Supplemental Information Table S3).

Among the most commonly observed species of anurans were Northern Cricket Frogs (*Acris crepitan*), Cope's Gray Treefrogs (*Hyla chrysoscelis*), American Bullfrogs *(L. catesbeianus*) and Green Frogs (*L. clamitans*). We documented Eastern Narrow-mouthed Toads (*Gastrophryne carolinesis*) and Eastern Spadefoot Toads (*Scaphiopus holbrooki*) less frequently. Finally, we found only one Wood Frog (*Lithobates sylvaticus*; Supplemental Information Table S3).

We found more Eastern Box Turtles (*Terrapene carolina*) than any other species of turtles. We found only one Painted Turtle (*Chrysemys picta*) and one Loggerhead Musk Turtle (*Sternotherus minor*). The most commonly seen lizard species were Eastern Fence Lizards (*Sceloporus undulatus*); whereas Slender Glass Lizards (*O. attenuatu*s), a species deemed in need of management, were rarely encountered. Snakes were the second most encountered group of herpetofauna during this survey following anurans. Among them were Eastern Copperheads (*Agkistrodon contortrix*), Timber Rattlesnakes (*Crotalus horridus)*, and Common Watersnakes (*Nerodia sipedon*). We found only one individual of each of the following three species: Eastern Hognose Snakes (*Heterodon platirhinos*), Rough Greensnakes (*Opheodrys aestivus*), and Queensnakes (*Regina septemvittata*; Supplemental Information Table S3).

Species found compared to expected.—We found 40 of the 59 species (67.8%) documented in Morgan and Cumberland counties. This included 45.4% of

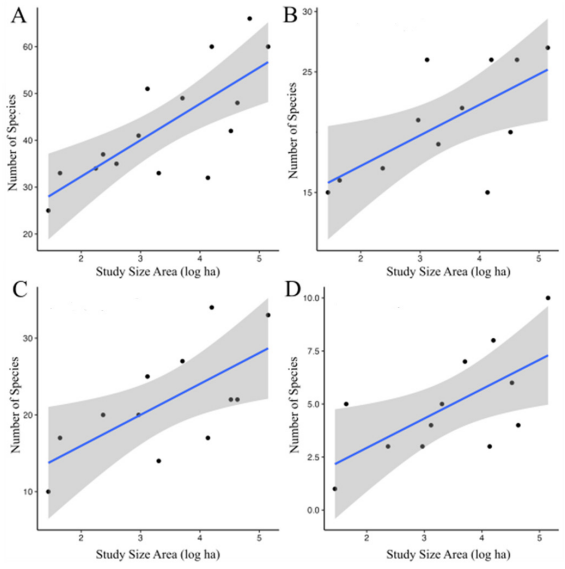

Figure 2. Relationship between the overall size of the sampled area and the number of species found during corresponding surveys: (A) all herpetofauna species in all included studies; Number of Species = 16.7 + 7.76 (Area), $r^2 = 0.57$; (B) only amphibian species in all included studies; Number of Species = 12.1 + 2.54 (Area), $r^2 = 0.43$; (C) only reptile species in all included studies; Number of Species = 7.90 + 4.03 (Area), $r^2 = 0.44$; and (D) amphibian and reptile species determined by Tennessee Wildlife Resources Agency to be of greatest conservation need Number of Species = 0.162 + 1.39 (Area), $r^2 = 0.43$. Refer to Table 1 for detailed study information. We were unable to obtain species specific occurrences for information in Snyder (1972), https://www.apsubiology.org/tnamphibiansatlas/index.html, or https://apsubiology.org/tnreptilesatlas.index.htm.

caudates, 83.3% of anurans, 80.0% of testudines, and 80.0% of squamates. Three species not previously recorded in Morgan or Cumberland counties (https://www.apsubiology.org/tnamphibiansatlas/index.html; https://apsubiology.org/tnreptilesatlas.index.htm) including *C. picta*, *O. aestivus*, and Spotted Salamanders (*Ambystoma maculatum*) were documented by us, in the Meade (2005) report, or in both. In both the current and the Meade (2005) studies, but not previously recorded in Cumberland and Morgan counties, was the *C. picta*. The two other species, *O. aestivus* and *A. maculatum*, were each documented by us and in the Meade (2005) study, respectively. None the species we found in the CWMA are included on state or federal lists of taxa considered threatened, or endangered; however, *O. attenuatus* are listed as in need of management (https://publications.tnsosfiles.com/rules/1660/1660-01/1660-01-32.20241225.pdf).

Species-area curves.—Including our data, 15 studies of herpetofaunal inventories yielded species numbers ranging from 25 to 66 (Supplemental Information Table S1). We found a significant positive correlation for all herpetofauna species ($t = 4.12$; df = 13, $P = 0.001$), amphibians only ($t = 2.74$; df = 10, $P = 0.020$), reptiles only ($t = 2.81$; df = 10, $P = 0.02$), and of amphibian and reptile species determined by TWRA to be of greatest conservation need ($t = 2.73$; df = 10, $P = 0.020$: Fig. 2).

Discussion

Species rarity in CWMA.—The herpetofauna recorded in our study include 10 of the 22 salamander species, 10 of the 12 species of anurans, and 20 of the 25 reptile species previously documented in Morgan and Cumberland counties. Among the salamander species documented in county records, but not encountered in this study were *D. abditus*, Allegheny Mountain Dusky Salamanders (*D. ochrophaeus*), and *D. welteri*. Additionally, encounters with *D. abditus* and *D. welteri* in the Meade (2005) study were uncommon. Although both species are deemed in need of management, Drukker et al. (2018) documented *D. abditus* throughout CWMA, indicating that we likely overlooked specific habitats during our searching efforts. Likewise, we did not find *H. scutatum*, also deemed in need of management, though a few records exist in and near Cumberland County. While county records indicate occurrences within Morgan and Cumberland counties, we did not find Cave Salamanders (*E. lucifuga*) or Blue Ridge Two-lined Salamanders (*E. wilderae*). *Eurycea wilderae* and *E. cirrigera,* commonly encountered species in CWMA, are difficult to distinguish using external characteristics, creating a possibility of overlap in documented occurrences. County records of *E. lucifuga* are limited to the very southern border of Cumberland County and indicate increased density throughout the central and eastern portion of the state. They are commonly found near caves and in mesic woodlands, so it is unclear why there are so few records of *E. lucifuga* throughout Morgan and Cumberland counties.

Anurans previously documented in Morgan or Cumberland counties but that we did not find include Pickerel Frog (*Lithobates palustris),* Southern Leopard Frog (*L. sphenocephalus)*, and Upland Chorus Frog (*Pseudacris feriarum)*. Records indicate distribution of *L. palustris* throughout Morgan County (https://www.apsubiology.org/tnamphibiansatlas/index.html); likewise, Meade (2005) reports finding several individuals, so we are uncertain why we were unable to detect this species in CWMA. Less surprising is

the lack of documentation for *L. sphenocephalus* as records of this species are limited to the southern end of Cumberland County near areas of lower elevation.

We were unable to find five species of reptiles in CWMA that have been documented in either Cumberland County or Morgan County: the Scarletsnake (*Cemophora coccinea)*, Eastern Black Kingsnake (*Lampropeltis nigra)*, Eastern Pinesnake (*P. melanoleucus)*, Eastern Musk Turtle (*Sternotherus odoratus)*, and Dekay's Brownsnake (*Storeria dekayi*). Records pertaining to *C. coccinea*, *L. nigra*, and *S. dekayi* in Morgan and Cumber-land counties are rare (https://www.apsubiology.org/tnamphibiansatlas/index.html). The Northern Pinesnake (*P. melanoleucus*) is listed as threatened by the TWRA and has been documented at several locations along the western border of Cumber-land County. Our inability to locate *P. melanoleucus* within CWMA could be concerning, given that we specifically targeted visual surveys in the small areas of potentially suitable habitat for *P. melanoleucus*. Because *P. melanoleucus* and *C. coccinea* are both secretive and fossorial, however, with inherently low detection probabilities (Gerald et al. 2006), a lack of detection does not necessarily indicate that these species are absent at CWMA. Additionally, we found only five *O. attenuatus,* which was among the least encountered reptile species. *Ophisaurus attenuatus* is an elusive fossorial species deemed in need of management, so although encounters were low relative to other lizards, our ability to detect five individuals was surprising. Lastly, very few records of *S. odoratus* exist within the central and northeastern counties of Tennessee, though they are known to occur throughout much of the rest of the state. There are a limited number of wetlands and ponds available at CWMA; thus, no detection of *S. ordoratus* may be a result of low amounts of suitable habitat.

Among the species not previously recorded in Morgan and Cumberland counties, but that were found in CWMA, were *O. aestivus* and *C. picta*. Records pertaining to *O. aestivus* indicate that the species is found in adjacent counties, though there is an apparent lack of records in Morgan and Cumberland counties as well as in the Meade (2005) study. We are uncertain why so few records exist in northeastern Tennessee as this species is regarded as occurring statewide.

Catoosa WMA herpetofauna and adjacent ecoregions.—Seven of the 15 survey inventories included in our study took place within Stewart or Montgomery counties. We suspect this has an impact on the overall range of species found throughout the sampled surveys. More specifically, because there were no relatively recent species inventories conducted along the central/southeastern border of Tennessee, several salamander species endemic to the Blue Ridge and Great Smoky Mountains were not included here. Our analyses between species numbers and survey area size found that within CWMA and all other studies in Tennessee, there was a significant positive correlation. Additionally, regardless of all herpetofauna, only amphibians, only reptiles, or only herpetofaunal species deemed as greatest conservation need were included, this relationship stayed the same, suggesting that survey area size plays a crucial role in determining species richness in both CWMA and other studies conducted in Tennessee. This finding supports that larger survey areas (i.e., undisturbed tracts of land) have the potential to support a greater diversity of herpetofaunal species, regardless of the specific taxonomic group or conservation status considered.

Conclusion.—From 2017 to 2020, we documented 42 herpetofaunal species in CWMA. This diversity includes 67.8% of species known to occur in Morgan and Cumberland counties. Two of the 42 documented species, *C. picta* and *O. aestivus*, had not been previously recorded in either county. Among the species recorded in this study, five are listed as species of greatest conservation need in the state of Tennessee. This includes two amphibian species (the Green Salamander, *Aneides aeneus*, and *P. dorsalis)* and three reptile species (*C. horridus, H. platirhinos,* and *O. attentuatus)* with efforts targeted toward preventing population decline to the point of endangerment. Furthermore, *O. attenuatus* is deemed in need of management by the TWRA and thus, this may be vital in future land management decisions. Finally, when comparing species numbers and corresponding survey area size from the CWMA with those of adjacent ecoregions, a significant positive correlation is found, corroborating the expectation that species diversity increases with study area size. This finding highlights the importance of considering the spatial scale of survey efforts and expanding the scope of future surveys to encompass larger areas and adjacent ecoregions. By doing so, we can gain a better understanding of regional species diversity patterns and develop more effective conservation strategies including habitat preservation. More

investigations are needed to explore the underlying factors influencing these patterns, such as habitat heterogeneity, landscape connectivity, and ecological interactions, which can contribute to our understanding of biodiversity dynamics and inform targeted conservation efforts.

Acknowledgments.—All research was conducted under a Tennessee Wildlife Resources Agency scientific collection permit (no. 2542).

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Marissa Strebler works as a Field Research Assistant after graduating from San Diego State University, California, USA, in 2023 with her Bachelor's degree in Biology with an Ecology emphasis. Her current focus is on the role of adaptive evolution in the Scarlet Monkeyflower (*Erythranthe cardinalis*) along latitudinal ranges throughout the western coastal U.S. While much of her research efforts have been concentrated in plant biology and evolution, she maintains strong interests in research involving herpetology and entomology. (Photographed by Jennifer Moreno-Frost).

Matthew Grisnik is an Assistant Professor of Biology at Coastal Carolina University in Conway, South Carolina USA. He received his B.S. from the University of Findlay, Ohio, USA, his M.S. from Marshall University in Huntington, West Virginia, USA, and his Ph.D. from Middle Tennessee State University in Murfreesboro, Tennessee USA. Matt then worked as a Postdoctoral Researcher at Tennessee State University, Nashville, USA, for two years, and began work at Coastal Carolina University in 2023. Matt is interested in understanding how disturbance influences both macro- and micro- organisms, as well as how these disturbances influence community assembly processes. (Photographed by Rachel Brubaker).

Mack White is an Ecosystem Ecologist who began his career with the U.S. Forest Service working on stream restoration prior to attending Tennessee Technological University in Cookeville, Tennessee, USA, where he completed his M.Sc. in Biology. Mack is currently a Ph.D. candidate at Florida International University in Miami, USA. Though most of his research involves fish, a desire to learn and progress his academic career alongside friends resulted in several summers conducting research on reptiles and amphibians in Tennessee. (Photographed by Ryan J. Hanscom).

Ryan J. Hanscom began his career as a Research Technician with The Nature Conservancy studying the freshwater turtles on the Outer Banks of North Carolina, USA, while working on his Bachelor's degree at Framingham State University, Massachusetts, USA. Ryan then completed his M.Sc. at Tennessee Technological University, Cookeville, USA, and his Ph.D. at San Diego State University, California, USA. He is an incoming Assistant Professor for the University of South Carolina Beaufort, USA. His research focuses on quantitative natural history and how anthropogenic activities impact the behavior and ecology of rattlesnakes, freshwater turtles, and small mammals. (Photographed by Jessica L. Hill).