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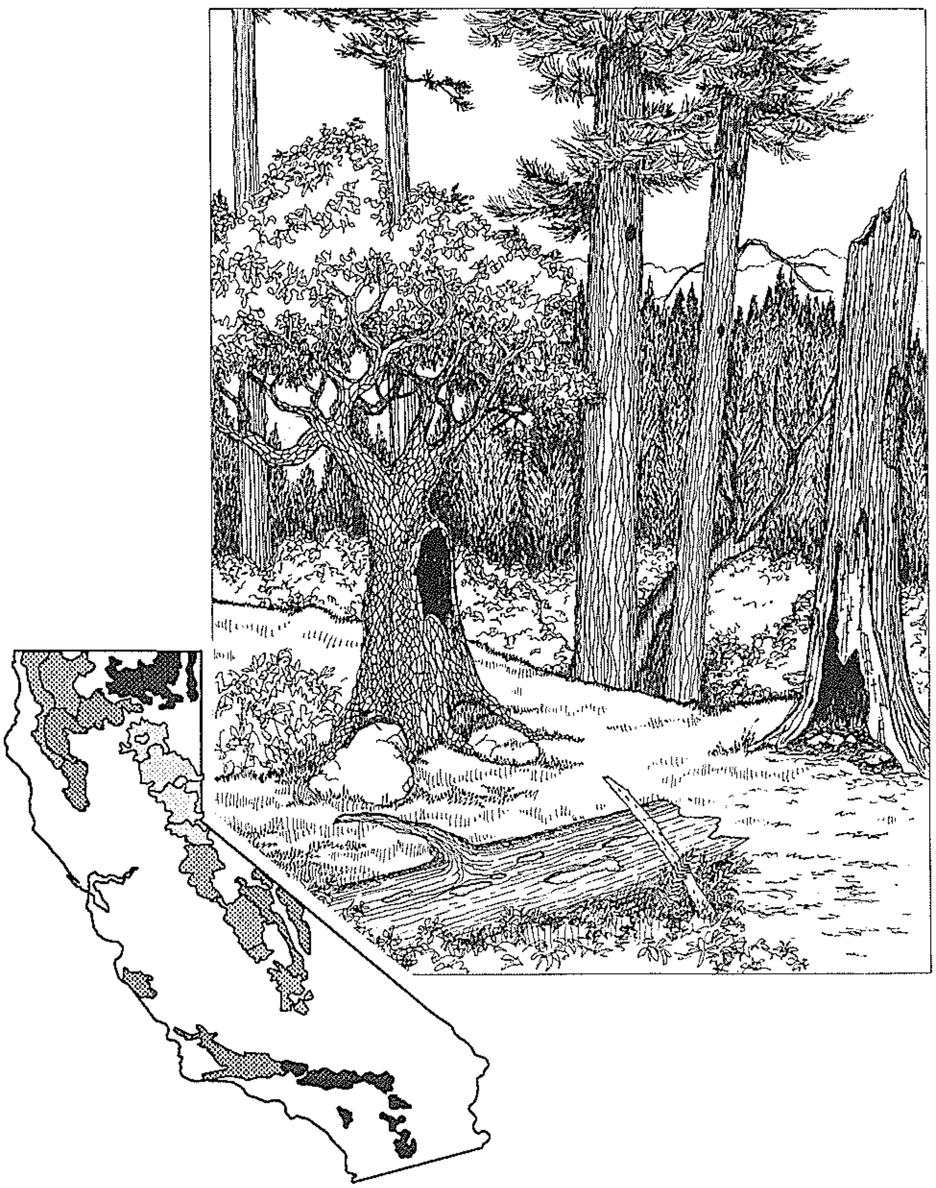
Snag Densities in Old-Growth Stands on the Gasquet Ranger District, Six Rivers National Forest, California

Thomas M. Jimerson



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Baseline levels for densities of snags (standing dead trees) were determined in undisturbed old-growth stands on the Gasquet Ranger District, Six Rivers National Forest, California. Snag species, number, diameter at breast height (d.b.h.), height, cavity type, cavity use, decay class, and snag origin were recorded on 317 plots over a 2-year period. The 2121 snags recorded consisted of *Pseudotsuga menziesii* (36 percent), *Abies concolor* (29 percent), *Abies magnifica* var. *shastensis* (7 percent), *Pinus lambertiana* (4 percent), *Chamaecyparis lawsoniana* (6 percent), hardwoods (10 percent), and other conifers combined (7 percent). Snags were categorized as large, medium or small. Large snags were characterized as snags ≥ 20 inches d.b.h. and ≥ 50 feet tall, the medium snags as snags ≥ 20 inches d.b.h. and 20-50 feet tall and the small snags as all other snags > 5 inches d.b.h. and ≥ 1 foot tall that did not qualify as large or medium snags. The snag densities for each category were then determined for each of the following conifer series: *Lithocarpus densiflora/Pseudotsuga menziesii, Chamaecyparis lawsoniana, Abies concolor* and the *Abies magnifica* var. *shastensis*. The snag densities for all four series combined in each category were 2.07 large snags/acre, 1.94 medium snags/acre and 20.67 small snags/acre.

Retrieval Terms: snags, old-growth, forest management, California, Pacific Northwest

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Snags (standing dead trees) and logs are an important component of forest wildlife habitat and are considered a distinctive characteristic of old-growth forests. Many of the terrestrial vertebrates found in forests live or depend on snags and logs. A knowledge of baseline snag densities is required in order to manage this important resource.

This study determined baseline levels for snag densities in undisturbed old-growth stands on the Gasquet Ranger District, Six Rivers National Forest, California. Stratified random sampling with a nested sub-plot design was used to sample snag species, number, diameter at breast height (d.b.h.), height, cavity type, cavity use, decay class, and snag origin on 317 plots throughout the study area over a 2-year period.

Snags were categorized as large, medium or small, based on their importance to wildlife. The snag densities for each category were then determined for each of the following conifer series: *Lithocarpus densiflora/Pseudotsuga menziesii, Chamaecyparis lawsoniana, Abies concolor* and *Abies magnifica* var. *shastensis*. In general, snag densities follow a moisture or elevation gradient or both. Snag densities were found to vary by category and conifer series; however, this difference was not statistically significant for all categories. The snag densities for all four series combined in each category were 2.07 large snags/acre, 1.94 medium snags/acre and 20.67 small snags/acre.

The total number of snags recorded was 2121. *Pseudotsuga menziesii* comprised 36 percent of the total, with *Abies concolor* contributing 29 percent, *Abies magnifica* var. *shastensis* 7 percent, *Pinus lambertiana* 4 percent, *Chamaecyparis lawsoniana* 6 percent, hardwoods 10 percent, and other conifers combined 7 percent. Snag characteristics are presented for each conifer series and species. *Pseudotsuga menziesii* had the highest representation of snags and the best hard-to-soft snag ratio 40:60 which indicates a constant rate of decay and suggests that *Pseudotsuga menziesii* snags should be retained over other species.

These data will be combined with data on use by cavity-nesting birds to develop snag retention guidelines for the Six Rivers National Forest.

INTRODUCTION

Old-growth conifer forests in the Pacific Northwest are valued economically for their timber and as wildlife habitat (Harris 1984). Snags (standing dead trees) and logs are an important component of this wildlife habitat (U.S. Dep. Agric. 1986), and large snags are considered as one of the distinctive features of old-growth forests (Franklin and others 1981). Ninety percent of the terrestrial vertebrates that exist in our forests live or depend on such coarse woody debris (Franklin [in press]). Snags provide habitat for foraging, nesting, resting or cover for many species of wildlife (Thomas and others 1979). Characteristics of snags, including state of decay, density, size, and species, influence their use by wildlife (Mannan and others 1980, Maser and others 1979, Raphael 1980). For example, soft snags are most often used for nesting whereas hard snags are most often used for foraging. In addition, the diameter at breast height and height of snags determine which species will use a snag for nesting (Thomas and others 1979).

Many research programs have focused upon old-growth Douglas-fir forests because they are a major vegetation type in the Pacific Northwest (Franklin and others 1981, Mannan and others 1980, Cline and others 1980) and particularly because intensive timber management tends to eliminate older stands, eliminate dead and dying trees, and remove snags as fire and safety hazards (Thomas and others 1979). These management strategies conflict with the goals of managing snags as wildlife habitat. Clear-cut logging, salvage logging, and short harvest rotation periods adversely alter or eliminate the potential of a timber stand to retain or produce snags (Mannan and others 1980).

The National Forests in the Pacific Southwest Region have established guidelines for the retention of snags (*table 1*). These guidelines are based on the work of Thomas and others (1979) in the Blue Mountains of Oregon. The guidelines are not specific to California and should be supplemented with site-specific information when possible. For example, the Tahoe National Forest modified Thomas and others' (1979) guidelines on the basis of the work of Raphael and White (1984). However, for many of the National Forests in California, information on baseline snag density and of snag management effects on snag-dependent wildlife is inadequate. To date, few studies examining snag densities by conifer series and vegetation types have been attempted.

Table 1—*USDA Forest Service guidelines for the retention of snags in the Pacific Southwest Region*

Direction for snag-dependent species
Within each timber compartment, provide, maintain, and manage, to the extent possible, for an average of 1.5 snags per acre with the following specifications:
(1) 1.2 snags per acre that are 15-24 inches d.b.h. and higher than 20 feet;
(2) 0.3 snags per acre that are greater than 24 inches d.b.h. and higher than 20 feet.
Other requirements for snag distribution (e.g., hard-to-soft ratios) will be included in Forestwide standards and guidelines, prescriptions, or management area direction in the Forest plan.

This paper reports baseline snag densities for the primary conifer series of the Gasquet Ranger District, Six Rivers National Forest, and describes snag characteristics by conifer series and species. The data generated by this study will be used by Six Rivers National Forest personnel to develop snag retention guidelines for the Forest.

STUDY AREA

The study was conducted on the Gasquet Ranger District in Del Norte County about 8 miles (13 kilometers) east of Crescent City (*fig. 1*). It includes about 249,000 acres (101,000 hectares) of primarily coniferous forest (U.S. Dep. Agric. 1976). The Gasquet Ranger District is characterized by warm dry summers and cool wet winters. It ranges in elevation from 100 to 6000 feet (30-1800 meters).

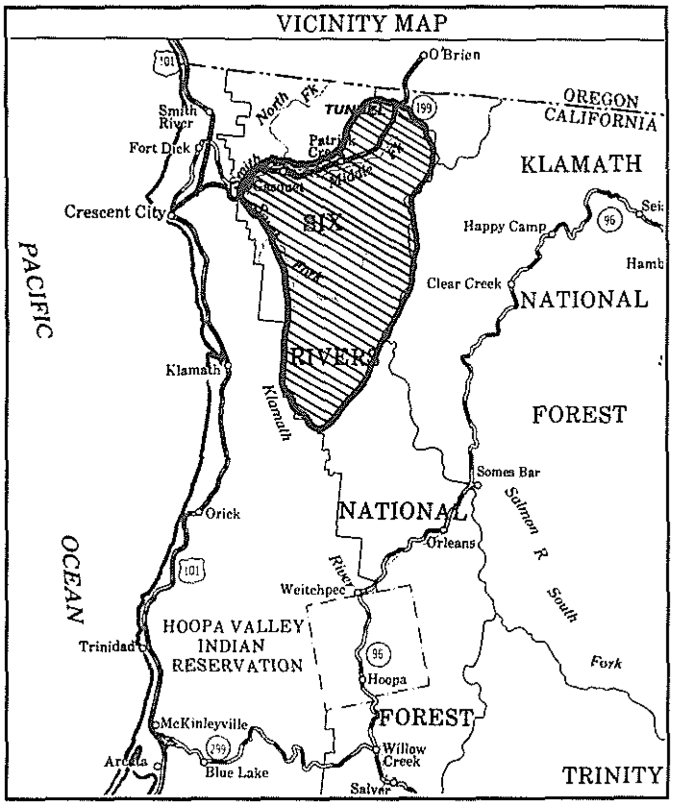

Figure 1—The Six Rivers National Forest in Northern California with the study area crosshatched.

The vegetation in the study area includes four conifer series (*fig. 2, table 2*). 1) The Port-Orford-Cedar (*Chamaecyparis lawsoniana* (A. Murr.) Parl.) series is located along the stream bottoms. 2) The tanoak/Douglas-fir (*Lithocarpus densiflora* (H. and A.) Rehd./*Pseudotsuga menziesii* (Mirb.) Franco.) series begins at the bottom of the slopes and continues upslope to approximately 4000 feet (1200 meters). 3) The white fir (*Abies concolor* [Gord. and Glendl.] Lindl.) series replaces the tanoak/Douglas-fir series above 4000 feet (1200 meters), and 4) the red fir (*Abies magnifica* A. Murr. var. *shastensis* Lemmon) series replaces the white fir series at the top of the highest mountains (*fig. 2*). Small pockets of Jeffrey pine (*Pinus jeffreyi* Grev. and Balf.), lodgepole pine (*Pinus contorta* Dougl.), and knobcone pine (*Pinus attenuata* Lemmon) are found throughout the study area, but were not sampled because of their limited extent and lack of management.

METHODS

This study was conducted in conjunction with the USDA Forest Service's ecosystem classification program (Allen 1987) being conducted on the Six Rivers National Forest. Late seral-stage stands (old-growth) were selected as study sites. Old-growth stands were located through a review of timber type maps (U.S. Dep. Agric. 1976) and verified through analysis of aerial photos and ground reconnaissance. Sample stands were selected by using the methodology of Pfister and Arno (1980). This methodology was modified to include only stands older than 150 years that displayed all or most of the characteristics

Table 2—*Approximate acreage for each conifer series in the study area*

Conifer series	Approximate acres	Pct
Tanoak/Douglas-fir	210,000	84
Port-Orford-Cedar	5,000	2
White fir	27,000	11
Red fir	2,000	1
Other[1]	5,000	2
Total	249,000	100

[1]Contains Jeffrey pine, lodgepole pine, and knobcone pine.

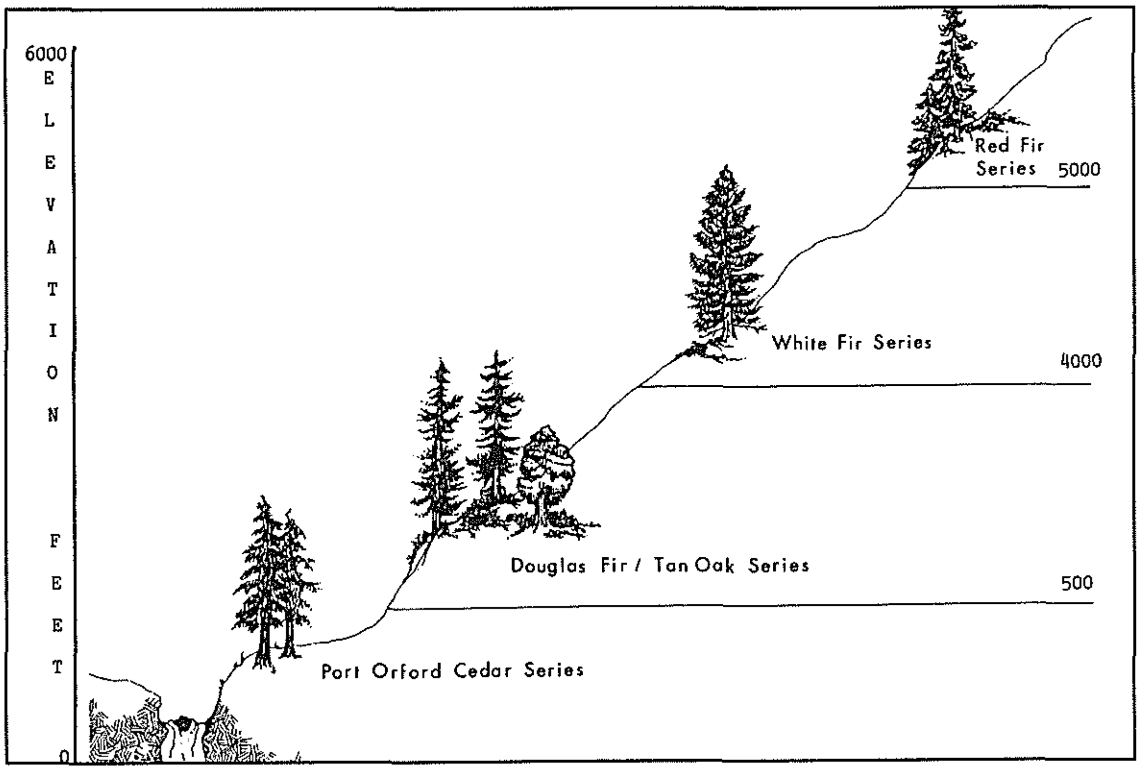

Figure 2—Relative positions of each conifer series within the study area.

defined by Franklin and others (1981) and the Old-Growth Definition Task Group (1986). Within selected stands, stratified random sampling was used to select the plot locations following the methodology of Noon (1981), which included placing non-overlapping plots within all distinct habitats within a stand. In watersheds with few remaining old-growth stands, all remaining stands were sampled. In designated wilderness areas in which the majority of the area is in old-growth stands, transects were located perpendicular to the slope with plots located every 300 feet (80 meters). Approximately 2 percent of the acreage in old-growth stands in the study area was sampled.

To determine the appropriate plot size, the pertinent literature on snag sampling was reviewed. The review indicated that plot sizes generally fell into three categories: large, medium, and small. These categories generally reflected the objectives of the particular study. The large plot category included the 21-acre (8.5-hectare) plots of Raphael and White (1984), 7.5- to 37-acre (3-15 hectare) plots of Gale (1973), 25- to 37-acre (10-15 hectare) plots of Cunningham and others (1980), and the 12-acre (5-hectare) plots of Marzluff and Lyon (1983). The medium plot category included the plots of Brush and others (1983) [2.5-acre (1-hectare) plots], Morrison and others (1986) [0.25-acre (0.1-hectare) plots], Carmichael and Guynn (1983) [0.25-acre (0.1-hectare) plots], and Cline and others (1980) [1.2-acre (0.5-hectare) plots]. The small plot category included several studies using a 0.1-acre (0.04-hectare) plot (Cline and others 1980, Mannan and others 1980, McComb and Muller 1983, Moriarty and McComb 1983, Morrison and others 1986, Swallow and others 1986).

The literature review indicated that the 0.1-acre plot was the preferred size for this type of study. However, because the studies that used the 0.1-acre plot were not conducted in northwest California, pre-study sampling was conducted. This sampling involved counting snags within plots of various sizes. We determined that adequate numbers of snags would be included in each plot if two nested study plots of 0.5 and 0.25 acres were used. The plot size of 0.5 acre was used to examine snags ≥20 inches in diameter at breast height (d.b.h.) and ≥50 feet tall (large snags). The 0.5-acre plot size was selected instead of the standard 0.1-acre plot size because of the low densities of large snags in the study area and their importance to wildlife (Bull and Meslow 1977, McClelland and Frissell 1975). A plot size of 0.25 acre was used to examine all snags with a d.b.h. >5 inches and >1 foot tall (small snags) that did not meet the requirements of large snags.

The following characteristics were recorded for all snags: (1) species; (2) d.b.h., measured with a diameter tape to the nearest inch (for snags <4.5 ft. tall, d.b.h. was estimated); (3) decay class (five decay classes according to Cline and others 1980); (4) height, measured directly with a tape or estimated with a Relaskop to the nearest foot; (5) cavities (presence of excavated nest cavities and presence and use of natural cavities in root, butt, or midbole of tree); and (6) origin (snag originated in previous or current stand of timber, or tree was cut). Decay classes 1 and 2 were considered hard snags, whereas decay classes 3 through 5 were considered soft snags. For the purpose of this study, snags were defined as standing dead trees >5 inches d.b.h. and >1 foot tall. In addition, snags were divided into three descriptive categories (large, medium, and small) on the basis of guidelines on snag retention, from the Pacific Southwest Region, USDA Forest Service, and the literature. Large snags are ≥ 20 inches d.b.h. and ≥50 feet tall (Mannan and others 1980, Bull and Meslow 1977), medium snags are ≥ 20 inches d.b.h. and 20-50 feet tall, and small snags are > 5 inches d.b.h. and do not meet the requirements of large or medium snags.

Presence of excavated cavities in snags was considered a sign of previous or current use of snags by wildlife. Use of natural cavities in snags by wildlife was determined by direct observation of animals in cavities or by inference. Use by inference was determined by an accumulation of scat or nesting material, or scratchings, scraping, clearing, or exposing of soil or bark.

The statistical program SPSS/PC+ (Norusis 1986) generated statistics mean, frequency, mode, density, standard deviation, and standard error.

RESULTS

Study Area (All Series Combined)

Data were collected at 317 plots, which contained 2121 snags. Snag densities for the total study area were highest for small snags, followed by large snags and medium snags (*table 3*).

Snags were composed primarily of conifer species; *Pseudotsuga menziesii* (36 percent) was the dominant species, followed by *Abies concolor* (29 percent), *Abies magnifica* var. *shastensis* (7 percent), *Chamaecyparis lawsoniana* (6 percent), and *Pinus lambertiana* (4 percent). Hardwoods made up 10 percent of the snags, most of which were found in the small-snag category (*table 4*).

The small-snag category had the largest number of trees (1638). The mean d.b.h. was 14 inches with a mean height of 18 feet. The small-snag category was dominated by *Pseudotsuga*

Table 3—*Snag summary for all conifer series combined, on 317 plots*

Snag size	Snags	Mean D.b.h.	Mean Height	Density	Standard deviation	Standard error
		in.	*ft.*	*snags/acre*		
Large[1]	328	32	94	2.07	1.49	0.08
Medium[2]	155	26	37	1.94	0.81	0.05
Medium + Large	483	30	75	4.01	4.92	0.28
Small[3]	1638	14	18	20.67	5.12	0.29

[1]Large snags are ≥ 20 inches d.b.h. and ≥ 50 feet tall.
[2]Medium snags are ≥ 20 inches d.b.h. and 20-50 feet tall.
[3]Small snags are all other snags that do not meet the requirements for large or medium snags.

Table 4—*Snag species composition summary for the study area, N=2121*

Species	Large snags		Medium snags		Small snags		Total	
	No.	*Pct*	*No.*	*Pct*	*No.*	*Pct*	*No.*	*Pct*
Pseudotsuga menziesii	155	47	79	51	521	32	755	36
Chamaecyparis lawsoniana	29	9	8	5	88	5	125	6
Abies concolor	55	17	39	25	502	31	596	29
Abies magnifica var. *shastensis*	27	8	7	4	110	7	144	7
Pinus lambertiana	44	13	8	5	41	3	93	4
Pinus monticola	11	3	6	4	38	2	55	3
Libocedrus decurrens	3	1	0	0	17	1	20	1
Unknown conifer	0	0	0	0	65	4	65	3
Hardwood	0	0	5	3	209	13	214	10
Others	4	1	3	1	47	3	54	2

menziesii, *Abies concolor*, and hardwoods. The large snag category had the second largest number of trees; it contained 328 snags with a mean d.b.h. of 32 inches and a mean height of 94 feet. It was dominated entirely by conifers, with *Pseudotsuga menziesii*, *Abies concolor*, and *Pinus lambertiana* as the primary species. The medium-snag category had the fewest snags (155). The mean d.b.h. was 26 inches and the mean height was 37 feet. The medium-snag category was primarily dominated by the conifers *Pseudotsuga menziesii* and *Abies concolor*.

The modal decay class for all snag categories in the study area was 2 (hard snags). The largest proportion of large and medium snags was found in decay class 2, followed by decay class 1 and decreasing rapidly in decay classes 3 through 5. This trend continued for the major conifer species with the exception of *Chamaecyparis lawsoniana* (*fig. 3*). In the small-snag category the proportion of snags in decay class 2 was again the highest. Hardwoods had the same proportion in each decay class, approximately 20 percent (*fig. 4*). The ratio of hard to soft snags indicates a greater proportion of snags are found in the hard category. The ratio of hard to soft snags varies by species. *Pseudotsuga menziesii* has a 40:60 ratio of hard to soft, followed by *Chamaecyparis lawsoniana* 65:35, *Abies concolor* 65:35, *Abies magnifica* var. *shastensis* 65:35, *Pinus lambertiana* 80:20, and hardwoods 45:55.

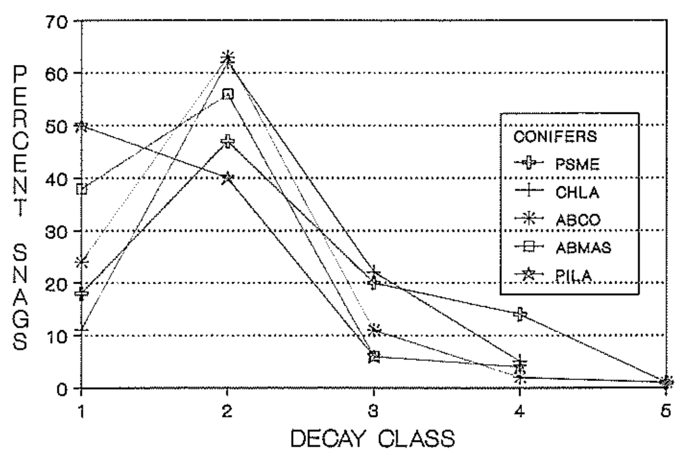

Figure 3—Percent of large and medium snags by decay class and species (PSME = *Pseudotsuga menziesii*, CHLA = *Chamaecyparis lawsoniana*, ABCO = *Abies concolor*, ABMAS = *Abies magnifica* var. *shastensis*, PILA = *Pinus lambertiana*).

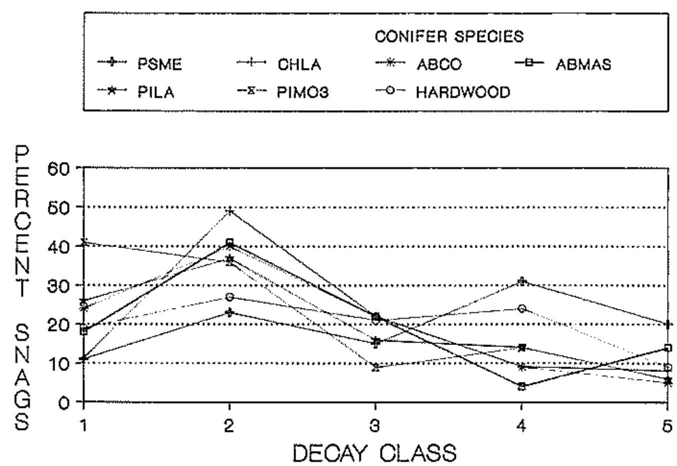

Figure 4—Percent of small snags by decay class and species (PSME = *Pseudotsuga menziesii*, CHLA = *Chamaecyparis lawsoniana*, ABCO = *Abies concolor*, ABMAS = *Abies magnifica* var. *shastensis*, PILA = *Pinus lambertiana*, PIMO3 = *Pinus monticola*).

Table 5—*Characteristics of snags in the tanoak/Douglas-fir* (Lithocarpus densiflora/Pseudotsuga menziesii) *series in 166 plots*

Snag size	Snags	Mean D.b.h.	Mean Height	Density	Standard deviation	Standard error
		in.	*ft.*	*snags/acre*		
Large[1]	130	34	100	1.57	1.11	0.09
Medium[2]	48	27	38	1.16	0.60	0.05
Medium + Large	178	32	83	2.72	3.45	0.29
Small[3]	566	14	16	13.64	3.25	0.25

[1]Large snags are ≥ 20 inches d.b.h. and ≥ 50 feet tall.
[2]Medium snags are ≥ 20 inches d.b.h. and 20-50 feet tall.
[3]Small snags are all other snags that do not meet the requirements for large or medium snags.

Table 7—*Characteristics of snags in the Port-Orford-Cedar* (Chamaecyparis lawsoniana) *series in 56 plots*

Snag size	Snags	Mean D.b.h.	Mean Height	Density	Standard deviation	Standard error
		in.	*ft.*	*snags/acre*		
Large[1]	86	32	94	3.07	1.88	0.25
Medium[2]	41	27	37	2.86	0.99	0.13
Medium + Large	127	31	74	5.93	6.59	0.88
Small[3]	350	15	20	25.00	5.09	0.68

[1]Large snags are ≥ 20 inches d.b.h. and ≥ 50 feet tall.
[2]Medium snags are ≥ 20 inches d.b.h. and 20-50 feet tall.
[3]Small snags are all other snags that do not meet the requirements for large or medium snags.

Conifer Series

The *Lithocarpus densiflora/Pseudotsuga menziesii* series contained 744 snags in 166 plots, most of which were found in the small-snag category. Densities varied from 13.64 snags/acre for small snags, to 1.57 and 1.16 snags/acre for the large- and medium-snag categories (*table 5*). *Pseudotsuga menziesii* and hardwoods were the dominant snag species (*table 6*). The modal decay class for large snags was 2, whereas the medium- and small-snag categories both had modes of 3 (*table 5*).

The *Chamaecyparis lawsoniana* series contained 477 snags in 56 plots. The small-snag category had the highest density, 25.00 snags/acre, followed by the large- and medium-snag categories, 3.07 and 2.86 snags/acre (*table 7*). *Pseudotsuga menziesii, Chamaecyparis lawsoniana* and *Abies concolor* were the dominant snag species (*table 8*). The modal decay class for the large- and small-snag categories was 2, whereas the medium-snag category had a mode of 3 or 4 (*table 7*). The *Abies concolor* series contained 596 snags in 70 plots. The small-snag category had the highest density, 26.86 snags/acre, followed by medium- and

Table 6—*Composition of snags in the tanoak/Douglas-fir* (Lithocarpus densiflora/Pseudotsuga menziesii) *series N=744*

Species	Large snags No.	Large snags Pct	Medium snags No.	Medium snags Pct	Small snags No.	Small snags Pct	Total No.	Total Pct
Pseudotsuga menziesii	102	78	40	83	297	53	439	59
Chamaecyparis lawsoniana	0	0	0	0	1	1	1	1
Abies concolor	1	1	0	0	24	4	25	3
Abies magnifica var. *shastensis*	2	2	0	0	1	1	3	1
Pinus lambertiana	19	15	3	6	30	5	52	7
Pinus monticola	2	2	0	0	3	1	5	1
Libocedrus decurrens	2	2	0	0	10	2	12	2
Unknown conifer	0	0	0	0	17	3	17	2
Hardwood	0	0	4	8	168	30	172	23
Others	2	2	1	2	15	2	18	2

Table 8—*Composition of snags in the Port-Orford-Cedar* (Chamaecyparis lawsoniana) *series N=477*

Species	Large snags		Medium snags		Small snags		Total	
	No.	*Pct*	*No.*	*Pct*	*No.*	*Pct*	*No.*	*Pct*
Pseudotsuga menziesii	33	38	21	51	130	37	184	39
Chamaecyparis lawsoniana	28	33	8	19	82	23	118	25
Abies concolor	6	7	4	10	50	14	60	13
Abies magnifica var. *shastensis*	2	2	0	0	8	2	10	2
Pinus lambertiana	16	19	4	10	6	2	26	5
Pinus monticola	1	1	3	7	11	3	15	3
Libocedrus decurrens	0	0	0	0	0	0	0	0
Unknown Conifer	0	0	0	0	20	6	20	4
Hardwood	0	0	1	2	38	11	39	8
Others	0	0	0	0	5	1	5	1

large-snag categories, 2.57 and 2.31 snags/acre (*table 9*). *Abies concolor* and *Pseudotsuga menziesii* were the dominant snag species (*table 10*). The modal decay class for all three categories was 2 (*table 9*).

The *Abies magnifica* var. *shastensis* series contained 304 snags in 25 plots. The small-snag category had a density of 40.32 snags/acre, followed by medium- and large-snag categories, 3.36 and 2.48 snags/acre (*table 11*). *Abies concolor* and *Abies magnifica* var. *shastensis* were the dominant snag species (*table 12*). The modal decay class for all three categories was 2 (*table 11*).

The *Chamaecyparis lawsoniana* series had the highest snag

Table 9—*Characteristics of snags in the white fir* (Abies concolor) *series in 70 plots*

Snag size	Snags	Mean D.b.h.	Mean Height	Density	Standard deviation	Standard error
		in.	*ft.*	*snags/acre*		
Large[1]	81	31	88	2.31	1.77	0.21
Medium[2]	45	25	36	2.57	0.93	0.11
Medium + Large	126	29	69	4.89	5.13	0.61
Small[3]	470	14	19	26.86	5.07	0.61

[1]Large snags are ≥ 20 inches d.b.h. and ≥ 50 feet tall.
[2]Medium snags are ≥ 20 inches d.b.h. and 20-50 feet tall.
[3]Small snags are all other snags that do not meet the requirements for large or medium snags.

Table 11—*Characteristics of snags in the Shasta red fir* (Abies magnifica *var.* shastensis) *series in 25 plots*

Snag size	Snags	Mean D.b.h.	Mean Height	Density	Standard deviation	Standard error
		in.	*ft.*	*snags/acre*		
Large[1]	31	32	82	2.48	1.59	0.32
Medium[2]	21	25	38	3.36	0.94	0.19
Medium + Large	52	29	64	5.84	2.23	0.44
Small[3]	252	13	19	40.32	8.42	1.68

[1]Large snags are ≥ 20 inches d.b.h. and ≥ 50 feet tall.
[2]Medium snags are ≥ 20 inches d.b.h. and 20-50 feet tall.
[3]Small snags are all other snags that do not meet the requirements for large or medium snags.

Table 10—*Composition of snags in the white fir* (Abies concolor) *series N=596*

Species	Large snags		Medium snags		Small snags		Total	
	No.	*Pct*	*No.*	*Pct*	*No.*	*Pct*	*No.*	*Pct*
Pseudotsuga menziesii	20	25	17	38	91	19	128	21
Chamaecyparis lawsoniana	1	1	0	0	5	1	6	1
Abies concolor	41	51	24	53	317	67	382	64
Abies magnifica var. *shastensis*	4	5	0	0	4	1	8	1
Pinus lambertiana	7	9	1	2	4	1	12	2
Pinus monticola	6	7	2	4	11	2	19	3
Libocedrus decurrens	0	0	0	0	2	1	2	1
Pinus attenuata	0	0	1	2	14	3	15	2
Unknown Conifer	1	1	0	0	17	4	18	3
Hardwood	0	0	0	0	3	1	3	1
Others	1	1	0	0	2	1	3	1

Table 12—*Composition of snags in the Shasta red fir* (Abies magnifica *var.* shastensis) *series N=304*

Species	Large snags		Medium snags		Small snags		Total	
	No.	*Pct*	*No.*	*Pct*	*No.*	*Pct*	*No.*	*Pct*
Pseudotsuga menziesii	0	0	1	5	3	1	4	1
Chamaecyparis lawsoniana	0	0	0	0	0	0	0	0
Abies concolor	7	23	11	52	111	44	129	42
Abies magnifica var. *shastensis*	19	61	7	33	97	38	123	41
Pinus lambertiana	2	6	0	0	1	0	3	1
Pinus monticola	2	6	1	5	13	5	16	5
Libocedrus decurrens	1	3	0	0	5	2	6	2
Unknown Conifer	0	0	1	5	11	4	12	4
Hardwood	0	0	0	0	0	0	0	0
Picea breweriana	0	0	0	0	11	4	11	4

Table 13—*Comparison of snag densities by conifer series*

Series	Large	Medium	Large + Medium	Small
	snags/acre			
Lithocarpus densiflora/				
Pseudotsuga menziesii	1.57	1.16	2.72	13.64
Chamaecyparis lawsoniana	3.07	2.86	5.93	25.00
Abies concolor	2.31	2.57	4.89	26.86
Abies magnifica var. *shastensis*	2.48	3.36	5.84	40.32

density for the large-snag category, the *Abies magnifica* var. *shastensis* series had the highest snag density in the medium-snag category, the *Abies magnifica* var. *shastensis* series had the highest density in the small-snag category (*table 13*).

The proportion of large to medium snags in each conifer series and decay class indicates that the majority of snags within the study area are included in decay class 2, followed by decay classes 1, 3, 4 and 5 (*fig. 5*). The small-snag category is more evenly distributed, with decay class 2 having a slightly higher proportion of snags (*fig. 6*). The proportion of hard to soft snags varied by conifer series in the large- and medium-snag categories. The *Chamaecyparis lawsoniana* series had a ratio of hard to soft snags of 60:40. The *Lithocarpus densiflora/Pseudotsuga menziesii* series had a ratio of 75:25, while the *Abies concolor* series had a ratio of 80:20 and the *Abies magnifica* var. *shastensis* series had a ratio of 85:15.

Snags varied in size and decay class according to species and d.b.h. Conifers dominated the large- and medium-snag categories. Hardwoods began to appear in the medium-snag category, and codominate in the small-snag category. Decay classes generally followed tree categories. Most of the large snags were found in decay class 2, whereas the number of snags in decay class 3 increased in the medium category, and decay class 4 appeared more frequently in the small-snag category (*table 14*).

Pinus lambertiana contributed the tallest snags, with a mean height of 107 feet in the large-snag category. It was followed by *Pseudotsuga menziesii* (94 feet), *Abies magnifica* var. *shastensis* (90 feet), *Chamaecyparis lawsoniana* (89 feet), and *Abies concolor* (87 feet) (*table 14*). Snag height increased by diameter class except for the 40-inch d.b.h. class (*table 15*). Decay class 2 was the modal decay class in all categories except the 40-inch d.b.h. category, for which the modal decay class was 5 (*table 15*).

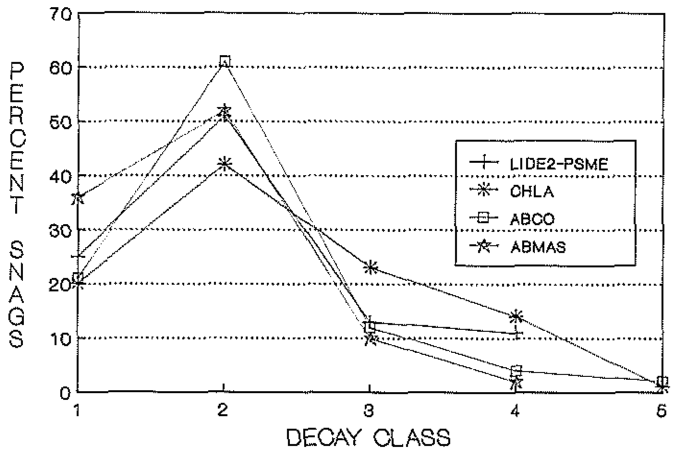

Figure 5—Percent of large and medium snags in each decay class by conifer series (LIDE2-PSME = *Lithocarpus densiflora-Pseudotsuga menziesii*, CHLA = *Chamaecyparis lawsoniana*, ABCO = *Abies concolor*, ABMAS = *Abies magnifica* var. *shastensis*).

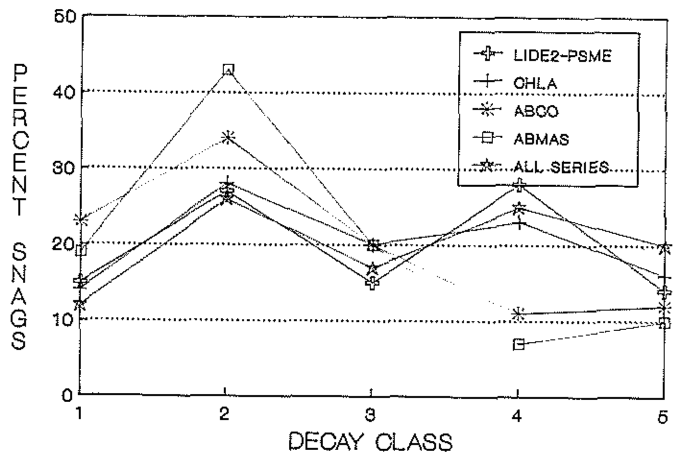

Figure 6—Percent of small snags in each decay class by conifer series (LIDE2-PSME = *Lithocarpus densiflora-Pseudotsuga menziesii*, CHLA = *Chamaecyparis lawsoniana*, ABCO = *Abies concolor*, ABMAS = *Abies magnifica* var. *shastensis*).

Table 14—*Snag species descriptions, by snag category*

Species	Large snags				Medium snags				Small snags			
	Snags	Mean D.b.h.	Mean Height	Decay class	Snags	Mean D.b.h.	Mean Height	Decay class	Snags	Mean D.b.h.	Mean Height	Decay class
Pseudotsuga menziesii	155	35	94	2	79	28	36	4	521	19	16	4
Chamaecyparis lawsoniana	29	26	89	2	8	26	35	3	88	12	26	2
Abies concolor	55	31	87	2	39	24	37	2	502	11	19	2
Abies magnifica var. *shastensis*	27	34	90	2	7	25	37	1-2	110	13	18	2
Pinus lambertiana	44	31	107	1	8	28	44	2-3	41	16	29	2
Hardwoods	0	0	0	0	5	22	32	2	209	10	13	3-4
Arbutus menziesii	0	0	0	0	1	21	45	2	43	10	15	2-3
Castanopsis chrysolepis	0	0	0	0	2	21	36	2	40	9	18	2
Lithocarpus densiflora	0	0	0	0	2	24	21	4	100	11	11	1-4
Quercus chrysolepis	0	0	0	0	0	0	0	0	10	9	12	1-4

Table 15—*Snag descriptions, by diameter class (d.b.h.)*

Diameter (D.b.h.)		Mean		Decay class				
Class	Range	N	Height	1	2	3	4	5
	in.		*ft.*	*Pct. frequency*				
2[1]	5 to 5.9	178	14	32	38	20	7	3
8	6 to 10.9	613	20	22	39	21	13	5
14	11 to 17.9	451	27	15	38	18	20	10
21	18 to 24.9	342	35	16	32	17	21	14
27	25 to 29.9	181	47	20	36	11	15	18
35	30 to 39.9	180	52	18	33	12	17	21
40	40 to 49.9	154	47	17	24	12	22	25
50+	50 to 74.9	22	103	23	68	9	0	0

[1]This diameter class normally ranges from 1 to 5.9 inches. In this study no snags were measured below 5 inches diameter.

DISCUSSION AND CONCLUSIONS

Snag densities for old-growth stands on the Gasquet Ranger District vary by snag category and by conifer series. In general, densities were highest in the small-snag category, followed by the large- and medium-snag categories (*table 13*). The small-snag category is expected to have the highest density because there were more small trees than large trees in the study stands. Also, because of competition for growing space, mortality is higher in the small-snag category. The lower density found in the medium-snag category seems to be related to the length of time since death and the decay rate of each species. Snags in the medium category are ≥20 inches d.b.h. and 20-50 feet tall. Snags included in this category could result from 1) the death of medium sized trees, 2) large snags with broken tops, or 3) the decay of large snags and associated reduction in size. The mean d.b.h. for the medium-snag category is lower than the mean d.b.h. for the large-snag category (*table 3*), thereby indicating that all three sources are probable contributors, with source 1 (death of medium sized trees) as the primary contributor.

In general, snag densities of conifer series follow a moisture or elevation gradient or both. The *Chamaecyparis lawsoniana* series has the highest overall snag densities. This series is located near streams with perennial water, which enables it to maintain a high density of stems.[1] The *Abies magnifica* var. *shastensis* series had the second-highest snag densities. It is located at the tops of the mountain peaks, on the upper third of the slope; here moisture and stand density (Davis and Johnson 1987) are higher than the locations of all other series except the *Chamaecyparis lawsoniana* series. The *Abies concolor* series has the third-highest snag density. It is located just below the *Abies magnifica* var. *shastensis* series, in the upper two thirds of the slope, where the amount of moisture drops with decreasing elevation along with stand density. The *Lithocarpus densiflora*/*Pseudotsuga menziesii* series is located in the lower one third of the slope. It had the lowest snag density and also the lowest stand density (Davis and Johnson 1987).

Snag densities also vary by category within a conifer series. These differences are related to the reproductive strategies employed by the dominant conifer species. The *Lithocarpus densiflora*/*Pseudotsuga menziesii*, *Chamaecyparis lawsoniana*, *Abies concolor*, and *Abies magnifica* var. *shastensis* conifer series follow a reproductive tolerance gradient (Sawyer and Thornburgh 1977). Reproduction in the *Lithocarpus densiflora*/*Pseudotsuga menziesii* series is the least tolerant to shading. Within this series, regeneration takes place primarily in the gaps left by falling trees or in openings created by fire or logging. Next in tolerance is the *Chamaecyparis lawsoniana* series, in which regeneration takes place under the forest canopy or in openings. The *Abies concolor* series is next in tolerance. It regenerates under the forest canopy and is distributed across the forest floor. The most tolerant series is the *Abies magnifica* var. *shastensis*. Reproduction takes place in thick clumps in small or large openings or is spread thinly throughout closed canopy stands. These varying reproductive strategies lead to the differences noted in small-snag densities (*table 13*).

[1]Unpublished data on file at Six Rivers National Forest, Eureka, Calif.

The composition of snag species was determined for the 2121 snags recorded. *Pseudotsuga menziesii* was the most important snag contributor because of its dominance or codominance within all conifer series except the *Abies magnifica* var. *shastensis* (Sawyer and Thornburgh 1977, Sawyer and others 1977). *Pseudotsuga menziesii* was followed by *Abies concolor*, which had high numbers and was also represented in all four series. *Abies concolor* was found in the higher-elevation portions of the *Lithocarpus densiflora*/*Pseudotsuga menziesii* series, the lower-elevation portions of the *Abies magnifica* var. *shastensis* series, in which it is a codominant conifer, in limited numbers in the *Chamaecyparis lawsoniana* series, and throughout the *Abies concolor* series in which it is the dominant conifer (Sawyer and Thornburgh 1977). Hardwoods had the next largest number of snags; they are found primarily in the *Lithocarpus densiflora*/*Pseudotsuga menziesii* series, in which they often codominate with *Pseudotsuga menziesii* (Sawyer and others 1977). Hardwood species were important snag contributors in the small-snag category only. *Abies magnifica* var. *shastensis* contributed the next largest number of snags. It was found in the higher elevation portions of the *Abies concolor* series, in which it can be a codominant, and throughout the *Abies magnifica* var. *shastensis* series in which it is the dominant conifer (Sawyer and Thornburgh 1977). *Abies magnifica* var. *shastensis* was followed closely in snag contribution by *Chamaecyparis lawsoniana*. *Chamaecyparis lawsoniana* was found primarily in its own series, which is of limited geographic extent in the study area (*table 2*). The smallest numbers of snags contributed by a major conifer species came from *Pinus lambertiana* (*fig. 3*). It was found in the *Lithocarpus densiflora*/*Pseudotsuga menziesii* series in which it can be a codominant conifer (Sawyer and others 1977) and in the *Chamaecyparis lawsoniana* series in which it is a minor forest component.

The process of change from decay class 1 through decay class 5 is related to the decay rate of wood. The principal organisms responsible for decay are fungi, insects, and bacteria (U.S. Dep. Agric. 1974). The rate of decay is influenced by climate, elevation, aspect, tree size, percent sapwood and tree species (Kimmey 1955). A resistance to decay rating of the principal conifer species shows that *Chamaecyparis lawsoniana* is rated as resistant or very resistant to decay. It is followed by *Pseudotsuga menziesii* and *Pinus lambertiana*, which are moderately resistant to decay, whereas *Abies concolor* and *Abies magnifica* var. *shastensis* are slightly or nonresistant to decay (U.S. Dep. Agric. 1974, Kimmey 1955). Decay state is very important to cavity-nesting birds. Excavation of cavities does not begin until the snags reach decay class 2 (Mannan and others 1980, Cline and others 1980) probably because the snags in decay class 1 are too hard for excavation (Mannan and others 1980).

A comparison of percent snags in each decay class by conifer series indicates small differences between series (*figs. 5 and 6*) which are due to the different decay rates and species composition of each series, whereas an examination by conifer species indicates much larger differences (*fig. 3*). *Chamaecyparis lawsoniana* is rated as resistant to decay (U.S. Dep. Agric. 1974). It has its lowest proportion of snags in decay class 1 and its highest proportion in decay class 2 (*fig. 3*). After reaching decay class 2, the decay rate seems to increase (*fig. 3*). The ratio of hard to soft snags is 2:1, indicating a slow decay rate during decay classes 1 and 2, and a more rapid decay rate in classes 3 through 5. *Pseudotsuga menziesii* is rated as moderately resistant to decay (U.S. Dep. Agric. 1974). It had the most even distribution throughout all decay classes (*fig. 3*), and the best ratio of hard to soft snags, 40:60. This ratio indicates a constant rate of decay across all decay classes, suggesting that *Pseudotsuga menziesii* should be selected over other snag species. *Pinus lambertiana* is also rated as moderately resistant to decay (U.S. Dep. Agric. 1974). Proportionately, the largest number of its snags appear in decay class 1. The proportion shows a moderate decrease in decay class 2, and a large drop in decay classes 3 through 5. The ratio of hard to soft snags is 4:1, which indicates that once the *Pinus lambertiana* snags reach decay class 2, they decay rapidly until they disappear from the stand (*fig. 3*). The results of this study indicate that *Pinus lambertiana* is less resistant to decay than *Pseudotsuga menziesii*. Both *Abies concolor* and *Abies magnifica* var. *shastensis* are rated as slightly or nonresistant to decay (U.S. Dep. Agric. 1974). Both have smaller proportions in decay class 1 and show their highest proportions in decay class 2 (*fig. 3*). The ratios of hard to soft snags for both species are approximately 2:1. The small proportion of soft snags indicates a limited time spent in decay classes 3 through 5. Kimmey (1955) found that *Abies concolor* snags decay rapidly and are not salvageable after 4 years. His findings, along with the results of this study, indicate that these species have limited longevity as snags.

Although snag age was not determined, the proportions of snags in each decay class indicate that snag longevity is greatest in decay class 2 since the proportion of all snags with the exception of *Pinus lambertiana* is highest here. Decay classes 3-5 contain smaller, decreasing numbers of snags for all species. In addition, snag longevity is influenced by size (Kimmey 1955). For the large- and medium-snag categories, the proportions of hard snags are much greater than soft snags for all conifers. The data indicate that snags decay slower in the large and medium categories and there are fewer soft snags. The importance of this soft-snag component to cavity-nesting birds (Thomas and others 1979, Mannan and others 1980, Cline and others 1980) indicates a need to maintain soft snags in higher proportions than hard snags.

The implication of this study for managers is that snag management must be site-specific because snag densities vary by conifer series and snag category, and snags decay at different rates.

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