REPTILE COMMUNITIES UNDER DIVERSE FOREST MANAGEMENT IN THE OUACHITA MOUNTAINS, ARKANSAS

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Abstract—From May 1995 to March 1999, we censused reptiles in the Ouachita Mountains, Arkansas, on approximately 60 plots on each of four forested watersheds five times per year, with new plots each year. We found that the least intensively managed watershed had significantly lower per-plot reptile abundances, species richness, and diversity. Despite these differences, community similarities were high (0.89-0.98, Morisita's index) between all watersheds. The least intensively managed watershed had nominally higher overall species evenness and diversity. Further inspection revealed that this was due to high dominance in the more intensively managed watersheds by two species that were not~~as~~ as dominant in the least intensively managed watershed. Detrended correspondence analysis revealed communities separating out on the basis of presumed gradients of canopy cover, terrestrial-aquatic, and a complex gradient of humidity/soil moisture.

INTRODUCTION

Recently, it has been reported that many reptile populations are experiencing global declines (Gibbons and others, 2000) akin to, if not more serious than, the highly publicized global declines in amphibian populations (Blaustein and Wake 1995, Houlahan and others 2000, Phillips 1990, Wake 1991). This realization has led to a call for increased long-term research on these often ignored taxa.

Reptiles, like amphibians, commonly experience natural population fluctuations and extinctions (Blaustein and others, 1994; Pechmann and others, 1991). However, not all observed declines can be categorized as natural (Gibbons and others, 2000). Possible causes for these declines include habitat loss and degradation, climatological change, introduction of exotic species, environmental pollution, disease and parasites, and unsustainable harvesting.

Loss of suitable habitat is considered by some scientists to be the largest single factor responsible for declines in amphibian populations (Alford and Richards, 1999). Likewise, it has been suggested that habitat loss due to urbanization, agriculture, and silviculture may play an important role in declines of reptile populations (Gibbons and others, 2000). Despite the implication of silvicultural practices in these declines, little is known about the habitat parameters that influence reptile communities, and even less is known about landscape-level environmental influences.

We report results of pretreatment data collection for a large-scale, long-term, field study of reptile communities and the influence of habitat and landscape environmental variables in four watersheds of the Ouachita Mountains of west-central Arkansas. Following the pretreatment stage, sections of the watersheds will be subjected to different forest management to achieve a variety of specific "desired future conditions." After treatment, data on reptile communities will again be collected and used to quantify community changes and to compare with the predictions of multivariate community models that we are developing. This long-term study is one component of Phase III of the Ouachita Mountains Ecosystem Management Research Project; the wildlife component of this cooperative effort involves Weyerhaeuser Company, National Council of the Paper Industry for Air and Stream Improvement, Oklahoma State University, Oklahoma Cooperative Fish and Wildlife Research Unit, University of Arkansas Monticello, Ouachita National Forest, and Southern Research Station of the USDA Forest Service.

The objectives of our overall study are to: (1) characterize reptile and amphibian communities in four watersheds representing markedly different forest-management strategies in the Ouachita Mountains, Arkansas; (2) develop and validate models for predicting community composition based on site, stand, and landscape parameters; and (3) develop recommendations to promote maintenance of reptile and amphibian communities in managed forest landscapes. This report contains results for reptiles of the pretreatment data analysis performed at the end of four survey years.

METHODS

Study Areas

The study was conducted on four 1500- to 4000-ha watersheds under different intensities of management in Garland and Saline counties near Hot Springs, Arkansas. The watersheds differed markedly with respect to factors such as mean rotation lengths, forest type diversity, stand sizes and ages, and the amount of natural second-growth coverage (Guldin and others, in press; Tappe and others, in press).

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Citation for proceedings: Guldin, James M., tech. comp. 2004. Ouachita and Ozark Mountains symposium: ecosystem management research. Gen. Tech. Rep. SRS–74. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 321 p.

Little Glazypeau, a watershed located some 22 km southwest of the other three watersheds (that were contiguous) and managed largely for sawlog production by Weyerhaeuser Company, represented our most intensively managed watershed. Much of the second-growth shortleaf pine (*Pinus echinata*)-hardwood forest that originally covered this watershed had been harvested and planted to loblolly pine (*P. taeda*) plantations of 9-142 ha. Typically, these plantations were thinned twice, pruned to 5-8 m high, fertilized, and harvested at 30-35 years old. The remaining, selectively-harvested acreage in the watershed occured on rocky ridgetops, steep slopes, and streamside management zones that were retained for watershed protection and to provide habitat diversity for wildlife. South Alum, an experimental section of the Ouachita National Forest that has received minimal logging for > 80 years, represented the least intense level of silviculture. South Alum was almost entirely USDA Forest Service land and consisted of mature forest over most of the area. Bread Creek and North Alum fell in between these extremes of forest management. From independent records of forest management and present composition of number, age, and distribution of pine (mostly *Pinus echinata*) plantations, Bread Creek was considered less intensely managed than North Alum (Tappe and others, in press). Bread Creek was primarily USDA Forest Service land and had been managed according to prevailing Forest Service standards and guidelines for several decades, whereas North Alum was of mixed ownership, with about half of the area under more intensive Weyerhaeuser Company management (comparable to Little Glazypeau) and half under USDA Forest Service management. North Alum displayed characteristics of a diverse range of management activities, ranging from no management along steeper slopes and higher elevations to intensively-managed pine plantations, mainly at lower elevations. Thus, the watersheds, in order of intensity of forest management (from least to most), were South Alum, Bread Creek, North Alum, and Little Glazypeau. These same watersheds, in order of size, were South Alum (1500 ha), Bread Creek (1535 ha), Little Glazypeau (2273 ha), and North Alum (3961 ha).

Sampling Plots

We surveyed reptiles and amphibians using area-constrained searches on a subset (56) of the 75-235 plots per watershed that were established each year for breeding bird surveys (Tappe and others, in press). Bird plots were established at 200-m intervals along >100 km of parallel transects (oriented approximately north-south across prevailing topography) that were established in 1995 over the 4 watersheds. These same transects were used in 1996, but new plots were established by shifting plot centers 100 m. In 1997, approximately 110 km of new transects were established between those of 1995; new plots were established in 1998 along these new transects as in 1996. The subset of plots that were used for reptile surveys were selected to represent a cross-section of slopes, aspects, forest types, stand conditions, and aquatic habitats. The center of our 20-m-radius (0.13-ha) plots also was the center of a bird sampling plot. Plastic flagging was used to delineate plot boundaries on all reptile plots. In each watershed, we selected reptile plots to ensure there were at least 12-15 of them in aquatic habitats, which consisted of springs, streams, and man-made ponds that had been established to benefit wildlife (Forest Service wildlife ponds) and/or as sources of water for fire fighting. An additional four plots per watershed per year were established off the transects at these ponds (or at wide pools in streams at the bottom of a watershed) to ensure that we had equivalent sampling effort at these aquatic habitats. Plots at these aquatic sites were established so that roughly half of the plot was water and half was land. Thus, we surveyed 60 plots per year per watershed.

Reptile Surveys

Trained crews of 3-5 individuals surveyed each set of 60 plots per watershed during daylight hours 5 times a year from May 1995 to March 1999: early May, late May, mid-June, early October, and early the following March. Plots were surveyed entirely by visually searching vegetation and the ground surface, and by lifting cover objects (rocks, logs, and debris); the latter were replaced to minimize impacts on subsequent surveys. Reptiles that were seen and identified were tallied; those that required capture for identification were released at the point of capture before leaving the plot.

Data Analysis

Reptile count data were pooled across the five sampling periods per year, but data from each plot served as separate samples. Data collected in the first year (1995) from South Alum and North Alum were excluded from analyses due to differences in sampling effort by former collaborators, and data from a few other plots were discarded when five surveys per year were not attained. Thus, analyses presented here are based on data from 833 plots, each censused five times, for a total of 4,165 censuses. Watershed- and plot-level data were analyzed differently as described in the following two paragraphs.

Watershed level—The following community indices were first calculated at the watershed level: number of individuals by species for all years combined, reptile abundance, species richness, (beta) species diversity [H'; Shannon-Wiener diversity index (Shannon and Weaver 1949)], and species evenness [diversity divided by maximal diversity, or H'/(ln number of species); Pielou 1966]. With only four watersheds to compare, no statistical tests were employed. Because the Shannon-Wiener diversity index is quite sensitive to sample size and because we did not have an equal effort among all watersheds (two watersheds with data from only three years; see above), we randomly reordered the plots within each watershed, pooling years, and plotted the Shannon-Wiener diversity index of each watershed for cumulative sets of plots up to the total number of plots for each watershed. Such a plot would show if diversity approached an asymptote as cumulative plots increased and if our total number of plots per watershed was sufficient to adequately estimate species diversity.

We computed Morisita's index of community similarity (Morisita 1959) between all pairs of watersheds, pooling data for the entire study for each watershed. This index is desirable because sample sizes and species diversities of the communities being compared have little influence on its calculation (Morisita 1959; Wolda 1981). To statistically compare the various Morisita's indices of community similarity, we conducted randomization tests (Biondini and others 1988). For each pair of watersheds, we randomly reassigned plots between them (retaining the sample size of each watershed) and computed Morisita's index for these two "synthetic" communities. We repeated this procedure 1000 times and tabulated the number of times the recomputed index was smaller than or equal to the "actual" index. If less than 100 recomputed indices fell below or equal to the "actual" index, then those two watersheds were considered different ($p < 0.10$) in species composition.

Plot level—For analyses at the plot level, we used mixed model, two-way ANOVAs (ANOVAs with both random and fixed effects; PROC MIXED, SAS 1999) to test for differences among watersheds, years, and year * watershed interaction. We recognize that our sample of plots drawn from each of four watersheds is pseudoreplicated (Hurlbert, 1984), but the large scale of this study prevented sampling of replicate watersheds for each treatment. While results of our ANOVA must be interpreted with caution due to this pseudoreplication, we feel that the analysis nevertheless suggests likely ecological patterns that deserve attention. The response variables of the ANOVAs were (1) reptile abundance per plot, (2) species richness per plot, and (alpha) plot diversity (Shannon-Wiener index). For count variables (1 and 2) we used a square root transformation, SQR (count + 0.5). Even with those transformations, our data did not fully meet assumptions of normality and homogeneity of variances, but the Satterthwaite algorithm of the mixed model ANOVA is relatively robust to abuses of these assumptions, especially of homogeneity of variances (SAS 1999), and so we proceeded with these parametric analyses. We recognized differences in weather between years, not of interest to us here, and included year effects and year * watershed interaction as random effects, not to be statistically interpreted. The fixed factor (watersheds) was tested for statistical significance at $p < 0.10$. If a significant watershed effect was found, we used LSD to evaluate pairwise differences between any two watersheds.

Detrended canonical correspondence analysis (DCA)—To appraise reptile community composition, develop preliminary hypotheses of presumptive environmental gradients influencing these communities, and compare graphically the environments and reptile communities of the four watersheds, we used DCA (ter Braak and Prentice 1988, ter Braak and Šmilauer 1998), pooling plots from all four watersheds and years. Application of DCA to our data allowed for a more detailed inspection of reptile communities at the plot level and how they were distributed along inferred environmental gradients. DCA is probably the most widely employed eigenanalysis-based ordination technique used by community ecologists. It is an indirect ordination method that orders plots with similar compositions of species along multiple axes simultaneously. The statistical algorithm is to calculate sample scores of each plot as a weighted average of the species scores, and species scores as a weighted average of samples scores; iterations are repeated until there is no further change in scores, at which time samples (plots) with similar animal communities appear clustered when plotted on multiple axes. Environmental gradients are inferred from the pattern of species and/or plots and the biologist's knowledge of the species. As a step beyond single-number summary statistics like diversity indices or Morisita's indices, DCA results in a cloud of points for separate species in n-dimensional space, conventionally viewed as centroids (averaged central tendency) in two dimensions at a time. In other words, DCA results in a pattern, not a number. For our analysis, rare species (less than three individuals encountered over all four watersheds for all four years) and plots where no reptile species were found were excluded due to computational constraints.

RESULTS AND DISCUSSION

We found 1,877 individuals of 35 reptile species during our four-year study (table 1). Total species diversity was 2.38 for all watersheds pooled. We found a mean of 2.25 reptiles per plot (median = 1.00, range = 0-22).

Watershed Level

Despite large differences in size of watersheds and substantial differences in management intensities, the reptile communities of these four watersheds were fairly similar. Species richness ranged from 26-28 species per watershed, and 19 of the total set of 35 species (54 percent) were found on all four watersheds (table 1). The watersheds differed some in both overall species diversity and evenness; the order from lowest to highest by diversity was Bread Creek, Little Glazypeau, North Alum, and South Alum (table 1). For evenness, the order from lowest to highest was similarly polarized as Bread Creek, North Alum, Little Glazypeau, and South Alum. The middle watersheds in both of these rankings, North Alum and Little Glazypeau, were virtually identical in these measures. Recalculated diversity indices against cumulative plots showed that diversity leveled off after about 40-100 plots (fig. 1), well below the lowest total of plots for any watershed. South Alum showed distinctly higher overall diversity than the other watersheds. Bread Creek had the lowest overall diversity and North Alum and Little Glazypeau were intermediate and nearly indistinguishible from each other.

The dominant species found in all watersheds were the ground skink *(Scincella lateralis)* and the western fence lizard (*Sceloporus undulatus*), representing on average 51.1 percent of total reptiles encountered in each watershed community. Additionally, species composition of the six most ubiquitous species of each watershed was strikingly similar (table 2).

We examined the overall set of species to see if there were any species absent from all but one watershed, or present in only one watershed. The flathead snake *(Tantilla gracilis)* was absent from Little Glazypeau; the six-line racerunner (*Cnemidophorus sexlineatus)* was not found on any Bread Creek plots; and the green anole (*Anolis carolinensis)* and the speckled kingsnake (*Lampropeltis getula)* were not found in South Alum watershed. The western diamondback rattlesnake *(Crotalus atrox)* was found only in Little Glazypeau; the Great Plains ratsnake *(Elaphe guttata)*, eastern coachwhip (*Masticophis flagellum)*, diamondback water snake (*Nerodia rhombifer)*, and the rough earth snake (*Virginia striatula)* were recorded only in North Alum; the scarlet snake (*Cemophora coccinea)* was found only in

Table 1—Reptile abundance on four watersheds in the Ouachita Mountains, Arkansas, 1995-1999

Species	Little Glazypeau	North Alum	Bread Creek	South Alum
Agkistrodon contortrix (copperhead)	16	7	8	16
Agkistrodon piscivorus (cottonmouth)	4	20	7	10
Anolis carolinensis (green anole)	43	4	18	0
Carphophis vermis (western worm snake)	11	9	29	13
Cemophora coccinea (scarlet snake)	0	0	1	0
Cnemidophorus sexlineatus (six-line racerunner)	2	7	0	1
Coluber constrictor (black racer)	8	11	7	1
Crotalus atrox (western diamondback rattlesnake)	1	0	0	0
Crotalus horridus (timber rattlesnake)	1	0	1	0
Diadophis punctatus (western ringneck snake)	35	18	44	29
Elaphe guttata (Great Plains ratsnake)	0	1	0	0
Elaphe obsoleta (black ratsnake)	3	1	1	1
Eumeces anthracinus (coal skink)	21	12	26	11
Eumeces fasciatus (five-line skink)	48	22	46	16
Eumeces laticeps (broadhead skink)	10	4	11	3
Heterodon platirhinos (eastern hognose)	0	0	1	1
Lampropeltis getula (speckled kingsnake)	5	3	1	0
Lampropeltis triangulum (milksnake)	1	1	4	2
Masticophis flagellum (eastern coachwhip)	0	1	0	0
Nerodia erythrogaster (yellowbelly watersnake)	2	8	1	2
Nerodia rhombifer (diamondback watersnake)	0	1	0	0
Nerodia sipedon (midland watersnake)	1	0	0	4
Opheodrys aestivus (rough green snake)	3	9	2	5
Scincella lateralis (ground skink)	187	111	160	69
Sceloporus undulatus (northern fence lizard)	93	110	209	47
Sistrurus miliarius (western pigmy rattlesnake)	2	4	1	3
Storeria dekayi (brown snake)	6	1	2	2
Storeria occipitomaculata (northern redbelly snake)	12	5	7	10

continued

Table 1—Reptile abundance on four watersheds in the Ouachita Mountains, Arkansas, 1995-1999 (continued)

Species	Little Glazypeau	North Alum	Bread Creek	South Alum
Tantilla gracilis (flathead snake)	0	3	4	1
Terrapene carolina (eastern three-toe box turtle)	46	20	16	26
Terrapene ornata *(ornate box turtle)*	7	0	0	1
Thamnophis proximus (western ribbon snake)	0	0	0	1
Thamnophis sirtalis (red-sided garter snake)	3	2	7	2
Virginia striatula (rough earth snake)	0	1	0	0
Virginia valeriae (smooth earth snake)	4	4	6	5
Total	575	400	620	282
Species richness	27	28	26	26
Species diversity	2.34	2.35	2.12	2.51
Species evenness	0.87	0.86	0.84	0.92

Data are arrayed (left to right) from the most to the least intensively managed watersheds.

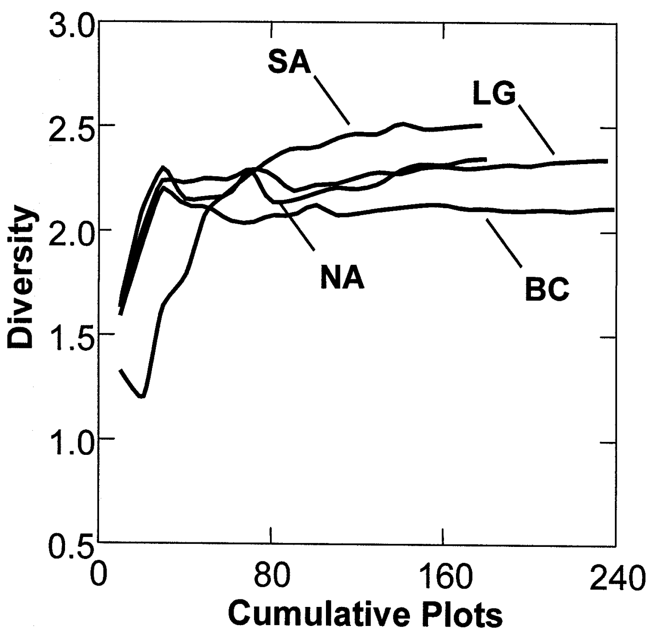

Figure 1—Diversity of each watershed against cumulative number of plots (in random order) included in recalculation. SA = South Alum; BC = Bread Creek; NA = North Alum; LG = Little Glazypeau.

Bread Creek; and the western ribbon snake (*Thamnophis proximus)* was found only in South Alum watershed.

Based on Morisita's index of community similarity, watershed reptile communities were highly similar, ranging from 0.89 to 0.98 (a value of 1.00 means identical communities; table 3). Bread Creek differed the most from the other watersheds, displaying an index of 0.89 with both Little Glazypeau and South Alum. Despite generally high indices of community similarity, all indices [except that between North Alum and Bread Creek (O.98)] were statistically significant by the randomization tests; i.e., all watershed pairs except this one were significantly different from each other beyond that expected by chance.

Plot Level

We found a significant watershed effect for all three plot-level measures (table 4): reptile abundance ($F_3 = 2.55$, $p = 0.05$), richness ($F_3 = 2.53$, $p = 0.06$), and diversity ($F_3 = 2.64$, $p = 0.05$). South Alum had plots with significantly fewer reptiles, lower species richness, and lower species diversity than each of the other watersheds based on ANOVA (table 4). None of the pairwise comparisons for the other watersheds were significant ($p > 0.10$).

Detrended Correspondence Analysis

Detrended correspondence analysis indicated relatively long environmental gradients along the first three axes for reptile communities in the four watersheds (table 5). The fourth and additional axes contributed little to the pattern of

Table 2—Six most common reptile species found in each watershed in order of decreasing abundance

Little Glazypeau	n	North Alum	n	Bread Creek	n	South Alum	n
Scincella lateralis (ground skink)	187	*Schincella lateralis* (ground skink)	111	*Sceloporus undulatus* (northern fence lizard)	209	*Scincella lateralis* (ground skink)	69
Sceloporus undulatus (northern fence lizard)	93	*Sceloporus undulatus* (northern fence lizard)	110	*Scincella lateralis* (ground skink)	160	*Sceloporus undulatus* (northern fence lizard)	47
Eumeces fasciatus (five-line skink)	48	*Eumeces fasciatus* (five-line skink)	22	*Eumeces fasciatus* (western ringneck snake)	46	*Diadophis punctatus* five-line skink)	29
Terrapene carolina eastern three-toe box turtle)	46	*Terrapene carolina* (eastern three-toe box turtle)	20	*Diadophis punctatus* (western ringneck snake	44	*Terrapene carolina* (eastern three-toe box turtle)	26
Anolis carolinensis (green anole)	43	*Agkistrodon piscivorus* (cottonmouth)	20	*Carphophis vermis* (western worm snake)	29	*Eumeces fasciatus* (five-line skink)	16
Diadophis punctatus (western ringneck snake)	35	*Diadophis punctatus* (western ringneck snake)	18	*Eumeces anthracinus* (coal skink)	26	*Carphophis vermis* (western worm snake)	13

Table 3—Morisita's index of community similarity for all pairs of watersheds

Watershed	Little Glazypeau	North Alum	Bread Creek	South Alum
Little Glazypeau	1.00			
North Alum	0.93[a]	1.00		
Bread Creek	0.89[a]	0.98	1.00	
South Alum	0.96[a]	0.94[a]	0.89[a]	1.00

Index ranges from 0 to 1, where 1 means communities are identical.
[a] Significantly dissimilar by Randomization Test, $p < 0.10$.

Table 4—Number of plots surveyed (1995–1999), mean reptile abundance per plot, mean species richness per plot, and mean species diversity per plot by watershed

Watershed	n	Mean abundance[a]	Mean species richness[b]	Mean species diversity[c]
Little Glazypeau	236	2.44	1.58	0.408
North Alum	180	2.22	1.54	0.404
Bread Creek	239	2.59	1.69	0.453
South Alum	178	1.58	1.23	0.292

Vertical bars connect those watersheds not statistically different as indicated by post-hoc pairwise contrasts.
[a] ANOVA: $F_3 = 2.55$, $p = 0.05$.
[b] ANOVA: $F_3 = 2.53$, $p = 0.06$.
[c] ANOVA: $F_3 = 2.64$, $p = 0.05$.

Table 5—Eigenvalues of first 4 axes of detrended correspondence analysis of 25 reptile species distributed among a pooled total of 403 plots on the 4 watersheds[a]

Axis	Eigenvalue
One	0.513
Two	0.441
Three	0.334
Four	0.287

[a] An eigenvalue is the correlation coefficient between the plot scores and species scores along a given axis where each axis is orthogonal [independent] to all previous axes in the analysis.

community organization because each additional axis explains only residual variation not already incorporated into the DCA. In other words, plots and species scores were relatively tightly correlated with each other along an appreciable stretch of at least the first three axes (eigenvalues range from 0 to 1: high eigenvalues meant that clouds of points were spread linearly along each axis, and low eigenvalues meant that points were clustered at the center of each axis). Species' centroids plotted against axes two vs. one (fig. 2) and against axes three vs. one (fig. 3) showed strong separation of species.

The pattern of species' centroids along axis one suggested that it was a measure of low-to-high canopy cover, left to right (fig. 2). Most of the species scoring lowest on this axis were typically found in more open or edge habitats. These species were *Tantilla gracilis* (flathead snake), *Sceloporus undulatus* (northern fence lizard), *Nerodia erythrogaster* (yellowbelly watersnake), *Elaphe obsoleta* (black ratsnake), and *Cnemidophorous sexlineatus* (six-line racerunner). To

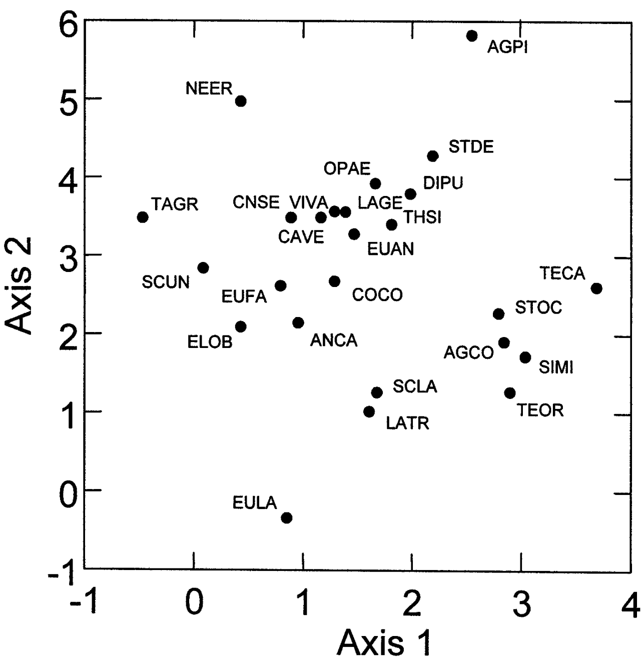

Figure 2—Centroids of species' scores from detrended correspondence analysis (DCA) of censused plots on all four watersheds pooled: DCA axis two vs. one. AGCO = *Agkistrodon contortrix*; AGPI = *A. piscivorous*; ANCA = *Anolis carolinensis*; CAVE = *Carphophis vermis*; CNSE = *Cnemidophorus sexlineatus*; COCO = *Coluber constrictor;* DIPU = *Diadophis punctatus*; ELOB = *Elaphe obsolete*; EUAN = *Eumeces anthracinus*; EUFA = *E. fasciatus*; EULA = *E. laticeps*; LAGE = *Lampropeltis getula*; LATR = *L. triangulum*; NEER = *Nerodia erythrogaster*, OPAE = *Opheodrys aestivus*; SCLA = *Scincella lateralis*; SCUN = *Sceloporus undulates*; SIMI = *Sistrurus miliarius*; STDE = *Storeria dekayi*; STOC = *S. occipitomaculata*; TAGR = *Tantilla gracilis*; TECA = *Terrapene Carolina*; TEOR = *T. ornate*; THSI = *Thamnophis sirtalis*; VIVA = *Virginia valeriae*.

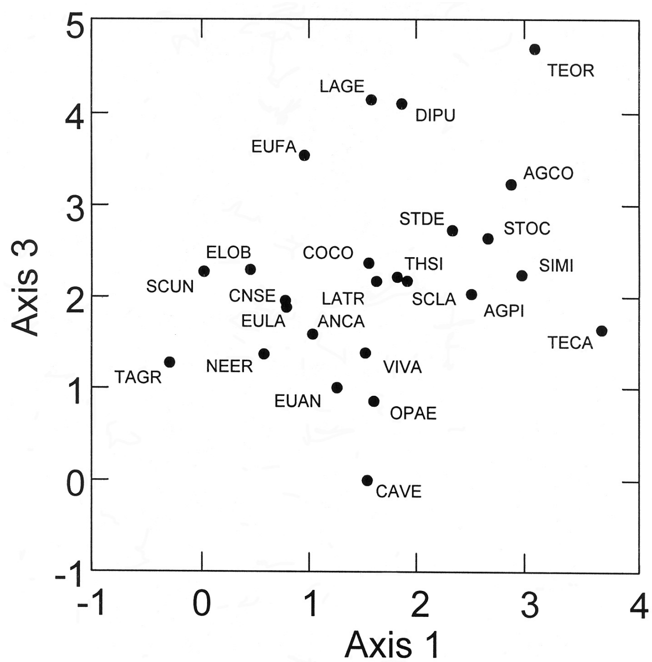

Figure 3—Centroids of species' scores from detrended correspondence analysis (DCA) of censused plots on all four watersheds pooled: DCA axis three vs. one. AGCO = *Agkistrodon contortrix*; AGPI = *A. piscivorous*; ANCA = *Anolis carolinensis*; CAVE = *Carphophis vermis*; CNSE = *Cnemidophorus sexlineatus*; DIPU = *Diadophis punctatus*; ELOB = *Elaphe obsolete*; EUAN = *Eumeces anthracinus*; EUFA = *E. fasciatus*; EULA = *E. laticeps*; LAGE = *Lampropeltis getula*; LATR = *L. triangulum*; NEER = *Nerodia erythrogaster*, OPAE = *Opheodrys aestivus*; SCLA = *Scincella lateralis*; SCUN = *Sceloporus undulates*; SIMI = *Sistrurus miliarius*; STDE = *Storeria dekayi*; STOC = *S. occipitomaculata*; TAGR = *Tantilla gracilis*; TECA = *Terrapene Carolina*; TEOR = *T. ornate*; THSI = *Thamnophis sirtalis*; VIVA = *Virginia valeriae*.

the far right, scoring highest on axis one, were mostly species typically associated with closed-canopy forested habitats, like *Terrapene carolina* (eastern three-toe box turtle), *Sistrurus miliarius* (western pygmy rattlesnake), *Storeria occipitomaculata* (northern redbelly snake), and A*gkistrodon contortrix* (copperhead). Species found at the middle of this axis were found in sites with intermediate or mixed canopy cover.

Axis two was interpreted as an aquatic gradient, with terrestrial sites having low scores on this axis and aquatic sites having high scores (fig. 2). The most terrestrial species (the lowest scores on axis two) included *Eumeces laticeps* (broadhead skink), *Lampropeltis triangulum* (milksnake), *Terrapene ornata* (ornate box turtle), and *Scincella lateralis* (ground skink). Scoring highest along axis two were the aquatic species, *Agkistrodon piscivorus* (cottonmouth) and *Nerodia erythrogaster* (yellowbelly watersnake).

Axis three was more difficult to interpret (and had less statistical explanatory power, table 5), but knowledge of the species displayed at the extremes of this presumed gradient led us to conclude that it reflected a complex gradient of humidity/soil moisture (fig. 3). Species located highest along axis three are typical of more western, arid habitats of the United States. These species are *Terrapene ornata* (ornate box turtle), *Lampropeltis getula* (speckled kingsnake), and *Diadophis punctatus* (ringneck snake). Species found lowest on the axis were associated with moist substrates or humid environments: *Carphophis vermis* (western worm snake), *Ophyeodrys aestivus* (rough green snake), and *Eumeces anthracinus* (coal skink).

Scattergrams of plot scores onto the same three axes, aggregating the plots of the separate watersheds, illustrated the overall similarity of the watersheds. Ellipses enclosing 95 percent of the plots of the watersheds overlapped considerably (figs. 4 and 5). In DCA, broader extent of plots along axes means that those plots offer more varied habitat (plot to plot) in which live more varied communities of the organisms studied, i.e., greater beta diversity. Except perhaps for Bread Creek, the watersheds had comparable reaches along each axis. The reptile communities of these four watersheds were so similar that drawing conclusions about minor differences among watersheds is not reasonable.

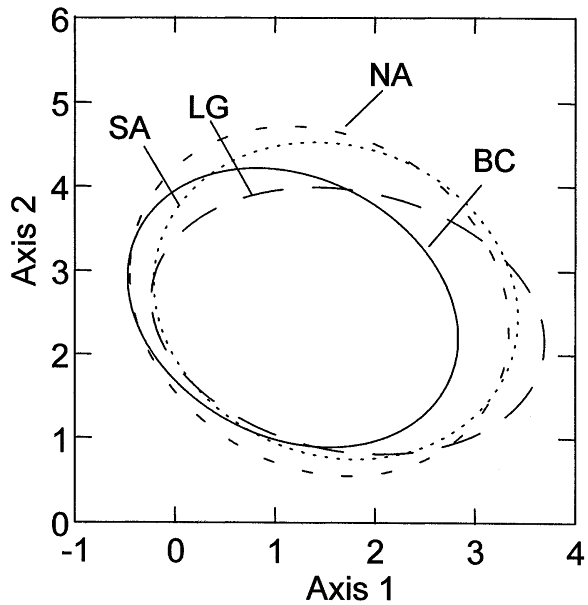

Figure 4—Ninety-five percent sample probability ellipses of the plot scores from detrended correspondence analysis (DCA) of the four watersheds: DCA axis two vs. one. LG = Little Glazypeau; NA = North Alum; BC = Bread Creek; SA = South Alum.

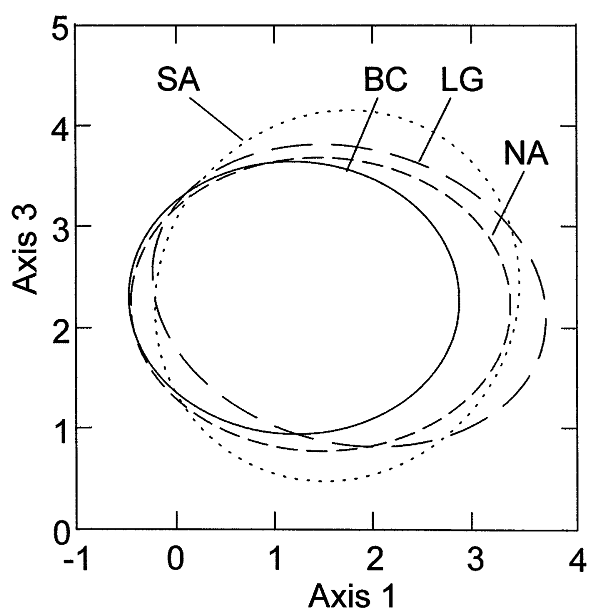

Figure 5—Ninety-five percent sample probability ellipses of the plot scores from detrended correspondence analysis (DCA) of the four watersheds: DCA axis three vs. one. LG = Little Glazypeau; NA = North Alum; BC = Bread Creek; SA = South Alum.

CONCLUSIONS

At the watershed level, total species richness per watershed varied little, 26-28 species, and most of these species were common to all watersheds, as indicated by Morisita's comparisons. Also, species diversity per watershed (beta diversity) differed little. The least intensively managed watershed, South Alum, had the nominally highest beta diversity. However, this is not necessarily due to a lack of species in the other watersheds, but instead is likely due to the dominance in the other watersheds of two species, *Scincella lateralis* (ground skink) and *Sceloporus undulatus* (northern fence lizard). The relative lack of dominance by these two species in South Alum results in greater evenness there. Because the Shannon-Wiener index incorporates evenness for its calculation, South Alum appears to be most diverse. Thus, if we reduce the recorded abundances of *S. lateralis* and *S. undulatus* in Little Glazypeau, North Alum, and Bread Creek to those found in South Alum, (69 and 47 animals, respectively) and then recalculate Shannon-Wiener diversity indices for these three watersheds, we find that our recalculated diversity index for each watershed exceeds that of South Alum (2.51) in all cases (Little Glazypeau = 2.65, North Alum = 2.67, Bread Creek = 2.59). In other words, these other watersheds possessed an inherent diversity that was higher than South Alum, plus more individuals of two reptile species.

It is well known that number of species increases with area of study plots; i.e., the familiar species-area curves of islands and mainland sites (Pianka 2000). This should relate to differences in beta diversity of entire watersheds. Little Glazypeau and North Alum were much larger than Bread Creek and South Alum. We expected, therefore, that the smaller watersheds should have had lower beta diversity. Our recalculated diversity indices adjusted for species dominance showed just this—elevated overall species diversity on the larger watersheds.

At the plot level, our data suggested that the less intensively managed watershed, South Alum, had plots with lower reptile abundance, fewer species, and decreased alpha diversity than the more intensively managed watersheds. But one must exercise some caution here; such differences may not relate to management at all. There may be other characteristics of Little Glazypeau, North Alum, and Bread Creek that affect species diversity of reptiles at the plot level. These are just four watersheds picked to vary along a management continuum, but they also may vary in other ways. Without a suitable set of replicate watersheds representing various levels of forest management, it is impossible to randomize all these other variables and to assess the relative effect of forest management on reptile communities. Nevertheless, the plot-level community differences may well be due to land management. South Alum, in contrast with the other watersheds, had virtually no logging for over 80 years and differed by having more mature, larger trees with intermediate canopy, and drastically less herbaceous vegetation, shrubs, and vines. Visually, South Alum appeared park-like. These differences made for structurally less complex within-plot habitats, possibly leading to the lower observed reptile numbers, species richness, and species diversity (alpha diversity).

MANAGEMENT IMPLICATIONS

Our study suggests that minimal forest management may result in lower local reptile abundances, species richness, and plot-wise (alpha) species diversity compared with more intensive management. However, overall watershed (beta) reptile species diversity differs little between watersheds of different management intensities. Overall reptile communities of the four watersheds were extremely similar. Taken together, our data suggest that intensive silviculture as practiced in the Ouachita Mountains of west-central Arkansas is not detrimental to landscape-level reptile communities and in fact, may be beneficial. This is probably true because even under the most intensive forest management, stand sizes are large, riparian zones are largely left intact, and ponds are created either for the benefit of wildlife or for a water supply for fire control. It is important to maintain those practices to conserve and maintain existing reptile diversity.

A possible concern with the suggestion that intensive forest management might benefit reptile communities is that rare or extremely habitat-sensitive species might suffer under this strategy. Nonetheless, we found no evidence of rare or sensitive reptile species that were being harmed by the more intensive land management. In fact, the one really rare species, C*rotalus atrox* (western diamondback rattlesnake), was found only on the most intensively managed watershed, Little Glazypeau. These findings must be tempered, though, by the fact that the Ouachita Mountains have been logged since the arrival of Europeans to the area, and because no baseline data exist for reptile communities prior to this, we have only the current diversity of all watersheds combined (gamma diversity) from our study to evaluate how rare or sensitive species might be affected by current forest management practices. Long-term monitoring is the only way to identify population trends of rare or sensitive species.

Our data suggest that diverse reptile communities in the Ouachita Mountains of west-central Arkansas would best be maintained by management decisions that create watershed-level landscape conditions with a diversity of canopy cover conditions and aquatic habitats. These two factors can be influenced and controlled by forest managers. Variation in humidity and soil moisture, also important for diverse reptile communities, may also vary with canopy cover and aquatic habitats, but these parameters might be less influenced by management decisions and more determined by the inherent physiography of a watershed (factors such as soil type, slope, aspect, elevation, and naturally-occurring aquatic habitats). We will use our data on reptile communities, plus available habitat data, to develop and validate quantitative models for predicting reptile community composition from habitat and landscape parameters.

ACKNOWLEDGMENTS

We thank the USDA Forest Service, Weyerhaeuser Company, and the National Council of the Paper Industry for Air and Stream Improvement for providing funding and logistical support. Additional logistical support was provided through the Oklahoma Cooperative Fish and Wildlife Research Unit (Oklahoma State University, Oklahoma Department of Wildlife Conservation, U.S. Geological Survey Biological Resources Division, and Wildlife Management Institute cooperating). We also thank a great number of paid and volunteer graduate and undergraduate field assistants for their help in data collection, entry, and error-checking.

Research support was provided through the study "Herpetological Communities under Diverse Forest Management Intensities: a Landscape-level Assessment of the Ouachita Mountains, Arkansas" dated May 1995 to March 1999 of Cooperative Agreement numbers 19-95-037, 30-96-022, and 33-CA-98-354. This research was supported by funds provided by the U.S. Department of Agriculture, Forest Service, Southern Research Station as part of the Phase III of the Quachita Mountains Ecosystem Mangement Research Project.

LITERATURE CITED

Alford, R.A.; Richards, S.J. 1999. Global amphibian declines: a problem in applied ecology. Annual Review of Ecology and Systematics. 30: 133-165.

Biondini, M.E.; Mielke, P.W., Jr.; Berry, K.J. 1988. Data-dependent permutation techniques for the analysis of ecological data. Vegetatio. 75: 161-168.

Blaustein, A.R.; Wake, D.B. 1995. The puzzle of declining amphibian populations. Scientific American. 272: 52-57.

Blaustein, A.R.; Wake, D.B.; Sousa, W.P. 1994. Amphibian declines: judging stability, persistence, and susceptibility of populations to local and global extinctions. Conservation Biology. 8: 60-71.

Gibbons, J.W.; Scott, D.E.; Ryan, T.J. [and others]. 2000. The global decline of reptiles, déjà vu amphibians. Bioscience.8: 653-666.

Guldin, James M. [In press]. Landscape-scale research in the Ouachita Mountains of west-central Arkansas: general study design. In: Guldin, James M., tech. comp. Ouachita and Ozark Mountains symposium: ecosystem management research. Gen. Tech. Rep. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.

Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological field studies. Ecological Monographs. 54: 187-211.

Morisita, M. 1959. Measuring of interspecific association and similarity between communities. Memoirs of Faculty of Science at Kyoto University. Series E (Biology) 3: 65-80.

Pechman, J.H.K.; Scott, D.E.; Semlitsch, R.D. [and others]. 1991. Declining amphibian populations: the problem of separating human impact from natural fluctuations. Science. 253: 892-895.

Pianka, E.R. 2000. Evolutionary ecology. 6th ed. San Francisco, CA: Addison Wesley Longman, Inc. 512 p.

Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. Journal of Theoretical Biology. 13: 131-144.

SAS Institute Inc. 1999. SAS/STAT user's guide. Version 8.01 ed. Cary, NC: SAS Institute Inc.

Sattath, S.; Tversky, A. 1977. Additive similarity trees. Psychometrika. 42: 319-345.

Tappe, Philip A.; Weih, Robert C., Jr.; Thill, Ronald E. [and others]. [In press]. Lanscape characterization of four watersheds under different forest management scenarios in the Ouachita Mountains of Arkansas. In: Guldin, James M., tech. comp. Ouachita and Ozark Mountains symposium: ecosystem management research. Gen. Tech. Rep. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.

ter Braak, C.J.F.; Prentice, I.C. 1988. A theory of gradient analysis. Advances in Ecological Research. 18: 271-313.

ter Braak, C.J.F.; Šmilauer, P. 1998. CANOCO reference manual and user's guide to CANOCO for windows: software for canonical community ordination. Version 4. Ithaca, NY: Microcomputer Power. 351 p.

Wolda, H. 1981. Similarity indices, sample size and diversity. Oecologia. 50: 296-302.