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Fall Rates of Snags:

A Summary of the literature for
California conifer species (NE-SPR-07-01)

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Introduction

Snags are an important component of a healthy forest, providing foraging and nesting habitat for many birds and mammals. However, excessive tree mortality caused by drought, insects, disease or wildfire can lead to increased surface and ladder fuels as the resulting snags fall over time. Therefore, land managers are often required to balance the needs of wildlife species, by retaining a minimum density of snags, with the need to keep fuels at manageable levels. Knowing how many snags exist in a given area is only part of the information required to meet management objectives. Other information, such as snag recruitment rates and fall rates, are essential to projecting and maintaining a specific snag density over time.

Snag recruitment rates are often related to stand density with denser stands experiencing higher levels of mortality due to inter tree competition for limited resources and consequent insect and disease activity. However, episodic events such as wildfires and prolonged droughts which typically result in increases in bark beetle-related tree mortality can create pulses of snags on the landscape. The species and size classes of snags created during these events are mostly determined by the existing component of live trees within the stand.

Land managers may be required to inventory tree mortality and determine the need for fuel reduction and salvage treatments, while considering the needs of wildlife species, after a snag creating event. Knowing how long a snag will persist on the landscape is critical in making these land management decisions. Several studies have been conducted throughout the west that monitored the fall rates of trees killed by fire, insects, disease and other factors such as mechanical girdling. This report summarizes the literature and briefly discussed the various factors that influence snag longevity.

Literature Summary

The longevity of snags is determined by many factors such as the size of the tree, species, cause of mortality, soils, climate, the occurrence of wildland or prescribed fire, and the occurrence of severe weather events such as heavy snows and high winds.

Tree Size

The size of the tree, especially in terms of diameter, is an important factor in snag longevity. Nearly every study reviewed found that the greater the snag diameter the longer it will stand, especially for trees greater than 16" DBH (diameter at breast height). Typically, larger snags have a greater amount of wood volume to decay, including a greater amount of decay-resistant heartwood, before they become unstable. Studies that found no difference in the fall rates among diameter classes for some species only considered small diameter trees (Everett et al. 1999, Harrington 1996, Lyon 1977, Schmid et al. 1985) or small diameter trees in unthinned stands (Mitchell and Preisler 1998).

Fall Rates by Species

Fall rates also varied by species with a few studies reporting a faster rate of fall for ponderosa and/or Jeffrey pine than white fir (Landram et al. 2002, Raphael and Morrison 1987), Douglas fir (Everett et al. 1999, Russell et al 2006) and lodgepole pine (Everett et al. 1999, Landram et al. 2002). Conversely, Raphael and Morrison (1987) found no difference in the fall rates between Jeffrey pine and lodgepole pine and Bull (1983) found no difference in the fall rates between ponderosa pine and lodgepole pine. Landram et al (1999) reported a lower fall rate for western juniper compared to all pine species and white fir. Raphael and Morrison (1987) also reported that red fir fell at a higher rate than Jeffrey pine, lodgepole pine and white fir.

Cause of Mortality

The cause of mortality may be an important factor in snag longevity but there is a lack of support for this in the literature. One study reported that fire-killed snags tended to fall at higher rates than beetle-killed snags or snags created by other factors (Raphael and Morrison 1987) but this study compared snags of unknown ages over a short observation period. Chambers and Mast (2005) suggested burned ponderosa pine snags may not last as long as unburned snags but they did not have enough data for statistical analysis. When results of studies of fire-killed trees are compared to results of studies of bark-beetle killed trees the fall rates appear similar for similar species and size classes. If a difference in fall rates exists between fire-killed trees and bark beetle-killed trees it may be more pronounced for trees killed quickly by higher levels of fire injury. Harrington (1996) reported that the longer it takes for a tree to succumb to fatal fire injuries the longer it stood as a snag. He also found that trees killed which had higher levels of crown scorch fell at higher rates.

Other Factors

Other factors were found to be important in a few studies. Soils were found to have an effect on snag longevity in beetle-killed ponderosa pine (Keen 1955). Keen found that snags on pumice soils tended to persist longer than snags found on loam soils. Schmid et al (1985) found that periodic wind events dictated when ponderosa pine snags killed by mountain pine beetle were likely to fall. Stand density was an important factor in a study of lodgepole pine where trees in unthinned stands fell at lower rates than trees in thinned stands (Mitchell and Preisler 1998). This study also discussed whether the lower tree density provided less protection from the wind or if it accelerated decay at the root collar due to increased sunlight and warmer soils. These same variables were discussed in a few studies trying to explain the perceived higher rates of falling for snags in large burned areas compared to smaller burned patches dispersed within adjacent unburned stands (Chambers and Mast 2005, Everett et al. 1999). Russell et al (2006) discussed differences in snag longevity based on the differences in snag density in salvaged versus unlogged wildfire areas.

Almost every study reported a post mortality delay of at least 2 years and as much as 5 years before snags began to fall or at least fall at a high rate. This was independent of the cause of mortality. Jeffrey and ponderosa pine were reported to break off incrementally more often than lodgepole pine, which tended to break off entirely at the base. The exception to this was ponderosa pine snags on pumice soils tended to uproot entirely (Dahms 1949).

Considerations

A few factors need to be considered when attempting to make comparisons between studies. First, annual fall rates were calculated in at least two ways depending on whether an original group of snags was followed over time or if a plot was followed over time that included original snags and snags recruited during the observation period. The first method reported a percentage using the number of original snags that fell and the number of years of observation. The second method reported the percentage of snags that fell each year based on the number of snags that existed each year. Another factor is that snags were determined by a minimum height definition that differed greatly between studies, ranging from 5 to 20' in height, while other studies did not state a minimum height criterion. Not knowing the year of death for snags in a couple of studies may confound the fall rates as trees tend to fall at higher rates over a certain time period after death. For example, if a study followed a group of 10-year-old snags and a group of 2-year-old snags over a 5 year period, the fall rate would likely be much faster for the 10-year-old group. Furthermore, a study where a group of snags are observed over a short time period of time may yield different results than a long term study. Comparisons between studies are also difficult since most were conducted in different geographic areas with different environmental conditions. It is recommended that when using information from this review, the original published papers should be referenced for more specific information on location, methods and results.

Annotated Bibliography of Snag Longevity Studies

- *Tables for quick reference to individual study results are provided in Appendix A.*

Bull, E.L. 1983. Longevity of snags and their use by woodpeckers. pp. 64-67 in "Snag Habitat Management", USDA Forest Service GTR-RM-99, Fort Collins, CO.

> Fifty percent of ponderosa pine snags and 38% of lodgepole pine snags were standing 8 years after being killed by mountain pine beetle in northeastern Oregon. Trees 10-19" DBH stood longer than trees < 10" DBH. The lower fall rate for ponderosa pine in this study is due to the larger average diameter of these trees in the sample. When trees of both species in the same diameter class are compared, the fall rates are similar. Ponderosa pine > 20" DBH tended to break off incrementally while lodgepole pine tended to break off at the base. The author suggests that thick bark on ponderosa pine probably retained moisture

allowing decay throughout the bole while the thin bark on lodgepole pine may have permitted the bole to dry rapidly and resist decay, except at the base.

Chambers, C. and J.N. Mast. 2005. Ponderosa pine snag dynamics and cavity excavation following wildfire in northern Arizona. *Forest Ecology and Management* 216: 227-240.

Snags in this study were at least 6ft (1.8m) in height. Most snags were standing 3 years post-fire and 41% fell after 7 years. Larger diameter snags fell at a lower rate than smaller diameter snags (46% of snags < 9" DBH fell after 7 years). Three year old snags were more likely to be standing if they had a higher surrounding basal area of live and dead trees. Snags most likely to persist after 7 years were straight (no lean), short (had top breakage), large DBH, and in clumps of live and/or dead trees. Snags appeared to be stable 3-4 years post-fire but began falling at higher rates thereafter. Authors suggest burned ponderosa pine snags may not last as long as unburned snags but did not have enough data to verify.

Dahms, W.G. 1949. How long do ponderosa pine snags stand? Research Note 57. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR. 3 p.

This study was conducted at the Pringle Falls Experimental Forest in Oregon over 22 years. Snags were located on pumice soils and had a large average diameter. Larger snags, averaging 26" DBH, stood longer than smaller snags which averaged 22" DBH. Fifty percent of the snags fell after ten years and 78% fell after 22 years. The highest rate of fall occurred between 3 and 14 years. Snags in this study tended to uproot rather than break off incrementally.

Everett, R., J. Lehmkuhl, R. Schellhaas, P. Ohlson, D. Keenum, H. Riesterer, D. Spurbeck. 1999. Snag dynamics in a chronosequence of 26 wildfires on the east slope of the Cascade Range in Washington State, USA. *International Journal of Wildland Fire* 9(4): 223-234.

This study was based on plots in previously burned areas and data was collected for up to 26 years post-fire. The number of immediate post-fire snags for a given plot was determined by looking at stumps, down logs and remaining snags. Snags were considered down to 6 ft. (1.8m) in height. The authors pointed out that these methods may not account for all post-fire snags (especially small diameter snags). The fall rates for snags in older fires were estimated from data gathered on more recent fires. Species included in the study were Engelmann spruce, Douglas fir, subalpine fir, western larch, whitebark pine, grand fir, ponderosa pine, silver fir, and western red cedar. Snags fell rapidly between 3 – 15 years post-fire for all species. Small diameter snags (<9" DBH) of thin-barked species such as lodgepole pine fell at a lower rate than small diameter snags of thick-barked species such as Douglas fir and ponderosa pine. Large diameter snags (> 9" DBH) of thin-barked species fell at a lower rate than large diameter snags of thick barked species with the exception lodgepole pine, which fell at the same rate as Douglas fir. Larger size classes of Douglas fir snags had a lower fall rate (50% after 15 years for snags > 16" DBH) than smaller size classes of Douglas fir snags (50% after 7-12 years for snags < 9" DBH) and the lowest fall rates found in the study. No significant difference was found for lodgepole pine among different size class and there was not enough data to compare different size classes of ponderosa pine. Douglas fir and ponderosa pine tended to decline incrementally with top breakage, whereas thin-barked species like lodgepole pine tended to fall entirely near the base.

Harrington, M.G. 1996. Fall rates of prescribed fire-killed ponderosa pine. USDA Forest Service, Intermountain Research Station, Research Paper INT-RP-489, Ogden, UT: 7 p.

This study documented fall rates of fire-killed ponderosa pine in southwestern Colorado. The majority of snags were between 4 to 11 inches DBH and diameter was not significant in fall rates. The snags were evaluated for 10 years post-fire. The probability of fire-created snags falling was largely determined by 2 factors: 1) the percent crown scorch and 2) the amount of time it took for a tree to die after injury by fire. Trees that died within the first year and had greater than 80% crown scorch had an 82% probability of falling within 10 years after the fire. Trees with less than 80% crown scorch, yet died within the first year had a 75% probability of falling. Trees with less than 80% crown scorch that survived for 2-3 years post-fire had a 27% probability of falling within the 10-year period. In addition, trees that died within the first year had a higher probability of imminent failure than those that initially survived but died in subsequent years. The author concluded that 75-80% of trees that die in the first post-burn year will fall within 10 years. Trees that provide extended use as snags will be those with moderate to low crown scorch that remain alive for at least 2 years post-fire.

Keen, F.P. 1955. The rate of natural falling of beetle-killed ponderosa pine snags. *Journal of Forestry* 53(10): 720-723.

Keen (1995) studied the fall rates of bark beetle-killed ponderosa pine in northern California and southern Oregon for 30 years. Snags had an average diameter of approximately 24" and were considered down if they broke off below 20 ft. in height. Larger snags stood longer than smaller snags and all snags combined had a half life of about 7 years. The half life is defined as the number of years required for half of the snags in a given sample to fall. Large diameter trees likely had more heartwood that resisted stem decays. Few trees fell the first two years and 85% of dead trees were still standing after 5 years. Snags began to fall rapidly in year 5 and continued at a high rate until year 15. After 10 years, 40% were still standing and after 25 years 10% were still standing. Snags lasted longer on pumice soils (half life 9-10 years) than on loam soils (half life 6-7 years). Trees with pitchy butts, those on dry sites, and those charred and "case-hardened" by fire were the last "ghost trees" still standing in areas where beetle epidemics had occurred decades before.

Landram, M.F, W.F. Laudenslayer, and T. Atzet. 2002. Demography of snags in eastside pine forests of California. USDA Forest Service, General Technical Report, PSW-GTR-181. 16p.

This study was conducted over a period of 9 years on snags in northeastern California on the Modoc and Lassen National Forests and in Lassen Volcanic National Park. It included ponderosa pine, Jeffrey pine, white fir, western juniper, incense cedar and lodgepole pine snags. The snags observed in the study were located in plots and included both the initial number of snags and any new snags that occurred over the nine year observation period. The half life for snags of pine species was about 6 years. White fir snags tended to stand longer, with a half life of about 8 years. The average annual snag fall rates were lower for larger diameter trees (> 15” DBH) for ponderosa pine, Jeffrey pine and white fir. The annual fall rate was defined as the number of snags falling in a given year expressed as a percentage of snags that were present at the beginning of the year. The authors found that Jeffrey and ponderosa pines tended to fall over entirely and white fir tended to break off incrementally.

Lyon, J. 1977. Attrition of lodgepole pine snags on the Sleeping Child Burn, Montana. United States Department of Agriculture, Forest Service, Research Note INT-219, Ogden, Utah.

Lodgepole pine snag attrition the first two years following fire was negligible (~ 1%). Nearly half of the snags fell within 10 years and only 31% were still standing after 15 years. For snags 3 – 12” DBH, the fall rate was variable, but averaged an annual rate of 8.6%.

Mitchell, R.G., and H.K. Preisler. 1998. Fall rate of lodgepole pine killed by the mountain pine beetle in central Oregon. *West. J. Appl. For.* 13:23–26.

This study looked at 5 – 16” DBH bark beetle-killed lodgepole pine snags on pumice soils in both thinned and unthinned stands. Smaller DBH trees (8” average DBH) fell at a faster rate than larger diameter trees (16” average DBH). Snags began falling after 3 years in thinned stands and after 5 years in unthinned stands. The fall rate was higher in thinned stands. This may be due to greater wind penetration within the stand or warmer soil temperatures leading to increased spread of decay. All trees broke off at ground line.

Parks, C.G., D.A. Conklin, L. Bednar, and H. Maffei. 1999. Woodpecker use and fall rates of snags created by killing ponderosa pine infected with dwarf mistletoe. USDA For. Serv. Res. Pap. PNW-RP-115. 11 p.

Snags in this study were created by mechanical girdling or heat girdling (burning piled slash around the tree bole). Snags killed by mechanical girdling generally broke at the girdle while heat girdled trees most often fell as a whole, breaking off below ground. Heat girdled trees fell at a faster rate than mechanically girdled trees but the mechanically girdled trees took longer to die. The actual fall rates after mortality were similar for both treatments. Fewer larger diameter trees fell over a nine year period than smaller diameter trees for both treatments (36% >16” DBH and 50% <16” DBH for mechanically girdled trees and 64% >16” DBH and 83% <16” DBH for heat girdled trees).

Raphael, M.G. and M. L. Morrison. 1987. Decay and dynamics of snags in the Sierra Nevada, California. *Forest Science* 33(3): 774-783.

This study was conducted in northeastern California on the Tahoe National Forest and included Jeffrey pine, lodgepole pine, white fir and red fir snags down to 5 feet in height. Snags were located in plots and included both the initial number of snags and any new snags that occurred over the five year observation period. Fifty-seven percent of snags of all species fell over a period of five years. Fall rates were highest for red fir and lowest for white fir. Some of the snags included in the study were from burned plots. Snags created by fire fell at a higher rate than bark beetle-killed snags. The authors suggested that fire-killed snags in large fires may be more prone to wind throw than snags protected by live trees. Larger diameter snags (>20" DBH) fell at roughly half the rate of smaller diameter ones for all species. The exception was lodgepole pine, where the difference in fall rates between size classes was minimal but slightly lower for large diameter trees.

Russell, R.E., V.A. Saab, J.G. Dudley and J.J. Rotella. 2006. Snag longevity in relation to wildfire and postfire salvage logging. *Forest Ecology and Management* 232, p. 179-187.

This study followed ponderosa pine and Douglas-fir snag longevity in both salvaged and unlogged wildfire areas that occurred in western Idaho. Snags were considered down to 9" (23cm) DBH and 4.5 ft. (1.37m) in height. Douglas-fir snags had a predicted half-life of 12-13 years in salvaged areas and 15-16 years in unlogged areas. Ponderosa pine snags had a predicted half-life of 7-8 years in salvaged areas and 9-10 years in unlogged areas. These differences in longevity in salvaged versus unlogged wildfire areas is likely due to the snags in salvaged areas having a smaller average diameter and shorter height than in unlogged areas. No significant difference was found for snags with similar characteristics, including DBH, between treatments. For both treatments, larger diameter snags and snags occurring in denser stands remained standing longer. Authors recommend leaving larger snags and leaving snag patches during salvage operations to promote greater snag longevity.

Schmid, J.M., S.A. Mata and W.F. McCambridge. 1985. Natural falling of beetle-killed ponderosa pine. USDA For. Serv. Res. Note RM-454. 3 p.

Snags in this study were ponderosa pine in the Colorado Front Range killed by mountain pine beetle. No snags fell in the first two years. Thereafter, the fall rate averaged about 3 – 5% per year, unless winds exceeded 75 miles per hour. Wind storms were the primary cause of snag failure. Most snags fell between years 4 and 10 and broke off within 2 feet of ground level.

The USDA Forest Service, Forest Health Protection, Missoula Field Office, Report 2000-13, "Survivability and Deterioration of Fire-Injured Trees in the Northern Rocky Mountains, A Review of the Literature, was referenced for this report and is a good source of information on the deterioration of fire-killed trees.

Appendix A. Quick reference to results of individual studies.

Bark Beetle-killed Snags

In all tables the column heading "Fall Rate (half life in years)" is the number of years required for half of the snags in a given sample to fall

Table 1. Bull 1983 (NE Oregon)

Species	# of Trees	# of Years Observed	DBH Range (inches)	Fall Rate	Fall Rate (half-life in years)	Differences in Fall Rate by DBH	Years Until First Snags Fell
PP	186	8	<10-20+	50% after 8 years	8	Larger DBH fell at lower rate	3
LP	50	8	<10-20+	38% after 8 years	6-8	Larger DBH fell at lower rate	3

Table 2. Keen 1955* (NE California)

Species	# of Trees	# of Years Observed	DBH Range (inches)	Fall Rate	Fall Rate (half-life in years)	Differences in Fall Rate by DBH	Years Until First Snags Fell
PP	4634	30	10-50+	90% after 30 years	6-9	Larger DBH fell at lower rate	Few fell before 5 years

**Difference in fall rates observed between snags on pumice and loam soils.*

Table 3. Raphael and Morrison 1987* (NE California)

Species	# of Trees	# of Years Observed	DBH Range (inches)	Fall Rate	Fall Rate (half-life in years)	Differences in Fall Rate by DBH	Years Until First Snags Fell
JP	396	5	5 – 21+	58% after 5 years	~4	Larger DBH fell at lower rate	N/A
LP	137	5	5 – 21+	58% after 5 years	~4	Larger DBH fell at lower rate	N/A
WF	387	5	5 – 21+	51% after 5 years	5	Larger DBH fell at lower rate	N/A
RF	183	5	5 – 21+	70% after 5 years	~3	Larger DBH fell at lower rate	N/A

**Year of tree mortality not known for this study, most snags were < 15" DBH and there are some snags included from burned areas. Defined snags as dead trees > 1.5m in height.*

Table 4. Landram et al 2000* (NE California)

Species	# of Trees	# of Years Observed	DBH Range (inches)	Fall Rate	Fall Rate (half-life in years)	Differences in Fall Rate by DBH	Years Until First Snags Fell
JP	1599	9	5-30 +	6.8%/year	6	Larger DBH fell at lower rate	N/A
PP	999	9	5-30 +	6.9%/year	6	Larger DBH fell at lower rate	N/A
WF	994	9	5-30 +	3.7%/year	8	Larger DBH fell at lower rate	N/A
WJ	84	9	5-30 +	2.3%/year	17	N/A	N/A
LP	50	9	5-30 +	3.8%/year	11	N/A	N/A
IC	43	9	5-30 +	2.5%/year	N/A	N/A	N/A

**Year trees died not known, other agents may have caused mortality such as root disease and drought. The annual fall rate is based on the population of trees at beginning of each year.*

Table 5. Mitchell and Preisler 1998 (Oregon)

Species	# of Trees	# of Years Observed	DBH Range (inches)	Fall Rate	Fall Rate (half-life in years)	Differences in Fall Rate by DBH	Years Until First Snags Fell
LP thinned	152	15	8-16	13%/year 90% after year 12	7	Larger DBH fell at lower rate	3
LP unthinned	450	15	8-16	10%/year 90% after year 14	9	Not significant	5

Table 6. Schmid et al 1985* (Utah)

Species	# of Trees	# of Years Observed	DBH Range (inches)	Fall Rate	Fall Rate (half-life in years)	Differences in Fall Rate by DBH	Years Until First Snags Fell
PP	84	10	7-22	3-5%/year	9-10	Not significant	2

**Average DBH of study trees was approximately 10-11 inches.*

Fire-killed Snags

Table 7. Chambers and Mast 2005* (Arizona)

Species	# of Trees	# of Years Observed	DBH Range (inches)	Fall Rate	Fall Rate (half-life in years)	Differences in Fall Rate by DBH	Years Until First Snags Fell
PP	1678	3 and 7	4 - 35	14% after 3 years 41% after 7 years	~8-9	Larger DBH fell at lower rate	N/A

**Defined snags as dead trees > 1.8m in height. Data collected from two fires that burned four years apart.*

Table 8. Dahms 1949 (Oregon)

Species	# of Trees	# of Years Observed	DBH Range (inches)	Fall Rate	Fall Rate (half-life in years)	Differences in Fall Rate by DBH	Years Until First Snags Fell
PP	212	22	~24	50% after 10 years 78% after 22 years	10	Larger DBH fell at lower rate	N/A

Table 9. Lyon 1977* (Montana)

Species	# of Trees	# of Years Observed	DBH Range (inches)	Fall Rate	Fall Rate (half-life in years)	Differences in Fall Rate by DBH	Years Until First Snags Fell
LP	223	15	3 to 12	36% after 5 years 69% after 15 years	9	Not significant	2

**Some subalpine fir, Douglas-fir and Engelmann spruce were included in the study. Only lodgepole data were considered in this table. Trees less than 3" DBH were mostly subalpine fir and trees > 12" were a mix of Douglas-fir and Engelmann spruce.*

Table 10. Harrington 1996* (SW Colorado)

Species	# of Trees	# of Years Observed	DBH Range (inches)	Fall Rate	Fall Rate (half-life in years)	Differences in Fall Rate by DBH	Years Until First Snags Fell
PP	123	10	1.5 – 15.0	92% after 10 years	~5-6	Not significant	3

**Most study trees were between 4 -11" DBH.*

Table 11. Everett et al 1999* (Washington)

Species	# of Trees	# of Years Observed	DBH Range (inches)	Fall Rate	Fall Rate (half-life in years)	Differences in Fall Rate by DBH	Years Until First Snags Fell
DF	N/A	26	1 – 16+	N/A	7-15	Larger DBH fell at lower rate	~2-3
PP	N/A	26	1 – 16+	N/A	7-12 (small DBH)	Not enough data for large trees	~2-3
LP	N/A	26	1 – 16+	N/A	7-15	Not significant	~2-3

**Retrospective study of old burns, many species covered but only DF, PP, and LP included in table. Number of snags and status reconstructed and extrapolated from plot data.*

Table 12a. Russell et al 2006 (Idaho), NO SALVAGE LOGGING*

Species	# of Trees	# of Years Observed	DBH Range (inches)	Fall Rate	Fall Rate (half-life in years)	Differences in Fall Rate by DBH	Years Until First Snags Fell
DF	390 total DF & PP	9	≥ 9	90% after 9 years	15-16	Larger DBH fell at lower rate	N/A
PP	390 total DF & PP	9	≥ 9	45% after 9 years	9-10	Larger DBH fell at lower rate	N/A

**Average DBH for ponderosa pine = ~16", Douglas-fir = ~15". The exact number of snags by species was not available.*

Table 12b. Russell et al 2006 (Idaho), SALVAGE LOGGED*

Species	# of Trees	# of Years Observed	DBH Range (inches)	Fall Rate	Fall Rate (half-life in years)	Differences in Fall Rate by DBH	Years Until First Snags Fell
DF	741 total DF & PP	11	≥ 9	85% after 11 years	12-13	Larger DBH fell at lower rate	N/A
PP	741 total DF & PP	11	≥ 9	25% after 11 years	7-8	Larger DBH fell at lower rate	N/A

**Average DBH for ponderosa pine = ~12", Douglas-fir = ~10". The exact number of snags by species was not available.*

Snags Killed by Mechanical Girdling

Table 12. Parks et al 1999* (New Mexico)

Species	# of Trees	# of Years Observed	DBH Range (inches)	Fall Rate	Fall Rate (half-life in years)	Differences in Fall Rate by DBH	Years Until First Snags Fell
PP	48	9	10 - 20	8% after 6 years 42% after 9 years	~10	Larger DBH fell at lower rate	2

**Mortality was delayed up to 3 years with this treatment.*

Snags Killed by Heat Girdling

Table 13. Parks et al 1999* (New Mexico)

Species	# of Trees	# of Years Observed	DBH Range (inches)	Fall Rate	Fall Rate (half-life in years)	Differences in Fall Rate by DBH	Years Until First Snags Fell
PP	43	9	10 - 20	40% after 6 years 77% after 9 years	~7-8	Larger DBH fell at lower rate	2

**slash piled and burned around tree base.*