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HERPETOFAUNA OF THE CEDAR GLADES AND ASSOCIATED HABITATS OF THE INNER CENTRAL BASIN OF MIDDLE TENNESSEE

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***Abstract.*—The cedar glades and barrens of the Inner Central Basin (ICB) of middle Tennessee support a unique and diverse flora and fauna and represent some of the state's most valued natural areas. We conducted herpetofaunal inventories of the cedar glades, associated barrens, cedar-hardwood forest, and adjacent aquatic habitats of the Stones River drainage of Middle Tennessee, focusing our sampling effort primarily at seven state- or federally owned properties in Rutherford and Wilson counties. These properties included Stones River National Battlefield (SRNB), Flat Rock State Natural Area (FRSNA), Vesta Cedar Glade State Natural Area (VSNA), Fall Creek Recreation Area (FCRA) on J. Percy Priest Wildlife Management Area, Cedars of Lebanon State Forest (CLSF), Cedars of Lebanon State Forest Natural Area (CLSNA), and Cedars of Lebanon State Park (CLSP). We used a variety of inventory techniques in terrestrial, aquatic, and subterranean habitats to survey these properties periodically from 1989 to 2010. We documented 49 species (22 amphibian and 27 reptile) accounting for 75.4% of the 65 herpetofaunal species thought to occur in the ICB, including records for *Cemophora coccinea, Aneides aeneus, Gyrinophilus palleucus, Ambystoma barbouri,* and *Pseudotriton montanus*. We found differences in alpha and beta diversity between sites, with the CLSF complex containing a high of 41 herpetofaunal species and FRSNA containing a low of 23 species. Beta diversity comparisons indicated similarity in amphibian species composition between FRSNA and CLSF and between SRNB and CLSF (9 shared species), and in reptile species composition between VSNA and the CLSF complex (16 shared species). We compare the results of our inventory with two previous studies conducted in the area and discuss the relative abundance, conservation, and threats to the herpetofaunal community of these habitats.**

Key Words.—amphibians; cedar glades; conservation; diversity; reptiles; Tennessee

INTRODUCTION

Cedar glades are a highly imperiled ecosystem found primarily in the Inner Central Basin (ICB) of Middle Tennessee (Noss et al. 1995). These fragile habitats support diverse and unique communities of specialized flora and fauna, and several species of plants are endemic to cedar glades (Baskin and Baskin 1986, 1989). Cedar glades in the ICB are developed on Ordovician-aged limestones (e.g., Lebanon Limestone and Ridley Limestone; Killebrew and Safford 1874; Wilson 1980; Hershey and Maher 1985) and are characterized by naturally treeless openings with soil depths less than 20 cm surrounded by Eastern Red Cedar (*Juniperus virginiana*), or cedar-hardwood forest developed on flat to gently sloping terrain with shallow soils (Quarterman 1950; Baskin et al. 1994). The vegetation of the glades is dominated by plants that are adapted to an extreme microclimate characterized by high summer soil temperatures, high irradiance, and extreme variation in soil moisture content (Baskin and Baskin 1999, 2003). It includes C_4 summer annual grasses, C_3 winter annual herbaceous plants, summer annual herbaceous plants, perennial herbaceous dicots, mosses, and lichens (Baskin and Baskin 2003, 2004). Two associated habitats occur adjacent to cedar glades: (1) xeric limestone prairies with 20–30 cm of soil that are kept open by periodic anthropogenic burning (Baskin et al. 1994; Baskin and Baskin 2000), and (2) cedar/cedar-hardwood forest with 30+ cm of soil. The mosaic of these habitats zones create gradients along which light intensity, soil temperature, soil moisture, and, consequently, floral and faunal species composition, vary.

The flora of cedar glades and associated xeric limestone prairie, and cedar/cedar-hardwood forest has been well described (reviewed in Baskin and Baskin 2004), and more than 230 plant taxa occur in cedar glades, at least 14 of which are endemic (Baskin and Baskin 1999; Cofer et al. 2008). Relatively fewer studies have been conducted on the fauna of the cedar glades in the ICB (reviewed in Baskin and Baskin 2004),

but include those on invertebrates (Meyer 1937), protozoa (Martin and Sharp 1983), birds (Schultz 1930), shrews (Relford 1999), and amphibians and reptiles (Jordan et al. 1968; Jordan 1986). Jordan et al. (1968) listed 15 amphibian and 18 reptile species from Cedars of Lebanon State Forest in Wilson County, whereas Jordan (1986) listed 16 amphibian and 18 reptile species from Cedars of Lebanon State Park, Cedars of Lebanon State Forest, and Cedars of Lebanon State Natural Area.

Herpetofaunal species richness is high in many ecosystems throughout the southeastern United States. Because of the abundance of individuals of many of these species, amphibians and reptiles add significantly to the overall vertebrate biomass in many southeastern ecosystems (Congdon et al. 1986; Hairston 1987; Petranka and Murray 2001; Peterman et al. 2008). There has been increased interest in documenting species composition and abundance, particularly on public lands (All Taxa Biological Inventory; Gibbons et al. 1997), as concerns over amphibian and reptile population declines have intensified in recent years (Gibbons et al. 2000; Collins and Crump 2009). Few species and areas have been adequately inventoried or monitored for a long period of time (Bury et al. 1995); consequently, a significant need exists to inventory and monitor herpetofaunal populations to better understand the factors behind and distribution of population declines.

The two inventories of herpetofaunal species in cedar glade habitats (Jordan et al. 1968; Jordan 1986) provide baseline data for examining temporal variation in species composition. Here, we report on a herpetological inventory of cedar glades and associated xeric limestone prairie, cedar/cedar-hardwood forests, and adjacent streams and other aquatic habitats on seven state- or federally owned properties located within the ICB of Rutherford and Wilson counties in middle Tennessee, including the study areas of Jordan et al. (1968) and Jordan (1986). Using a variety of inventory techniques during periodic surveys from 1989–2010, we document the herpetofauna and relative abundance of each species in terrestrial, aquatic, and accessible subterranean habitats on each property if present, and we compare species composition among these land holdings. We also compare our results with those of the two previous studies conducted in the study area and discuss the conservation of and threats to the herpetofauna associated with cedar glades and barrens of Middle Tennessee. Collectively, we provide much needed data to develop effective monitoring programs and management strategies for the herpetofauna of this unique ecosystem.

MATERIALS AND METHODS

Study area.—We periodically inventoried seven state- or federally owned properties in the ICB of Middle Tennessee: Stones River National Battlefield (SRNB), Flat Rock Cedar Glades and Barrens State Natural Area (FRSNA), and Fall Creek Recreational Area (FCRA) on J. Percy Priest Wildlife Management Area in Rutherford County; as well as Vesta Cedar Glade State Natural Area (VSNA), Cedars of Lebanon State Park (CLSP), Cedars of Lebanon State Forest (CLSF), and Cedars of Lebanon State Forest Natural Area (CLSNA) in Wilson County (Fig. 1; Table 1; Appendix 1). All of these properties lie within the Stones River watershed, which ultimately flows into the Cumberland River. One major impoundment, J. Percy Priest Reservoir, borders FCRA. Dammed at mile 6.8 on the Stones River in 1968, this reservoir aids in flood control and has a surface area of 5,746 ha at full pool. Much of the land now under state or federal ownership was farmland, pastureland, or forest that was heavily timbered, burned, or damaged by grazing in the 19th and early 20th centuries (Noss et al. 1995). Size (in hectares) and dominant terrestrial and aquatic habitats varies among the seven properties (Table 1).

SRNB encompasses six separate units on the north side of the city of Murfreesboro: the Main Battlefield Park (MB), Artillery Monument (AM), Fortress Rosecrans (FR), Redoubt Brannan (RB), and the headquarters for General Bragg (HGB) and General Rosecrans (HGR). The 205 ha MB is primarily dry to mesic oak and oak-hickory-cedar forest with 24 ha of cedar glades and barrens (Hogan, T.L., and M. Webber. 1999. Vascular flora of Stones River National Battlefield including notes on natural communities and rare species. Unpublished report for Stones River National Battlefield, Murfreesboro, Tennessee.). Old-field communities and three agriculture fields are also present. The 65 ha AM is situated along the West Fork of the Stones River and is dominated by open-field habitats with some floodplain forest. A permanent pond, ephemeral stream, and two agricultural fields also are present on this tract. FR is 10 ha of predominantly mixed hardwood forest, rock outcrops, and the remnants of the original earthworks from the Civil War. A third-order stream, Lytle Creek, flows into an impoundment that overflows into the West Fork of the Stones River at FR. Several karst features, such as sinkholes and fissures, are present on MB, AM, and FR. The 2.2 ha RB also is situated along the West Fork of the Stones River and consists of floodplain forest, rock outcrops, and earthworks. A small pond is located on the property. HGB and HGR cover 2.8 and 0.16 ha, primarily as manicured lawn, and were not inventoried.

FRSNA is a state natural area just east of the city of Murfreesboro in Rutherford County and supports a mosaic of vegetative communities, including cedar hardwood forest, oak barrens, open grassland barrens, and cedar glades. Numerous ephemeral streams, sinkholes, and other karst features are present. FCRA is a

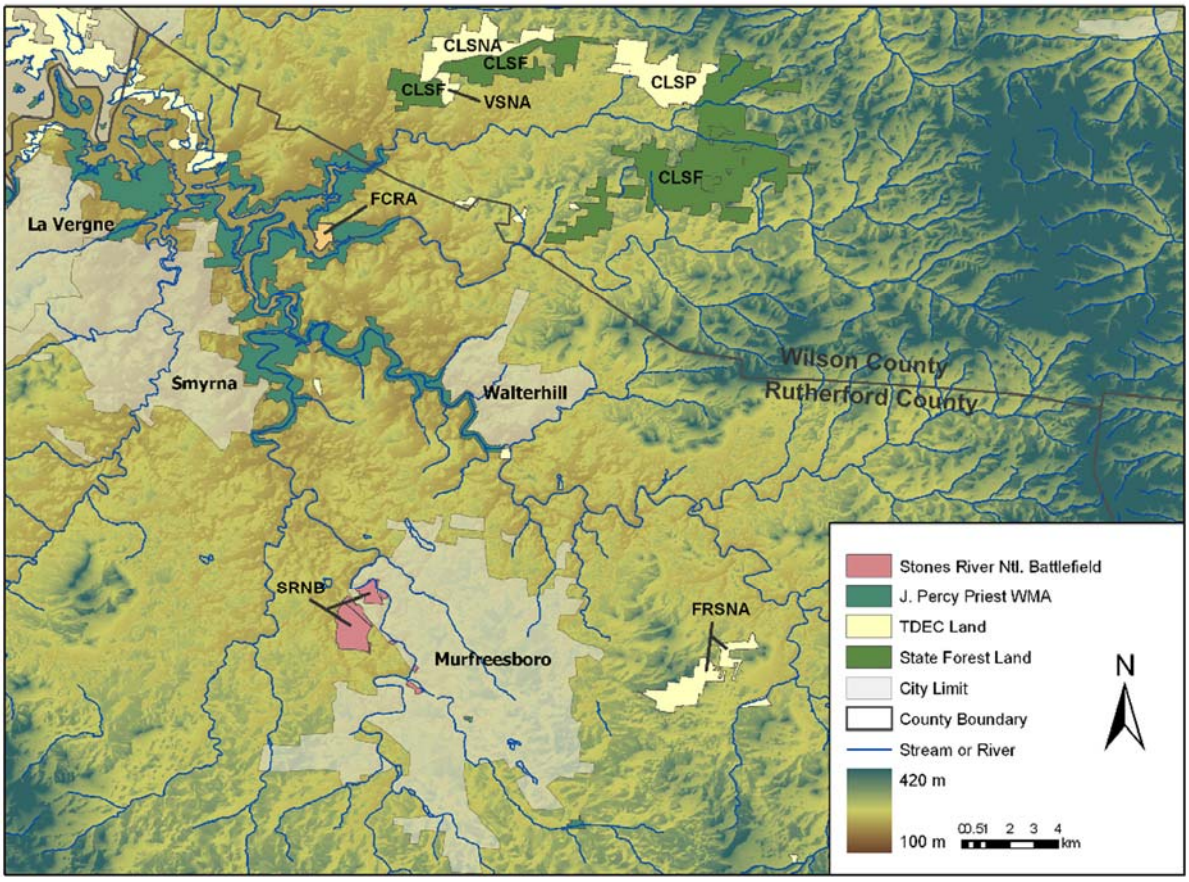

FIGURE 1. Locations and extent of state and federally-owned properties surveyed during the study of the herpetofauna of selected cedar glades and associated habitats in the Stones River drainage of the Inner Central Basin of middle Tennessee. Properties surveyed include Stones River National Battlefield (SRNB), Flat Rock Cedar Glades and Barrens State Natural Area (FRSNA), Fall Creek Recreational Area (FCRA), Vesta Cedar Glade State Natural Area (VSNA), Cedars of Lebanon State Park (CLSP), Cedars of Lebanon State Forest (CLSF), and Cedars of Lebanon State Forest Natural Area (CLSNA). Elevation is show in heat colors. Note that FCRA is located adjacent to the larger J. Percy Priest Wildlife Management Area (WMA), and VSNA is adjacent to the CLSF/CLSNA complex.

mixed-use area in Rutherford County bordered by the much larger J. Percy Priest Wildlife Management Area. It consists of a peninsula jutting into J. Percy Priest Lake and supports a mosaic vegetative community consisting of open grasslands, oak barrens, cedar forest, and cedar glades.

CLSP and CLSF are located 16 km south of the city of Lebanon in southern Wilson County. CLSP consists of 318 ha and is surrounded by the 3,812 ha CLSF. Included within CLSF is the 422 ha CLSNA. Because these properties are contiguous, we included them as a single property (listed as CLSF) in our statistical analyses. VSNA is a small preserve, 24 ha of which are located in the southwest corner of CLSF. Collectively, these lands represent the largest contiguous cedar glade-barren complex in public ownership in Tennessee. Moreover, karst topography dominates these four properties, which, therefore, lack perennial streams; rather, water drains into subterranean streams that flow into J. Percy Priest Reservoir. Numerous caves, sinkholes, and fissures are present; however, a few semi-permanent ponds also are found. Similar to many state parks, CLSP attracts much recreational activity including camping, picnicking, hiking, horseback riding, and other activities. Numerous trails are maintained on all these properties, especially on CLSF. Furthermore, off-road traffic has resulted in formation of ruts, many of which hold water throughout much of winter and spring seasons.

Survey methods.—The years that surveys were conducted and the techniques used differed among the seven properties (Table 1). We conducted surveys at SRNB from 15 April 2003 to 12 July 2004 during a federally funded inventory. Surveys on other properties were associated with undergraduate and graduate classes, other research projects, or direct surveys conducted by the authors. We conducted surveys at VSNA, FRSNA, and CLSFNA primarily from 2003–2010. Although conducted throughout the year, we

TABLE 1. Size, years surveyed, sampling effort, dominant terrestrial habitats, aquatic habitats present, and inventory techniques employed for the study sites in the Inner Central Basin of Middle Tennessee, USA, surveyed in the current study. Cedars of Lebanon State Forest includes Cedars of Lebanon State Park (CLSP; 318 ha) and Cedars of Lebanon State Forest Natural Area (CLSNA; 422 ha). Units for VES sampling effort is in average person hours per year.

Study Site	Size (ha)	Years Surveyed	VES Sampling Effort	Dominant Terrestrial Habitats	Aquatic Habitats	Techniques Employed
Rutherford County, TN						
Stones River National Battlefield (SRNB)	288	2003–2004	100	cedar/cedar-hardwood forest, cedar glades and barrens, old-field and agricultural fields, karst features and caves	perennial and ephemeral ponds, ephemeral streams, third-order streams, river	VES; dipnetting; minnow traps; road cruising; aural surveys; coverboards; drift-fence/funnel box arrays; hoop nets; crawfish nets
Flat Rock Cedar Glades and Barrens State Natural Area (FRSNA)	342	2003–2008	25	cedar/cedar-hardwood forest, cedar glades and barrens, old fields, karst features	ephemeral ponds, ephemeral streams	VES; dipnetting; minnow traps; aural surveys
Fall Creek Recreational Area on the J. Percy Priest Wildlife Management Area (FCRA)	250	1990–1992, 2010	8	Cedar-hardwood forest, cedar glades and barrens, karst features	ephemeral streams, reservoir	VES; road cruising; aural surveys
Wilson County, TN						
Cedars of Lebanon State Forest (CLSF)	4130	1989–2010	54	cedar/cedar-hardwood forest, cedar glades and barrens, old fields, karst features and caves	ephemeral ponds, ephemeral streams	VES; dipnetting; minnow traps; road cruising; aural surveys
Vesta Cedar Glade State Natural Area (VSNA)	61	2003–2010	12	cedar/cedar-hardwood forest, cedar glades and barrens, old fields, karst features	ephemeral streams	VES; aural surveys

intensified survey effort from March to October when most herpetofaunal species are active on the surface. We performed visual encounter surveys (VES) on all properties at different times of day and, because of use of students in vertebrate zoology and herpetology classes, of variable durations. Consequently, search effort differed among the sites (Table 1). We employed VES in as many terrestrial habitats as possible and included searching underneath natural (e.g., rocks and logs) and artificial cover objects for species that seek shelter under cover during unfavorable surface environmental conditions. All objects were returned to their original positions to reduce habitat disturbance. We also employed VES in several caves located on CLSF, CLSNA, and CLSP. We used dip nets (associated with VES), seines, and minnow traps to sample for aquatic amphibians in permanent and ephemeral ponds and wetlands. We conducted day and night road cruises (Karns 1986) along paved and unpaved roads at CLSF, CLSNA, and SRNB. Road cruises were primarily conducted during heavy precipitation events typically no more than two times per year and were often coupled with aural surveys for calling anurans. We employed aural surveys not in conjunction with road cruises at night and during the daytime on all properties. At SRNB, we checked coverboard arrays consisting of two wood and two tin coverboards weekly in conjunction with area-constrained VES at 17 randomly selected localities. Additionally, we employed two drift-fence/funnel box arrays at AM and MB at SRNB, which we checked daily while in operation. At the permanent pond on the AM at SRNB, we installed a 135 m drift fence with pitfall traps and checked this array daily while in operation. Additionally, we used baited hoop nets and modified deep-water crawfish nets (Glorioso and Niemiller 2006) to sample aquatic turtles at the permanent pond at AM, the permanent pond at RB, the West Fork of the Stones River at AM and RB, and the Lytle Creek impoundment at FR. Trapping for turtles occurred biweekly on average from April through June 2004. Furthermore, we augmented our inventory list by including amphibians and reptiles that were salvaged from pitfall traps used to examine the shrew community at CLSP and CLSF (Relford 1999).

We compiled a list of herpetofaunal species that potentially occur within the ICB. This was accomplished by reviewing existing museum records

TABLE 2. Protected and rare amphibians in the Inner Central Basin of Tennessee (after Withers 2009). State Status is a formal listing by the Tennessee Wildlife Resources Agency. State Ranks derive from a ranking system by The Nature Conservancy for estimating the abundance of animals tracked by Natural Heritage programs. Abbreviations are: Sites Observed: CLSF = Cedars of Lebanon State Forest, which includes Cedars of Lebanon State Park (CLSP) and Cedars of Lebanon State Forest Natural Area (CLSNA); State Status: E = Endangered, T = Threatened, D = Deemed in Need of Management; State Rank: S1 = Critically Imperiled, S2 = Imperiled, S3 = Vulnerable, S4 = Apparently Secure.

Common Name	Scientific Name	Sites Observed	State Status	State Rank
Amphibians				
Streamside Salamander	*Ambystoma barbouri*	CLSF	D	S2
Green Salamander	*Aneides aeneus*	CLSF	N/A	S3, S4
Eastern Hellbender	*Cryptobranchus alleganiensis*		D	S3
Tennessee Cave Salamander	*Gyrinophilus palleucus*	CLSF	T	S2
Reptiles				
Eastern Slender Glass Lizard	*Ophisaurus attenuatus longicaudus*	--	D	S3

and published range maps or species lists in the literature (Jordan et al. 1968; Jordan 1986; Redmond and Scott 1996; Conant and Collins 1998; Petranka 1998; Scott, A.F., and W.H. Redmond. 2008 [latest update: 15 June 2010]. Atlas of Reptiles in Tennessee. The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee. Available at http://apsu.edu/reptatlas/ [Accessed 18 June 2010]); Niemiller and Reynolds in press). We then compiled a list of species documented in either Wilson or Rutherford counties based on published sources, museum records, or our own observations from this study. These records represent a subsample of the potential species list and delimit the actual species composition of the Stones River drainage of the ICB (Wilson and Rutherford counties). In addition, we included records of species found by Jordan et al. (1968) and Jordan (1986) in the ICB. Finally, we recorded the species encountered at each property during our surveys. Nomenclature follows Crother et al. (2008). We took voucher specimens of each species observed in most cases and accessioned into the Herpetological Collection at Middle Tennessee State University. In other cases, we took photographic vouchers with a film or digital camera and accessioned these into the Herpetological Collection at Austin Peay State University. We defined alpha diversity as the number of species at a site and beta diversity as the difference in species between two sites.

RESULTS

The distributions of 29 species of amphibians and 36 species of reptiles involve all or portions of the Inner Central Basin (ICB) of middle Tennessee (Appendix 1) and, therefore, potentially occur on the state- or federally managed properties we surveyed. Six of these species (four amphibians and one reptile) are endangered, threatened, deemed in need of management, or otherwise tracked by state agencies (Table 2). Based on published sources and this study, 27 of 29 (93.1%) amphibian species and 33 of 36 (91.7%) reptile species with distributions potentially associated with the ICB have been documented in Rutherford or Wilson County. This includes 11 of 12 (91.6%) anuran, 17 of 17 (100%) salamander, 17 of 20 (85.0%) snake, 7 of 7 (100%) lizard, and 9 of 9 (100%) turtle species (Appendix 1). During this study, we documented 22 amphibian and 27 reptile species in the cedar glades, associated xeric barren habitat, and adjacent streams and other aquatic habitats (e.g., rivers, ponds, and reservoirs) on the publicly owned lands surveyed (Appendix 1). These records represent 81.5% of the 27 amphibian species and 81.8% of the 33 reptile species documented in Rutherford or Wilson County. Three of the species we documented on at least one of the state- or federally owned properties are state-listed or tracked (e.g., *Ambystoma barbouri*, *Aneides aeneus*, and *Gyrinophilus palleucus*).

We conducted surveys for > 20 years only at CLSF, and hence this is the only site for which we have good relative abundance through time data. In general, the herpetofaunal community of CLSF remained largely unchanged during this period, though some notable exceptions follow. *Plestiodon inexpectatus* was not identified until 2003, and since this initial discovery, this species has been routinely identified during surveys. Similarly, *Ambystoma barbouri* was not discovered at CLSF until 2010. This species was found only at one ephemeral stream, which was not searched during the first 20 years. In contrast, we found *Cemophora coccinea*, and *Pseudotriton montanus* only during early survey years, and these species were never abundant. We found only one *C. coccinea* during May 1990, and we found < 10 *P. montanus* at one ephemeral stream during 1990 and 1991. Neither of these species has been found since. Similarly, we found only one *Aneides aeneus* and three *Gyrinophilus palleucus* during our surveys.

Change in relative abundance of other species was not observed. For example, the snake community was

TABLE 3. Number of herpetofaunal species found by site, followed by proportion (in parentheses) of species for which records exist in the each county. Abbreviations are: SRNB - Stones River National Battlefield, FRSNA - Flat Rock Cedar Glades and Barrens State Natural Area, VSNA - Vesta Cedar Glade State Natural Area, FCRA - Fall Creek Recreational Area on the J. Percy Priest Wildlife Management Area, and CLSF - Cedars of Lebanon State Forest, which includes Cedars of Lebanon State Park (CLSP) and Cedars of Lebanon State Forest Natural Area (CLSNA) for this analysis.

Major group	Rutherford Co.			Wilson Co.	
	SRNB	FCRA	FRSNA	VSNA	CLSF
Amphibians	11 (0.42)	9 (0.35)	9 (0.35)	8 (0.35)	20 (0.87)
Reptiles	18 (0.58)	15 (0.48)	14 (0.45)	16 (0.67)	21 (0.88)

dominated by three large-bodied species (*Lampropeltis getula, L. triangulum,* and *Coluber constrictor*), and several small-bodied species (*Carphophis amoenus, Diadophis punctatus, Tantilla coronata,* and *Virginia valeriae*) that we commonly encountered during surveys, particularly those conducted during the spring and fall (Appendix 1). The snake community also included *Crotalus horridus* and *Pantherophis spiloides*, though these two species were not encountered as frequently as other species listed above. We found < 10 individuals of each species, with the occurrences scattered during the years, such that no trend in change of abundance of *C. horridus* and *P. spiloides* was detected. Aside from the discovery of *P. inexpectatus* 15 years into the project, the lizard community was relatively stable (Appendix 1). The salamander community at CLSF was dominated by two species, and both were common inhabitants of the glades and surrounding habitats. *Eurycea lucifuga* was most commonly encountered from spring through early summer; whereas, *Plethodon dorsalis* was most commonly encountered from late fall (November) through early spring (April). Aside from the seasonal shift in abundance, we detected no trend in relative abundance for either species. Also seasonally abundant were *Ambystoma maculatum* and *A. opacum*. Although not as widely distributed as *E. lucifuga* and *P. dorsalis*, we found these two ambystomatid species often in association with breeding sites, such as ditches and ruts made from off-road vehicles. Also, we commonly encountered *Notophthalmus viridescens* in these same bodies of water. We detected no change in the anuran community, with all species encountered being relatively abundant throughout the areas surveyed (Appendix 1).

Alpha diversity was highest for amphibians (20 species) and for reptiles (21 species) at CLSF (including CLSP and CLSNA; Appendix 1; Tables 3 and 4). Indeed, we found 87% of the herpetofaunal species documented in Wilson County at CLSF, and 68.3% of the species found in either Rutherford or Wilson counties. Furthermore, Jordan (1986) reported three species at CLSF that we did not document (*Lithobates sphenocephalus*, *Heterodon platirhinos*, and *Trachemys scripta*). When these three species are included, CLSF includes 10 of 10 (100%) frog, 11 of 13 salamander (84.6%), 14 of 15 (93.3%) snake, 6 of 6 (100%) lizard, and 3 of 3 (100%) turtle species documented from Wilson County. Amphibian alpha diversity was lowest at VSNA (eight species), whereas reptile alpha diversity was lowest at FRSNA (14 species; Appendix 1; Tables 3 and 4).

Beta diversity, or the difference in species composition between two sites, indicates similarity of species composition when the proportion of shared species between sites is maximized. Highest similarity of species composition for amphibians was found for the properties FRSNA and VSNA, which shared nearly 80% of species (Table 4). Non-shared species include *Gastrophryne carolinensis* (VSNA only), *Ambystoma opacum* (FRSNA only) and *Notophthalmus viridescens*

TABLE 4. Intersite comparisons of alpha and beta diversity of reptile and amphibian communities at five sites in Middle Tennessee. Abbreviations are: SRNB - Stones River National Battlefield, FRSNA - Flat Rock Cedar Glades and Barrens State Natural Area, VSNA - Vesta Cedar Glade State Natural Area, FCRA - J. Percy Priest Wildlife Management Area, and CLSF - Cedars of Lebanon State Forest. For this analysis, CLSF includes CLSF, Cedars of Lebanon State Park (CLSP), and Cedars of Lebanon State Natural Area (CLSNA).

Sites being compared		No. of Species Observed					
		Amphibians			Reptiles		
Site1	Site 2	Site 1	Site 2	Shared	Site 1	Site 2	Shared
SRNB	FRSNA	11	9	6	18	14	9
SRNB	VSNA	11	8	6	18	16	9
SRNB	FCRA	11	9	6	18	15	11
SRNB	CLSF	11	20	9	18	21	12
FRSNA	VSNA	9	8	7	14	16	13
FRSNA	FRSNA	9	9	6	14	15	8
FRSNA	CLSF	9	20	9	14	21	14
VSNA	FRSNA	8	9	6	16	15	10
VSNA	CLSF	8	20	8	16	21	16
FCRA	CLSF	9	20	8	15	21	13

(FRSNA only). Highest amphibian beta diversity, or least similarity of species composition, occurs between FCRA and CLSF (Table 4).

Reptile beta diversity comparisons indicated highest similarity of species composition between FRSNA and VSNA (Table 4) and between VSNA and CLSF (Table 4). Least similarity of reptile species composition was found between SRNB and VSNA (Table 4).

DISCUSSION

The cedar glades and associated xeric barren habitat in the ICB of Rutherford and Wilson counties in Middle Tennessee support a diverse flora and fauna, and the herpetofauna is no exception. Of the 65 species of amphibians and reptiles with distributions potentially including the ICB, 60 (92.3%, 27 amphibian and 33 reptile) have been documented from these two counties. Nonetheless, five species thought to occur in the ICB have never been reported from Rutherford County or Wilson County: *Storeria dekayi, Storeria occipitomaculata, Lampropeltis calligaster*, *Pseudacris crucifer*, and *Hemidactylium scutatum*. Three of these species are snakes (i.e., *S. dekayi, S. occipitomaculata,* and *L. calligaster*) that are found throughout the Eastern and Western Highland Rim and, therefore, have distributions that border or surround the Central Basin (Scott and Redmond *op cit.*). Each of these species is associated with the mesic forest understory common in these ecoregions, and though much less common, this habitat is present in the ICB of Rutherford and Wilson counties. Searches that focus on locating these species in the mesic forest understory in these counties are needed to help us better understand their distribution.

The lack of records for *Pseudacris crucifer* in these counties is perplexing. This species is found throughout the Eastern and Western Highland Rims and in much of the Outer Central Basin (Redmond and Scott 1996; Niemiller and Reynolds in press). Furthermore, this species is vocal and easily identified, and suitable habitat exists, as indicated by the presence of *P. feriarum*. We are unable to explain the lack of records for *P. crucifer* at our study sites in particular, and in Rutherford and Wilson counties in general.

Hemidactylium scutatum, suggested as an inhabitant of the ICB (Conant and Collins 1998), has yet to be documented in either Rutherford or Wilson counties. This species is tracked by state agencies (Withers 2009), and has been documented from nearby adjacent counties in the Eastern Highland Rim (Redmond and Scott 1996; Miller et al. 2005; Niemiller and Reynolds in press). Although found in counties bordering the ICB, breeding habitat required by *H. scutatum* (e.g., vernal ponds with mossy banks) is limited in the ICB. Consequently, we doubt that this species is a component of the herpetofauna of Rutherford or Wilson counties.

We documented 49 herpetofaunal species (22 amphibians and 27 reptiles) from the seven state and federal properties inventoried. The only species not observed, but previously documented from Rutherford or Wilson County include *Cryptobranchus alleganiensis*, *Necturus maculosus*, *Desmognathus conanti*, *Eurycea cirrigera*, *Plethodon glutinosus*, *Heterodon platirhinos*, *Pantherophis guttatus*, *Ophisaurus attenuatus*, and *Kinosternon subrubrum*. *Cryptobranchus alleganiensis* and *N. maculosus* are associated with permanent, aquatic habitats that are largely absent from the study areas, with the exception of the Stones River that borders SRNB and FCRA. Although published records are lacking, *N. maculosus* occurs in the Stones River of Rutherford County (B.T. Miller, pers. obs.). The only published record for *C. alleganiensis* in the Stones River is from the Spring Creek confluence of J. Percy Priest Reservoir, just north of FCRA (Miller and Miller 2009). *Desmognathus conanti*, *E. cirrigera*, *Plethodon glutinosus*, and *Pantherophis guttatus* are associated with mesic hardwood forests, habitat found along the escarpment of the Eastern Highland Rim in southeastern Rutherford County; however, *E. cirrigera* occurs in ephemeral streams in the ICB (Niemiller et al. 2009) and in the perennial Lytle Creek in the city limits of Murfreesboro (Miller and Niemiller, pers. obs.). There is a single record of *D. conanti* from Rutherford County in the ICB (Redmond and Scott 1996); however, no individuals have been found recently, suggesting that most populations of *D. conanti* in the ICB have been extirpated or that this species was never abundant. *Heterodon platirhinos* was previously documented from CLSF by Jordan et al. (1968) and Jordan (1986), though we failed to locate this species in our surveys.

We documented 15 of the 16 species of amphibians and 16 of the 18 species of reptiles reported by Jordan et al. (1968) and Jordan (1986) from the CLSF (CLSF, CLSNA, and CLSP), as only *Lithobates sphenocephalus*, *Trachemys scripta*, and *H. platirhinos* were not observed. However, we documented an additional five species of amphibians and five species of reptiles not reported previously. Other than *Scincella lateralis*, *Virginia valeriae*, and *Agkistrodon contortrix*, these species records were based on just a few individuals observed (e.g., *Ambystoma tigrinum*, *Eurycea longicauda*, *Gyrinophilus palleucus*, *Nerodia sipedon*, and *Chelydra serpentina*) or from a single locality (e.g., *A. barbouri* and *Pseudotriton montanus*). Long-term studies allow for more accurate estimations of total species richness (Gibbons 1997; Gibbons et al. 1997); consequently, we suspect that the longer duration of our study enabled us to discover more species than reported previously (Jordan et al. 1968; Jordan 1986). However, we are uncertain why *Virginia valeriae* and *Scincella*

lateralis, common inhabitants of the glades during the 1990s and 2000s, were not encountered during earlier surveys.

Three species documented during the current study are species of conservation concern and tracked by state agencies in Tennessee. *Aneides aeneus* is typically associated with rock outcrops along the escarpments of the Cumberland Plateau in Tennessee (Redmond and Scott 1996; Petranka 1998; Niemiller and Reynolds in press). However, this species was reported from a sinkhole in CLSP by McKinney and Snyder (1973) and included in the species list of Jordan (1986). In a study that examined the shrew community at CLSP and CLSF (Relford 1999) several amphibians and reptiles, particularly salamanders, were unintentionally captured in pitfall traps. Upon examination of the bycatch, a juvenile *A. aeneus* was identified representing the second record from CLSP. These records are a 90-km western range extension and likely represent a relic population (Jordan 1986). *Gyrinophilus palleucus* was reported from Jackson Cave in CLSP by Miller and Walther (1994) but has not been observed since despite numerous surveys (Miller and Niemiller 2008). In November 2008, a cave mapping expedition led by Ken Oeser observed a *G. palleucus* in an upstream extension to Jackson Cave reconfirming its presence in the cave system (K. Oeser, pers. comm.). Finally, *A. barbouri* has a very limited distributed in the Central Basin of middle Tennessee, and few breeding streams have been identified (Niemiller et al. 2006, 2009; Niemiller and Reynolds in press). Several egg masses attached to the undersurfaces of rocks in a perennial stream in CLSNA were observed in March 2010 (A. Fowler and F. Scott, pers. comm.). On 5 April 2010, we visited the stream and observed a few hundred ambystomatid larvae, which were later confirmed as *A. barbouri*. This record extends the range of *A. barbouri* northeast in the ICB towards the presumably disjunct record from Jackson County, Tennessee (Scott et al. 1997).

Considerable diversity in herpetofaunal species composition occurs among the five properties. Alpha diversity is highest for amphibians and for reptiles in the CLSF area, which is composed of the CLSP, CLSF, and CLSNA and is the largest of the properties surveyed at 4,130 ha. However, survey work was localized within CLSF, such that we surveyed only a small portion of the entire property. CLSF contains a variety of habitats, including open cedar glades, hardwood forest, ephemeral ponds and streams, and karst features, such as caves, sinkholes, and fissures. This diversity of habitats likely accounts for the high alpha diversity observed at this site, and emphasizes the importance of protecting large diverse habitats. The other properties had similar alpha diversities of amphibians, with a high of 11 species at SRNB and a low of eight species at VSNA. VSNA is a small, xeric property that largely lacks water features, though some ephemeral streams occur on the property, and hence we expected amphibian diversity to be lower at this site. Reptile alpha diversity was also similar among properties other than CLSF, with a high of 18 species at SRNB and low of 14 species at FRSNA. Though smaller at only 288 ha, SRNB includes cedar glades and barrens habitat, hardwood forest, floodplain forest, permanent water sources, and old-field communities representing a diverse array of reptile habitats. FRSNA is larger (342 ha), but lacks old-field, floodplain forest, or permanent aquatic features; hence, turtles are underrepresented there and reptile alpha diversity is lower. The diversity in herpetofaunal species composition across these properties highlights the importance of conserving varied habitats regardless of how small an area in an already fragmented landscape in the ICB.

Beta diversity comparisons indicate that the highest similarity of species composition between FRSNA and VSNA and the least similarity of species composition between FCRA and CLSF. These properties are of similar terrestrial habitat, though considerable differences exist in availability and type of aquatic habitat. CLSF and FRSNA both contain numerous ephemeral streams and ponds as well as sinkholes and other karst features, providing breeding habitat for a variety of amphibians. Aquatic habitat at FCRA consists only of margins of J. Percy Priest Reservoir and no other permanent or ephemeral water sources, hence reducing the diversity of amphibians at that site. Two hylid and three ranid frogs were found at CLSF but were not documented at FCRA. It is possible that this is an artifact of sampling error, as *Acris crepitans*, *Lithobates catesbeianus*, *L. clamitans,* and *L. palustris* likely occur at FCRA, though our surveys did not document these species. Salamander diversity was quite different between the two sites, likely due to the dissimilarity of habitats included within the two properties. All salamander species found at FCRA were also located at CLSF, though CLSF has ephemeral ponds and karst features, and hence includes salamanders associated with these habitats (e.g., *Ambystoma spp.*, *Aneides aeneus*, and *Gyrinophilus palleucus*).

Reptile beta diversity comparisons indicated highest similarity of species composition between FRSNA and VSNA and between VSNA and CLSF. These three properties are all of similar cedar glade, barren, and hardwood forest habitat, and the small differences in reptile species composition are driven by the occurrence of uncommon species, such as *Cemophora coccinea* (VSNA only), *Tantilla coronata* (VSNA and CLSF), and *Crotalus horridus* (FRSNA and CLSF). Least similarity of reptile species composition was found between SRNB and VSNA. This is largely due to the lack of aquatic turtles at VSNA, and the documentation of secretive

snakes at VSNA (e.g., *C. coccinea*, *Virginia valeriae*, and *T. coronata*).

According to data provided by the Tennessee Department of Environment and Conservation in 1993, Tennessee lost approximately 50% of total cedar glade area and 90% of ecologically intact cedar glades, rendering cedar glades an endangered ecosystem within the Central Basin (Noss et al. 1995). The loss of glade habitat will likely continue as the human population is projected to continue to grow in Rutherford and Wilson counties during the next 20 years. For example, the population of Rutherford County was 182,023 in the year 2000, estimated at 251,596 in 2010, and projected to be 420,465 in 2030 (Middleton and Murray 2009). Of note, the population of the unincorporated areas of this county is projected to nearly double that of the 2000 level in the next two decades (2000: 68,487; 2010: 81,715; 2030:133,377; Middleton and Murray 2009). Furthermore, fire is an important technique used to maintain cedar glade habitats, but agencies responsible for the conservation of these habitats are hesitant to burn as human habitation encroaches. The consequence of loss of cedar glade habitat to amphibian and reptile distribution or abundance is difficult to assess, because none of these species are known glade endemics. Several species are, however, more frequently encountered in rocky glade openings than in more mesic forests, including *T. coronata*, *Plestiodon inexpectatus*, and *Aspidoscelis sexlineata*. Many of the cedar glades, barrens, and surrounding cedar hardwood forest on the CLSF have been severely eroded and degraded because of high off-highway vehicle (OHV) use. In addition, exposed rocks are often removed from glades for use in landscaping, a practice which can severely degrade habitat for reptiles (Webb and Shine 2000; Pike et al. 2010).

In summary, this study synthesizes knowledge of the occurrence and distribution of reptiles and amphibians in the cedar glades and associated habitats of the Inner Central Basin of Tennessee. Building on the work of Jordan et al. (1968) and Jordan (1986), we incorporated 20 years worth of survey data on seven properties to calculate alpha and beta diversity between sites and identify properties that maintain high levels of herpetofaunal diversity. This is especially important given the significant and continuing loss of cedar glades habitat and its modification through human activities such as off-road vehicle use and rock gathering.

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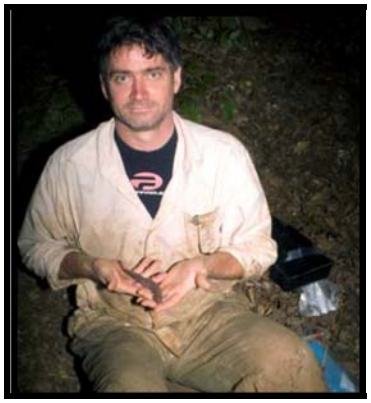

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APPENDIX 1. Records (denoted by triangles) and relative abundance (denoted by + symbols) of herpetofaunal species known from five sites in the Inner Central Basin of Middle Tennessee based on published records and results of the current study. Historic records are from Jordan (1986) and Jordan et al. (1968). All species known from Rutherford and Wilson counties are also indicated (see text). Abbreviations are as follows: SRNB - Stones River National Battlefield, FRSNA - Flat Rock Cedar Glades and Barrens State Natural Area, FCRA - Fall Creek Recreational Area on the J. Percy Priest Wildlife Management Area, VSNA - Vesta Cedar Glade State Natural Area, and CLSF - Cedars of Lebanon State Forest, which includes Cedars of Lebanon State Park (CLSP) and Cedars of Lebanon State Forest Natural Area (CLSNA). Relative abundance denoted as follows: + = < 2 occurrences/yr, ++ 2–10 occurrences/yr, +++ 10–20 occurrences/yr, and ++++ > 20 occurrences/yr.

Scientific Name	Common Name	SRNB	FRSNA	FCRA	VSNA	CLSF	Jordan et al. 1968	Jordan 1986	Rutherford Co.	Wilson Co.
Anurans										
Family Bufonidae										
Anaxyrus a. americanus	Eastern American Toad		++++	++++	++++	++++	▲	▲	▲	▲
Anaxyrus fowleri	Fowler's Toad		++++	++++	++++	++++	▲	▲	▲	▲
Family Hylidae										
Acris crepitans	Eastern Cricket Frog	++	+		++	++	▲	▲	▲	▲
Hyla chrysoscelis	Cope's Gray Treefrog	+++	++	+++	++	+++	▲	▲	▲	▲
Pseudacris crucifer	Spring Peeper									
Pseudacris feriarum	Upland Chorus Frog	+	++++		++	+++	▲	▲	▲	▲
Family Microhylidae										
Gastrophryne carolinensis	Eastern Narrow-mouthed Toad	++		+++	++	++	▲	▲	▲	▲
Family Pelobatidae										
Scaphiopus holbrookii	Eastern Spadefoot	++		+					▲	
Family Ranidae										
Lithobates catesbeianus	American Bullfrog	++++				++	▲	▲	▲	▲
Lithobates clamitans melanotus	Northern Green Frog					+++	▲	▲		▲
Lithobates palustris	Pickerel Frog					+++	▲	▲	▲	▲
Lithobates sphenocephalus utricularius	Southern Leopard Frog	+++					▲	▲	▲	▲
Salamanders										
Family Cryptobranchidae										
Cryptobranchus a. alleganiensis	Eastern Hellbender								▲	
Family Proteidae										
Necturus m. maculosus	Common Mudpuppy								▲	▲
Family Ambystomatidae										
Ambystoma barbouri	Streamside Salamander					++			▲	▲
Ambystoma maculatum	Spotted Salamander			++		+++	▲	▲	▲	▲
Ambystoma opacum	Marbled Salamander		+			+++	▲	▲	▲	▲
Ambystoma t. tigrinum	Eastern Tiger Salamander	+				+			▲	▲
Family Salamandridae										
Notophthalmus v. viridescens	Red-spotted Newt	+	+++	++		++++	▲	▲	▲	▲

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APPENDIX I. *Continued.*

Family Plethodontidae										
Aneides aeneus	Green Salamander					+		▲		▲
Desmognathus conanti	Spotted Dusky Salamander								▲	
Eurycea cirrigera	Southern Two-lined Salamander								▲	
Eurycea l. longicauda	Long-tailed Salamander					++			▲	▲
Eurycea lucifuga	Cave Salamander	+	++	++	++	++++	▲	▲	▲	▲
Gyrinophilus palleucus necturoides	Big Mouth Cave Salamander					+			▲	▲
Hemidactylium scutatum	Four-toed Salamander									
Plethodon dorsalis	Northern Zigzag Salamander	+++	++++	+++	++++	++++	▲	▲	▲	▲
Plethodon glutinosus	Northern Slimy Salamander								▲	▲
Pseudotriton montanus diastictus	Midland Mud Salamander					+			▲	▲
Snakes										
Family Colubridae										
Carphophis amoenus helenae	Midwestern Wormsnake		++	++	+++	++++	▲	▲	▲	▲
Cemophora coccinea copei	Northern Scarletsnake				+	+	▲	▲	▲	▲
Coluber c. constrictor	Northern Black Racer	++	+++		++	++	▲	▲	▲	▲
Diadophis punctatus stictogenys	Mississippi Ring-necked Snake		++		+++	++++	▲	▲	▲	▲
Heterodon platirhinos	Eastern Hog-nosed Snake						▲	▲		▲
Lampropeltis calligaster rhombomaculata	Mole Kingsnake									
Lampropeltis getula nigra	Eastern Black Kingsnake	++	++	+	++	++	▲	▲	▲	▲
Lampropeltis triangulum triangulum	Eastern Milksnake	+	++	+	++	++	▲	▲	▲	▲
Opheodrys a. aestivus	Northern Rough Greensnake	++		+					▲	
APPENDIX *continued*										
Pantherophis guttatus	Red Cornsnake								▲	
Pantherophis spiloides	Gray Ratsnake	++	++	++	++	++	▲	▲	▲	▲
Tantilla coronata	Southeastern Crowned Snake			++	++	++	▲	▲	▲	▲
Family Natricidae										
Nerodia sipedon pleuralis	Midland Watersnake	++				+			▲	▲
Regina septemvittata	Queen Snake	++							▲	▲
Storeria dekayi wrightorum	Midland Brownsnake									
Storeria occipitomaculata occipitomaculata	Northern Red-bellied Snake									
Thamnophis s. sirtalis	Eastern Gartersnake	++	++		+	+	▲	▲	▲	▲
Virginia v. valeriae	Eastern Smooth Earthsnake			+	++	++			▲	▲
Family Viperidae										
Agkistrodon contortrix mokasen	Northern Copperhead		+		++	++			▲	▲
Crotalus horridus	Timber Rattlesnake		++			++	▲	▲	▲	▲
Lizards										
Family Anguidae										

APPENDIX I. *Continued*.

Ophisaurus attenuatus longicaudus	Eastern Slender Glass Lizard								▲	
Family Phrynosomatidae										
Sceloporus undulatus	Eastern Fence Lizard	+++	++++	++	++++	++++	▲	▲	▲	▲
Family Scincidae										
Plestiodon fasciatus	Common Five-lined Skink	++	++	++	++	++++	▲	▲	▲	▲
Plestiodon inexpectatus	Southeastern Five-lined Skink			+		++	▲	▲	▲	▲
Plestiodon laticeps	Broad-headed Skink	++		+		++	▲	▲	▲	▲
Scincella lateralis	Little Brown Skink	+	+++	++	++	+++			▲	▲
Family Teiidae										
Aspidoscelis s. sexlineata	Eastern Six-lined Racerunner		+++		++	++	▲	▲	▲	▲
Turtles										
Family Chelydridae										
Chelydra s. serpentina	Eastern Snapping Turtle	++		+		+			▲	▲
Family Kinosternidae										
Kinosternon s. subrubrum	Eastern Mud Turtle								▲	
Sternotherus odoratus	Stinkpot	++++							▲	
Family Emydidae										
Chrysemys picta	Eastern Painted Turtle								▲	
Graptemys geographica	Northern Map Turtle	++		+					▲	
Pseudemys c. concinna	Eastern River Cooter								▲	
Terrapene c. carolina	Eastern Box Turtle	++	++	++	++	++	▲	▲	▲	▲
Trachemys scripta elegans	Red-eared Slider	++++					▲	▲	▲	▲
Family Trionychidae										
Apalone s. spinifera	Eastern Spiny Softshell	++							▲	