EFFECT OF WILDFIRE ON ABUNDANCE, DETECTION PROBABILITY, AND ARTHROPOD PREY BASE OF SACRAMENTO MOUNTAIN SALAMANDERS (*Aneides hardii*)

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Distribution of the Sacramento Mountain salamander within Lincoln and Otero counties, New Mexico.

Map of the 18 study sites used in this study to examine the impact of the Scott Able Fire on arthropods and Sacramento Mountain salamanders. The perimeter of the fire is labeled in red.

INTRODUCTION

The Sacramento Mountain salamander, *Aneides hardii*, occurs within three disjunct mountains of south-central New Mexico, the Capitan, White, and Sacramento mountains, in Lincoln and Otero counties. Within mesic mixed-habitat forest above 2,400 m, the salamander is found on the surface in association with decayed logs, bark, rocks, and small woody debris, where it feeds on ground-dwelling arthropods, primarily ants, beetles, and spiders. Salamanders are potentially vulnerable to actions such as logging and fire that dry the habitat and reduce the amount of moisture available to them for respiration. Salamanders apparently survived the frequent, low-intensity fires that occurred historically in the Sacramento Mountains, but fire suppression has created opportunities for large, catastrophic, “stand-reducing” fires.

An opportunity to study how salamanders respond to fire occurred on May 11, 2000, when a wildlife burned 16,034 acres across a narrow 15-mile stretch in the Lincoln National Forest. Included in the fire’s path were almost 8,000 acres of high-elevation forest inhabited by the salamander. The U.S. Geological Survey conducted a 5-year study to evaluate effects of the wildfire on (1) relative abundance of Sacramento Mountain salamanders; (2) diversity and abundance of ground-dwelling arthropods; and (3) soil characteristics such as pH, water-holding capacity, and organic matter. The results of objectives 1 and 2 are reported here.

MATERIALS AND METHODS

The study was conducted from June – September 2001 to 2005 on 18 sites within the Lincoln National Forest. Six sites were located in each of three categories, unburned, severely burned, and lightly burned, using the following criteria: unburned or control (CNTL) = no known record of fire in the last 30 years; severely burned (BURN) = areas with no live trees (100 % tree kill), no litter, and most logs on the ground completely burned on the outside; and lightly burned (LOWB) = not fewer than 75% live (green) trees, some litter present.

Relative abundance was determined by counting numbers of salamanders found under coverboards. Coverboards consisted of similar-sized sections of wood from Douglas fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor*), species commonly used by *A. hardii* (Fig. 1). There were 20 coverboards per site and each was checked 1-3 times annually. Time-constrained searches were effective in detecting salamanders in 2000 but, due to the need to conduct repeated searches for salamanders over the course of the 5-year study and concern for repeated disturbance of the natural ground cover, coverboards were used. Because count data can underestimate the population if not all animals have the same likelihood of being detected (detection probability), a mark-recapture study was conducted from 2003 to 2005 on six sites, 2 from each category. Salamanders were uniquely marked using fluorescent elastomer and censused during 3 activity periods. Detection probabilities and population estimates were calculated using the constant model, closed captures design model of the MARK Program.

Pitfalls (16-ounce plastic drinking cup) were installed (at 12 per site) to sample the ground-dwelling arthropods. Arthropods were counted and identified to Family. To compare mean numbers of arthropods among treatments, the count data were log-transformed and analyzed using analysis of variance (PROC ANOVA) and the General Linear Model (PROC GLM) procedure followed by Duncan’s multiple range.

RESULTS

Abundance

During time-constrained searches in 2000, salamander numbers were highest on the lightly burned plots, followed by the severely burned and control sites (Table 1). A total of 324 salamanders were found under coverboards during eight surveys conducted between August 2001 and September 2005 (Table 2). Averaged across all years, relative abundance of salamanders was highest on lightly burned sites with an average of 24 salamanders per survey, intermediate on unburned sites (mean = 10), and lowest on the severely burned sites (mean = 6). Interestingly, no salamanders were found under coverboards on the lightly burned sites on two occasions when surface conditions were unusually dry, yet they were found on one unburned site. Counts of salamanders varied annually among treatments and control, but with one exception, were always higher on the lightly burned sites.

	Number	Date surveyed
CNTL 1	69	26 Jul 2000
CNTL 2	47	17 Aug 2000
CNTL 3	94	15 Aug 2000
CNTL 4	74	14 Aug 2000
CNTL 5	7	18 Aug 2000
CNTL 6	60	15 Aug 2000
Mean	58	
BURN 1	125	27 Jul 2000
BURN 2	93	27 Jul 2000
BURN 3	89	27 Jul 2000
BURN 4	20	26 Jul 2000
BURN 5	65	26 Jul 2000
BURN 6	161	23 Aug 2000
Mean	92	
LOWB 1	105	22 Aug 2000
LOWB 2	126	22 Aug 2000
LOWB 3	215	22 Aug 2000
Mean	149	

Table. 1. Numbers of salamanders found on plots during 2 hour time-constrained searches, Lincoln National Forest, NM, summer 2000.

SITE	2001 20-22 Aug	2002 15-28 Aug	2003 23-24 July	2003 13-14 Sep	2004 12-13 July	2005 30 Jun-1 Jul	2005 1-2 Aug	2005 7-9 Sep	Grand Total
CNTL 1	0	0	0	1	1	0	0	0	2
CNTL 2	0	1	0	1	2	0	0	1	5
CNTL 3*	8	3	7	1	7	0	5	1	32
CNTL 4*	6	1	0	2	8	0	9	0	26
CNTL 5	0	0	0	0	0	0	0	1	1
CNTL 6	1	3	0	0	1	0	5	4	14
	15	8	7	5	19	0	19	7	80
BURN 1	1	3	0	7	3	0	1	6	21
BURN 2*	0	1	0	0	0	0	1	0	2
BURN 3*	1	7	0	2	1	0	1	2	14
BURN 4	1	0	0	0	0	0	0	2	3
BURN 5	3	1	0	1	1	0	1	3	10
BURN 6	0	0	0	0	0	0	0	0	0
	6	12	0	10	5	0	4	13	50
LOWB 1*	3	3	0	0	4	0	1	3	14
LOWB 2*	12	7	0	7	8	0	10	7	51
LOWB 3	17	8	0	8	1	0	0	4	38
LOWB 4	-	13	0	12	9	0	16	11	61
LOWB 5	-	1	0	4	3	0	0	2	10
LOWB 6	-	6	0	4	3	0	3	4	20
	32	38	0	35	28	0	30	31	194
Grand Total	**53**	**58**	**7**	**50**	**52**	**0**	**53**	**51**	**324**

Table 2. Numbers of salamanders found under coverboards on controls (CNTL), severely burned (BURN), and lightly burned (LOWB) plots in the Lincoln National Forest, NM, 2001–2005.

Detection Probability

A total of 1657 salamanders were marked on the six sites, with sufficient numbers of recaptures on the unburned and lightly burned sites to allow for estimation of detection probabilities in all years. Detection probabilities could only be estimated on the severely burned sites in 2005. On unburned and lightly burned sites detection probabilities of salamanders were relatively comparable in 2004 and 2005 and ranged from 18 to 29% (Table 3). Therefore, the counts of salamanders under coverboards are presumed to be real, and we can directly compare them without violating assumptions of unequal detection probabilities. Although detection probabilities were higher in 2003, the detection probabilities in 2004 and 2005 more accurately reflect true conditions due both to higher numbers of marked salamanders and better precision of estimates. The higher detection probabilities on severely burned sites likely reflect the reduced cover due to fire and the greater consistency in detecting salamanders under this limited cover.

Fig. 1. Coverboard on an unburned site that has been on the site for 4 years. The round aluminum tag has a unique number. Salamanders were found both under the coverboard and under loose bark.

Site	2003	2004	2005
Control 3	N/A	27%	26%
Control 4	53%	24%	25%
Mean	N/A	25.5%	25.5%
Low Burn 1	59%	29%	18%
Low Burn 2	7%	24%	20%
Mean	33%	26.5%	19%
Burn 2	N/A	N/A	46%
Burn 3	N/A	N/A	24%
Mean	N/A	N/A	35%

Table 3. Detection probabilities of Sacramento Mountain salamanders from a mark-recapture study conducted on six sites in the Lincoln National Forest, NM, 2003-2005. N/A indicates that detection probability could not be estimated due to low numbers of either marked or recaptured salamanders.

RESULTS

Arthropod Prey Base

13,807 individuals were identified within 117 Families from 24 Orders and 7 Classes. Coleopterans (beetles) represented the most diverse group with 34 families, followed by Hymenoptera (ants, bees, and wasps) with 13, and Araneae (true spiders) with 10. Mean numbers of arthropods were significantly different in 2001, the year following the fire ($F = 14.09$, $p < 0.0007$), and in 2003 ($F = 4.40$, $p < 0.03$), and 2004 ($F = 6.41$, $p < 0.0079$; Fig. 2). In general, mean numbers of arthropods on the severely burned sites were always lower than those on the lightly burned and control sites throughout this study. Family richness was higher on burned sites (severely and lightly burned) than on unburned sites 4 months after the fire but was more stable on unburned sites (Fig. 3).

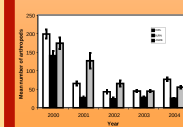

Fig. 2. Mean number of arthropods on unburned (CNTL), lightly burned (LOWB), and severely burned (BURN) sites, Lincoln National Forest, NM, 2000–04. The asterisk indicates a significant effect by year. Error bars represent standard errors.

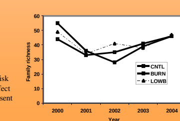

Fig. 3. Arthropod family richness (number of families) on unburned (CNTL), lightly burned (LOWB), and severely burned (BURN) sites, Lincoln National Forest, NM, 2000–2004.

DISCUSSION AND CONCLUSIONS

Although the fire caused an immediate temporary increase in our ability to detect salamanders on severely burned sites, counts of salamanders on those areas declined sharply 1 year after the fire and have remained low for 5 years. Based on low population estimates of salamanders on severely burned sites as of 2005, these sites have not recovered sufficiently for salamanders to reoccupy the surface habitats. This generally reflects the suboptimal quality of the sites and reoccupation of these sites will not be possible until canopy cover develops, depth of litter increases, and large natural cover objects become more common. Conversely, this study suggests that the effects of fire on salamanders on lightly burned sites are not extreme.

Coverboards may be useful in future studies of this salamander when comparisons across more or less similar areas are needed. The primary caveat is that to compare trends of salamanders in different areas, the detection probabilities must be equal or nearly so. When comparing count indices in very different habitats or with different levels of perturbations, however, researchers should calculate detection probabilities at least initially then follow up every few years. Coverboard surveys may be preferable over time-constrained searches because the size of the search area is standardized and the relationship to actual population levels is known. Detection probabilities of *Aneides hardii* are much higher than those found in eastern plethodontid salamanders and reflect the drier, less hospitable, and more open nature of forests in southern New Mexico.

Overall effects of the Scott Able fire on the abundance and community composition of forest floor arthropods appear to be moderate after 5 years. The beetle and spider community composition changed as a result of the fire by becoming less diverse and less abundant. While the fire did result in declines of some common arthropod groups, a few groups showed the opposite response. Family richness has not yet returned to pre-burn levels on burned sites after 5 years. Most likely the full recovery of the arthropod community will be dependent on recovery of the vegetation upon which many of them depend.

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