Douglas-Fir Tussock Moth, *Orgyia pseudotsugata* (McDonnough)
Western Spruce Budworm, *Choristoneura occidentalis* Freeman
Lepidoptera: Lymantriidae

Mason, R. R.; Paul, H. G. 1994. Monitoring larval populations of the Douglas-fir tussock moth and the western spruce budworm on permanent plots: sampling methods and statistical properties of data. Gen. Tech. Rep. PNW-GTR-333. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; 23 p.

Objective: To describe sampling methods for determining larval densities of *O. pseudotsugata* and *C. occidentalis*.

Abstract: Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDonnough), is a periodic defoliator of Douglas-fir, *Pseudotsuga menziesii* (Mirb.), and true firs, *Abies* spp., in western North America. Outbreaks occur quite unexpectedly every 7–10 years and usually persist for 3–4 years. Defoliation by *O. pseudotsugata* can be severe and cause widespread tree mortality during the first year of an outbreak. Surviving trees may exhibit growth loss, top-kill, and tree deformity. Western spruce budworm, *Choristoneura occidentalis* Freeman, also attacks Englemann spruce, *Picea englemannii* Parry ex. Englem., and larch, *Larix occidentalis* Nutt., in addition to Douglas-fir and true firs in western North America. Infestation of *C. occidentalis* in mature stands can result in growth loss, top kill, and occasional tree mortality.

This work is an extensive summary of earlier published studies and is derived from research conducted in eastern Oregon and Washington. The authors demonstrate that permanent plots in a geographical monitoring unit offer a statistically reliable tool for monitoring densities of *O. pseudotsugata* and *C. occidentalis*. Typically, larval population densities are estimated by sampling a number of tree clusters in a small area and a number of small areas in a stand. The mid-crown of Douglas-fir <15 m tall is the preferred region for sampling branches. Traditionally three 45-cm branch tips are sampled per tree on each of 20 to 50 trees in a plot, depending on larval densities (low and high populations requiring a larger number of samples). Sampling should be timed to coincide with presence of first and second instars of *O. pseudotsugata* and nominal fourth instars of *C. occidentalis*. Alternatively, branches in the lower crown can be sampled and the resulting estimates of larval density per sampling unit converted to mid-crown density per m^2 using a corrective equation. Equations are presented to estimate the number of plots needed given the size of the area of concern. Roughly 50 plots would be needed to estimate tussock moth density at the size of a state or Canadian province. Sampling methods must be consistent across regions and time to build a meaningful database monitoring population trends.

Sampling Procedure: Permanent sample plots are generally about 2 ha in size. Plots should be selected to adequately reflect the larger monitoring unit, whether the unit is a ranger district or a national forest. Each sample plot should contain a cluster of Douglas-fir and true fir trees. Trees should have canopies accessible from the ground.

Randomly select trees to reflect the species composition within plots. Plots should be sampled annually to monitor population trends over time and regions.

Begin sampling after budburst when new shoots are ≤4–6 cm long. Sample the same instars each year. Typically early instars (i.e., first and second instars) are preferred for *O. pseudotsugata*, while nominal fourth instars (i.e., instars III, IV, and V) are preferred for *C. occidentalis*. Sample three 45-cm branch tips from the lower crown of each tree using a beat sheet and a beat stick. Be aware that *C. occidentalis* larvae on webbed shoots may require more vigorous beating to dislodge them than *O. pseudotsugata* larvae. Sampling 20–50 trees in a plot provides a density estimate with a standard error of <20% of the mean at the 68% probability level. Lower pest densities require a larger sample size than higher pest densities at the same precision level. Examine arthropods dislodged onto the beat sheet and record the number of *O. pseudotsugata* and *C. occidentalis* larvae found separately for each 3-branch sample.

Calculate the mean number of larvae for each species per sampling unit, $\bar{y}$, using the following formula:

$$\bar{y} = \frac{1}{m}\sum_{i=1}^{m} y_i$$

where y_i = the number of larvae in the sampling unit of the *i*th tree and m = the number of trees sampled per plot. Sample variance among the 3-branch sampling units, $V(y)$, can be calculated for each cluster of trees using the following formula, with y_i and m described as above:

$$V(y) = \frac{1}{m-1}\sum_{i=1}^{m}\left(y_i - \bar{y}\right)^2$$

Calculate the mean population density for a monitoring unit (M) using the following equation:

$$\overline{M} = \frac{1}{n}\sum_{i=1}^{n} M_i$$

where M_i = the larval density in the *i*th sampling plot of the unit and n = the number of plots per unit. The interplot variance, $V(M)$, can be calculated among the sampling plots using the following formula, with M*i* and n described as above:

$$V(M) = \frac{1}{n-1}\sum_{i=1}^{n}\left(M_i - \overline{M}\right)^2$$

Calculate the appropriate number of permanent sampling plots required by solving for interplot variance (*V*) in the following equation:

$$V(M) = a\overline{M}^{b}$$

where *a* and *b* = parameters reflecting the spatial variation of larval populations and $\overline{M}$ = the population mean. Substitute the value of *V* in the following equation:

$$n = \frac{t^2 V(M)}{E^2}$$

where *t* = Student's *t* for a specified confidence probability and *E* = the desired standard error of estimate to determine the number of permanent plots required within a monitoring unit. Both *O. pseudotsugata* and *C. occidentalis* larvae can be monitored simultaneously on the same plots within a management unit. District-sized, forest-sized, and province-sized units will generally need 15–20, 25–30, and 50–60 units, respectively. These numbers of plots should be sufficient for a precision of estimate of 20 percent of the mean and a confidence level of 68%.

Larval densities estimated from the lower crown should be converted to a standard abundance index in the mid-crown (*M*) using the following equation:

$$M = \left(3.1\,\overline{y}\right)R$$

where 3.1 = the average number of 3-branch sampling units per m^2, $\overline{y}$ = the mean density of larvae per sampling unit, and *R* = the correction factor, which is a ratio of mid-crown to lower crown density of larvae. Substitute 2.0 as *R* for early instar *O. pseudotsugata* and 2.23 for nominal fourth instar *C. occidentalis* to convert estimates of lower crown density per sampling unit to mid-crown density per m^2.

Notes: Often early instar *O. pseudotsugata* and nominal fourth instar *C. occidentalis* can be sampled together at the same time, but not always. The two species should be sampled separately if *C. occidentalis* larvae become active in the spring weeks before *O. pseudotsugata* due to cool spring weather.

Refer to the original publication for greater details regarding the calculations summarized here and additional information about monitoring permanent plots for *O. pseudotsugata* and *C. occidentalis* larvae.