# COMPARISON OF BINOCULAR AND CUT-BRANCH METHODS FOR ESTIMATING BUDWORM DEFOLIATION OF DOUGLAS-FIR

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## Abstract

Defoliation caused by the western spruce budworm, *Choristoneura occidentalis* Freeman, was estimated on 91 Douglas-fir trees *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco, by both close examination of cut-branches and by observation with binoculars. For individual trees the accuracy attained with the binoculars was within 23% for current year's and 19% for foliage of all ages, with respect to the estimates made from cut branches. Inaccuracy was found to be mainly due to lack of precision as bias was minimal. When the trees were assigned, by each method, into the broad defoliation classes of light (1-25%), moderate (26-65%), and severe (66-100%), as used in forest insect surveys in British Columbia, the results agreed in 89% of the trees studied for defoliation estimates of current foliage and 68% of the trees for defoliation of total foliage. Classification of the location averages into severity classes agreed for all 5 locations studied for damage to current and total foliage. We concluded that the binocular method is a quick and useful means of classifying stands into broad defoliation severity classes, but is not suitable if a high degree of accuracy and precision is needed.

## Résumé

Par l'examen physique de branches coupées et l'examen à la jumelle, on a évalué la défoliation causée par la tordeuse occidentale de l'épinette (*Choristoneura occidentalis* Freeman) à 91 douglas taxifoliés (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco). pour chaque arbre, la fidélité des évaluations à la jumelle ne s'écartait pas de plus de 23 %, pour le feuillage de l'année, et de 19 %, pour le feuillage total (feuillage de tous les âges), des évaluations sur les branches coupées. Il a été constaté que l'inexactitude est principalement liée au manque de précision, car l'erreur systématique est minime. Lorsqu'on on distribué les arbres dans les grandes classes de défoliation (légère [1-25 %], modérée [26-65 %] et grave [66-100] %), de l'inventaire des insectes forestiers en Colombie-Britannique, les résultats concordaient pour 89 % des arbres évalués pour la défoliation du feuillage total. En outre, le classement de cinq stations selon les mêmes critères a donné dans chaque cas un résultat identique, pour les deux types de feuillage. La jumelle est donc un moyen rapide et utile de classer les peuplements en grandes classes de défoliation, mais elle ne convient pas lorsqu'on recherche une fidélité et une précision élevées.

## INTRODUCTION

Forest defoliator damage depends on the intensity and duration of the defoliation (Alfaro *et al.* 1982; Alfaro 1985). For this reason workers in forest pest management are often confronted with the need to measure the intensity of defoliation of individual trees or stands.

Several methods for individual trees have been developed and used to estimate defoliation by the eastern spruce budworm *Choristoneura fumiferana* (Clem.) in Canada (Sanders 1980; Dorais and Kettela 1982). The methods involving removal of branches and evaluation of defoliation by foliage age class (cut-branch method) (e.g. Fettes 1950) are considered to be the most accurate (MacLean and Lidstone 1982). These methods have the disadvantages of being slow, laborious and of needing cumbersome field equipment. They produce estimates that are unnecessarily precise for some survey purposes. More rapid estimates of percentage defoliation can be obtained by visual examination of the standing tree using the naked eye or binoculars. These estimates are relatively crude and subjective.

The purpose of this study was to examine how estimates of defoliation of Douglas-fir *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco caused by the western spruce budworm *C.*

*occidentalis* (Freeman), and made by a trained observer using binoculars, compared in accuracy and precision with estimates made by the cut-branch method.

## METHODS

Both binocular and cut-branch estimates were made on a total of 91 Douglas-fir trees at five locations (Table 1), during late July and early August, 1980. The areas selected had a history of recent budworm damage and the trees sampled represented a wide range of defoliation intensities. These locations were located between the towns of Ashcroft and Clinton.

*Binocular method*

The upper crown half of each tree was scanned by an experienced observer using 7 X 50 binoculars. Separate estimates, to the nearest 5%, were made of the percentage defoliation of current year's (1980) and of older foliage (1979 and before).

*Cut-branch method*

Table 1. Number, mean diameter at breast height (DBH) and height of Douglas-fir trees sampled at five locations in British Columbia.

| Location | No. of Trees | Mean (± s.e.) | |
|---|---|---|---|
| | | D.B.H. (cm) | Height (m) |
| 1. Veasy Lake | 20 | 12.6 (0.5) | 8.4 (0.2) |
| 2. Hart Ridge | 18 | 16.7 (0.6) | 9.4 (0.3) |
| 3. Loon Lake | 19 | 15.0 (0.7) | 9.0 (0.2) |
| 4. Dude Ranch | 10 | 14.8 (0.6) | 10.1 (1.5) |
| 5. Highland Valley | 24 | 15.3 (0.9) | 8.6 (0.4) |
| All Locations | 91 | 14.9 (0.4) | 9.0 (0.2) |

Two 50 cm branches were cut from opposite aspects of the upper half of each tree crown. Defoliation was then separately estimated for each of the last three foliage age classes: current (grown in 1980), 1-year-old (grown in 1979), and 2-year-old (grown in 1978). All shoots in each of these age classes were counted and individually assigned to one of the following percentage defoliation classes (adapted from Fettes 1970), 0, 1-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, 81-90, 91-99, 100. The average defoliation for each of the 1978-1980 foliage age classes on each branch was calculated as the average of the defoliation classes of all shoots on the branch. For foliage grown in 1977 and before, shoots were not examined individually, but assigned as a whole to one of the 12 defoliation classes. Defoliation estimates of both branches were averaged to yield a single estimate for each foliage age class per tree.

*Calculation of average tree defoliation*

Average defoliation for each tree, by both binocular and branch methods, was calculated by weighting the defoliation measurement of each foliage age class by the proportion of the tree's foliage in that age class. We assumed that the amount of foliage in each age class was proportional to the number of shoots in that class. The number of shoots was counted on each branch sample for the last three foliage age classes (1978-1980). The number of shoots in the remaining foliage age classes in each branch were estimated by calculating, based on the available shoot counts, the average ratio of the number of shoots in one year to the number of shoots in the previous year. Separate ratios were developed for each locality; they varied from 1.2 to 1.6, and the average ratio for all localities combined was 1.4 (Table 2). Because of the branching pattern of Douglas-fir, the number of shoots in one age class is always greater than the number in the previous year's class. The method assumes that the ratios are constant from one year to the next.

Table 2. Average ratio of the number of shoots in one foliage age class to the number of shoots in the previous foliage age class, and percentage of all shoots in 50-cm branches by foliage age class in young interior Douglas-fir at five locations in British Columbia.

| Location | Ratio | Percentage of shoots by foliage age class | | | |
|---|---|---|---|---|---|
| | | Current | 1-year-old | 2-year-old | >2-year-old |
| 1 | 1.3 | 25.4 | 24.2 | 16.6 | 33.8 |
| 2 | 1.3 | 23.0 | 23.4 | 16.0 | 37.6 |
| 3 | 1.4 | 30.2 | 23.3 | 16.1 | 30.4 |
| 4 | 1.2 | 24.4 | 21.0 | 16.1 | 38.5 |
| 5 | 1.6 | 37.5 | 25.5 | 15.9 | 21.4 |
| All | 1.4 | 29.0 | 23.8 | 16.1 | 31.1 |

For each branch, the number of shoots in the 1977 age class was calculated by dividing the shoot counts for 1978 by the average ratio for the locality where the branch was collected. The resulting number of shoots was again divided by the same ratio to obtain the 1976 shoot counts. This iterative process was repeated until the calculated shoot counts equaled 1 shoot, i.e. the initiation of the branch. This usually occurred after the calculation of the 6th or 7th foliage age class, which are the commonly observed number of age classes for Douglas-fir in interior British Columbia. Finally, shoot counts for all age classes in each branch were totaled and the percentages of this total that consisted of current shoots (1980), 1 year-old shoots, 2 year-old shoots and shoots older than two years were calculated (Table 2) and used as weighting factors in the tree defoliation calculations for both binocular and cut-branch estimates.

The binocular and cut-branch estimates of defoliation of both current year's and total foliage were compared using Freese's test of accuracy (Freese 1960) in which the accuracy of a new measuring technique is compared against an established or "true" method. In this study the binocular method was considered the new technique and the cut-branch the established method; cut-branch estimates are usually considered more accurate than binocular estimates (Fettes 1950; MacLean and Morgan 1981; MacLean and Lidstone 1982).

In the discussion that follows we use the terms "bias", "precision" and "accuracy" as defined in Freese (1962) where bias is a systematic distortion, accuracy refers to the success of estimating the true value of a quantity, and precision refers to the clustering of sample values around their own average. Accuracy, or closeness to the true value, may be absent because of bias, lack of precision or both.

As recommended by Freese (1960), the accuracy test was performed after removal of the bias. For this purpose, the linear regressions of the binocular estimates on the cut-branch estimates were calculated for both the current and total defoliation estimates. Then, the following $\chi^2$ value was tested against the tabular $\chi^2(P = 0.05)$ (Freese (1960).

$$\chi^2_{(n-2)df} = \text{Residual SS} / \sigma^2$$

where:

Residual SS = the regression residual sum of squares
$\sigma^2$ = the hypothesized variance calculated as:

$$\sigma^2 = E^2 / t^2$$

where:

E = required accuracy (expressed in the same units as the mean)
t = standard normal deviate

In this study, the binocular method was considered accurate if it provided estimates that were within 10% of the cut-branch estimates (E = 10%).

After testing the accuracy using the 10% defoliation criterion selected (E), Freese's equation was rearranged, solving for E, to determine the accuracy achieved by the binocular estimates, as compared with the cut-branch estimates, for each location.

## RESULTS

The average foliage distribution by age class for all locations (Table 2) agreed very closely with Silver's (1962) estimates for coastal Douglas-fir *P. menziesii* var. *meeenziesii* (Mirb.) Franco of 28, 23, 17, and 32% for current, 1 year-old, 2 year-old, and older foliage, respectively. Mitchell (1974) found a larger proportion of current and 1 year-old foliage than in Silver's or our study with his comparative values of 43, 28, 18, and 11%. Differences in branching pattern due to tree age, size or location may account for the variation in results.

The regression of the binocular estimates on the cut-branch estimates showed a strong relationship between the two variables for both current and total foliage (Fig.1). The binocular estimates showed a slightly negative bias with respect ot the cut-branch estimates indicating that 12% and 7.5%, respectively, of current year's and total foliage was defoliated as detected by the cut-branch method, before any defoliation was detected using binoculars (Fig.1).

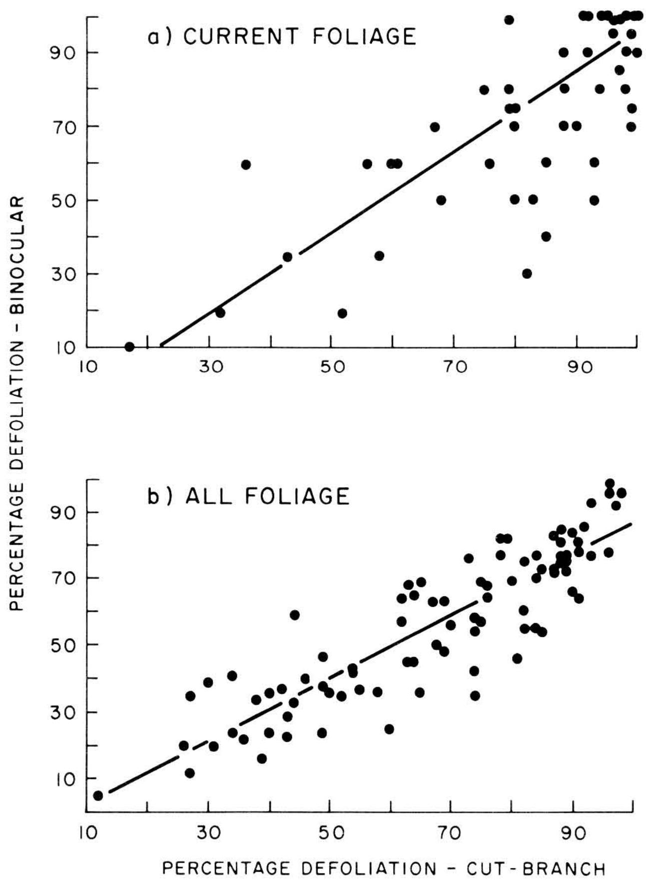


Figure 1. Regression of the estimates of western spruce budworm defoliation on 91 Douglas-fir trees, using the binocular method, on estimates made using the cut-branch method.
a. Current Year's Foliage: $y = -13.3 + 1.09x$; $R^2 = 0.67$
b. total foliage: $y = -7.1 + 0.942x$; $R^2 = 0.78$

The binocular method failed to meet our accuracy requirement of ± 10% of the defoliation as estimated by the cut-branch method, based on Freese's test. The accuracy obtained with the binocular method, after elimination of bias, was 23% for current year's and 19% for total foliage.

The difference between the two methods varied by location from 0.3 to 15.6% defoliation (average 4%) for current year's foliage, and from 4.5 to 15.9% (average 11%) for total foliage (Table 3). Estimates of mean defoliation for all locations were lower using the binocular method than the cut-branch method. Standard errors were consistently higher with the binocular than the cut-branch method (Table 3).

Table 3. Binocular and cut-branch estimates of interior Douglas-fir defoliation by the western spruce budworm at five locations in British Columbia.

| Location | Estimated Mean Percentage Defoliation (s.e.) | | | | | |
|---|---|---|---|---|---|---|
| | Current Year's Foliage | | | Total Foliage | | |
| | Cut-branch | Binocular | Diff. | Cut-branch | Binocular | Diff. |
| 1 | 93.6 (1.6) | 91.8 (3.6) | 1.8 | 82.9 (2.1) | 67.1 (4.2) | 15.8 |
| 2 | 99.2 (0.4) | 97.5 (1.5) | 1.7 | 81.3 (2.7) | 65.4 (3.8) | 15.9 |
| 3 | 84.0 (3.1) | 68.4 (4.8) | 15.6 | 47.2 (3.4) | 38.5 (3.2) | 8.7 |
| 4 | 99.8 (0.1) | 99.5 (0.5) | 0.3 | 82.8 (4.6) | 77.8 (5.7) | 4.5 |
| 5 | 77.5 (5.2) | 73.5 (5.8) | 4.0 | 55.5 (4.3) | 47.5 (4.9) | 8.0 |
| All | 89.1 (1.8) | 84.1 (2.4) | 5.0 | 67.8 (2.3) | 56.8 (2.40 | 11.0 |

The two methods were compared for estimation of defoliation in broad severity classes of light (1-25%), moderate (26-65%), and severe (66-100%), as used by the Forest Insect and Disease Survey of the Canadian Forestry Service in British Columbia. Eighty-one (89%) and 62 (68%) of the 91 trees for current year's and total foliage, respectively, were assigned to the same class using the two methods.

When classification was based on the average defoliation of the sampled trees for a location, as is the usual practice, there was complete agreement between the two methods as to the assigned defoliation class for all locations for both current and total foliage (Table 3).

## DISCUSSION

The accuracy obtained with the binocular estimates of defoliation on individual trees, relative to the cut-branch method, was lower than the arbitrary 10% set as a threshold in this study. Bias in the relationship between the two estimates of defoliation was minimal (i.e. intercept not significantly different from zero, slope not significantly different from 1, t-ratio p > 0.05); therefore much of the lack of accuracy can be attributed to poor precision. In other words, on the average the binocular method will provide an unbiased estimate of mean defoliation as determined by the cut-branch method, but estimates for individual trees may fluctuate widely.

Our relative accuracy of 22.6% for defoliation of current year's Douglas-fir foliage by the western spruce budworm compares with 16.8% obtained in a comparison of mid-crown ocular estimates with cut-branch estimates for the eastern spruce budworm on balsam fir, *Abies balsamea* (L.) Mill. (MacLean and Lidstone 1982). In that study there was a bias towards overestimating defoliation on individual trees with the ocular method, especially at low levels of defoliation. The difference between the two studies in terms of bias may be due to the different tree and insect species involved, differences in individual observer bias or sample size. When mean current year's defoliation for a location was estimated using the two different methods the two studies produced similar results; MacLean and Lidstone (1982) found the cut-branch estimates averaged 8% higher than the ocular estimates whereas we found they averaged 5% higher (Table 3).

Bias and precision may vary with the observer. MacLean and Lidstone (1982) found that an experienced observer was generally 5 to 10% closer to the "true" value than an inexperienced observer. They also found consistent bias between the defoliation estimates made by three pairs of observers. Silver (1959) on the other hand, found that only one out of 5 observers was consistently biased while the estimates of the other 4 observers fluctuated around the average plot defoliation. We found that defoliation estimates made by our experienced observer were relatively unbiased with respect to the "true" mean, but we did not test differences between observers.

Our results indicate that the binocular method will not produce accurate or precise estimates of current or total defoliation for individual trees, as determined by the cut-branch method. However, mean defoliation estimates for a plot or location, based on a number of trees, showed fairly good agreement between the two methods. Similarly, the assignment into broad defoliation classes by the two methods did not result in close agreement for individual trees, especially for total foliage, but was acceptable for location averages. As most general surveys are based on the average defoliation of a number of trees, and because of the economy of time and labour, the binocular method is acceptable for this purpose.

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