CHANGES IN SPRUCE BUDWORM DEFOLIATION WITH CROWN LEVEL

HARALD PIENE
Canadian Forest Service - Fredericton, PO Box 4000, Fredericton, New Brunswick, Canada E3B 5P7

Abstract

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Detailed estimates of defoliation caused by spruce budworm [*Choristoneura fumiferana* (Clem.)] over the crown length of young balsam fir [*Abies balsamea* (L.) Mill.] were made throughout a spruce budworm outbreak from 1976 to 1984 in the Cape Breton Highlands, Nova Scotia. The results show no clear tendency for a particular level of the crown to be damaged more heavily than any other. Thus, there is no reason to continue the common practice of taking samples from the mid-crown level on the assumption that they represent an 'average' level of defoliation either for high or low populations. Sampling from the bottom of the crown should provide a more convenient and cost-effective approach for estimating defoliation.

Piene, H. 1996. Défoliation par la Tordeuse des bourgeons de l'épinette: Variations en fonction de la hauteur du feuillage. *The Canadian Entomologist* **128**: 1109–1113.

Résumé

Des estimations détaillées de la défoliation par la Tordeuse des bourgeons de l'épinette, *Choristoneura fumiferana* (Clem.), à tous les niveaux de feuillage chez de jeunes sapins baumiers, *Abies balsamea* (L.) Mill., ont été relevées pendant toute l'épidémie de tordeuses de 1976 à 1984, dans les hautes terres de l'île du Cap-Breton, Nouvelle-Écosse. Les résultats ont démontré qu'il n'y a pas de tendance particulière à ce qu'un niveau du feuillage soit plus endommagé que tout autre. Il n'y a donc pas de raison de continuer à échantillonner plus particulièrement le niveau moyen du feuillage sous prétexte que ces échantillons représentent un degré 'moyen' de défoliation tant pour les populations de haute densité que pour les populations de faible densité. L'échantillonnage du feuillage inférieur constitue une approche plus commode et moins onéreuse d'estimation de la défoliation.

[Traduit par la Rédaction]

Introduction

Estimating defoliation caused by feeding of spruce budworm [*Choristoneura fumiferana* (Clem.)] commonly involves visual observations of individual trees from the ground. Defoliation is estimated either with binoculars, obtaining values for the whole tree or from sections of the crown, or by the removal of single branches, usually from the mid-crown, to evaluate damage from single shoots.

Visual estimation of defoliation from mid-crown branches has had widespread use since the early 1950s, both for large-scale surveys (Webb et al. 1956; Sanders 1980; Dorais and Kettela 1982) and for research purposes (Ford 1980; Blais et al. 1981; MacLean and Ostaff 1989). Selection of mid-crown branches is based on the assumption that there is a gradient in intensities of defoliation throughout the crown, such that a mid-crown branch approximates the average tree condition. There is no comprehensive study that has examined changes in spruce budworm defoliation with crown level. The objective of this paper is to relate defoliation to crown level at both low and high spruce budworm densities.

Methods

Study Area. The study area was located in the Cape Breton Highlands, Nova Scotia, Canada, in an almost pure 20- to 30-year-old forest of balsam fir [*Abies balsamea* (L.) Mill.]. A severe spruce budworm outbreak started in the study area in 1976, when most of the current-year foliage was consumed. Because of a severe increase in spruce budworm population levels in 1977 and 1978, the current-year foliage was destroyed in the early stages of shoot

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elongation, accompanied by severe backfeeding on older age classes. After 1978, the population decreased, and, in general, only current-year foliage was defoliated until the population decreased to low levels in 1983 (Piene 1989). For a further description of the study area, see Piene (1981). Four 0.025-ha plots, two in a spaced, defoliated stand, and two in an adjacent unspaced, defoliated stand, were established in 1976.

Defoliation Measurements. Defoliation of the current-year foliage was estimated on a subset of trees in each plot representing the range of diameters present. Defoliation was estimated on one branch per whorl from 1976 to 1979, and on one from every second whorl from 1980 to 1984. The same branches were sampled each year and from 1976 to 1978 defoliation for each branch was assessed visually on single shoots along the mid-rib of each second-order branch (laterals growing from the main branch axis). In 1976, defoliation was estimated in 10% classes. However, these classes were felt to be too narrow, and from 1977 defoliation was estimated in 20% classes. The current-year foliage was completely destroyed by the spruce budworm in the early stages of shoot elongation in 1977 and 1978, causing a prolific production of epicormic buds. Following a decrease in spruce budworm populations in 1979, these epicormic buds developed into shoots and this destroyed the regular growth pattern of the branches (Piene 1989). The sampling effort was, therefore, increased and defoliation of post-1978 foliage on a branch was estimated for each shoot on all the second-order branches each year. The total number of trees sampled each year ranged from 26 to 5 and from 24 to 6 for the spaced and unspaced trees, respectively. The decreasing number of trees sampled each year was a result of tree mortality caused by spruce budworm defoliation. For a more detailed description of the procedure of estimating defoliation see Piene and Eveleigh (1996).

Statistical Analysis. The relative height of each sample branch in the live crown was calculated as the ratio of its height above the base of the live crown to the length of the live crown. Accordingly, the relative height ranges from 0 at the base of the crown to 1.0 at the top. The relative tree height was divided into four levels. If more than one sample branch was located within a level, average defoliation was based on all sample branches present in that level. Analysis of variance was used to test for differences in defoliation between crown levels. First, the whole data set was used from both spaced and unspaced trees, and second, only the data from the unspaced trees was used. For both analyses, year was used as a covariate. The probability level was set to 0.05. As there was no significant difference in percentage defoliation between plots within the spaced and unspaced stands, the trees were pooled for the analyses (Piene 1989).

Results and Discussion

The intensity of defoliation of the current-year foliage did not show any relationship with crown level. There was also no spacing effect on defoliation (Table 1). Although the defoliation was most severe at the base of the crown from 1981 to 1983 for the unspaced trees (Fig. 1), there was no significant difference between crown levels (Table 1). This was true regardless of spruce budworm population levels, even though defoliation of the current-year foliage each year from 1976 to 1981 was severe (averaging 83.5%) and that from 1982 to 1984 was light (averaging 28.1%).

Because of the greater level of defoliation of the spaced, compared with the unspaced, trees in 1977–1978 (Piene 1989), topkill of spaced trees was common. As the budworm populations decreased in 1979 and thereafter (Piene 1989), trees that recovered generally grew a new top. Thus crown condition changed during the spruce budworm outbreak, but this did not seem to influence the feeding pattern of the budworm, which continued to feed uniformly throughout the crown (Fig. 1; Table 1). Previous work has suggested that greater defoliation occurs at the top and base of the crown for dense and thinned crowns of balsam

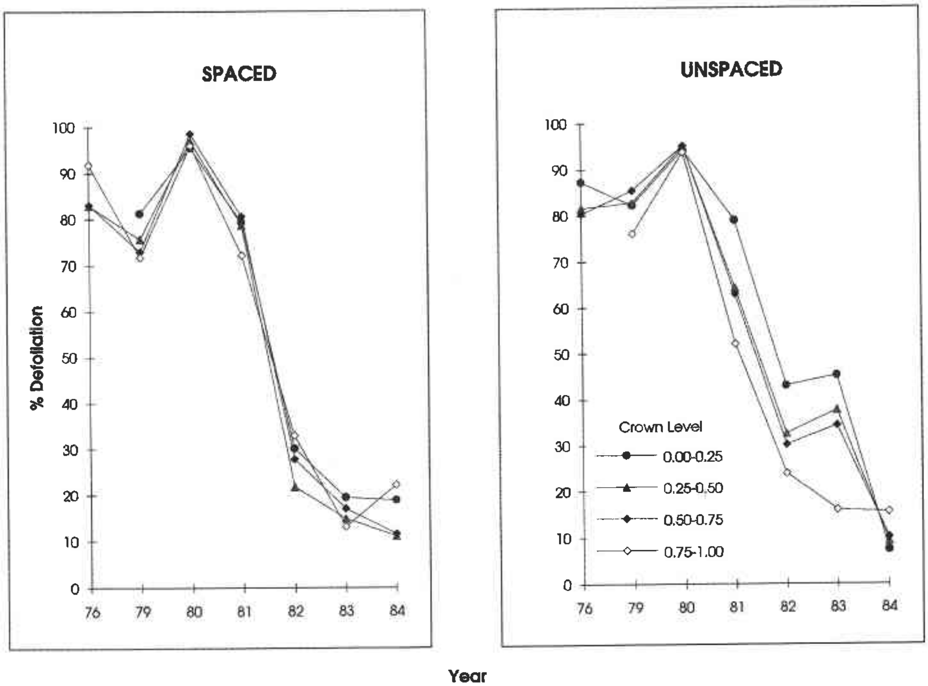

FIG. 1. Average percentage defoliation of current-year foliage for the four different crown levels for spaced and unspaced trees from 1976 to 1984. No data were presented for 1977–1978, because of a complete defoliation of the current-year foliage in the early stages of shoot elongation.

TABLE 1. Analysis of variance for differences in defoliation between crown levels: (A) using the whole data set of both spaced and unspaced trees and (B) for the unspaced trees only. For both analyses, year was used as a covariate. The probability level was set to 0.05

Source	df	Sum of squares	F	$P > F$
(A)				
Model	8	128 237.5	56.68	0.0001
Spacing	1	178.3	0.63	0.4276
Crown level	3	1 150.4	1.36	0.2556
Spacing * crown level	3	633.5	0.75	0.5247
Year	1	121 447.5	429.40	0.0001
Error	485	137 172.7		
Total	493	265 410.2		
(B)				
Model	7	69 214.7	40.51	0.0001
Crown level	3	1 274.0	1.74	0.1597
Year	1	64 731.9	265.19	0.0001
Year * crown level	3	1 325.0	1.81	0.1463
Error	225	54 921.2		
Total	232	124 135.8		

Note: analysis was performed on transformed data (arcsin).

fir, respectively (Fettes 1950). However, he presented data for only 1 year and, in most cases, the relationships were not statistically significant.

Although there was no relationship between defoliation and crown level (Fig. 1; Table 1), a few trees each year showed significant changes (regression analysis) in defoliation with crown level. These trees were almost without exception not the same trees from any given year to the next. Also, tree and crown characteristics did not separate these trees from the rest of the trees in the stand.

The density of egg masses and the population of early-instar larvae have been shown to be higher at the upper, more exposed, part of the crowns of balsam fir (Morris 1955). However, regardless of the position of the early-instar larvae, it is during the fifth- and sixth-instar stages that the majority of the damage is done (Miller 1977). This is a time during which the larvae wander around in search of feeding sites (Fettes 1950) resulting in defoliation being evenly distributed throughout the crown, as observed in the present study.

Information is scarce on changes in current-year defoliation with crown level. In a 1-year study in the Green River area of New Brunswick, MacGillivray (1952) estimated defoliation visually on individual shoots from four crown levels in two immature (five trees each) and four mature (three to five trees) stands. He found significantly higher defoliation in the top and bottom levels of the crowns for the trees in one of the immature and mature stands, but the trees from the remaining plots did not show any relationship between defoliation and crown level. MacLean and Lidstone (1982) found no relationship between defoliation and crown level in a 1-year study involving six trees.

Concluding Remarks

There is no particular reason for selecting mid-crown branches to estimate defoliation. Perhaps the decision to collect branches from the mid-crown is based on results presented by Fettes (1950): in 4 out of 6 years, he found the most severe and the lightest budworm feeding at the highest and the lowest crown levels, respectively, and he concluded that the mid-crown level would usually provide a representative estimate. However, Fettes studied only one tree, which of course is not adequate. The decision may also stem from Morris' (1955) comment: "in rapid sampling work for extensive surveys, where only one level can be sampled, it is generally necessary to assume that the mid-crown level is representative of the tree." However, Morris was referring to egg masses and, for the most part, early-instar larvae, and not to changes in defoliation with crown level.

In conclusion, the results presented in this paper show that there is no clear relationship between spruce budworm defoliation and crown level of balsam fir under either low or high defoliation intensities. Also, the condition of the crown does not seem to affect this feeding pattern. Thus, sampling from any crown level would represent an average tree condition. Sampling from the bottom of the crown should provide a more convenient and cost-effective approach to estimating defoliation than taking mid-crown samples.

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