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Influence of Habitat Characteristics on Detected Site Occupancy of the New Mexico Endemic Sacramento Mountains Salamander, *Aneides hardii*

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Abstract.—**The Sacramento Mountains Salamander (*Aneides hardii*) is a state-listed threatened species endemic to three mountain ranges in south-central New Mexico. Information about the ecological requirements of this species is inadequate for managers to make informed conservation decisions, yet changes in management practices are needed throughout the species range because of poor forest health. During summer 2004, we examined patterns of *A. hardii* distribution in relation to several abiotic and biotic parameters on 36 plots, each of which was 9.6-ha in area and located in mixed conifer forest. We evaluated 18 a priori logistic regression models using Akaike's Information Criterion corrected for small-sample bias (AIC_c). The model with the highest ranking (lowest AIC_c value) included soil moisture and soil temperature, and the second highest ranked model ($\Delta AIC_c = 0.05$) included only soil temperature. Soil temperature was lower, and soil moisture was higher on plots where salamanders were detected. The relative importance of canopy cover and log volume was low in this study likely because the study plots, all of which had sufficient canopy cover and log volume, had similar disturbance history. We recommend managers focus on practices that ensure salamander microhabitats remain cool and moist in conservation areas.**

Resource managers are challenged with balancing human interests and the conservation of threatened and endangered species. This is a current issue in the western United States because of the need to manage forests for catastrophic fire prevention while considering the response of sensitive forest species to silvicultural practices. Fire suppression has resulted in dense stands and fuel accumulation throughout the western United States (Dahms and Geils, 1997). The United States Forest Service has recommended the use of mechanical thinning or prescribed fire to prevent potential property damage and to restore forests to historic conditions (Dahms and Geils, 1997). Timber harvesting and the resulting microhabitat modification generally adversely affect plethodontid salamanders because their physiological requirements constrain them to specific microhabitats (Feder, 1983; Petranka et al., 1993; deMaynadier and Hunter, 1998), although forestry practices do not always result in negative impacts (Ash, 1997; Messere and Ducey, 1998; Aubry, 2000).

Several habitat characteristics identified as important in the ecology of plethodontid salamanders are likely to be modified by forestry practices. Forest thinning decreases canopy cover and the input of coarse woody debris. A positive association has been demonstrated between both of these variables and detections (Dupuis et al., 1995; deMaynadier and Hunter, 1998) and estimated abundance of plethodontid species (Butts and McComb, 2000). Soil moisture is an influential factor in terrestrial salamander distribution and abundance (Taub, 1961; Heatwole, 1962; Dupuis et al., 1995). Increased solar radiation resulting from a more open canopy can decrease soil moisture and increase soil temperatures (Bury, 1983; Petranka et al., 1993; deMaynadier and Hunter, 1998).

Soil temperature may be among the most important variables in the management of the Sacramento Mountains Salamander (*Aneides hardii*), an endemic, New Mexico state-listed threatened plethodontid species. Whitford (1968) found the critical thermal maximum temperature of *A. hardii* to be relatively low in comparison to other terrestrial salamanders and speculated that this reflects adaptations to

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TABLE 1. Ranges, means, and standard errors (SE) for habitat variables. Separated by whether or not Sacramento Mountains Salamanders were detected on plots in 2004 in Lincoln National Forest, New Mexico. Values for aspect were excluded because it is a categorical variable. BA = Basal Area.

		Detected			Not detected		
Habitat variable	Units	Range	Mean	SE	Range	Mean	SE
Soil moisture[a]	(%)	22.65–77.15	38.92	0.82	10.03–84.93	35.88	0.61
Log volume[a]	(m^3/m^2)	0.22–1.16	0.64	0.11	0.10–1.37	0.61	0.07
Soil temperature[a]	(°C)	6.67–28.33	10.28	0.19	6.67–33.33	13.35	0.18
Canopy cover[a]	(%)	47.63–77.73	65.35	2.49	48.50–75.00	63.85	1.44
Aspect[a]	—	—	—	—	—	—	—
Humidity	(%)	46.52–99.11	60.89	5.16	24.16–86.93	54.24	4.01
Precipitation	(mm)	0.00–8.80	0.96	0.87	0.00–2.60	0.30	0.14
6-day precipitation	(mm)	0.40–16.60	6.20	1.87	0.00–48.41	9.76	2.87
Large dead tree BA	(m^2/ha)	0.95–7.13	3.61	0.66	0.60–20.57	3.38	0.77
Large live tree BA	(m^2/ha)	16.24–34.31	23.58	1.71	4.34–24.26	21.17	0.97
Small dead tree BA	(m^2/ha)	1.41–9.18	3.41	0.88	0.29–28.92	3.17	1.06
Small live tree BA	(m^2/ha)	5.30–15.56	10.53	0.94	4.36–24.26	11.15	0.92
Litter and fine woody debris cover	(%)	41.67–75.26	59.40	3.64	8.33–81.09	49.21	3.93
Soil pH	—	4.60–8.40	6.91	0.05	3.40–8.30	6.90	0.03

[a] A priori explanatory variable.

cooler microhabitats typically occupied by this species. *Aneides hardii* generally occurs at elevations ≥ 2400 m in its range of the Capitan, White, and Sacramento Mountains of south central New Mexico (Degenhardt et al., 1996). The limited distribution and elevation range of this species places it at particular risk of habitat modification impacts, whether related to catastrophic fire, forest thinning, or other factors. The range of *A. hardii* is primarily within Lincoln National Forest (Ramotnik, 1997), making the U.S. Forest Service largely responsible for the conservation and management of this species.

There is little known about the specific ecological requirements of *A. hardii* (but see Ramotnik and Scott, 1989). Improved knowledge of habitat relationships will help managers ensure the maintenance of sufficient areas meeting microhabitat requirements, identify appropriate conservation areas, and predict salamander response to forestry practices. Our objective was to provide information for the conservation of *A. hardii* by establishing patterns of distribution in relation to several abiotic and biotic parameters. We modeled habitat characteristics indicative of salamander distribution, focusing on variables likely to be modified by forestry practices. We hypothesized that detection of *A. hardii* would be related to habitat characteristics, especially at the microhabitat scale. We predicted that sensitivity to soil temperature, soil moisture, and volume of coarse woody debris would have the greatest influence on detected site occupancy based on previous literature (Whitford, 1968; Grover, 1998; Butts and McComb, 2000).

MATERIALS AND METHODS

Study Area.—The study was conducted in the Sacramento Mountains of Lincoln National Forest in south-central New Mexico. We used plots from a concurrent study on the impacts of forest thinning on the Mexican Spotted Owl (*Strix occidentalis lucida*; J. P. Ward Jr., J. L. Ganey, and G. Sorrentino, Unpubl. Tech. Report, Lincoln National Forest Supervisor's Office, Alamogordo, NM, http://www.rmrs.nau.edu/lab/4251/spowmon/, 2003). Both studies were in the pretreatment phase of a large-scale experiment to examine the effects of forest thinning on sensitive species. We sampled 36, 240 × 400-m (9.6-ha) plots within estimated foraging areas of Mexican Spotted Owls chosen for their similarity in elevation, vegetative composition, and disturbance history. We did not include elevation, vegetative composition, or disturbance history in our analyses because we controlled for these variables. The plots were in mixed conifer forests of high elevation (2400–2900 m). Dominant tree species in the plots were Douglas fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), quaking aspen (*Populus tremuloides*), southwestern white pine (*Pinus strobiformis*), and ponderosa pine (*Pinus ponderosa*). Soil texture classes on the plots were mostly loam and clay loam (U.S. Forest Service, unpubl. data).

Sampling Protocol.—Table 1 lists all habitat variables included in this study. Humidity and precipitation were recorded by HOBO weather stations located in the center of each of the 36 plots. We summarized two measures of precipitation from the weather station data to be included in the analyses: total precipitation on the survey date and total precipitation on the survey date plus the previous five days (six-day precipitation).

We surveyed for salamanders and collected data on soil temperature, soil moisture, soil pH, and aspect within four randomly selected 5 × 20-m quadrats on each plot. The measurements from these four quadrats were averaged for each plot, and plot-level variable estimates were used in our analyses. Our surveys for salamanders were conducted during 31 July to 13 September 2004 and consisted of an area-constrained search on each quadrat (0900–1800 h), which entailed turning over and searching beneath all potential cover objects ≥ 5 cm long that could be safely lifted by two people.

Within each of the four quadrats on each plot, we quantified soil characteristics (temperature, moisture, and pH) at five randomly selected points. Soil temperature was measured with a ReoTemp soil thermometer. Soil samples to measure moisture content were collected from 15 cm deep with a trowel, put into Whirlpak bags, and weighed in a laboratory. Moisture samples were dried in an oven for 24 h at 105°C (Brady and Weil, 1999). Soil moisture was estimated by the gravimetric method, in which percent moisture is determined by the following formula: (weight of wet soil − weight of dry soil /weight of dry soil) × 100 (Brady and Weil, 1999). We measured soil pH with a Hanna Instruments portable soil pH meter. We measured aspect in the center of each quadrat with a compass, which was classified into one of four categories (North, South, East, or West).

Data on trees, logs, litter and fine woody debris, and overhead canopy cover were collected in 24 subplots arranged in a 4 × 6 grid within each 9.6-ha plot. The measurements from these 24 subplots were averaged for each plot, and plot-level variable estimates were used in our analyses. Grid stations were spaced 80 m apart. We measured the diameter at breast height (dbh) of large trees (dbh ≥ 30 cm) in a 10-m radius subplot centered around each grid station. We measured the dbh of small trees (10–29 cm) in a 5-m radius subplot nested within the 10-m radius subplot. The status of each tree was classified as live, which was defined as a tree with any green foliage, or dead, which was defined as no sign of green foliage and > 2 m tall. We estimated the basal area of trees using the formula for the area of a circle (Young, 1982). The length and diameter of all logs (> 2 m in length and > 10 cm in diameter) were measured within the 5-m radius subplot. We used the formula of a cylinder to estimate log volume (modification of line intercept method of Van Wagner, 1968).

In each 10-m radius subplot, we established two transects (20 m) using randomly chosen compass bearings separated by 90°. Percent cover of overhead canopy and litter and fine woody debris were measured along each transect using the point-intercept method (Bonham, 1989). We recorded presence or absence of overhead canopy and litter and fine woody debris (< 10 cm diameter) at 1-m intervals along each transect for a total of 40 readings at each subplot. We used an ocular tube to measure overhead canopy because of the bias associated with spherical densiometers (Cook et al., 1995). This tube was constructed of PVC pipe with two strings arranged over one end of the pipe to create cross-hairs. We counted only canopy falling in the center of the cross-hairs as present when looking upward through the level ocular tube.

Statistical Analysis.—We reduced field salamander counts to presence/absence data because of difficulties in estimating individual detection probability for this species (Haan and Desmond, 2005). Differences in counts were not assumed to reflect true differences in abundance. This method did not eliminate the possibility of false absences, however, because plethodontid salamander detection probability varies with temporal and environmental conditions (Bailey et al., 2004a,b; Williams and Berkson, 2004). We computed estimates for all habitat variables by averaging values from quadrats and subplots for each plot and used habitat variable estimates at the plot level in analyses.

We evaluated 18 a priori models using logistic regression with Akaike's Information Criterion corrected for small-sample bias (AIC_c) for model selection (Burnham and Anderson, 2002). Logistic regression uses a nonlinear model to predict a binary response (detected/nondetected) based on explanatory variables that may be categorical or numerical. Akaike's Information Criterion is a measure based on the relationship between Kullback-Liebler information and maximum likelihood, which estimates how well a priori models represent a process or system and penalizes models that are overparameterized (Burnham and Anderson, 2001, 2002). Models with smaller AIC values are preferred based on parsimony; however, the metric is only useful with respect to the model set being studied. Therefore, substantial a priori thought must be made in identifying plausible models.

Relative importance of each variable used in the a priori analysis was estimated by summing the Akaike weights across all models in which each variable (j) occurred to calculate the cumulative model weight ($w_+(j)$; Burnham and

Anderson, 2002). Of the 14 habitat variables measured, we limited our models to the five that were considered most influential in terrestrial salamander ecology in this analysis. Our sample size was not large enough to support models with all possible parameters (Burnham and Anderson, 2002). Variables included in the models were soil moisture, log volume, soil temperature, canopy cover, and aspect.

Plethodontid salamanders require sufficiently moist soil surfaces for foraging and other activities (Feder, 1983), and the importance of soil moisture in terrestrial salamander ecology has been well demonstrated (Taub, 1961; Sugalski and Claussen, 1997; Grover, 1998). Plethodontid salamanders have displayed intolerance for high temperatures, and temperature is influential in terrestrial salamander distribution (Taub, 1961; Whitford, 1968). In addition, researchers have demonstrated a positive association between plethodontid salamander numbers and coarse woody debris volume and canopy cover (Dupuis et al., 1995; deMaynadier and Hunter, 1998; Butts and McComb, 2000). Borg (2001) found evidence for the importance of aspect to *A. hardii*, which was significantly more abundant on northerly aspects when compared to south-facing slopes. When selecting these variables, we also considered the potential for modification by forestry practices.

After completing the analysis of a priori models, we conducted an exploratory post hoc analysis to examine parameters not included in the a priori models and to generate future hypotheses (Anderson and Burnham, 2002). We added 11 post hoc models to the original 18 a priori models and used AIC_c for model selection. For this exploratory analysis, we used a global model containing three of the a priori variables (soil moisture, canopy cover, and soil temperature) and the previously unexamined habitat parameters, and then we analyzed 10 subsets of the global model. Although these post hoc analyses are not congruent with the information theoretic approach in the strict sense, we felt their inclusion was warranted because all measured variables had some support in the terrestrial salamander ecology literature (Wyman and Hawksley-Lescault, 1987; Butts and McComb, 2000; Williams and Berkson, 2004) and future research could be improved with the information (Anderson and Burnham, 2002). We did not make inferences about these post hoc models, however, because they would need to be evaluated with additional data (Burnham and Anderson, 2002).

When a parameter was missing an explanatory value for a plot, we excluded the values for all parameters for that plot in the analysis. This was necessary so that the sample size was the same for all models considered within each selection technique, but it resulted in different sample sizes between a priori and post hoc selection. To estimate the predictive power of the logistic regression models in both a priori and post hoc analyses, we calculated the max-rescaled R^2, which behaves similarly to the linear model R^2 and is scaled for occurrences when the discrete dependent variable is < 1 (Allison, 1999). We used PROC LOGISTIC in SAS to conduct the a priori and post hoc analyses (SAS Institute, Cary, NC, 1999). Aspect of each plot was treated as a categorical variable with four classes (North, South, East, or West) in the analyses. We tested for multicollinearity between all a priori variables and variables included in the top six ranked post hoc models using PROC CORR in SAS after the modeling process to assist with interpretation (SAS Institute, Cary, NC, 1999).

Results

Salamanders were detected on 10 of the 36 plots; environmental variables on plots where salamanders were detected and not detected are summarized in Table 1. Six of the 18 a priori models were supported empirically according to AIC criteria ($\Delta AIC_c < 3$, Table 2). The model including soil moisture and soil temperature was selected as the ''best'' approximating model. This model explained 37% of the observed variation in salamander detection (Table 2).

The model including soil temperature alone was strongly competitive and explained 29% of the observed variation (Table 2). Soil temperature was in each of the top six models and negatively influenced salamander detection. Soil temperature had the highest cumulative model weight ($w_+(j) = 0.96$; Table 3), which is an estimate of the relative importance of predictor variables (Burnham and Anderson, 2002). Soil moisture was in four of the top six models with a cumulative model weight of 0.60. The evidence ratio, which provides a weight of evidence for each model when compared to another model (Burnham and Anderson, 2002), for model 1 versus model 2 was low, as were the evidence ratios for model 1 versus models 2–6 (Table 4). These low evidence ratios indicated that strong support did not exist for any one model. Of the 10 positive detection plots, seven had northerly aspects (70%), whereas 10 of 26 nondetection plots were north-facing (38%). This association with aspect was not statistically detectable ($\chi^2_2 = 3.4$; $P > 0.10$).

TABLE 2. A priori logistic regression models, in order of importance, evaluating habitat characteristics for the Sacramento Mountains Salamander (*Aneides hardii*) in 2004 in Lincoln National Forest, New Mexico, using Akaike's Information Criterion corrected for small sample size (AIC_c; $N = 35$). SM = Soil Moisture, ST = Soil Temperature, CC = canopy cover, LV = Log Volume, and A = aspect.

Model	K[a]	AIC_c	ΔAIC_c	w_i[b]	R^2[c]
1) 1.31 (β_0) + 10.21 (SM) − 0.53 (ST)	3	38.26	0.00	0.289	0.37
2) 4.78 (β_0) − 0.50 (ST)	2	38.31	0.05	0.282	0.29
3) 4.54 (β_0) + 11.75 (SM) − 0.59 (ST) − 4.86 (CC)	4	40.32	2.06	0.103	0.38
4) 0.84 (β_0) + 10.42 (SM) + 0.01 (LV) − 0.53 (ST)	4	40.48	2.22	0.095	0.38
5) 5.76 (β_0) − 1.35 (CC) − 0.51 (ST)	3	40.66	2.40	0.087	0.29
6) 1.46 (β_0) + 10.05 (SM) − 0.52 (ST) + 0.93 (A)	4	41.16	2.90	0.068	0.42
7) 0.73 (β_0) + 10.50 (SM) + 0.01 (LV) − 0.97 (ST) + 1.02 (A)	5	43.27	5.01	0.024	0.44
8) −2.82 (β_0) + 5.08 (SM)	2	45.13	6.87	0.009	0.05
9) 3.76 (β_0) − 0.18 (CC) + 0.01 (LV) − 0.44 (ST) + 1.04 (A)	5	45.30	7.04	0.009	0.38
10) −1.65 (β_0) + 0.01 (LV) + 1.09 (A)	3	45.84	7.58	0.007	0.18
11) −2.47 (β_0) + 3.98 (SM) + 0.91 (A)	3	46.04	7.78	0.006	0.18
12) −1.22 (β_0) + 0.01 (LV)	2	46.08	7.82	0.006	0.01
13) −2.13 (β_0) + 1.85 (CC) + 0.99 (A)	3	46.47	8.21	0.005	0.16
14) −5.11 (β_0) + 5.22 (SM) + 3.47 (CC)	3	47.08	8.82	0.004	0.06
15) −3.21 (β_0) + 5.21 (SM) + 0.01 (LV)	3	47.31	9.05	0.003	0.05
16) −3.24 (β_0) + 4.14 (SM) + 0.01 (LV) + 1.03 (A)	4	47.84	9.58	0.002	0.20
17) −3.82 (β_0)+ 0.01 (LV) + 3.86 (CC)	3	47.96	9.70	0.002	0.03
18) −6.10 (β_0) + 4.18 (CC) + 5.40 (SM) + 0.01 (LV)	4	49.27	11.01	0.001	0.08

[a] Number of parameters.
[b] Akaike weight.
[c] Max-rescaled R^2.

None of the variables tested for muliticollinearity were correlated at $r \geq 0.70$. In the post hoc exploratory analysis, the highest-ranked models were similar to the highest-ranked a priori models (Appendix 1). As in the a priori models, soil temperature and soil moisture were frequently included in the best approximating post hoc models. The addition of six-day precipitation and litter and fine woody debris cover, however, improved the model of salamander detection as evident by inclusion of these variables in the first and third ranked models, respectively (Appendix 1).

DISCUSSION

Through our modeling of environmental variables, we found that soil temperature was likely an important variable predicting the detection of *A. hardii*. Higher soil temperatures were negatively associated with salamander detection. The relatively low critical thermal maximum temperature of *A. hardii* compared to other terrestrial salamanders may restrict it to cooler microhabitats (Whitford, 1968). Taub (1961) found that *Plethodon cinereus*, a common eastern woodland salamander, avoided high temperatures in the laboratory and field. Soil moisture was also an important predictor, positively influencing *A. hardii* detection. Evaporative water loss is high through the permeable skin of amphibians, but their skin must remain moist for respiration (Stebbins and Cohen, 1995). It is essential for plethodontid salamanders that exposed soil

TABLE 3. Cumulative model weights of variables used in a priori logistic regression models used to identify habitat characteristics that predicted detection of the Sacramento Mountains Salamander (*Aneides hardii*).

Variable (j)	$w_+(j)$
Soil temperature	0.96
Soil moisture	0.60
Canopy cover	0.21
Log volume	0.15
Aspect	0.12

TABLE 4. Evidence ratios for the top seven a priori logistic regression habitat characteristics models (j) compared to the top model (model 1). Model numbers correspond to the numbering in Table 2. Evidence ratios provide a relative measure of importance for each model when compared to another model (Burnham and Anderson, 2002).

w_1/w_j	Evidence ratio
w_1/w_2	1.02
w_1/w_3	2.81
w_1/w_4	3.04
w_1/w_5	3.32
w_1/w_6	4.26
w_1/w_7	12.24

surfaces be sufficiently moist for foraging and other activities (Feder, 1983). Many studies have demonstrated the influence of moisture in terrestrial salamander distribution, abundance, and activity level (Taub, 1961; Sugalski and Claussen, 1997; Grover, 1998). It seems likely that we were able to detect salamanders during times when the combined influence of soil moisture and temperature signaled suitable soil surface conditions.

The low percentage of salamander detection among all study plots (28%) resulted in low predictive power for the evaluated models. The amount of variation explained by the top models ranged from 29–42%. The small evidence ratios among models also suggested that strong support did not exist for any single model (Burnham and Anderson, 2002). False absences can underestimate species occurrence at a site (MacKenzie et al., 2004; Williams and Berkson, 2004). MacKenzie et al. (2002) developed a model for estimating occupancy rates that account for detectabilities less than one, however, their method relies on multiple visits at each site, which we were unable to perform because of the limited activity period of this species, few personnel, and large study area. It is probable that we had false absences and underestimated *A. hardii* detection in this study because salamanders could have been compensating for unfavorable surface conditions by remaining in subterranean habitat. Higher detection may have improved the predictive power of our models.

We were unable to estimate individual detection probability and were, therefore, unable to differentiate factors that affect salamander detection from those that influence distribution. Future researchers may want to consider methods for conducting more intensive salamander sampling and estimating individual detection probability. Haan and Desmond (2005) were unable to recapture any marked *A. hardii* individuals in an effort to estimate detection probability with mark-recapture techniques when sampling with two arrangements of pitfall traps and repeated area-constrained searches. These results indicate that this species may exhibit a negative response to capture, or it may be sensitive to variation in precipitation events and/or the apparent microhabitat desiccation that results from repeated area-constrained searches in the study area. Researchers have demonstrated success with investigating population parameters of salamanders with temporary removal methods (Bruce, 1995; Salvidio, 2001), and this may be a suitable alternative strategy for future researchers of *A. hardii*.

Aneides hardii was widely distributed throughout the Sacramento Mountains, but we only detected its presence on 28% of study plots, indicating site-specific factors affected its detected presence on plots. We found that the most influential parameters in determining salamander detections were soil temperature and soil moisture, but related variables, such as aspect and litter and fine woody debris cover, may have been secondary factors affecting salamander detection. Because south-facing slopes receive more sun exposure in the northern hemisphere, they are warmer and drier than north-facing slopes (Geiger, 1965). Seventy percent of positive detection plots in this study were on north-facing slopes, although this difference was not statistically detectable. Borg (2001) found that *A. hardii* was significantly more abundant on northerly aspects when compared to south-facing slopes. South-facing slopes are less suitable for *A. hardii* because plethodontid salamanders generally select cooler and moister microhabitats (Taub, 1961; Heatwole, 1962; Welsh and Lind, 1995). Litter and fine woody debris cover was included in one of the top ranked models of our post hoc analyses, which indicates that future researchers should consider examination of this variable. Litter is important for plethodontid salamanders, because they tend to forage mainly in the litter when it is sufficiently moist (Jaeger, 1980). In addition, we found in our post hoc analysis that six-day precipitation negatively affected the detection of salamanders, which seems counterintuitive and may warrant further investigation.

Our results suggest that conservation of *A. hardii* should focus in part on retaining cool and moist microhabitats, at least within the ranges included in this study. Silvicultural practices that open canopy cover generally result in warmer and drier microhabitats (Petranka et al. 1993; Ash, 1997; deMaynadier and Hunter, 1998). Borg (2001) found that logged sites ($\leq$ 10 yr) had significantly warmer substrates than less disturbed sites in the Sacramento Mountains. Welsh and Lind (1995) demonstrated a positive association of *Plethodon elongatus* abundance with percent canopy closure in northwestern California. In this study, canopy cover and log volume did not differ significantly between positive and nondetection plots likely because the study plots had similar disturbance history. This may explain the low relative importance of these variables in the pretreatment phase of our study. It seems probable that relative importance of canopy cover to *A. hardii* detection would be higher in areas subjected to management practices that greatly reduce canopy. Forestry practices that retain large trees with greater canopy cover should help keep soils cool and moist.

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Appendix 1. The top six ranked post hoc logistic regression models, in order of importance, evaluating habitat characteristics for the Sacramento Mountains Salamander (*Aneides hardii*) in 2004 in Lincoln National Forest, New Mexico, using Akaike's Information Criterion corrected for small sample size (AIC_c; $N = 33$). SM = Soil Moisture, ST = Soil Temperature, CC = canopy cover, LV = Log Volume, SDP = 6-day Precipitation, and FWD = Litter and Fine Woody Debris Cover.

Model	K[a]	AIC_c	ΔAIC_c	w_i[b]	R^2[c]
1) $-2.66\ (\beta_0) - 0.51\ (ST) + 22.94\ (SM) - 0.10\ (SDP)$	4	35.39	0.00	0.28	0.50
2) $-0.90(\beta_0) + 14.45\ (SM) - 0.46\ (ST)$	3	36.35	0.96	0.17	0.40
3) $-3.66\ (\beta_0) - 0.45\ (ST) + 15.12\ (SM) + 4.32\ (FWD)$	4	37.20	1.81	0.11	0.45
4) $4.51\ (\beta_0) - 0.47\ (ST)$	2	37.29	2.30	0.09	0.28
5) $-1.77\ (\beta_0) + 15.24\ (SM) + 0.01\ (LV) - 0.46\ (ST)$	4	38.36	2.97	0.06	0.42
6) $1.70\ (\beta_0) - 0.50\ (ST) + 15.36\ (SM) - 3.78\ (CC)$	4	38.68	3.29	0.05	0.41

[a] Number of parameters.
[b] Akaike weight.
[c] Max-rescaled R^2.