REPTILES & AMPHIBIANS

Living on the Edge: Status of *Eurycea lucifuga* (Cave Salamander) and *Gyrinophilus porphyriticus* (Spring Salamander) at the Periphery of their Ranges in Mississippi, USA

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Abstract.— The northeastern corner of Mississippi is at the southwestern periphery of the Cumberland Plateau, and little is known about most of the salamander species in this region. Further, much of what we know about Cave Salamanders (*Eurycea lucifuga*) and Spring Salamanders (*Gyrinophilus porphyriticus*) in the state is based on anecdotal encounters. Both *E. lucifuga* and *G. porphyriticus* are state-endangered in Mississippi and both are considered species of greatest conservation need. To further assess their conservation status, we completed distribution and encounter-rate surveys during July/August 2021–2023 in Tishomingo County, Mississippi. For *E. lucifuga*, we completed 37 surveys at ten caves and rock-face recesses (total effort: 35.8 person-hours). We made 32 observations of *E. lucifuga* at four sites (catch-per-unit effort [CPUE]: 1.5/h), and also opportunistically documented the species along two Hartselle Sandstone rock faces during a related study of Green Salamanders (*Aneides aeneus*). For *G. porphyriticus*, we completed 65 surveys at 36 sites that included caves, streams, springs/seeps, and waterfall-splash zones (total effort: 92.4 person-hours) and conducted leaf-litter-bag sampling at three streams in 2022. We observed a total of eight *G. porphyriticus* during surveys (two adults and six larvae from three different sites) (CPUE: 0.06/h); two of the six larvae were captured in 84 leaf-litter-bag checks (CPUE: 0.02/bag check). Both *E. lucifuga* and *G. porphyriticus* appear to be rare members of the salamander community in northeastern Mississippi, as both are known from fewer than 10 localities in Mississippi and have low encounter rates. Periodic surveys are needed to determine if future changes occur in the distribution or abundance of either species. Future surveys, especially on private properties, could reveal additional localities for both species.

Global salamander biodiversity reaches its highest levels in the southeastern Appalachian Mountains, and relatively high salamander diversity extends to the southwest from this hotspot into northern Alabama and northeastern Mississippi (Petranka 1998; Milanovich et al. 2010). In northeastern Mississippi, the geology is quite different from that in the rest of the state because the rock formations were deposited during the Carboniferous Period (~360–299 mya; Thompson 2011); these geologic formations are more similar to those found in Alabama, Tennessee, and Georgia rather than southern Mississippi. Along with geologic differences, northeastern Mississippi also contains a small portion of the Tennessee River System. Bear and Cedar Creeks, both Tennessee River tributaries, originate in Alabama, flow south-to-north through Mississippi, and then drain into Pickwick Lake, an impoundment of the Tennessee River. Because of the unique geology and hydrology of this region in Mississippi, many unique fishes, mussels, and amphibians occur here and nowhere else in the state. Several species of salamanders are considered species of greatest conservation need in Mississippi, and two of these species are Cave Salamanders, *Eurycea lucifuga* Rafinesque 1822, and Spring Salamanders, *Gyrinophilus porphyriticus* Green 1827 (Mississippi Museum of Natural Science 2015).

Eurycea lucifuga is found in areas with deep limestone formations and the range of the species is centered in two regions of the United States. One is east of the Mississippi River and extends from central Kentucky and Tennessee north into southern Indiana, south into northern Alabama and northeastern Mississippi, and northeast into northern Virginia; the other is west of the Mississippi River and is centered in southern Missouri and northern Arkansas and extends west into northeastern Oklahoma and southeastern Kansas (Petranka 1998). These areas include ecoregions of the Cumberland and Interior Plateaus, as well as the Ridge and Valley and Ozark Highland (USEPA 2013). *Eurycea lucifuga* is considered a facultative cave-dweller that is dependent on resources from outside of the cave (i.e., epigean resources; Bradley and Eason

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2022). Suitable habitats are rare in northeastern Mississippi and the species had been reported from only five localities in Tishomingo County. Two specimens (Museum of Vertebrate Zoology, University of California, MVZ: Herp 91953–4) were collected from "Tishomingo State Park" and "Mingo Cave" in 1967 and surveys by Cliburn (1990) reported *E. lucifuga* from Mingo Cave (aka Cave Springs) and from Pavilion Cliff in Tishomingo State Park (TSP). Incidental surveys recorded the species from two additional sites on private property in the same area (Q. Fairchild, pers. comm).

Conversely, the range of *G. porphyriticus* extends almost continuously from southeastern Quebec and Maine southwest into Alabama, Georgia, and northeastern Mississippi (Petranka 1998), with primary ecoregions occupied including the Northeastern Highlands, Cumberland Plateau, Allegheny Plateau, the Ridge and Valley, Blue Ridge, and southern Piedmont ecoregions (USEPA 2013). Contrary to *E. lucifuga*, *G. porphyriticus* is absent from regions west of the Mississippi River. The habitat of *G. porphyriticus* includes caves where they are sympatric with *E. lucifuga*, but they also can be found in springs, high-gradient headwater streams lacking fish, and hillside seeps (Petranka 1998; Bruce 2003). These habitats, like those of *E. lucifuga*, also are rare in northeastern Mississippi, and *G. porphyriticus* had been reported from only five sites in Tishomingo County. Surveys by Cliburn (1990) reported the species from Mingo Cave and several sites inside TSP. A single record from east of Iuka near the Mississippi-Alabama border (United States National Museum, Smithsonian Institution, USNM 319502) collected 17 March 1967 is 14–19 km NNE of the TSP sites reported by Cliburn (1990).

Because of the scarcity of records, presumed relatively small ranges, and limited potential habitat in Mississippi, both species are considered state endangered (Mississippi Museum of Natural Science 2015). Current information is needed to more accurately assess their status in the state and provide a baseline for future surveys. Our objectives were to determine the distribution and encounter rates of both *E. lucifuga* and *G. porphyriticus* in northeastern Mississippi using multiple sampling methods.

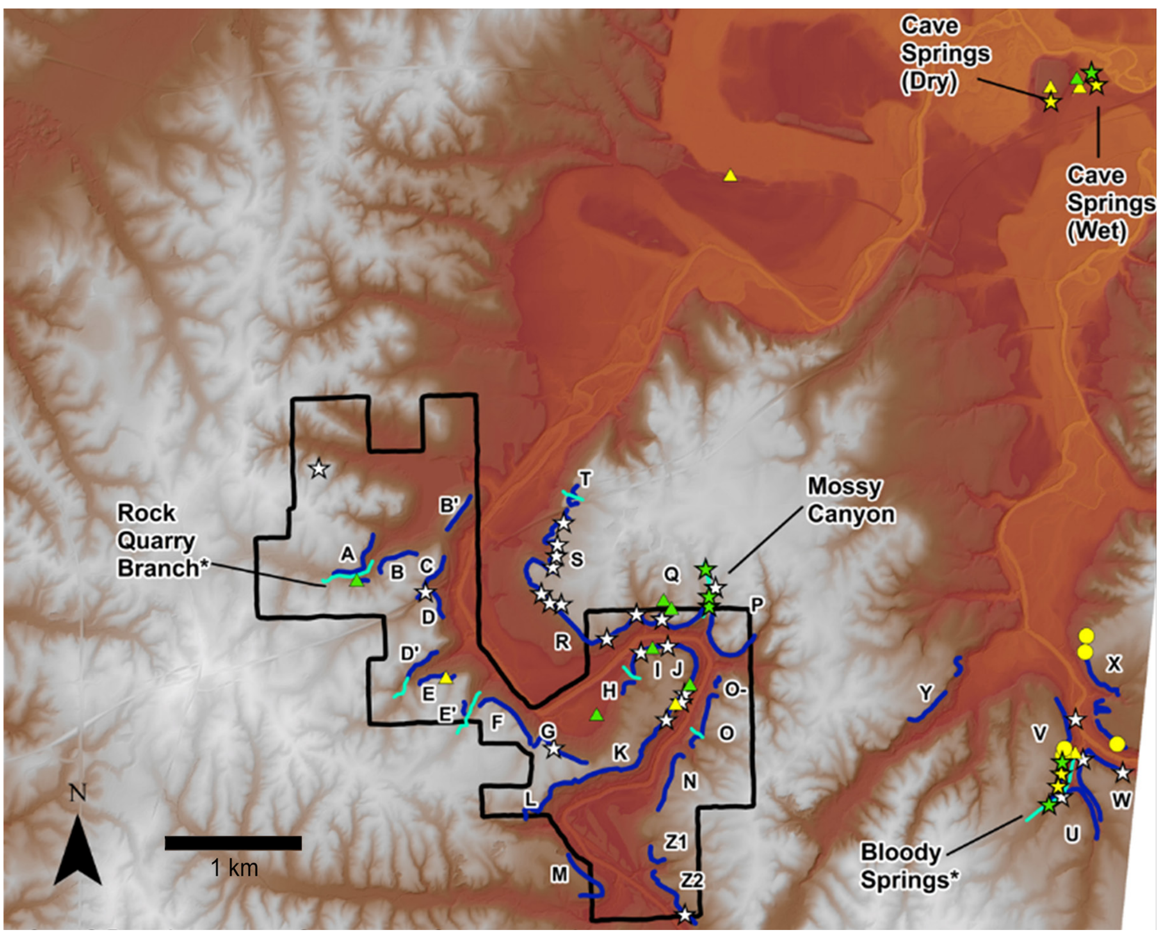

Figure 1. Historic and current localities in Tishomingo County for Cave Salamanders (*Eurycea lucifuga*) and Spring Salamanders (*Gyrinophilus porphyriticus*) (green symbols) and *E. lucifuga* (yellow symbols). Triangles represent historic localities and stars represent new/confirmed localities from this study; yellow circles represent records of *E. lucifuga* from searching rock faces; white stars represent recesses or caves that were surveyed without detecting either species; light blue lines represent high-gradient streams that were searched manually or sampled with leaf-litter bags (*); dark blue lines represent the approximation of rock outcrops that were surveyed. All letters correspond to those in Table 1.

Methods

During July and August of 2021–2023, we conducted area-constrained surveys for both *E. lucifuga* and *G. porphyriticus* along 32 rock outcrops in Tishomingo County (Fig. 1); most of these sites were in or near TSP and were previously described by Watkins et al. (2025). The Hartselle Sandstone rock formations that were searched ranged from scattered boulders to continuous rock walls (Fig. 2A), and records of both *E. lucifuga* and *G. porphyriticus* were known from some of these locations. Most sites were heavily forested with moderate to steep topographic terrain. Using hand-held flashlights and headlamps, we searched crevices and openings in the rock formations by day and night. Every salamander observed was identified when possible, and we also recorded lithophilic reptiles and anurans. For both target species, we recorded locations with a handheld GPS, and catch-per-unit effort (CPUE) was calculated by dividing the number of salamanders encountered per person-hour (p-h) of searching.

While searching along rock faces, we located and carefully searched ten caves (Fig. 2B) or deep recesses (Fig. 2C) under large overhangs on both public and private properties by night (n = 28) and day (n = 9) (Table 1). Like other sites, we recorded locations and the presence and number of all salamanders observed.

For *Gyrinophilus porphyriticus*, we also conducted area-constrained manual searches of high-gradient rocky streams, hillside seeps, and springs. All sampled streams had flowing water; a combination of large rocks (sometimes bedrock), cobble, gravel, and sand; and an alternating riffle/pool hydrology (Fig. 2D). During both day and night, we used flashlights to search the undersides of the rocks in and along streams, using small aquarium nets to catch adults and larvae. We recorded beginning and ending locations of all searches and quantified the time searched in person-hours. We also deployed leaf-litter bags (LLBs) (Waldron et al. 2003) in 2022 to sample adult and larval salamanders along three streams, two on

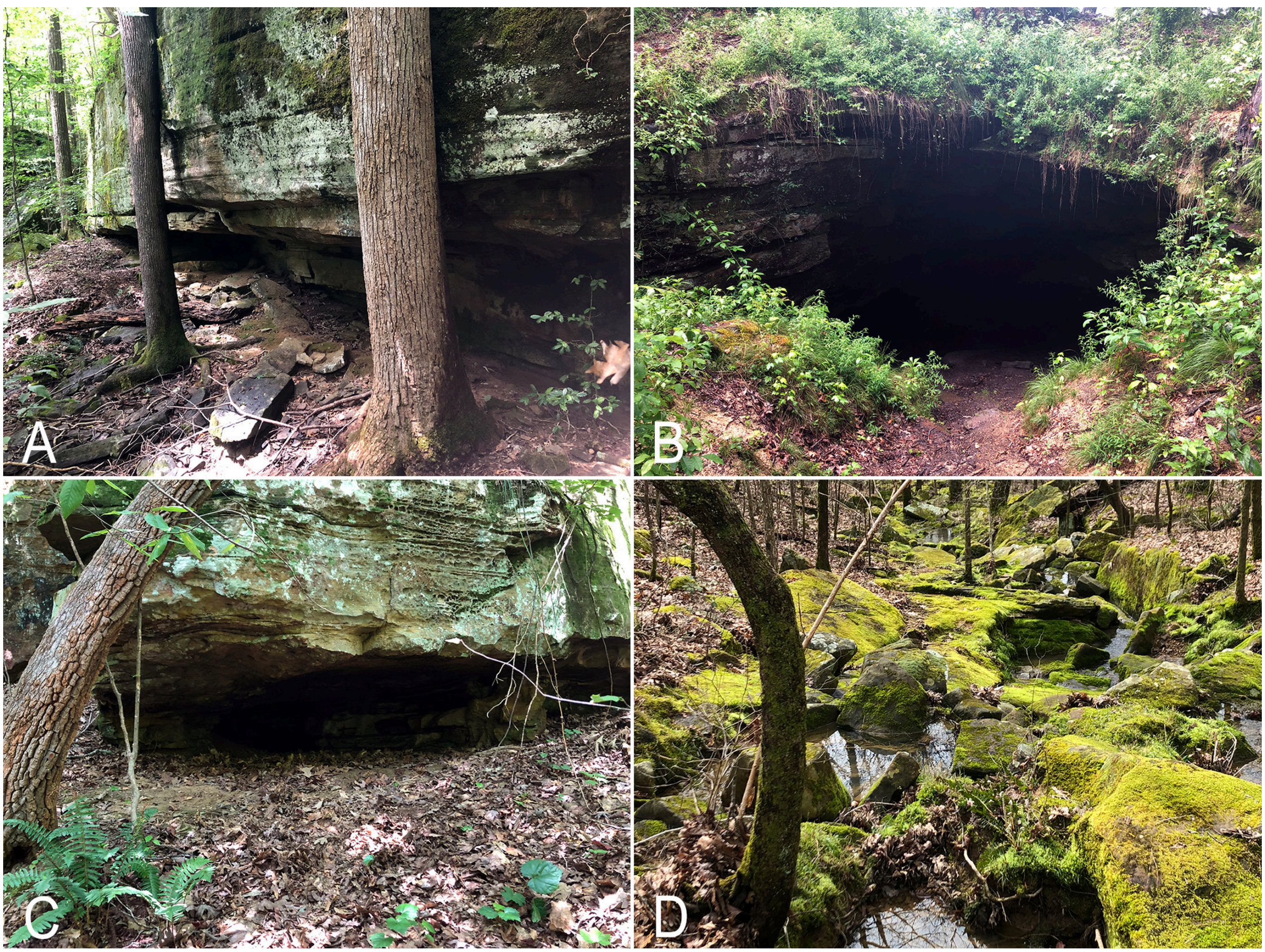

Figure 2. Representative habitat and search locations for Cave Salamanders (*Eurycea lucifuga*) and Spring Salamanders (*Gyrinophilus porphyriticus*) in Tishomingo County, Mississippi: (A) Hartselle Sandstone rock outcrops with recesses (Site V); (B) large cave system (Cave Springs/Mingo Cave); (C) small cave recess along Hartselle Sandstone rock outcrop (Bloody Springs Cave 1); (D) high gradient, rocky stream (Mossy Canyon Stream). Photographs by Will Selman.

Table 1. Site-specific results from manual searching for Cave Salamanders (*Eurycea lucifuga*) and Spring Salamanders (*Gyrinophilus porphyriticus*) in Tishomingo County, Mississippi, USA, in the summers 2021–2023. Cave/recess locations are in bold, and asterisks (*) denote larval *G. porphyriticus* observed in a stream. Abbreviations: Dc = *Desmognathus conanti*, Ec = *Eurycea cirrigera*, Elo = *Eurycea longicauda*, Elu = *Eurycea lucifuga*, E? Larvae = unknown larval *Eurycea*, Gp = *Gyrinophilus porphyriticus*, Pd = *Plethodon dorsalis*, Pg = *Plethodon glutinosis*, Pr = *Pseudotriton ruber*.

Site	Number of Surveys	Effort	Dc	Ec	Elo	Elu	E? Larvae	Gp	Pd	Pg	Pr
Spring Hill Spring	3	10.10	4	12			75				
CC pond	1	3.40	6	1			2				
Rock Quarry Branch	1	6.25		8			2				
Pavilion Spring	2	1.00	10								1
Cabin Cliff Seep 1	1	4.65	6	1			1				
Cabin Cliff Seep 2	1	0.50									
S.B. Waterfall	1	1.00	6								
Trickle Falls	1	0.50									
Bloody Springs	1	0.50					41				
Bloody Springs Seep	1	4.15									
Bedrock Spring	1	2.00	5	1			4				
S.B. Large Waterfall	1	0.50								1	
Mossy Canyon	2	5.80	5	11			108	2*			
Powerline Stream	1	2.15	2	2			2				
Pavilion Seep 1	1	0.50	2								
Pavilion Seep 2	1	0.15	2		1		2				
Bull Spring	1	0.42					4				
Mossy Canyon Seep	1	0.24									
North Hollow Spring	1	0.05	2								
O Spring	1	1.15		1			4				
Natchez Trace Stream	1	2.15	5	5			6				
Upper Rock Quarry	1	2.65		1			42				
JP Coleman Stream	1	6.25	30							3	
JP Coleman Creek Wall	1	0.64	2								
Bloody Springs Cave 1	**7**	**2.62**			**2**	**5**				**9**	
Bloody Springs Cave 2	**6**	**0.98**				**1**		**1**		**4**	
Bloody Springs Recess	**1**	**0.10**									
Cave Springs-Dry Cave	**9**	**12.05**			**1**	**6**			**1**	**148**	
Cave Springs-Wet Cave	**9**	**14.42**			**2**	**10**		**3***		**50**	
Gurgling Rock Recess	**1**	**0.10**									
Mossy Canyon Recess	**1**	**0.08**									
Pavilion Cave 1	**1**	**0.50**									
Pavilion Cave 2	**1**	**0.80**								**1**	
Powerline Cave	**1**	**4.15**								**1**	
Total (n = 34)	**65**	**92.4**	**87**	**43**	**6**	**22**	**293**	**6**	**1**	**217**	**1**

TSP property (Rock Quarry Branch, Mossy Canyon) and a third on private property (Bloody Springs). At each stream, we deployed 15 LLBs on either 14 or 15 July. Each bag was composed of a double layer of 70 × 70 cm plastic deer fencing (1.5 cm square pores) to which we added rocks and terrestrial leaves to simulate habitat for adults and larvae. Each bag was cinched tight with nylon string, and the string was secured to a limb, branch, or root of a tree or shrub. Each bag was checked after two and four weeks by rinsing and agitating the bags in a 5-gallon bucket partially filled with water; the agitation flushed larvae out of the bags and into the bucket. Leaf-litter bags usually were rinsed, agitated, and filtered multiple times until no larvae remained. Larvae were identified to species when possible, with *G. porphyriticus* larvae generally having: (1) a relatively large, paddle-like head, (2) relatively large gills, (3) relatively large body size compared to other local salamander larvae, and (4) small light flecks interspersed on a grayish dorsum.

Results

Cave Salamander Distribution.—We conducted 37 surveys for *Eurycea lucifuga* at 10 cave and rock-face recesses (4 were searched at least twice; total effort: 35.8 p-h; Table 1), and *E. lucifuga* were documented at four sites (40%), including three of the five previously documented localities (Table 1). Even though considerable effort was expended with special attention to sites described by Cliburn (1990), we did not detect the species in TSP. Also, one historic location on private property northwest of TSP could not be surveyed due to the high number of small property owners in that area and an inability to gain access from all landowners. In addition to the cave-specific searches, we found seven individuals at multiple locations along shallow rock crevices at two Hartselle Sandstone rock outcrops (Fig. 1). We observed two individuals in horizontal crevices at Site V and found 5 salamanders at three separate locations at site X (Fig. 3A–B) in 2022. The former is the same outcrop where we observed *E. lucifuga* in Bloody Springs Cave 1 (Fig. 3C) and 2 (Fig. 3D), whereas the latter is a new locality for the species along a rock outcrop on private property.

Cave Salamander CPUE.—We made 32 observations of *E. lucifuga* at four of the ten cave/recess sites including Bloody Springs Cave 1 (n = 6 individuals in 6 surveys; Fig. 3C), Bloody Springs Cave 2 (n = 1 in 5 surveys; Fig. 3D), Cave Springs Wet Cave (n = 17 in 9 surveys; Fig. 3E–F), and Cave Springs Dry Cave (n = 8 in 9 surveys; Fig. 1). The mean CPUE at all cave site surveys was 1.5/h (0.0–16.7/h). In all three years, *E. lucifuga* was most consistently present at three sites: Bloody Springs Cave 1 (CPUE: 3.56/h), wet cave at Cave Springs (CPUE: 1.4/h), and dry cave at Cave Springs (CPUE: 0.87/h).

Spring Salamander Distribution.—We completed 65 surveys for *G. porphyriticus* at 36 sites (total effort 92.4 p-h) including both cave (n = 10 sites and 37 surveys; 35.8 p-h) and non-cave (n = 24 sites and 28 surveys; 56.6 p-h) habitats. For the latter, this included streams (n = 15), springs/seeps (n = 8), and waterfall-splash zones (n = 3) (Table 1).

We confirmed *G. porphyriticus* at the historical locality at Cave Springs (wet cave) by observing a single adult (29 August 2021; Fig. 4A) and two large larvae. We also docu-

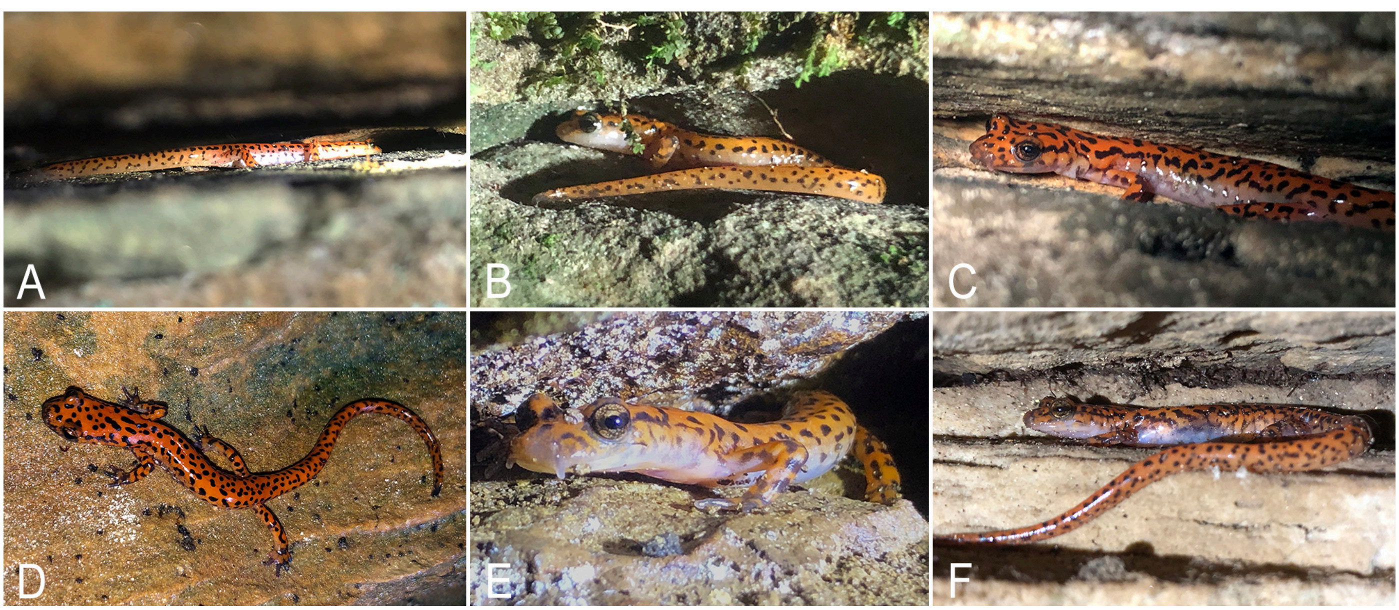

Figure 3. Observations of Cave Salamanders (*Eurycea lucifuga*) in Tishomingo County, Mississippi, with museum accession numbers to the digital archives of the Florida Museum of Natural History: (A) northern end of rock outcrop X (2 August 2022; UF 195472); (B) southern end of rock outcrop X (3 August 2022; UF 195473); (C) Bloody Springs Cave 1 (20 July 2021; UF 195467); (D) Bloody Springs Cave 2 (20 July 2021; UF 195468); (E) wet cave of Cave Springs (4 August 2022; UF 195474); (F) dry cave of Cave Springs (25 July 2023; UF 195477). Photographs by Will Selman.

mented several new localities for the species including a single adult at Bloody Springs Cave 2 (21 August 2021; private property), three larvae at Mossy Canyon stream (2 searching, 1 LLB) in TSP; Fig. 4B), and one larva captured in an LLB at a rocky stream site at Bloody Springs. We did not detect individuals at a handful of prior localities in TSP, and we were unable to survey a historical record east of Iuka near Hwy 72 on private land.

Spring Salamander CPUE.—During searches and surveys at all sites, we observed six *G. porphyriticus* (two adults, four larvae) (CPUE: 0.06/hr). Encounter rates for *G. porphyriticus* were higher in cave sites (2 adult, 2 larvae; 0.11/h) compared to non-cave sites (2 larvae; 0.02/h).

In 2022, we sampled 45 LLBs 84 times at three different sampling locations (Bloody Springs, n = 30; Mossy Canyon, n = 26; Rock Quarry, n = 28), and conducted LLB sampling two weeks after deployment (n = 43 bag checks) and four weeks after deployment (n = 41 bag checks). The site and weekly differences in bags sampled were primarily due to some litter bags being set in intermittent stream pools at Mossy Canyon that dried completely over the course of the study (n = 4) or to high rainfall in Rock Quarry Branch that shifted litter bags to a dry section of the stream (n = 2). We found a total of 429 larvae and adults during the 84 LLB checks, with the dominant species being Southern Two-lined Salamanders (*Eurycea cirrigera*) (391 larvae and 28 adults; 97.7% relative abundance). We also encountered eight Southern Spotted Dusky Salamanders (*Desmognathus conanti*) (3 larvae and 5 adults; 1.9%), seven unidentified larvae (1.6%), and two *G. porphyriticus* larvae (0.4%). For the latter, we found one larva at Bloody Springs (Fig. 4C) and one at Mossy Canyon (Fig. 4D).

Discussion

Cave Salamander Distribution.—*Eurycea lucifuga* were detected in a small subset of locations that were surveyed, and these included both historic and newly documented sites. Of those historic sites that could be accessed, *E. lucifuga* were present at all except TSP, despite extensive searches within the park boundaries. Several explanations are possible. The species might have been extirpated from this location over the last 50 years, although that seems improbable as the habitat has underdone little or no changes during that period and because other rare and site-specific species (e.g., Green Salamanders, *A. aeneus*) have been found continuously in the park during the same period (Watkins et al. 2025). Another possibility is that the species might have been misidentified. Because no specimens were collected in TSP by Cliburn (1990), the *E. lucifuga* reported from TSP could have been a Long-tailed Salamander (*Eurycea longicauda*); the latter is a frequently observed species that can resemble *E. lucifuga*. A third possibility is that the specimens from TSP were collected elsewhere, and the locality was mislabeled. For example, photographs provided to WS of the 1967 TSP specimens (MVZ: Herp 91953–4) were positively identified as *E. lucifuga*, but five additional specimens (MVZ:

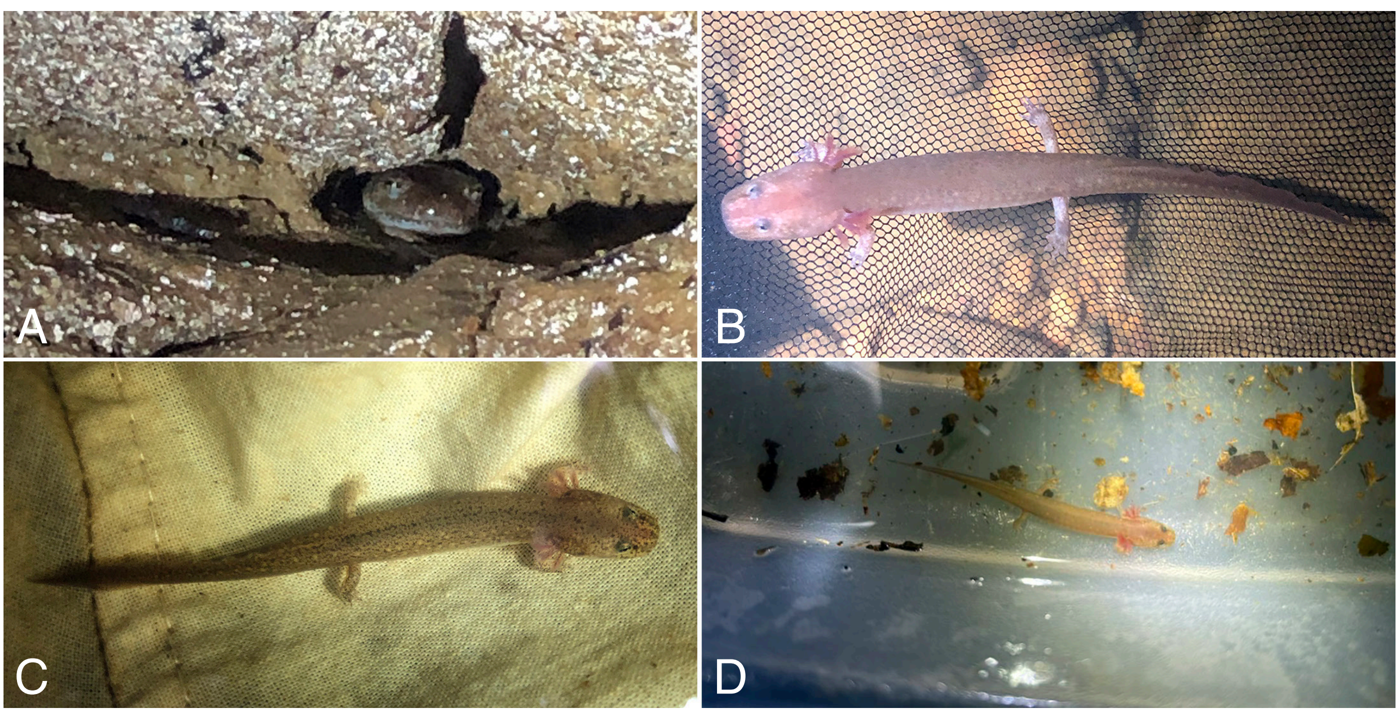

Figure 4. Observations of Spring Salamanders (*Gyrinophilus porphyriticus*) in Tishomingo County, Mississippi, with museum accession numbers to the digital archives of the Florida Museum of Natural History: Individuals observed during manual searching from (A) wet cave of Cave Springs (adult; 29 July 2021; UF 195470); (B) Mossy Canyon stream (larva; 21 July 2021; UF 195469); larvae captured with leaf-litter bags from (C) Bloody Springs (11 August 2022; UF 195475); (D) Mossy Canyon (28 July 2022; UF 195476). Photographs by Will Selman.

Herp 91955–9) were collected on the same day (3 April 1967) from "6 miles NE Tishomingo, Mingo Cave." Thus, all of the specimens from 3 August 1967 could have been collected at Mingo Cave (aka Cave Springs). Also, we do not know who collected the TSP and Mingo Cave specimens nor is any other information associated with the accession cards (C. Spencer, pers. comm.). In summation, we consider the TSP locality as "problematic" for numerous reasons, including the lack of specimen records by Cliburn (1990) and the possibilities of misidentification and erroneous collection locality plus the unknown provenance of the MVZ records. If we exclude the problematic TSP records because they are possibly extirpated/erroneous, the species is currently known from a small area along the Alabama state line in eastern Tishomingo County. Most of these locations are specifically associated with Hartselle Sandstone rock outcrops near Cedar Creek.

Although most observations of *E. lucifuga* were associated with caves/deep recesses, we also found them associated within crevices of Hartselle Sandstone. The crevice habitat used by *E. lucifuga* was similar to that typically occupied by *A. aeneus* (Watkins et al. 2025). Thus, finding additional *E. lucifuga* at Bloody Springs (sites U, V, W) or at site X would not be surprising. Nonetheless, although we did not document *E. lucifuga* in TSP, and future surveys should be conducted within the park to determine if the species is indeed not present in TSP. In summary, *E. lucifuga* appears to be a rare member of the salamander community and is currently known from only ~10 km^2 in Mississippi.

Cave Salamander CPUE.—Relatively little has been reported on the densities of *E. lucifuga* throughout its range, but our results suggest that *E. lucifuga* encounter rates are low in Mississippi compared to other locations in their range. Bradley and Eason (2022) conducted 73 surveys in Sauerkraut Cave in Kentucky, and the average count of *E. lucifuga* was 66 per visit with a maximum abundance of 492 individuals. Similarly, Hutchison (1958) found relatively high numbers of salamanders in several caves in western Virginia, with counts peaking at 3–20 individuals at multiple sites and estimated abundances varying from 36–63 individuals. In comparison, the highest number of *E. lucifuga* we recorded on a single visit was seven individuals in both the wet and dry sides of Cave Springs in 3.1 p-h (CPUE: 2.24/h). However, higher encounter rates have been recorded during spring and fall, suggesting the likelihood of seasonal differences in abundance (Hutchison 1958; Camp and Jensen 2007; Bradley and Eason 2022). Consequently, future spring or fall surveys at Mississippi sites might yield higher encounter rates than what we observed during our summer surveys. Also, mark-recapture studies would provide a better understanding of the abundance of *E. lucifuga* in Mississippi.

Spring Salamander Distribution.—Including both searches and LLB sampling, we documented *G. porphyriticus* at only four of 36 locations (11.1%), and only two of those generated consistent observations. The Cave Spring/Mingo Cave site is the largest known cave system in the area, and individuals have been observed here consistently since the 1960s and 1970s. At the Mossy Canyon site in TSP, we detected only larvae, but an adult individual was observed and photographed at this location in March 2022 (M. Jaunsen, pers. comm.), indicating a presence of both life history stages. Other historic localities were surveyed in TSP without detecting any individuals.

Although individuals were not detected at historic sites in TSP, suitable habitat remains there and on nearby private properties (sites R, X) where future surveys might detect them. Like *E. lucifuga*, *G. porphyriticus* also appears to be a rare member of the salamander community known from only ~20 km^2 in Mississippi. Future efforts should employ multiple methods at a broad range of locations during different seasons (e.g., spring and summer).

Spring Salamander CPUE.—We found *G. porphyriticus* to be a rare species in the salamander community in northeastern Mississippi, and this is similar to what is known about the species in other parts of its range. Williams (2015) found that *G. porphyriticus* comprised only 9% of the salamander community in groundwater seeps in Pennsylvania, and most of the observed individuals were larvae (79%) much like our study. Using LLBs in North Carolina, Mackey et al. (2010) found *G. porphyriticus* to be rare (2 of 374 total salamanders; 0.5%) and none were found using visual encounter surveys (0 of 316 total salamanders) (note, however, that the two individuals encountered during visual encounter surveys in this study were larvae). Using pitfall trap arrays in West Virginia, only four of 858 total salamanders captured were *G. porphyriticus* (0.46%; Anderson et al. 2012). One exception was when Miller and Niemiller (2007) found that *G. porphyriticus* were 37% of the salamanders encountered in cave streams in Tennessee, a very different habitat than the other studies mentioned. However, similar to other reports, Miller and Niemiller (2007) found mostly larval *G. porphyriticus* during surveys.

Because the species is often found in low abundance, detection probabilities likely are quite low even when the species is present, and detection probabilities likely vary by season as described for other similar salamander species (e.g., Bradley and Eason 2022). Indeed, a paired study in Quebec, Canada, found that traditional visual encounter surveys underestimated the presence of *G. porphyriticus* in streams compared to eDNA surveys; multiple stream sites had positive eDNA detections where no animals were observed with traditional visual encounter surveys (Plante et al. 2021). Because so little is known about the species and the seasonal abundance/detection rates of both larvae and adults, determining the optimal time for sampling is difficult. However, observations of the species appear to occur more frequently during the spring and early summer (March to June; iNaturalist 2025), suggesting that optimal times for surveys are likely during that period.

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