# HERPETOFAUNAL RESPONSES TO EVEN-AGED MANAGEMENT AND SELECTIVE HARVESTING IN THE OUACHITA MOUNTAINS, ARKANSAS

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# PREFACE

In response to growing public concern regarding management of national forests in Arkansas, the Ouachita National Forest was designated a "New Perspectives Lead Forest" in 1990. The purpose of the New Perspectives concept is to advance the use of ecological principles for attaining environmentally sound forest management. New Perspectives brings together researchers, managers, and the public to evaluate and develop new techniques for forest, landscape, and ecosystem management. As a result, the Southern Forest Experiment Station (New Orleans, Louisiana) began a long-term, interdisciplinary research initiative to assess the environmental impacts of various silvicultural practices within the Ouachita Mountains.

Past studies have suggested that clearcutting may have negative influence on herpetofaunal diversity, especially for amphibians, but most of this work has been conducted in the northwestern, eastern, and southeastern United States. This study began in March, 1993, as part of the New Perspectives research initiative. Our objective was to assess the impact of clearcutting and selective harvesting practices on herpetofaunal community structure in an upland pine-oak ecosystem.

Chapters in this thesis are written in manuscript format suitable for submission to scientific journals. The following formats are used: chapters one and two, *Journal of Herpetology*, chapter three, *Southwestern Naturalist* and chapter four *Conservation Biology*. Manuscripts are complete without supporting materials.

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# CHAPTER I

# INTRODUCTION AND LITERATURE REVIEW

## Geography

The Ouachita Mountains and the Ozark Plateau compose a unique isolated upland area known as the Interior Highlands (Atwood, 1940). The region includes over 80,000 $km^2$ of mountainous relief topographically and geologically similar to the Appalachian Mountains (Dowling, 1956). The Ouachita Mountains comprise a series of east-west trending ridges and valleys that lie between the Gulf Coastal Plain to the south and the broad Arkansas River valley to the north. This portion of the uplift averages 80-90 km wide and is more than 300 km long, extending from Atoka County, Oklahoma, to near Little Rock, Arkansas. Elevations range from 150 to 760 m.

## Soils

The Ouachitas are made up mostly of sedimentary rocks of sandstone, limestone, and conglomerate, and metamorphic rocks such as shale and chert (Mohlenbrock, 1993). Soils are predominately silty clay and silty loam and are very shallow and stony on the ridgetops, becoming progressively deeper down slope. These soils are of medium texture and are moderately permeable (Reagan, 1974).

## Climate

Climate has played an important role in the maintenance of faunal assemblages in the Interior Highlands. In the past, dry cycles have dominated the southwestern United States, but they were moderated in this region due to its relief and geographic proximity to northern glaciers (Dowling, 1956). Presently the Ouachita Mountains receive over 127 cm of annual precipitation (Webb, 1970). Average daily temperature is near 15° C (United States Department of Agriculture, 1982).

## Biogeography

Several geographical factors have contributed to the unique fauna and flora of the Interior Highlands. Unlike the southwestern United States, the Interior Highlands were not covered by shallow inland seas during the Cretaceous period (Dowling, 1956) and served as an island refuge for species. The region also may have served as a refuge for plants and animals during the Pleistocene epoch when glaciers covered adjacent northern regions (Dowling, 1956). During the late Cenozoic era, sediments that had been deposited by inland seas were eroded, further defining boundaries and isolating the uplift. Finally, during the Pleistocene, the existing river systems were formed. Formation of the Arkansas River divided the region into the Ozark Mountains to the north and the Ouachitas to the south.

The northern Ouachitas are drained by the Fourche and Poteau Rivers while the southeastern Ouachitas are drained primarily by the Kiamichi River drainage of the Red River system.

The topographic and climatic situation in the Ouachita uplift has created a unique habitat that supports a rich flora and fauna, including more than a dozen endemic plant species (Mohlenbrock, 1993). The herpetofauna is likewise rich, with high species densities of both reptiles and amphibians (Kiester, 1971). Most reptile species are less confined by ecological factors than some other taxa. Thus, reptile faunal assemblages are more or less representative of adjacent regions and no endemic species are found within the uplift. Anurans, which are relatively mobile, also are not represented by endemic forms. Salamanders, however, are represented by five or more endemic species, and several endemic subspecies (Connant and Collins, 1991).

Many of the species of reptiles and amphibians in the Ouachitas are relatively uncommon and some are considered threatened due to limited distributions or low population densities. Ashton (1976), Black (1977), and Reagan (1974) list the following as rare or threatened: *Amphiuma tridactylum*, three-toed amphiuma, *Ambystoma annulatum*, ringed salamander, *Ambystoma talpoideum*, mole salamander, *Plethodon ouachitae*, Rich Mountain salamander, *Plethodon caddoensis*, Caddo Mountain salamander, *Hyla avivoca*, birdvoiced tree frog, Cemophora coccinea, scarlet snake, and Terrapene ornata, ornate box turtle.

## Silvicultural Effects

Topography in the mountainous areas of the Ouachitas is often too rugged for intensive agricultural use. This has led to a local economy which is heavily reliant upon livestock, poultry production, and a large timber industry.

Two different silvicultural systems are employed in the region: even-aged management (i.e., clearcutting) and uneven-aged management (i.e., selective harvesting). In even-aged management, all trees are harvested from an area such that the "forest influence" is removed from most of the area (Kimmins, 1992). The resulting new population of seedlings is established through natural regeneration or planting such that only one age-class of trees is represented in the stand. In uneven-aged forest management, individual trees or groups of trees are removed periodically throughout a predetermined period. The resulting forest contains trees from several age-classes (Kimmins, 1992).

Even-aged silviculture employing clearcutting, site preparation, and planting of pines has been the primary method of pine regeneration on southern forests for 25 years. Although young pine plantations provide excellent habitat for many wildlife species adapted to early successional stages (such as deer, rabbits, and quail), clearcutting is generally detrimental to species that require an abundance of snags and cavity trees, hardwoods, hard mast, coarse woody debris, and other mature forest habitat features (Thill, 1990; Kimmins, 1992). It has been shown that some reptiles and amphibians require similar habitat features; e.g., oak-hickory habitats supported greater numbers of amphibians than nearby managed-pine habitats in South Carolina (Bennett et al., 1980). Similarly, Enge and Marion (1986) found that clearcutting and site preparation in Florida had a negative impact on reptile and amphibian numbers and on reptile species richness. The decrease in numbers of amphibians in heavily treated areas was primarily due to reduced reproductive success in certain species, such as Scaphiopus spp., Rana sphenocephala, and Gastrophryne carolinensis. Low numbers of young-of-the-year were noted in clearcut areas, possibly due to disappearance of standing water before young anurans could metamorphose. In another study, presence and numbers of amphibians in managed stands were strongly affected by the occurrence and longevity of intermittent ponds and streams during winter (Whiting et al., 1987).

Clearcutting causes changes in soil structure, hydrology, and horizontal and vertical vegetation structure that subsequently affect temperature and moisture regimes (Geiger, 1971). These altered characteristics affect microhabitats important to amphibians (Heatwole and Lim, 1961; Heatwole, 1962; Bury, 1983; Feder, 1983; Pough et al., 1987; Ash, 1988; Pechman et al., 1991; Matlack, 1994). These changes are in part facilitated by canopy removal, elimination of moisture-retaining forest floor litter, and soil compaction (Bury, 1983; Raymond and Hardy, 1991; Bratton, 1994).

One of the most important habitat components for terrestrial salamanders is deciduous leaf litter, a likely prerequisite for colonization by many species. Deciduous leaf litter retains moisture that plays a significant role in the distribution and activity patterns of terrestrial salamanders (Jaeger, 1971). Pure stands of conifers are generally unsuitable for salamanders in the eastern and central United States (Bennett et al., 1980; Pough et al., 1987; Williams and Mullin, 1987). In loblolly-shortleaf pine (Pinus taeda and P. echinata) stands of east Texas, Whiting et al. (1987) found that understory development and degree of deciduous litter accumulation strongly influenced herpetofaunal communities.

Petranka et al. (1993) compared 5-year-old clearcuts with mature stands over 80 years old and found that terrestrial salamanders were completely eliminated or reduced to very low numbers after the mature forest was cut. The authors estimated that 75-80% of salamanders were lost following clearcutting. Furthermore, Petranka et al. (1994) estimated that it would require a century or more for populations to return to predisturbance levels. There is concern that this reduction could produce population bottlenecks and decreased genetic diversity. In some cases, local populations of sedentary species may be prone to extinction (Petranka et al., 1993).

On a regional scale, survival of a reduced population depends upon recolonization through immigration from undisturbed areas (Fahrig and Merriam, 1994). Constraints on such immigration, however, are 1) that salamanders generally only migrate under a narrow set of environmental conditions, 2) migrating individuals may have difficulty establishing territories in new areas due to interspecific competition with other herps, and 3) adult salamanders are often highly philopatric (Petranka et al., 1993; Petranka, 1994). As a result of these factors, recolonization of heavily disturbed areas is slow.

As with amphibians, differences in reptile species richness and community composition have been observed between different silvicultural treatments (Enge and Marion, 1986; Whiting et al., 1987). Populations of some reptiles have been shown to increase in response to clearcutting. This may be due to increased abundance of certain types of prey as well as the creation of favorable microhabitats or refugia (Enge and Marrion, 1986). Cnemidophorus sexlineatus, a cursorial lizard that prefers open sandy areas, was favored in the most intensively managed clearcut sites (Enge and Marion, 1986). Several grassland species also seemed to favor very young plantations, including *Thamnophis proximus*, *Masticophis flagellum*, *Lampropeltis calligaster*, and *L. getula* (Whiting et al., 1987). Evidence suggests that clearcutting is followed by increases in small-mammal densities and species diversity (Kirkland, 1977; Atkinson and Johnson, 1979; Kirkland, 1990). This may provide a greater food base for snake species that feed primarily on small rodents.

In summary, various biotic and abiotic factors have major effects on community composition and relative abundances of reptiles and amphibians. For amphibians, availability of water and presence of deciduous leaf litter seem important. Of course, these factors are not independent of other habitat characteristics such as overstory composition, soil structure, weather, and season. Reptile community composition is related to understory and overstory development as well as presence of coarse woody debris or rocky outcroppings. Some reptile species also seem particularly dependent upon presence of various prey. All habitat characteristics affecting herpetofaunal community composition are ultimately dependent upon age of the forest and degree of disturbance.

Reptiles and amphibians can be important components of forest food-webs and sometimes contribute a surprising amount of biomass to the community (Burton and Likens, 1975;

Pough et al., 1987). For example, population densities of Plethodon cinereus in deciduous forests of the eastern United States can be as high as 0.9-2.2 individuals/$m^2$ (Heatwole, 1962; Jaeger, 1980). Because amphibians are often habitat specialists with restricted distributions, they may be valuable indicators of ecosystem health and stability. Despite new evidence that reptiles and amphibians are important components in many ecosystems, they continue to be neglected by land managers (Pough et al., 1987). Some management plans may even promote mid-successional stages to maximize alpha diversity of other taxa at the cost of sensitive reptile and amphibian species (Faaborg, 1980; Sampson and Knopf, 1982).

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LRH: D. CROSSWHITE ET AL.

RRH: COLLECTION OF REPTILES AND AMPHIBIANS

# Techniques and a Comparison of Methods for Collecting Reptiles and Amphibians in a Pine-Oak Forest of the Ouachita Mountains, Arkansas

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## Abstract

We present a quantitative comparison of pitfall arrays, double-ended funnel traps, and time-constrained searching as methods for capturing reptiles and amphibians. We conducted the study in the forested upland areas of the Ouachita Mountains, Arkansas. Capture methods were appraised for heterogeneity across taxonomic groups (anurans, salamanders, and squamates) using contingency table analysis. Trends and differences between reptile and amphibian capture success over time were analyzed by two-way analysis of variance. Capture success for types of funnel traps were compared across different size classes of squamates.

We sampled a total of 91 days in six trapping periods during the spring and summer months of 1993 and 1994. Eight-hundred eighty-six individuals representing 38 species of reptiles and amphibians were captured. The most productive sampling technique was drift fences and associated pitfall traps. Pitfall traps effectively captured most anurans, salamanders, lizards, and small snakes, while double-ended funnel traps captured most large squamates. Funnel traps made of aluminum window screen were significantly better for catching small squamates than funnel traps made of hardware cloth because small individuals could pass through the larger mesh of the latter.

Several factors affect capture success when surveying herpetofaunal communities, including animal body size, home range size, daily and seasonal activity patterns, trap avoidance behavior, and environmental fluctuation. For example, reptile and amphibian activity often is irregular and highly correlated with temperature and precipitation (Gibbons and Bennett, 1974; Gibbons and Semlitsch, 1982; Jones, 1986; Bury and Corn, 1987). Because of complex relationships between herpetofaunal communities and these various factors, designing a sampling protocol can be difficult. Vogt and Hine (1982) suggested using multiple short sampling periods during the activity season to obtain the most accurate estimates of species composition and abundance.

Drift fences in combination with pitfall and funnel traps often are used to determine the species richness of an area, detect the presence of rare or secretive species, estimate relative abundances, and determine habitat use by individual species (Campbell and Christman, 1982; Bury and Corn, 1987; Dodd, 1991; Corn, 1994; Greenburg et al., 1994). However, the ability of certain species to circumvent particular types of traps complicates the design of a comprehensive sampling protocol. For example, animals may be prone to burrow under or climb over the drift fence. Dodd (1991) confirmed that several frog species were able to cross a drift fence by climbing or hopping over it. Several studies have suggested that drift fences and pitfalls alone are unable to accurately sample large snakes, turtles, and tree frogs (Gibbons and Bennett, 1974; Gibbons and Semlitsch, 1982; Jones, 1986). While several studies have compared the relative effectiveness of various capture methods used to sample reptiles and amphibians (Campbell and Christman, 1982; Vogt and Hine, 1982; Jones, 1986; Dodd, 1991; Greenberg et al., 1994), few have focused on the upland herpetofauna of the central United States and none have been conducted in the Ouachita Mountains. As part of a larger study comparing effects of clearcutting and selective harvesting on herpetofaunal community composition in forested uplands of the Ouachita Mountains of Arkansas, we present a quantitative comparison of capture success with four different methods: drift fences, pitfall traps, double-ended funnel traps, and time-constrained searching.

## Materials and Methods

Study sites were located in Perry County, Arkansas, on the eastern edge of the Ouachita Mountains about 70 km north of Hot Springs. Two replicates of each of the following timber stands were sampled for reptiles and amphibians: (1) previously clearcut 3 to 4-year-old pine plantations, (2) stands subjected to selective harvest of pines, and (3) 80-year-old clearcut stands. All stands had a predominately south, southeast, or southwest aspect and slopes of 5-20%.

Because we were interested in comparing trap efficiency apart from treatment effects, the results from these samples were pooled for purposes of the present evaluation.

Three drift fence arrays were equally spaced along a central transect which angled down slope and bisected each timber stand. Arrays consisted of drift fences, pitfall traps, and funnel traps arranged in a trapping system specifically designed to capture reptiles and amphibians (Fig. 1) and modified from Jones (1981), Campbell and Christman (1982), and Vogt and Hine (1982). Arrays were positioned at least 100 m from any road, stream or timber stand border. Arrays were spaced at 100-m intervals, making each central transect approximately 300 m in total length. Each array consisted of three 15.2-m x 30.5-cm sections of drift fence (galvanized metal flashing) that originated at a central point and radiated outward at approximately 120° (Fig. 1a). Drift fences were buried about 5 cm below the surface of the soil to prevent animals from burrowing under them. An 18.9-l pitfall trap (plastic paint bucket) was buried at the central point and at the end of each of the three sections of the array. Holes were punched in the bottom of each trap to drain standing water. Pitfall traps were buried flush with the ground surface, allowing the drift fence to overhang the lip of each pitfall trap (Fig. 1b). This helped in intercepting and guiding animals into the traps (Clawson and Baskett, 1982). Two double-ended funnel traps were placed on each side of each arm of the arrays for a total of 12 funnel traps per array. Six funnel traps were constructed of 0.64-cm mesh hardware cloth (Fitch, 1951) and six were of 1.5-mm mesh aluminum window screen (Jones, 1986). Funnel traps were molded and positioned to fit as close to the drift fence as possible to prevent animals from moving between the traps and the fence. We attempted to make the entrance from the substrate into the trap as smooth a transition as possible by placing soil and detritus so that it led into the trap opening. We periodically removed herbaceous vegetation when it threatened to overgrow the arrays. This was most problematic near the funnel traps and along the fence where a buildup of vegetation and debris could potentially reduce trapping success by deterring small snakes, lizards, or frogs away from the fence.

Seventy-eight additional double-ended funnel traps were placed on transects in a 100-m x 300-m grid within each stand. Four transects were established parallel to the array transect, two on either side. These transects were placed 25 m and 50 m, respectively, to either side of the central transect. Seventeen double-ended funnel traps made of 1.5-mm mesh aluminum window screen (Jones, 1986) were placed at 15-m intervals along each of these four transects. These traps were positioned along fallen logs, rocky outcroppings, or in shallow depressions. Also, ten 0.64-cm mesh hardware cloth funnel traps (Fitch, 1951) were placed on the center transect in line with the arrays. Thus, a total of 114 funnel traps, including those associated with the arrays, were placed within each stand.

When pitfall traps were not in use, they were closed with tight-fitting snap lids. Likewise, funnel traps were closed by lodging a plug of aluminum foil into the entrance of each. During sampling periods, a square section of roofing material was draped over each funnel trap to provide shade for captured animals. Pitfall traps were shaded using small sticks to prop the lids 10-15 cm above the container (Fig. 1b). These measures helped minimize mortality from overheating and desiccation.

Arrays were installed during March, 1993, about two months prior to trapping. Over the spring and summer seasons, traps were opened during three periods in 1993 (22 May-6 June, 15-30 June, and 15-25 July) and three periods in 1994 (6-21 March, 14-29 May, and 15-29 June). Traps were checked on alternate days.

Time-constrained searches also were conducted to sample sedentary animals or those that are otherwise difficult to trap. We dedicated six person-hours of searching to each stand during each of the six sampling periods. Additionally, six person-hours of time-constrained searching were conducted for each stand during 8-10 April 1994. Searches consisted of turning cover objects (rocks, logs and bark), probing crevices, and visually looking for active animals.

Animals captured by each method were identified to species, permanently marked, and released unharmed at the point of capture or recapture. Our original intent was to estimate abundances using the Lincoln-Peterson index; however, this was precluded by insufficient recaptures.

Chi-square contingency table analyses were used to assess capture methods for heterogeneity across taxonomic groups. Trends and differences between reptile and amphibian capture success over time were analyzed by two-way analysis of variance with month and taxonomic class as main effects.

Capture success for types of funnel traps were compared across different size classes of snakes and lizards. This test was used to detect any trap bias toward capture of larger individuals by the hardware cloth traps. Because these funnel traps were constructed of 0.64-cm mesh hardware cloth, it was possible that small snakes and lizards with a maximum body diameter less than the mesh size could escape. Using preserved specimens from the vertebrate collection of Oklahoma State University, we determined that small individuals of some species could potentially pass through the mesh of our hardware cloth funnel traps. Because we had measured only snout-vent length (SVL) of our field specimens, we used preserved specimens to estimate maximum body diameter (usually head width) based on SVL. From this, we estimated that small snakes (except for viparids) with SVL <340 mm and lizards with SVL <40 mm could possibly pass through the hardware cloth. Consequently, snakes and lizards captured in both screen and hardware cloth funnel traps were grouped into small and large size-classes according to these thresholds of SVL. We then used chi-square analysis to test the null hypothesis that proportions of captures were the same for small and large squamates (snakes and lizards pooled) in both types of funnel traps.

## Results

During 91 total days of collecting over the spring and summer of 1993 and 1994, we captured 886 individuals representing 38 species of reptiles and amphibians (Appendix 1). As expected, capture success was significantly different for various taxa among the sampling methods tested (Table 1). Lizards were captured most frequently during both years, representing 66% of total captures. Sceloporus undulatus and Scincella lateralis were the most common species, representing 42% and 25% of all lizards, respectively (Appendix 1). Drift fences (Table 1) and especially pitfall traps associated with drift fences (Table 2) were the most effective methods for capturing lizards. Time-constrained searching and funnel traps made of hardware cloth were the least successful methods.

Snakes composed 11% of the total captures (Table 1). The most commonly encountered species were *Agkistrodon contortrix* and *Coluber constrictor*, representing 21% and 20% of all snakes (Appendix 1). Snakes were most effectively sampled using the drift fence arrays (Table 1). Snake captures within the arrays were nearly equally divided among pitfall traps, screen, and hardware cloth funnel traps (Table 2).

Based on a chi-square test for heterogeneity, small snakes and lizards were caught significantly less frequently in hardware cloth funnel traps than in screen traps ($X^2 = 7.62$, df=1, p=0.006).

Anurans were the second most frequently captured taxon, representing 20% of total captures (Table 1). More than 89% of these anurans were captured along the drift fences (Table 1), and more than 95% of these in pitfall traps (Table 2). *Bufo americanus* and *Gastrophryne carolinensis* were the most commonly encountered species, representing 70% and 25% of all anurans captured, respectively (Appendix 1).

Nineteen salamanders were captured during the study (Table 1). Fourteen of the 19 salamanders encountered were *Eurycea multiplicata* (Appendix 1), and all (74%) were captured in or near seeps during time-constrained searches. Salamanders were most often found by turning over rocks or logs. One each of *Ambystoma talpoideum* and *A. opacum* were captured in pitfall traps associated with the arrays, and both captures occurred after rains (Table 2).

Two terrestrial turtle species were encountered, two *Terrapene ornata* and four *T. carolina* (Appendix 1). Four of these individuals were encountered during time-constrained searches, one was captured in a screen funnel trap on a transect, and one was captured in a screen funnel trap along a drift fence (Table 1).

Reptiles were captured significantly more often than amphibians ($F_{1,60} = 59.9$, $p < 0.001$) (Fig. 2). There also was a significant change in trap success over time ($F_{5,60} = 4.4$, $p = 0.002$), with captures of both taxa generally declining over the entire study. Interaction between month and taxonomic class was significant ($F_{5,60} = 4.691$, $p = 0.001$), due mostly to a decrease in numbers of reptiles collected in July, 1993, while amphibian numbers remained about the same. Reptile captures then rebounded the following March. Amphibians generally increased in abundance during the summers while reptile abundances were inconsistent across the same months of the two years but generally declined over the entire study.

## Discussion

Our findings suggests that a comprehensive sampling design is important to adequately survey herp communities. We recommend incorporating several trapping strategies to sample animals with a wide variety of habits. Within the array design itself, the pitfall traps performed well by capturing most frogs and toads, salamanders, lizards, and small snakes. Bury and Corn (1987) and Greenburg et al. (1994) also reported high numbers of anurans and lizards captured by pitfall traps. Pitfalls were not effective at capturing large snakes. These results are similar to those of others (Campbell and Cristman, 1982; Gibbons and Semlitsch, 1982; Voght and Hine, 1982; Bury and Corn, 1987; Greenburg et al., 1994), where funnel traps were responsible for the capture of most large squamates. The hardware cloth funnel traps positioned along the drift fences in particular contributed most by capturing medium and large snakes and large lizards; smaller individuals apparently escaped through the mesh of these traps. Screen funnel traps mostly captured small snakes and lizards, as was reported by Greenburg et al. (1994).

Anurans were especially abundant immediately after rains in June and July and, more than any other taxon, tended to be captured in pitfall traps, even though some species probably were able to climb or hop over the drift fence (Dodd, 1991). Anurans may have been attracted to shallow, standing water in the bottom of some pitfall traps, as they were often found in those containing water. Shields (1985) observed preferential use of pitfall traps by *Rana utricularia*.

Although we caught few turtles in our study, most were captured by hand, which suggests that turtles, like salamanders, may be more effectively sampled by this method. No turtles were captured in pitfall traps, which may have been due to avoidance behavior (Gibbons and Semlitsch, 1982).

Because terrestrial and semi-aquatic salamanders are often restricted to moist habitats and are active only under narrow sets of environmental conditions, they are most effectively sampled by hand-collecting (Petranka et al., 1993; Diller and Wallace, 1994; Dupuis et al., 1995). Reptile and amphibian activity often is irregular and highly correlated with temperature and precipitation (Gibbons and Bennett, 1974; Gibbons and Semlitsch, 1982; Jones, 1986; Bury and Corn, 1987), and the presence of water is an important determinant in the distribution of amphibians (Blymyer and McGinnes, 1977; Petranka et al., 1993). Therefore, because of higher temperatures, lower relative humidity, and greater insolation associated with south-facing slopes, we expected to capture fewer amphibians. Unlike amphibians, reptiles generally prefer the warm, dry conditions that are common during summers in the uplands of the Ouachitas. Reptiles were especially abundant in the open sunny habitats of clearcut stands.

Capture success of both reptiles and amphibians generally declined over the study. One possible reason for this may be the accelerated growth of early successional plant species near the arrays. This may have reduced trapping success by deterring small snakes, lizards or frogs away from the fence. We observed that grasses and forbs were especially dense where disturbance occurred during installation of the trapping arrays. To maintain good capture success of drift fence installations, vegetation should be kept clear of the fence.

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Table 1. Number (percent in parentheses) of captures by taxa for different sampling methods.[1]

| | Drift Fence Arrays | Transects | Time-constrained searches | Total |
|---|---|---|---|---|
| Frogs and Toads | 155(89.1%) | 1 (0.6%) | 18(10.3%) | 174 (19.7%) |
| Salamanders | 2(10.5%) | 1 (5.3%) | 16(84.2%) | 19 (2.1%) |
| Turtles | 1(16.7%) | 1(16.7%) | 4(66.7%) | 6 (0.7%) |
| Lizards | 358(61.1%) | 138(23.6%) | 90(15.4%) | 586 (66.1%) |
| Snakes | 53(52.5%) | 22(21.8%) | 26(25.7%) | 101 (11.4%) |
| Total | 569(64.2%) | 163(18.4%) | 154(17.4%) | 886(100.0%) |

[1] $X^2=138.97$, df=8, $p<<0.001$

Table 2. Number (percent in parentheses) of captures by taxa for different kinds of traps associated with drift fence arrays.

|  | Pitfall Traps | Funnel Traps |  | Total |
|---|---|---|---|---|
|  |  | Screen | Hardware Cloth |  |
| Frogs and Toads | 148 (95.5%) | 5 (3.2%) | 2 (1.3%) | 155(27.2%) |
| Salamanders | 2(100.0%) | 0 (0.0%) | 0 (0.0%) | 2 (0.4%) |
| Turtles | 0 | 1(100.0%) | 0 | 1 (0.2%) |
| Lizards | 270 (75.4%) | 65 (18.2%) | 23 (6.4%) | 358(62.9%) |
| Snakes | 19 (35.9%) | 20 (37.7%) | 14(26.4%) | 53 (9.3%) |
| Total | 439 (77.2%) | 91 (16.0%) | 39 (6.9%) | 569(100.0%) |

Fig. 1. a). Array design showing configuration of drift fences, pitfall, and double-ended funnel traps; b) side view of an array segment showing the intersection of a pitfall trap with the drift fence.

Fig. 2. Total reptiles and amphibians captured by month at six sites (array and funnel trap captures combined).

Fig. 1a.

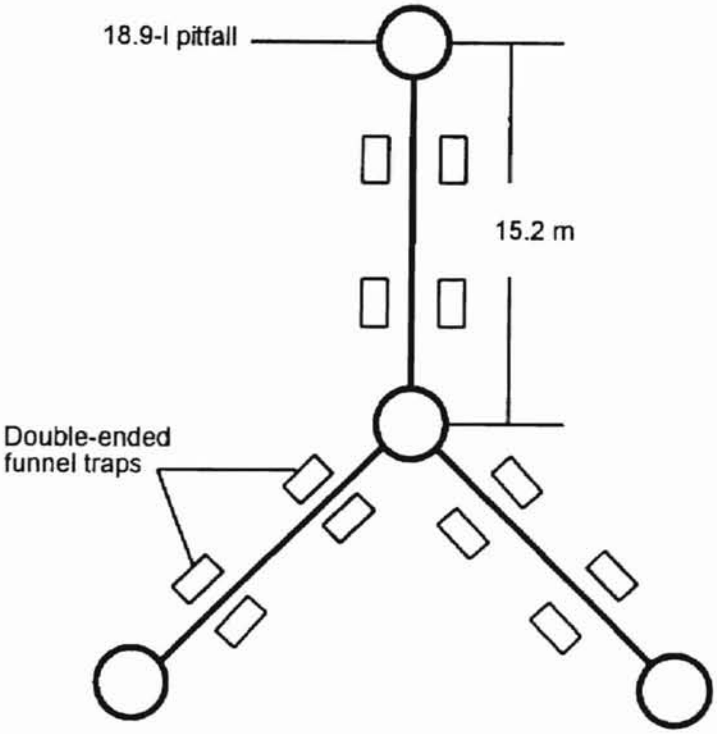


Fig. 1b.

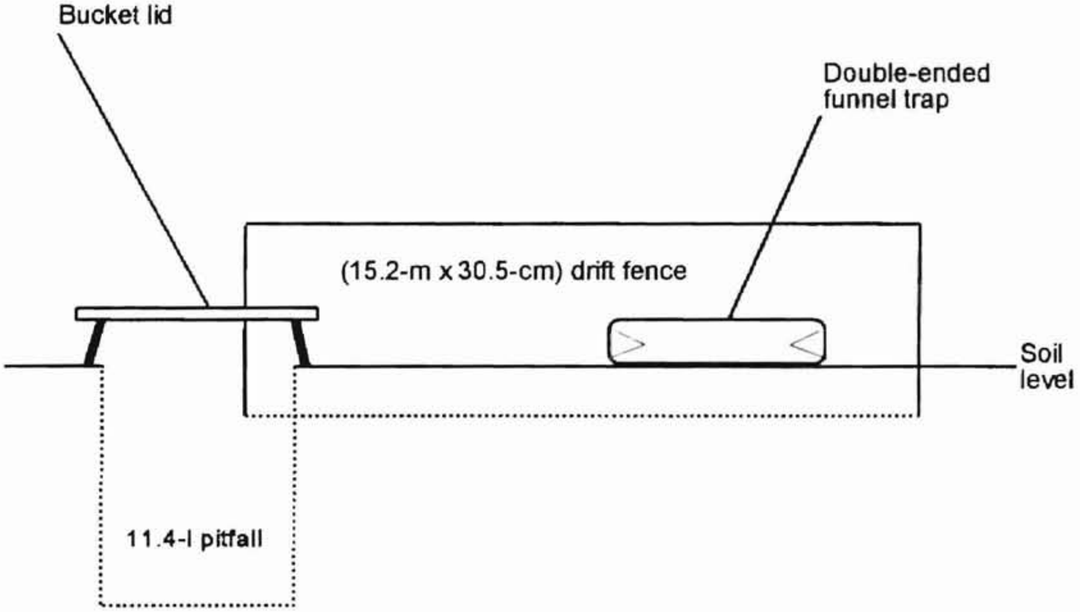
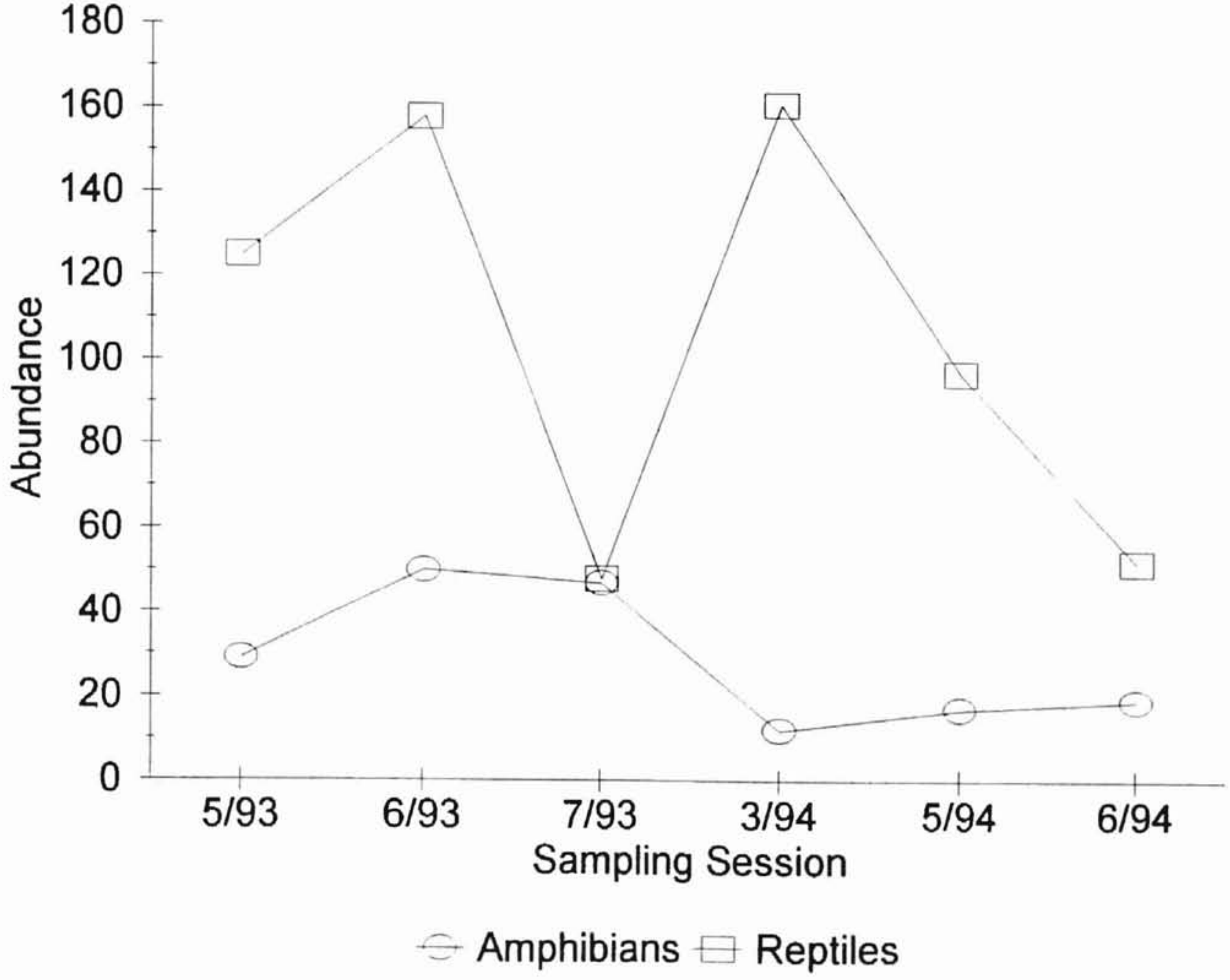

Bucket lid
Double-ended
funnel trap
(15.2-m x 30.5-cm) drift fence
Soil
level
11.4-l pitfall

Fig. 2


180
160
140
120
100
80
60
40
20
0
Abundance
5/93
6/93
7/93
3/94
5/94
6/94
Sampling Session
○ Amphibians
□ Reptiles

Appendix 1. Captures of species by month employing drift fences, funnel traps, and time-constrained searches.

| | 1993 | | | 1994 | | | | |
|---|---|---|---|---|---|---|---|---|
| Species | May | Jun | Jul | Mar | Apr[1] | May | Jun | Total (%) |
| Anurans | | | | | | | | |
| *Gastrophryne carolinensis* | 2 | 16 | 15 | 0 | 0 | 3 | 8 | 44 (5.0) |
| *Bufo americanus* | 26 | 32 | 32 | 1 | 9 | 16 | 5 | 121 (13.7) |
| *Rana clamitans* | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 (0.7) |
| *Rana catesbeiana* | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 (0.2) |
| *Rana utricularia* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 (0.1) |
| Salamanders | | | | | | | | |
| *Ambystoma opacum* | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 (0.1) |
| *Ambystoma talpoideum* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 (0.1) |
| *Eurycea multiplicata* | 2 | 0 | 0 | 11 | 1 | 0 | 0 | 14 (1.6) |
| *Plethodon albagula* | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 3 (0.3) |
| Turtles | | | | | | | | |
| *Terrapene carolina* | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 4 (0.5) |
| *Terrapene ornata* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 (0.2) |

Appendix 1. Continued

| | 1993 | | | 1994 | | | | |
|---|---|---|---|---|---|---|---|---|
| Species | May | Jun | Jul | Mar | Apr[1] | May | Jun | Total (%) |
| Lizards | | | | | | | | |
| *Anolis carolinensis* | 3 | 5 | 0 | 1 | 1 | 1 | 1 | 12 (1.4) |
| *Cnemidophorus sexlineatus* | 12 | 14 | 14 | 0 | 1 | 16 | 6 | 63 (7.1) |
| *Sceloporus undulatus* | 55 | 36 | 6 | 95 | 6 | 39 | 9 | 246 (27.8) |
| *Scincella lateralis* | 23 | 53 | 4 | 23 | 13 | 15 | 18 | 149 (16.8) |
| *Eumeces fasciatus* | 11 | 20 | 12 | 7 | 5 | 7 | 2 | 64 (7.2) |
| *Eumeces laticeps* | 5 | 6 | 3 | 0 | 1 | 4 | 4 | 23 (2.6) |
| *Eumeces anthracinus* | 0 | 0 | 0 | 23 | 1 | 3 | 2 | 29 (3.3) |
| Snakes | | | | | | | | |
| *Thamnophis sirtalis* | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 3 (0.3) |
| *Thamnophis proximus* | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 5 (0.6) |
| *Virginia valeriae* | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 (0.2) |
| *Storeria occipitomaculata* | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 4 (0.5) |
| *Storeria dekayi* | 1 | 2 | 1 | 1 | 0 | 0 | 1 | 6 (0.7) |
| *Heterodon platyrhinos* | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 3 (0.3) |

Appendix 1. Continued

| Species | 1993 May | 1993 Jun | 1993 Jul | 1994 Mar | 1994 Apr[1] | 1994 May | 1994 Jun | Total | (%) |
|---|---|---|---|---|---|---|---|---|---|
| *Diadophis punctatus* | 0 | 0 | 0 | 1 | 5 | 0 | 1 | 7 | (0.8) |
| *Carphophis amoenus* | 0 | 0 | 2 | 0 | 1 | 0 | 1 | 4 | (0.5) |
| *Opheodrys aestivus* | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 4 | (0.5) |
| *Coluber constrictor* | 3 | 6 | 1 | 2 | 1 | 5 | 2 | 20 | (2.3) |
| *Masticophis flagellum* | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 3 | (0.3) |
| *Elaphe guttata* | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 4 | (0.5) |
| *Elaphe obsoleta* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | (0.1) |
| *Cemphora coccinea* | 1 | 2 | 1 | 0 | 0 | 0 | 1 | 5 | (0.6) |
| *Lampropeltis triangulum* | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 4 | (0.5) |
| *Lampropeltis calligaster* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | (0.1) |
| *Lampropeltis getula* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | (0.1) |
| *Agkistrodon contortrix* | 3 | 6 | 2 | 5 | 1 | 3 | 1 | 21 | (2.4) |
| *Sistrurus miliarius* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | (0.1) |
| *Tantilla gracilis* | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | (0.2) |
| Totals | 162 | 209 | 97 | 175 | 51 | 118 | 74 | 886 | (100.0) |

[1] Time constrained searching was the only capture method employed during April.

# HERPETOFAUNAL COMMUNITY RESPONSES TO EVEN-AGED MANAGEMENT AND SELECTIVE HARVESTING IN THE OUACHITA MOUNTAINS, ARKANSAS

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Abstract- We studied the herpetofauna inhabiting forest stands representing two different silvicultural systems within the Ouachita Mountains of west-central Arkansas; 1) even-aged management (clearcutting) and 2) uneven-aged management (selective harvesting). Reptiles and amphibians were monitored on 2 replicates of 3 timber treatments. Timber treatments included: 1) previously clearcut, young pine plantations, 2) selectively harvested pine/oak woodlands, and 3) 80-year-old regenerated clearcut stands. We employed drift fences, pitfall traps, double-ended funnel traps, and time-constrained searching to sample reptiles and amphibians. Abundances and species richness were determined for each of the timber stands. Differences in abundances and richness among treatments and over time were analyzed by two-way analysis of variance.

We monitored traps for 91 total days during 7 separate periods in spring and summer, 1993 and 1994. We captured 886 individuals, representing 38 species. Reptiles and amphibians responded differently to selective harvesting and clearcutting. Species richness and abundance of amphibians were lowest on the recently clearcut pine plantations and highest on the selectively harvested stands. Species richness and abundance of reptiles were highest within the recently clearcut pine plantations and lowest within the late seral stands. Species diversity of reptiles and amphibians showed no clear trend; however, several species did show preferences for particular habitats.

## INTRODUCTION

Reptiles and amphibians are important components of many food webs and can contribute a surprising amount of biomass to communities (Burton and Likens, 1975; Pough et al., 1987). Furthermore, because reptiles and amphibians are often habitat specialists with restricted distributions, they may be valuable indicator species capable of revealing the overall health and stability of ecosystems. The abundance and diversity of particular reptile and amphibian taxa indicate their importance in a community (Gibbons and Bennett, 1974). Recently, awareness of the importance of the wildlife community as a whole has led to concern for nongame wildlife and their habitats (Jones, 1986). One product of this concern has been a need to determine effects of silvicultural practices on herpetofaunal communities.

We studied herpetofaunal communities within the Ouachita Mountains, which lie between the Gulf Coastal Plain and the Arkansas River valley on the border between Oklahoma and Arkansas. This physiographic region averages 80 to 90 km wide and is more than 300 km long, extending from Atoka County, Oklahoma, to near Little Rock, Arkansas. The topography and climate of the Ouachita uplift have created a unique habitat that supports a rich herpetofauna with several endemic species. Many of the endemic species are relatively uncommon and some are considered threatened due to limited distribution or low population density (Reagan, 1974; Ashton, 1976; Black, 1977).

Topography in the mountainous areas of the Ouachitas is often too rugged for intensive agricultural use, which has led to a local economy heavily reliant upon a large timber industry. Two different silvicultural systems are employed in the region: clearcutting and selective harvesting. Clearcutting is defined as harvesting of all trees from an area such that the 'forest influence' is removed from the majority of the harvested area (Kimmins, 1992). The resulting new population of seedlings is established through natural regeneration or planting such that only one age-class of trees is represented in the stand. In contrast to clearcutting, forests managed under a selective harvest system experience removal of individual large trees (single tree selection) or groups of trees (group selection) periodically throughout the stand rotation. The resulting forest contains trees from several age-classes. Pine plantations have been the primary method of forest regeneration on many southern national forests for the past three decades.

Although young pine plantations provide excellent habitat for many wildlife species adapted to early successional stages (e.g., deer, rabbits, and quail), clearcutting on short rotations may be detrimental to those species requiring an abundance of snags and cavity trees, hardwoods, coarse woody debris, and other mature forest habitat features (Enge and Marion, 1986; Pough et al., 1987; Thill, 1990; Kimmins, 1992). Reptiles and amphibians have been shown to require these habitat components; e.g., oak-hickory habitats supported greater numbers of individual amphibians than nearby managed pine habitats (Bennett et al., 1980). Enge and Marion (1986) found that clearcutting and site preparation had a negative overall impact on reptile and amphibian numbers and on reptile species richness.

Our objectives were as follows: 1) to compare herpetofaunal community structure among three timber treatments; and 2) to compare temporal variation in herpetofaunal community structure among timber treatments.

## Materials and Methods

Our study sites were located in Perry County, Arkansas, on the eastern edge of the Ouachita Mountains about 70 km north of Hot Springs. A total of six study sites (two replicates of three timber treatments) were established in the Fourche Mountain subdivision of the Ouachita Mountains (Table 1). Treatments included: (1) previously clearcut 3 to 4-year-old pine plantations (hereafter clearcut), (2) stands subjected to selective harvest of pines, and (3) 80-year-old clearcut stands (hereafter late seral stands). All stands had a predominately south, southeast, or southwest aspect and slopes of 5 to 20%.

We employed three collecting methods (drift fences with pitfall traps, double-ended funnel traps and time-constrained searching) to compare herpetofaunal communities among treatments. On each replicate we established three drift fence arrays (Fig. 1a) consisting of drift fences, pitfall traps, and double-ended funnel traps arranged into a system specifically designed to capture reptiles and amphibians. Our design was modified from Campbell and Christman (1982), Vogt and Hine (1982), and Jones (1986). Within each stand, three drift fence arrays were placed on a central transect. This transect was positioned at least 100 m from any road, stream, or stand border, providing a buffer zone between our study site and adjacent habitats (i.e., riparian areas, roadsides, disparate timber stands). Arrays were spaced at 100-m intervals along this transect, making the central transect approximately 300 m in total length. Each array consisted of three 15.2-m x 30.5-cm sections of drift fence (galvanized metal flashing) originating at a central point and radiating outward at approximately 120°. Drift fences were buried roughly 5 cm below the surface of the soil to prevent animals from burrowing under them. An 18.9-l pitfall trap (plastic paint bucket) was buried at the central point and at the end of each of the three sections of the array. Pitfall traps were buried flush with the ground surface, allowing the drift fence to overhang the lip of each pitfall trap (Fig. 1b). Finally, two double-ended funnel traps, one of hardware cloth (Fitch, 1951) and one of aluminum window screen (Jones, 1986), were placed on each side of each arm of the arrays for a total of 12 funnel traps per array. Funnel traps were molded and positioned to fit as close to the drift fence as possible in order to prevent animals from moving between the funnel traps and the fence.

Four additional transects were established parallel to the central array transect, two on either side. These transects were spaced 25 m and 50 m to either side of the central transect. Seventeen double-ended funnel traps made of aluminum window screen (Jones, 1986) were placed at 15-m intervals along each of these four transects. Finally, 10 hardware cloth funnel traps (Fitch, 1951) were evenly spaced along the central transect. Thus, a total of 114 funnel traps were placed within each stand (including those associated with the arrays).

Arrays were constructed during 5 to 13 March 1993 and additional funnel trap transects were established 17 to 21 May 1993. All traps were monitored and time-constrained searches were conducted during six periods over the spring and summer months (22 May to 6 June, 15 to 30 June, 15 to 30 July 1993; and 15 to 30 March, 15 to 30 May, and 15 to 30 June 1994). During 8 to 10 April 1994, six person-hours of time-constrained searches also were carried out on each timber stand. We sampled for a total of 91 days during the six trapping periods and the searches in April.

Data from all capture techniques were combined within sampling sessions for each stand. Two-way ANOVA was used to compare taxon abundances (total number of individuals of reptiles or amphibians) and richness (the number of species encountered per stand) across season (sampling session) and treatment. Although we also calculated Shannon diversity (Shannon and Weaver, 1963), these data were not analyzed by ANOVA because this measure is itself a statistic.

Our original intent was to use the Lincoln-Peterson index to estimate population sizes; however, this was precluded by insufficient recaptures. We did, however, compare abundances by assuming that capture probabilities for each species are the same among treatments. We used two-way ANOVA to test for the effects of treatment and sampling session on abundance and richness. When the interaction was significant ($P < 0.05$), ANOVA was followed by pairwise comparisons among treatments within each sampling session using the sequential Bonferroni correction (Rice, 1989). Because we had only two replicates per cell of the two-way ANOVA, it was not possible to adequately test for normality and homogeneity of variances. However, if the results of the ANOVA tests are consistent with differences observed in the plotted data (Figs. 2-5), then those statistical tests are probably valid. All statistical analyses were performed using SYSTAT for Windows, version 5 (Wilkinson et al., 1992).

## Results

Altogether, 886 individuals representing 38 species of reptiles and amphibians were captured. Numbers within each silvicultural treatment for the ten most abundant species overall are given in Table 2. The most productive sampling technique was the drift fences and pitfall traps, which resulted in the capture of 439 animals--more than 77% of all captures.

Amphibian densities remained low relative to those of reptiles throughout most of the study (Figs. 2 and 3). The highest amphibian abundances occurred in selectively harvested treatments and the lowest occurred in clearcut stands (Fig. 2). Main effects of sampling session ($F_{5, 18}$ = 4.1, P = 0.01) and silvicultural treatment ($F_{2, 18}$ = 17.5, P < 0.001), and their interaction ($F_{10, 18}$ = 4.6, P = 0.002) were statistically significant. Amphibian abundances in the selectively harvested stands were generally greater than in the other two treatments (Fig. 2), and significantly so (table-wide P < 0.05) during both June and July of 1993.

Reptiles were significantly more abundant in the clearcut stands and least abundant in the late seral stands ($F_{2, 18}$ = 8.0, P = 0.003) (Fig. 3). Capture success generally behaved the same over time for all treatments, declining significantly into each summer ($F_{5, 18}$ = 11.6, P < 0.001). The interaction of treatment and sampling session was not significant ($F_{10,18}$ = 2.2, P= 0.073).

Amphibians exhibited significant among-treatment variation in species richness ($F_{2, 18}$ = 6.4, P = 0.008). Richness remained highest in selectively harvested stands during all sampling sessions except May 1993 (Fig. 4). Sampling session ($F_{5,18}$ = 2.1, P = 0.115) and its interaction with treatment ($F_{10,18}$ = 0.7, P = 0.708) showed no statistically significant differences.

Reptile species richness also varied significantly among treatments ($F_{2, 18}$ = 3.7, P = 0.047) (Fig. 5), but unlike amphibians, maintained the highest richness within the clearcut stands in all but the last two sampling sessions of 1994 (Fig. 5). Sampling session ($F_{5,18}$ = 2.6, P

= 0.062) and its interaction with treatment ($F_{10,18}$ = 1.4, P = 0.268) showed no statistically significant differences.

## Discussion

Amphibians were least abundant and generally maintained the lowest species richness in the clearcut treatments while exhibiting the greatest abundance and richness in the selectively harvested stands. This is in part because moisture is an important factor determining the distribution of amphibians (Blymyer and McGinnes, 1977; Petranka et al., 1993) due to the necessity for cutaneous gas exchange (Duellman and Trueb, 1986). Because of higher temperatures, lower relative humidity, and greater insolation in clearcuts, we expected fewer amphibians in these areas. This agrees with Petranka et al. (1993), who reported that salamander populations were eliminated or severely reduced following clearcutting.

The especially high amphibian abundance on the selectively harvested stands during June and July 1993 was primarily due to emergence of large numbers of two anurans, Gastrophryne carolinensis and Bufo americanus, following precipitation and cooler weather during each sampling period. Together these two species represented 95% of amphibian captures during the 1993 season and 85% for both seasons combined. These were the only amphibians among the ten most frequently captured species in our study (Table 2). Apparently, habitats of selectively harvested stands favored these species more than habitats in the other treatments and precipitation caused them to emerge. One possible reason for the greater abundance of these species on selectively harvested stands could be the presence of standing water that collects in shallow depressions created by heavy equipment during the harvesting operation. These depressions occur on clearcut stands as well; however, due to higher evaporative rates, they contain water only temporarily, probably not long enough for anurans to undergo metamorphosis.

Unlike amphibians, reptiles were more abundant and maintained the highest species richness in the clearcut stands. We believe that this is mostly because clearcuts have open, sunny habitats that provide thermoregulatory opportunities for reptiles. Clearcutting especially benefits certain reptile species. For example, we found the six-lined racerunner, Cnemidophorus sexlineatus, to be abundant in clearcut stands but rare in the other treatments. Enge and Marion (1986) also reported a greater abundance of C. sexlineatus in clearcut stands; they attributed this to the cursorial lizard's preference for open, sandy habitats. Higher abundances of prey is another possible explanation for the greater diversity of reptiles (especially snakes) in clearcuts. Clearcutting is usually followed by an increase in small mammal abundance and diversity that persists until canopy closure (Kirkland, 1977; Atkeson and Johnson, 1979; Kirkland, 1990). A sharp increase in small mammal densities may attract large snakes such as *Elaphe obsoleta* and *E. guttata*. The Fulvous Harvest Mouse, *Reithrodontomys fulvescens*, Southern Short-tailed Shrew, *Blarina carolinensis*, Golden Mouse, *Ochrotomys nuttalli*, and White-footed Deer Mouse, *Peromyscus leucopus* were all commonly captured by our pitfall traps in the early seral stands, while only *P. leucopus* was observed in the other two treatments.

In summary, clearcut habitats in the Ouachita Mountains produce a positive community response for most reptiles. For amphibians, these habitats seem to support fewer species and reduced population densities. Declines in abundances of both reptiles and amphibians in all treatments over time is in part due to the inhospitable weather conditions during the months of June and July in our study area. During this time many species (especially amphibians) became inactive except during periods of precipitation and cooler temperatures.

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Table 1--Silvicultural treatment histories for each of the six forest stands.

| Stand # | Treatment | Year of Harvest | Year[1] of Burn | Year of Herbicide Treatment |
|---|---|---|---|---|
| Ia | selective harvest | 1972,92 | 1985,88 | 1973(2,4,5-T) |
| Ib | selective harvest | 1976,91 | 1988 | 1973(2,4,5-T) |
| IIa | late seral clearcut | 1912 | --- | --- |
| IIb | late seral clearcut | 1912 | --- | --- |
| IIIa | early seral clearcut | 1990 | --- | 1990(Garlon 3A) |
| IIIb | early seral clearcut | 1988 | --- | 1988(Garlon 3A) |

[1] Controlled burning of understory was conducted to eleminate slash and/or young hardwoods.

Table 2--Number (%) of captures by treatment for the ten most abundant species.

| Species | Treatment | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Early Seral Clearcut | | Late Seral Clearcut | | Selective Harvest | | | |
| Frogs and Toads | | | | | | | | |
| *Bufo americanus* | 5 | (1.3) | 47 | (20.1) | 69 | (20.1) | 121 | (13.7) |
| *Gastrophryne carolinensis* | 2 | (0.6) | 5 | (2.1) | 37 | (10.8) | 44 | (5.0) |
| Lizards | | | | | | | | |
| *Sceloporus undulatus* | 117 | (38.0) | 53 | (22.7) | 76 | (22.1) | 246 | (27.8) |
| *Scincella lateralis* | 25 | (8.1) | 61 | (26.1) | 63 | (18.3) | 149 | (16.8) |
| *Eumeces fasciatus* | 18 | (5.8) | 12 | (5.1) | 34 | (9.9) | 64 | (7.2) |
| *Cnemidophorus sexlineatus* | 55 | (17.9) | 3 | (1.3) | 5 | (1.5) | 63 | (7.1) |
| *Eumeces anthracinus* | 9 | (2.9) | 7 | (3.0) | 13 | (3.8) | 29 | (3.3) |
| *Eumeces laticeps* | 10 | (3.3) | 5 | (2.1) | 8 | (2.3) | 23 | (2.6) |
| Snakes | | | | | | | | |
| *Agkistrodon contortrix* | 6 | (2.0) | 7 | (3.0) | 8 | (2.3) | 21 | (2.4) |
| *Coluber constrictor* | 9 | (2.9) | 5 | (2.1) | 6 | (1.7) | 20 | (2.3) |
| All Remaining Species | 52 | (16.9) | 29 | (12.4) | 25 | (7.3) | 106 | (12.0) |
| Totals | 308 | (100.0) | 234 | (100.0) | 344 | (100.0) | 886 | (100.0) |

Fig. 1. a). Array design showing configuration of drift fences, pitfall, and double-ended funnel traps; b) side view of an array segment showing the intersection of a pitfall trap with the drift fence.

Fig. 2. Mean abundances of amphibians for each treatment over six sampling sessions.

Fig. 3. Mean abundances of reptiles for each treatment over six sampling sessions.

Fig. 4. Mean species richness of amphibians for each treatment over six sampling sessions.

Fig. 5. Mean species richness of reptiles for each treatment over six sampling sessions.

Fig. 1a.

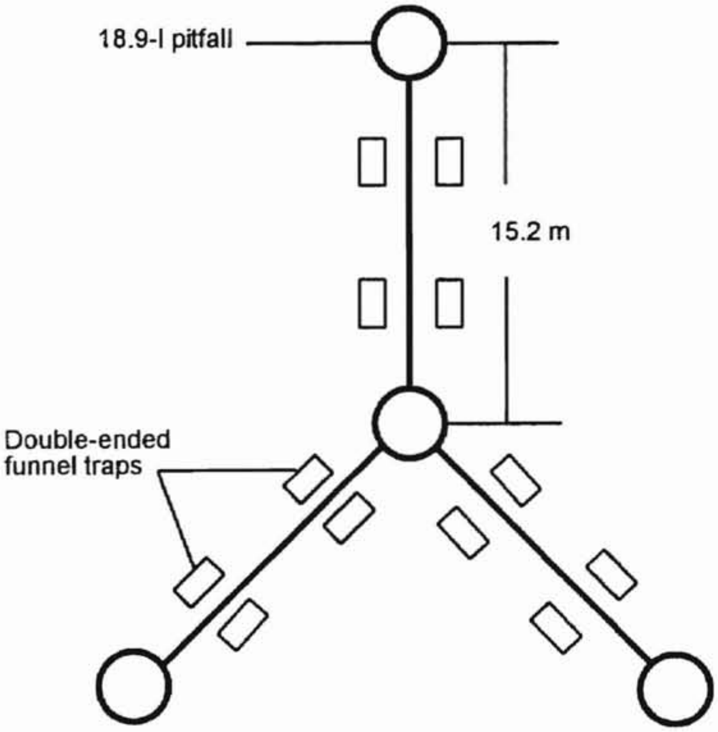
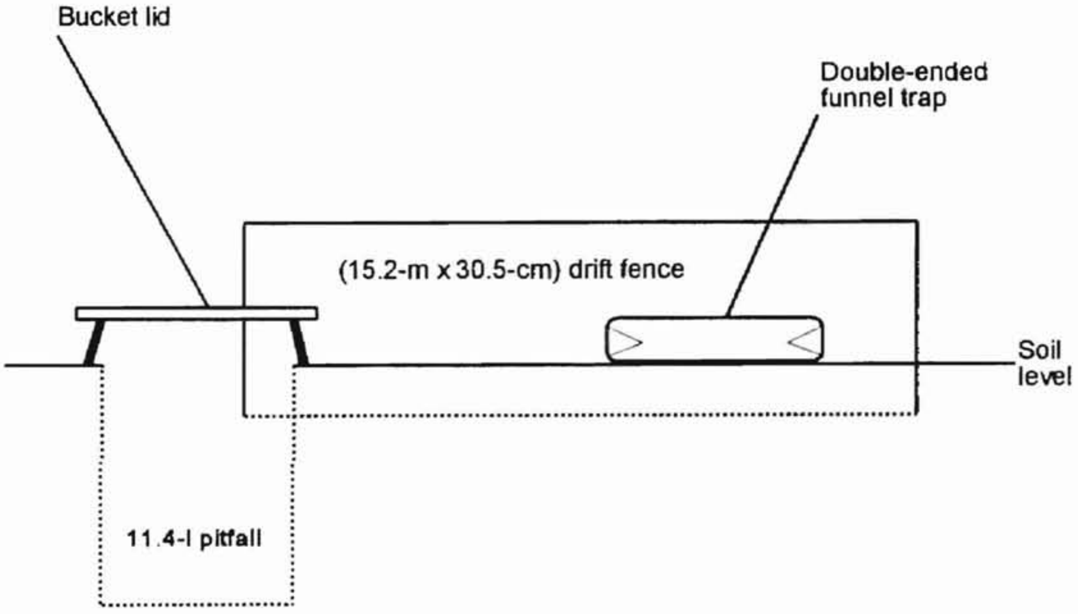


Fig. 1b.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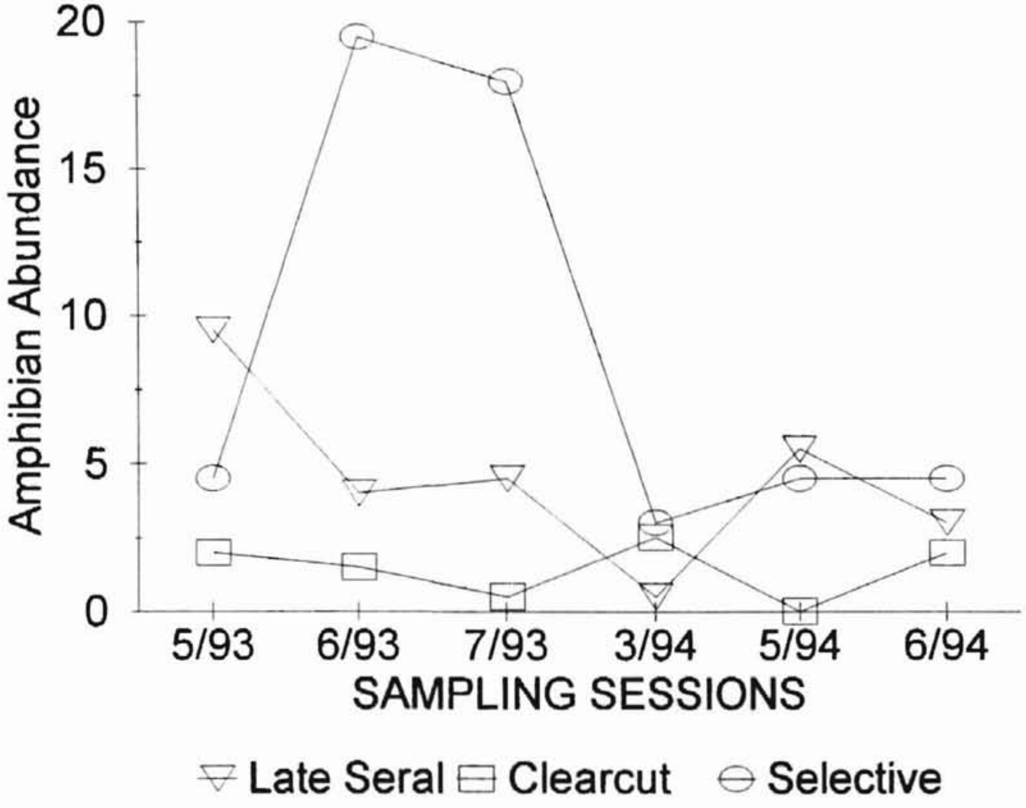
Double-ended funnel trap
(15.2-m x 30.5-cm) drift fence
Soil level
11.4-l pitfall

Fig. 2



20
15
10
5
0
Amphibian Abundance
5/93
6/93
7/93
3/94
5/94
6/94
SAMPLING SESSIONS
Late Seral
Clearcut
Selective

Fig. 3

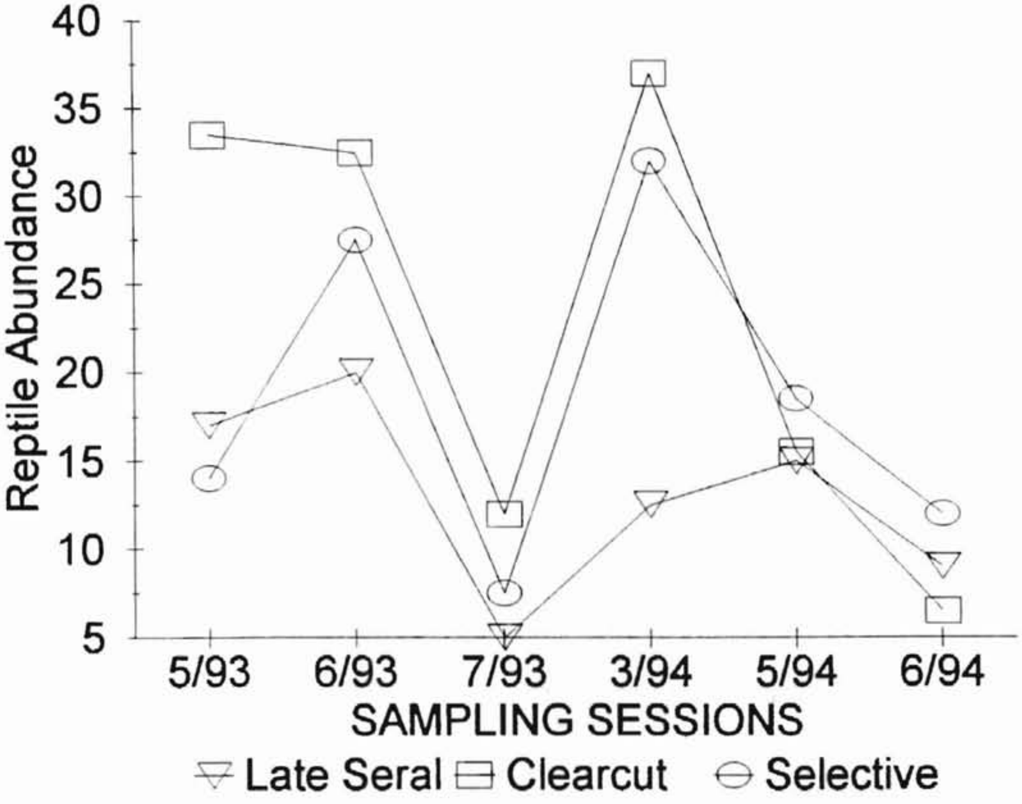

40
35
30
25
20
15
10
5
Reptile Abundance
5/93
6/93
7/93
3/94
5/94
6/94
SAMPLING SESSIONS
Late Seral
Clearcut
Selective

Fig. 4

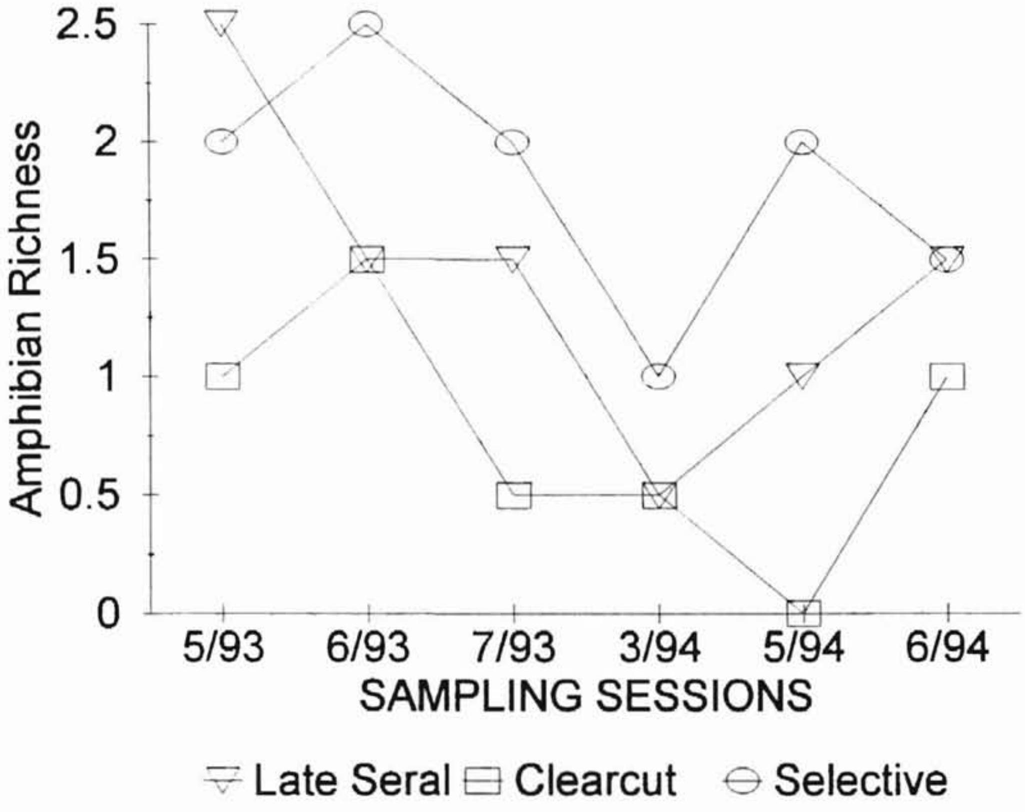
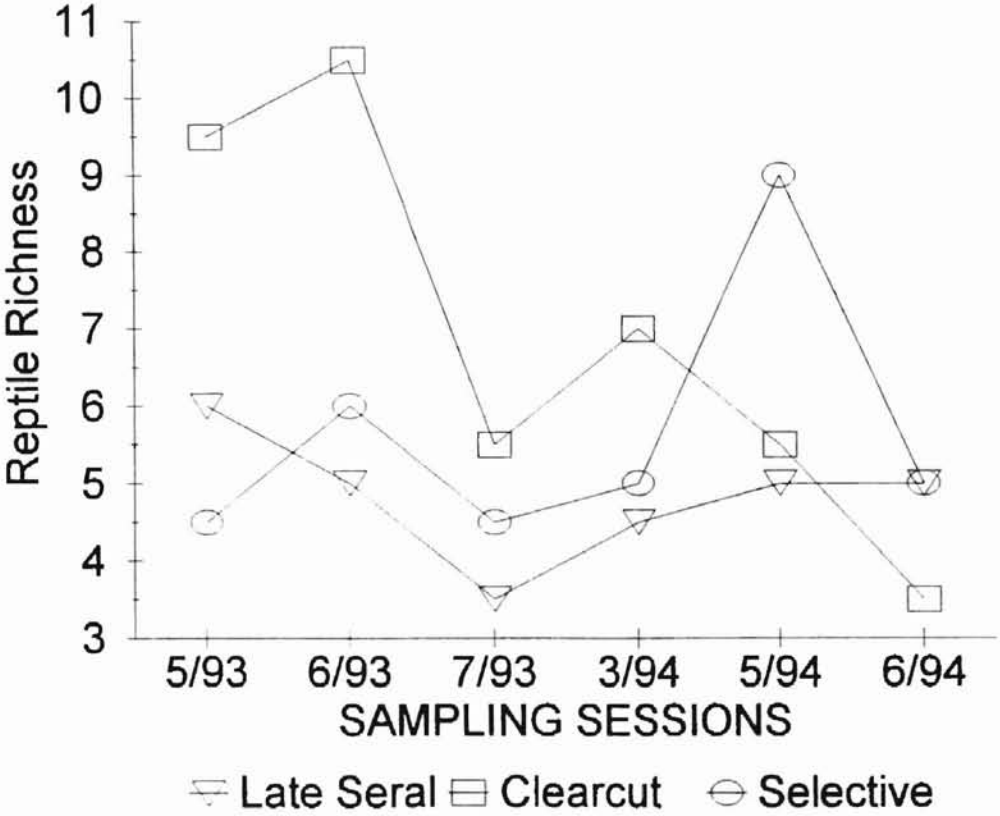

2.5
2
1.5
1
0.5
0
Amphibian Richness
5/93
6/93
7/93
3/94
5/94
6/94
SAMPLING SESSIONS
Late Seral
Clearcut
Selective

Fig. 5


Reptile Richness
11
10
9
8
7
6
5
4
3
5/93
6/93
7/93
3/94
5/94
6/94
SAMPLING SESSIONS
▽ Late Seral
⊟ Clearcut
⊖ Selective

# HERPETOFAUNAL HABITAT RELATIONS ON CLEARCUT AND SELECTIVELY HARVESTED FOREST STANDS IN THE OUACHITA MOUNTAINS, ARKANSAS

by

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## ABSTRACT

We studied habitat relationships of the herpetofauna inhabiting managed pine-oak woodlands of the Ouachita Mountains, Arkansas. Our objectives were to identify herpetofaunal community structure and microhabitat associations among different silvicultural treatments. We employed drift fences with pitfall and double-ended funnel traps to sample young pine plantations, 80-year-old regenerated clearcuts, and selectively harvested stands. Ninety-one days of monitoring produced 633 individuals representing 35 species. Canonical correspondence analysis indicated that species composition differed significantly among forest treatments. The most distinct separation of species groups was between reptiles and amphibians; reptiles generally inhabited clearcuts while amphibians were most abundant on forested stands. Clearcuts were characterized by dense ground cover and abundant coarse woody debris. Late seral and selectively harvested stands had greater litter accumulation, canopy coverage and more mature trees. In turn, selective harvest and late seral stands differed from one another in that the former had greater herbaceous cover and large, coarse, woody debris, while the latter had more woody cover. Four environmental parameters (canopy coverage, litter, woody cover, and large, woody debris) explained most of the variation in species composition among

sample sites. Several species showed clear preferences for particular habitats.

## INTRODUCTION

Reptiles and amphibians are important components in temperate ecosystems of North America (Kiester 1971; Burton and Likens 1975; Hairston 1987). Thirty percent of the native vertebrate fauna of the United States and Canada consists of reptiles and amphibians (Bury et al. 1980). The Ouachita Mountains have an especially rich herpetofauna (Kiester 1971). The Ouachitas lie between the Gulf Coastal Plain and the Arkansas River valley, extending from Atoka County, Oklahoma, to near Little Rock, Arkansas. The topography and climate of the area have created a unique environment supporting several endemic species of amphibians. Some of these are relatively uncommon and in some cases are considered threatened due to limited distribution or low population density (Reagan 1974; Ashton 1976; Black 1977).

Topography in the mountainous areas of the Ouachitas is often too rugged for intensive agricultural use, which has led to a local economy heavily reliant upon livestock, poultry production, and a large timber industry. Two different silvicultural systems are employed in the Ouachita Mountains, clearcutting and selective harvesting. Clearcutting is defined as harvesting of all trees from an area such that the 'forest influence' is removed from the majority of the harvested area (Kimmins 1992). Typically, populations of shortleaf pine (Pinus echinata) seedlings are reestablished via natural regeneration or planting such that only one age-class of trees is represented in the stand. Until canopy closure, clearcuts are dominated by grasses such as Andropogon virginicus and Schizachyrium scoparium. After the first growing season, stump sprouts and vigorous regrowth of woody plants such as Quercus spp., Carya spp., Rhus spp., Acer rubrum, and Cornus florida begin to create a dense understory. In contrast to clearcutting, stands managed under a selective harvest system experience removal of individual large trees (single tree selection) or groups of trees (group selection) periodically throughout the stand rotation. The resulting forest contains pine trees from several age-classes and is a mosaic of habitats including open grassy areas, brushy thickets and park-like woodlands.

The objectives of this study were to 1) determine if herpetofaunal community structure differs among silvicultural treatments, 2) determine how microhabitats differ among treatments, and 3) identify and quantitatively describe the influence of microhabitat on the herpetofauna.

## MATERIALS AND METHODS

We established study sites on six forest stands (two replicates of three treatments) located within Perry County, Arkansas, about 70 km north of Hot Springs. We studied early and late seral stage clearcuts and selectively harvested stands (Table 1); the late seral clearcut stands were used as a control approximating old growth conditions. Treatments included (1) previously clearcut 3 to 4-year-old pine plantations (hereafter clearcut), (2) 80-year-old clearcut stands (hereafter late seral stands), and (3) stands subjected to selective harvest.

Vegetation in the region is a complex and variable combination of shortleaf pine and upland hardwoods (Reagan 1974). Because of the east-west orientation of mountain ridges, temperature and humidity vary with aspect: north slopes are cooler and more moist than south-facing slopes. Therefore, north-facing slopes tend to be dominated by oaks (Quercus spp.) and hickories (Carya spp.); while south-facing slopes are dominated by shortleaf pine (P. echinata). We chose stands with a predominately southerly aspect because these best support P. echinata, the most important timber species in the region. This somewhat constrained the number and types of species we expected to encounter. The more xeric upland nature of these stands likely limited the numbers of amphibian species we encountered, but these are the stands where timber harvest is most intensive and so were of the most interest for our purposes.

Within each replicate, we established three drift fence arrays with associated pitfall and funnel traps (Fig. 1).

The array design was modified from Campbell and Christman (1982), Vogt and Hine (1982), and Jones (1986). Within each stand, the three drift fence arrays were positioned along a transect approximately 100 m from any road, stream, or stand border. Arrays were spaced at 100-m intervals along this transect, making it approximately 300 m in total length. Each array consisted of three 15.2-m x 30.5-cm sections of drift fence (galvanized metal flashing) originating at a central point and radiating outward at approximately 120° angles. Drift fences were buried 5 cm below the surface of the soil in order to prevent animals from burrowing under them. An 18.9-l pitfall trap (plastic paint bucket) was buried at the central point and at the end of each of the three sections of drift fence. Pitfall traps were buried flush with the ground surface, allowing the drift fence to overhang the lip of the pitfall (Fig. 1a). Two double-ended funnel traps, one of hardware cloth (Fitch 1951) and one of aluminum window screen (Jones 1986), were placed on each side of each arm of the arrays for a total of 12 funnel traps per array. Funnel traps were molded and positioned to fit as close to the fence as possible in order to prevent animals from moving between the funnel traps and the drift fence.

We monitored the sampling arrays for a total of 91 days during six periods (22 May to 6 June, 15 to 30 June, 15 to

30 July 1993; and 15 to 30 March, 15 to 30 May, and 15 to 30 June 1994).

Twelve different microhabitat measurements were collected at each of the 18 arrays once during the study (15-30 July 1993). Habitat changes from 1993 to 1994 were negligible, so the measurements made in 1993 were characteristic of the total study period. Leaf litter, exposed rock, woody cover, herbaceous cover, and coarse, woody debris (slash) were quantified by visually estimating, with an ocular tube, the percent of the ground surface covered by each. Percent coverage by coarse woody debris was grouped into two size categories (Maser et al. 1979): total coarse woody debris and debris with a diameter >20 cm. Forest overstory density was estimated using a spherical densiometer (Lemmon 1957). Litter depth, vegetation density, and basal area for pine and hardwood were also quantified within each stand. We recognized two categories for vegetation density: at ground level and at a height of 1 m. These data were collected at six habitat sampling points for each array. The six sampling points were standardized by placing them at right angles to the drift fence 2 m to either side of each of the peripheral pitfall traps. Thus, microhabitat samples were collected away from the disturbed area directly adjacent to the array. Vegetation density, litter depth, and all percent coverage estimates were recorded at these points while basal area was recorded by standing directly over the pitfall trap. The data for each parameter were then averaged for each array to characterize the sample site.

## Data Analysis

We employed canonical correspondence analysis (CCA) to examine differences among herpetofaunal communities inhabiting silvicultural treatments as well as to identify associations of microhabitat variables with the treatments and with particular reptiles and amphibians. CCA is a gradient analysis that utilizes aspects of multivariate regression and correspondence analysis to directly relate species composition of the samples with measured environmental variables. Ordination axes are constrained such that they are linear combinations of the environmental variables. Ordination diagrams show the relationships among species abundances, sample site characteristics, and/or environmental variables (Ter Braak 1987; Taylor et al. 1993).

In CCA ordination diagrams, sites and species are represented by symbols (points) while environmental variables are represented by vectors. The length of a vector symbolizes the importance of the environmental variable while the direction of vectors indicates the degree of correlation among environmental variables and sites, and/or environmental variables and species. Only the positive end of environmental vectors are shown in the CCA diagrams; therefore, one must remain aware of the equally important negative portion of each vector. For each environmental variable shown in the ordination, one can imagine a vector of equal length extending from the center of the figure and in the opposite direction. The closer environmental vectors are to one another the more they are correlated, and the closer these vectors align with an axis the more the nature of that axis is identified. The location of sites relative to environmental vectors indicates the habitat characteristics of the sites, while the position of species points relative to vectors shows the environmental associations of individual species.

Analyses were performed using the program CANOCO (Ter Braak 1987) with downweighting of rare species. Each drift fence array was considered a sample site. Species abundances were $\log_{10}$ transformed and environmental data expressed as proportions were transformed to the arcsine of the square root of the value. For purposes of ordination it was valid to incorporate the total set of variables, but for purposes of hypothesis testing, the number of environmental variables (12) was large in relation to the number of samples (18) (Ter Braak 1987). Therefore, before applying the CCA for hypothesis testing, we reduced the number of environmental variables using Principal Components Analysis

(PCA) to identify those variables that were redundant or superfluous. From this analysis and a review of current literature, we identified four environmental variables (canopy density, litter depth, woody cover, and slash >20 cm) that seemed most influential in determining herpetofaunal community structure. Although canopy density and litter depth are strongly correlated with one another, both were included in the model because of the known importance of a well-developed litter layer to amphibians (Bury 1983; Diller and Wallace 1994).

Monte Carlo permutation tests were used to test the overall effects of 1) treatment and 2) the selected environmental variables on species composition. Monte Carlo permutation tests were also used to test the effect of the first CCA axis (CCA1) for each of the analyses.

## RESULTS

We captured 633 individuals representing 35 species of reptiles and amphibians (Appendix 1) within or directly adjacent to the arrays. Of these 633 individuals, 62% (395) were lizards (Phrynosomatidae, Teidae, Scincidae), 26% (162) were anurans (Microhylidae, Bufonidae, Ranidae), and 10% (66) were snakes (Colubridae, Viperidae). Salamanders and turtles (Ambystomatidae, Plethodontidae and Testudinidae) combined represented < 2% of all captures and therefore will only be briefly discussed.

We first analyzed our data to see if species abundances were nonrandomly arranged among the three forest treatments. For this analysis, we conducted CCA using treatment as the only environmental variable. The overall pattern of species abundances (overall ordination) was nonrandom along CCA1 (Monte Carlo test, $p < 0.01$). We performed this same analysis using the four preselected environmental variables (forest overstory density, litter depth, woody cover, and slash >20 cm) and likewise identified a nonrandom pattern of species abundances among treatments ($P < 0.01$).

In the ordination using all environmental variables (Fig. 2), CCA1 was positively correlated with leaf litter and several other variables, including pine basal area, forest overstory density, litter depth, and hardwood basal area; CCA 1 was negatively correlated with vegetation density at 1 m. Over the first three canonical axes, the three silvicultural treatments are well separated from one another (Fig. 3). CCA1 provides the greatest separation. Overlaying the environmental variables (Fig. 2), clearcut stands are characterized by dense ground cover including woody and herbaceous vegetation as well as an abundance of coarse, woody debris. As expected, clearcut stands had scanty leaf litter, sparse forest overstory density, and minimal basal area of pines and hardwoods. Late seral and selectively harvested stands are closely grouped along CCA1 to the right and share several habitat characteristics like greater litter accumulation and depth, greater forest canopy coverage, and greater basal area for both pines and hardwoods. In turn, selective harvest and late seral stands differed from one another along CCA3 (Fig. 3b). This difference is mainly due to a greater herbaceous cover component and more coarse, woody debris with a diameter >20 cm in selectively harvested stands, whereas late seral stands maintained less of these, but a higher proportion of woody cover.

The most distinct separation of species groups (Fig. 4) was between reptiles and amphibians. Reptiles generally inhabited clearcuts while amphibians were most abundant on forested stands.

Although not abundant at any of our study sites, salamanders were never observed on the clearcut stands. Eurycea multiplicata, the most abundant of the three salamander species observed (Appendix 1), was not strongly associated with any single habitat variable (Fig. 5) but was usually captured by hand under rocks near ephemeral streams. All salamanders and most anurans were collected in forested areas. Gastrophryne carolinensis and Bufo americanus were the most abundant anurans (Appendix 1) and were strongly associated with forested habitats, canopy, and litter accumulation (Fig. 5).

The most commonly encountered snakes were Agkistrodon contortrix and Coluber constrictor (Appendix 1). These species occurred in a broad range of habitats within both forested and open, grassy areas. Both species were associated with coarse, woody debris, woody vegetation, and exposed rock (Fig. 5).

Thamnophis spp. were encountered within forested stands and were generally observed near water, while both Elaphe guttata and Storeria dekayi were commonly observed within the clearcut stands. E. guttata was strongly associated with dense, herbaceous ground cover (Fig. 5).

Lizards were the most abundant taxon (Appendix 1), occupying most habitats (Fig. 5). The most abundant species, Sceloporus undulatus (n = 179), was found in a wide variety of habitats and thus is found near the center of the ordination. Scincella lateralis and Eumeces fasciatus were most commonly encountered in forested areas in association with leaf litter (Fig. 5). Cnemidophorus sexlineatus and Eumeces laticeps were more prevalent in clearcut areas (Figs. 3 and 5), while Anolis carolinensis and Eumeces anthracinus were not clearly associated with any of the timber treatments. Anolis carolinensis was linked positively and Eumeces anthracinus negatively to an abundance of coarse, woody debris with a diameter >20 cm.

## DISCUSSION

Herpetofaunal communities differed significantly among forest treatments. Generally, microhabitat preferences of species explain the differences, with reptiles and amphibians responding predictably to gross changes in habitat structure among treatments. For example, because amphibians must maintain moist skin surfaces for cutaneous gas exchange, moisture is important in the distribution of amphibians (Blymyer and McGinnes 1977; Petranka et al. 1993). Because of increased insolation, higher ground temperatures, and higher evaporative water loss, fewer amphibians would be expected on early seral clearcuts (Geiger 1971; Bennett et al. 1980; Petranka et al. 1993; Petranka et al. 1994). Although there was considerable overlap of taxa among habitats, our results suggested that amphibians generally favored forested areas. In particular, leaf litter was strongly correlated with the two most common amphibians, Gastrophryne carolinensis and Bufo americanus. The retention of moisture by leaf litter and shading by the forest canopy provide the cool, moist microclimate necessary for amphibians (Jaeger 1971; Pough et al. 1987; Bury and Corn 1988).

Unlike amphibians, reptiles preferred the open sunny habitats present in the clearcut stands. Of the variables examined, vegetative cover and presence of coarse, woody debris (positively), and forest overstory density and leaf litter (negatively) seemed to be the most important ecological gradients determining species composition within clearcuts. In loblolly-shortleaf pine (Pinus taeda and P.

*echinata*) stands of east Texas, Whiting et al. (1987) also found that vegetative cover and the degree of deciduous litter accumulation strongly influenced herpetofaunal communities. We found that *E. guttata* and *C. sexlineatus*, two grassland species, were both positively associated with dense, herbaceous ground cover and negatively with forested stands. *Eumeces laticeps*, an arboreal lizard, was strongly associated with woody cover. Surprisingly though, *E. laticeps* was more abundant in clearcuts than in either of the forested stands. Enge and Marion (1986) found populations of *E. laticeps* to be reduced within clearcuts.

Some reptiles (especially lizards) may be attracted to recently clearcut areas because the dense, low-growing vegetation provides an abundance of perching sites. For example, *Anolis carolinensis* was associated with dense, woody ground cover and large, coarse, woody debris. *C. sexlineatus*, a cursorial lizard, often inhabits early successional habitats, shrubby hillsides, and open, grassy areas (Collins 1993; Webb 1970). Enge and Marion (1986), found this lizard to favor the most intensively-treated clearcut sites, and that is also where we found it.

A greater abundance and diversity of prey (invertebrates, birds, and small mammals) may contribute to higher abundances of some reptile species (especially snakes) within the clearcuts. Clearcutting is usually followed by increased small-mammal abundance and diversity that persists until canopy closure (Kirkland 1977; Atkeson and Johnson 1979; Kirkland 1990). A sharp increase in small mammal densities could attract large snakes such as *E. obsoleta* and *E. guttata*, which were found primarily in clearcut stands. The Fulvous Harvest Mouse, *Reithrodontomys fulvescens*, Southern Short-tailed Shrew, *Blarina carolinensis*, Golden Mouse, *Ochrotomys nuttalli*, and White-footed Deer Mouse, *Peromyscus leucopus*, were all commonly captured by our pitfall traps in the clearcut stands, while only *P. leucopus* was observed in the other two treatments.

The most significant limitation of this study is pseudoreplication (Hurlbert 1984). Our samples were arrays within a single treatment instead of spatially independent sites. Given adequate resources, it would be best to have three or more spatially independent replications of each treatment. We attempted to limit effects of this problem by separating sample sites by 100 m or more, but still one must use caution in interpreting the results.

Another problem is that some species may be responding to unknown environmental gradients (e. g., *Thamnophis proximus*, *Storeria dekayi*, and *Eurycea multiplicata*). Some potentially important variables might be invertebrate and small-mammal prey densities, local weather conditions, and proximity of sample sites to water. These habitat parameters may be easily collected, thus we recommend that future studies make an effort to quantify them. The latter two are probably quite important for predicting occurrence of most amphibians (especially semiaquatic salamanders such as *E. multiplicata* and *Desmognathus brimleyorum*) as well as reptiles such as *T. proximus* and *T. sirtalis*, species known to inhabit riparian areas or sloughs (Webb 1970; Collins 1993).

Finally, this study and others (Gibbons and Bennett 1974; Gibbons and Semlitsch 1982; Jones 1986; Dodd 1991) suggest that some species are not effectively sampled using pitfall and funnel traps. Several species are better sampled using alternate techniques such as quadrat sampling, aural transects for anurans, or artificial habitat, i.e., cover boards, frog houses and artificial pools (Heyer et al. 1994).

In summary, various biotic and abiotic factors have major influences on reptile and amphibian community composition and relative abundances. For amphibians, moisture and leaf litter seem to be important. Of course these factors are not independent of other habitat characteristics such as vegetative cover, soil structure, weather, and season. Reptile community composition is reliant on understory and overstory development, as well as the presence of coarse, woody debris or rocky outcroppings. Some reptile species also seem dependent upon the presence of various prey. All habitat characteristics determining herpetofaunal community composition are ultimately dependent upon the age of the forest and the degree of disturbance to which it has been subjected.

Reptiles and amphibians are significant members of many ecosystems. They can be important components of the food web and may contribute a surprising amount of biomass to the community (Burton and Likens, 1975; Pough et al., 1987). Furthermore, because amphibians are often habitat specialists with restricted distributions, they may be valuable indicator species revealing overall health and stability of ecosystems. Despite the importance of reptiles and amphibians in many ecosystems, they continue to be neglected by land managers (Pough et al., 1987). Some management plans may even promote mid-successional stages to maximize alpha diversity of other taxa at the cost of sensitive reptile and amphibian species (Faaborg, 1980; Sampson and Knopf, 1982). We hope our findings will aid land managers to better protect habitat for reptiles and amphibians.

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Table 1. Silvicultural treatment histories for each of the six forest stands.

| Stand # | Treatment | Year of Harvest | Year[1] of Burn | Year of Herbicide Treatment |
|---|---|---|---|---|
| Ia | selective harvest | 1972,92 | 1985,88 | 1973(2,4,5-T) |
| Ib | selective harvest | 1976,91 | 1988 | 1973(2,4,5-T) |
| IIa | late seral clearcut | 1912 | --- | --- |
| IIb | late seral clearcut | 1912 | --- | --- |
| IIIa | early seral clearcut | 1990 | --- | 1990(Garlon 3A) |
| IIIb | early seral clearcut | 1988 | --- | 1988(Garlon 3A) |

[1] Controlled burning of understory was conducted to eleminate slash and/or young hardwoods.

Fig. 1. a) Array design showing configuration of drift fences, pitfall, and double-ended funnel traps; b) side view of an array segment showing the intersection of a pitfall trap with the drift fence.

Fig. 2. CCA ordination of environmental variables: CANOPY = forest overstory density, DENSG = vegetation density at ground level, DENS1M = vegetation density at 1 m above the ground, HARDWD = basal area of hardwoods, HERBS = herbaceous cover, LITDEPTH = litter depth, LITTER = leaf litter, PINE = basal area of pines, ROCK = exposed rock, SLASH20 = coarse, woody debris with a diameter >20 cm, TSLASH = total coarse, woody debris, and WOODY = woody cover.

Fig. 3. CCA ordination of sample sites against (a) axes 1 and 2, and (b) axes 1 and 3.

Fig. 4. CCA ordination of species groups, which can be superimposed on Figures 2a and 3a in order to interpret patterns of community composition along silvicultural treatments and environmental gradients.

Fig. 5. CCA ordination of species and environmental variables. See Appendix 1 for a key to species' abbreviations.

Fig. 1a.

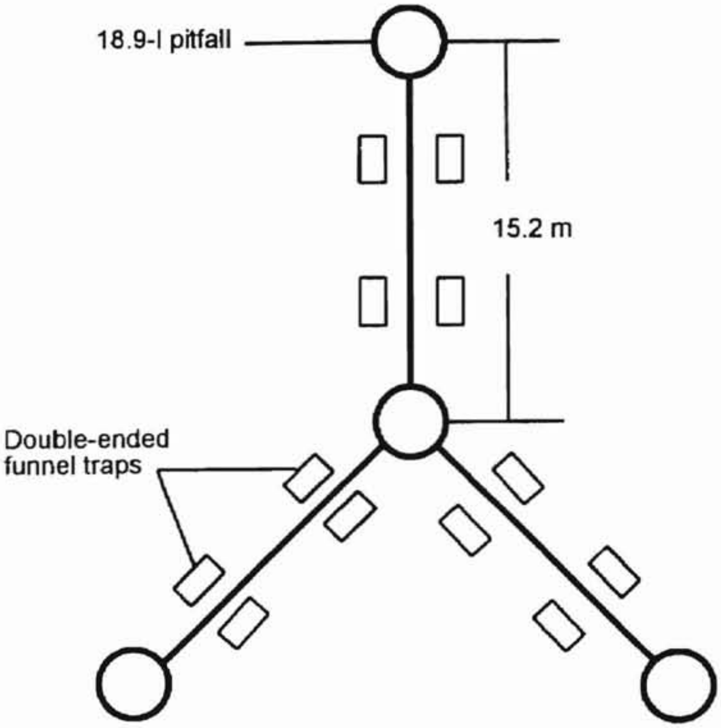


Fig. 1b.

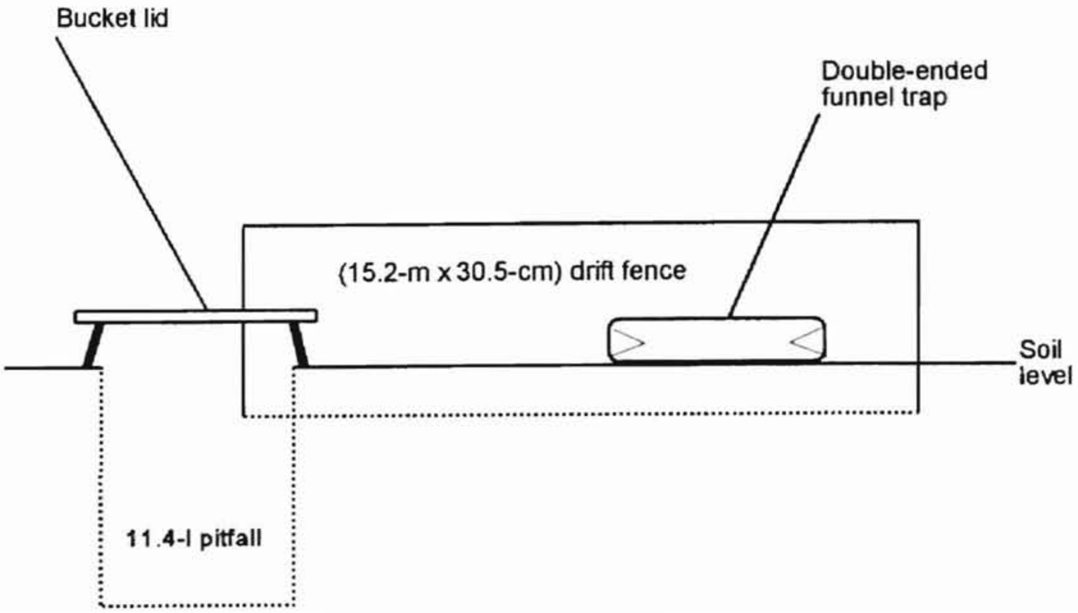
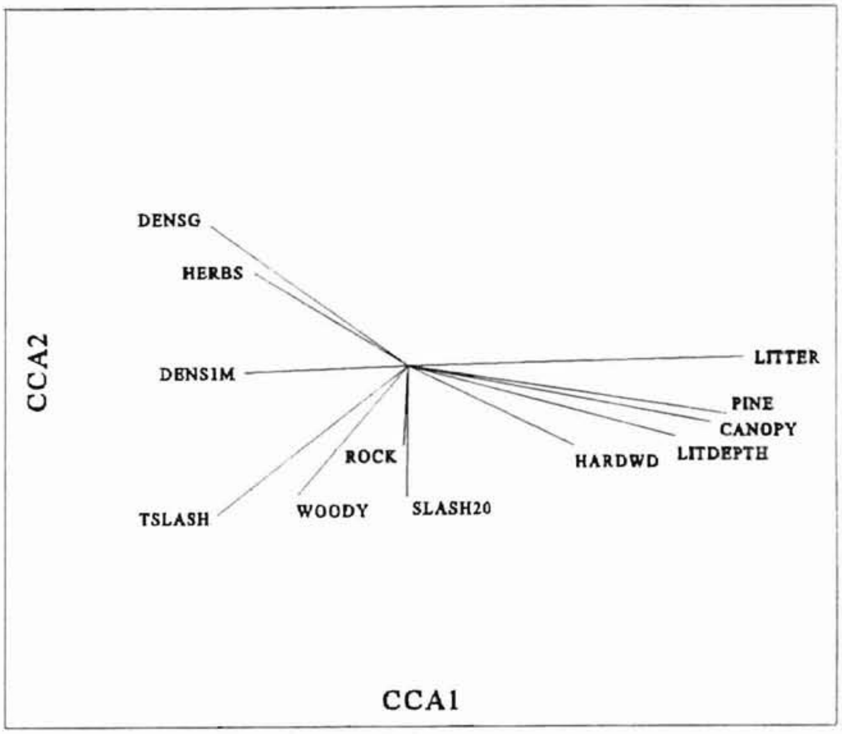

Bucket lid
Double-ended funnel trap
(15.2-m x 30.5-cm) drift fence
Soil level
11.4-l pitfall

Fig. 2


DENSG
HERBS
DENS1M
LITTER
PINE
CANOPY
LITDEPTH
HARDWD
ROCK
TSLASH
WOODY
SLASH20
CCA2
CCA1

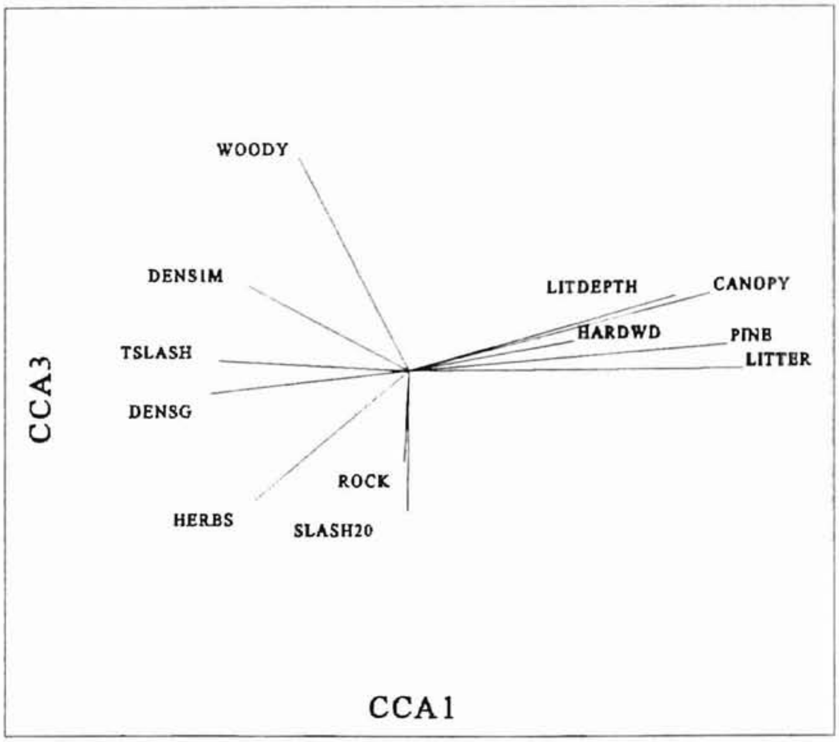
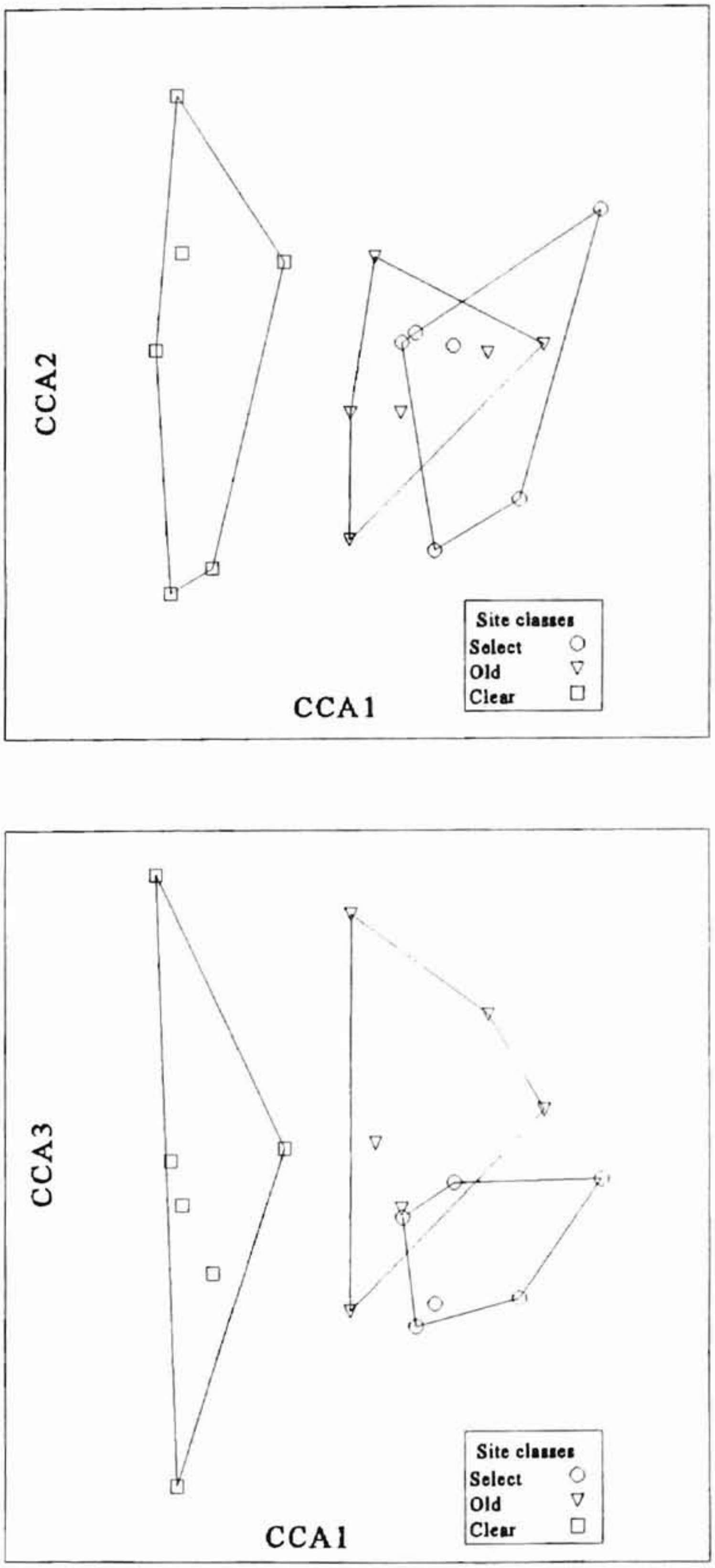

WOODY
DENS1M
LITDEPTH
CANOPY
HARDWD
PINE
LITTER
TSLASH
DENSG
ROCK
HERBS
SLASH20
CCA3
CCA1

Fig. 3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CCA1
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Old ▽
Clear □
CCA3
CCA1
Site classes
Select ○
Old ▽
Clear □

Fig. 4

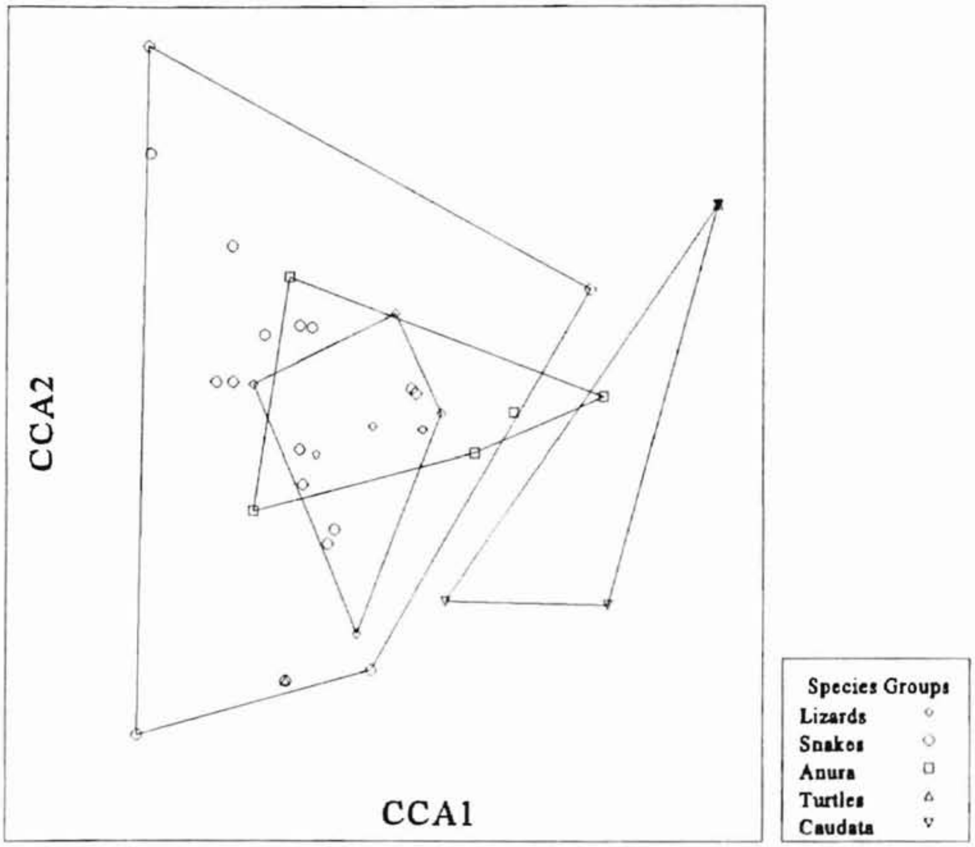
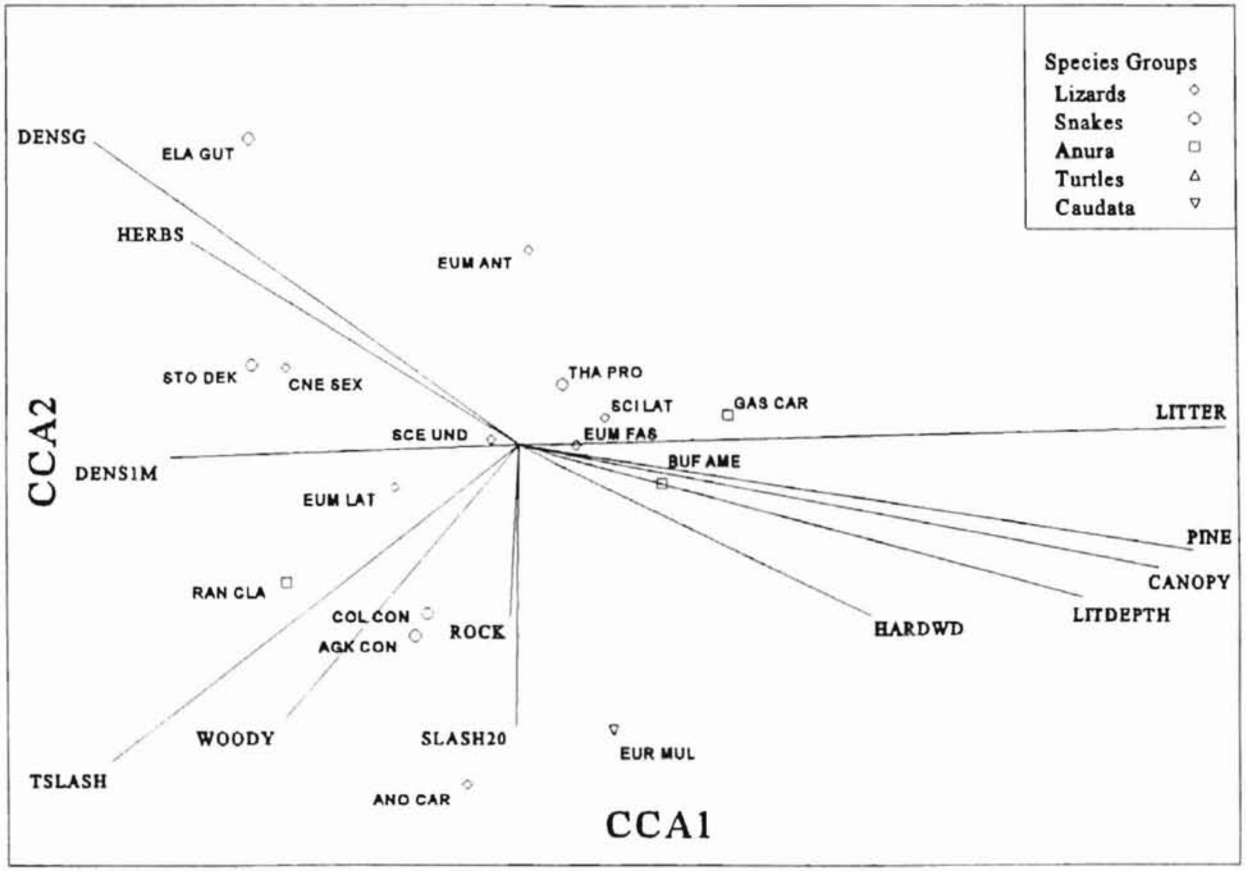

CCA2
CCA1
Species Groups
Lizards
Snakes
Anura
Turtles
Caudata

Fig. 5


Species Groups
Lizards ◇
Snakes ○
Anura □
Turtles △
Caudata ▽
DENSG
ELA GUT
HERBS
EUM ANT
STO DEK
CNE SEX
THA PRO
SCI LAT
GAS CAR
LITTER
SCE UND
EUM FAS
BUF AME
CCA2
DENS1M
EUM LAT
PINE
CANOPY
RAN CLA
COL CON
AGK CON
ROCK
HARDWD
LITDEPTH
WOODY
SLASH20
EUR MUL
TSLASH
ANO CAR
CCA1

Appendix 1. Reptiles and amphibians captured employing drift fence arrays.

| Species | Abbreviation | N | % |
|---|---|---|---|
| Anurans | | | |
| *Gastrophryne carolinensis* | GASCAR | 44 | 7.0% |
| *Bufo americanus* | BUFAME | 109 | 17.2% |
| *Rana clamitans* | RANCLA | 6 | 0.9% |
| *Rana catesbeiana* | RANCAT | 2 | 0.3% |
| *Rana utricularia* | RANUTR | 1 | 0.1% |
| Salamanders | | | |
| *Ambystoma opacum* | AMBOPA | 1 | 0.1% |
| *Ambystoma talpoideum* | AMBTAL | 1 | 0.1% |
| *Eurycea multiplicata* | EURMUL | 5 | 0.7% |
| Turtles | | | |
| *Terrapene carolina* | TERCAR | 2 | 0.3% |
| *Terrapene ornata* | TERORN | 1 | 0.1% |
| Lizards | | | |
| *Anolis carolinensis* | ANOCAR | 9 | 1.4% |
| *Cnemidophorus sexlineatus* | CNESEX | 55 | 8.7% |
| *Sceloporus undulatus* | SCEUND | 179 | 28.3% |
| *Scincella lateralis* | SCILAT | 78 | 12.3% |
| *Eumeces fasciatus* | EUMFAS | 34 | 5.4% |
| *Eumeces laticeps* | EUMLAT | 17 | 2.7% |
| *Eumeces anthracinus* | EUMANT | 23 | 3.6% |

Appendix 1. Continued.

| Species | Abbreviation | N | % |
|---|---|---|---|
| Snakes | | | |
| *Thamnophis proximus* | THAPRO | 5 | 0.8% |
| *Thamnophis sirtalis* | THASIS | 3 | 0.4% |
| *Virginia valeriae* | VIRVAL | 2 | 0.3% |
| *Storeria occipitomaculata* | STOOCC | 3 | 0.4% |
| *Storeria dekayi* | STODEK | 5 | 0.7% |
| *Heterodon platyrhinos* | HETPLA | 2 | 0.3% |
| *Diadophis punctatus* | DIAPUN | 2 | 0.3% |
| *Carphophis amoenus* | CARVER | 3 | 0.4% |
| *Opheodrys aestivus* | OPHAES | 2 | 0.3% |
| *Coluber constrictor* | COLCON | 11 | 1.7% |
| *Masticophis flagellum* | MASFLA | 3 | 0.4% |
| *Elaphe guttata* | ELAGUT | 4 | 0.6% |
| *Elaphe obsoleta* | ELAOBS | 1 | 0.1% |
| *Cemphora coccinea* | CEMCOC | 2 | 0.2% |
| *Lampropeltis triangulum* | LAMTRI | 3 | 0.4% |
| *Agkistrodon contortrix* | AGKCON | 12 | 1.9% |
| *Sistrurus miliarius* | SISMIL | 1 | 0.1% |
| *Tantilla gracilis* | TANGRA | 2 | 0.3% |
| Total | | 633 | 100.0% |

# VITA

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