Are There Snags in the System? Comparing Cavity Use among Nesting Birds in “Snag-rich” and “Snag-poor” Eastside Pine Forests[1]

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Abstract

We compared the density of snags, snags with cavities, and cavity-nesting bird use at two sites in northern California: Blacks Mountain Experimental Forest, a site with large trees and large snags because of protection from logging, contrasted with the Goosenest Adaptive Management Area, where a century of logging left this forest with few large trees and snags. Indeed, there was a threefold difference between sites in total snags, and a fifteenfold difference in cavity-nesting bird use. However, we feel finding a “snags per acre” prescription is inadequate, as tree size, rate of snag generation, and mode of tree death have been disrupted this past century. We argue that understanding the interactions between fire, bark beetles, woodpecker foraging and excavating, sapwood decay organisms, snag “demography,” and cavity-nesting species ecological requirements apart from simply cavities are required in place of simply counting snags in landscapes.

Introduction

The habitat structure and ecological processes for our western coniferous forests have changed dramatically in the past century primarily because of extensive logging and fire suppression. The forests of today often are denser, have a larger component of shade tolerant species, and have fewer large, older trees (Bonnicksen 2000, Covington and Moore 1994). This is particularly true of eastside pine forests of California and Oregon, dominated by ponderosa pine *(Pinus ponderosa)* and Jeffrey pine *(P. jeffreyi)* (Covington and Moore 1994, Laudenslayer and Darr 1990).

The density of large snag trees and the processes of their creation have been greatly altered as well. Logging and salvage logging have reduced densities of potential and actual snags from many landscapes. The suppression of fire has suppressed the naturally prevalent mode of snag generation (Horton and Mannan

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1988). Understanding these changes in the world of snags in forests is important because snags with cavities are essential to wildlife populations. Snags with cavities are needed as nesting sites for many species of birds and are used by other wildlife (Bu1l 1983, Cline and others 1980, Ganey 1999, Mannan and others 1980, Miller and Miller 1980, Moorman and others 1999, Raphael and White 1984, Scott 1978). The issue of snag management, and prescribing adequate "snags per acre" for wildlife in forests, has been and continues to be a major focus of forest management (Brawn and Balda 1988, Brawn and others 1987, Bull and others 1997, Ganey 1999, Horton and Mannan 1988, Martin and Eadie 1999, McClellan and Frissell 1975, McComb and others 1986, Morrison and others 1986, Ohmann and others 1994, Raphael and White 1984, Ross and Niwa 1997, Scott 1979, Schreiber and deCalesta 1992, Thomas and others 1979, Zarnowitz and Manuwal 1985).

We have been studying wildlife-forest relationships at two sites in northern California (Zack and others 1999). The eastside pine forests at the Goosenest Adaptive Management Area in the Klamath National Forest are more or less "typical" in that they have been logged and fire suppressed this past century, resulting in a dense forest with few large tree and few snags. In contrast, the eastside pine forests of the Blacks Mountain Experimental Forest in the Lassen National Forest, particularly those in the Research Natural Areas, have not been extensively logged (but have been fire suppressed), and so contain many large pine trees and snags (Oliver and Powers 1998).

In this paper, we compare the abundance of snags and snag cavity use at these sites from data collected in 1999, and discuss the implications of our results for eastside pine forest management and wildlife. We also present data on bark beetle and woodpecker foraging patterns in relation to snags and cavity prevalence.

Methods

This study was conducted at two sites in northern California: the Blacks Mountain Experimental Forest (BMEF), in the Lassen National Forest, northeast of Lassen National Park, and at the Goosenest Adaptive Management Area (GAMA), Klamath National Forest, east of Mount Shasta. These sites are currently part of large-scale experimental research intent on restoring, and evaluating responses to, late successional forest structures (and contrasting treatments with controls) in eastside pine forests (Oliver and Powers 1998, Zack, and others 1999).

For this study, we wished to evaluate the snag densities in plots not subjected to experimental manipulation. Thus, at BMEF we opted to evaluate snag density at three of four of the existing Research Natural Areas (RNAs) that are part of our study plots. These RNAs had no prior logging history and an 80+ years of history of fire suppression. One RNA—RNA C—was subject to a prescribed fire in 1997. At GAMA, we randomly chose three plots from the 14 plots that, in 1999, had not yet been logged or had a prescribed fire treatment as part of our experimental study there.

The three RNAs at BMEF comprised a total of 284 acres (ca. 115 ha.), while all plots at GAMA are exactly 100 acres in size so the total there was 300 acres (about 40.5 ha.) *(table 1).* All plots at both sites are gridded with spikes and uniquely numbered caps at 100-m intervals.

At each plot at both GAMA and BMEF we mapped and individually tagged (with numbered round aluminum tags nailed on the north side of the snag at dbh height) all snags 20 cm dbh or greater and at least 1 m tall. A given tree was considered a snag if it was dead or clearly dying. Dying trees were detected by the color change in all leaves. In most all cases, the leaf color change was obvious and ranged from yellow to red to brown.

Table 1—*Total snags and acreage at Blacks Mountain Experimental Forest (BMEF) and at the Goosenest Adaptive Management Area (GAMA) sites for those plots assessed Research Natural Areas (RNAs) at BMEF and plot numbers at GAMA. Also noted are the total numbers of "yellow" pine snags (*Pinus ponderosa *and* P. jeffreyi *at BMEF,* P. ponderosa *only at GAMA) for these eastside pine sites.*

	Acres	Snags	S/Acre[1]	Pines[2]	P S/Ac[3]	Percent pine[4]
BMEF						
RNA C	126	389	3.09	259	2.06	66.58
RNA B	91	723	7.95	358	3.93	49.52
RNA D	67	700	10.45	318	4.75	45.43
TOTAL	284	1,812	6.38	935	3.29	51.60
GAMA						
Plot 4	100	181	1.81	46	0.46	25.41
Plot 10	100	245	2.45	72	0.72	29.39
Plot 13	100	186	1.86	24	0.24	12.90
TOTAL	300	612	2.04	142	0.47	23.20

[1] Snags per acre
[2] Total *Pinus* pine snags
[3] Pine snags per acre
[4] Percent of all snags that are pine.

For each snag, we recorded the following information (snag evaluation methods developed by Farris and others 2002): the site (BMEF or GAMA), the plot number or name, the tag number applied to the snag, and the tree species of each snag encountered. For each snag, we measured the diameter at breast height (dbh) in cm and the height to the nearest decimeter (measured with use of clinometers). The condition of the top of the snag (intact, broken, or with multiple leaders) and the color of remaining leaves was recorded. The degree of branching was estimated (from one to four degrees of branching). The percent bark remaining to the nearest 10 percent was recorded for each snag. Bark integrity was judged to be either tight or loose by examination.

The following data were obtained to evaluate the previous history of beetle infestation and woodpecker foraging response. These variables were judged primarily on the snag from diameter-at-breast-height to about 4 meters height. We evaluated and categorized the number of pitch tubes seen, the number of beetle (primarily *Dendroctonus*) exit tubes observed, the number of fungal bodies on the snag observed (primarily *Cryptoporus*), and finally the number of woodpecker foraging sites seen. Each variable was scored into one of five categories: 0 detected, 1-10, 10-20, 20-30, or 30+ detected.

If the snag had bird-excavated cavities, the number was noted. We also noted if the cavity was likely drilled by a woodpecker or by a nuthatch (*Sitta* spp.), which was determined by the size of the hole.

To determine if a given cavity was in use by a breeding bird, we monitored the snag for about 10-minute periods during the breeding season of 1999, as possible. We also used a "Tree-Peeper" extensively. The "Tree-Peeper" is a cavity-examining tool equipped with a small camera lens and light (at BMEF) or with an infrared camera (at GAMA) mounted on a telescoping set of PVC tubing. A small screen for cavity viewing is at the base of the apparatus. The "Tree-Peeper" was able to access almost all cavities up to about 15 m. We believe we detected almost all cavity use by breeding birds in 1999 on our snag plots with these methods in combination, with the likely exception of early season failed nesting efforts. In no case did we examine a cavity thought to have no breeding by the "Tree-Peeper" and find evidence of breeding.

Results

As expected, there were far more snags at BMEF than at GAMA *(table 1)*. There are more than three times as many snags (6.38/acre vs. 2.04/acre, respectively) of all tree species at BMEF compared to GAMA overall, and the density of *Pinus* snags represents a sevenfold difference between the sites (3.29 snags/acre at BMEF, 0.47 at GAMA, *table 1)*. More than 50 percent of the snags at BMEF were *Pinus*, while less than 25 percent were *Pinus* at GAMA.

There were also dramatic differences in the density of cavities available for cavity-nesting species between the two sites. We counted 0.90 snags with cavities/acre at BMEF compared to 0.42/acre at GAMA, and the total cavities/acre difference was even more pronounced (2.38 vs. 0.56, respectively; *table 2)*.

Table 2—*Snag densities with cavities and cavities per acre at BMEF and GAMA.*

	Total snags	Snags with cavities	Snags with cavities per acre	Cavities per acres
BMEF	1,812	257	0.90	2.38
GAMA	612	125	0.42	0.56

We portray the percent of trees with cavities by species for each site in *table 3*. At BMEF, *Pinus* species have cavities more often than either white fir *(Abies concolor)* or incense-cedar *(Calocedrus decurrens)*. At GAMA, although *P. ponderosa* has a higher percentage of snags with cavities than the other conifers, the difference between it and white fir is far less pronounced than at BMEF. The proportion of snags designated as "unknown" species is higher at GAMA; we presume most of those snags are indeed very decayed *Pinus* that our crews couldn't discern.

Table 3—*Snags with and without cavities arranged by species. "Yellow"* Pinus *include* P. ponderosa *and* P. jeffreyi.

BMEF	Snags without cavities	Snags with cavities	Percent of snags with cavities
Abies concolor	651	48	6.87
Calocedrus decurrens	99	7	6.60
Yellow *Pinus* spp.	746	189	20.21
Unknown	239	13	5.16
GAMA			
Abies concolor	362	81	18.28
Calocedrus decurrens	1	0	0.00
Pinus lambertiana	13	1	7.14
Pinus ponderosa	97	30	23.62
Unknown	15	11	42.31

The use of snags by cavity-nesting bird species was dramatically different between the sites. Thirty-one cavity-nesting pairs from 10 species were detected at BMEF, while only one pair each of two species were detected at GAMA *(table 4)*. Red-breasted nuthatches *(Sitta canadensis)* (seven pairs), northern flickers *(Colaptes auratus)* (six), and mountain chickadees *(Poecile gambeli)* (five) were the more commonly encountered nesting species at BMEF. Other species included white-breasted nuthatches *(S. carolinensis)* (three pairs found), Williamson's sapsuckers *(Sphyrapicus thyroideus)* (two), and single nesting pairs of American kestrel *(Falco sparvarius),* white-headed woodpecker *(Picoides albolarvatus),* black-backed woodpecker *(P. arcticus),* and brown creeper *(Certhia americana)*. Two nuthatch and one woodpecker species nested but were not identified to species with certainty, and one other cavity-nesting species was not identified at all, but the nest had eggs. Only one nesting pair each of mountain chickadees and red-breasted nuthatch were found at GAMA. This fifteenfold difference is much greater than any measure of snags or cavities reported above. Overall, nesting use as a function of available cavities was surprisingly low (about 12 percent of snags with cavities used at BMEF and only 2 percent at GAMA; *table 4)*.

Table 4—*Number of bird pairs nesting, total number of bird species nesting, and relationships to the number of snags and cavities at BMEF and GAMA sites.*

	Total individual nests	Total number of bird species nesting	Nests per snag	Nests per snag with at least one cavity	Nests per total available cavities
BMEF	31	10	0.017	0.12	0.05
GAMA	2	2	0.003	0.02	0.01

There was a tendency for cavity-nesting birds to use snags of larger size than snags with cavities overall, and further for cavity-bearing snags to be larger than snags without cavities (with size based on dbh) at BMEF *(fig. 1).* A similar pattern of snags with cavities being larger overall than snags without cavities occurred at GAMA as well *(fig. 2).* At both sites (BMEF and GAMA), the majority of snags are in the most decayed category (decay measured as percent bark remaining) *(fig. 3).*

There are weak tendencies of bark beetle activity and whether the snag has cavities *(table 5).* Recognizing that almost all "0 exit tube" entries come from snags that have no bark and thus the details of bark beetle activity are lost, we found that at both BMEF and GAMA the highest percentage of snags with cavities were those that had the highest counts (31+ exit tubes). More compelling is the fact that 23 out of 28 snags that had the highest beetle exit tube counts had cavity-nesting birds at BMEF. Further, 20/28 snags that had nesting birds had the highest category of woodpecker foraging (31+ woodpecker foraging excavations) on the bark.

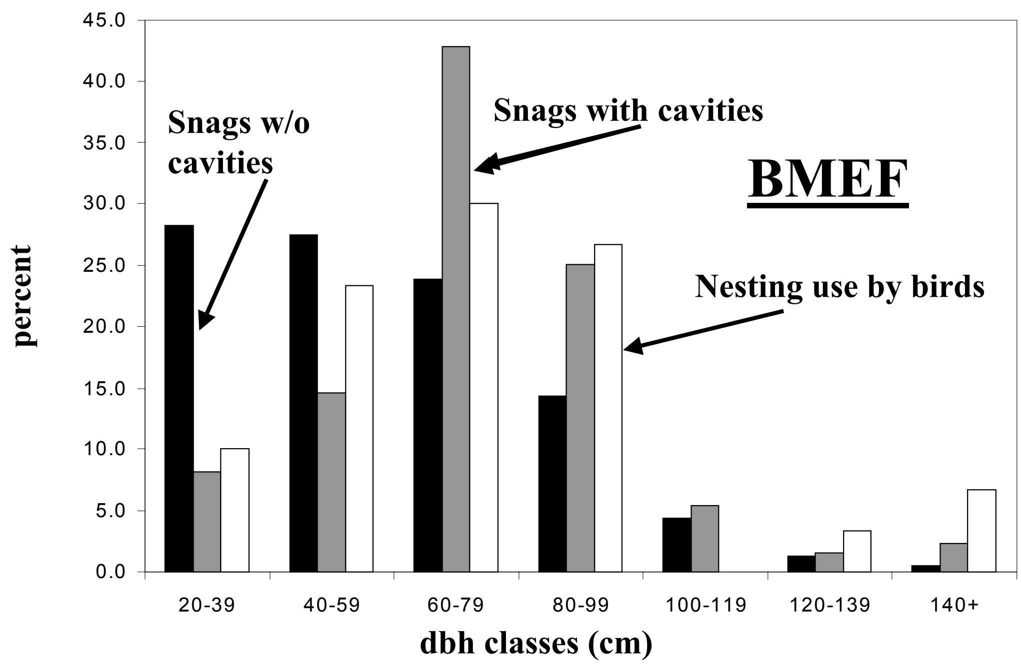

Figure 1—Percent representation of snags without cavities (black bars), snags with cavities (white bars), and snags with cavity-nesting birds (gray bars) as a function of dbh size classes at BMEF.

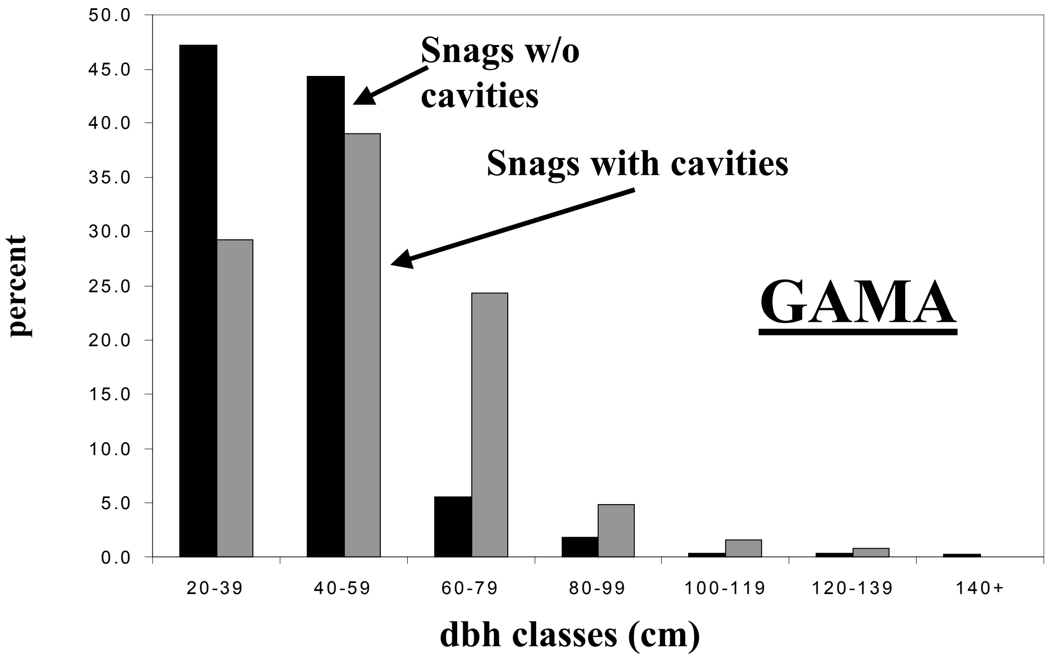

Figure 2—Percent representation of snags without cavities (black bars) and snags with cavities (white bars) at GAMA (cavity-nesting birds [N=2] not represented).

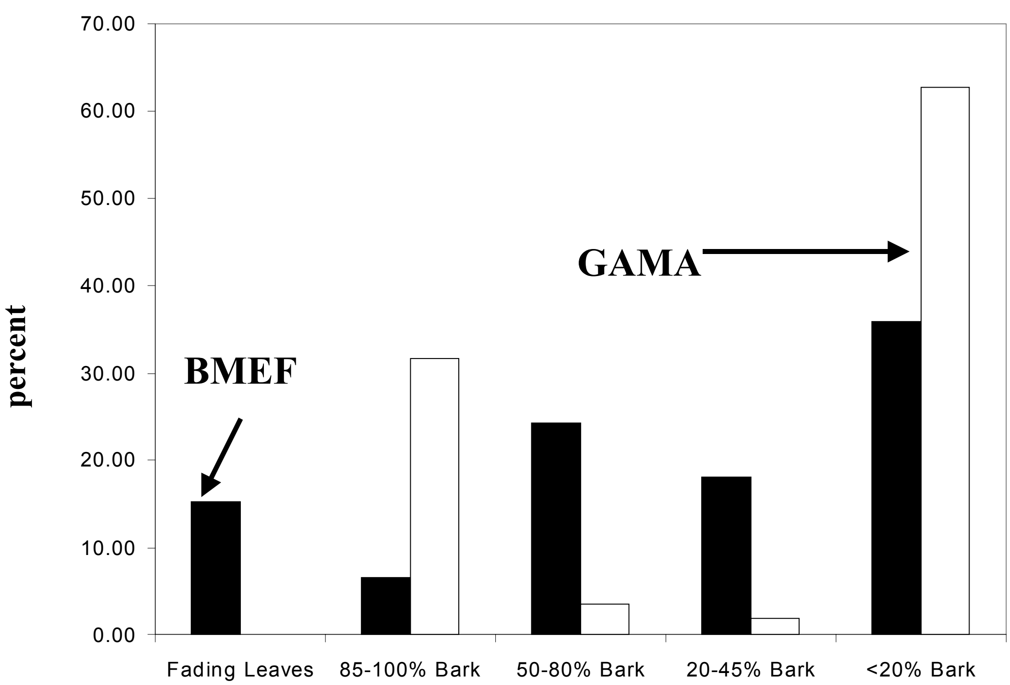

Figure 3—Percent representation of snags in various categories of decay (portrayed as the percent bark remaining) at BMEF (black bars) and at GAMA (white bars).

Table 5—*The relationship between beetle exit tubes detected on a snag and the occurrence of cavities on the snag for BMEF and GAMA.*

BMEF	Total snags	Snags with cavities	Percent of snags with cavities
0 exit tubes[1]	7	7	50.00
1-10 exit tubes	27	4	12.90
11-20 exit tubes	42	7	14.29
21-30 exit tubes	56	11	16.42
31+ exit tubes	624	177	22.10
GAMA			
0 exit tubes[1]	12	8	40.00
1-10 exit tubes	9	3	25.00
11-20 exit tubes	28	5	15.15
21-30 exit tubes	37	8	17.78
31+ exit tubes	24	10	29.41

[1] The "0 exit tubes" category includes snags with no remaining bark, thus no possibility of detecting exit tubes.

Discussion

We initiated this study to begin to quantify what would seem to be straightforward relationships of "snags per acre" and wildlife use. As we previously noted, quantifying and implementing this relationship is an essential element of forest management for wildlife.

For our study, we quantified cavity-nesting bird use of cavities. The use of the "Tree Peeper" would allow us to detect nocturnal small mammal use (none were detected in cavities). As expected, we found strong differences in both snags and cavity-nesting birds between our two sites. At the Blacks Mountain Experimental Forest (BMEF), with a history of little logging and thus large stands of large ponderosa and Jeffrey pine, we found snags at three times the density compared to our Goosenest Adaptive Management Area (GAMA) site, a site with a long history of logging and thus few large trees. The cavity-nesting bird density was even more pronounced, as BMEF had 15 times the nesting pairs as GAMA (31 vs. 2 breeding birds in cavity nests, respectively).

These main results, however, do not afford us a start in enumerating a "snags per acre" prescription in eastside pine forests for several reasons. First and foremost, the majority of *Pinus* snags in the landscape do not have cavities, so simply counting "snags per acre" dramatically underestimates the potential density of cavities for wildlife. In our study, three-fourths or more of yellow pine snags did not have cavities, and this disparity was true for all snag species *(table 3)*. The seeming "requirement" of sapwood decay in yellow pine snags in order for woodpeckers to excavate cavities requires further study. Snag numbers differed dramatically between sites, and so did nesting bird response, but at both sites there were many available cavities unused.

We feel that forest managers may well be asking a misleading question. "Snags per acre" requirements implicitly assume an equilibrium condition and reflect only one ecological requirement for a given cavity-nesting species. Our subsequent discussion will address these concerns and indicate the direction our research is taking as a result.

First, the vanishingly few cavity nesters detected on our GAMA plots is remarkable and suggests strongly that a consideration of foraging habitat and other ecological requirements must be part of the "snags per acre" management considerations. This is an important, but somewhat daunting proposition, as potential cavity-nesting species are diverse, and each species likely has very different foraging ecologies, as well as other differences in habitat requirements. There were an abundant number of unused cavities at both sites (about 88 percent of the cavity-bearing snags were unused at BMEF and 98 percent at GAMA, derived from *table 4),* suggesting that cavity availability is not driving the differences between sites. However, we have no measure of cavity "quality." Thus, we cannot know if unused cavities were for some reason unusable by birds. Their interiors may have been too decayed, or previous use by nesting birds may have fouled the nest environs.

The size of snags does differ between sites, with BMEF having an apparent abundant population of large snags, while GAMA has very few large snags (compare the distributions of snag dbh sizes and proportions in *figs. 2, 3).* As cavity nesters at BMEF used larger snags on average *(fig. 2),* it is possible that one explanation for the dramatic difference in cavity-nesting birds between sites is the presence of large snags available for nesting at BMEF, and their paucity at GAMA, even though excavated cavities are apparently abundant at both. This assertion cannot be a complete explanation, however, because there is wide variation in the height of cavities used *(fig. 2)* at BMEF and in other studies (Bu1l 1983, Cline and others 1980, Ganey 1999, Laudenslayer this volume, Mannan and others 1980, Miller and Miller 1980, Moorman and others 1999, Raphael and White 1984, Scott 1978). Nonetheless, the loss of large trees due to logging in eastside pine and other forests, over the past century has major implications for cavity-nesting birds.

A consideration of snag "demography" is also important (Bull 1983, Cline and others 1980, Harmon 1982, Huggard 1999, Keen 1955, Moorman and others 1999), as snags do not stand forever in forests, and in eastside pine they may, on the average, fall 8 years after tree death (Landram and others 2002). In our study, the majority of standing snags are very decayed (i.e., have less than 20 percent of their bark remaining; *fig. 3).* This suggests an uneven recruitment of trees into snags, such that it seems possible that the density of snags in our forests is declining. Clearly, forest managers must have a sense of snag recruitment in relationship to snag fall, and the patterns and processes that underlie them, when addressing wildlife needs.

Our results suggest an intriguing connection with biological activity early in the decay process of snags, its relation to a snag's eventual capacity to have cavities, and whether those cavities have nesting birds using them. Our collaborations (Farris and others 2002, Shea and others 2002) suggest that for ponderosa pine, the key to snags containing cavities may lie in the understanding how and if sapwood decay organisms are part of the decay process. In ponderosa pine, it is the sapwood (Rayner and Boddy 1988), not heartwood as in most other conifers, that is the tissue excavated by woodpeckers into nesting cavities. Experimental comparisons between pheromone-baited killed ponderosa pines and girdled pines (Shea and others 2002) reveal that far more cavities have been excavated in trees that were experimentally killed by bark beetles. Those results, and our correlations reported here, suggest that it might be that the action of bark beetle infestation and woodpecker foraging response increases the probability that sapwood decay organisms are part of the decay process, increasing the likelihood that a given snag may later be capable of cavity excavation. As only about 20-24 percent of our pine snags at both sites had cavities *(table 3),* it seems possible that sapwood decay does not occur in the majority of decaying snags.

It is also important to remember that the coupling of fire and bark beetle attack has been dramatically disrupted in the century of fire suppression. In the context of snag ecology, the historical prevalence of frequent, low intensity fires in eastside pine has been altered to infrequent, high intensity fires (Agee 1993, Skinner and Chang 1996), which changes how trees respond (survive or succumb) to fire (see Jackson and others 1999). Our understanding of bark beetles, their natural forest ecology, and rates of infestation (e.g., Christiansen and others 1987, Goyer and others, 1988, Ross and Niwa 1997) is likely incomplete because we rarely have observed the coupling of bark beetle activities in natural fire regimes. Certainly, the response to fires by woodpeckers (Blackford 1955, Koplin 1969) and how that was likely central to their life histories has been dramatically disrupted. These issues are interrelated and were likely historically intertwined in generating historical "snags per acre" levels lost in the past century.

We view the understanding of these complexities to be of primary importance in forest management for wildlife. Our ongoing collaborative research is focused on efforts to reconstruct historic forest structure and fire regimes in eastside pine, evaluate the wildlife and bark beetle responses to prescribed fire, and understand the interactive ecology of snag decay (including bark beetles, woodpeckers, and sapwood decay onset) as it relates to the possibility of cavity excavation. We feel it crucial to understand snags not as entities for simple enumeration (a "snags per acre" prescription), but as the result of complex interactions in dynamic forests. We hope this research pathway affords us a view of how snags develop and proliferate in the eastside pine forest system.

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