

USING THE FOREST TIMBER INVENTORY FOR SAMPLING THE OCCURRENCE OF PESTS ON INTERIOR DOUGLAS-FIR

Michael A. Marsden, Gregory M. Filip and Paul F. Hessburg

ABSTRACT

In east-side forests of the Pacific Northwest Region, inland Douglas-fir should be managed with consideration for two major native pests: Douglas-fir dwarf mistletoe and western spruce budworm. Dwarf mistletoe is widespread and destructive to inland Douglas-fir in this area. A recent outbreak of western spruce budworm has severely defoliated Douglas-fir and the true firs throughout these forests. This outbreak drew the attention of pest management specialists, foresters, politicians and congressional representatives. While the budworm may have received greater press coverage, both pests cause severe growth loss and tree mortality. When estimating impacts, resource managers need to examine both the individual and collective impacts of these pests. Work presented here shows how to use the timber inventory databases to estimate the budworm defoliation history by management strata, and how to estimate the joint occurrence of budworm and dwarf mistletoe on inland Douglas-fir.

Keywords: Inventory, dwarf mistletoe (*Arceuthobium*), western spruce budworm (*Choristoneura occidentalis* Freeman), interior Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco, var. *glauca*)

INTRODUCTION

Federal foresters are faced with the challenge of managing forest resources for a wide variety of commodity and non-commodity outputs. Major forest pests such as western spruce budworm, dwarf mistletoes, mountain pine beetle and root diseases exert an underestimated and usually severe degenerative influence on forest resources often requiring a complex resource management decision process. Accurate quantitative measures of the presence, severity, and impact of these pests are needed to make sound resource management decisions. Data used to predict forest growth should include changes in growth expected under pest management policies.

Douglas-fir dwarf mistletoe (*Arceuthobium douglasii* Engelman) is widespread and destructive to inland Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco, var. *glauca*) in the Pacific Northwest Region. Over 42% of the inland Douglas-fir timber type is infested with dwarf mistletoe (Bolsinger 1978).

Western spruce budworm (*Choristoneura occidentalis* Freeman) episodes can be equally destructive. In the Pacific Northwest, outbreaks of western spruce budworm over the last

9 years have produced moderate to severe damage on over 7 million acres, drawing the attention of pest management specialists, foresters, politicians, and congressional representatives (personal communication, D. Bridgewater and J. Hadfield). Defoliation is highly visible and visually unappealing, and outbreaks develop rapidly and collapse slowly.

Both pests are widespread and cause severe growth loss and tree mortality to Douglas-fir. It is not an appropriate scientific method to estimate the effects of each separately and combine them without investigating the possibility of non-additive or synergistic effects. In so doing we would inaccurately account for growth and mortality losses associated with each pest.

Although some pest information is collected in most forest-level timber inventories, pest management specialists are hesitant to use these data. The quality of the pest information is highly variable, and sampling systems are not designed to estimate pest populations or impacts associated with them. For these reasons, special inventories are often conducted to gather specific information on pest conditions. The problem of reconciling the quality of pest data in the timber inventories remains.

This paper demonstrates the use of the timber inventory to sample for defoliation by western spruce budworm in terms of timber management strata for a national forest. We also show how to use the timber inventory to design an efficient sampling scheme to estimate the joint occurrence of two potentially damaging pests, dwarf mistletoe and western spruce budworm, on inland Douglas-fir.

DATA

Timber inventories are usually one of four types: (1) forest-wide surveys, (2) timber stand examinations or other intensive reconnaissance surveys to assess impacts associated with specific insects, diseases, animal pests, or abiotic damages, (3) timber cruises prior to sales, or (4) plantation survival surveys for stocking certification. Use of information from forest-wide surveys is the subject of this paper.

Forest-wide timber inventories characterize forest lands with information on tree species, size and age-classes, diversity, volume, growth, and mortality at a level that supports the Land Management Planning process (Schreuder and Bonnor 1987). Foresters and land use planners recognize that tree growth and mortality are often dramatically influenced by endemic and epidemic pest populations. For this reason, more pest population and impact information is added to forest inventory databases each year. Since forest tree disease conditions change slowly when compared to forest insect conditions, an inventory that is several years old may still be useful for assessing growth and mortality impacts associated with certain tree

diseases, e.g., dwarf mistletoes. Impacts associated with other diseases (e.g., root diseases) are more difficult to measure, and a change in conditions may go unnoticed until the location is again inventoried. In contrast, insect conditions may change substantially over one or two years.

Pest inventories are usually designed to assess abundance and damage associated with a single pest or pest complex. For example, roadside surveys have been completed on each national forest in the Southwest Region to assess the incidence and severity of dwarf mistletoes in southwest ponderosa pine (*Pinus ponderosa* Laws. subsp. *scopulorum* E. Murray). Rarely are pest inventories designed to detect multiple pests. A notable exception is the annual aerial detection survey conducted by forest pest management units in each region. A skilled aerial observer records damage to vegetation, determines the probable causal agent, and plots this information on a base map. Pest damage is diagnosed with reasonable accuracy, sketch mapped and coded, and maps are sent to forests. Forest personnel may conduct the necessary ground-checking and take appropriate actions.

Symptoms of forest pathogens are often more difficult to detect, although severe dwarf mistletoe, root disease, and needle cast infestations are detectable from the air (Beveridge and Knapp 1984). On the Coeur d'Alene National Forest a root disease sampling system was superimposed over an existing timber inventory using vertical aerial photography with followup field evaluations. This two-stage sampling system was conducted to improve the forest's estimate of impact associated with a particular root disease and tie that estimate directly to the information base used for land use planning (Williams and Leaphart 1978).

OBJECTIVES

The objectives of this paper are to show how pest inventory and timber inventory data can be used to estimate:

1. The frequency of defoliation by western spruce budworm by management strata for the Wallowa-Whitman National Forest, and
2. The co-occurrence of infection by dwarf mistletoe and defoliation by western spruce budworm on inland Douglas-fir in east-side forests of the Pacific Northwest Region.

METHODS

The entire timber inventory for the Wallowa-Whitman National forest was used to evaluate the frequency of defoliation by budworm. Western spruce budworm was the primary defoliating insect during the past twenty years. Copies of the aerial survey defoliation maps for this national forest were made for the period 1968-1987. Each forested plot in the inventory was located by its legal description (Township, Range, Section) on defoliation maps to determine the past defoliation history. Plots were rated for each year of the period for defoliation as: 0-no defoliation; 2-light defoliation; 3-moderate defoliation; 4-heavy defoliation including top kill and tree mortality. These ratings were combined and summarized over two ten-year

periods. The sum of the ratings over a ten-year period is the cumulative defoliation index. The three classes based on this index for the period are: 0-no defoliation; 1-5-light defoliation; 6 and greater-moderate to heavy defoliation. A history of control action (application of insecticides) against western spruce budworm was also recorded for each plot. The process was similar to that used in the development of defoliation vectors, except that maps from the pest aerial suppression projects served as base maps. This information on control actions was used to verify sudden changes in defoliation history.

Each forested inventory plot is classified as being in one of several timber management strata. The frequency of plots within a stratum was set to obtain a desired level of precision. The strata and plot frequencies are given in Table 1. The "Extensive" management strata is a collection of plots used as a "working group" in planning. This working group consists of plant associations having ponderosa pine or ponderosa pine/Douglas-fir climax plant communities. The "Intensive" category is the mixed conifer working group which includes all plant associations with white fir (grand fir) climax plant communities and some subalpine fir community types. To estimate the defoliation impact on a forest-wide basis we would need to know the sampling intensity for each strata in the table, and the pest impact within each cell. Here we will only report defoliation patterns. Cumulative defoliation ratings are given by strata in Table 2. The percent of plots within a management stratum with heavy defoliation estimates the percent of the area so defoliated.

Table 1.—Inventory plots on the Wallowa-Whitman National Forest by forest management strata.

Treatment Strata	Management Strata		
	Extensive PP, PP/DF	Intensive Mix Conifer	Lodgepole LPP
Regeneration (XR1)	23	81	43
Regeneration (XR2)	32	31	0
Commercial Thinning	38	30	0
Fiber Opportunity	20	34	15
Final Harvest	31	47	0
Multi-Treatments	35	17	8
Total	179	240	66

To estimate the co-occurrence of dwarf mistletoe and western spruce budworm on interior Douglas-fir we did not confine the sampling to one national forest. We were interested in plots with the host tree inland Douglas-fir in relative abundance. We selected three east-side national forests, the Okanogan, Wenatchee, and Wallowa-Whitman, as our area of study. With no prior knowledge of either pest population, we would select a simple random sample without replacement of stands from this area. However, the recent timber inventories on these forests provide a sampling frame of the timber stands. The data also contain information on the presence of dwarf mistletoe and sometimes budworm. The budworm was recorded if the pest

was present and damaging to the plot at the time of inventory. Dwarf mistletoe infection was recorded for individual trees on the sample plots but the quality of such data varied by inventory crew. Stand and host attribute data were accurate.

Table 2.—Inventory plots on the Wallowa-Whitman National Forest by primary forest strata and defoliation history classes.

Cumulative Defoliation Index	Management Strata		
	Extensive PP, PP/DF	Intensive Mix, Conifer	Lodgepole LPP
1968-1977			
0,none	156 87.2%	200 83.3%	63 95.5%
1-5,light	23 12.8%	36 15.0%	3 4.5%
6 +,mod.-heavy	0 0.0%	4 1.7%	0 0.0%
1978-1987			
0,none	62 34.6%	29 12.1%	3 4.5%
1-5,light	30 16.8%	60 25.0%	21 31.8%
6 +,mod.-heavy	87 48.6%	151 62.9%	42 63.6%
Total	179	240	66

Forest inventory databases for the Okanogan, Wenatchee, and Wallowa-Whitman National Forests were retrieved from the Pacific Northwest Region's timber database. A program was written to generate summary files for each forest. This file contained the location information: forest code, date of last inventory, plot number, slope, aspect, elevation, basal area factor (BAF) for variable plots, site index species, and site index (base age-100 years). This file also characterized the following stand attributes: basal area per acre, trees per acre, quadratic mean diameter, percent of all Douglas-fir trees ≥ 3 " DBH with dwarf mistletoe infections, stand dwarf mistletoe rating (DMR), and average rating for infected trees only, DMI (Geils and Mathiasen in press).

In this study, we assumed that host attribute data were precisely measured in the timber inventory. Dwarf mistletoe incidence and severity data were considered to have been measured with less precision. Western spruce budworm defoliation data from this inventory represent conditions for only the year of inventory. For our analyses we needed a defoliation history over many years. A separate data set was used for defoliation. This defoliation data set was derived from sketch maps of defoliation incidence and severity recorded over a 20-year period during annual aerial detection surveys of these same east-side forests. These data were combined and summarized over two ten-year periods. Each stand in the inventory data set was assigned a defoliation index indicating severity during each of the ten-year periods.

We selected plots using the following criteria:

1. At least 30% of the live tree basal area composed of Douglas-fir ≥ 3 " DBH.
2. At least one Douglas-fir 6" DBH or greater in the inventory plot data.

Each inventory plot with our quota of Douglas-fir was classified into one of four dwarf mistletoe classes based on number of infected trees: zero, 1-2, 3-6, 7 or more trees infected. The list of stands was then further sub-divided into strata representing defoliation classes within dwarf mistletoe infestation severity classes. Each plot was also classified by a defoliation class based on the cumulative defoliation index following the method described for the Wallowa-Whitman National Forest (Table 3). This provided a sampling frame with which to estimate the combined effects of both pests without fear of double counting.

Table 3.—Inventory plots from the Okanogan, Wenatchee, and Wallowa-Whitman National Forests with 30% or more of Basal Area in Douglas-fir and at least one Douglas-fir ≥ 6 " DBH, by defoliation history and dwarf mistletoe infection class.

Cumulative Defoliation Index (10 yrs)	No. of Douglas-fir trees with dwarf mistletoe/plot				
	None	1,2	3-6	7+	Total
1968-1977					
0,none	87	60	58	96	312
1-5,light	41	30	32	46	150
6 +,mod.-heavy	31	11	12	25	67
1978-1987					
0,none	92	42	50	83	267
1-5,light	37	24	20	35	116
6 +,mod.-heavy	30	35	32	49	146
Total	159	101	102	167	529

We only report the co-occurrence of the two pests; growth impacts are reported elsewhere in these proceedings by Filip and others. In defining the strata with respect to both pests we have constructed a sampling frame that could be used to sample for impact as well. In each stratum pest population and associated impacts are assumed to be more homogeneous than in the total sampling frame. Each plot could be remeasured to get impact data, or a stratum could be sub-sampled for this information. By sub-sampling in this manner, considerable gains in precision are anticipated (Stuart 1968). This is the primary benefit of stratified random sampling.

The data from each forest are classified by dwarf mistletoe frequency on Douglas-fir and defoliation for each of two ten-year periods, 1968-1977, and 1978-1988. Chi-square was used to test if the occurrence of the two pests are independent (Tables 4A to 4F). Because the sampling plans for each forest were different, they were tested separately.

Table 4A.—Douglas-fir component of the inventory plots on the Okanogan National Forest by defoliation history, 1968-1977, by dwarf mistletoe infection class.

Cumulative Defoliation Index (10 yrs)	No. of Douglas-fir trees with dwarf mistletoe/plot				Total
	None	1,2	3-6	+	
1968-1977					
0,none	31	11	16	23	81
1-5,light	13	5	4	11	33
6+,mod.- heavy	16	8	8	15	47
Total	60	24	28	49	161
Chi-square = 1.45 DF = 6 Significance = 0.96					

Table 4B.—Douglas-fir component of the inventory plots on the Okanogan National Forest by defoliation history, 1978-1987, by dwarf mistletoe infection class.

Cumulative Defoliation Index (10 yrs)	No. of Douglas-fir trees with dwarf mistletoe/plot				Total
	None	1,2	3-6	7+	
1978-1987					
0,none	44	12	15	30	101
1-5,light	12	7	4	9	32
6+,mod.- heavy	4	5	9	10	28
Total	60	24	28	49	161
Chi-square = 11.52 DF = 6 Significance = 0.07					

Table 4C.—Douglas-fir component of the inventory plots on the Wenatchee National Forest by defoliation history, 1968-1977, by dwarf mistletoe infection class.

Cumulative Defoliation Index (10yrs)	No. of Douglas-fir trees with dwarf mistletoe/plot				Total
	None	1,2	3-6	7+	
1968-1977					
0,none	35	21	17	39	112
1-5,light	23	11	12	21	67
6+,mod.- heavy	15	8	13	26	64
Total	73	42	42	86	243
Chi-square = 3.12 DF = 6 Significance = 0.79					

Table 4D.—Douglas-fir component of the inventory plots on the Wenatchee National Forest by defoliation history, 1978-1987, by dwarf mistletoe infection class.

Cumulative Defoliation Index (10 yrs)	No. of Douglas-fir trees with dwarf mistletoe/plot				Total
	None	1,2	3-6	7+	
1978-1987					
0,none	46	21	19	49	135
1-5,light	24	19	19	29	91
6+,mod.- heavy	3	2	4	8	17
Total	73	42	42	86	243
Chi-square = 6.09 DF = 6 Significance = 0.41					

Table 4E.—Douglas-fir component of the inventory plots on the Wallowa-Whitman National Forest by defoliation history, 1968-1977, by dwarf mistletoe infection class.

Cumulative Defoliation Index (10 yrs)	No. of Douglas-fir trees with dwarf mistletoe/plot				Total
	None	1,2	3-6	7+	
1968-1977					
0,none	21	28	23	24	96
1-5,light	5	6	9	6	26
6+,mod.- heavy	0	1	0	2	3
Total	26	35	32	32	125
Chi-square = 4.76 DF = 6 Significance = 0.58					

Table 4F.—Douglas-fir component of the inventory plots on the Wallowa-Whitman National Forest by defoliation history, 1978-1987, by dwarf mistletoe infection class.

Cumulative Defoliation Index (10 yrs)	No. of Douglas-fir trees with dwarf mistletoe/plot				Total
	None	1,2	3-6	7+	
1978-1987					
0,none	13	9	18	14	54
1-5,light	2	6	4	5	17
6+,mod.- heavy	11	20	10	13	54
Total	26	35	32	32	125
Chi-square = 7.82 DF = 6 Significance = 0.25					

RESULTS

One may expect defoliation history differs by strata on the Wallowa-Whitman National Forest because the species composition differs. Independence of the management stratum and defoliation stratum was tested by Chi-square for each time

period. The frequency of plots by defoliation stratum is not independent of the management stratum in either time period: Chi-square = 9.41, $\alpha = 0.05$, for 1968-1977; Chi-square = 45.39, $\alpha = 0.01$, for 1978-1987. The impact on forest-wide bases must therefore be estimated for each strata separately and then weighted by the area represented in each strata.

Not only is the defoliation frequency different by stratum but the impacts can be different. For example, in the two regeneration classes for "Extensive" and "Intensive" management, reduced growth on Douglas-fir or even tree mortality can be a positive effect in one case and a negative impact in the other. This may be a useful reference for the evaluation of the budworm impact on the forest. The impact of defoliation of Douglas-fir in strata where the emphasis is on ponderosa pine will be viewed differently than the same level of defoliation in mixed conifer strata. Cumulative defoliation ratings are given by strata in Table 2.

The co-occurrence of dwarf mistletoe and western spruce budworm was found to be independent when examined on plots with a substantial component of inland Douglas-fir. When tested using Chi-square, in only one case in six did the joint frequency challenge this hypothesis. On the Okanogan National Forest between 1978-1987 the plot frequency was different than expected for independence; Chi-square = 11.52, $\alpha = 0.07$. We conclude that the defoliation pattern is similar for Douglas-fir plots infested with dwarf mistletoe as it is for noninfested plots. This result indirectly supports the data of Filip and Parks (1987) who found that western spruce budworm had no preference for foliage on Douglas-fir branches infected by dwarf mistletoe or for noninfested branches during an outbreak. A synergistic effect in terms of growth loss on individual trees is not addressed here.

CONCLUSIONS

We have shown that estimates of pest occurrence can be made on a forest-wide basis. Further, these estimates are different forest management strata. This should be helpful in the evaluation of the damage done by the pest, since impact must be measured with respect to the management goals. If we are to get pest information into forest planning, one approach is to relate the pest inventory directly to the data on which the planning is done. We have shown that joint occurrence of pests on the same host can be estimated. Pest models have been developed to predict the impact of western spruce budworm and dwarf mistletoe on inland Douglas-fir. These findings suggest that both of these models should be used when estimating the effects of management on stands with inland Douglas-fir. In both of these efforts designing the sampling around the forest inventory proved to be efficient.

ACKNOWLEDGEMENTS

We acknowledge the capable assistance of Tommy Gregg for developing the computer programs to extract plot data from each of the timber inventory databases and summarizing this data. We thank Tim Rose, Kevin Hosman and Bobbi Fuller for their painstaking efforts in extracting defoliation incidence and severity information from annual aerial insect detection survey maps.

We also thank Everett Hansen, Frank Hawksworth, Ralph Johnson, Rudy King, and Robert Mathiasen for their reviews.

LITERATURE CITED

- Beveridge, R. L. and K. A. Knapp. 1984. Detection and dissemination of forest pest data in the intermountain region utilizing aerial detection surveys and computer mapping systems. For. Pest Manage. Rep. No. 84-8. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Exp. Sta. 114 pp.
- Bolsinger, C. L. 1978. The extent of dwarf mistletoe in six principal softwoods in California, Oregon, and Washington, as determined from forest survey records. *In: Proceedings-symposium on dwarf mistletoe control through forest management: April 11-13, 1978, Berkeley, CA.* Gen. Tech. Rep. PSW-31, Berkeley, CA: USDA Forest Service, Pacific Southwest Forest and Range Exp. Sta. p. 45-54.
- Filip, G. M., J. J. Colbert, C. G. Shaw III, P. F. Hessburg, K. P. Hosman and C. A. Parks. [unpub.]. Some relations among dwarf mistletoe, western spruce budworm, and Douglas-fir: modeling and management implications. Interior Douglas-fir Symposium: The Species and Its Management, February 27-March 1, 1990, Spokane, WA.
- Geils, B. W. and R. L. Mathiasen. [In press]. Intensification of dwarf mistletoe on southwestern Douglas-fir. *Forest Science*.
- Schreuder, H. T. and G. M. Bonner. 1987. Forest inventories in the United States and Canada. *The Forestry Chronicle*. 63(6):431-434.
- SPSS X User's Guide. 1986. 2d. ed. Chicago, IL: SPSS Inc. 988 pp.
- Stuart, A. 1968. Basic ideas of scientific sampling. *In: Griffin's statistical monographs & courses.* London: Charles Griffin & Company Limited. 99 pp. No. 4.
- Williams, R. A. and C. D. Leaphart. 1978. A system using aerial photography to estimate area of root disease centers in a forest. *Can. J. For. Res.* 8(2):214-219.

Authors

Michael A. Marsden
Rocky Mountain Forest and Range Experiment Station
240 West Prospect
Fort Collins, CO 80526

Gregory M. Filip
Pacific Northwest Research Station
1401 Gekeler Lane
La Grande, OR 97850

Paul F. Hessburg
Pacific Northwest Region
P.O. Box 3623
Portland, OR 97208