Spruce Budworm

Choristoneura fumiferana (Clemens)
Lepidoptera: Tortricidae

Objective: To determine the sampling intensity required to predict *C. fumiferana* defoliation accurately as a function of host tree species.

Abstract: Spruce budworm, *Choristoneura fumiferana* (Clemens), is the most destructive defoliator of balsam fir, *Abies balsamea* (L.) Mill., and white spruce, *Picea glauca* (Moench) Voss, in eastern North America. The last three larval instars cause most of the defoliation. Periodic outbreaks occur every 30 years, with epidemics lasting 5–10 years.

An assessment of 172,300 individual shoots from 6,890 mid-crown branches taken from 135 spruce and balsam fir stands throughout New Brunswick was conducted to determine sample sizes required for estimating *C. fumiferana* defoliation. Dominant host species were white spruce, red spruce (*P. rubens* Sarg.), and black spruce [*P. mariana* (Mill.) B.S.P.], as well as balsam fir. Host species and the mean defoliation level, as classified with a preliminary assessment, determine the required sample size of shoots per branch or branches per stand needed to predict budworm defoliation. Sample sizes were estimated at the 90 or 95% probability level that the confidence interval was within ±10% defoliation as a function of average defoliation level and tree species. For a desired probability level of 90%, 17-19, 24-37, and 44-58 shoots per branch should be sampled when mean defoliation is light, moderate, and severe, respectively. For a desired probability level of 95%, 26-28, 67-88, and 44-56 shoots per branch should be sampled when mean defoliation is light, moderate, and severe, respectively. The mean number of branches required to estimate defoliation ranged from 7-24 per stand, depending on tree species and the desired probability level. Sampling took about 5-10 min to collect mid-crown branches with an additional 10-30 sec per shoot to estimate defoliation.

Sampling Procedure: Select the desired probability level and appropriate tree species to be sampled from Table 1 if sampling individual trees or from Table 2 if sampling stands. The minimum number of shoots per branch or branches per stand required for sampling each species is given in the 'light' defoliation columns. Collect the appropriate minimum number of branches from randomly selected trees and rate the observed defoliation on the minimum number of shoots or branches into the following classes:

Percent defoliation observed	Defoliation level
0-30%	Light
31-70%	Moderate
71-100%.	Severe

This preliminary assessment provides a rough idea of the defoliation on a tree or within the stand and can be used to eliminate unnecessary sampling.

Sampling individual trees: Reference Table 1 to determine the required number of shoots to assess on each branch given the desired probability level, tree species, and mean defoliation level determined from the preliminary assessment of the minimum number of shoots. Using pole pruners, remove one whole branch sample from the mid-crown of randomly selected, dominant or co-dominant trees. Assess defoliation only on current year foliage, moving from the tip of the branch to the base until the required number of shoots on a branch has been processed. In general, sampling a whole branch will provide sufficient shoots for classifying individual trees, but a second mid-crown branch from the same tree may be necessary if few shoots are present on the first branch. Classify the tree according to the percentage of observed defoliation as described above.

Sampling stands: Reference Table 2 to determine the required number of branches to assess within a stand given the desired probability level, tree species, and mean defoliation level determined from the preliminary assessment of the minimum number of branches. Using pole pruners, remove one whole branch sample from the mid-crown of randomly selected, dominant or co-dominant trees in each stand. Sample only one branch from each tree (i.e., the number of branches required is also the number of trees to be sampled). If the average defoliation level from the initial sample of the minimum number of branches is moderate or severe, reference Table 2 to determine the additional number of whole, mid-crown branch samples required. Assess defoliation only on current-year foliage. Classify the stand according to the percentage of defoliation observed on the branches as described above.

Notes: The effort required to process the full range of shoots or branches justifies the recommended practice of first sampling the minimum number of required shoots or branches to classify the stand as having light, moderate, or severe defoliation. Increasing the probability level from 90 to 95% increases the sampling effort by 50%. This sampling plan assumes that no backfeeding occurred and all defoliation within an age class resulted from feeding during the year the foliage was produced. Red and black spruces were combined into a single class for this study because they hybridize readily. No red-black spruce stands with severe defoliation were sampled in this study. Managers should select the dominant susceptible species in each stand as the host species in Tables 1 and 2.

Tables

Table 1. Mean number of shoots per branch required to estimate spruce budworm defoliation with 90 or 95% probability that the 95% confidence interval is within ±10% defoliation, as a function of average defoliation level and tree species.

Variable	Species	Average Defoliation Level[a]			Total[b]
		Light	Moderate	Severe	
A. No. of observations[c]	Balsam fir	1,610	970	395	2,975
	White spruce	757	470	96	1,323
	Red-black spruce	2,208	361	25	2,594
B. Required no. of shoots per branch with 90% probability	Balsam fir	19	44	24	29
	White spruce	18	45	27	30
	Red-black spruce	17	58	37	37
C. Required no. of shoots per branch with 95% probability	Balsam fir	28	67	36	44
	White spruce	27	68	40	45
	Red-black spruce	26	88	55	56

[a] Defoliation classes for calculating sample sizes were defined as light 0-30%, moderate 31-70%, and severe 71- 100%.
[b] Total values are sums for number of observations and means per species for required number of shoots per branch.
[c] Number of branches sampled per species and defoliation level, with individual ratings of defoliation on 25 shoots per branch.

Table 2. Mean number of branches per stand required to estimate spruce budworm defoliation with 90 or 95% probability that the 95% confidence interval is within ±10% defoliation, as a function of average defoliation level and tree species.

Variable	Species	Average Defoliation Level[a]			Total [b]
		Light	Moderate	Severe	
A. No. of observations[c]	Balsam fir	165	156	38	359
	White spruce	30	31	3	64
	Red-black spruce	295	31	0	326
B. Required no. of branches per stand with 90% probability	Balsam fir	9	24	13	15
	White spruce	8	17	10	12
	Red-black spruce	7	19	—	13
C. Required no. of branches per stand with 95% probability	Balsam fir	14	39	21	25
	White spruce	13	26	15	18
	Red-black spruce	10	30	—	20

[a] Defoliation classes for calculating sample sizes were defined as light 0-30%, moderate 31-70%, and severe 71- 100%.

[b] Total values are sums for number of observations and means per species for required number of branches per stand.

[c] Number of stands sampled per species and defoliation level, with ≥5 mid-crown branches sampled per stand.

Tables 1 and 2 reprinted with permission from the Society of American Foresters, granted June 9, 2009.