Girdled versus Bark Beetle-created Ponderosa Pine Snags: Utilization by Cavity-dependent Species and Differences in Decay Rate and Insect Diversity[1]

Patrick J. Shea,[2] William F. Laudenslayer Jr.,[3] George Ferrell,[4] and Robert Borys[5]

Abstract

Snags are a natural component of forest ecosystems and provide a variety of functions and values to forests and their constituents. Snags provide important feeding substrates, nesting sites, and habitat for a variety of invertebrates and vertebrates, and many of these functions continue after the snag eventually falls and becomes a log (coarse woody debris). Some forest landscapes are thought to be "snag deficient" for wildlife needs because of the direct action of forest managers or because of natural events such as winter storms or fire. Therefore, it is not unusual for forest managers to desire to create snags by various means. In this study we compared snags created by mechanical girdling (chainsaw) and bark beetle (western pine beetle aggregation pheromone) attack to determine acceptability and suitability to cavity dependent species, tree decomposition characteristics, and insect diversity. After 6 years we have found differences in the rate of deterioration (tree fading rates, branchlet retention, bole failure, top breakage, bark sloughing), woodpecker feeding activity, cavity excavation, and insect diversity. Our data indicate that bark beetle-killed trees provide a more biologically rich snag that is both suitable and acceptable to cavity dependent species.

Introduction

Snags are a natural component of ecosystems that have a variety of values to sustainable forest ecosystems. Snags provide important feeding substrates, nesting sites, and habitat for a variety of invertebrates and vertebrates, and these functions continue long after the snag eventually falls and becomes course woody debris (Laudenslayer 1997, Thomas and others 1979). Historically, snags have been removed from the forest to meet a variety of objectives, including timber production,

---

removal of hazardous trees, and to reduce the potential of crown fires. Currently, snags in many areas appear to be in low numbers for wildlife use, and managers may need to create snags to meet management objectives. Methods for stressing trees to kill them for this purpose have been the subject of several studies (Bull and others 1981, Bull and Partridge 1986, Conner and others 1981, Parks and others 1996). Some of these methods can be expensive and hazardous (topping trees with chainsaws and explosives) (Lewis 1998) or could be environmentally problematic (application of chemical herbicides). Less understood, however, are factors, many of them episodic (i.e., fire and insects), affecting the process of snag creation and longevity (Morrison and Raphael 1993).

Prime among these factors, in addition to the nature of the stress causing death, is the physiological condition of the tree when the stress occurs. Among the factors influencing tree stress are tree condition, tree size (age), and the season at which the stress occurs. Together, these factors probably determine in large part the particular sequence of decay-promoting organisms (i.e., insects and fungi) invading the tree as it is dying and afterward. This invasion sequence likely has a strong influence on how quickly the tree dies, how long the resulting snags stand erect, and those characteristics affecting its suitability and acceptability for use by wildlife. It is thus important to understand the process of snag creation, and the factors affecting it, in both artificially and naturally created snags. In this experiment we examined some of these processes.

To the extent possible, processes used to create snags should mimic natural processes to ensure resulting snags are ecologically optimal. In other words, these snags should contribute to a fully functional forest rather than simply meeting snag standards for wildlife. However, technical factors, such as safety and cost, are also important. Two likely methods for creation of snags are girdling and baiting with bark beetle pheromones. Bark beetle pheromones are chemical messengers between conspecifics that create a mass attack on an individual tree for the purpose of killing it (Bedard and Wood 1974). Commercially available pheromones that are species-specific can be deployed in an economic and safe manner that creates a mass attack on a target tree (Browne 1978, Byers 1989). Resulting tree death can be rapid and is followed by an apparently natural sequence of secondary insects, fungi, other arthropods, and vertebrates. This method thus closely mimics natural tree killing by bark beetles.

Mechanical girdling, while technically acceptable, does not closely mimic natural tree death. Girdled trees may not die promptly or at all. Snags created by girdling may be structurally weakened and fall sooner (Bull and Partridge 1986). In California, neither method has been adequately investigated in the large diameter trees favored by woodpeckers as nesting sites (Landram and others 2002, Laudenslayer 1997).

This study investigates processes of snag formation in trees killed by girdling or with bark beetle pheromones with the goal of developing methods that are both technically and ecologically optimal. Specifically, the objectives were to compare the differences between girdled and bark beetle-killed trees relative to the use by cavity-dependent species, decomposition rate, and diversity of insect fauna. We were also interested in whether season of death or diameter of tree had an influence on these variables.

Methods

This study was conducted at the Blacks Mountain Experimental Forest (BMEF) located within the Eagle Lake District of the Lassen National Forest in northeastern California. It was an adjunct study to an interdisciplinary research program also sited within BMEF. This large, long-term research program compares the effects of treatment combinations that include, vegetation structure, livestock grazing, and prescribed fire on forest ecosystem structure and function. BMEF lies ~60 km northwest of Susanville, California, in the eastside pine type. This forest type is representative of a forest assemblage that extends north from Baja California into central British Columbia and is characterized by temperature extremes, low average annual precipitation, and episodic fire. Growing sites tend to be uniform in slope and exposure. The forests of eastside pine are growing on volcanic soils characteristic of the region. BMEF includes a relatively large acreage of old-growth pine forests that, except for fire exclusion, have not been extensively altered.

Except as noted, experimental trees consisted of 48 ponderosa pine (*Pinus ponderosa* Laws), 24 in each of two diameter classes (38-64 and >76 cm dbh). Eight (4 in each dbh class) trees, each no less than 100 m from other groups, will constitute an experimental plot or block. The six plots were selected on the basis of having a high stand complement of ponderosa pine with adequate representation of the diameter classes defined above. Half of the trees within each dbh class on each plot were assigned at random to one of the following treatments:

- Girdling: Two girdling chainsaw cuts, 20 cm apart, and 5 cm into the sapwood were made 61 cm above ground level. Bark and phloem were removed between the chainsaw cuts to prevent healing.

- Pheromone-baiting: A pheromone dispenser obtained from Phero Tech Inc., containing the western pine beetle (*Dendroctonus brevicomis* Leconte) aggregation pheromone, was fixed to the bole of each tree at 2 m above the ground. The western pine beetle aggregation pheromone dispenser contains specific amounts of exo-brevicomin, frontalin, and myrcene. Baits were placed during times of western pine beetle flight that was determined by baited monitoring traps placed in the general vicinity.

Half of the trees in each of the above treatment combinations on each plot were assigned at random to spring (June 1993) and half to fall (September 1993) treatment periods. Thus, there will be one tree with each snag creation method by dbh by time of treatment combination.

Pheromone treated trees were monitored every 2 to 3 weeks after bait placement to assess the progress of mass attack by western pine beetle. All trees in all treatment combinations were visited every month post-treatment (except during the winter) to assess fading rates (foliage color changed) during the first year and then twice yearly thereafter. Pheromone baited trees were judged to be successfully attacked by western pine beetle when more than 50 red pitch tubes could be counted in the lower 4 m of the bole. Pheromone baits were then removed.

One, two, three and five years after baiting and girdling, each tree was visited to assess the amount of secondary insect and woodpecker activity. Insect activity was monitored by Lindgren funnel traps hung on pulleys next to the bole of the tree at three heights (dbh, 6 m, and 12 m). Insects from these traps were collected approximately every 2 weeks from June to September from 1993 to 1997. They were

identified to either order or family, counted, and selected specimens were mounted for future reference. In 1995 each tree was also assessed for emergence of secondary insects. This was done by counting and characterizing the shape and size of emergence holes (Furniss and Carolin 1977) on the surface of the bole that fell within a 30 X 30 cm template. The template was placed at dbh and 4 m above the ground. The circumference of the bole at each height was divided as closely as possible to 12-inch segments, and the site of sampling was randomly selected.

Flaking of bark by woodpeckers is used to extract prey items from within the bark and is defined as pieces of bark being chipped away from the bole. Flaked areas can be readily recognized by the discolored area of the bark. The bark surface remains relatively flat in contrast to feeding holes drilled by a different woodpecker feeding activity. Drilling is defined as woodpecker action that actually drills a hole through the bark to the xylem tissue to access prey. The hole is wider at the surface and narrows as it reaches the xylem. The surface of the drilled hole is ragged and uneven. Chips from both methods accumulate around the base of the tree. During surveys the presence or absence of the two woodpecker feeding activities on the experimental trees was recorded.

Beginning in the fall of 1994 and each year thereafter, all trees were visually inspected for the presence of nesting cavities. Full cavities are defined as an almost perfectly round excavation in the bole of study trees with perceptible depth to the hole. A cavity start is defined as a full cavity where the excavation has little depth but does reach the xylem tissue. Observers used various types of binoculars to make these inspections.

In 1999 in addition to rating the type and degree of woodpecker activity, observers also assessed tree decomposition characteristics. The amount and location of bark sloughing was noted as well as whether there was top breakage. Sloughing of the bark is defined as the bark separated from the xylem and either falling away from the bole or sliding apart. Either action exposed the xylem tissue. Finally, each study tree was observed for the presence or absence of branchlets. These are defined as the outmost woody tissue on each branch. These data were taken in 1999.

We are in the sixth year of this continuous study and much data has been collected. In this paper we only present a portion of the data collected, mostly in the form of qualitative observations.

Results and Discussion

Three years into this study there appeared to be no difference between spring- and fall-treated trees for any variable tested; therefore, the treatments of interest became method of snag creation and diameter class. There was no significant difference in mean tree diameter for each of the two classes between the methods used to create snags *(table 1)*. All the ponderosa pine trees baited with western pine beetle aggregation pheromone were successfully attacked by western pine beetle and no additional adjacent trees were attacked. One tree within the pheromone baited/small diameter treatment group failed to be attacked because it was misidentified as a ponderosa pine when in fact it was a Jeffrey pine *(Pinus jeffreryi* Grev. and Balf.). Consequently this tree was not considered as part of the experiment. Bark-beetle killed trees faded rapidly whereas girdled trees showed no sign of needle fade for 23 months. Those trees baited with pheromones in July of 1993 turned

yellow or straw colored by August/September of the same year, whereas those trees baited in September began to fade in late-June/early-July 1994.

Secondary insects including adult members of the family Buprestidae (primarily *Melanophila* spp.), Cerambycidae (in particular *Ergates* spp and *Monochamus* spp.), Elateridae, and Bostrichidae were captured in the Lindgren funnel traps from both girdled and pheromone-baited trees. However, the numbers of insects captured from girdled and pheromone-baited trees were considerably different. An example of the difference in numbers of emerging woodboring insects collected from the two treatment groups is presented in *table 2*. By September 1995, over 2 years after treatment, the number of emergence holes counted in the 12 large diameter pheromone-baited trees were approximately 16 to 20 times greater than occurred on those trees that were girdled. This same relationship, albeit with a somewhat smaller difference, also occurred on the small diameter trees for both snag creation methods. Colonization by red turpentine beetle (RTB) *Dendroctonus valens* LeConte on both treatment groups also appeared to be different. Typically RTB attacks occur at the base of trees and usually follow colonization by western pine beetle or other primary *Dendroctonus* attacks. They also are quite common in trees of sufficient diameter that have been injured by fire (Furniss and Carolin 1977). Experimental ponderosa pine baited with pheromone averaged 74.6 attacks by RTB compared to 23.6 attacks on the girdled trees.

Tree decomposition appeared to be quite different for some variables, depending on whether the snag tree was girdled or killed by bark beetles. Of the 24 trees in the girdled treatment, three trees have fallen. Two of the trees belong to the small diameter group and the remaining tree was a large diameter tree. Two of these trees (one in each of the diameter groups) were uprooted and one tree broke at 0.6 m above ground level. In the pheromone-baited treatment four trees have fallen: two within the small diameter group and two in the large diameter treatment. One tree (small diameter) was uprooted and three trees broke at 1.5 (small diameter), 10.6, and 15.5 m (both large diameter) above ground level. We consider the latter trees as viable snags as evidence by the occurrence of cavities in each. Girdled trees showed a lower percentage of bark sloughing and a higher percentage of branchlets still present than pheromone-baited trees 6 years after treatment *(table 3)*. Neither observation is surprising considering that the girdled trees did not begin to fade or show outward signs of mortality (i.e., fading) until 23 months after girdling.

Table 1—*Mean (+/-sem) diameter at breast height and range for all ponderosa pine trees in girdled/pheromon- baited/diameter/treatment combinations.[1]*

Treatments	N	Mean (+/-sem)	Range
Girdled			
Small diameter	12	18.90(0.83)a	15.1 – 24.0
Large diameter	12	40.80(2.73)b	30.1 – 62.4
Pheromone			
Small diameter	12	19.14(0.76) a	15.6 – 24.4
Large diameter	12	37.31(1.98)b	30.1 – 51.6

[1]Means followed by the same letter are not different from each other at alpha=0.05 by one-way ANOVA using Bonferroni mean separation test.

Table 2— *Number of emergence holes made by secondary insects from girdled and bark beetle-killed ponderosa pine trees 2 years after treatment, 1995. The number is the sum of the holes counted in a 30.4 cm X 30.4 cm template, one at breast height (DBH) and the other at approximately 4 m above the ground.*

Girdled large diameter			Baited large diameter		
Tree No.	DHB	4 m	Tree No.	DBH	4m
5	0	0	6	1	12
11	0	0	8	8	14
14	0	0	13	2	11
15	0	0	16	0	8
21	0	0	22	14	21
24	0	0	23	3	7
29	2	6	31	4	3
30	2	6	32	7	8
38	0	0	37	2	12
40	0	0	39	17	13
45	0	0	46	4	3
48	0	0	47	19	1
Mean	.33	1.0		6.75	10.91
+/- sem	0.22	0.67		1.87	1.43

Table 3—*Percent of trees in each treatment group according to tree decomposition characteristics, woodpecker activity, and presence/absence of cavities, 1999, 6 years after treatment.[1]*

Treatment	GSD	GLD	PSD	PLD
Bark sloughing	18	9	66	66
Presence of branchlets	100	100	40	50
Flaking	0	0	100	100
Drilling	58	75	66	100
Cavity starts	0	0	33	33
Cavities	0	0	44	44

[1]GSD – Girdled, small diameter; GLD – Girdled, large diameter;
PSD – Pheromone, small diameter; PLD – Pheromone, large diameter.

Trees killed by colonization by western pine beetle clearly showed considerably more woodpecker activity than girdled trees *(table 3)*. Whereas 100 percent of the trees baited with western pine beetle pheromones showed evidence of the flaking feeding behavior, none of the girdled trees had evidence of this behavior *(table 3)*. All trees baited with pheromones in the spring of 1993 had woodpecker feeding activity (flaking) by September of that year. For those trees baited in the fall of 1993 all showed woodpecker activity by July of 1994. It seems reasonable to assume that the flaking feeding behavior is aimed at capturing pre-emergent western pine beetle adults. It is characteristic of this bark beetle to turn out into the outer bark in the early larval stage, where it continues development, pupates, and rests as a callow adult prior to emergence (Furniss and Caroline 1977, Miller and Keen 1960, Stark and Dahlsten 1970). Thus, these insect stages would be readily available to foraging woodpeckers flaking or scaling. The precise method by which woodpeckers find

these areas of dense prey is unknown. Several of the authors (PJS, WFL, RB) have observed numerous occasions where large areas of the bark of lodgepole pine have been removed down to the xylem tissue by woodpeckers in search of mountain pine beetle (*Dendroctonus ponderosa* Hopk.) larvae, pupae and callow adults.

Drilling is the other feeding behavior recorded to measure woodpecker feeding activity. The percentage of trees showing this type of feeding activity varied across all treatment groups *(table 3)*. It should be noted however that 100 percent of the large diameter trees that were baited with pheromones had feeding behavior characterized as drilling. We point out also that the number of holes drilled by woodpeckers varied greatly across treatments. Those trees killed by western pine beetle, regardless of diameter class, showed considerably more drilled holes than the trees that were girdled. Of the 12 trees in the girdled/small diameter treatment group that showed evidence of woodpecker drilling, seven trees had two to seven holes each. In the girdled/large diameter treatment, 10 of the 12 trees showing evidence of woodpecker drilling had one to nine holes each. In contrast none of trees in pheromone baited treatments (small and large diameter classes) had fewer than 15 drilled holes in any tree. Several (8) pheromone baited/large diameter trees had > 350 woodpecker holes, whereas no tree in the girdled treatment group had in excess of 60 holes.

The construction of cavities in snags is the definitive answer to whether snags, artificially created or not, are acceptable and suitable to cavity-dependent species. In this study the data as of 1999 strongly suggests that bark beetle-killed ponderosa pine offer those characteristics that are acceptable and suitable to these vertebrates. Six years after pheromone-baiting, 44 percent of the trees in both diameter classes had full cavities compared to no cavities in the girdled treatment groups *(table 3)*. Further, an additional 33 percent of the pheromone-baited snags had cavity starts, while no cavity starts where found in the girdled snags *(table 3)*. In those pheromone-baited snags that had cavities, the number of cavities in any particular tree ranged from one to eight. Those trees that had multiple cavities were always found in the large diameter class, and a high proportion (62 percent) of the cavities were found in the upper 50 percent of the bole.

It is apparent that not all snags/trees are suitable for wildlife. The results of this study differ somewhat from others (Bull and Partridge 1986, Bull and others 1981, Chambers and others 1997, Conner and others 1981, Parks and others 1996) that investigated various means of creating viable snags needed by cavity-dependent species. The percent of cavity construction was higher in the bark beetle-killed trees; none of the girdled trees were used by woodpeckers as sites for cavities as was seen in previous studies. However, even in this study many questions remain. For instance, do secondary insects, particularly woodborers, carry inoculum for sapwood and heart rots into the tree that make a particular site favorable for cavity excavation? In the process of using bark beetle-killed trees as feeding sites, do woodpeckers become favorably inclined to use these as cavity trees? Unfortunately, little information exists to answer these questions and many others. Research and monitoring are needed to evaluate wildlife use of created snags both at the individual snag/tree and landscape levels.

When selecting a particular method of creating snags in snag deficient areas, land managers must consider a number of factors. Whether the particular method creates a snag that the targeted wildlife will use is crucial. We point out that snags created by bark beetle colonization serve multiple objectives. First, these snags serve

as feeding sites from the time they are colonized by a particular bark beetle species, and then for a number of years after this event as secondary beetles cycle through the snag. Second, they serve as suitable sites for cavity excavation that are used by a number of different cavity-dependent species.

Lewis (1998) points out that safety and economics are other factors that land managers must consider when selecting a method to create wildlife snags. He suggests that blasting and saw-topping are both extremely dangerous, in addition to being costly, compared to basal and crown girdling and fungal inoculation. The use of bark beetle pheromones is quite inexpensive. Western pine beetle pheromones cost approximately $8.00/unit and can be used several times if stored properly, and no machinery is needed as with girdling. The most obvious concern about the use of bark beetle pheromones is whether or not their use could create unwanted bark beetle mortality. Although the probability of starting a bark beetle epidemic (local or otherwise) with their use is remote, common sense should be used. If local populations are sparse and stand and tree conditions are thrifty, there is little risk in using bark beetle pheromones. In this study no collateral mortality was associated with either pheromone baiting or girdling. Conversely, if local populations of bark beetles are rising or locally epidemic because of droughty conditions or other predisposing conditions, this method of creating snags should be used with great care.

Finally, whatever method is used to create wildlife snags to meet standards and guides concerning snag densities, the resulting snags must be suitable and acceptable to the wildlife species of concern.

References

Bedard, William D.; Wood, David L. 1974. **Bark beetles—the western pine beetle.** In: Birch, Martin C., ed. Pheromones. Sec. 22.8. Frontiers of biology, Vol 32, North Holland Amsterdam; 441-449.

Browne, Lloyd E. 1978**. A trapping system for the western pine beetle using attractive pheromones.** Journal of Chemical Ecology 4(3): 261-275.

Bull, Evelyn L.; Partridge, Arthur D.; Williams, W. G. 1981. **Creating snags with explosives.** Res. Note PNW-393. USDA Forest Service; 4 p.

Bull, Evelyn L.; Partridge, Arthur D. 1986. **Methods of killing trees for use by cavity-nesters.** Wildlife Society Bulletin 14: 142-146.

Byers, John A. 1989. **Chemical ecology of bark beetles.** Experientia 45: 271-283.

Chambers, Carol L.; Carrigan, Tara; Sabin, Thomas E.; Tappeiner, John; McComb, William C. 1997. **Use of artifically created Douglas-fir snags by cavity nesting birds**. Western Journal of Applied Forestry 12: 93-97.

Conner Richard N.; Dickson, J. G.; Locke, B. A. 1981**. Herbicide-killed trees infected by fungi: potential cavity sites for woodpeckers.** Wildlife Society Bulletin 9(4): 308-310.

Furniss, Rober L.; Carolin, Val M. 1977. **Western forest insects.** Miscellaneous Publication No. 1339. U.S. Department of Agriculture Forest Service; 654 p.

Landram; F. Michael; Laudenslayer, William F., Jr.; Atzet, Thomas. 2002. **Demography of snags in eastside pine forests of California.** In: Laudenslayer, William F., Jr.; Shea, Patrick J.; Valentine, Bradley E.; Weatherspoon, C. Phillip; Lisle, Thomas E., technical coordinators. Proceedings of the symposium on the ecology and management of dead

wood in western forests. 1999 November 2-4; Reno, NV. Gen. Tech. Rep. PSW-GTR-181. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; [this volume].

Laudenslayer, William, F. Jr. 1997**. Dead, dying, and diseased trees and their values to wildlife.** In: Dams, D.; Rios, J. E., eds. Proceedings, 45th animal damage meeting of the California Forest Pest Council, November 13-14, 1996. Sacramento, CA: California Dept of Forestry and Fire Protection; 9-14.

Lewis, Jeffrey C. 1998. **Creating snags and wildlife trees in commercial forest landscapes.** Western Journal of Applied Forestry 13(3) 97-101.

Miller, John M.; Keen, Frank P. 1960. **Biology and control of the western pine beetle**. USDA Forest Service Miscellaneous Publication 800; 381 p.

Morrison, Michael; Raphael, Martin G. 1993. **Modeling the dynamics of snags.** Ecological Appliations 3: 322-330.

Parks, Catherine G.; Bull, Evelyn L.; Filip, Greg M. 1996. **Using artificially inoculated decay fungi to create wildlife habitat.** In: Bradford, P.; Manning, Todd; l'Anson, Bill, eds. Wildlife tree/stand-level biodiversity workshop proc B.C. Min. of forestry Victoria, B.C.; 87-89.

Stark, Ronald W.; Dahlsten, Donald L. 1970. **Studies on the population dynamics of the western pine beetle,** *Dendroctonus brevicomis* **LeConte**. University of California, Agricultural Science Publication; 174 p.

Thomas, Jack W.; Anderson, Ralph G.; Maser, Chris; Bull, Evelyn L. 1979. **Snags.** In: Thomas, J. W., tech. ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agric. Handb. 533. USDA Forest Service; 60-77.