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Snag Recruitment in Subalpine Forests

Abstract

Information on snag locations and densities is useful for managing many species of wildlife. Using a combination of belt transects, fixed plots, and aerial photographs, we recorded snag species, locations, and causal agents of tree mortality in subalpine forests in the Entiat watershed in Washington State. The overall snag density (all standing dead trees) was 51 per hectare. Subalpine fir (*Abies lasiocarpa*) and lodgepole pine (*Pinus contorta*) were the most common species of snags. Weather-related effects created more snags than any other disturbance in the period between stand-replacing fires. The density of dominant and codominant snags did not differ by aspect or slope categories, but the density of intermediate and suppressed snags was highest on steep south-facing slopes. Snag densities were lowest in stand initiation and open stem exclusion structural stages. More study is needed to determine if fire history data combined with aerial photo interpretation offer a potential method of estimating snag densities in subalpine forests.

Introduction

Size, density, and species of snags are among the numerous factors influencing local abundance of many species of animals and birds. Snags serve as sites for roosting, nesting, denning, and foraging. Snag species important to wildlife have been identified (Parks et al. 1997) and recommendations for snag density levels have been proposed for forests in the interior Pacific Northwest (Thomas et al. 1979, Bull and Holthausen 1993, Bate 1995, Craig 1995, Evans and Martens 1995). To provide snags over time, several authors suggest designating specific green trees as snag replacements (Bull et al. 1980, Cimon 1983, Schommer et al. 1993) or developing techniques to create suitably decayed living trees (Parks et al. 1996).

How a tree dies influences its longevity as a snag and its usefulness to wildlife (Bull et al. 1997). Snag longevity is site- and species-specific (Keen 1929), and is increased by larger bole diameter and shorter height (Raphael and Morrison 1987). Wildfire is an important cause of snags. Although historically common in lower elevation forest types, wildfires are infrequent in subalpine forests. The fire return interval of forests in the Pacific Northwest is 250+ years for subalpine fir plant associations, 100 to 600 years for Pacific silver fir (*Abies amabilis*) plant associations, and 500 to 1500 years for mountain hemlock (*Tsuga mertensiana*) plant associations (Agee 1993). When killed by fire, thin-barked species such as Engelmann spruce (*Picea engelmannii*), lodgepole pine, and subalpine fir dry quickly (Bull 1983), making them resistant to insects and decay fungi (Parry et al. 1996, Hadfield and Magelssen 1997) and increasing their longevity as snags. In most forests, pathogens and insects break down far more biomass than do fires (Hagle et al. 1995) and consequently contribute more snags over the course of stand development.

Studies on size, recommended densities, and wildlife use of snags in the Northwest have focused on low and mid-elevation forests (McClelland et al. 1979, Bull 1986, Dixon 1995, Bevis 1996, Steeger and Machmer 1996, Bull et al. 1997, Saab and Dudley 1997), presumably because this is where most tree harvest occurs. However, subalpine forests are extensive, covering over 1,400,000 ha in the Cascade Mountains of Washington State. Although Thomas et al. (1979) recommended snag densities for numerous plant communities including subalpine fir, the recommendations were based only on the biology and likely occurrence of species of woodpeckers in a specific plant community, and they did not consider causes of conifer mortality and the importance of snags to overall plant community dynamics. Our objective was to document snag recruitment processes by analyzing the relative sizes, densities, causal agents of mortality, and species of snags in subalpine forests. This information will provide baseline data on snag availability in high elevation forests and may provide useful insight for developing snag management strategies.

Study Area

The study site is located in subalpine forests of the Entiat Ranger District, Wenatchee National Forest, on the eastern slope of the Washington Cascade Range (Figure 1). Subalpine forests encompass 32,923 ha of the Ranger District. Glacial troughs are the dominant landform of the study area (USFS 1991). Trough walls are the upper side slopes of glacially eroded U-shaped valleys and are underlain by bedrock, often with bedrock outcrops. Trough bottoms are mantled by glacial till, avalanche debris, and colluvium. Till has a sandy loam or loamy sand texture, occasionally with volcanic ash and pumice. Deposits of till, ash, and pumice are thicker on northern and eastern aspects, and thinner on southern and western aspects. Slope ranges from 60 to 90 percent on upper trough walls and 10 to 35 percent on trough bottoms. Avalanche paths are common on glacial trough walls, especially at higher elevations (Holdorf and Donahue 1990).

Elevations in the study area range from 1280 to 2150 m above sea level, and mean annual precipitation in the study area is estimated to range from 100 to 230 cm (T. R. Lillybridge pers. comm.). Subalpine forests in the upper Entiat watershed are classified into five major plant series: whitebark pine (*P. albicaulis*), subalpine larch (*Larix lyalii*), subalpine fir, mountain hemlock, and Pacific silver fir (Lillybridge et al. 1995). The westernmost forests in the study area are in the Glacier

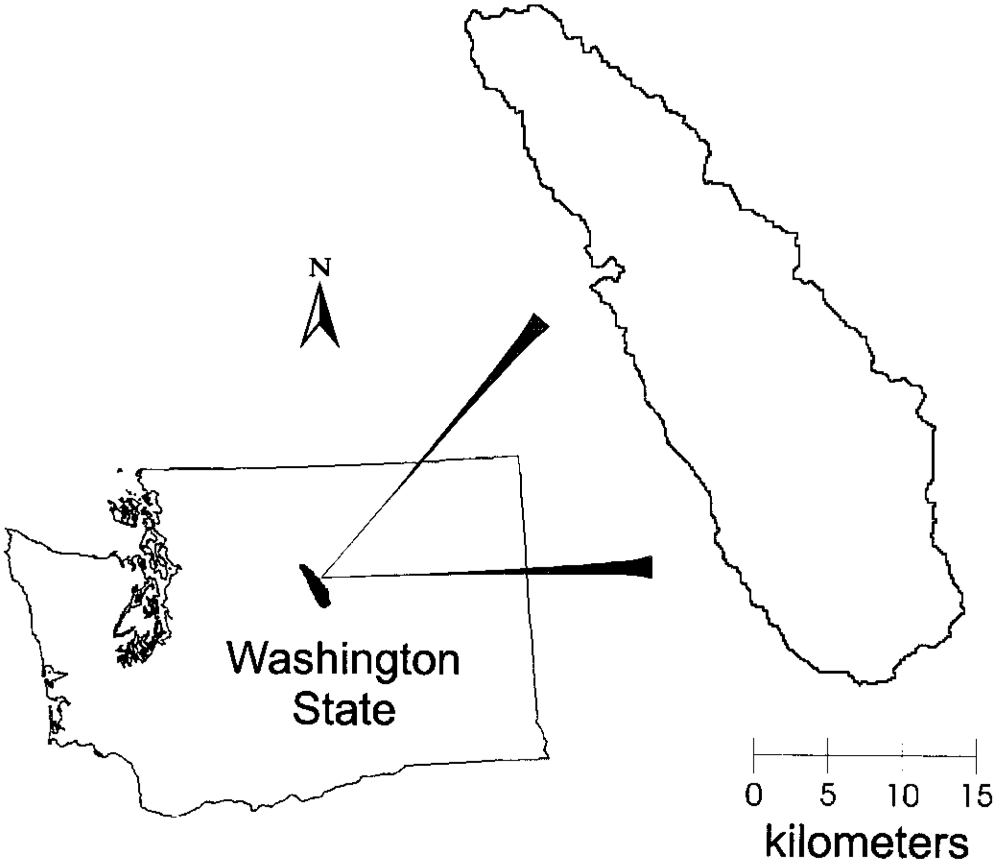

Figure 1. Location of study area in the Entiat watershed, Wenatchee National Forest.

Peak Wilderness Area. Remaining forests have a low road density and a history of little timber harvesting. Most forests within the study area have not burned for at least 100 years.

Methods

Aerial photographs taken in 1992 at a scale of 1:16,000 were used to delineate polygons, classified by predominant aspect and slope categories. Eighteen polygons were randomly selected from a total of 93. The area represented by these polygons is 5,686 ha. Stand types within polygons were subjectively classified by crown density and whether crowns had single or multiple layers. Aerial photographs were also used to assign stand types to one of seven structural stages: stand initiation, open stem exclusion, closed stem exclusion, understory reinitiation, young multi-strata, old forest multi-strata, and old forest single-stratum (Oliver 1981, O'Hara et al. 1996). Polygon and stand type boundaries were drawn on 1:24,000 scale black and white USDA Forest Service resource orthophoto quadrangles.

Both belt transects and circular fixed area plots were used to collect data. Five 9.1 m wide belt transects were established in each polygon and were oriented to cross all stand types within each polygon, beginning and ending at polygon boundaries. Belt transects were of variable lengths and compass bearings. The following data were recorded in each transect: conifer species and crown class of dead trees; starting and ending distances of stand types encountered along the transect; and whenever possible, agent(s) responsible for mortality. Crown classes were assigned according to the following criteria (Oliver and Larson 1990): dominant tree crowns that extended above the general level of crown canopy and were not physically restricted from above, and only slightly crowded by other trees on the sides; codominant trees crowns that were part of the general level of crown stratum, not physically restricted from above, and more or less crowded by other trees from the sides; intermediate trees were shorter but their crowns extended into the general level of dominant and codominant trees, were free from physical restrictions from above and quite crowded on the sides; suppressed tree crowns were entirely below the general level of dominant and codominant trees and were physically restricted from immediately above. All agents potentially contributing to mortality were recorded for each dead tree, and a determination was made of the primary agent responsible. For example, the primary agent for a tree with evidence of both moderate to aggressive root disease and bark beetle galleries was determined to be root disease. One fixed 0.02 ha plot was established where a belt transect crossed closest to the center of each stand type. Diameter at breast height (dbh) and crown position were recorded for every live and dead tree in each plot.

The Kruskal-Wallis nonparametric test was used to test two hypotheses: 1) There is no difference in snag density among six slope and aspect categories, and 2) There is no difference in snag density among structural stages. Statistical tests were performed using Statistical Analysis Systems software (SAS 1997).

Results and Discussion

A total of 6629 snags was recorded along 142 km of 9.1 m wide belt transects, representing 130 ha. The overall snag density was 51 per ha. An additional 329 snags were recorded in 77 fixed area plots. Snags were combined into two groups based on similarities in diameter: dominant and codominant snags, and intermediate and suppressed snags. Mean dbh for dominant and codominant snags was 32.5 cm (se=17.6). Mean dbh for intermediate and suppressed snags was 14.1 cm (se=10.8). The majority of the snags (83%) occupied dominant or codominant crown positions relative to the surrounding trees.

We rejected the hypothesis that there is no difference in snag density among six slope and aspect categories. The number of intermediate and suppressed snags per ha (Table 1) was significantly higher ($p < 0.05$) for steep (> 50%) south-facing slopes, which had a preponderance of relatively pure, dense lodgepole pine stands, than for other slope and aspect categories. The number

TABLE 1. Snags per hectare by aspect and slope in two crown class categories

Aspect	% Slope					
	10-30%		30-50%		50+%	
	DC*	IS	DC	IS	DC	IS
north	36	5	36	7	47	7
south	47	3	48	9	51	37•

*DC = dominant + codominant. IS = intermediate + suppressed
•significantly different from other IS values (p<0.05)

of dominant and codominant snags per ha (Table 1) did not differ significantly by aspect and slope categories (p = 0.744).

We also rejected the hypothesis that there is no difference in snag density among structural stages. Less than 1 ha in the study area was classified as old forest single-stratum. Therefore, data from old forest single-stratum and old forest multistrata were combined. Snag density was significantly different among the six structural stages for both the dominant and codominant snag category ($p < 0.01$) and the intermediate and suppressed snag category ($p < 0.01$). A majority of the total snags (88%) were found in 4 structural stages: closed stem exclusion, understory reinitiation, young multi-strata, and old forest (Figure 2).

Although subalpine fir and lodgepole pine represented the majority of snags (Table 2), it is unknown whether or not these two species are more likely to form snags than other species because the total numbers of live stems of the different species was not recorded. The larger subalpine fir and lodgepole pine snags are suitable for some cavity nesters; a few species such as downy (*Picoides pubescens*) and three-toed (*P. tridactylus*) woodpeckers seem to prefer smaller trees (Bull et al. 1997). Both of these tree species are also important to foraging woodpeckers (Parks et al. 1997).

Weather-related effects created more snags than any other identified category (Table 2). In subalpine forests, weather may be the most consistent agent that creates snags between stand-replacement wildfires. Most of the snags killed by weather had the live crowns removed by snow, wind, or ice. Bull and Partridge (1986) report that removing the live crowns of trees with explosives or by cutting produced snags that stood a relatively long time and received the greatest nest use by woodpeckers. Top breakage allows relatively slow decay from the point of breakage downward and lowers the chance of windthrow. In contrast to trees killed by weather, trees killed by root pathogens probably stand the shortest amount of time because the decayed roots are likely to fail.

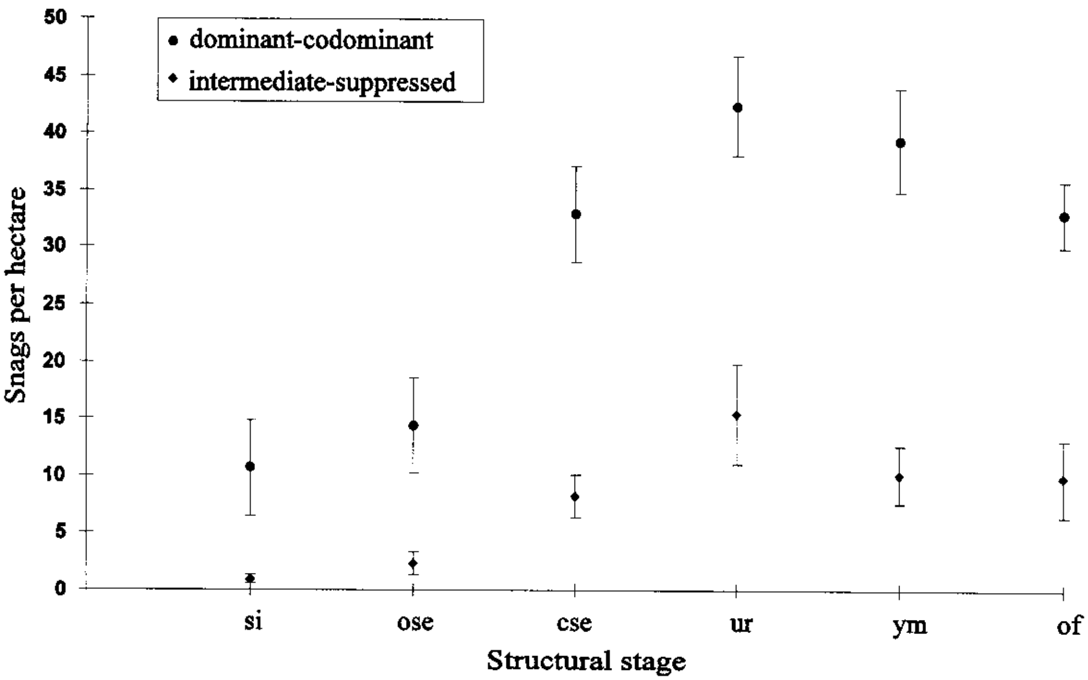

Figure 2. Snag density per hectare for two crown class categories by structural stage: si = stand initiation, ose = open stem exclusion, cse = closed stem exclusion, ur = understory reinitiation, ym = young multistrata, of = old forest. Vertical bars represent standard errors of the means.

TABLE 2. Disturbance agents affecting conifers in two crown class categories: numbers of snags per 100 hectares

Species	Weather		Animal		Root disease		Blister rust		Dwarf mistletoe		Bark beetles		Other insects		Suppressed or unknown		Total snags	
	DC[1]	IS	DC	IS	DC	IS	DC	IS	DC	IS	DC	IS	DC	IS	DC	IS	DC	IS
Engelmann spruce	52	3	6	1	88	3	-	-	-	-	102	5	5	-	74	10	327	22
Subalpine fir	378	65	15	2	176	3	-	-	-	-	17	-	45	4	628	167	1259	241
Lodgepole pine	252	25	29	1	145	28	-	-	87	3	329	31	25	-	423	269	1290	357
Douglas-fir	12	5	-	-	29	-	-	-	14	-	31	-	10	2	26	12	122	19
Whitebark pine	42	18	52	13	13	1	238	87	-	-	121	2	13	2	192	43	671	166
Subalpine larch	26	3	8	2	18	-	-	-	-	-	1	-	2	-	43	10	98	15
Pacific silver fir	19	15	2	-	52	5	-	-	-	-	15	2	12	1	86	7	186	30
Mountain hemlock	10	-	-	-	7	1	-	-	-	-	-	-	1	-	21	1	39	2
Other species	10	14	1	-	14	2	11	4	-	-	54	1	4	2	42	12	136	35
Unknown	15	-	-	-	1	1	-	-	-	-	4	-	22	-	44	3	86	4
Totals	816	148	113	19	543	44	249	97	101	3	674	41	139	11	1579	536	4214	891

[1] DC = dominant + codominant. IS = intermediate + suppressed

Bark beetles killed at least 674 trees per 100 ha, especially favoring the two pine species and Engelmann spruce (Table 2). Trees killed by bark beetles are successively colonized by a variety of insects and fungi, and provide unique habitat (Parks and Shaw 1996). Notable among the colonizers are fungi that decay sapwood, and wood boring insects.

Subalpine fir, lodgepole pine, and whitebark pine had the highest numbers of trees that died from suppression or undetermined causes (Table 2). Subalpine fir killed by insects or root pathogens deteriorates rapidly after it dies and the signs and symptoms of causal agents are soon lost. Much of the lodgepole pine mortality listed is probably attributable to suppression, because overall, 44% of the lodgepole pine snags were in the stem exclusion stage. Rodents chew the cankers on whitebark pine produced by white pine blister rust (*Cronartium ribicola*) (Mielke 1935, Hoff 1992), effectively removing evidence of infection in some cases, so it is reasonable to assume that the incidence of mortality from white pine blister rust is even higher than indicated in Table 2.

Snag creation is a combination of individual and episodic events. The size, intensity, type, and frequency of disturbances affect forest development and composition (White 1979, Gray and Franklin 1997) and also affect snag density. Disturbances such as fire or bark beetle outbreaks create pulses of snags at specific landscape locations. In this study, we recorded fewer snags in the stand initiation and open stem exclusion structural stages than might be expected. Possible reasons include reburns, which would significantly reduce snag densities in the stand initiation stage, conifer encroachment on alpine meadows, and unusual weather such as high winds or heavy wet snows that may have reduced the number of snags.

This study identified structural stages from aerial photographs and from crown class information collected in ground surveys. A logical follow-up study is to determine whether structural stages, crown classes, and vegetation types identified from aerial photographs can be combined with fire history data to provide a reasonable estimate of snag densities in subalpine forests of the Northwest.

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