Habitat Associations of the Sagebrush Lizard (*Sceloporus graciosus*): Potential Responses of an Ectotherm to Ponderosa Pine Forest Restoration Treatments

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Abstract—Little is known about the response of ectotherms to ponderosa pine (*Pinus ponderosa*) restoration treatments. The ambient body temperature of an ectotherm affects its physiology, development, and behavior. Microhabitat availability and heterogeneity are critical factors in determining which thermoregulation choices are available to a terrestrial ectotherm (Stevenson 1985). Forest restoration treatments (for example, thinning and burning) will alter herpetofauna microhabitats by decreasing tree canopy cover and allowing more sunlight penetration to the forest floor. This change could, depending on the species, have positive or negative effects on the populations of the area. We sampled microhabitat use by *Sceloporus graciosus* (sagebrush lizards) in northern Arizona at Grand Canyon-Parashant National Monument using standard "pitfall-array" sampling methodology. Univariate analyses were used to relate lizard abundance to ponderosa pine tree density, percent soil cover, percent rock cover, litter depth, and insect density. In a multivariate analysis, ponderosa pine density (negatively correlated) and bare soil cover (positively correlated) were the best predictors of lizard abundance. Restoration treatments will increase small-scale heterogeneity within *S. graciosus* territories by increasing accessibility into and out of sunlight. Based on the thermoregulatory demands of this species, these changes should benefit *S. graciosus*. However, other possible indirect effects of restoration treatments such as increases in predation on lizards (due to greater visibility), as well as changes in food availability, could negatively impact lizard populations. Future research should focus on pre- and postrestoration treatment monitoring of herpetofauna, and on the direct effects of fire on herpetofauna populations within restoration sites.

Introduction

Ponderosa pine (*Pinus ponderosa*) forest restoration is an experimental management practice currently being applied in the Southwest. This practice varies depending on the management objectives, but generally consists of some combination of forest thinning and prescribed burning. Covington and others (1997) has shown increases in: (1) forest floor sunlight penetration, and (2) herbaceous productivity (grasses, forbs, and shrubs) among restoration-treated ponderosa pine stands. These changes are expected to benefit the fauna of the area, although the direct effects of forest thinning and prescribed fire are poorly represented in scientific literature.

Data from Germaine (1999), in an ongoing restoration study at Grand Canyon-Parashant National Monument, suggest that lizards of the *Sceloporus* genus (*Sceloporus graciosus* and *Sceloporus undulatus*) are more abundant in areas with lower ponderosa pine density. This suggests that restoration treatments could result in higher densities of these *Sceloporus* lizards. However, studies of herpetofauna responses to ponderosa pine restoration before and after treatment do not currently exist.

The direct effects of fire on herpetofauna populations are also poorly understood. Cunningham and others (2000) pitfall-trapped lizards in burned and unburned chaparral and Madrean evergreen forests the year following a high-intensity wildfire, and captured primarily immature lizards. Subsequent trapping over the following two seasons resulted in higher species richness, diversity, and capture rates, indicating rapid settlement of the burned area by adjacent residents. Lizard genera represented in this study included *Sceloporus undulatus* and numerous *Cnemidophorus* species.

A few studies have shown that certain lizard species of fire-dependent ecosystems, such as long-leaf pine (Mushinsky 1985), chaparral (Lillywhite 1977a,b), and sandpine scrub (Greenberg 1993), increase in diversity or density following fire. Both Mushinsky (1985) and Greenberg (1993) found that some lizards of the genus Eumeces remained more abundant in control areas (unburned and unharvested for at least 20 years in both cases). It is apparent that different species have different thermoregulatory demands and should be addressed on a species-specific basis.

In this study we identified current forest condition microhabitat characteristics of the sagebrush lizard (*Sceloporus graciosus*) in a Southwestern ponderosa pine forest.

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Microhabitat preferences for this species were determined, based on habitat variation within the study area. Potential responses of *S. graciosus* to restoration treatments were determined by extrapolating habitat relationships from current condition forests to conditions expected in treated forest areas. In the future, these data will be further applied to a long-term study measuring the posttreatment effects of restoration on the age structure, composition, and abundance of this lizard population.

Methods

The study site was in northern Arizona at Grand Canyon-Parashant National Monument. The elevation ranges from approximately 2,080 m to 2,290 m, and the area is comprised primarily of ponderosa pine forest, with abundant sagebrush meadows. During May and June of 1999, prerestoration treatment microhabitat data were collected from 56 pitfall arrays. Arrays consisted of four 5-gallon buckets buried in a "peace-sign" configuration (Jones 1986). Each array included three wire mesh drift fences radiating out 7 m from the center bucket, connected to the other three buckets (fig. 1). Arrays were opened and checked every third day, for a total of 168 trap days. At each array, percent soil cover, percent rock cover, litter depth, and insect density were sampled within a 1 m circular radius surrounding each bucket. Insect density was sampled along four 1 m transects per bucket. The data were collected at timed intervals of 10 seconds per transect, scanning the entire transect length. All insects within the top 2.54 cm of litter were tallied during sampling.

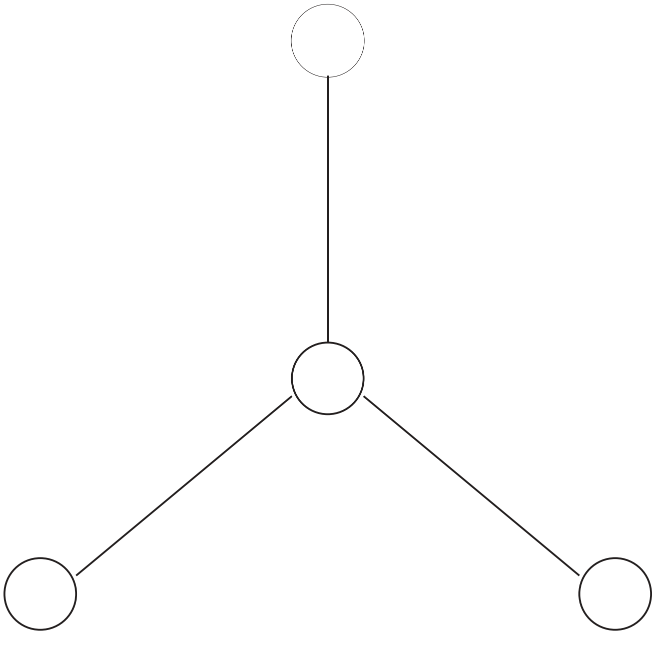

Figure 1—Aerial view of a pitfall array used to sample sagebrush lizard abundance at Grand Canyon-Parashant National Monument in June 1999, assembled in a peace-sign configuration with drift fence delineated by lines radiating out from the center bucket at 0°, 120°, and 240°, respectively.

Germaine (1999) gathered percent coniferous canopy closure and ponderosa pine density at each array. Coniferous canopy closure was measured at four transects as 40 "hits" or "misses", out to a 25 m radius, originating from the center of each array. Ponderosa pine stem density was measured in a 6 m belt running N-S and E-W across each array.

Values for each microhabitat variable collected were averaged for each array. We used stepwise linear regression analyses, with entry and exit levels of alpha = 0.15, to identify those habitat variables that, in combination, were associated with lizard abundance (Sokal and Rohlf 1981; SAS Institute Inc. 1985). Spearman correlations were used to determine univariate relationships between lizard abundance and microhabitat variables that were selected in multivariate models (SAS Institute Inc. 1985). Those microhabitat variables that were not normally distributed, or with unequal variance, were transformed by taking the square root of each variable (Sabin and Stafford 1990).

We calculated the Mallow's Cp statistic to select the best fitting model. This statistic is a measure of total squared error for each model and should be approximately equal to the number of parameters (including the intercept) in the model to choose a parsimonious model (Younger 1979: 493–495).

Results

Three species of lizards were captured during the trapping period. Captures consisted of *Sceloporus graciosus* (n = 81), *Eumeces skiltonianus* (n = 4), and *Sceloporus undulatus* (n = 1). *S. graciosus* abundance ranged from 0 to 9 (± 2.06) captures per array. Ponderosa pine density ranged from 0 to 1,968 (± 466.84) trees per hectare. Bare soil cover ranged from 0 to 91.25 (± 18.84) percent per array. Results from the stepwise linear regression analyses are presented for *Sceloporus graciosus* (table 1). The best model for explaining the variation in *S. graciosus* abundance contained the variables of ponderosa pine density (trees/ha) and percent bare soil cover:

$$\textit{S. graciosus}\text{ abundance} = 1.78 - 0.06\,(\text{ponderosa pine density}) + 0.24\,(\text{percent bare soil cover})$$
$$C(p) = 2.16$$

This model explained 34 percent of the variance. Ponderosa pine density was negatively correlated with *S. graciosus* abundance (fig. 2). *S. graciosus* abundance peaked in areas that contained 50–200 ponderosa pine trees/ha. Bare soil cover was positively correlated with lizard abundance (fig. 3).

Table 1—Summary of the stepwise linear regression analysis of the sagebrush lizard with habitat variables at Grand Canyon-Parashant National Monument in June 1999.

Parameter	Partial R^2	Model R^2	C(p)[a]
Pine density per hectare	0.28	0.28	3.43
Percent bare soil cover	0.06	0.34	2.16

[a] Mallow's Cp statistic is a measure of the total squared error for each model and should be approximately equal to the number of parameters (including the intercept) in the model.

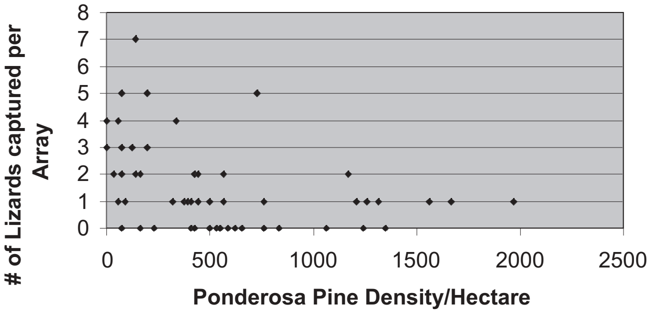

Figure 2—Sagebrush lizard abundance at Grand Canyon-Parashant National Monument in June 1999 was negatively associated with ponderosa pine density in a univariate analysis.

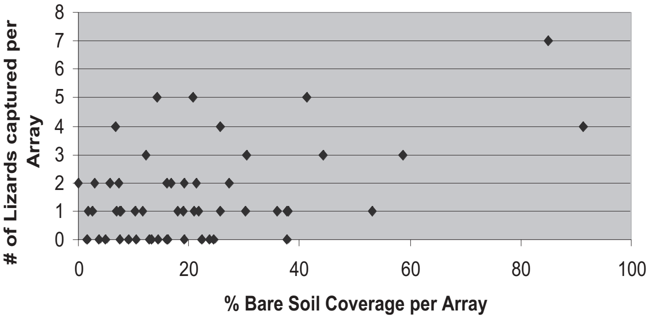

Figure 3—Sagebrush lizard abundance at Grand Canyon-Parashant National Monument in June 1999 was positively associated with bare soil coverage in a univariate analysis.

Discussion

This study indicates the need for small-scale heterogeneity within *Sceloporus graciosus* territories. Contiguous, homogeneous, fire-suppressed ponderosa pine forests inhibit adequate sunlight penetration to the forest floor. This can reduce sunlight accessibility for ectothermic animals with small home ranges, such as most lizards and snakes, which rely upon solar heat for metabolic processes and mobility.

Previous research has established that current Southwestern ponderosa pine forests contain much higher densities of ponderosa pine than were present in these same forests before Euro-American settlement (Cooper 1960; Covington and Moore 1994b). This suggests that sunlight penetration to the forest floor has also decreased during this period due to large increases in ponderosa pine densities. Covington and others (1997) have shown that forest restoration treatments, through reduction in forest tree density and prescribed fire, do in fact open up the canopy and create a more open, parklike landscape. Restoration, carried out through these means, will enhance the thermoregulation options available to *S. graciosus* by lowering litter accumulations (which will provide easier access to burrows), and ultimately increasing accessibility into and out of sunlight.

Ponderosa pine forest restoration treatments, implemented on an adaptive management basis, have potential to increase the habitat suitability of some terrestrial ectotherms by increasing small-scale heterogeneity. Thinning dense stands of ponderosa pine will not only allow more sunlight penetration, but will also create a more patchy distribution of sunlight at the ground layer level. Results of this study suggest that optimal *S. graciosus* habitat for thermoregulation would entail leaving between 50–400 trees/ha after forest thinning treatments.

It is important to recognize the many other factors that could change as a result of restoration treatments, which may inadvertently affect *S. graciosus*. Lawrence (1966) found increases in predatory birds and mammals after a chaparral fire in the Sierra Nevada foothills. Increases in predation and competition, as well as changes in food availability, may also play significant roles in the postrestoration habitat of terrestrial ectotherms.

We were able to explain one-third of the variance in sagebrush lizard abundance. Possible explanations for the lack of a model that explains a considerable amount of the variance can be attributed to several factors: (1) It is possible that the collective contribution of several microhabitat variables determines the success of the animal. (2) There is a high degree of difficulty associated with accurately sampling small-scale heterogeneity within the small territories of Sceloporus lizards. (3) The sample size could have been too small. (4) The length of the sampling period could have been too short. (5) Thorough seasonal population representation of an animal that spends two-thirds of its life below ground is questionable.

Suggestions for future research include the need for detailed behavioral studies that capture common behavior patterns of these lizards. Other recommendations include the need to obtain larger sample sizes, as well as long-term (>5 years) studies. Studies on the direct effects of fire on lizard fitness are essential to correctly understand which scale and intensity of prescribed fires to use in restoration treatments.

Although no studies exist that measure lizard responses directly to forest restoration before and after treatment, we hope that this study will encourage additional research. In those ecosystems where restoration treatments increase sunlight availability to the forest floor, terrestrial ectotherms can be significant indicators of thermal change. Data from this and related studies need to be incorporated into future restoration treatment prescriptions to ensure that habitat needs are met for all native wildlife species during forest restoration activities.

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