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Distribution and Abundance of Snags in the Sagehen Creek Basin, California

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The distribution of snags by tree species in the eastern Sierra Nevada of California generally reflects the associated timber type. Where present, however, lodgepole pine (*Pinus contorta* Dougl.) forms a large proportion of the snags present. Few snags of any species were present in the Jeffrey pine (*P. jeffreyi* Grev. & Balf. in A. Murr.) timber type in a study at Sagehen Creek Basin, in Nevada County. Simple regression analysis showed weak but significant relationships between snag density and canopy height, canopy cover, and slope. Multiple regression analysis were also weak, but revealed that snag density increased as size of natural openings increased. These results indicate that most snags in the study area were formed by the action of water (i.e., meadows, creeks) and fire. Thus, managers could concentrate snag surveys (and protective measures) near water and natural openings. Management of riparian areas is especially important because such areas are usually readily accessible to the public (e.g., fuelwood cutters). Aerial photography should be useful in locating areas of highest snag density; regression analysis appears to be of marginal usefulness.

Retrieval Terms: snags, fuelwood, regression analysis, coniferous forests, Sierra Nevada, California

The National Forests have established guides for the retention of standing dead trees, or snags. These guides were developed because of the dependence of numerous species of wildlife on snags for roosting and nesting,[1,2] and because snags are subject to removal in response to demands for fuelwood, disease control, and reduction of potential safety hazards.

Before a Forest can determine if established guides are being met, the land base must be surveyed. It would be desirable, therefore, to use methods that are inexpensive, while at the same time yielding a reasonably accurate picture of the distribution and abundance of snags.

Using data collected during a study of snags and habitat characteristics in the Sagehen Creek Basin, Nevada County, California, we sought to develop regression models that predict the most likely areas to direct survey efforts for snags. The models could be based on an existing data base (e.g., vegetation survey), or one that can be collected rapidly (e.g., from aerial photographs).

This note describes a statistical approach to predicting the distribution and abundance of snags in the eastern Sierra Nevada of California. Regression analyses done in this study are of marginal usefulness, but can be used to identify general trends in snag density and can be applied to any suitable existing data base. Future studies should concentrate efforts in areas of highest snag abundance. These areas can be identified by using aerial photographs and a general knowledge of the landscape. A more cost-effective approach would be to center survey efforts in and around openings and water. Results of the study can help resource managers design future surveys based on study and site-specific problems.

STUDY AREA

Field work was done at the Sagehen Creek Field Station of the University of California, Berkeley, located on the Tahoe National Forest, Nevada County, California. The Sagehen Creek Basin encompasses about 3500 ha at 2000- to 3000-m elevations on the east side of the Sierra Nevada crest. The Basin is characterized by second-growth mixed-conifer—primarily Jeffrey pine (*Pinus jeffreyi* Grev. & Balf. in A. Murr.), and white fir (*Abies concolor* [Gord. & Glend.] Lindl.)

Brush fields and conifer plantations, resulting from the 1960 Donner Ridge fire, cover the eastern quarter of the Basin. Small patches of red fir (*Abies magnifica* A. Murr.) are found at higher elevations. Meadows, lodgepole pine (*Pinus contorta* Dougl.), and quaking aspen (*Populus tremuloides* Michx.) grow in wet areas and along springs and streams.[2]

METHODS

We sampled snags in 15 parallel transects installed by following the Universal Transverse Mercator (UTM) grid system

Table 1—*Variables used to characterize habitat in 10-m-radius plots surrounding transect grid points in the Sagehen Creek Basin*

Variable	Description
Forest type	Predominate tree species and habitat condition (e.g., lodgepole pine, riparian).
Canopy height	Mean height of canopy tree species (m); visually estimated.
Canopy cover[1]	Percent of sky occluded by tree canopy; visually estimated.
Shrub cover[1]	Percent of ground covered by shrubs; visually estimated.
Slope[1]	Percent of slope at plot center; visually estimated.
Aspect[1]	Direction slope facing in degrees with compass (coded to dummy variable for analysis).
Distance to water[1]	Distance of plot center to water; measured from aerial photographs.
Size of opening[1]	Size of natural opening (ha); measured from aerial photographs.
Distance to opening[1]	Distance of plot center to opening; measured from aerial photographs.
Number of snags[1]	Number of snags > 1.5 m tall and > 8 cm d.b.h.

[1]Variable entered in multiple regression analysis.

previously established in the Basin. Transects were 600 m apart on a north-south heading; permanent grid points had been marked at 200-m intervals along each transect. We established additional transects parallel to, and 200 m away from, the permanent UTM transects; grid points were also marked at 200 m intervals along each new transect. These additional transects were used to increase sampling effort to a total of 435 grid points.

During spring and summer 1983, we counted snags (>1.5 m tall and > 8 cm d.b.h.) and characterized habitat in 20-m- and 10-m-radius plots, respectively, surrounding each grid point (*table 1*). Habitat and snag characteristics were summarized by individual timber types occurring in the Basin. Although the Basin has been previously categorized by timber type,[2, 3, 4] we defined our own timber types based on our transect surveys (which were more extensive than previous studies). Our terminology, however, generally follows that of Raphael and White:[2] timber types were based on the predominant tree species (e.g., Jeffrey pine) or mix of species (e.g., Jeffrey pine-white fir), and the general habitat condition (e.g., edge, meadow) *within* a single plot.[5]

Simple (r) and multiple (R) regression (with stepwise inclusion of variables) analyses were used in an attempt to relate the number of snags to the habitat characteristics occurring in each plot. One member of a pair of redundant variables (i.e., variables with $r > 0.6$) was removed before multiple regression analysis (*table 1*). Standard errors (S.E.) of the multiple regression models were calculated (i.e., prediction error).[6] Preliminary regression models were also evaluated for two-way interactions between some independent variables.[7] Statistical analyses were conducted using appropriate programs in the Statistical Package for the Social Sciences,[7] version 9.[8]

RESULTS

The species of snag present in a plot generally reflected the composition of the surrounding timber or timber type (*table 2*). Lodgepole pine snags, however, formed a large part of two timber types.The lodgepole pine-riparian type contained about 90 percent lodgepole pine snags. In the mixed-conifer type, lodgepole comprised about 31 percent of the snags (but lodgepole comprised only about 13.1 percent of the live basal area). A nearly even mixture of red fir and white fir snags was found in the white fir-pine timber type. The red fir-white fir type was dominated, however, by red fir snags. The few snags in the Jeffrey pine type were almost evenly distributed between Jeffrey pine and white fir.

Simple regression analysis between habitat characteristics and the density of snags showed weak but significant correlations (r) for canopy height, canopy cover, and slope when all timber types were combined (*table 3*). By individual timber type, the density of snags increased as canopy height and canopy cover increased for mixed-conifer, lodgepole pine-riparian, and white fir-pine. This relationship held for canopy cover in the red fir-white fir type. The density of snags decreased as shrub cover increased in the lodgepole pine-riparian type, and increased as slope increased in the mixed conifer and Jeffrey pine types.

For all timber types combined, multiple regression analysis showed that the number of snags increased as size of an opening increased; this relationship was statistically significant ($P < 0.02$) but very weak ($R^2 = 0.05$; S.E. = 1.20). By in-

Table 2—*Density (no./ha) and relative frequency of snags by species for major timber types occurring in Sagehen Creek Basin. Values are snag density (pct)*

Timber Type	Snag Species					
	Unknown	Jeffrey pine	Lodgepole pine	Red fir	White fir	TOTAL
Mixed-conifer	1.8 (5.0)	7.4 (21.0)	10.8 (31.0)	6.2 (17.0)	8.5 (24.0)	34.7
Jeffrey pine	—	3.0 (44.0)	0.2 (2.0)	0.2 (2.0)	3.4 (50.0)	6.8
Red fir-white fir	0.8 (0.0)	2.1 (2.0)	0.1 (0.0)	75.2 (92.0)	2.8 (3.0)	81.0
Lodgepole-riparian	0.9 (2.0)	—	33.7 (91.0)	1.6 (4.0)	0.7 (1.0)	36.9
White fir-pine	0.2 (1.0)	2.3 (13.0)	1.6 (9.0)	5.8 (34.0)	6.9 (40.0)	16.8
Total	3.7 (2.0)	14.8 (8.0)	46.4 (26.0)	89.0 (50.0)	22.3 (12.0)	

Table 3—*Simple correlation coefficients (r) between number of snags and habitat characteristics for timber types in the Sagehen Creek Basin (n = number of study plots)*[1]

Habitat Characteristic	Mixed-conifer (n = 158)	Jeffrey pine (n = 35)	Red fir-white fir (n = 89)	Lodgepole-riparian (n = 71)	White fir-pine (n = 66)	Overall (n = 431)
Canopy height (m)	0.22**	0.21	0.15	0.35**	0.24*	0.24**
Canopy cover (pct)	0.27**	0.03	0.23*	0.39**	0.37**	0.29**
Shrub cover (pct)	0.2	0.28	0.11	−0.45*	−0.54	−0.03
Slope (pct)	0.16*	0.32*	−0.01	0.05	0.18	0.11*
Aspect	−0.01	0.21	0.06	−0.04	−0.14	−0.03
Distance to water (m)	0.09	0.20	−0.13	0.01	0.11	0.01
Distance to opening (m)	0.04	−0.13	−0.14	0.11	−0.09	−0.05
Size of opening (ha)	−0.10	−0.18	0.06	0.10	−0.12	−0.04

*$P < 0.5$; **$P < 0.01$; $P > 0.05$ = nonsignificant.
[1]Includes burned and edge habitats in each timber type.

dividual timber type only the multiple regression analysis for the mixed-conifer type (excluding burned and edge habitats)—where the density of snags increased with an increasing size of an opening—was also statistically significant (R^2 = 0.24, $P < 0.02$; S.E. = 0.45); other variables entering the model added little predictive power. No significant ($P >$ 0.1) interactions were found to affect model results.

DISCUSSION AND CONCLUSIONS

The positive relationship between the density of snags and canopy cover is likely a reflection of live stem density. That is, if canopy cover reflects stem density, then more stems potentially can become snags. The increase in density of snags as slope increases may reflect increasing harshness of the site as slopes increase and soils thin. Steeper slopes in the Sagehen Creek Basin tend to be near rocky ridgetops. In the lodgepole pine-riparian type, the negative relationship between density of snags and shrub cover likely reflects the fact that most lodgepole snags are located along the edge of or in water and meadows. These snags are created as the stream shifts direction and floods, and as meadows and other wet areas expand and contract—such areas usually have little shrub cover relative to the surrounding drier slopes.

The weak but positive and significant relationship between the size of natural openings and number of snags is clearly related to the effects of fire and water. Openings in the Basin are created by flooding and wet depressions. In addition, snags have been created on several occasions by natural and human-caused fires (most notably, the 1960 Donner Ridge fire that burned about 16,000 ha). These fires have created large openings throughout the Basin that become brush fields with numerous standing trees killed by the fire; these trees become a concentrated source of snags. We found a relationship between snag density and the distance from openings and water (*table 4*). About 54 percent of all snags in the Basin were located within 75 m of an opening. The two timber types with the lowest snag density—Jeffrey pine and white fir-pine—also were lo-

Table 4—*Distribution of snags by distance from natural openings for the Sagehen Creek Basin, Nevada Co., California*

Distance from opening (m)	Timber type[1] MC	JP	RF-WF	LP-R	WF-P	Overall
	Percent					
0	12.3	13.3	22.9	6.0	2.1	11.2
>0–25	21.5	10.0	14.5	44.0	5.0	24.4
25–50	10.3	0.0	3.9	16.9	0.0	8.1
50–75	7.3	10.0	12.3	4.2	23.6	10.3
75–100	2.3	3.3	3.9	3.6	5.0	3.2
100–125	6.9	6.7	8.4	4.8	2.9	5.6
125–150	2.3	0.0	5.6	1.2	0.0	2.1
150–175	3.4	20.0	1.7	13.3	12.9	6.9
175–200	4.2	0.0	3.4	3.0	14.3	5.0
200–250	7.7	10.0	9.5	1.8	10.0	6.8
250–300	5.7	0.0	3.9	0.0	13.6	4.9
>300	16.0	26.6	10.2	1.2	10.6	10.1

[1]MC = mixed conifer; JP = Jeffrey pine; RF-WF = red fir-white fir; LP-R = lodgepole pine-riparian; WF-P = white fir-pine.

Table 5—*Number of 20-m-radius plots surveyed for snags in the Sagehen Creek Basin, Nevada Co., California. Values in parentheses are percent of column total*

	Timber type[1] (No. plots)									
	JP		RF-W		MC		LP-R		WF-P	
Plot location	Plots	Pct	Plots	Pct	Plots	Pct	Plots	Pct	Plots	Pct
≤ 100 m water	5	(13.5)	7	(7.4)	29	(17.1)	44	(50.0)	8	(11.1)
≤ 100 m opening	7	(18.9)	29	(30.5)	54	(31.8)	26	(29.5)	16	(22.2)
> 100 m of opening or water	25	(67.6)	59	(62.1)	87	(51.2)	18	(20.5)	48	(66.7)
Total[2]	35		89		158		71		66	

[1]MC = mixed conifer; JP = Jeffrey pine; RF-WF = red fir-white-fir; LP-R = lodgepole pine-riparian; WF-P = white fir-pine.

[2]Total plots surveyed; does not result directly from column total, because some plots were both near water and near large openings.

cated the farthest from openings (and water) in the Basin (compare *tables 2* and *5*).

Our results indicate that, insofar as they are applicable to areas outside of the Sagehen Creek Basin, forested lands within 100 m of water (e.g., meadows, streams, and other wet depressions) and natural openings should be surveyed for snags and carefully managed to retain an adequate density for wildlife. Guides concerning the number and size of snags required by wildlife are reported elsewhere.[2,5] Management of riparian areas, for example, is extremely important given that streams are often readily accessible to the fuelwood cutters using roads established for recreational purposes. The relatively few snags located away from openings and water are less subject to removal because of their inaccessibility. Further, timber salvage following forest fires should be designed so a high density of snags (relative to areas located away from openings and water) is retained.

These results should be significant to the forest manager. Guides established for snag retention in the Tahoe National Forest, for example, apply to *all* lands, not just those close to water and openings. The Sagehen Creek Basin has been protected from heavy fuelwood removal relative to areas outside the Basin (because of its use as a research area; fuelwood has been removed from the Basin over the years, however). Therefore, we would expect a higher density of snags on lands away from water and openings in the Basin relative to areas elsewhere. But given the low snag density we found on areas away from water and openings, this difference indicates that managers can concentrate their efforts to locate and manage snags in areas that are easy to identify—water and openings. Management of snags in readily identifiable areas will be easier than trying to dilute protection/management efforts over an entire forest.

Our analyses were simplified in that we did not subdivide our data by the size of the snag (d.b.h.). But others have found a strong relationship between d.b.h. and the use of snags for nesting by cavity nesting birds.[1, 2, 5] Therefore, when considering our recommendations, resource managers should attempt to retain the largest snags available (i.e., > 40 cm d.b.h.) for use as nest and roost sites by birds.

Our objective—the establishment of simple statistical models for predicting the distribution and abundance of snags—was only partially met by this analysis. While some weak correlations were found, it is apparent that the density of snags in the Sagehen Creek Basin is primarily a function of "nonhabitat" factors. It appears, however, that the areas identified as of highest potential for snags—burns, meadows, and other natural openings—may be easily identified using, for example, aerial photographs. Initial surveys could then be focused in areas of highest potential for snags. Analyses of snags in these areas will likely result in the greatest percent of snags coming under a management scheme. The distribution of snags in areas of secondary potential—dense canopies—could then be selected for surveying (using, for example, aerial photographs). Alternatively, areas with low snag density could be identified so the remaining snags in these locations could be surveyed and managed.

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