Capture-site Characteristics for Eastern Spotted Skunks in Mature Forests during Summer

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Abstract - *Spilogale putorius* (Eastern Spotted Skunk) is an increasingly rare species undergoing population declines throughout many portions of its range. We incidentally captured Eastern Spotted Skunks in snake traps during a study examining effects of woodland restoration on herpetofauna in the Ouachita Mountains of Arkansas. We used extensive habitat data collected at each trap site to determine potential characteristics of sites where Eastern Spotted Skunks were more likely to occur during summer. We recorded 18 Eastern Spotted Skunk captures in 10 of our 36 drift-fence traps. Capture rates of Eastern Spotted Skunks were 6 times greater and occupancy rates were 9 times greater in unmanaged, mature forests with a well-developed midstory than in frequently burned woodlands that lacked a midstory. Higher-occupancy rates were associated with greater total cover, greater cover of woody-understory vegetation, and sparse forb cover. Our data support those of previous studies that suggest Eastern Spotted Skunks occur in areas with dense cover, which may include mature forests with well-developed midstories.

Introduction

Spilogale putorius (L.) (Eastern Spotted Skunk) has undergone widespread declines in abundance over several decades and is a species of concern in many states across its range (Gompper and Hackett 2005). Despite its increasing rarity, studies of Eastern Spotted Skunk habitat use are limited and its habitat associations remain unclear. For example, Eastern Spotted Skunks have been associated with prairies (Crabb 1948), *Quercus* spp. (oak)–*Carya* spp. (hickory) forests (forest-age unknown; McCullough and Fritzell 1984), or young, regenerating forest and mature hardwood forests (Lesmeister et al. 2009). In the Appalachian Mountains, they were found in dense thickets of *Rhododendron* (rhododendron) and *Kalmia latifolia* L. (Mountain Laurel) (Diggins et al. 2015, Reed and Kennedy 2000, Wilson et al. 2016), and in young to mid-successional (<50 years old) forest (Thorne et al. 2017). To achieve better understanding of this species and potential reasons for its decline, more information is needed on the species' habitat associations and how land management may affect presence.

Land managers throughout North America are implementing woodland and savanna restoration programs to recreate the open forest conditions that historically existed in many regions prior to European settlement (e.g., Spetich et al. 2011). In the Ouachita National Forest (ONF) of Arkansas and Oklahoma, ~142,000 ha have been targeted for restoration of *Pinus* (pine) woodlands. To restore this community,

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the overstories of mature (generally >50 years old) forests are thinned, midstories are removed or reduced, and stands are subjected to prescribed burns at 3–5-year intervals. These efforts result in open forest stands with an herbaceous understory and little or no midstory (Fig. 1).

Lesmeister et al. (2013) examined habitat use by Eastern Spotted Skunks in restored woodlands of the ONF and found that the species was negatively associated with restored woodlands. In that study, Eastern Spotted Skunks were associated with young, cluttered, regenerating forests and with mature hardwood forests. However, during a study comparing herpetofauna communities in 2 types of mature forest (restored pine woodlands and unmanaged pine-dominated forests >60 years old) in the ONF (Perry et al. 2009), we incidentally captured Eastern Spotted Skunks in many of our traps. These captures presented an opportunity to delineate structural characteristics of mature forests that may affect the presence of Eastern Spotted Skunks. We analyzed capture data for Eastern Spotted Skunks along with several vegetation measures collected at each trap site with the goal of determining attributes of mature forests that may affect presence of this rare species.

Materials and Methods

We conducted our study on the Poteau–Cold Springs Ranger District of the ONF (Scott County, AR) in the Ouachita Mountains. The Ouachita Mountains extend from central Arkansas into eastern Oklahoma and consist of a series of east–west-oriented mountains, with elevations varying from 100 m to 800 m. The predominant forest type in the area is mixed *Pinus echinata* Mill. (Shortleaf Pine)–hardwood forests, but hardwood and riparian forests occur throughout the

Figure 1. Mature, unmanaged forest (left) and restored Shortleaf Pine woodland (right) where Eastern Spotted Skunks were captured in the Ouachita Mountains of Arkansas, 1999−2001. Photographs © Roger W. Perry (left) and James Guldin (right).

region. Hardwoods in these forests are diverse and include oaks, hickories, and *Acer rubrum* L. (Red Maple).

We sampled 2 types of forest stands: (1) mature unmanaged (>60 years old), second-growth pine–hardwood forest; and (2) restored Shortleaf Pine woodlands (Fig 1). Restoration of pine woodlands consisted of thinning forest overstories to retain 13.7–16.1 m^2/ha of pine basal area (BA) and 1.4–1.6 m^2/ha of hardwood BA; all or most midstory trees were removed. In woodlands, cutting treatments were followed by prescribed burns conducted at 2–5-year intervals, and unmanaged forests were not burned. For additional details on the restoration process and our sampling design, see Perry et al. (2009).

We surveyed 12 forest stands: 9 restored pine woodlands and 3 unmanaged mature stands. During the 3 years of our study (1999–2001), restored woodland stands were burned on a 3-year rotation. Three of the 9 woodland stands were burned each year in March or April, and all burned stands were part of larger burning units (64.8–1335.5 ha). Thus, most woodland stands were contiguous with large areas of burned forest.

Our overall trapping goal was to capture herpetofauna. However, in the course of sampling, we captured numerous small and medium-sized mammals. We used drift-fence traps designed to capture large snakes (Fig. 2). Each trap array consisted

Figure 2. A drift-fence trap used for capturing herpetofauna that also captured Eastern Spotted Skunks in the Ouachita Mountains of Arkansas, 1999−2001, based on a modified design presented by Burgdorf et al. (2005). Photograph © Josh Pierce.

of four 15-m linear fences arranged at 90º angles to one another and constructed of steel hardware cloth (3.2-mm mesh) with a 1.2 m x 1.2 m x 0.46 m (l x w x h) box trap in the center (Burgdorf et al. 2005). Our traps had 10-cm–diameter entrance funnels that allowed larger animals to enter; this entrance size differed from traps presented by Burgdorf et al. (2005), which had 5-cm–diameter entrance holes.

We installed 3 traps in each stand. Trap were >150 m apart, >50 m from roads or stand edges, and >75 m from permanent or intermittent streams, ponds, and stream buffers. We checked traps weekly from early April until late September for 3 y (1999–2001); trapping effort was equal among all stands and years (24 weeks each year), and trapping occurred concurrently at all sites. Each box trap contained a water dispenser that maintained a continuous water source in each trap. We recorded all captured vertebrates and immediately released them >50 m from the trap (with the exception of skunks, see below). We did not mark captured mammals because our overall goal was sampling herpetofauna. We released captured Eastern Spotted Skunks at the site of capture by opening trap doors and placing a log in the trap opening to act as a ramp that allowed skunks to exit on their own. We followed the guidelines of the American Society of Mammalogists for the capture, handling, and care of mammals (Animal Care and Use Committee 1998).

We measured vegetation in September and early October at 4 plots surrounding each trap (Table 1). Plots were located 7 m beyond the distal end of each drift fence. We measured percent canopy closure (Cover) at plot center with a spherical densiometer held at breast height, and overstory and midstory BA (conifer and hardwood combined) using a prism. We visually estimated (± 10%) downed-wood cover in 3 adjacent 2 m x 2 m subplots. In 3 nested 1 m x 1 m subplots, we visually estimated percent cover of grass, forbs, leaf litter, bare ground, and woody understory vegetation (≤1 m high). We measured litter depth in the center of each 1 m x 1 m subplot. We employed a 0.5 m x 0.5 m density board (Nudds 1977) to

Table 1. Vegetation parameters used in models to determine effects of forest condition on Eastern Spotted Skunk presence in the Ouachita Mountains of Arkansas, 1999−2001. Dens1–Dens3: lower values = less distance that can be viewed at that height; thus, lower values indicate the presence of thicker vegetation.

Parameter	Description
Overstory	BA (m^2/ha) of overstory trees (measured with prism)
Midstory	BA (m^2/ha) of midstory trees (measured with prism)
Cover	Canopy cover (%) at breast height (measured with densitometer)
Woody	Percent cover of woody plants in the understory (visually estimated)
Forbs	Percent cover of forbs in the understory (visually estimated)
Grass	Percent cover of grasses in the understory (visually estimated)
Leaf	Percent cover of leaf litter on the forest floor (visually estimated)
Bare	Percent cover of bare ground on the forest floor (visually estimated)
LitterD	Depth (mm) of leaf litter on the forest floor (measured)
Dwood	Percent cover of down/dead wood on the forest floor (visually estimated)
Den1	Index of vegetation density 0−0.5 m above the forest floor (density board)
Den2	Index of vegetation density 0.75−1.25 m above the forest floor (density board)
Den3	Index of vegetation density 1.75−2.25 m above the forest floor (density board)

estimate horizontal vegetation density by measuring the distance at which 50% of the density board was obscured by vegetation at 3 heights: ground level–0.5 m high (Den1), 0.75–1.25 m above the ground (Den2), and 1.75–2.25 m above the ground (Den3). With this measure, denser vegetation resulted in lower numbers and sparser vegetation resulted in higher numbers.

We modeled occupancy (Ψ) and detectability (P) of Eastern Spotted Skunks in each trap, each year, using the program PRESENCE (MacKenzie et al. 2006) to determine vegetation parameters (Table 1) at each trap site that affected presence/absence of skunks. To increase model stability, we removed 5 highly correlated variables (≥0.60) prior to analysis (Overstory, Grass, LitterD, Den3, and Bare). We compared 23 a priori models that included effects of vegetative parameters on occupancy (Table 2). We included effects of detectability in our model set; models contained either the effects of woodlands/unrestored sites on detectability [P(Woodland)] or similar detectability between the 2 forest types [P(.)]. We compared models and selected the best model based on values of Akaike's information criterion (AIC; Burnham and Anderson 2002).

Vegetation parameters were highly correlated. Therefore, we conducted principal components analysis (PCA), using all vegetative parameters, to

Table 2. Model parameters included in models of occupancy (Ψ) and detectability (P) of Eastern Spotted Skunks in restored woodlands and unrestored mature forests in the Ouachita Mountains of Arkansas, 1999–2001, including values of AIC, difference from the best model in each set (ΔAIC), and weight of each model among all models (ω_i). An asterisk (*) indicates models that failed to converge or produced highly improbable parameter estimates and standard errors (Dail and Madsen 2011).

Model	AIC	ΔAIC	ω_i
Ψ(Cover, Woody, Forbs) P(.)	91.02	0.00	0.65
Ψ(Cover, Woody, Forbs) P(Woodland)	93.00	1.98	0.24
Ψ(Cover, Woody) P(Woodland)	96.88	5.86	0.03
Ψ(Cover) P(.)	97.06	6.04	0.03
Ψ(Cover) P(Woodland)	98.62	7.60	0.01
Ψ(Woody) P(Woodland)	98.63	7.61	0.01
Ψ(Den2) P(Woodland)	99.36	8.34	0.01
Ψ(.) P(Woodland)	102.13	11.11	0.00
Ψ(Midstory) P(.)	107.18	16.16	0.00
Ψ(.) P(.)	110.81	19.79	0.00
Ψ(Woody) P(.)	112.81	21.79	0.00
*Ψ(Forbs) P(.)			
*Ψ(Cover, Forbs) P(.)			
*Ψ(Forbs) P(Woodland)			
*Ψ(Cover, Forbs) P(Woodland)			
*Ψ(Cover, Woody, Den2) P(Woodland)			
*Ψ(Cover, Woody) P(.)			
*Ψ(Cover, Woody, Den1) P(Woodland)			
*Ψ(Midstory, Cover) P(Woodland)			
*Ψ(Woody, Den1, Den2) P(.)			
*Ψ(Midstory) P(Woodland)			
*Ψ(Burn, unburn) P(Woodland)			
*Ψ(Midstory) P(.)			

characterize vegetation at trap sites and to differentiate vegetative characteristics between woodlands and unrestored sites. We also used this analysis to better characterize sites where we captured Eastern Spotted Skunks.

Results

We recorded 18 Eastern Spotted Skunk captures over 3 growing seasons (18,144 trap nights) in 6 of the 12 forest stands and in 10 of the 36 traps. Although there were 3 times as many traps in woodlands ($n = 27$) than in unmanaged stands ($n = 9$), we captured Eastern Spotted Skunks twice as often in unmanaged stands (12 captured in unmanaged stands versus 6 captured in woodlands). Capture rate (mean number of captures per week) of Eastern Spotted Skunks was 6 times greater in unmanaged stands (0.019 ± 0.005 SE) than in woodlands (0.003 ± 0.001). The number of Eastern Spotted Skunks captured in woodlands was similar (2 each) among stands sampled the first, second, and third year after burning.

Of the 23 a priori models, 11 converged and 12 either did not converge or produced highly improbable parameter estimates and standard errors (e.g., >5000 ± 100,000; Dail and Madsen 2011), likely due to the sparse capture data for Eastern Spotted Skunks (Table 2). The best model included positive effects of total cover (Cover), positive effects of understory woody vegetation (Woody), and a negative effect of forb presence (Forbs) (Tables 2, 3). The best model did not contain effects of woodland restoration on detectability. Mean probability of occupancy at unrestored sites (0.569 ± 0.063 SE) was 9 times greater than at woodland sites (0.063 ± 0.034). Detection probability was similar between restored and unrestored sites (0.108 ± 0.050).

The first 6 principal components in our PCA of vegetative parameters at trap sites accounted for 84% of the variance in the data, with components 1 and 2 explaining 52% of the variance (Table 4). Principal component Axis 1 explained 34% of the variance in the data (Table 4, Fig. 3). At higher values of PC1, sites increased primarily in total cover, midstory BA, and horizontal vegetation cover at 1.75−2.25 (Den3), and decreased in amount of horizontal cover at 0−0.5 m (Den1) and forb/grass cover. Sites in unmanaged stands (grouped to the right on PC1) were distinctly separate from woodland sites, which were grouped to the left on PC1. Eighty-one percent of sites with Eastern Spotted Skunk captures had positive values of PC1. Component 2 explained an additional 18% of the variance. At higher values of PC2, sites increased

Table 3. Parameter estimates (Betas) from the best model predicting occupancy of Eastern Spotted Skunks in restored woodlands and unrestored mature forests in the Ouachita Mountains of Arkansas, 1999–2001, including parameter effects on occupancy (Ψ) and detectability (P).

Model parameter	Estimate	SE
Intercept	-7.99	4.13
Ψ(Cover)	2.41	2.19
Ψ(Woody)	2.14	1.22
Ψ(Forbs)	-7.15	5.09
P	-2.12	0.52

mostly in bare ground, but decreased in vegetation density at 0.75−1.75 m (Den2), and understory woody vegetation (Fig. 3). No obvious relationship existed between sites where Eastern Spotted Skunks were captured and PC2.

Table 4. Principal component analysis loadings for the first 6 components (Prin1−Prin6) and percent of variance explained by each component using 13 vegetation parameters collected at trap sites (Table 1) in both woodlands and unmanaged forests combined in the Ouachita Mountains of Arkansas, 1999−2001.

Parameter	Prin1	Prin2	Prin3	Prin4	Prin5	Prin6
Overstory	0.177	0.207	0.487	-0.485	0.084	0.332
Midstory	0.325	0.163	-0.317	0.237	0.059	-0.086
Cover	0.398	0.188	0.181	-0.265	-0.017	0.092
Forbs	-0.338	0.128	0.326	0.261	-0.099	-0.146
Grass	-0.271	-0.230	-0.372	0.021	-0.081	0.610
Woody	-0.192	-0.393	0.045	-0.296	0.025	-0.464
Leaf	0.286	-0.259	0.365	0.310	-0.289	-0.073
Bare	-0.262	0.339	-0.211	-0.353	0.286	-0.313
LitterD	0.313	-0.205	-0.265	-0.157	0.293	0.174
Down	-0.068	-0.090	0.288	0.380	0.834	0.107
Den1	0.326	0.244	-0.162	0.250	-0.031	-0.118
Den2	-0.063	0.568	-0.084	0.157	-0.020	-0.022
Den3	-0.342	0.240	0.136	0.078	-0.156	0.326
% variance explained	34	18	12	8	7	5

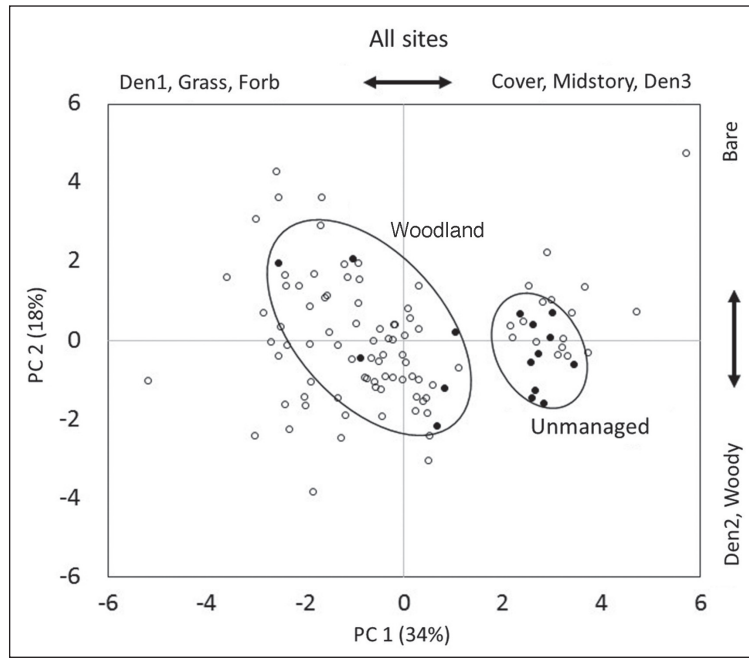

Figure 3. Principal component analysis based on vegetation parameters (Table 1) of sites where Eastern Spotted Skunks were captured (closed circles) and sites with no captures (open circles) in woodlands and mature unmanaged forests. On PC1, sites to the left represented more-open forest conditions, whereas sites to the right represented denser forest condition with more total cover and midstory. Sites where Eastern Spotted Skunks were captured in unmanaged stands are circled on the right, whereas capture sites in woodlands are circled on the left.

Discussion

Mean probability of occupancy of Eastern Spotted Skunks was 9 times greater and capture rates (mean captures/week) were 6 times greater in mature, unmanaged, second-growth forest than in restored, frequently burned woodlands. Similarly, studies within this same landscape found that Eastern Spotted Skunks used restored woodlands less than their availability (Lesmeister et al. 2013). One of the primary differences between woodlands and unmanaged stands is the presence of a dense midstory in unmanaged stands, which is lacking in woodlands (Fig. 1). Masters et al. (2002) found the density of woody stems (1−15-cm diameter) was 12 times greater in unmanaged mature forests than in woodlands of the ONF. Midstory (BA of midstory trees) was an important predictor in our PCA, but was not included in our best occupancy model. However, our midstory measure only included trees 10−15 cm dbh and did not account for smaller trees, which likely accounted for the lack of inclusion of Midstory in the best occupancy model. Nevertheless, this forest layer provides dense cover, which could potentially deter avian predation, and may provide needed cover for Eastern Spotted Skunks. Lesmeister et al. (2010) found that mortality of Eastern Spotted Skunks in our study area was attributable mostly (63%) to avian predators (e.g., *Bubo virginianus* [Gmelin] [Great Horned Owl]); the dense canopy and understory vegetation in younger (<30 years old) forests is believed to provide protection from aerial predation. Further, 92% of avian-caused mortality reported by Lesmeister et al. (2010) was in restored woodlands.

Our occupancy model indicated total cover and understory woody-plant cover had the greatest positive effect, and cover of forbs had a negative effect on captures of Eastern Spotted Skunks. Further, our PCA also indicated Eastern Spotted Skunks were more likely to occur in areas with greater total cover and a lower amount of herbaceous vegetation. Areas with dense cover may be used disproportionally more by Eastern Spotted Skunks than open areas (Lesmeister et al. 2009). Greater total cover was the strongest factor affecting den sites selected by Eastern Spotted Skunks in the Ouachita Mountains (Lesmeister et al. 2008), and Sprayberry and Edelman (2018) found midstory and understory density provided a critical layer of cover for Eastern Spotted Skunk den sites. Forb cover is associated with more-open conditions (sunlight reaching the forest floor), and areas that are frequently burned have lower amounts of woody vegetation in the understory and greater forb coverage (Perry et al. 2009); thus, it seems logical that skunks may avoid areas with dense herbaceous vegetation and forb coverage.

Lesmeister et al. (2009) found that Eastern Spotted Skunks used hardwood-dominated forests (stream buffers and north slopes) more than or in proportion to their availability across the landscape. Similar to our unmanaged, pine-dominated stands, hardwood stands in the area were typically not subject to woodland restoration. These hardwood stands typically received little or no thinning and limited burning, which produces a structure similar to our unmanaged pine-dominated stands, including a dense midstory. Consequently, we believe that both young stands and mature forests with dense midstories (regardless of forest type) may

provide comparable conditions in terms of structural protection from predators. Although previous studies found that Eastern Spotted Skunks avoid woodlands and are more likely to use hardwood stands or young−intermediate seral stages with a dense midstory (Lesmeister et al. 2009, Sprayberry and Edelman 2018, Thorne et al. 2017), our data suggests that mature pine-dominated forests with a well-developed midstory may also be important habitat. The importance of a dense midstory and woody understory for Eastern Spotted Skunks is becoming more apparent as additional studies throughout the range of this species are conducted (e.g., Sprayberry and Edelman 2018).

The 10-cm–diameter opening size of our trap-entrance holes was an earlier trap design that allowed large snakes access but prevented larger mammals, such as mature *Mephitis mephitis* (Schreber) (Striped Skunk) and *Didelphis virginiana* (Kerr) (Opossum) from entering. However, size of the entry hole allowed juvenile *Sylvilagus floridanus* (J.A. Allen) (Eastern Cotton-tailed Rabbit), juvenile Opossum, and mature Eastern Spotted Skunks to enter. Later refinements of these traps for other studies changed the opening size to 5 cm, which prevented Eastern Spotted skunks and other medium–large mammals from entering (Burgdorf et al. 2005). During our trapping, we captured numerous herpetofauna and other animals, possibly providing an attractant to Eastern Spotted Skunks, which are known to consume and feed their young snakes, lizards, and small mammals (Sprayberry and Edelman 2016). In addition to the animals captured in the traps, the Eastern Spotted Skunks may also have been attracted to the permanent water source. Food resources for Eastern Spotted Skunks are likely more abundant in woodlands than unrestored mature forest, and studies of primary food types, including herpetofauna (Perry et al. 2009) and small mammals (Masters et al. 1998) have found a greater abundance of those taxa in woodlands. Thus, predator avoidance may override food-resource abundance as a driver of habitat use. Further, greater capture rates and occupancy rates of Eastern Spotted Skunks at unrestored sites and the lack of evidence for differences in detectability between these 2 forest types suggest that presence of prey items in traps did not bias habitat comparisons.

Pine woodlands provide important habitat for a number of species and taxa, including endangered *Picoides borealis* (Vieillot) (Red-cockaded Woodpecker) and other bird species (Wilson et al. 1995), small mammals (Masters et al. 1998), and a number of reptiles (Perry et al. 2009). However, not all species benefit from restoring woodlands. Species such as *Seiurus aurocapilla* (L.) (Ovenbird; Wilson et al. 1995), *Plethodon glutinosus* (Green) (Slimy Salamander; Perry et al. 2009), and Eastern Spotted Skunk may be less abundant or absent in these woodlands. Therefore, to provide for diverse faunal assemblages, both woodlands and mature forests with an obvious midstory should be maintained across the landscape. Providing these denser forested areas may provide favored habitats for Eastern Spotted Skunks.

On the Ouachita National Forest, the east–west oriented mountain range creates a landscape with sunny, south-facing slopes and shaded north slopes. South-slope areas typically consist of pine-dominated forests and are targeted for pine-woodland restoration, whereas north-slope areas are dominated by hardwood and mixed

hardwood–pine forests that are not typically managed as open woodland. Only around 19% of the total acreage (~142,000 ha) of the ONF has been designated for pine-woodland restoration. Furthermore, maintenance of unharvested riparian buffers or streamside management zones creates additional habitat throughout the woodland areas. Research by Lesmeister et al. (2009) indicated that Eastern Spotted Skunks favored these hardwood-dominated areas (along with regenerating forests) in the Ouachita Mountains. Consequently, a large portion of the forest is currently maintained in the forest conditions that Eastern Spotted Skunks apparently favor.

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