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Woodpecker Use and Fall Rates of Snags Created by Killing Ponderosa Pine Infected With Dwarf Mistletoe

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Abstract

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Ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) killed as part of a forest management project to reduce dwarf mistletoe *(Arceuthobium* sp.) in the Gila National Forest, New Mexico, were evaluated for wildlife value. One hundred and two dwarf mistletoe-infected trees were killed by basal burning, basal girdling or by a combination of both burning and girdling. Trees began to fall within 2 years. Most killed trees (96 percent) served as forage substrate for woodpeckers. Twenty percent of the trees contained woodpecker nest cavities 7 or 9 years after treatment. Larger diameter trees of all treatments contained more cavities and stood longer than smaller diameter trees. The probability of cavity presence was best predicted by regression that included diameter and decay class. Standing life of the snag was not a significant predictor of cavity presence. The use of predictive models for analyzing the utility of snag-creation treatments is discussed.

Keywords: Girdling, fire-killed trees, wildlife trees, cavity nesters, *Arceuthobium* sp.

Summary

We evaluated the woodpecker use and fall rates of ponderosa pine (*Pinus ponderosa*) killed by basal burning, girdling, or a combination of both burning and girdling. The trees were located in two areas and were killed as part of a dwarf mistletoe *(Arceuthobium* sp.) suppression effort. One-hundred and two ponderosa pine infected with southwestern dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum* (Engelm.)) were treated and then monitored annually for 7 or 9 years. All treated trees, except one, were dead within 3 years. Woodpecker foraging was observed on 96 percent of all trees throughout the monitoring period. Snags began to fall after 2 years. Burned trees fell sooner and had fewer cavities than girdled-only trees. Larger diameter trees stood longer and contained more woodpecker nest cavities than smaller diameter trees in both treatments. We used logistic regression to model the probability of nest cavity presence after investigating the associations between snag characteristics and presence of cavities. Because of the great number of trees that are being altered annually in "snag creation" projects across the managed forests of the West, we discuss the need for monitoring of created snags intended for use by wildlife and for the development of models to predict their use.

Introduction

Management of dead trees (snags) for wildlife is a fundamental part of land management practices on public lands in the Western United States. Many species of wildlife are dependent on dead trees, particularly those species that nest in cavities. Most woodpecker species excavate one or more cavities in snags or dead trees with decay each year as part of their breeding behavior, but many cavity dwellers are unable to excavate their own cavities and depend on woodpecker-excavated cavities. Guidelines are available that prescribe the number and kind of snags required to provide habitat for woodpeckers (Bull and others 1997; Neitro and others 1985; Thomas and others 1979; USDA and USDI 1997a, 1997b). Managers find it difficult, however, to meet the recommended numbers of snags in some forests because of past intensive timber harvest strategies that removed snags. Consequently, there is great interest in developing ways to create suitable snags from living trees. Methods to create snags that have been tested include topping, girdling, herbicide injection (Bull and Partridge 1986), inoculation with decay fungi (Parks and others 1996), as well as burning. Although the use of various methods to alter trees to create habitat is becoming a widespread practice in managed forests of the West, the effectiveness of these methods has largely been undocumented.

As a retrospective study, we evaluated the woodpecker use and fall rates of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) killed by basal burning and girdling in two dwarf mistletoe *(Arceuthobium* sp.) reduction projects. Dwarf mistletoes are parasitic, perennial plants that derive water and nutrition from the tree. Forest managers sometimes seek to limit dwarf mistletoe infection because it causes decreased tree growth and can cause extensive tree mortality in heavily infected stands (Hawksworth and Wiens 1996). Dwarf mistletoe reduction projects are designed to kill infected trees in the overstory, and thereby kill the parasite; halting spread from infected trees to uninfected adjacent and understory trees. If dwarf mistletoe reduction projects not only reduce infection potential but also create quality habitat for cavity nesting birds, they could provide an important forest management tool.

Methods

One-hundred and two ponderosa pine that were infected with southwestern dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum* (Engelm.)) were selected for treatment in two study areas in the Luna Ranger District in the Gila National Forest in southwestern New Mexico. The Underwood Project Area (UPA) was treated in 1987 and comprised 32 monitored trees: 11 were girdled, 11 were burned, and 10 were both girdled and burned. The Luna Project Area (LPA) was treated in 1989 and comprised 70 trees: 37 were girdled, 32 were burned, and 1 was both burned and girdled. Before treatment, all trees were mapped and tree diameter at 1.4 meters aboveground (diameter at breast height [d.b.h.]) was recorded. Basal girdling was accomplished by cutting two parallel rings around the base of the tree 10 to 15 centimeters apart with a chain saw, and then chipping the bark off with a poulaski. Basal burning was done by piling slash 1 to 1.5 meters high around the base of the tree and igniting with a drip torch. Although some green slash was used, crews included some older wood containing a high pitch content. Fires were hot enough to blacken or completely consume the bark around the base, but not so hot as to penetrate beyond the cambium into the sapwood. Scorch was kept to the base of the tree and not allowed to climb high on the bole or into the crown. The production rates averaged 15 minutes per tree for girdling and 1 hour per tree for burning.

Trees were visually monitored annually for mortality, condition (standing or down), and bird forage activity (holes drilled for feeding on insects in the bark or wood). In the last evaluation (year 9 for UPA; year 7 for LPA), we also recorded the presence of woodpecker nest cavity excavations and snag structural class (1-3). Structural class 1 represents those snags that are entire, that is, they retain their bark, branches, and top and show little evidence of decay; class 2 represents those snags that have loose bark, have often lost some bark, main branches, and the top, and show evidence of moderate decay; and class 3 snags have advanced decay, are missing the top, most branches, and bark, and appear to have soft wood (Parks and others 1997).

All data analyses were performed by using guideline procedures in SAS V6.11 and SAS V6.12 (SAS Institute 1990b). Initial exploratory investigations of data used the INSIGHT procedure (SAS Institute 1995). Because preliminary examinations indicated nonlinear relations within the data, the life table approach (Cox and Oakes 1984) was used for initial analysis of snag survival times. Life table analysis used the LIFETEST procedure (SAS Institute 1990a). The life table approach uses tests that are robust to nonlinearity in potential covariates.

Results, Discussion, and Model Development

Data from the two project areas were combined after exploratory investigation found no obvious site differences to dictate that the sites should not be combined for statistical analysis.

Mortality and Forage Activity

In both project areas, all treated trees, except one, were dead within 3 years after treatment. Burned trees, on average, died more rapidly than girdled trees. During the first year, over half of the burned trees were dead but only one of the girdled trees. Within 1 year after death and throughout the monitoring period, nearly all the treated trees (96 percent) showed evidence of foraging activity within the bark.

Snag Survival

Snags in both project areas began to fall after 2 years. Nine years after treatment at UPA, 15 trees were standing and 17 had fallen (table 1). At LPA, 30 of 70 trees were still standing 7 years after treatment. In both project areas, there was a distinct pattern of tree breakage in fallen snags. Burned trees most often fell as a whole unit, usually breaking off belowground owing to structural failure of buttress roots. We speculate that the intense basal fires caused the buttress roots to burn extensively, thereby making them more susceptible to colonization by decay fungi. The intense heating of the main root structure and subsequent root failure of burned trees may be in part due to the light, volcanic soils common to the project areas. Girdled snags that fell (20) generally broke at the girdle (16), leaving the root system intact. Of the 11 snags resulting from the burned and girdled treatment, 4 fell during the study period, 2 had broken at the girdle, and 2 had broken belowground.

The d.b.h. distribution of treated trees was displayed by using empirical cumulative distribution functions (ECDF). The ECDF plots sample quantiles corresponding to variable values. Areas in which the ECDF approaches vertical represent intervals in which many elements of the sample fall. The Smirnov test (Conover 1980) was used to evaluate observed differences in d.b.h. distributions between treatments, and results indicated significant differences between the d.b.h. distributions of trees selected for treatments (two-tailed pairwise tests, comparison-wise type I error rate of 0.05). Burned trees tended to be of smaller diameter than girdled or burned and girdled trees (fig.1).

In life table analysis the distribution of snag survival times differed significantly ($p < 0.05$) between treatments (Wilcoxon test [Conover 1980]). Diameter at breast height and interaction between d.b.h. and treatment were significant covariates.

Table 1—Fall rates and cavity nester use of artificially produced ponderosa pine snags

Site	Treatment year 1987	D.b.h. cm	Years since treatment: 0		6		9	
			Standing	Down	Standing	Down	Standing (Number with nest cavities)	Down (Number with nest cavities)
Underwood Project Area	Burn	25.4-40.4	6	0	0	6	0	6
		40.6-50.8	5	0	4	1	1	4
	Girdle	25.4-40.4	5	0	3	2	2(1)	3
		40.6-50.8	6	0	5	1	5(3)	1
	Burn and girdle	25.4-40.4	2	0	2	0	0	2
		40.6-50.8	8	0	7	1	7(3)	1
Total			32	0	21	11	15(7)	17

Site	Treatment year 1989	D.b.h. cm	Years since treatment: 0		4		7	
			Standing	Down	Standing	Down	Standing (Number with nest cavities)	Down (Number with nest cavities)
Luna Project Area	Burn	25.4-40.4	23	0	14	9	5(2)	18
		40.6-50.8	9	0	8	1	4(2)	5
	Girdle	25.4-40.4	13	0	13	0	7(2)	6
		40.6-50.8	24	0	23	1	14(6)	10(1)
	Burn and girdle	25.4-40.4	0	0	0	0	0	0
		40.6-50.8	1	0	1	0	0	1
Total			70	0	59	11	30(12)	40(1)

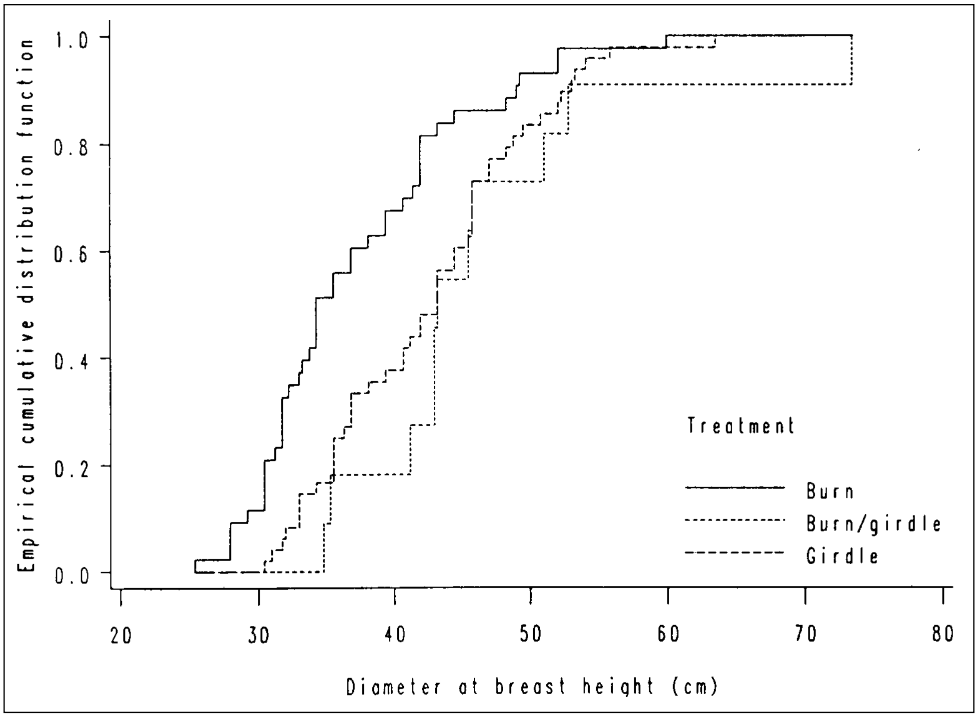

Figure 1—Diameter at breast height distribution of subject trees selected for treatments, presented as empirical cumulative distribution functions.

Results of the Wilcoxon test were then applied in development of predictive models of survival. Because of the significant d.b.h. and treatment interaction ($p < 0.05$) and significant differences in d.b.h. distribution of subject trees in different treatments, a separate regression was fit in each treatment. In each case, a normal distribution of survival times was specified, resulting in a parallel-lines regression for trees of different d.b.h. (fig. 2). The estimated prediction models were,

“Burn” treatment $Pr\{survival \geq t\} = 1 - \Phi\left[\frac{t - 4.67 - 0.0836 \bullet dbh}{1.32}\right]$,

“Burn-girdle” treatment $Pr\{survival \geq t\} = 1 - \Phi\left[\frac{t - 7.97 - 0.0554 \bullet dbh}{3.54}\right]$, and

“Girdle” treatment $Pr\{survival \geq t\} = 1 - \Phi\left[\frac{t - 2.64 - 0.140 \bullet dbh}{1.85}\right]$,

where Φ represents the cumulative distribution function for the standard normal distribution, and t represents the time in years (table 2). Graphs of predicted survival probability against time show that variation in d.b.h. has a notable effect on survival time distribution for the “girdle” treatment (fig. 2), with a 10-centimeter d.b.h. increase resulting in a shift of about 3 years in survival time distribution. In the “burn-girdle” treatment, d.b.h. has a smaller effect on the survival time distribution, with a 10-centimeter d.b.h. increase resulting in a shift of about 1.5 years. In the “burn” treatment, the influence of d.b.h. is of intermediate magnitude.

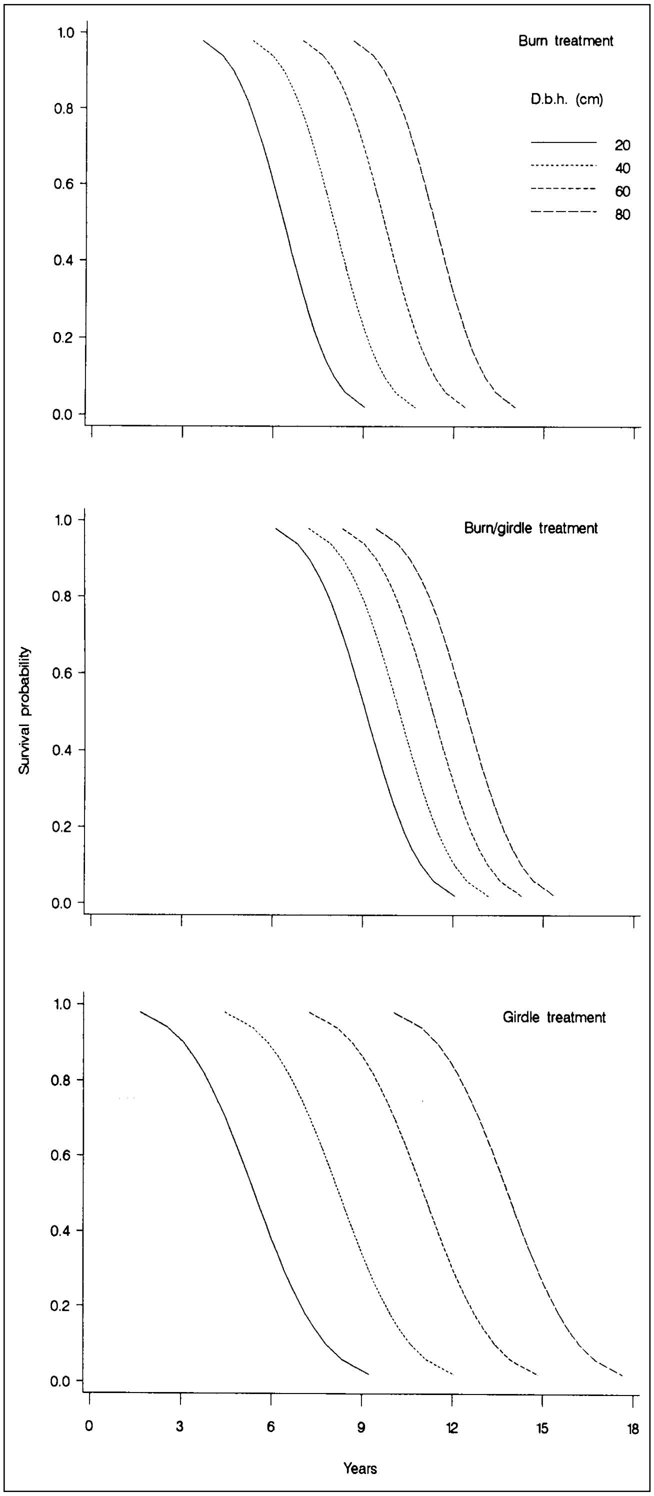

Figure 2—Predicted distribution of snag survival times for trees of stated d.b.h. under different snag creation treatments, developed from survival regressions fit to study data.

Table 2—Evaluation statistics for survival regression of artificially produced ponderosa pine snags

Variable	Degrees of freedom	Estimate	Standard error	Chi-square	Attained significance
		Burn treatment[a]			
Intercept	1	4.66028	1.18570	15.44794	0.0001
D.b.h.	1	.08365	.03221	6.74298	.0094
Normal scale parameter	1	1.31586	.16673		
		Burn/girdle treatment[b]			
Intercept	1	7.97232	6.62588	1.447711	0.2289
D.b.h.	1	.05544	.15104	.134754	.7136
Normal scale parameter	1	3.54355	1.44697		
		Girdle treatment[c]			
Intercept	1	2.64495	2.20199	1.442794	0.2297
D.b.h.	1	.14016	.05485	6.528725	.0106
Normal scale parameter	1	1.85204	0.33053		

[a] Overall log likelihood statistic for normal distribution = -61.00745411.

[b] Overall log likelihood statistic for normal distribution = -14.30556929.

[c] Overall log likelihood statistic for normal distribution = 50.07906996.

In this sample, because many of the trees are still standing, the actual survival time has not been observed. The actual survival time therefore has not been observed. Monte Carlo simulations performed during the analysis show that the moderate sample size and survival time truncation jointly prevent discrimination among several plausible survival time distributions. The choice of the normal distribution is not rejected by the data, but another distribution might be selected when the actual survival times of remaining trees are obtained.

Nest Cavities

Nest cavities were found associated with snags resulting from each of the three treatments (table 1). At UPA, seven standing trees contained woodpecker nest cavities at the year 9 monitoring. At LPA, 12 standing trees contained nest cavities at the year 7 monitoring. In addition, one tree at LPA that had fallen during the period between the 1995 and 1996 monitoring contained one nest cavity. Kendall correlations (Conover 1980) were used to investigate associations between snag characteristics and numbers of cavities present. Correlation analysis used the CORR procedure (SAS Institute 1990b). Several statistically significant correlations were revealed (table 3). A partial correlation analysis (table 4) indicates that the association of snag decay class with cavity count is largely independent of snag survival times or d.b.h.. Much of the association of snag survival time and cavity count may be attributed to correlations of cavity count with d.b.h. and snag decay class.

Table 3—Pairwise Kendall correlations between selected characteristics of subject trees

	D.b.h.	Survival time	Cavity count	Snag decay class
D.b.h.	1.00	0.21**	0.23**	0.22**
Survival time	.20**	1.00	.17	.19*
Cavity count	.23**	.17*	1.00	.37**
Snag decay class	.22**	.19**	.37**	1.00

* = attained significance < 0.05.
** = attained significance < 0.001.

Table 4—Partial Kendall correlations between selected characteristics of subject trees

Variable pair	Estimated correlation	Correlation effects removed
Cavity count, snag survival time	0.17	None
	.12	D.b.h.
	.11	Snag decay class
	.08	D.b.h., snag decay class
Cavity count, d.b.h.	.23	None
	.20	Snag survival time
	.17	Snag decay class
	.15	Snag survival time, snag decay class
Cavity count, snag decay class	.37	None
	.33	D.b.h.
	.34	Snag survival time
	.32	Snag survival time, d.b.h

Probability of nest cavity presence was modeled by using logistic regression. Logistic regressions were fit by using the GENMOD (SAS Institute 1993) and LOGISTIC procedures (SAS Institute 1990b). Snag decay class, d.b.h., and squared d.b.h. were specified as possible explanatory variables. Snag decay class and d.b.h. were selected for inclusion using type III hypothesis tests, ($p < 0.05$) (table 5). The estimated model is,

$$Pr\{cavities\} = \frac{1}{1 + e^{-[-19.9 + \tau_{class} + 0.801(dbh)]}} ,$$

where

$\tau_{\text{moderate or no decay}}. = 0$

$\tau_{\text{advanced decay}} = 3.18.$

This model predicts the probability of nesting cavities will increase as d.b.h. increases, with “advanced decay” snags having a probability equal to or higher than “moderate or no decay” snags at all d.b.h.s (fig. 3).

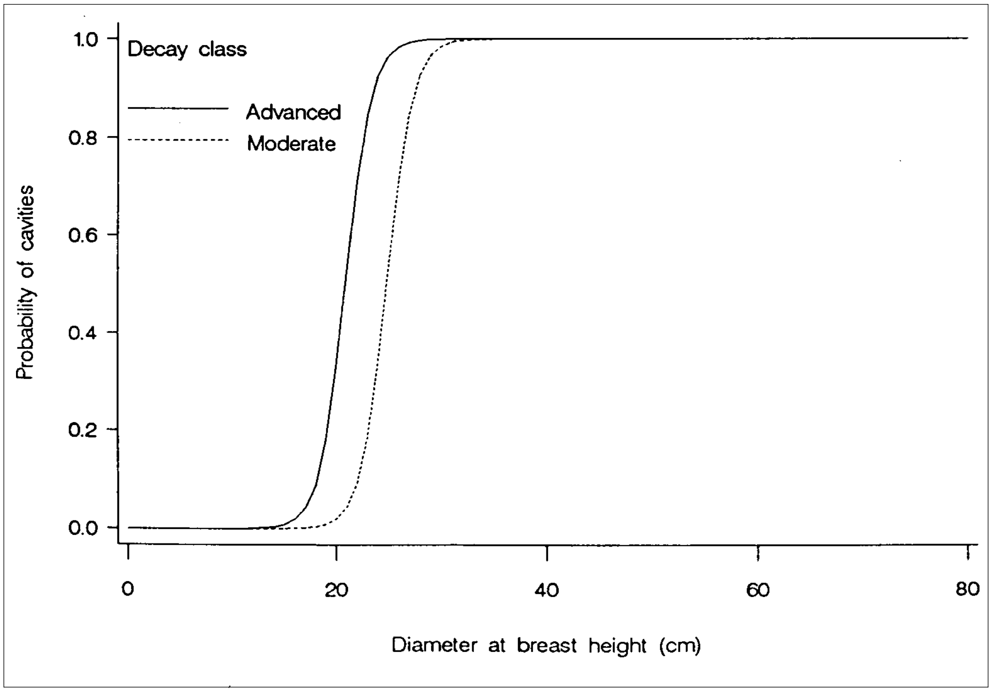

Figure 3—Predicted probability of cavity nest presence for treated trees of differing snag decay classes. Only model parameters with attained significance of 0.05 or less are used.

Table 5—Evaluation statistics for logistic regression of nesting activity in artificially produced ponderosa pine snags

Analysis of maximum likelihood estimates[a]

Parameter	Degrees of freedom	Estimate	Standard Error	Chi-square	Attained significance
Intercept	1	-19.907	8.8232	5.0905	0.0241
Decay class:					
Loose bark, broken top	1	-2.1018	1.2192	2.9720	.0847
Advanced	1	3.1772	1.0868	8.5473	.0035
D.b.h^2	1	-.00843	.00456	3.4182	.0645
D.b.h	1	.8012	.4053	3.9087	.0480

[a] Overall model likelihood ratio statistic = 100.963 (chi-square = 26.552, 4 degrees of freedom, attained significance = 0.0001).

Conclusions

All treatments (burning, girdling, and the combination treatment of burning and girdling), accomplished the objective of dwarf mistletoe reduction because 99 percent of the trees were killed. Burning was somewhat more effective than girdling for reducing infection potential because it killed trees sooner than girdling. All treatments also provided feeding substrate for birds that fed on beetles within and beneath the bark. Larger diameter trees of all treatments stood longer and had nest cavities more often than smaller diameter trees. Although burned trees fell sooner and had fewer cavities than trees that received other treatments, this may be explained in part by the fact that burned trees had smaller diameters and died up to one year sooner than girdled trees. The burn intensity may have been excessive, leading to the failure of the main root system. A lower intensity burn may provide snags that stand longer.

Nevertheless, we believe that girdling may be a more effective method than basal burning for creating decay conditions suitable for cavity excavation in ponderosa pine. One-fourth of all girdled trees of the combined project areas contained nest cavities during the last monitoring. Girdling appeared to initiate decay that was suitable for nest cavities. Our observations found that the outer column of wood (sapwood) of girdled trees was softened by decay, and the interior wood (heartwood) remained sound. The group of fungi that cause decay of sapwood are often different than those that will act on heartwood (Rayner and Boddy 1988). Large-diameter ponderosa pine has a thick layer of sapwood—thick enough to contain a nest (Bull and others 1997). Girdling, however, may not be effective in tree species other than ponderosa pine because other tree species have relatively thin sapwood that, when decayed, is not wide enough to accommodate a cavity nest. Because girdling weakens the bole at the point of girdle, as demonstrated by the fact that most fallen snags of the girdled treatment broke at the girdle, we believe that girdling higher on the bole (>3.5 meters) of ponderosa pine may be a technique worth investigating.

More monitoring of these project areas will be needed to fully access the merits of using girdling and burning as tools to create cavity nester habitat. Woodpeckers that are weaker excavators such as the Northern flicker (*Colaptes auratus*) and Lewis' woodpecker (*Melanerpes lewis*), excavate nests in extensively decayed wood. In time, treated trees that remain upright will become more decayed and may attract more species than they have to date.

The predictive models developed here could be used as components of a system for analyzing the utility of snag-creation treatments. The addition of predictive models for snag decay class and treatment expense would be required. Average treatment cost per snag used by cavity-nesting bird species might be a useful evaluation statistic. Monte Carlo simulation using the resulting system of models could provide bounds for treatment outcomes expected from snag creation treatments. Although average treatment cost per nest cavity might be a superior statistic, poisson regressions attempted during our analysis did not fit the observed data well. A more complex prediction model is probably needed—perhaps employing a compound distribution for cavity count. The sample size in the current study was inadequate for reliable development of such models. The need for model development is great because the number of trees that are being altered annually in “snag creation projects” across the managed forests of the West is tremendous. If more projects were initially designed to provide efficacy information, models could soon be developed to assist managers in effective management of cavity-nester habitat.

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Keywords: Girdling, fire-killed trees, wildlife trees, cavity nesters, *Arceuthobium* sp.

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