Effects of Prescribed Fire on Live Trees and Snags in Eastside Pine Forests in California

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Abstract

Snags are important to forests because they contribute to the development, maintenance, and productivity of soils and provide habitat for an array of life forms. Historically, fire has played an important role in shaping the composition and structure of many forests in the western United States and fire is now being reintroduced to restore the natural process. However, the effect of fire on the snag resource is not well known and responses may differ depending on the length of time between fires. Preliminary data from two fires in eastside pine forests, burning after a long fire-free interval, suggest that fire-killed trees deteriorate at faster rates than trees dying from other causes and fires remove many of the existing snags. Of 14 trees dying after a prescribed burn in 1990, eight lost large portions of their tops by 1997. In an unburned plot, only six of 21 trees dying in that period lost large portions of their tops. Eight trees on the burned plot lost more than 10 percent of their bark, whereas none of the trees on the unburned plot lost even 10 percent of their bark. In an area burned in 1995, 39 of 71 snags survived the burn but some were heavily scorched or incurred other damage from the fire. These results suggest that fire may have a great effect on the characteristics and numbers of snags in eastside pine forests. However, additional studies are necessary to determine if these results are typical of a more frequent fire regimes.

Introduction

Standing dead trees (snags) are an important component of a functioning forest as they contribute nutrients to the soil, provide habitat for a variety of fungi, and provide habitat and food sources for a myriad of invertebrate and vertebrate species (Balda 1975, Laudenslayer 1997, Maser and others 1988). The number of snags in a forest varies spatially and temporally as a consequence of diverse patterns of snag creation and loss. Creation of new snags depends on spatial and temporal patterns of the agents that cause tree mortality including insects, disease and fire. Spatial and temporal patterns of snag loss and rates of deterioration are also important characteristics of snags and may be related to the cause of tree mortality as well as tree species, size (diameter), soil characteristics, and topographic location.

Although much research has been devoted to gaining a better understanding of the value of snags to forest wildlife, especially birds, little research has been done to evaluate the characteristics and deterioration rates of snags created by different mortality agents. Fire, which historically has played an important role in a functioning forest, may be an important cause of tree mortality and snag loss. The lack of knowledge about the effects of fire on trees and snags is of concern because fire is now being reintroduced into forests after long fire-free periods (e.g., Agee 1993; Kilgore 1973a, 1973b; Kilgore and Briggs 1982; Skinner and Chang 1996). This paper provides preliminary results on the effects of prescribed fire, such as tree mortality, deterioration of trees dying after the fire, as well as snag persistence after a long period without fire.

Materials and Methods

The study area is located just north of Butte Lake in Lassen Volcanic National Park, Lassen County, California. Topography of the study area is variable and includes relatively flat areas interspersed with short, steep slopes. The forest is dominated by yellow pines (*Pinus ponderosa* and *P. jeffreyi)* with smaller numbers of white fir (*Abies concolor*), red fir (*A. magnifica)*, lodgepole pine (*P. contorta)*, and incense cedar (*Calocedrus decurrens*). Mean basal area approximates 26 sq. m/ha with much of the basal area present in trees with diameters at breast height (dbh) greater than 80 cm. Few grasses, forbs, shrubs, or sapling trees are present and the soil is covered by 10 to 25 cm of volcanic ash. Thickness of the forest floor (organic material deposited on the mineral soil) surrounding trees is quite variable with thickness generally increasing with tree diameter. For trees with diameters greater than 80 cm, litter depth adjacent to the trees varies from 9 cm to 38 cm and litter depth 1 m away from the trees varies from 5 cm to 21 cm.

In 1988, two 500 m long by 100 m wide study plots were randomly located in the eastside pine forest north of Butte Lake. On each plot, all existing dead trees were mapped, individually marked, and dbh, heights, percent of bark remaining, number of nesting cavities, were measured. Each year since 1988 as part of an ongoing study, all existing snags were examined to determine if they had changed substantially (e.g., lost height, bark, limbs, or added new nest cavities) and all new snags were mapped and measured.

Prescribed burning is being conducted in Lassen Volcanic National Park to reduce the fuel loading. In late June 1990, one ha of one plot was prescribed burned and in September 1995, the remaining four ha were burned. The other, parallel plot, was not prescribed burned.

Yellow pines dying between June 1990 and summer 1994 on the portion of the plot burned in 1990 and the entire unburned plot were selected to compare deterioration rates. Criteria to determine tree death were conservative: foliage had to be at least fading before a tree was judged as dead. Trees dying after 1994 were not included in the deterioration study because death was probably not directly related to the consequences of fire and there was insufficient time to evaluate deterioration. Deterioration characteristics (measured by loss of tree height) and loss of bark of all snags from time of death through 1997 on both plots were compared. Deteriorated trees were those losing at least 10 percent of their bole, whereas trees losing less than 10 percent of their bole were considered intact. Trees losing bark were grouped into trees losing more than 10 percent and trees losing less than 10 percent. Because all of the trees dying after fire, had a diameter greater than 46 cm, only snags in the unburned plot with diameters greater than 46 cm were compared.

The condition of all yellow pine snags existing on the unburned section of the plot was evaluated after the September 1995 prescribed fire. Trees were classified as intact (not substantially affected by the fire); charred (snag relatively intact but light scorching to deep charring), and consumed (most or all of the snag consumed by the fire). Responses of snags to the prescribed fire were further described using the amount of bark remaining on the snag (< or > 50 percent) and the diameter of the snag (< or > 60 cm).

Results

Mortality and Deterioration

After the June 1990 prescribed fire, all 14 yellow pines >46 cm in diameter in the 1 ha burned plot died between 1992 and 1994. In the 5 ha unburned plot, 21 yellow pines >46 cm died between 1991 and 1994 (table 1).

Table 1. Time for loss of tops (>10 percent) to occur in yellow pine snags by death year cohorts on a 1 ha plot burned in 1990 and a 5 ha unburned plot in an eastside pine forest, Lassen Volcanic National Park.

	No. Snags			No. Deteriorated snags					
Plots	Year	Cohort	Intact	1992	1993	1994	1995	1996	1997
Burned (1 ha)	1991	0	ù	ù	Ù	ù	ù	ù	ù
	1992	3	2	ù	Ù	ù	ù	1	ù
	1993	9	3	ù	ù	ù	3	2	1
	1994	2	1	ù	ù	ù	ù	1	ù
Unburned (5 ha)	1991	1	0	ù	1	ù	ù	ù	ù
	1992	0	0	ù	ù	ù	ù	ù	ù
	1993	8	4	ù	ù	ù	2	2	ù
	1994	12	11	ù	ù	ù	ù	1	ù

Trees dying after the 1990 burn deteriorated more quickly than those on the unburned plot dying from agents not directly related to fire (e.g., bark beetles). Large cracks often developed in the wood and more than half of the trees in the burned plot lost large portions of their tops, whereas about one-third of the trees in the unburned plot lost large portions of their tops by 1997 (fig. 1). On both plots, it took approximately 2 years after death for snags to begin losing their tops (table 1). Bark on all snags in the burned plot loosened quickly, but little fell from the snags until the 1997 assessment by which time large portions of bark had sloughed off of eight of the trees (fig. 1).

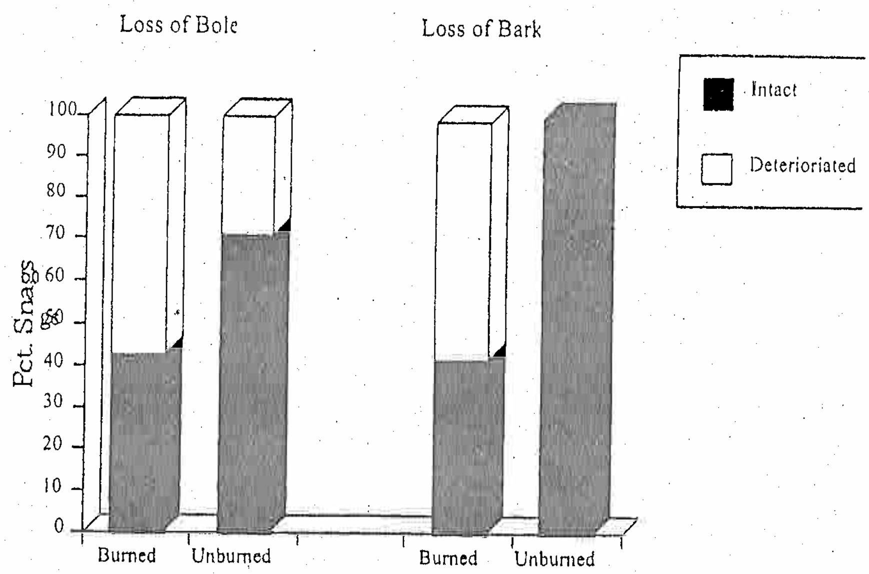

Figure 1. *Loss of tops of boles and bark by 1997 in yellow pine snags (intact <10 percent loss; deteriorated >10 percent loss) with diameters >46 cm dying between 1990 and 1994 on a 1 ha plot burned in 1990 and a 5 ha unburned plot in an eastside pine forest, Lassen Volcanic National Park.*

Loss of Existing Snags

After the 1995 fire, snags generally survived relatively intact or were mostly or completely consumed (fig. 2). Fifty-nine percent of the 71 snags on the 1995 burned plot (4 ha) were either scorched or charred (10 snags) or largely or completely burned (32 snags). More than half of the snags with <50 percent bark survived the fire relatively intact, whereas less than 40 percent of the snags with >50 percent bark survived the fire relatively intact.

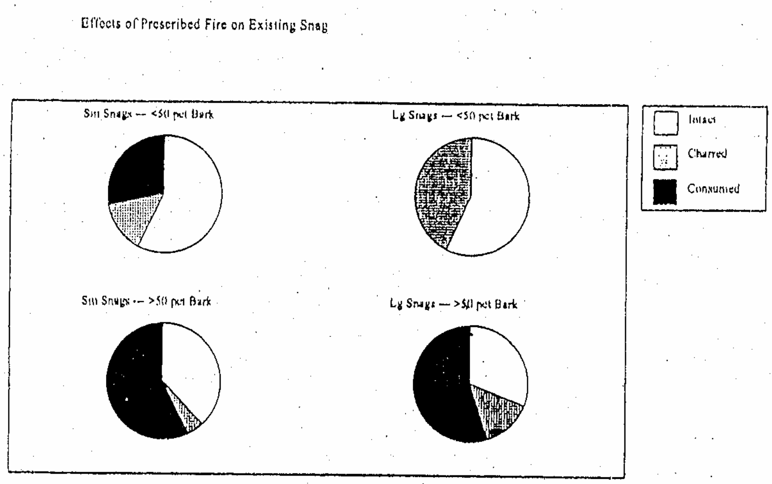

Figure 2. Response of existing yellow pine snags to prescribed fire on a 4 ha plot burned in 1995 in an eastside pine forest, Lassen Volcanic National Park. Snags are grouped by the diameters of the snags (sm. snags are <60 cm and lg. snags are >60 cm in diameter) and by the amount of bark on the snag before the fire (< or > 50 percent). Intact snags were not substantially affected by the fire, charred snags incurred light scorching to deep charring, and consumed snags were mostly consumed by the fire.

Discussion

Mortality and Deterioration

All of the large diameter trees (>46 cm diameter) within the area burned in June 1990 died within 4 years. Mortality of these large diameter trees was incomplete in other areas of the burn. Mortality of smaller diameter trees (<46 cm diameter) also was incomplete. The portion of the study area where the mortality of the large diameter trees was complete was on a relatively short, steep slope which probably contributed to the high death rate.

Tree mortality after fire is often delayed from 2 to 5 years (Swezy and Agee 1991), which is reflected in this study. The first death of a large tree was detected 2 years after the burn, with the majority of the mortality occurring 3 years after the fire. All 14 of the trees with diameters >46 cm on the plot had died by 1994 -- within 5 years of the burn.

Tree mortality after fire varies greatly depending on variables such as bark thickness, fuel loadings, fire temperature, and length of time maximum temperatures persist (Ryan 1990, Sackett and Haase 1996). After prescribed fires in Idaho, Montana, Oregon, and Washington, tree mortality ranged from 0 to 97 percent and mortality varied among the tree species examined. Mortality ranged from 87 percent for western hemlock (*Tsuga heterophylla*) and Englemann spruce (*Picea engelmannii*) to 15 percent for western larch (*Larix occidentalis*), with mortality for Douglas fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), lodgepole pine (*Pinus contorta*), and subalpine fir (*Abies lasiocarpa*) falling between those extreme values (Reinhardt and Ryan 1989, Ryan and Reinhardt 1988).

Mortality of trees also varies with the time of the fire. Swezy and Agee (1991) conclude that mortality of old ponderosa pine trees in their study area was as much as three times higher from early season burns in June (37.6 percent) and July (31.6 percent) compared with mortality from burns later in the season in September (12.0 percent).

Rates of Deterioration

Rates of deterioration of trees dying after fire have not been well studied. Kimmey (1955) has summarized the general pattern of deterioration. In the third year after fire, smaller diameter (as high as 30 cm in diameter) fire-killed ponderosa and Jeffrey pines begin to break up at a variety of heights. In the fourth and fifth years, tops of additional trees including large trees begin to break out and some entire trees come down. Dahms (1949) indicates that by 10 years after a fire, more than half of the ponderosa pine snags were down and after 22 years, 78 percent had fallen.

In a paper on fall rates of fire-killed ponderosa pines, Harrington (1996) reported that trees began to fall 3 years after the burn and 60-70 percent of the trees fell within 7 years of the fire. A fallen tree in Harrington's study is one where a maximum of 0.3 m stub remained after falling. In the results of this study, none of the trees fell as in Harrington's study; a substantial amount of bole remained of even the shortest stub (about 5 m). The time since the burn for the top to break away from the first tree was 5 years, substantially longer than Harrington showed. These differences may be attributable to environmental characteristics of the study areas (southwestern Colorado versus northern California), tree diameters (ranging from small to large versus >46 cm in diameter), and tree species (ponderosa pine versus ponderosa and Jeffrey pine).

Bark beetle-killed ponderosa pines also start falling shortly after death, starting in the first year. Keen (1955) found that the rate of fall in the first 5 years after death was relatively slow but accelerated rapidly between the 5th and 15th years; soil characteristics and tree diameter both influence falling rates. In contrast to Harrington's (1996) study, by 7 years after death, Keen (1955) found 50-60 percent of the trees had fallen, less than the 60-70 percent recorded by Harrington (1996) in 7 years after the fire. Because there is often a lag time between the timing of the fire and tree death, the disparity between Keen's and Harrington's results is probably higher.

Loss of Existing Snags

Loss of existing snags to a prescribed fire in a southern Arizona ponderosa pine forest was influenced greatly by snag diameter. More than half of the snags >50 cm in diameter (56 percent) were consumed by the fire and 51 percent of the snags between 30 and 50 cm (Horton and Mannan 1988). The results for this study are quite similar to the Arizona results, despite the differences in diameters classified as small versus large snags; 44 percent of the snags >60 cm in diameter and 46 percent of the snags <60 cm in diameter were consumed by the fire.

Implications

Deterioration of yellow pines dying after a fire appears to occur at a faster rate than those killed by other causes and the characteristics of the decaying snags may differ. Further, after a fire, many of the existing snags have been consumed and new snags created. These patterns suggest that the snag environment in a forest with fire may differ substantially from a forest without fire. Different decay agents may be active and the resulting snags may provide a different suite of habitat characteristics to species who depend on snags for foraging, cover, and reproduction. The large loss of snags to prescribed fire suggests that a fire affected landscape would have few snags than one without fire. If fires are relatively frequent, the snag resource may be dominated by relatively young, presumable hard snags. These results are from forests without fires for long periods; the responses of snags under a more frequent fire regime may be quite different. These conclusions should be considered as hypotheses to be tested in future experiments, and additional study of the relationships of fire to tree mortality, decay, and snag demise is necessary to better understand the role of fire in forests.

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