Survivorship of Raked and Unraked Trees Through Prescribed Fires in Conifer Forests in Northeastern California[1]

William F. Laudenslayer, Jr.,[2] George N. Steger,[2] and Jonathan Arnold[3]

Abstract

Large diameter, old trees are an important component of functioning forests, as they provide habitat for many wildlife species and add value to the scenery along roads and trails that cross our National Forests and Parks. Tree mortality, from prescribed or wild fire, is of great concern to forests managers, especially mortality of those of large diameter. Raking away the litter and duff around the base of these desired trees has been advocated as a way to reduce tree mortality during prescribed burns. We tested the effectiveness of raking to reduce tree mortality in two burn areas in Lassen Volcanic National Park (Lake and Lost Creek) by randomly selecting large and small diameter trees and removing the litter and duff to bare mineral soil for 1 m in radius around the base of each sample tree. The areas were prescribed burned in the fall of 1997. Results varied considerably between study plots, with 37 percent of all the sample trees (raked and unraked) in the Lake burn dying, in contrast with the Lost Creek burn where 25 percent of the sample trees died. Raked trees, however, did survive better than unraked trees in both study areas. Twenty-seven percent of the raked trees died in the Lake burn in contrast with 47 percent of the unraked trees. In the Lost Creek burn, none of the raked trees died whereas 50 percent of the unraked trees died.

Introduction

Reintroducing fire into western forests, whether by permitting naturally ignited fires to burn or applying prescribed fire, is widely being employed to reduce fuel loadings and to restore fire as a process to forests where fire historically has had a profound influence. However, because of the absence of fire, fuel accumulation may increase fire severity in prescribed burns, causing unacceptable mortality in large trees. As an example, following a prescribed burn in an eastside pine forest comprised mostly of Jeffrey pine (*Pinus jeffreyi*), all 14 of the large, old Jeffrey pines in a study plot died, apparently from effects of the fire, within 3 yr of the fire (Laudenslayer 2002). The crowns of these trees did not appear to be scorched severely enough to have caused death, but the fire appears to have been intense and fire-elevated temperatures prolonged at the soil surface where litter and duff accumulations were as deep as 30 cm.

The literature reports a number of methods that might be effective in reducing large tree mortality during and following prescribed fire (Weatherspoon and others 1989, Fulé and others 2002a, Jerman and others 2004). One of these methods is to

---

[1]An earlier version of this paper was presented at the 2002 Fire Conference: Managing Fire and Fuels in the Remaining Wildlands and Open Spaces of the Southwestern United States, December 2–5, 2002, San Diego, California.

[2]Research wildlife biologist, and biological technician, respectively; U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 2081 E. Sierra Ave., Fresno, CA 93710. e-mail: blaudenslayer@fs.fed.us.

[3]U.S. Department of the Interior, National Park Service, Lassen Volcanic National Park, P.O. Box 100, Mineral, CA 96063.

physically remove the heavy deposits of litter and duff from around the bases of large, old trees that have not seen fire in decades. We, in cooperation with Lassen Volcanic National Park, decided to test this method on two upcoming prescribed burns. Our objective was to determine if removal of litter and duff down to bare mineral soil in the fall can improve survivorship of both large and smaller diameter trees following a prescribed fire.

Study Areas

The prescribed burn areas are located in the southern extremity of the Cascade Range in California. Both burn areas are within Lassen Volcanic National Park. The Lake burn is just northeast of Butte Lake, and the Lost Creek burn is adjacent and to the south of the Crags Group campground, approximately 8 km east of Manzanita Lake (*fig. 1*).

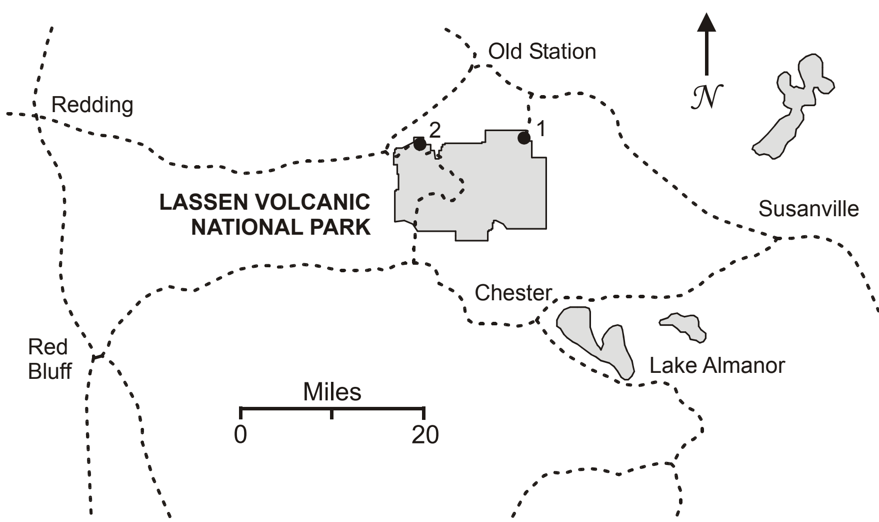

Figure 1–Vicinity of Lassen Volcanic National Park in Northeastern California; locations of the burns are at the closed circles: 1 is the Lake burn and 2 is the Lost Creek burn.

The Lake burn area is dominated by an eastside pine forest comprised primarily of Jeffrey pine with smaller numbers of ponderosa pine (*P. ponderosa*), white fir (*Abies concolor*), and red fir (*A. magnifica*). The stands are very open and dominated by relatively few, sparsely distributed, large diameter trees, with very few seedlings, saplings or smaller trees. Shrubs are rare and herbaceous growth is uncommon. Topography is variable, ranging from nearly level to very steep. Elevation generally increases from the periphery of the burn toward several high points. The soil surface is dominated by a layer of volcanic ash (approximately 25 to 35 cm deep), which resulted from an eruption of a nearby cinder cone sometime between A. D. 1630 and 1670 (Clynne and others 2000). Frequency of rocky outcroppings of older volcanic rocks increases as elevation increases. Prior to the burn, deposition of needles and other organic debris was generally restricted to within a few meters of the boles of large diameter trees and areas between trees were relatively free of dead organic material.

The Lost Creek burn area is dominated by mixed conifer forest, including white fir, ponderosa, sugar pine (*P. lambertiana*), and incense cedar (*Calocedrus decurrens*). Canopy closure is much higher than in the Lake burn area, and trees ranging from saplings to very large are present. Shrubs are rare and herbaceous growth is uncommon. Topography is variable, but sample trees were all on rather gentle slopes (<10%). The soil surface, before the burn, was dominated by a continuous layer of needles and other organic debris with deposits accumulating around the bases of the large diameter trees.

Methods

In September 1996, we randomly selected pine trees (Jeffrey, ponderosa, or sugar) for the experiment in the Lake burn and Lost Creek burn areas to be treated by prescribed fire. Trees were selected by choosing a random direction and distance from an initial start point, and then that process was repeated from selected tree to selected tree. On occasion, a direction/distance for a tree would place that tree outside the proposed burn unit, and for these trees a new random direction and distance were selected. When arriving at the location of the next tree, a random number generator determined if the tree was to be of large diameter or small and whether or not it was to be raked. Once a tree was selected, it was tagged with a uniquely numbered stainless steel label and flagged so it could be readily relocated. The raked trees had all of the litter-duff within 1 m radius of the tree removed to bare mineral soil using pitchforks and McClouds. The litter-duff was then scattered beyond the duff mound but generally within the dripline.

The sample size for the Lake burn was 30 trees: 20 large trees (>61 cm in diameter at breast height [dbh]) and 10 small trees (<61 cm dbh); the sample size for the Lost Creek burn was 20 trees: 10 large and 10 small. Half of each of the four groups of trees was raked and half was left with the litter and duff intact.

Prior to the burns, information collected on each tree included tree species, tree dbh, tree risk (a visual evaluation of the "health" of each subject tree using criteria developed by George T. Ferrell from Dunning [1928], Keen [1936], and Salman and Bongberg [1942]) [*table 1*]), description of fire scars, and bark thickness at the litter-duff layer taken at 4 points 90^{o} apart with two coinciding with litter-duff depth measurement points. Information about the fuels associated with sample trees included subjective characteristics of the litter-duff and other adjacent fuels (especially the presence of downed wood >12 cm in diameter within 3 m of the tree) and litter-duff depth on the upslope side of the tree and on the downslope side of the tree both at the bole and 1 m away from the bole (for the raked trees, these measurements were taken after raking whereas duff pins were set for the unraked trees so that depths could be measured after the fire). Information on the topographic context of each sample tree included an estimate of the slope of the landscape to the nearest 5 degrees and an estimate of the aspect in 45^{o} classes (0, 45, 90, 135, 180…).

Table 1–*Risk Rating Criteria summarized from George T. Ferrell (pers. com) afterDunning (1928), Keen (1936), and Salman and Bongberg (1942).*

Risk rating	Characteristics of risk
1-Low	Crowns: full foliage, healthy appearing; no weakened parts Foliage: thick and continuous; most twigs with normal foliage complement Needles: long and dark green in color
2-Moderate	Crowns: incomplete in spots, moderately healthy Foliage: some areas thin or bunchy but not concentrated Needles: average length or better; color fair to good
3-High	Crowns: somewhat ragged or thin Foliage: in parts of crown thin or bunchy; some to many twigs fading or dead Needle: length average to shorter than average; color fair to poor
4-Very High	Crowns: in poor condition, ragged or thin Foliage: thin or bunchy; twigs/branches dead or dying; weakening crown parts Needles: short or sparse, color poor

Immediately after the burns, data collected from each tree included scorch height on tree trunk at both upslope and downslope points, insect activity less than 3.5 m high on the bole (where *Dendroctonus valens* activity is generally found) and at greater than 3.5 m where other bark beetle activity is generally found, tree risk, and any noticeable change in fire scars. Bark beetle activity was categorized as clear or red in color and placed into 1 of 4 categories: none, <5 pitch tubes, from 6 to 20 pitch tubes, and >20 pitch tubes in the respective height band. The change in the depth of litter-duff layer was measured from the duff pins, and degree of litter-duff consumption was determined.

In the years after the fires (1997 through 2002), each tree was examined yearly. Each tree was classified as alive or dead and each tree was rated for risk. Bark beetle activity, by each of the four categories described above, below and above 3.5 m, as well as bird foraging activity were noted for each tree.

Prescribed fire was applied to both study areas in the fall of 1996. The Lake burn was ignited late in the afternoon on 28 September 1996 and continued into 29 September until the entire unit was burned. Firing was by spot ignition. Ignition was generally started at the higher elevations and allowed to back down the slope with 1-2 ft. flame lengths. Torching was common in small trees and occasionally occurred in large trees. Winds were relatively light and supported the ignition tactics. Mature ponderosa pines in the burn area, including both raked and unraked large trees, were ring-fired and fire behavior at 5 study trees was observed (Rankin 1996a) (*table 2*).

The Lost Creek burn (identified as the Crags Management Ignited Prescribed Fire by Lassen Volcanic National Park) was ignited late in the afternoon of 1 October 1996 and continued into 2 October. Firing was a combination of spot and strip ignitions. Ignitions proceeded generally from higher to lower elevations, resulting in a backing fire with flame lengths of 1 to 2 feet. Torching, common in small trees and occasional in large trees, resulted from jackpots of heavy fuels and frequent fuel ladders. Winds were relatively light and supported the ignition tactics. Mature ponderosa pines in the burn area were ring-fired, and fire behavior at 5 study trees was observed (Rankin 1996b) (*table 2*).

Table 2–*Weather and fire characteristics (from Rankin 1996a and 1996b).*

Ignition		Relative Humidity	Temp	Wind		Fuel moisture (pct)		Rate of Spread (chains/hr)		Flame length
Date-Time	Method	pct	ºF	Dir.	Speed (mph)	Log	Duff	Backing fire	Head fire	ft
Lake burn										
Sep 28-29, 1996-17:40	spot & ring	24-49	50s-70s	NE to SE	3-5	not recorded		1/2	3-4	1-3
Lost Creek burn										
Oct 1-2, 1996-15:55	spot & strip	30-53	50s-60s	SE to SW	0-4	15	29	1/4	>1	0.5-2

Results

Sample trees in both burn areas were primarily Jeffrey pines; only the Lost Creek burn included sugar pines (*table 3*). Risk ratings increased in both burns following the fires, especially in the trees that eventually died. Scorch heights were generally greater for the unraked trees, although the highest scorch heights were recorded for the raked trees in the Lake burn. Both scorch heights and bark beetle activity were greater in the trees that died. Bark thickness did not vary appreciably before and after fire.

Twelve (40 percent) of our sample trees within the Lake burn died within 2 to 3 years after the prescribed burn, and more unraked trees (8) died than raked (4). Mortality was greater among the larger than the smaller diameter trees, especially in the unraked group (*fig. 2*). In contrast, 5 (25 percent) of our sample trees within the Lost Creek burn died in the same time period after the prescribed burn, and all mortality was among the unraked trees (*fig. 2*).

Amounts of litter and duff close to the sample trees prior to raking and burning was similar for members of each size class; the average litter depth for trees <61 cm dbh was substantially less than for trees >61 cm dbh. The amount of litter and duff associated with the unraked dead trees was greater than that associated with the unraked live trees (*fig. 3*). All trees that died in the Lost Creek burn were in close proximity (within a meter or two) to a relatively large log or snag, making it unclear how much the litter and duff or the logs and snags contributed to the mortality of the trees.

Discussion

In the Lake burn area, tree mortality was twice as likely to occur on the unraked trees as the raked; although mortality did occur in the raked group, the larger diameter trees were more likely to die than smaller diameter trees. Heavy deposits of litter, duff, and larger dead material were associated with the majority of the mortality events. Some surviving unraked trees were also associated with relatively thick deposits of litter and duff, albeit substantially less than the trees that died. However, topography and subtle shifts in fire behavior, related to winds and fuel loadings, and the layer of volcanic ash likely played a role in tree mortality (Fulé and others 2002).

Table 3–*Tree characteristics before and after the prescribed fires.*

							Before fire	After fire				
					Diameter (cm)		Risk rating median	Risk rating median	Scorch height (m)[3]		No. pitch tubes[2] (range)	
	n=	Pije[1]	Pipo	Pila	Mean	St. dev.			Mean	St dev	<3.5 m	>3.5 m
Lake burn												
Dead Trees												
Unraked Lg Trees	6	1	5	0	108.5	16.45	2	2.5	8.2	8.57	0-H	0-H
Raked Lg Trees	2	0	2	0	100.2	1.06	3.5	4	12.0	4.24	M-H	L-M
Unraked Sm Trees	2	1	1	0	30.5	14.85	2	4	4.0	0.71	0-L	0-L
Raked Sm Trees	2	2	0	0	29.0	1.41	2	Dead[4]	0	-	L-H	L-H
Live Trees												
Unraked Lg Trees	4	3	1	0	79.2	15.31	2	3	5.5	5.17	0-H	0-M
Raked Lg Trees	8	4	4	0	105.3	23.17	2	2	1.4	1.71	0-H	0-H
Unraked Sm Trees	3	3	0	0	33.8	6.33	2	3	3.2	1.04	L-H	0-M
Raked Sm Trees	3	3	0	0	34.5	13.48	1	2	1.0	1.73	0-M	0-L
Lost Creek burn												
Dead Trees												
Unraked Lg Trees	3	1	2	0	118.5	32.97	1	1	2.1	2.24	H	L-M
Raked Lg Trees	0	0	0	0	-	-	-	-	-	-	-	-
Unraked Sm Trees	2	2	0	0	36.5	2.12	2	3	2.8	2.40	L-H	0-M
Raked Sm Trees	0	0	0	0	-		-	-	-	-	-	
Live Trees												
Unraked Lg Trees	2	0	2	0	113.2	16.62	1	1	3.2	1.61	M	0-L
Raked Lg Trees	5	1	3	1	108.5	21.04	2	2	0	-	0-L	0
Unraked Sm Trees	3	1	0	2	45.5	17.39	1	1	5.2	8.93	0	0-M
Raked Sm Trees	5	3	1	1	30.4	9.67	1	2	0.01	0.02	0-L	0

[1] Pije=Jeffrey pine; Pipo=ponderosa pine; Pila=sugar pine.
[2] 0=no pitch tubes detected; L= <5 pitch tubes counted; M=6-20 pitch tubes; H>20 pitch tubes.
[3]total scorch height measured from the ground; generally scorched bark but may include scorch in crown if trees are short enough
[4]both trees were dead on first visit following the prescribed burn.

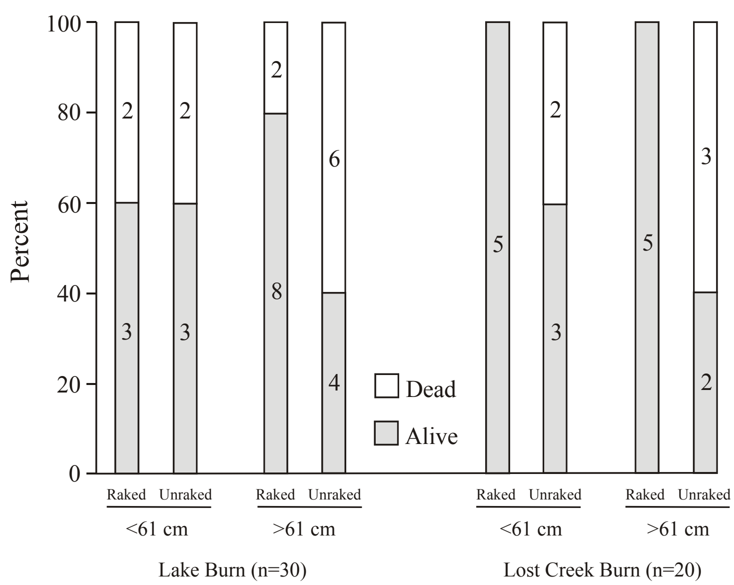

Figure 2–Tree mortality of sample trees in the Lake burn (Eastside burn) and Lost Creek burn (Westside) by tree diameter class and whether raked to bare mineral soil or left unraked.

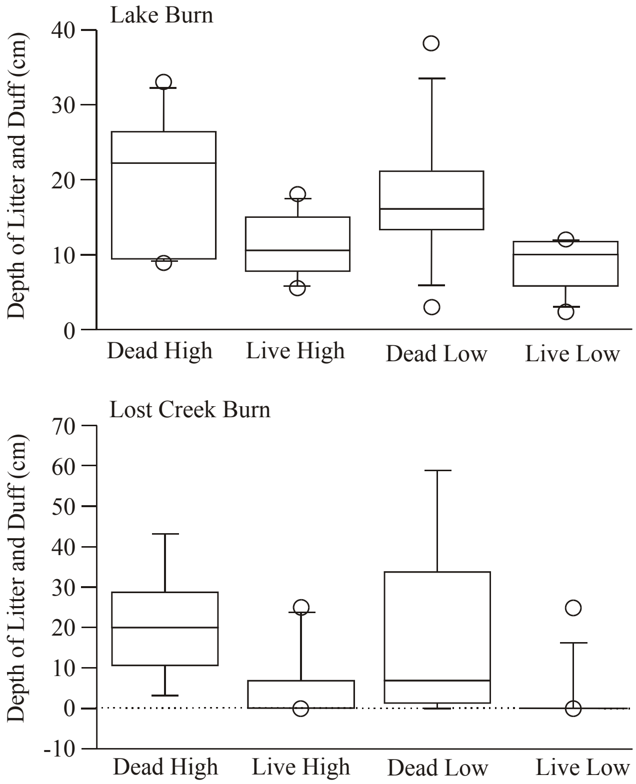

Figure 3–Distribution of litter and duff of the unraked trees in the Lake (upper figure) and Lost Creek (lower figure) burns contrasting the amounts associated with the trees that died with that associated with the trees that survived on both the uphill (High) and downhill (Low) sides of the trees.

Within the Lost Creek burn, tree mortality only occurred in the unraked trees, and all of the trees that died were closely associated with a relatively large log or snag that contributed to the fire's intensity close to the experimental tree. In addition, the unraked trees that died had substantially thicker deposits of litter and duff than the unraked trees that survived–range of 0 to 59 cm and 0 to 25 cm, respectively.

Removal of the litter and duff from around the bases of trees prior to initiating a prescribed burn may be beneficial in preventing undesirable effects such as tree girdling and bole scorching, thus benefiting tree survival (Sackett and others 1996, Kolb and others 2001, Jerman and others 2004) or possibly to have no effect or increase tree mortality through damage to the fine rootlets (Fulé and others 2002b). Our work suggests that removal of litter and duff from an area around the bole of a tree, in both eastside and westside burns, may reduce mortality that is related to burning in areas where fire has been excluded for many years.

Timing of litter and duff removal may also be a factor in tree response. In this study, we removed the litter and duff in the fall, when soils were dry, the trees inactive, and when the trees may have been less susceptible to rootlet damage. In our initial experimental design we had prepared three sites for the raked vs. unraked tree experiment. Trees within the third area, pines as well as firs, were raked in the fall in the same manner as the two experimentally burned plots. This third plot was not burned in the fall of 1997 because the weather conditions did not meet the fuels prescription and was not burned until the spring of 1999. To date, we have not observed any mortality of any of the sample trees whether raked or not. Whether these results are related to the timing of the burn or some other factor is not known but it suggest that further experimentation on the season of burning and raking, size of area raked and tree health are needed.

While our results indicate that litter and duff removal may improve survival of selected trees during prescribed burning, our design may not have been sufficient to permit very strong conclusions. Fire intensity and the resulting severity varies greatly relative to variables such as the distribution of fuels, weather conditions during the burn, topographic variation, and characteristics of surface soils at the site. Pairing of sample trees, with a raked and unraked tree within close proximity of each other, may help filter out some of these variables that could influence survival.

Acknowledgments

We greatly appreciate the contributions of Jim Baldwin, Ken Castro, George Ferrell, Pat Shea, Carl Skinner, Nicole Tancreto, and Phil Weatherspoon to the design, execution, and data collection for this study. We also thank Ken Castro and the Lassen Volcanic National Park fire personnel for conducting the prescribed burns and the Park administrators for cooperating with this project. Finally we thank Sally Haase and Marcia Narog for their helpful comments on the draft manuscript.

References

Clynne, Michael A.; Champion, Duane E.; Trimble, Deborah, A.; Hendley II, James W.; Stauffer, Peter H. 2000. How old is “Cinder Cone”?–Solving a mystery in Lassen Volcanic National Park, California. USGS Fact Sheet-023-00. U. S. Department of Interior, U. S. Geological Survey; 4 p.

Dunning, Duncan. 1928. A tree classification for the selection forests of the Sierra Nevada. Journal of Agricultural Research 36(9): 755–771.

Fulé, Peter Z.; Verkamp, Greg; Waltz, Amy E.; Covington, Wallace W. 2002a. Burning under old-growth ponderosa pines on lava soils. Fire Management Today 62(3): 47–49.

Fulé, Peter Z.; Covington, W. Wallace; Smith, H. B.; Springer, Judith D.; Heinlein, Thomas A.; Huisinga, Kristin D.; Moore, Margaret M. 2002b. Comparing ecological restoration alternatives: Grand Canyon, Arizona. Forest Ecology and Management 170: 19–41.

Jerman, Jason L.; Gould, Peter J.; Fulé, Peter Z. 2004. Slash compression treatment reduced tree mortality from prescribed fire in southwest ponderosa pine. Western Journal of Applied Forestry 19(3): 149–153.

Keen, F.P. 1936. Relative susceptibility of ponderosa pines to bark-beetle attack. Journal of Forestry 34: 919–927.

Kolb, T.E.; Fulé, P.Z; Wagner, M.R.; Covington, W.W. 2001. Six year change in mortality and crown condition of old-growth ponderosa pines in different ecological restoration treatments at the G.A. Pearson Natural Area. In: Vance, G.K.; Edminster, C.B.; Covington, W.W.; Blake, J.A., compilers. Proceedings of the symposia Ponderosa Pine Ecosystems Restoration and Conservation: steps towards stewardship, 2000, April 25–27; Flagstaff, AZ. Gen. Tech. Rep. RMRS-22. Ogden, UT: Rocky Mountain Research Station, Forest Service, U.S. Department of Agriculture; 61–66.

Laudenslayer, William F., Jr. 2002. Effects of prescribed fire on live trees and snags in eastside pine forests in California. In: Sugihara, Neil G.; Morales, Maria E.; Morales, Tony J., eds. Proceedings of the Symposium: Fire in California Ecosystems: Integrating Ecology, Prevention and Management. Association for Fire Ecology, Davis, Calif. Misc. Publ. No. 1: 223–236.

Rankin, Todd. 1996a. Fire Monitor Report—Lake Management Ignited Prescribed Fire. Lassen Volcanic National Park Fire Monitor Report, Mineral, CA. 3 p.

Rankin, Todd. 1996b. Fire Monitor Report–Crags Management Ignited Prescribed Fire. Lassen Volcanic National Park Fire Monitor Report, Mineral, CA. 3 p.

Sackett, Stephen S.; Haase, Sally M.; Harrington, Michael G. 1996. Lessons learned from fire use for restoring southwestern ponderosa pine ecosystems. In: Covington, Wallace; Wagner, Pamela K. technical coordinators, Gen. Tech. Rep. RMFRES-278. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 54–61.

Salman, K.A.; Bongberg, J.W. 1942. Logging high-risk trees to control insects in the pie stands of Northeastern California. Journal of Forestry 40: 533–539.

Weatherspoon, C. Phillip; Almond, George A.; Skinner, Carl N. 1989. Tree-centered spot firing-a technique for prescribed burning beneath standing trees. Journal of Applied Forestry 4(1): 29–31.

This page intentionally left blank.