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Tree Growth in Thinned and Unthinned White Fir Stands 20 Years After a Douglas-Fir Tussock Moth Outbreak

Boyd E. Wickman

Abstract

Twenty-year postoutbreak growth was compared in thinned and unthinned, severely defoliated stands. Basal area of unthinned white fir has declined 37 percent and pine basal area has increased 32 percent since 1964. The stand thinned in 1960 has the lowest basal area in the study area, but the greatest tree growth before and after the outbreak. All defoliated fir are growing significantly faster during the 16 years after the outbreak compared to before the outbreak. Thinned stands, even though not resistant to defoliation, may be able to recover more rapidly and to a much greater magnitude than unthinned stands after an outbreak.

Keywords: Thinned stands, unthinned stands, tree growth, Douglas-fir tussock moth, defoliation.

Introduction

In 1964-65, the Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough), caused heavy defoliation of white fir, *Abies concolor* (Gord. and Glend.) Lindl., over thousands of acres in northeastern California. Scattered patches of saplings and pole-sized trees were completely stripped of needles. By late summer 1964, tree mortality was occurring on heavily defoliated areas in the largest recorded outbreak in California history: 76,000 acres in five infestation centers. Stough[7] (Stowe) Reservoir was one of those infestation centers and, although the smallest, it was the most intensely affected in the entire outbreak (Pierce 1964).

In.June and July 1965, 57,079 acres including 2,098 acres around Stough Reservoir were aerially treated with DDT. The combined effects of the insecticide, a natural virus, and other natural enemies halted the outbreak. But tree damage of varying degrees was obvious over a wide area (Wickman 1978).

BOYD E. WICKMAN is a research entomologist and project leader, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry and Range Sciences Laboratory, 1401 Gekeler Lane, La Grande, OR 97850.

[1] The spelling of Stowe Reservoir was changed to Stough by the Forest Service about 1980 to conform with older records for the area.

Because the infested area at Stough Reservoir was typical of a normal large outbreak in northeastern California, a tree-damage study was undertaken there in 1967 (Wert and Wickman 1970). Ten years after the infestation a second study investigated stand mortality, tree growth, and ingrowth on the seriously damaged outbreak area (Wickman 1978).

The objectives of this paper are to examine growth 20 years after the outbreak on the small area left undisturbed and compare growth of thinned and unthinned white fir stands in the outbreak area.

Study Area

Stough Reservoir (fig. 1) is 1 mile east of Cedar Pass on Highway 299 in the Warner Mountains of Modoc County, California. The Warner Mountains are an isolated range lying north-south about 100 miles long. The south portion, about 60 miles, is in California just east of Alturas; the remainder extends into Oregon. The range is in the form of a tilted block, with a steep slope along the fault on the east side. Elevations over 9,000 feet (ft) occur, but the crest of the range averages 7,000 to 8,000 ft. Cedar Pass is the lowest pass and bisects the range in the middle of the California portion. The west flanks of the Warner Mountains are heavily timbered with pine and fir. Stough Reservoir is on the drier, east flank where timber grows in scattered patches along with sagebrush and juniper.

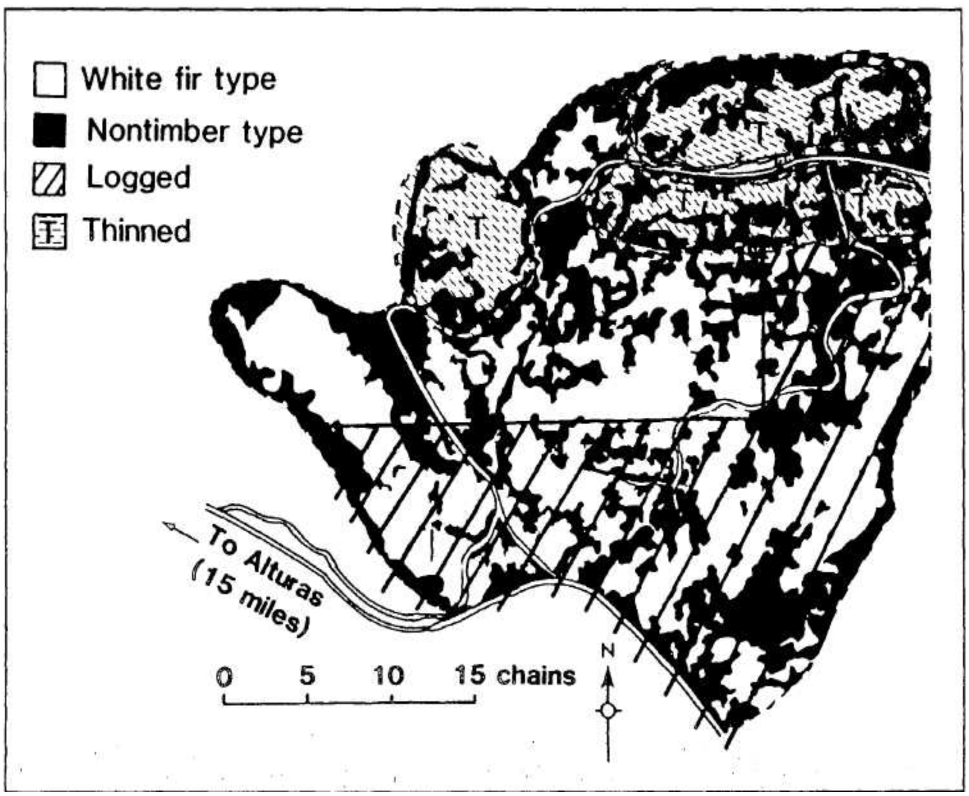

Figure 1—White fir type defoliated by Douglas-fir tussock moth and logged and thinned areas at Stough Reservoir. Adapted from Wickman (1978).

The 1964-65 tussock moth infestation occurred on 450 acres in a moderately sloping basin with mainly south and east exposures. The elevation ranges from 5,600 to 6,200 ft with higher elevations and rocky escarpments immediately to the north and west. The second-growth stand is predominantly white fir with a scattering of ponderosa pine, *Pinus ponderosa* Laws., Washoe pine, *P. washoenis* Mason and Stockwell, and at the lower elevations and southern exposures, western juniper, *Juniperus occidentalis* Hook.

The original stand was heavily logged about the turn of the century and the stumps show that a pine stand of large trees (about 36 inches diameter at breast height) covered all but the upper elevations on the west and north edges. It was logged a second time for fir overstory in all but the campground area in 1954. No fires have burned in the stand for a least 70 years and probably none since the turn of the century. White fir is now the predominant tree species, growing as scattered patches of saplings, poles, and young sawtimber throughout the basin.

Management activities since 1978 (logging, thinning and fertilizing) have drastically altered the character of the stand (fig. 1). Consequently, our planned stand examination 20 years after the outbreak could not be done with the same design or on the same scale as in 1967 and 1975.

Methods

In 1967, as part of an aerial-photography study, a crew systematically sampled the area by examining conditions on 1/50th-acre circular plots, established at 2-chain intervals along cruise lines 5 chains apart (Wert and Wickman 1970). Small-scale (1:8,000 ft) aerial photographs were used to determine cruise lines. Large-scale. (1:1,500 ft) aerial-photo coverage and data from the plots provided an estimate of preoutbreak stand conditions and total white fir damage in the area (Wert and Wickman 1970).

In 1975, using the same small-scale aerial photographs to establish cruise line locations, I repeated the examinations (Wickman 1978).

In 1985, because of the management activities mentioned earlier, only tree growth and basal area were measured on a smaller number of plots in each of the following classes: defoliated white fir (unthinned), defoliated white fir (thinned in 1960), defoliated white fir (thinned in 1980-81), pine in the defoliated unthinned area, and undefoliated white fir.

Two east-west compass lines 5 chains apart were run through the center of the defoliated unthinned area, and 40 dominant or codominant white fir and 20 dominant ponderosa pine were selected at 5-chain intervals for increment boring. Two increment cores going back to 1945 were taken at breast height on each sample tree, and basal area was measured with a 10 basal area factor prism at each of the 40 sample points.

A similar sampling scheme was used in the four blocks thinned in 1980-81. Ten trees and prism points were taken in each block. The two small plots of 0.2 and 0.6 acres thinned to about 20-foot spacing in 1960 had 20 basal area points and trees cored at random from each plot.

A check plot, to the south and adjacent to the outbreak area, had 20 basal area points and dominant or codominant white fir cored.

Results

Changes In basal area

The defoliated, unthinned white fir stand had a fir basal area of 121 square feet (ft^2) and a pine basal area of 28.6 ft^2. The defoliated white fir stand thinned in 1980-81 had a fir basal area of 126.5 ft^2 and a pine basal area of 4 ft^2. The stand thinned in 1960 had the lowest basal area (67.5 ft^2) because of wide tree spacing (about 25 by 25 ft) partly because scattered tree mortality occurred after the outbreak (table 1).

A comparison of green-stand basal area for each tree species on the unthinned defoliated stand before the outbreak (1964) and immediately after (1967), 10 years after (1975), and 20 years after (1985) is summarized in table 2. The column on the right shows the percentage difference in basal area before the outbreak and 20 years after. The white fir component of the stand declined 37 percent in basal area from tree mortality, and the ponderosa pine increased 32 percent, from 19.5 to 28.6 ft^2 in 1985. Western juniper showed a 92 percent gain in basal area consistent with the sharp upward trend found in 1975 (Wickman 1978), but the apparent gain may be because of small sample size.

Table 1—Green-stand basal area for each tree species by stand class in 1985, Stough Reservoir, California

Stand class (white fir)	Prism points	Sample tree D.b.h. (in)	Species: White fir	Ponderosa pine	Western juniper
	Number	$\bar{x}$ inches	$\bar{x}$ basal area (ft^2)		
Defoliated (unthinned)	40	18	121	28.6	12
Defoliated (thinned 1960)	40	18	67.5	0	0
Defoliated (thinned 1980-81)	40	17	126.5	4	2
Nondefoliated (unthinned control)	20	21	295	0	0

Table 2—Green-stand basaS area on the defoliated, unthinned area at Stough Reservoir, California

Species	Basal area: 1964	1967	1975	1985	± Difference 1964-85
	- - - - - - - - - Square Feet - - - - - - - -				Percent
White fir	193.2	142.0	132.4	121.0	-37
Pine[a]	19.5	18.6	16.0	28.6	+32
Western juniper	1.0	1.0	2.1	12.0	+92
Total	213.7	161.6	150.5	161.6	-24

[a] Includes ponderosa and Washoe pine.

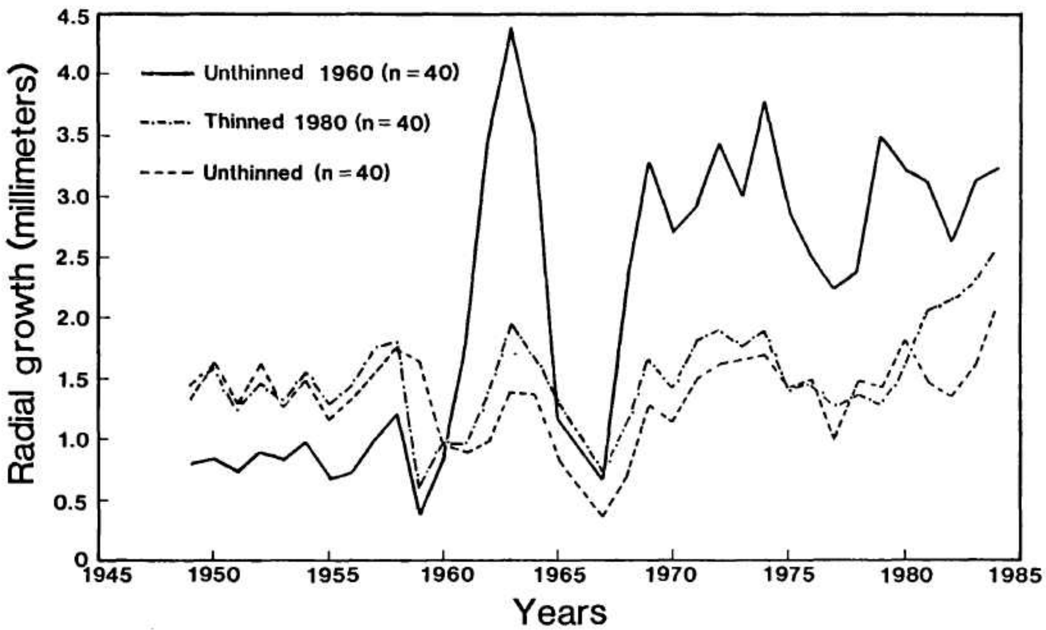

Figure 2—Average annual radial increment at d.b.h. Comparison of thinned and unthinned white fir, Stough Reservoir.

Radial growth

The pattern of radial growth in defoliated white fir stands, as measured from increment cores, for 1949 to 1984 showed the plots thinned in 1960 had the lowest growth rates from 1949-60, the highest growth from 1961-64, the greatest proportion of growth loss from defoliation from 1965-67, and the best recovery and highest growth rates since 1968 (fig. 2). The stands thinned in 1980-81 have a pattern similar to the unthinned stands before and after the outbreak, but, in 1981, growth increased sharply and is still on an upward trend (fig. 2).

Average annual growth of the nonhost pine in the unthinned defoliated stand has more than doubled since before the outbreak (fig. 3). This growth pattern is similar to that of pine 36 years after another Douglas-fir tussock moth outbreak in California (Wickman 1980). Growth of undefoliated white fir in the check area has declined slightly since the outbreak (fig. 3).

Average growth in the five tree classes for 16 years before the outbreak (1949-64) was compared with growth 16 years after it (1969-84)[2]. Paired t-tests were then made to compare growth in each of the five tree classes during these periods.

Growth of all classes except the nondefoliated host was significantly greater ($p < 0.05$ or 0.01) during the 16 years after the outbreak than before the outbreak (table 3).

[2] The outbreak was terminated by DDT treatment and natural causes in 1965, but tree growth did not return to preoutbreak rates until 1969.

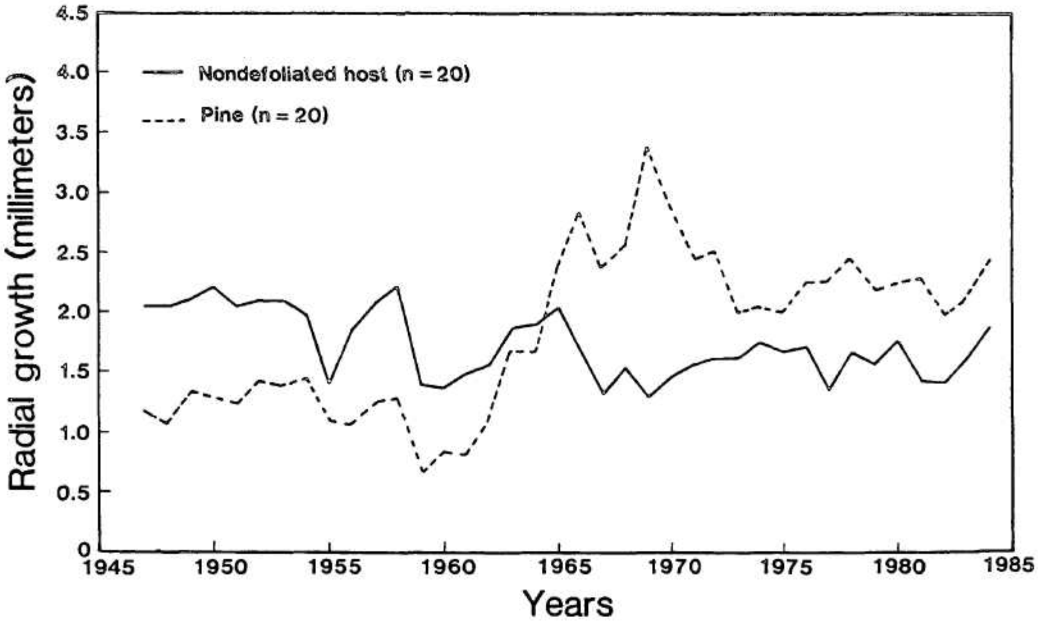

Figure 3—Average annual radial increment at d.b.h. comparison of nondefoliated white fir and pine, Stough Reservoir.

Table 3—Comparisons by paired t-tests of average radial growth In 5 tree classes before and after outbreak of the Douglas-fir tussock moth, Stough Reservoir. California

Tree class	Means of radial growth			Growth period (before vs. after)	
	Before (1949-64)	Outbreak (1965-68)	After (1969-84)		
		Millimeters		T-value	Significance
Nondefoliated white fir	1.844	1.637	1.614	1.99	NS
Nonhost (pine)	1.225	2.493	2.313	5.20	0.01
Defoliated white fir	1.296	.580	1.536	2.01	.05
Defoliated and thinned, 1960	1.382	1.216	3.074	9.47	.01
Defoliated and thinned, 1980-81	1.366	.995	1.773	4.17	.01

NS = Not significant

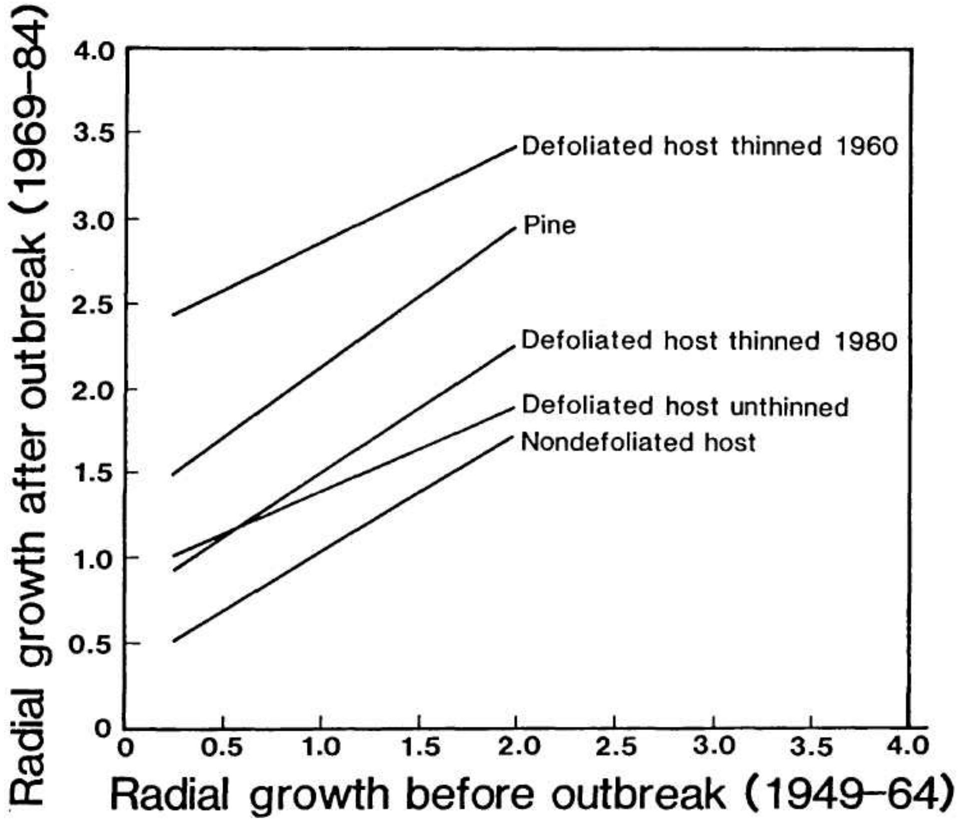

Figure 4—Comparison of radial growth before the outbreak with growth after the outbreak, Stough Reservoir.

Another comparison of growth rates with regression analysis tested whether a linear relation exists between growth before and after the outbreak and whether the relations differ among classes. These linear relations were found to be significant ($p < 0.01$ or 0.05) for every class but the white fir defoliated and thinned in 1960 (fig. 4, table 4).

The slopes and elevations of the regression lines for the five classes of trees were tested for significance by analysis of covariance (Snedecor and Cochran 1967) to determine if the classes had different relations. Difference in elevation was significant ($p < 0.01$) but not in slope (fig. 4, table 5).

Nondefoliated white fir has apparently been growing slightly slower since the outbreak, and the defoliated white fir thinned in 1960 and nonhost pine are growing much faster. The other defoliated white fir are intermediate, growing only slightly faster since the outbreak.

Table 4—Regressions of growth before (1949-64), (x), and after (1969-84), (y), growth by tree classes,

Species	n	a	b	r^2	F	p
Defoliated white fir	40	0.885	0.503	0.15	6.56	0.05
Defoliated white fir (thinned 1960)	40	2.303	0.558	0.04	1.47	NS
Defoliated white fir (thinned 1980-81)	40	0.739	0.757	0.46	32.47	0.01
Nondefoliated white fir	20	0.363	0.678	0.89	140.09	0.01
Pine (nonhost)	20	1.285	0.839	0.24	5.66	0.05

NS=Not significant

Table 5—Comparison of 5 tree classes with analysis of covariance to test the slope and elevation of regressions before (1949-64) and after (1969-84) a Douglas-fir tussock moth outbreak, Stough Reservoir, California

Five classes	F	Degrees of freedom	Significance
Slope	0.304	4 and 150	NS
Elevation	16.654	4 and 154	0.01

NS = Not significant

Discussion

The most spectacular growth occurred on the two plots thinned 4 years before the outbreak. These trees, dominants stagnating in an overdense stand, prior to thinning, were growing slowest of any class before the outbreak. This sample is very small, but it shows consistency with another thinning study conducted on the same National Forest (Heninger 1982). It also shows that thinned white fir stands, even though not resistant to defoliation and suffering heavy growth loss, may be able to recover more rapidly and to a much greater extent than unthinned stands after a Douglas-fir tussock moth outbreak. Further study of the relation of thinning and defoliator outbreaks is warranted.

Tree growth patterns after the outbreak were consistent with other studies, especially for the nonhost pine in the outbreak area (Wickman 1978, 1980, 1986). The thinning effect of white fir mortality and increased nutrient cycling from insect frass and litter are likely to have benefited the nonhost pine (Wickman 1980). The original stand was mostly pine before logging at the turn of the century. One of the important effects of the Douglas-fir tussock moth outbreak to date is a slow increase of the pine component of the stand as basai area and diameter growth increase. If future management activities favor pine, then the long-term result could be a stand more resistant to tussock moth outbreaks.

The areas thinned in 1980-81 have little relevance to the current analysis of growth patterns, but the data are included because they are likely to be important in the future if another Douglas-fir tussock moth outbreak occurs in the Stough Reservoir area. The long-term growth patterns of these thinned areas will also be useful in determining economic justification for thinning white fir on such poor sites. Recent white fir thinning trials by Weyerhaeuser Company near the Modoc National Forest showed that thinning to 10- by 10-ft and 16- by 16-ft spacing increased diameter growth rates 40 percent on crop trees (Heninger 1982). This stand was about 30 years younger than at Stough Reservoir, yet growth rates were comparable.

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Metric Equivalents

1 acre = 0.405 hectare

1 foot = 0.3048 meter

1 inch = 2.54 centimeters

1 mile = 1.61 kilometers

1 square foot = 0.0929 square meter

1 square foot per acre = 0.2296 square meter per hectare

1 tree per acre = 2.47 trees per hectare

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Appendix

Originally the stands at Stough Reservoir were to be left unmanaged for 20-25 years after the outbreak so stand recovery and growth could be studied. Unfortunately, a series of management activities starting in 1978 destroyed the integrity of the original 450-acre study area. In 1978, 160 acres of private land on the east and south half of the area were heavily logged (fig. 1). Almost every merchantable ponderosa pine and white fir were removed, leaving the stand seriously understocked. This activity destroyed about one-third of the original sample plots. In 1980 and 1981, 150 acres in the north half of the area were commercially thinned by the Forest Service in four units of various sizes. Two areas totalling about 90 acres in the center and west edge were left unthinned for research. The thinning changed another one-third of the original study plots. Then in October 1984, 80 acres of the thinned area were fertilized with nitrogen and sulfur. Finally, the 40-acre check white fir stand at the Warner Pass ski area was logged in August 1985, destroying the integrity of the undisturbed, undefoliated host stand.

The original study areas were thus altered so thoroughly that the planned 20-year postoutbreak stand examination could not be done with the same design or on the same scale as in 1967 and 1975. Long-term growth data in the small undisturbed areas and on the check area could still be sampled while logging was taking place, however. In addition, the thinning operations in 1980 plus two small plots thinned in 1960 before the outbreak offered the opportunity to examine the effects of Douglas-fir tussock moth outbreak on thinned and unthinned areas.

Pacific Northwest Research Station
319 S.W. Pine St.
P.O. Box 3890
Portland, Oregon 97208

U.S. Department of Agriculture
Pacific Northwest Research Station
319 S.W. Pine Street
P.O. BOX3890
Portland, Oregon 97208