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Sampling Western Spruce Budworm by Counting Larvae on Lower Crown Branches

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Abstract

A technique is described for sampling spruce budworm larvae after bud flush by nondestructively beating branches in the lower crown. Sample data were collected from 32 plots representing a wide range of budworm densities. Statistical analyses indicated that larvae were less aggregated in the lower crown than at the same density in the middle crown. In an independent sample of 12 plots, estimates of larval density in the middle crown were 2.5 times higher than but strongly correlated with estimates of density in the lower crown. Sampling in the lower crown is quick and efficient and especially recommended for the annual monitoring of larvae or for estimating densities before spraying in control programs.

Keywords: Sampling insects, insect defoliators, western spruce budworm, *Choristoneura occidentalis*.

Introduction

Larval populations of the western spruce budworm, *Choristoneura occidentalis* Freeman, have traditionally been quantified by their density in the middle of the crown of host trees. Density on a plot is usually estimated directly by removing a sample of branch tips from the middle one-third of the crowns of a cluster of trees, counting all the larvae, and expressing their number in terms of some standard unit such as branch area, branch tip, or per 100 buds (Carolin and Coulter 1972, Srivastava and others 1984). Such density in the middle of the crown of trees 7 to 20 m tall has been used for years as a relative index of absolute numbers of budworm. Collecting middle crown branches by pole pruner and basket, and beating and measuring them over a ground cloth, however, is labor intensive and expensive. Considering the purpose for which most budworm density data are used, simpler and cheaper methods of estimating density would usually be adequate.

In this paper, we describe an alternative method by which an index of density is determined, after larvae have quit mining buds, by sampling branches in the lower crown instead of the middle crown. Branches within reach from the ground are sampled by beating over a handheld cloth without having to measure or remove them from the tree. The technique is particularly efficient because all phases of the procedure—branch selection, beating, counting, and recording—are done by one person on each sample tree. The three required branches per tree can be sampled in 1-2 minutes, permitting a person to examine many trees in a short period of time.

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Methods

Sample Plots and Locations

Data were collected from 44 plots, 1-2 hectares each, in the early summer of 1987. On 32 plots, lower branches only were sampled to determine statistical properties of larval densities in the lower crown. Most of these plots, located in northeastern Oregon and north-central Washington, were at permanent sample sites where populations of the Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough), have been monitored annually for many years. On a smaller group of 12 plots, the middle crown was sampled in addition to the lower crown. These plots, located primarily in northeastern Oregon but also in adjacent western Idaho, were used to generate an independent data set for verifying the relation of middle and lower crown densities.

All plots were in mixed conifer types dominated by budworm host species of grand fir, *Abies grandis* (Dougl.) Lindl., and Douglas-fir, *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco. Nonhost species like ponderosa pine, *Pinus ponderosa* Lawson, and lodgepole pine, *Pinus contorta* (Dougl. ex Loud.), were sometimes minor components in the stand. In 1987, budworm populations were in outbreak numbers on most of the sample sites in Oregon and Idaho, but were at low densities on the sites in Washington.

Sampling Procedures

Sampling was timed after bud flush to coincide with nominal 4th instars; that is, when the majority of larvae were in instars 3, 4, and 5, based on phenological development and degree-day accumulation (Beckwith and Kemp 1984, Wickman 1988). From 25 to 51 host trees were sampled in the lower crown on each plot. Grand fir and Douglas-fir were sampled without preference depending on their occurrence in the stand. The only criterion for tree selection was that it have current foliage on low branches that could be reached from the ground. The primary sample unit was three 45-cm branch tips on each tree. Each branch was separately rapped 10-12 times to dislodge all budworm larvae onto a handheld dropcloth from which they were counted (Paul 1979) (fig. 1). The total count for the three branches was a sample.

Sampling in the middle crown (12 plots) for verification was done by conventional methods using a pole pruner (Srivastava and others 1984). All budworm larvae were counted on two 45-cm branch tips cut from the middle one-third of the tree crown. Sample size varied from 12 to 58 trees per plot.

Calculations

For lower crown data collected in 1987, the mean number of larvae per sample unit $\bar{y}$ on each plot was calculated by:

$$\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n} \quad , \tag{1}$$

where yi is the number of larvae on three branches of the i'th tree and n is the number of trees sampled. Assuming an infinite population of trees, the estimated sample variance $V(\bar{y})$ for a cluster of trees was:

$$V(\bar{y}) = \frac{1}{n-1} \sum_{i=1}^{n} (y_i - \bar{y})^2 \quad . \tag{2}$$

Figure 1—Sampling budworm larvae on lower tree branch by beating 45-cm branch over a handheld dropcloth. Any branch within 7 feet of the ground can be easily sampled by a person of average height.

The relation between variance and the mean was determined by transforming all values to logarithms and solving the linear regression,

$$\log V(\bar{y}) = a + b \log \bar{y} \, . \tag{3}$$

The number of trees n needed for different levels of precision was then estimated by:

$$n = \frac{t^2 V(\bar{y})}{E^2} \quad , \tag{4}$$

where E is the specified error for a given mean per sample unit.

The factor used to convert the number of larvae per sample unit to the number per square meter was 3.10, the average number of sample units in a square meter of branch area (Mason 1977, 1987).

Results

A wide range of budworm numbers, from very low to severe outbreak densities, were encountered on the sample plots (table 1). Densities were highest in northeast Oregon in the Umatilla and Wallowa-Whitman National Forests where budworm numbers had increased at a near geometric rate from 1984 to 1987. Densities were also high in the Malheur National Forest in east-central Oregon reflecting the outbreak that had persisted since the early 1980's. The populations on plots sampled in Washington were sparse.

Table 1—Mean densities of budworm larvae in lower crowns on 32 sample plots, June 1987

National Forest	Number of trees	Larvae per 3-branch sample	Larvae per 45-cm branch tip[a]	Larvae per sq. meter of branch area[b]
Umatilla (OR)	50	25.64	8.54	79.48
	50	23.30	7.76	72.23
	50	22.96	7.65	71.17
	50	24.16	8.05	74.89
	50	20.96	6.98	64.97
	50	16.22	5.40	50.28
	25	6.00	2.00	18.60
	50	2.82	.94	8.74
	25	5.72	1.90	17.73
	25	1.60	.53	4.96
Wallowa-Whitman (WA)	51	2.14	.71	6.63
	51	7.92	2.64	24.55
	51	6.92	2.30	21.45
	25	14.96	4.98	46.37
	25	8.04	2.68	24.92
	25	32.64	10.88	101.18
	50	15.30	5.10	47.43
	50	29.38	9.79	91.07
Wenatchee (WA)	50	.30	.10	.93
	50	.42	.14	1.30
	50	.06	.02	.18
	50	.02	0	.06
Okanogan (WA)	50	.06	.02	.18
	50	.02	0	.06
	50	.06	.02	.18
	50	.12	.04	.37
Malheur (OR)	25	4.92	1.64	15.25
	25	9.00	3.00	27.90
	25	10.72	3.57	33.23
	25	6.68	2.22	20.70
	25	4.40	1.46	13.64
	25	7.32	2.44	22.69

[a] Larvae per sample divided by 3.0.

[b] Larvae per sample multiplied by 3.1.

Intraplot Variability

The variability between samples on plots is best shown by the linearized variance-mean relation calculated from equation (3) and plotted in figure 2. The regression coefficient b in this equation is a useful index of the degree to which budworm larvae were aggregated in the lower crown branches (Taylor 1961). When larvae are randomly distributed, b = 1; but b increases as larvae become more aggregated. The coefficient for our data (b = 1.24) shows aggregation, but it is considerably smaller than that calculated by others for three-branch sample data in the middle of the crown.[1] This implies that budworm larvae are less aggregated on lower branch tips than on tips higher in the tree. Therefore, at the same larval density lower foliage may be more efficient to sample simply because larvae are better distributed in that stratum.

Determination of Sample Size

The numbers of trees required for standard errors of 10, 15, and 20 percent of the mean at a confidence level of 68 percent (t = 1) were computed by substituting the appropriate values and solving equation (4). The curves generated in figure 3 show that means with a 15-percent precision can be estimated for lower crown populations greater than 15 larvae per m2 from a sample of 25 trees or less. A doubling of the sample size to 50 trees would produce similar precision with at least an 80-percent confidence level (t = 1.4).

Comparison of Middle and Lower Crown Densities

The utility of density in the lower crown as an index of density in the middle crown was verified by comparing estimates in the two crown strata on the additional 12 independent plots. The ratios of middle to lower crown density were variable with an average of 2.5 (table 2). The regression of middle densities on lower densities was highly significant ($r = 0.910$; $p < 0.001$); however, the regression line does not pass through the origin so it probably overestimates very low densities (fig. 4). If the line is forced to run through the origin by setting a = 0, the regression coefficient b becomes 2.41. This coefficient can be used as a correction for translating indexes of lower crown density to middle crown densities.

Discussion

The nondestructive sampling of lower tree branches for western spruce budworm has promise as an alternative to midcrown methods of estimating densities after larvae have left the buds. The density of nominal 4th instars can be quickly determined in lower branches and, thus, is an especially useful index of budworm abundance in control operations and annual monitoring programs. Larval numbers also appear to have a smaller variance on lower branches, probably because larvae have redistributed from a more aggregated state higher in the tree. This would normally give a statistical advantage to sampling in the lower crown; the advantage is cancelled, however, because middle crowns have a higher density than lower crowns and fewer samples are required as density increases. Nonetheless, lower branches are physically much easier to sample, even if a larger sample size is required.

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[1] Colbert, J.J.; Beckwith, R.C. Manuscript in preparation. Unpublished data on file at the Forestry and Range Sciences Laboratory, La Grande, Oregon.

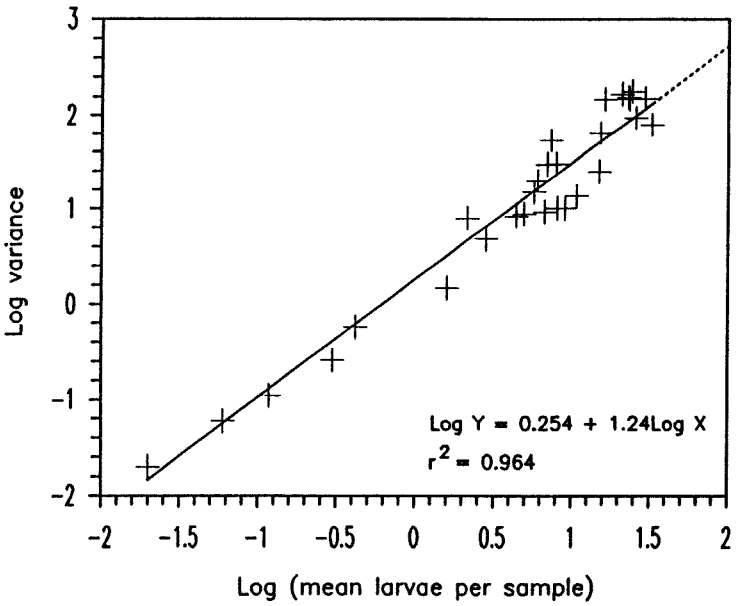

Figure 2—Relation between log-transformed values of variance and the mean on 32 sample plots.

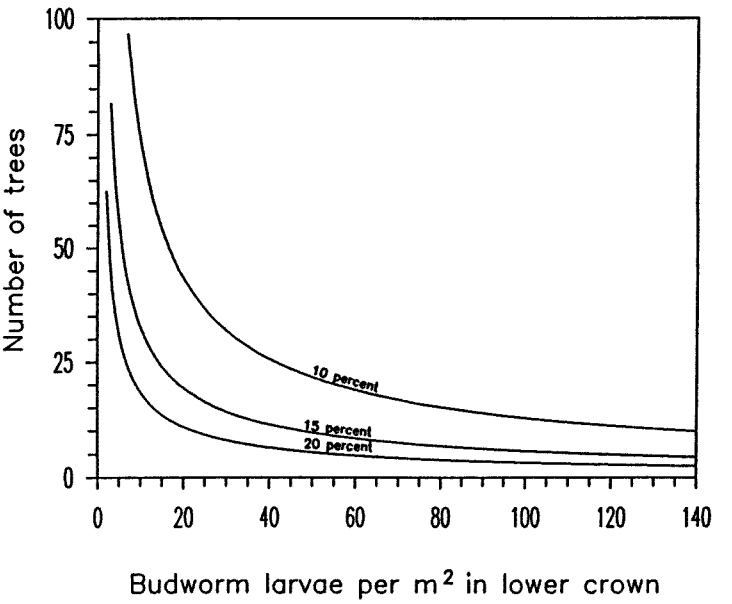

Figure 3—Sample sizes required to estimate larval density on a plot with a standard error of 10, 15, or 20 percent of the mean.

Table 2—Comparison of larval densities estimated in 2 different crown levels on the same plots

National Forest	Middle crown	Lower crown	Middle crown/ lower crown
	- - - - *Larvae/m²* - - -		*Ratio*
Wallowa-Whitman (OR)	197.63	66.34	2.98
	184.80	73.78	2.50
	69.07	18.91	3.65
	124.70	75.95	1.64
	66.50	39.80	1.67
Malheur (OR)	23.40	7.13	3.28
	81.03	27.12	2.99
	81.97	22.85	3.59
	25.22	16.68	1.51
Payette (ID)	28.12	16.00	1.76
	33.04	14.01	2.36
	13.87	6.54	2.12
Mean ± standard error			2.50 ± 0.23

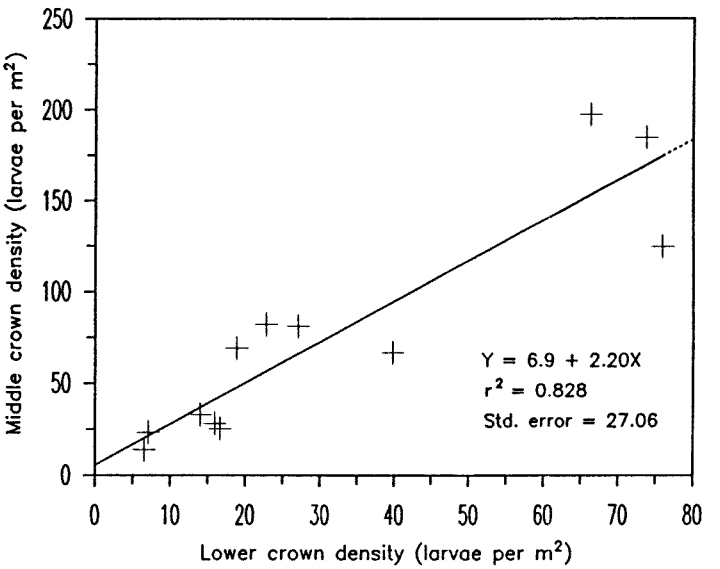

Figure 4—Comparison of larval densities estimated in the middle and lower crown on 12 sample plots.

For most monitoring studies a reliable estimate of larval density in the lower crown can be made by sampling 25 to 50 trees on a plot. If, however, the plot comprises several hectares, care must be taken that sample trees are not clustered in one portion of the plot but are well distributed within the area for which the population estimate is being made.

To be consistent with previous estimates of population density, which have traditionally been expressed in terms of midcrown foliage, indexes estimated in the lower crown may be converted to middle crown densities by multiplying by a correction factor. The best current estimate of the factor is 2.41, although it will undoubtedly be improved after other data sets are analyzed (see footnote 1). Until more is known about how larval distribution varies within the crown, this value can be treated as a constant for samples of nominal 4th instars. As long as the same correction is used, the value will have no effect on analyses of population change between years. Ultimately, indexes derived from sampling lower branches should have as much reliability for interpreting population changes of budworm as those from other parts of the crown.

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English Equivalents

1 centimeter (cm) = 2.54 inches
1 meter (m) = 39.7 inches
1 hectare (ha) = 2.47 acres

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