Effects of Site on the Demographics of Standing Dead Trees in Eastside Pine Forests[1]

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Abstract

In the last several decades there has been a growing awareness of the value of snags in forests. Recent work has resulted in management standards and guidelines that set objectives for species such as cavity-nesting birds, but the numbers of snags required may not be attainable or sustainable across the landscape. Work reported here on snag demography in eastside pine forests was initiated in 1989. While snags have been present on most of the sites throughout the study period, the number of snags and their "life-spans" depends on tree species, tree size, soil characteristics, and topography. Snags persisted for longer periods at Lassen Volcanic National Park sites where the soils are covered by up to 0.5 m of volcanic ash, but snag density was less than our other sites because of the low tree density. These findings suggest that standards and guidelines for snag management incorporate variation at local scales.

Introduction

Availability of standing dead trees, or snags, has long been a management issue in forests (Brawn and Balda 1988, Bull and others 1997, Cline and others 1980, Raphael and Morrison 1987, Raphael and White 1984, Rosenberg and others 1988, Swallow and others 1988, Thomas and others 1979, Waters and others 1990, Welsh and Capen 1992, Zack and others 2002), particularly in eastside pine forests – those forests dominated by ponderosa (*Pinus ponderosa* P. & C. Lawson) or Jeffrey pine (*P. jeffreyi* Grev. & Balf.) lying east of the crest of the Cascades and Sierra Nevada in California, Oregon, Washington, and Nevada (Studinski and Ross 1986). These concerns have resulted in management standards that are applied across large landscapes. For example, the Lassen National Forest requires 1.2 snags per acre (3 per ha) between 15 and 24 inches (38-61 cm) diameter at breast height (dbh) and 0.3 snags per acre (0.7 per ha) in excess of 24 inches (61 cm) dbh and 20 feet (6 m) in height (Lassen National Forest 1993).

While these standards may be relevant (but see Oliver 2002), there is such a wide variety in landscape variables in eastside pine forests, such as elevation, precipitation, soil composition, soil depth, and water holding capacity, as well as existing vegetation composition and structure, and historical vegetation trajectories, that the standards may not be applicable to certain areas or spatial and temporal

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scales. Gaining an understanding of snag demographics in eastside pine forests that differ in composition and site conditions is critical to evaluating the efficacy of the snag standards and guidelines for these forests. Variation observed should also help focus research and management attention to the processes underlying snag recruitment and loss rather than a forest's capacity to maintain a specific number of snags.

Eastside pine forests were burned frequently prior to about the turn of the beginning of the 20th century. Since then, fire has generally been excluded. Our knowledge of snag processes in these forests is from this long fire-free period and is unlikely to accurately reflect snag processes under frequent fire regimes. Changes in fire management practices coupled with the increased use of prescribed fire as a forest management tool will likely influence snag longevity.

The objectives of this paper are to (1) illustrate some of the variation in snag recruitment, loss, and occupancy in four relatively undisturbed eastside pine stands (stands that have not seen wildfire or lost large trees to timber harvest) and (2) discuss the ramifications of this variation relative to the snag management standards that are applicable to eastside pine forests.

Methods

The study sites discussed in this paper were established during a larger study of 24 sites (initiated in 1988) to evaluate the responses of birds to snag density and subsequent snag dynamics in eastside pine forests (see Landram and others 2002, Laudenslayer 2002). The four study sites were chosen because they had little historic management and reflected two different patterns of snag demography.

Snags on each study site were counted, mapped and their condition evaluated on 5-ha (12.4-ac), 100 x 500m (328 x 1640 ft) strip plots annually from 1989 to the present. All snags greater than 15 cm (6 in) dbh were included in the snag inventory. For this analysis, snags were divided into two groups. Small snags were those with diameters between 15 and 38 cm (6 and 15 in) dbh and with any height, or greater than 38 cm (15 in) dbh but less than 6 m (20 ft) tall. Large snags were those with diameters greater than 38 cm (15 in) dbh and height greater than 6 m (20 ft). The dividing line, 38 cm (15 in), separates those snags targeted by various snag retention standards (usually greater than 38 cm [15 in] dbh) from those smaller snags that are not generally considered for retention. Snag heights and diameter were also measured annually. Snags remained in the inventory until they were completely down (uprooted or broken at ground level) or had less than 1 m of bole remaining.

Study Sites

The four study sites chosen for this report were located in northeastern California on the Modoc and Lassen National Forests and within Lassen Volcanic National Park *(fig. 1)*. All sites were dominated by either ponderosa or Jeffrey pine and had little to no active management activity except fire exclusion.

Old Forest

The Old Forest study site was located within Blacks Mountain Experimental Forest (within the Lassen National Forest) (lat. 40^{o}42'45" N, long. 121^{o}9'45" W) between 1730 and 1740 m (5676 and 5709 ft) in elevation, and was primarily ponderosa pine with small numbers of white fir (*Abies concolor* (Gord. & Glend.) Lindl. ex. Hildebr) and incense cedar (*Calocedrus decurrens* (Torr.) Florin). It is a rather open forest dominated by small numbers of widely-spaced large diameter trees (>61 cm [> 24in] dbh). The understory was occupied by grasses, forbs, shrubs, and small trees. The only manipulations included a thinning and prescribed burn in 1996 (Oliver and Powers 1998, Oliver 2000).

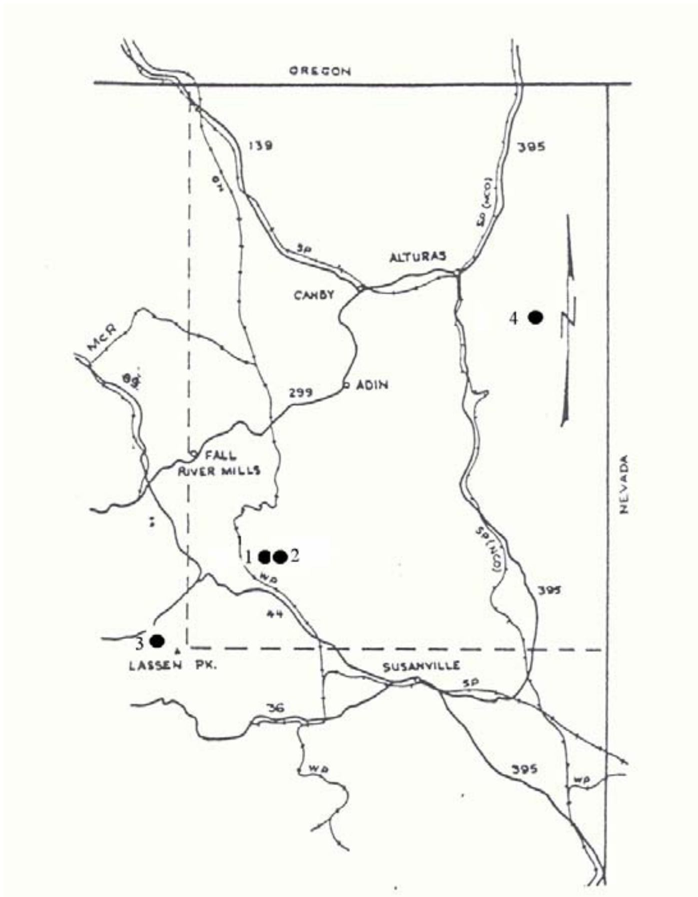

Figure 1—Four snag study sites in northeastern California: 1 = Old Forest; 2 = Research Natural Area; 3 = Hot Rock; and 4 = Soup Creek.

Research Natural Area

The Research Natural Area, also located within Blacks Mountain Experimental Forest (lat. 40°42'30" N, long. 121°8'15" W), was dominated by ponderosa pine and had a considerable amount of white fir and incense cedar in the understory. It lies between 1820 and 1830 m (5971 and 6004 ft) in elevation. White fir likely has been a natural component at this site for at least the last century. This site had the greatest canopy closure of the four study sites but rarely exceeds 50 percent, except in dense thickets of fir reproduction. The forest was dominated by relatively large diameter trees (>61 cm [>24 in] dbh), snag recruitment is high, and the numbers of large live trees is declining. Under the large trees are thickets of small trees, generally white fir with smaller amounts of incense cedar, and openings occupied by grasses, forbs, and shrubs.

Hot Rock

Hot Rock is located within Lassen Volcanic National Park (lat. 40°32'15" N, long. 121°29'30" W) and was dominated by Jeffrey pines with a small amount of white fir, generally in the understory. The elevation is about 1890 m (6200 ft). This site has the most open canopy of the four and the openness of the site increased through the study period. This site supported a noticeable number of snags that diameter appear to have been recruited in the 1970s. The forest was dominated by large trees (>61 cm [>24 in] dbh) but snag recruitment was high and the numbers of large live trees was declining. Generally, few young trees, shrubs, grasses, or forbs appeared in the understory, likely because of the thick layer of volcanic ash – up to 0.5 m in depth in some areas. However, where mass mortality occurred in the mid 1990s abundant fir regeneration has since established.

Soup Creek

Soup Creek is located in the Warner Mountains on the Modoc National Forest (lat. 41°18'0" N, long. 120°18'0" W) and is dominated by ponderosa pine with white fir both in the overstory and understory. The average elevation is about 1890 m (6200 ft). This site is on a steep slope in a canyon. The site includes several large aggregations of boulders, occupying as much as 0.5 ha (1.2 ac) of the site. The forest is dominated by large diameter trees (>61 cm [>24 in] dbh) but the density of large trees declines as one moves upslope. Past timber harvesting occurred on about 10 percent of the site.

Results

Most snags in the overstory were pines, but white fir comprised most of the snags in the understory of all sites, except Old Forest where firs were nearly absent. Numbers of snags increased substantially in two of these study sites, Research Natural Area and Hot Rock, and generally increased slightly in Old Forest and Soup Creek. Snag numbers increased starting in the early 1990s and generally ending about

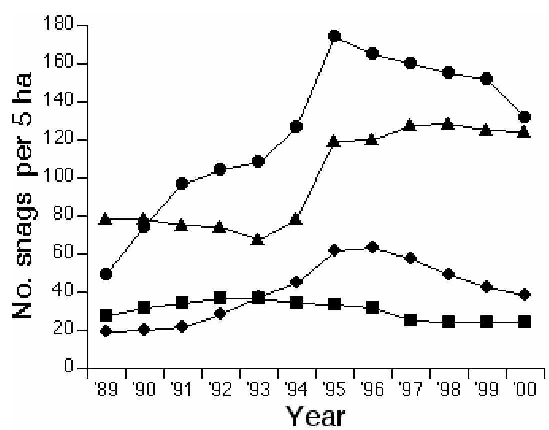

Figure 2—Numbers of snags greater than 15 cm dbh in each of four 5-ha eastside pine study sites over a 10-year period: Old Forest = squares; Research Natural Area = circles; Hot Rock = triangles; and Soup Creek = diamonds.

1996. Since then, snag numbers have declined at Old Forest, Research Natural Area, and Soup Creek (*fig. 2*). Numbers of large snags also increased substantially in all sites but Old Forest. At Hot Rock, large snag recruitment increased substantially in 1995. Large snag recruitment was greatest in the early 1990s and declined as the decade progressed. At the end of the decade, the number of large snags was beginning to decline in all but Old Forest (*fig. 3*).

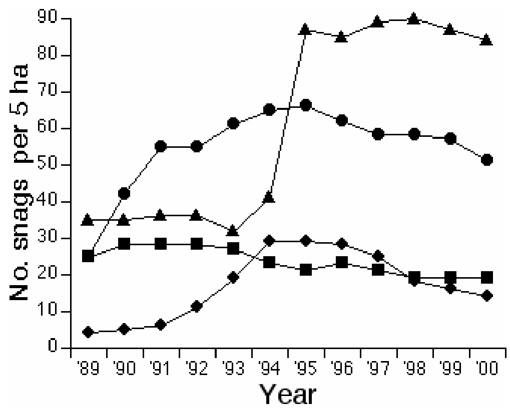

Figure 3—Numbers of snags greater than 38 cm dbh and 6 m in height in each of four 5-ha eastside pine study sites over a 10-year period: Old Forest = squares; Research Natural Area = circles; Hot Rock = triangles; and Soup Creek = diamonds.

At Old Forest, recruitment of large snags increased in 1990 and 1996 and recruitment of smaller snags was greatest in 1991 and 1997. Many large snags were lost in 1994 and 1997, whereas small snag losses were concentrated in 1996 and 1997. In high recruitment years only 3 - 5 snags were recruited and in high loss years 5 - 7 snags were lost (*fig. 4*). As a result, numbers of snags at this site changed little during this study period.

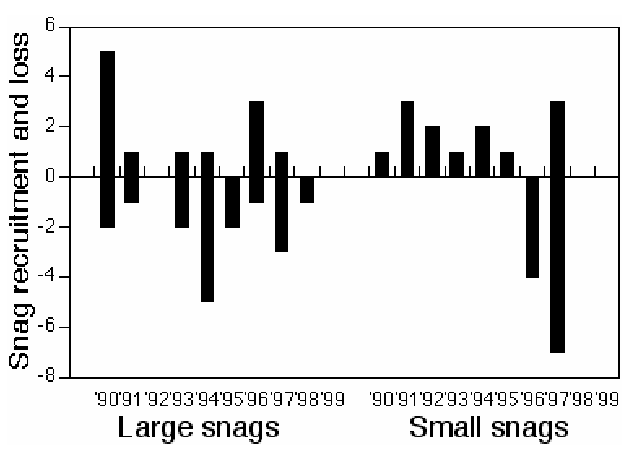

Figure 4—Recruitment and loss of large (greater than 38 cm dbh and greater than 6 m in height) and small snags (15-38 cm dbh and any height, and greater than 38 cm dbh and less than 6m in height) in the 5-ha study site at Old Forest.

At Research Natural Area, the best years for large snag recruitment were 1990 and 1991, but there was some recruitment from 1994-1996. For small snags, 1995 and to a lesser extent 1994 were high recruitment years. Relatively few large snags were lost during the observation period, with 1996 having the greatest loss. For small snags, however, 1996 and 1997 were high loss years. In contrast to Old Forest, Research Natural Area gained approximately 4 times as many large snags as it lost in a high recruitment year, and perhaps 15 times as many small snags (*fig. 5*). The trend at this site is characterized by high snag recruitment and declining numbers of large live trees.

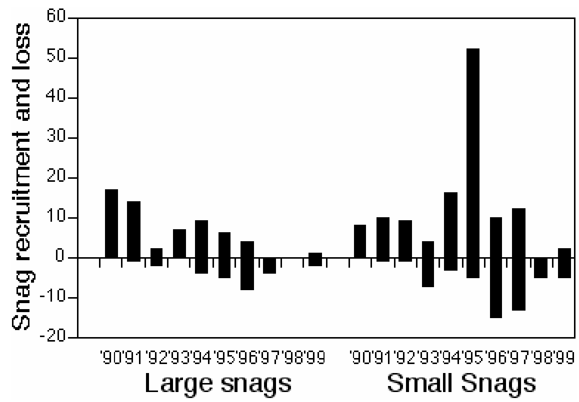

Figure 5—Recruitment and loss of large (greater than 38 cm dbh and greater than 6 m in height) and small snags (15-38 cm dbh and any height, and greater than 38 cm dbh and less than 6m in height) in the 5-ha study site at Research Natural Area.

At Hot Rock, the years of highest recruitment for large snags were 1994 and 1995. In 1995, all of the large live trees in approximately 0.05 ha (0.12 ac) died. Recruitment of small snags was low, with the largest recruitment occurring in 1997. Relatively few large snags were lost in this decade, and the loss was distributed over a number

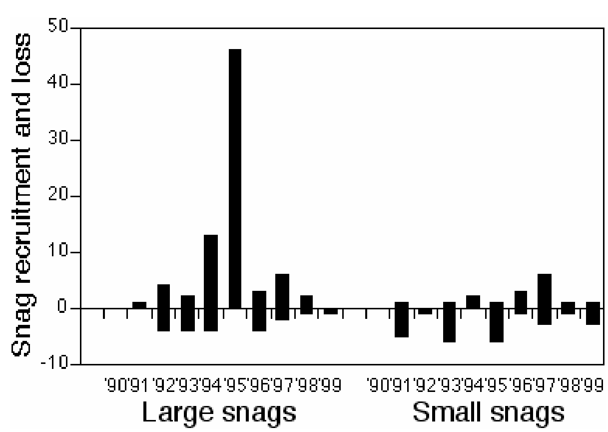

Figure 6—Recruitment and loss of large (greater than 38 cm dbh and greater than 6 m in height) and small snags (15-38 cm dbh and any height, and greater than 38 cm dbh and less than 6m in height) in the 5-ha study site at Hot Rock.

of years (1992-94 and 1996). Losses of small snags were distributed over several years (1991, 1993, and 1995). Hot Rock recruited the majority of snags, mostly large snags, in one year (1995) and without that large pulse of recruitment, the general magnitude of recruitment and loss would resemble Old Forest more than Research Natural Area (*fig. 6*).

At Soup Creek, 1992-1995 were high years for large snag recruitment. Recruitment of small snags was high in 1995 and 1996. Large snags were lost at a greater rate in 1995 and 1998. Small snags were lost at a relatively high rate from 1992 through the rest of the decade (*fig. 7*).

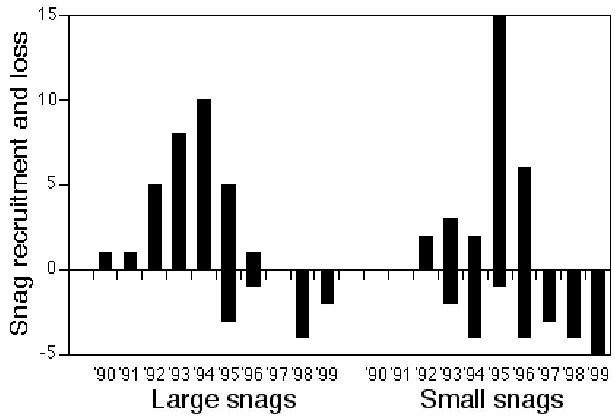

Figure 7—Recruitment and loss of large (greater than 38 cm dbh and greater than 6 m in height) and small snags (15-38 cm dbh and any height, and greater than 38 cm dbh and less than 6m in height) in the 5-ha study site at Soup Creek.

Discussion

Historically, management standards and guidelines for snags in eastside pine forests were based on numbers of snags with different characteristics. The standards and guidelines also often specified a certain number of live trees for future snag recruitment (Studinski and Ross 1986). The principal purpose for retaining and recruiting snags was to provide nesting sites for primary and secondary cavity nesters. Studies of snag densities in eastside pine forests (Dahms 1949, Keen 1929, 1955, Landram and others 2002, Zack 2002) suggest that many sites have low numbers of snags relative to other forest types, and that even better sites may not be able to meet the standards and guidelines for snag numbers in a sustainable manner.

However, snag density may not be as important to the system as ensuring recruitment and a continuous flow of snags through time. *Picoides* woodpeckers generally forage for only a few years on dying or freshly dead trees and prey especially on scolytid, buprestid, and cerambycid larvae (Farris and others 2002, Hughes 2000). Insect residence and thus woodpecker foraging occurs early in the life of a snag; the half-life of a ponderosa pine snag in northeastern California is between 7 and 10 years (Landram and others 2002). Primary tree-killing bark beetles [e.g., fir engraver (*Scolytus ventralis* LeConte), mountain pine beetle (*Dendroctonus ponderosae* Hopkins), and western pine beetle (*D. brevicomis* LeConte)] generally persist in a dying or dead tree for only 60 days to less than a year, depending on the time of attack, whereas the longer developing beetles, like California prionus

(*Prionus californicus* Motschulsky) may be present for 3 to 5 years (Furniss and Carolin 1977).

Tree mortality patterns reported here indicate that even at the relatively fine scale of 5 ha (12.4 ac), most plots had a flow of dying and dead trees to replace those lost. However, many of the recruited snags were of small diameter (less than 38 cm [15 in] dbh), which are unlikely to support the diversity or abundance of beetle larvae found in larger diameter snags. The temporal pattern of mortality suggests that much of the mortality in the early 1990s was related to the drought coupled with bark beetle attack. However, beetles may successfully attack trees that are overmature, are adjacent to windfalls, have root-rot, or are in overstocked or stagnant stands (Cobb and others 1974, Furniss and Carolin 1977, Oliver 1995), leading to some constant rate of background mortality even when moisture is not limiting.

Tree mortality generally consisted of single trees or small groups of trees scattered throughout each site with the exception of the large mortality event at Hot Rock. This event was largely confined to an area of about 0.75 ha (1.9 ac), within which all of the large pine trees died. Oliver (1995) reported that there may be mortality thresholds related to the basal area present and the growing capability of a site, so this mortality event at Hot Rock may have been driven by overstocked conditions. Since this site is near Mount Lassen, other less well known causes of mortality may be responsible, such as excessive carbon dioxide gas in the soil (Sorey and others 2000).

Generally, snag loss occurred in all years, but was punctuated with pulses that followed pulses of recruitment. Fall rates for snags in northeastern California vary from seven percent per year for ponderosa pine and Jeffrey pine to four percent per year for white fir (Landram and others 2002). Snag half-life is related to species and diameter. For small (13-38 cm [5-15 in] dbh) ponderosa or Jeffrey pines, half-life ranged from five to six years whereas for small white firs, the half-life was seven years. For larger (greater than 38 cm [15 in] dbh) ponderosa or Jeffrey pines, half-life was eight and seven years whereas for larger white firs, half-life was 10 years (Landram and others 2002).

Soil characteristics may also be important in controlling tree stocking, snag recruitment, and snag longevity. At Old Forest, Research Natural Area, and Soup Creek, there were areas greater than 100 m^2 (1076 ft^2) in size where trees were not present because of soil characteristics, soil depths, presence of rock, or some other factor. At Hot Rock, much of the site was covered by a layer of volcanic ash averaging about 0.5 m (1.6 ft) in depth (Clynne and others 2000). This thick layer of ash probably made it more difficult for young trees to get established and may have contributed to greater snag longevity by not retaining moisture close to the tree base, thereby reducing the rate of decay. Within the area experiencing very high mortality at Hot Rock, there were very few small trees present prior to the event. Following the event, a “carpet” of seedlings became established; however, most of the seedlings were white fir, suggesting that the tree species composition within this area may be shifting toward white fir in the foreseeable future. Further, it will take decades for these tree cohorts to grow to sufficient size to meet snag guidelines. In the interim, about 0.75 ha (1.8 ac) will shortly lack snags. However, snags may persist longer on these Lassen Volcanic Park sites than the other sites, likely because of the volcanic ash layer. At Hot Rock, trees that died in the bark beetle outbreak in the mid-1970s remain standing.

Conclusions

Snag recruitment and loss are likely related to local site characteristics and vegetation structure interacting with weather, climate, insects, and disease. Considerable variation in recruitment and loss occurs across the landscape even in sites that have not been managed or seen wildfire in decades. This variation suggests that standards and guidelines for snag retention should incorporate information from local scales rather than regional or larger scales. Work reported here suggests that processes contributing to snag recruitment and fall down operate at spatial and temporal scales that are highly variable. Thus management guidelines may need to reflect this variability.

While current numbers of snags are indeed important, managing for a suitable population of future snags is more critical to the continued functioning of forests over time. If forests are composed of appropriate sizes of living trees, then drought, insect and disease, and fire will create snags in an appropriate pattern.

This study focused on forests that have burned frequently under natural disturbance regimes. Reintroduction of prescribed fire, and more frequent occurrence of wildfire, will substantially alter forest structure, and therefore the snag component of forests as well.

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