Spruce Budworm

Choristoneura fumiferana (Clemens)
Lepidoptera: Tortricidae

Fowler, G. W.; Simmons, G. A. 1985. Spruce budworms handbook: sampling procedures for spruce budworm egg-mass surveys (with reference to the Lake States). Agric. Handb. 635. Washington, D.C.: U.S. Department of Agriculture, Forest Service; 33 p.

Objectives: To summarize the methods used to estimate the density of *C. fumiferana* egg masses in spruce-fir stands and calculate the associated variance of the mean, the allowable error percentage, and the 75% upper and lower error boundaries.

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, while epidemics can last 5–10 years.

The methods for sampling *C. fumiferana* egg masses summarized in this handbook are a compilation resulting from a cooperative effort between the U.S. Department of Agriculture and the Canadian Department of the Environment (CANUSA). Sampling procedures and associated statistics are described in detail for single stands as well as forest management units and larger areas. A system to determine the hazard rating and treatment priority of stands is presented as well. These methods are appropriate for pure or mixed stands of white and black spruce, *Picea mariana* (P. Mill.) B.S.P., or balsam fir.

Sampling Procedure:

Estimating egg mass density for a single stand: Choose high risk stands to sample based on whether an outbreak is in progress, the stand value is high, the stand is ≥2 ha, the stand contains more than 30% spruce-fir, dominant/codominant trees are ≥9 m tall, and the area is accessible for management and harvesting. Determine the number of plots appropriate for the size of the stand based on the following:

Stand size	Size and rank of stand	Recommended number of sampling plots (consisting of 3 trees each)
<10 ha	Small, rank 1	2
10–20 ha	Medium, rank 2	3
20–40 ha	Large, rank 3	4
>40 ha	Very large, rank 4	5

Determine where to place the plots using a compartment map or aerial photo of the stand. Draw a line bisecting the long axis of the stand. Divide the number of samples to be taken into the length of the line to determine the interval between sample points on the line. Use a random number generator to pick a random number between 0 and the interval length. This number determines how far into the plot the first sample point will be located. Space the remaining sample points along the line from this initial point using the interval length.

In the field, randomly select the 3 host trees closest to the designated sample point. Selected trees should be either spruce or fir if the stand is mixed. Trees should be dominant/codominant and between 9–18 m tall, have a 50–100% live crown ratio, and be relatively open grown. For each tree in a sampling point, cut two branches randomly selected from the midcrown of each sample tree, being sure that each sample includes all the live foliage on the branch. Clip all the live foliage off the branches and place together in one large bag labeled with the date, stand number or name, the plot number, and the tree number.

In the laboratory, carefully measure the length and width of foliage on each branch and record the measurements on the data sheet (Table 1). Clip the foliage into 10–15 cm sections and examine each for fresh egg masses. Any egg masses on new foliage are considered fresh. Egg masses on old foliage are considered fresh if they are a clean white, fully inflated, and show no signs of damage or parasitization. Grey, deflated, or otherwise damaged egg masses are considered old. Egg masses with at least 50% black eggs are considered parasitized. Remove all egg masses and needles and place in a container. Record the total number of fresh egg masses and the total number of parasitized egg masses found on the datasheet. Return the branch segments and egg masses back to the labeled bag if a checker is re-examining bags for searcher accuracy.

To check the accuracy of personnel searching for egg masses, re-examine 25–50 randomly selected bags previously processed by one searcher. The original searcher should not know which bags will be selected and should not do the re-examination. Using Table 2, calculate the accuracy proportion of each searcher by adding the total number of new egg masses found in a bag by the first searcher to the number of new egg masses found during re-examination. Divide this number into the total number of new egg masses found in a bag by the first searcher to generate the accuracy proportion for the searcher. Correct future egg mass counts by that searcher by dividing the number of egg masses found in a bag by the accuracy proportion calculated for that searcher.

$$\text{Accuracy proportion} = \frac{\text{Total number new egg masses found by searcher}}{\text{Total number new egg masses found by searcher + total number of egg masses found during re-examination}}$$

As a rule, all samples should be checked twice for accuracy if populations of spruce budworms are low (>0.4 egg mass/1,000 cm^2 foliage). There is no need to calculate a correction factor in this case.

Use the following formulae to calculate the average stand egg mass density (SA), the variance of the average [s^2(SA)], the allowable error percent (AE%), and the 75% error boundaries per stand:

$$SA = \sum PD_i / n$$

where n = the number of plots of three trees each, $PD_i = \Sigma\ T_j/3$ represents the plot average egg mass density for the i^{th} plot, and T_j is the tree egg mass density for the j^{th} tree as determined from the two branches sampled from that tree.

$$s^2(SA) = \frac{\sum PD_i^2 - \left(\sum PD_i\right)^2 / n}{n(n-1)}$$

$$AE\% = [2s(SA)/SA] \times 100$$

$$\text{Upper bound} = SA + 2s(SA)$$
$$\text{Lower bound} = SA - 2s(SA)$$

These sample statistics provide current information on *C. fumiferana*, which can be used to estimate the potential for defoliation and damage in the future. A hazard rating and treatment priority can be determined for the stand using these sample statistics as described below under "Estimating Egg mass Density in a Forest Management Unit."

Estimating Egg Mass Density in a Forest Management Unit: Sampling all stands within the forest management unit allows a manager to determine if harvest is needed and, if so, which stands should be harvested first. Calculate egg mass density and associated sample statistics for each stand sampled using the procedures described above. Continue by determining the hazard rating and treatment priority for the unit using the procedures described below.

1. Rank each stand based on the stand's vulnerability to spruce budworm damage. These hazard ratings are based on the particular system used, such as Batzer and Hastings (1981) for Minnesota and Lynch et al. (1984) for the Upper Peninsula of Michigan.

Rank of stand	Vulnerability rating
1	Low
2	Moderate
3	High
4	Extreme

2. Rank each stand based on the defoliation of current-year foliage (Montgomery et al. 1982):

Rank of stand	Defoliation of current-year foliage	% Defoliation
1	None; defoliation minimal or not observed	0–20%
2	Light to moderate	21–50%
3	Heavy	51% or more but no evident topkill
4	Severe	51% or more; topkill evident

3. Rate each stand equal to the number of successive years visible defoliation has occurred.
4. Add +2 if the spruce budworm population is increasing or −2 if the population is declining.
5. Rate each stand based on the estimated future defoliation based on the following:

	Average egg mass density		Expected defoliation	
Rating	*Pure Fir or mixed spruce-fir*	*Pure spruce*	*Percent*	*Intensity*
1	<0.4	<0.8	<26	Light
2	0.4–1.09	0.8–2.19	26–50	Moderate
3	1.1–1.7	2.2–3.4	51–75	Heavy
4	>1.7	>3.4	>75	Severe

The level of expected defoliation on white spruce should be lower than defoliation on balsam fir for similar egg mass densities, so the critical values for average egg mass density are raised for stands of pure spruce.

Sum the five ratings described above for each stand to determine the treatment priority for the stand. Stands rated as “high” should be harvested immediately. Harvest can be postponed 2–3 years for stands rated as “intermediate”, while stands rated as “low” should be monitored for a change in treatment priority until harvested.

Treatment priority	Sum of 5 ratings
1 = low	2–7
2 = intermediate	8–11
3 = high	12+

Notes: Not all stands in a forest management unit need to be sampled for *C. fumiferana*. Egg mass density can be estimated from at least half of the stands in the unit or from at least five stands; managers should choose whichever is greater in number. The guidelines for sampling a limited number of stands within a forest management unit, instead of sampling all stands in the unit, are based on the authors' experiences. Refer to the original publication for the formulae used to calculate the sample statistics for a management unit if sampling a selected number of stands instead of all stands.

Refer to the original publication for detailed information regarding the calculations and formulae used with these methods, and for methods used to monitor *C. fumiferana* populations over larger regions. The authors also suggest that the procedures used for egg mass estimates could be adopted for use with sampling overwintering larvae and pupae from foliage samples, or sampling adult moths using light/pheromone traps.

References:

Batzer, H. O.; Hastings, A. R. 1981. Rating spruce-fir stands for spruce budworm vulnerability in Minnesota. In: Hedden, R. L.; Barras, S. J.; Coster, J. E., technical coordinators. Hazard-rating systems in forest insect pest management. Gen. Tech. Rep. WO-27. Washington, D.C.: U.S. Department of Agriculture, Forest Service; p. 105-108.

Lynch, A. M.; Fowler, G. W.; Witter, J. A. 1984. Development of empirical models to rate spruce-fir stands in Michigan's upper peninsula for hazard from the spruce budworm (Lepidoptera: Tortricidae): a case history. Great Lakes Entomologist 17: 163-174.

Montgomery, B. A.; Simmons, G. A.; Witter, J. A.; Flexner, J. L. 1982. The spruce budworm handbook: a management guide for spruce-fir stands in the Lake States. Handb. 82-7. Ann Arbor, MI: Michigan Cooperative Forest Pest Management Program; 35 p.

Table

Table 1. Field data sheet for recording data to estimate stand egg mass density.

Stand no. or name:						
			Foliage measurements (cm)		No. of new egg masses	
Plot no.	Tree no.	Branch no.	Length	Maximum width	Total	Parasitized
1	1	1				
		2				
	2	1				
		2				
	3	1				
		2				
2	1	1				
		2				
	2	1				
		2				
	3	1				
		2				
3	1	1				
		2				
	2	1				
		2				
	3	1				
		2				
4	1	1				
		2				
	2	1				
		2				
	3	1				
		2				
5	1	1				
		2				
	2	1				
		2				
	3	1				
		2				

Table 2. Data sheet for recording data to estimate a searcher's accuracy proportion.

Bag no.	No. egg masses found			Bag no.	No. egg masses found			Bag no.	No. egg masses found		
	Searcher	Checker	Total		Searcher	Checker	Total		Searcher	Checker	Total
1				18				35			
2				19				36			
3				20				37			
4				21				38			
5				22				39			
6				23				40			
7				24				41			
8				25				42			
9				26				43			
10				27				44			
11				28				45			
12				29				46			
13				30				47			
14				31				48			
15				32				49			
16				33				50			
17				34							
								Total			

P = Searcher accuracy proportion
S = Total number of egg masses found by searcher
SC = Total number of egg masses found by searcher and checker

$P = \frac{S}{SC} =$ _____ [ ] =