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Habitat relationships of reptiles in pine beetle disturbed forests of Alabama, U.S.A. with guidelines for a modified drift-fence sampling method

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Abstract Understanding vertebrate habitat relationships is important to promote management strategies for the longterm conservation of many species. Using a modified drift fence method, we sampled reptiles and compared habitat variables within the William B. Bankhead National Forest (BNF) in Alabama, U.S.A from April 2005 to June 2006. We captured 226 individual reptiles representing 19 species during 564 total trap nights. We used canonical correspondence analysis to examine habitat associations for the reptiles sampled and we detected a distinct habitat gradient ranging from sites with greater litter depth and percent canopy cover to more open sites with greater woody, herbaceous, and coarse woody debris (CWD) coverage, and CWD volume. Little brown skinks *Scincella lateralis* and eastern worm snakes *Carphophis a. amoenus* were associated with sites with greater litter depth and canopy cover, whereas eastern fence lizards *Sceloporus undulatus*, copperheads *Agkistrodon contortrix*, and gray ratsnakes *Pantherophis spiloides* were associated with sites possessing greater CWD coverage and volume. We found that disturbances due to the southern pine beetle *Dendroctonus frontalis* were likely important for influencing reptile distributions through the creation of canopy gaps and fallen coarse woody debris. Compared to other studies, our modified drift-fence trap technique was successful for sampling larger snake species (66 snakes in 564 trap nights). We have also provided detailed schematics for constructing drift fence array and box traps used in this study [*Current Zoology* 56 (4): 411–420, 2010].

Key words William B. Bankhead National Forest, Canonical Correspondence Analysis, *Dendroctonus frontalis*, Drift-fence Arrays, Reptiles, Southern Pine Beetle

Examining species and habitat relationships is important for understanding species habitat requirements and predicting the potential impacts of future habitat changes. Some reptile species (e.g., semi-fossorial snakes) may be sensitive to habitat alterations, whereas other species (e.g., heliothermic lizards) may respond positively to drastic disturbances (Dodd et al., 2007; Greenberg, 1994a; Todd and Andrews, 2008; Vitt et al., 1998). Recent documentation of reptile declines has made it critical to understand habitat relationships of these species (Gibbons et al., 2000). Although a majority of the research examining herpetofaunal response to habitat disturbances have been biased towards amphibians (Greenberg, 2001), reptiles appear to respond positively to habitat disturbances including silvicultural practices (Goldstein et al., 2005; Greenberg and Waldrop, 2008; Renken et al., 2004) and minor urbanization (Barrett and Guyer, 2008). However, large-scale urbanization and habitat alteration appear to be the major cause of widespread reptile population declines (Gibbons et al., 2000).

Habitat disturbances have the potential to affect reptile species in a variety of manners. High intensity disturbances initially tend to favor reptile species that require characteristics of open, early successional habitats (Greenberg et al., 1994a; Mushinsky, 1985), whereas disturbances that maintain the structural integrity of the habitat (e.g., shelterwood timber harvesting and stochastic events) may favor species that benefit from lower-intensity disturbances (Vitt et al., 1998; Greenberg, 2001; Todd and Andrews, 2008). A majority of studies have examined reptile response to anthropogenic habitat disturbances (Russell et al., 2004), but little research has examined reptile response to stochastic forest disturbances (but see Greenberg, 2001). The southern pine beetle *Dendroctonus frontalis* is native to southeastern forests and can cause major disturbances in pine dominated forests (Duncan and Linhoss, 2005; Gaines

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and Creed, 2003). If allowed to spread unimpeded, this pest can have drastic effects on forest structure because it leads to the creation of standing snags, large canopy gaps, and increased downed woody debris. However, no research has evaluated reptile response to this type of disturbance and it is likely that these disturbances greatly influence reptile populations.

A wide array of techniques exists to sample the overall reptile community including drift-fence arrays, artificial cover objects, visual encounter surveys, and road-cruising (Hutchens and DePerno, 2009a, b). It is important for researchers to evaluate sampling requirements and employ several techniques in order to obtain a complete sample of the overall herpetofaunal community (Hutchens and DePerno 2009a; Ryan et al., 2002). For example, visual encounter surveys may work well for litter-dwelling herpetofauna, but may be ineffective for fast moving, cryptic, or rare herpetofauna such as medium to large-bodied snakes (Ryan et al., 2002). Furthermore, most reptile survey methods are not effective for sampling larger snake species and therefore overlook an important portion of the reptile diversity (Enge, 2001).

Drift-fence arrays provide an effective way to sample many reptile species (Enge, 1997; Ryan et al., 2002), but larger snakes are not sampled adequately unless large box traps are employed (Burgdorf et al., 2005; Enge, 2001). Drift-fence arrays are useful for collecting amphibian and reptile population data and have been used in many studies including evaluations of herpetofaunal response to forest disturbances (Greenberg, 2001; Renken et al., 2004; Schurbon and Fauth, 2003). Numerous drift-fence array designs have been employed (Corn, 1994), with some designs more effective than others. Greenberg et al. (1994b) utilized a combination of pitfall traps and box traps, but acknowledged that funnel traps were much better for determining herpetofaunal species diversity than pitfall traps. Intensive long-term sampling can be time consuming and cost prohibitive; therefore passive sampling techniques such as drift-fence surveys can serve as one potential option to effectively sample rare and elusive species. Unfortunately, there is a lack of published literature detailing the construction of box traps capable of capturing larger snake species (but see Burgdorf et al., 2005).

Our objectives were to (1) evaluate relationships between reptile community and habitat characteristics in pine-hardwood forests of northwestern Alabama, U.S.A. and (2) test the effectiveness of an alternative drift-fence trapping method to sample the reptile species at these sites.

1 Materials and Methods

1.1 Study site

Our study sites were located in the William B. Bankhead National Forest (BNF) along the southern terminus of the highly dissected portion of the Southern Cumberland Plateau in Lawrence, Winston, and Franklin Counties of northwestern Alabama, U.S.A. (Central Work Station, 34°20′38.0″N, 87°20′17.7″W). Bankhead National Forest is nearly 72,000 ha in size and represents one of the largest tracts of contiguous forests in the southeastern United States. Forests of the BNF are typically composed of upland hardwood and pine species, such as chestnut oak *Quercus prinus*, sourwood *Oxydendron arboretum*, red maple *Acer rubru*m, black gum *Nyssa sylvatica*, loblolly pine *Pinus taeda*, and Virginia pine *Pinus virginiana*. Over the last 30 years, loblolly pine has been used to reforest areas of the BNF that were traditionally cleared for agricultural purposes (Gaines and Creed, 2003). The combination of overstocked loblolly pine stands along with dry growing seasons have lead to widespread infestations of the southern pine beetle, causing extensive damage to many of the loblolly pine plantations. An estimated 7530 acres of pine forest have been killed by this epidemic in the BNF (Gaines and Creed, 2003), a majority of which occurred during the 2001 growing season (Duncan and Linhoss, 2006). Ultimately, these disturbances have led to a large increase in fallen trees and canopy gaps (CWD) throughout many forest stands of the BNF. Throughout BNF, we randomly selected 18 forest stands based on site accessibility, stand size (~9 ha), and similarity of past and future management plans.

The selected forest stands were generally located on upland sites that were composed of loblolly pine 25–50 years of age that also possessed a considerable hardwood component (Gaines and Creed 2003). At the time of this study, these stands had not been recently harvested and each stand had varying levels of damage from the southern pine beetle. Other past disturbances included the clearing of hardwood stands throughout the region for loblolly pine plantations during the early 1970’s (Gaines and Creed, 2003).

1.2 Reptile sampling

We sampled reptiles using a trapping system consisting of three drift fences (aluminum flashing) 15 m in length radiating from a central triangular box trap (see appendices 1–3) modified from Bugdorf et al. (2005) and Renken et al. (2004). Large box traps have been proven successful for capturing reptiles, particularly medium to large snake species (Burgdorf et al., 2005). We installed one drift-fence unit per study plot after randomly determining the trap unit location by dividing each study plot into four equal quadrants corresponding to the four cardinal directions. Drift fence arrays were buried approximately 10 cm into the ground and included one large box trap at the terminus of each drift fence (three per array) and two pitfall traps at the mid-point of each drift fence (six per array). We designed a triangular-array system because it covers the same area as a four-fence array system, but reduces the labor and cost of installing an additional drift-fence and the accompanying traps. This trap arrangement presents the best use of the entire trapping unit because a reptile can encounter the drift-fence at any point and potentially be captured in the center or terminal box traps.

We sampled intermittently throughout March and April 2005 and began sampling continuously from May through mid-November 2005. We resumed trapping from March 2006 and continued through June of the same year. During intermittent sampling periods, we would open traps only for rain events, whereas during continuous sampling periods, traps were open for a three-four day period and then closed for two to three days. We checked traps daily when open between 0700–1400 hours to minimize animal mortality. Across all sites we sampled a total of 584 trap nights (i.e., sites 1–6, 120 trap nights, sites 7–12, 204 trap nights, and sites 13–18, 240 trap nights). For each animal capture, we recorded trap type (pitfall or box trap), species, sex, age (juvenile, sub-adult, and adult), snout-vent length (mm), total length (mm), mass (g), and animal viability. We marked each animal with a plot-specific mark through toe-clips (lizards), scale clips (snakes), and scute etching (turtles) to ensure that recaptured individuals would not be counted in subsequent captures (Enge, 1997). We released all marked individuals at a minimum of 10 m on the side of the drift fence in which they were captured. We acknowledge that our results are limited to reptile species that were sampled via drift-fence arrays.

1.3 Habitat sampling

We quantified habitat features using a line transect method modified from Greenberg (2001) and Herbeck and Larsen (1999). We established three habitat sampling plots at each trapping site, and determined plot placement *a priori* via a random compass bearing (0°–360°) and distance (30–50 m) originating from the center of each trapping array. We restricted habitat sampling to these distances to minimize the effects of habitat disturbances created during trap installation. Each habitat sampling plot consisted of two 20 m perpendicular transects placed north-south and east-west from the habitat plot center. We used a two meter piece of 1.9 cm diameter polyvinyl chloride pipe as a transect marker, and recorded the presence or absence of microhabitat features every 0.5 m along the transect line. Based on these data, we calculated percent coverage of litter, bare ground, herbaceous and woody vegetation, slash, and coarse woody debris (CWD), and rock (Table 1). We measured CWD length and diameter to determine CWD volume based on the volume of a cylinder ($V_C = \pi r^2 \times L$), and measured litter depth with a metric ruler (measured every 2 m) and estimated percent canopy cover with a spherical densiometer (measured every 5 m; Table 1). We assigned vertical forest structure values on a scale of 1–4 by estimating the height of the dominant forest structure every 5 m along the transect and assigned values according to the designations described in Forest Inventory Analysis (1998; Table 1).

1.4 Statistical Analysis

We examined correlations and relationships between habitat variables with principal components analysis (PCA). After examining the biological relevance of the resulting components, we retained one variable from highly correlated ($\geqslant$ 0.90) variable sets for subsequent analyses (Crosswhite et al., 2004). Ater determining the total number of each reptile species captured, we corrected for differences in sampling effort at each survey site by dividing species counts by the total number of trap nights (1 trap night = 1 trap opened for 24 hrs), and used canonical correspondence analysis (CCA) to examine relationships between the animal capture data and habitat features using CANOCO v.4.5. Canonical correspondence analysis is a direct gradient analysis technique where the ordination is constrained by a set of *a priori* covariates (e.g., habitat and climate data) predicted to affect the observed distribution of the organismal group in question (ter Braak, 1995). Ordination techniques are essential when inter-specific and habitat relationships are compared among large species groups. To improve the quality of the CCA output, we did not include species with only one detection. Ter Braak (1995) suggests that rare species have little influence on the analysis and can be removed if necessary.

2 Results

We captured a total of 19 reptile species representing 226 individuals during 564 trap nights (Table 2). The most commonly captured lizard species were little brown skinks (*Scincella lateralis*, *n*=70) and green anoles (*Anolis carolinensis*, *n*=29), whereas the most commonly captured snake species were copperheads

Table 1 Habitat variables assessed at each survey point

Habitat variable	Code	Habitat description
Percent Litter	%_litt	Presence (%) of ground cover such as leaves or small woody debris measured at every 0.5 m.
Percent Bare Ground	%_bare	Absence (%) of ground cover (e.g., exposed soil) measured at every 0.5 m.
Percent Herbaceous	%_herb	Presence of non-woody stems (%) such as grasses, ferns, and *Smilax* and *Vitus* sp. measured at every 0.5 m.
Percent Woody	%_wood	Presence of any woody stems (%) such as seedlings and large trees (living or dead) measured at every 0.5 m.; woody stems taller than one meter had to contact transects directly to be counted
Percent Rock	%_rock	Presence of rocky substrate (%) greater than 10 cm in size measured at every 0.5 m.
Percent CWD	%_cwd	Presence of any fallen woody debris larger than 10 cm in diameter (must touch the ground somewhere along the length to be counted) measured at every 0.5 m.
Percent Slash	%_slash	Presence of any woody debris (%) composed of two or more stems 30 cm or higher from the ground (e.g., fallen treetops) measured at every 0.5 m.
CWD volume	cwd_vol	Calculated as volume of a cylinder (m^3) for each enumerated CWD (see text).
Litter Depth	l_dep	Determined by measuring depth of the substrate to the nearest 0.5 cm with a metric ruler measured at every 2 m.
Canopy Cover	can_cov	Estimated with a spherical densiometer as the sum percentage of open points subtracted from 100% measured at every 5 m.
Forest Level 1	for_lev1	Percent coverage of forest levels ≤ 2m (classified as ground cover) measured at every 5 m.
Forest Level 2	for_lev2	Percent coverage of forest levels > 2 m – ≤ 4 m (classified as understory) measured at every 5 m.
Forest Level 3	for_lev3	Percent coverage of forest levels > 4 m – ≤ 6 m (classified as midstory) measured at every 5 m.
Forest Level 4	for_lev4	Percent coverage of forest levels > 6 m (classified as overstory) measured at every 5 m.

Table 2 Total reptile captures in the Bankhead National Forest, Alabama, U.S.A.

Scientific Name	Common name	Code	Number of captures	Percentage of captures	No. of plots where a species was detected
Agkistrodon contortrix	Copperhead	AGCO	27	11.9	13
Anolis carolinensis	Green Anole	ANCA	29	12.8	11
Carphophis a. amoenus	Worm Snake	CAAM	4	1.8	3
Coluber c. constrictor	Northern Black Racer	COCO	9	4.0	7
Crotalus horridus	Timber Rattlesnake	CRHO	4	1.8	3
Diadophis p. punctatus	Southern Ring-necked Snake	DIPU	4	1.8	4
Lampropeltis getula nigra	Eastern Black Kingsnake	LAGE	4	1.8	4
Lampropeltis triangulum syspila	Red Milksnake	LATR	1	0.4	1
Nerodia s. sipedon	Northern Watersnake	NESI	1	0.4	1
Pantherophis guttatus	Red Cornsnake	PAGU	4	1.8	4
Pantherophis spiloides	Gray Ratsnake	PASP	6	2.7	6
Plestiodon fasciatus	Common Five-lined Skink	PLFA	20	8.8	14
Plestiodon laticeps	Broad-headed Skink	PLLA	17	7.5	10
Sceloporus undulatus	Eastern Fence Lizard	SCUN	12	5.3	5
Scincella lateralis	Little Brown Skink	SCLA	70	31.0	15
Storeria dekayi wrightorium	Midland Brownsnake	STDE	1	0.4	1
Storeria o. occipitomaculata	Northern Red-bellied Snake	STOC	1	0.4	1
Terrapene c. carolina	Eastern Box Turtle	TECA	2	0.9	2
Thamnophis s. sirtalis	Eastern Gartersnake	THSI	10	4.4	7
Totals			226	100	NA

(*Agkistrodon contortrix*, *n*=27) and eastern garter snakes (*Thamnophis s. sirtalis*, *n*=10; Table 2). Overall, lizards (Phrynosomatidae, Polychrotidae, and Scincidae) accounted for 65% (*n*=148) of the total reptile captures, whereas snakes (Colubridae and Viperidae) accounted for 34% (*n*=76) and turtles (Emydidae) accounted for <1% (*n*=2) of the total reptile captures (Table 2). Our box traps captured 66 total snakes in 564 trap nights (one trap night equaled one trap array passively sampled for 24 consecutive hours), equaling 0.117 snake captures per trap night.

Plots were considerably different in terms of overall habitat composition. Vegetative and woody coverage ranged from 3.8%–49.6% and 3.3%–31.7%, respectively, whereas canopy cover and CWD ranged from 72.8%–90.1% and 0–491.1 m^3, respectively (Table 3). Principal components analysis revealed five components that explained 85% of the habitat variance (Table 4). Component one described a gradient ranging from sites with high percent canopy cover to sites with less canopy cover and greater CWD volume with greater woody, herbaceous, slash, and CWD cover, whereas component two described a gradient ranging from sites with greater overstory percent cover and litter depth to sites with less canopy cover and litter depth (Table 4). Components three and four described gradients ranging from sites with greater understory, overstory, and percent litter coverage to sites with less litter and tree coverage, whereas component five described rock coverage across sites (Table 4).

Table 3 Range of habitat variables (Table 1) derived from 18 forest stands of the Bankhead National Forest, Alabama, U.S.A.

Habitat code	Range of habitat variables
%_litt	98.3 – 100
%_bare	0.0
%_herb	6.3 – 49.6
%_wood	3.3 – 31.7
%_rock	0.0 – 0.8
%_slash	0.0 – 2.5
%_cwd	0.0 – 4.2
can_cov	72.8 – 98.1
l_dep	4.0 – 7.6
for_1	25.0 – 100.0
for_2	54.2 – 95.8
for_3	35.7 – 95.8
for_4	75.0 – 100.0
cwd_vol	0.0 – 491.1

Table 4 Principal components matrix derived from habitat variables collected in 18 forest stands of the Bankhead National Forest, Alabama, U.S.A.

Variable	Component 1	Component 2	Component 3	Component 4	Component 5
%_litt	–0.25	0.08	0.71	0.44	0.02
%_herb	0.91	0.19	–0.06	0.11	–0.01
%_wood	0.91	0.26	–0.05	0.24	–0.11
%_rock	–0.29	0.60	–0.05	–0.04	0.69
%_slash	0.77	0.33	–0.15	0.28	–0.15
%_cwd	0.56	–0.25	0.32	–0.61	–0.04
cancov	–0.81	–0.01	–0.37	–0.19	0.03
l_dep	0.05	–0.90	–0.13	0.05	–0.06
for_1	0.66	0.11	–0.30	–0.03	0.36
for_2	–0.21	0.54	–0.45	–0.04	–0.54
for_3	–0.16	0.19	0.89	0.11	–0.12
for_4	0.26	–0.59	–0.23	0.57	0.20
cwd_vol	0.81	–0.09	0.25	–0.47	0.08
Eigenvalue	4.60	2.14	1.99	1.32	1.00
% Variance	35.38	16.48	15.30	10.15	7.67
Cumulative % Variance	35.38	51.86	67.16	77.31	84.97

Canonical correspondence analysis accounted for 40% (Axis 1: 16%, Axis 2: 13%, and Axis 3: 11%) of the overall variance in the species relationships and 58% (Axis 1: 24%, Axis 2: 18%, and Axis 3: 16%) of the species–habitat relationships. A distinct habitat gradient was revealed, ranging from sites with greater canopy cover and litter depth to sites with more woody, herbaceous, CWD, and percent slash coverage (Fig. 1). A secondary gradient orthogonal to the first gradient ranged from sites with greater percent CWD coverage to sites with greater percent rock coverage (Fig. 1). Eastern worm snakes *Carphophis a. amoenus* and little brown skinks were associated with sites with greater percent canopy cover and greater litter depth, whereas copperheads, gray ratsnakes *Pantherophis spiloides*, eastern garter snakes, and eastern fence lizards *Sceloporus undulatus* were associated with sites that had greater CWD volume and percent CWD coverage (Fig. 1). Interestingly, green anoles were located at the ordination center indicating a broad, generalized distribution. Eastern kingsnakes *Lampropeltis getula nigra*, timber rattlesnakes *Crotalus horridus*, and red cornsnakes *Pantherophis guttatus* were located along the periphery of the ordination plot indicating their rarity throughout the sampled plots. A majority of the plots were located along the portion of the gradient associated with greater litter depth and canopy coverage (Fig. 2). Fewer plots were located along the portion of the gradient associated with greater woody, herbaceous, and CWD coverage and greater CWD volume (Fig. 2).

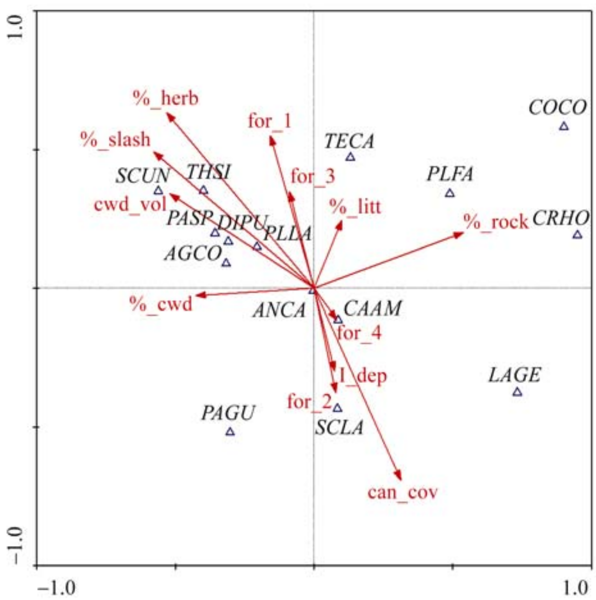

Fig. 1 Canonical correspondence analysis ordination plot displaying reptile species and habitat relationships in the Bankhead National Forest, Alabama, USA

Triangles with four-lettered abbreviations represent species scientific names (Table 2) and arrowed lines represent habitat variables (Table 1).

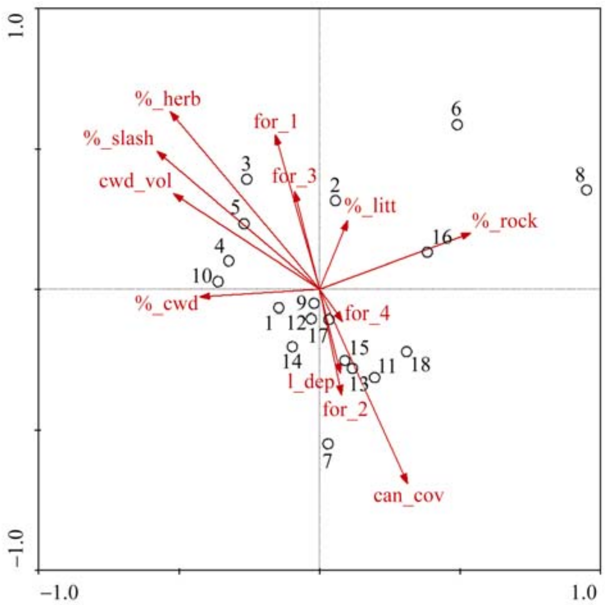

Fig. 2 Canonical correspondence analysis ordination plot displaying sample plot and habitat relationships in the Bankhead National Forest, Alabama, USA

Numbered points represent survey points and arrowed lines represent habitat variables (Table 1)

3 Discussion

We detected distinct relationships between several reptile species and habitat characteristics. Our data illustrate that little brown skinks and eastern worm snakes were associated with greater litter depth and canopy cover, whereas eastern fence lizards, gray ratsnakes, and copperheads were associated with greater CWD coverage, CWD volume, and less canopy coverage.

Eastern fence lizards were associated with abundant canopy gaps and relatively high CWD levels. This species is commonly associated with highly disturbed sites (Greenberg et al., 1994a; Greenberg and Waldrop, 2008), indicating that intense habitat disturbances would likely benefit this species. Copperheads were also associated with open sites possessing relatively high CWD volume. Cross and Peterson (2001) determined that copperheads commonly utilized microhabitats that possessed structural diversity and CWD cover. Little brown skinks and eastern worm snakes primarily occupy the forest floor and were associated with greater litter depth and canopy cover. Other species of litter-dwelling snakes have been detected in higher densities in forest stands possessing greater canopy cover and litter depth (Todd and Andrews, 2008). In addition to single species responses, CCA is advantageous because it permits analysis of species relationships. Our analysis revealed two distinct reptile groups including species associated with greater percent litter and canopy cover (e.g., semi-fossorial snakes and litter-dwelling lizards) and species associated with less percent canopy cover and greater percent structural cover (e.g., heliothermic lizards and larger snake species). Examining species data at the community level is advantageous because it may reveal multiple species that share similar habitat associations (Crosswhite et al., 2004). In addition, habitat management strategies can be developed from a multiple species perspective. By understanding organismal habitat requirements from through this perspective, forest managers can simultaneously develop conservation strategies that benefit multiple species groups (Lindenmayer et al, 2000).

Although CCA was only able to explain 40% of the species relationships and 58% of the species-habitat relationships, we believe that the results provide useful information regarding reptile species and habitat relationships in disturbed forest stands. The low variance explained is typical for this type of study because wildlife community data along with the associated habitat relationships are often complicated by many confounding variables and stochastic variations, which are difficult to be quantified or explained (Palmer, 1993). Interpretability of the CCA output is the most important part of this analysis technique (Ter Braak, 1995), and the gradients described in this study were biologically relevant.

Many of the forest stands examined during this study had a history of damage through southern pine beetle infestations. This insect pest is a normal inhabitant of southeastern forests where it along with natural fire, play an important role in maintaining equilibrium in pine-dominated forests (Knebel and Wentworth, 2007; Land and Rieske, 2006). Environmental stressors such as prolonged drought and overstocking of *Pinus* species tends to increase the severity of southern pine beetle infestations (Gaines and Creed 2003; Duncan and Linhoss 2005). Although loblolly pine is a natural component of southern forests, it was planted in unnaturally high densities in the BNF, easing to the spread of the southern pine beetle throughout the forest. Damage from southern pine beetle infestations usually leads to an increase of fallen logs and large canopy gaps (Duncan and Linhoss 2005). Our data suggests that these disturbances were likely important for influencing the observed reptile community by creating large changes in the overall forest structure. Although no published work has examined herpetofaunal response to southern pine beetle infestations, increased snag density has been found to influence the presence and aboreal activity of certain lizard species (James and M'Closkey, 2003), whereas the creation of canopy gaps by anthropogenic and natural means has been found important for colonization of lizards in disturbed tropical forests (Vitt et al., 1998). Moreover, Owens et al. (2008) determined that total reptile counts and species richness were relatively unaffected by experimental CWD additions, suggesting that some reptile species respond positively to the combination of both canopy gaps and increased structural diversity. Further examination of herpetofaunal response to stochastic disturbances is necessary to provide forest managers with information to guide management strategies that mimic natural disturbance patterns.

Our trap design provides an effective way to sample many reptile species, particularly larger snakes. We were unable to directly compare our trap results with those based on other trap methods. However, a similar study in an adjacent area of northeastern Alabama that used straight line drift fences captured 64 total snakes during 3030 trap nights (0.021 snakes per trap night; Felix, 2007). In addition, we captured considerably more snakes in less trap nights than Burgdorf et al. (2005; 224 individual snakes during 13,920 trap nights; 0.016 snakes per trap night). We encourage researchers to compare the effectiveness of our modified box trap design to traditional straight-line drift-fences to determine the efficiency of our design.

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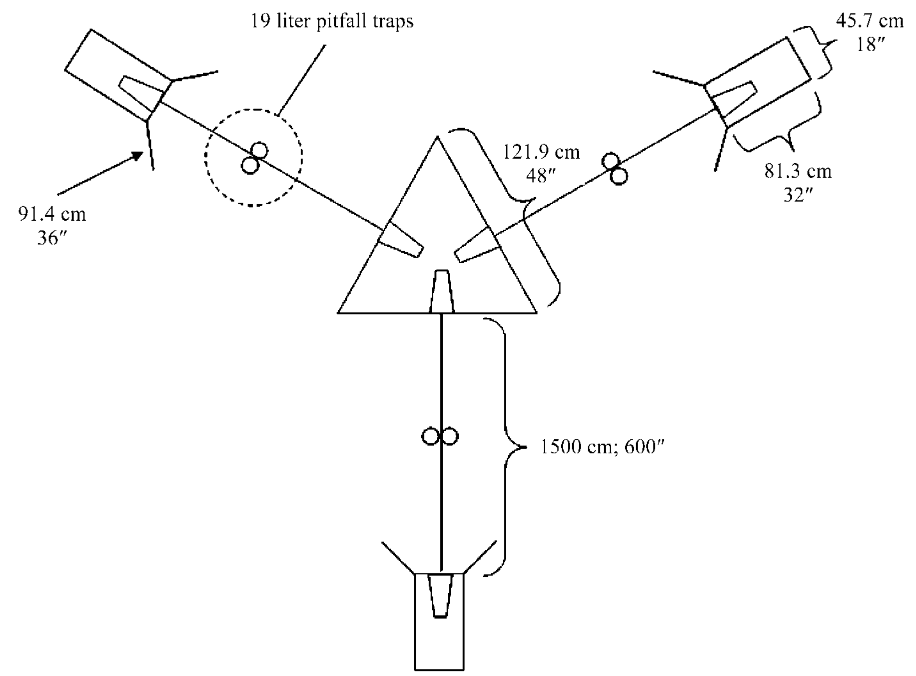
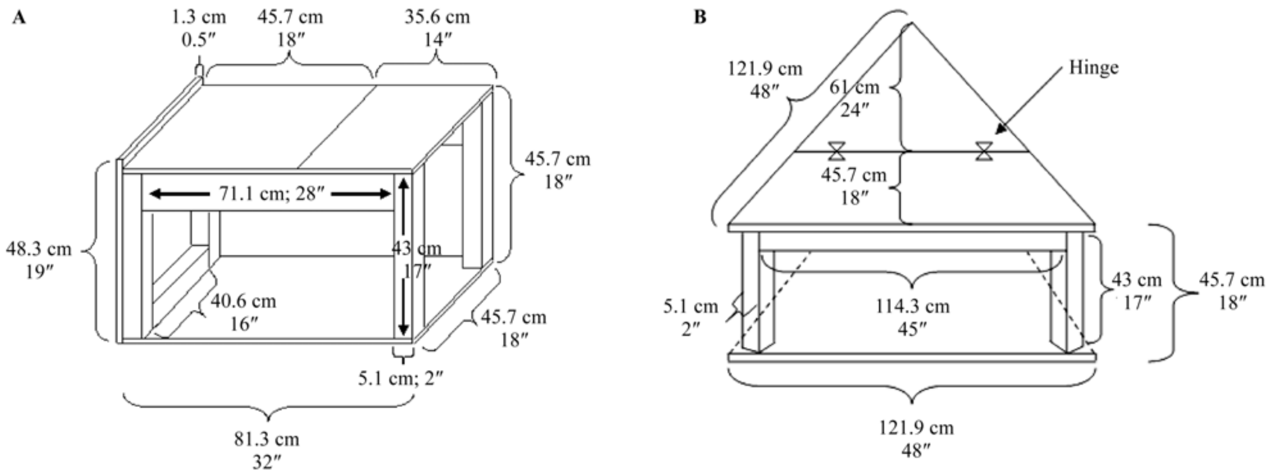


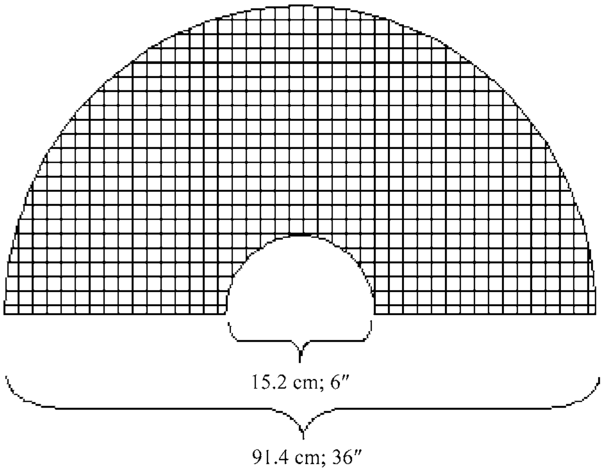
Appendix 1 Overhead schematic of drift-fence trapping array

The central triangle represents a large triangular box trap, while the rectangles represent box traps. The straight lines spanning between the box traps and triangle traps represent the three 15 m pieces of aluminum flashing (drift-fence). Pitfall traps were 19 L plastic utility buckets buried flush with the ground surface. The small lines originating from the corners of the box traps represent 1 m pieces of aluminum flashing used to direct the animals into the traps.



Appendix 2 Schematics for the construction of terminal box traps (A) and center triangle box traps (B)

The frame of each trap was constructed from pressure-treated lumber. We used 23-gauge hardware cloth with 0.64 cm (¼”) mesh openings. We secured the main portion of the frame (i.e., legs and main braces) using 5.1 cm (2”) galvanized screws and smaller 2.5 cm (1”) zinc-plated screws to attach the tops, bottoms, and back portions of the traps. The hardware cloth was attached to the trap body using 0.95 cm (3/8”) staples.



Appendix 3 Schematic for conical trap funnels

Funnels can be formed by placing the two pieces of the hardware cloth together. Once the funnel has been shaped, small cable ties can be used to hold the funnel in place. If a large number of funnels are to be made, a pattern will make constructing the funnels much easier. Figure adapted from Enge (1997).