Donnie, this was the basis for us using 1/2 acre plots for snags; and it's my biggest argument against using TSMRS inferred data for snags-

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HOW TO DETERMINE SNAG DENSITY

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ABSTRACT. We determined snag density with 9 types of plots and compared it with the actual known density in 5 study areas. In areas with snag densities > 0.7 snags/acre, the 1-acre plot or the factor 5 prism gave an accurate estimate of actual snag density with a reasonable amount of effort. In areas with < 0.2 snags per acre, conducting 100% complete counts took less time than the number of plots that were required to achieve the desired accuracy. Methods of quantifying snag numbers over large areas are essential to the management of this resource.

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Management of dead trees is an integral part of land management practices, particularly on public lands in the western United States. These dead trees or snags are critical habitat for those species of birds and mammals that nest in cavities. There are numerous guidelines available that prescribe the number and kind of snags required to provide habitat for a desired density of cavity nesters (Thomas et al. 1979, Brown 1985). In addition there are sophisticated models available to determine how to maintain a desired density of snags over time (Bull et al. 1980, Cimon 1983).

Unfortunately, there is little information on accurate and efficient methods of determining actual snag density in the field. This information is absolutely critical to the management of this resource. Presumably, searching 100% of the area and counting all the snags (referred to as complete count survey) is the most accurate method; however, we know of an area that was counted twice and many more snags were found the second time through than the first. It can be extremely difficult and costly to thoroughly cover a large area and find all the snags. The objective of our study was to determine an accurate and efficient method of quantifying the density of snags.

STUDY AREA AND METHODS

We selected 5 study areas in mixed coniferous forests on the Wallowa-Whitman National Forest in northeastern Oregon. Each study area was 3,000-4,000 acres in size and was comprised of stands with ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), lodgepole

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pine (Pinus contorta), and western larch (Larix occidentalis).

We searched each study area and counted all snags greater than 20 inches dbh and 20 ft tall. For each tree we recorded tree species, dbh, and height; each tree was painted to signify that it had been counted, and its location was plotted on an aerial photograph. We calculated an actual density by dividing the total number of snags in each area by the number of forested acres. Openings larger than 2 acres were excluded because they did not serve as cavity-nester habitat and rarely contained snags.

After calculating the actual density in each study area we tested 9 types of plots to determine the accuracy of each in predicting actual density. We selected 6 sizes of fixed radius plots (0.05, 0.1, 0.2, 1, 2.5, and 5 acre) and 3 types of variable radius plots using prism factors of 5, 10, and 20 (using a relaskop).

To select locations for the plots we put a 0.25-mile grid over a map of each study area and did plots at every other point, up to a total of 40 points in each study area. At these points we did each of 7 types of plots; the 2.5- and 5-acre plots were done from aerial photographs that contained the location of all snags found during our complete count surveys. Points falling in openings larger than 2 acres were excluded. For trees falling in each plot we recorded species, dbh, height, and the presence or absence of paint.

For each of the 9 plot types in each study area we calculated a mean density and variance using the 40 samples. Trees per acre (TPA) were calculated for the prism plots using the

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formula:

$$TPA = \sum \frac{\text{basal area factor}}{(\text{tree diameter})^2 \ (0.005454154)}$$

For the fixed radius plots mean density was simply the average number of trees per size of plot. Then we calculated the number of plots needed to obtain a snag density within 75% of the actual density. We used the following formula to calculate this sample size (Steel and Torrie 1960):

$$n = \frac{t^2 s^2}{d^2}$$

where t is the tabulated t value for the 95% confidence level and for 39 degrees of freedom because the initial sample size was 40 plots; s^2 is the variance of the initial sample size; and d is the half-width of the desired confidence interval (25% of the actual density). We also calculated the number of 1-acre plots necessary to come within 80, 90, and 95% of the actual density using a 80, 90, and 95% confidence level.

We also calculated the percent of trees that were not painted that we had missed during the complete count survey to determine how accurately we conducted that search.

We calculated the number of man/days it took to conduct the complete count survey in each area, and the number of man/days it would take to do all the plots required to determine snag density by each method of plot. We assumed 3 5-acre plots, 6 2.5-acre plots, or 10 of the other sized plots could be done in a 10-hour

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day with 2 hours required for travel to and from the area.

RESULTS AND DISCUSSION

From the number of painted trees we found in the plots, we calculated that we located 96% of the snags in all study areas during our complete count surveys. However, it can be extremely difficult to obtain high accuracy in complete count surveys over large areas.

In areas with a snag density of > 0.7 snags/acre (study areas A and B) the data from the plots that were 1-acre or larger and the factor 5 plots provided the most accurate estimate of the actual density and required the fewest number of plots (Table 1). The 2.5- and 5-acre plots required more time to complete, thus it was more efficient to use 1-acre or factor 5 plots. More plots were required with the 0.2-acre and factors 10 and 20 plots; however, these were still cheaper in terms of man/days than complete count surveys (Table 2). Table 3 is a matrix showing how the confidence level and the degree of accuracy selected affects the number of plots required to estimate snag density.

In areas with a snag density < 0.2 snags/acre (study areas C, D, and F), fewer man/days were required to conduct complete surveys than to conduct the required number of plots (Tables 1 and 2). In these areas with few snags no sampling method worked well, and complete count surveys were done fairly quickly because of the lack of snags. However, if a complete count survey is conducted it is absolutely essential to have quality control checks as it is possible to be grossly off in snag density. If there is some question as to reliability of the crew, it is safer to do 1-acre plots (although more expensive) as there is less opportunity for error.

The basic principle is to select a plot size or prism factor that detects a fairly large number of snags. Larger plots detected more snags; therefore, the variance was lower and fewer plots were needed to get closer to the actual density. The smaller plots and higher prism factors detected very few snags, particularly in study areas with low snag densities, and consequently required many more plots to achieve the desired accuracy in snag density.

Conducting varible radius plots with a relaskop was faster than measuring out the fixed radius plots. However, visibility of snags was a problem with the relaskop because some large trees should have been detected up to 150 ft away with a factor 5 prism, yet often they could not be seen. In this case, the distance from the plot center to the tree was measured as well as the dbh, and we checked tables to see if the tree should be counted. If an area has a high density of live trees limiting visibility of snags, prisms should not be used.

RECOMMENDATIONS

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We recommend using 1-acre or factor 5 plots to determine snag density in a large area (several thousand acres) where it is known that the snag density is > 0.7 snags/acre. The logistics of conducting 2.5-acre and 5-acre plots are somewhat difficult because of their large size and the more time required to do them; thus we do not recommend them. The number of plots required depends on how even the distribution of snags is; fewer

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plots are required if snags are distributed fairly evenly. We found one plot for every 15-23 acres was adequate with a 95% confidence level and a 25% confidence interval for snag density when areas surveyed were 3,208-3,411 acres in size. Different confidence intervals and levels can be selected and a number of plots determined from the formula using a preliminary sample of snag plots. In areas where snags are scarce (< 0.2/acre), we recommend complete count surveys. However, it is absolutely essential to have quality control checks as it is possible to be grossly off in snag density.

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Table 1. Number of plots required to estimate snag density to within 75% of the actual density in 5 study areas with different densities of snags. This number includes the 40 plots in each initial sample.

	Study Area				
	A	B	C	D	E
Snag density (No./100 acres)	109	70	18	15	7
No. forested acres	3,411	3,208	3,325	3,305	3,280
Fixed radius plots					
5-acre plot	65	193	198	332	681
2.5-acre plot	71	172	257	296	917
1-acre plot	151	143	646	622	1,243
0.2-acre plot	710	573	3,577	--	8,392
0.1-acre plot	1,188	1,240	5,092	--	33,448
0.05-acre plot	2,883	3,774	--[a]	--	133,634
Variable radius plots					
5-factor prism	225	164	869	506	2,980
10-factor prism	407	236	1,293	477	7,390
20-factor prism	512	620	3,051	--	25,564

[a] No snags occurred in the 40 plots.

Table 2. Number of man/days required to determine snag density by complete count survey and 7 different plot methods.

	Study Area				
	A	B	C	D	E
Snag density (No./100 acres)	109	70	18	15	7
No. forested acres	3,411	3,208	3,325	3,305	3,280
Complete count	78	59	37	24	10
Fixed radius plots					
5-acre plot	22	64	66	111	227
2.5-acre plot	12	29	43	49	153
1-acre plot	15	14	65	62	124
0.2-acre plot	71	57	358	--[a]	839
0.1-acre plot	119	124	509	--	3,345
0.05-acre plot	288	377	--	--	13,363
Variable radius plots					
5-factor prism	23	16	87	51	298
10-factor prism	41	24	129	48	739
20-factor prism	51	62	305	--	2,556

[a] No snags occurred in the 40 plots.

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Table 3. Number of 1-acre plots required in study area A to estimate snag density within 80-95% of the actual density using 80-95% confidence levels. These numbers include the 40 plots in the initial sample.

Confidence Interval of Snag Density	Confidence Level		
	95%	90%	80%
Margin of Error			
5%	2,989	2,086	1,265
10%	747	541	346
20%	224	168	117