## Spruce Budworm

*Choristoneura fumiferana* (Clemens)
Lepidoptera: Tortricidae

Sanders, C. J. 1980. A summary of current techniques used for sampling spruce budworm populations and estimating defoliation in eastern Canada. Rep. O-X-306. *Canadian Forest Service, Great Lakes Forestry Centre*; 34 p.

**Objectives:** To provide a summary of population level estimates for various life stages of *C. fumiferana*; to summarize techniques for estimating defoliation levels; and to summarize two hazard prediction systems.

**Abstract:** The spruce budworm 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 and epidemics can last 5-10 years.

Methods used by the Canadian Forestry Service and by provincial agencies in Ontario (ONT), Quebec (PQ), New Brunswick (NB), Nova Scotia (NS), Prince Edward Island (PEI) and Newfoundland (NF) up to 1980 are described for estimating population densities of the eggs, overwintering second instars, large larvae, pupae and adults, and defoliation levels. Methods dealing with extensive and intensive surveys are described in detail in this report.

The egg, larval and pupal surveys used either a 45-cm branch tip or a whole branch taken either from the mid-crown or from each of the upper, mid- and lower crown positions of host trees. Light, Malaise, and pheromone traps were used to determine population trends or to detect new budworm moth invasions. Tables are provided to assess budworm infestation levels for each survey method presented. Four methods were used to evaluate defoliation: aerial assessments, ground assessments with binoculars, and two ground assessments methods that are hands on examination of foliage (i.e., the Fettes and the Dorais-Hardy methods). A hazard prediction system based on current defoliation, previous damage, recovery and egg mass counts was presented.

**Sampling Procedure:** This document describes procedures specific to extensive and intensive sampling plans within plots only. The number of plots to be sampled depends upon the size of the area of concern.

Surveys for eggs: The egg mass survey is used widely for predicting budworm population levels. Egg mass sampling should be carried out as soon as possible following the end of oviposition. For extensive egg mass surveys, cut a whole branch from the mid-crown of each sample tree. For example, the maximum number of branches (trees) sampled at each plot is 5 for PQ, 3 for NB, and 6 for

ONT. For intensive surveys, cut one whole branch from each of the lower, mid- and upper crown positions.

Estimate carefully the foliated area for each branch sampled. The most accurate method is to multiply the length of green branch by the width of green branch and divide this product by 2. Examine visually the foliage for all egg masses in the laboratory, and remove and count all egg-bearing needles. Keep a subsample of the egg-bearing needles to estimate the number of viable eggs per egg mass. UV light can also be used to detect egg masses, but this technique is time consuming. Each branch should be rechecked by another worker in case some egg masses were missed initially. It takes 60 and 120 minutes per branch to check for egg masses on balsam fir and spruce, respectively. Express egg mass density as the number of egg masses per 10 square meters pooled for all samples taken per plot. Egg mass densities are then classified as light (<25 egg masses/10 $m^2$), moderate (50-100 egg masses/10 $m^2$), or severe (>200 egg masses/10$m^2$), or simply as low or high (Table 1).

Surveys for overwintering larvae: This survey is also used widely and tends to be less labor intensive than the egg survey. Sample any time from September to April of the next year. Sample a whole branch, or a 45-cm branch in PQ, from the mid-crown of host trees in extensive surveys. One branch should be sampled in each crown zone during intensive surveys. Five to 14 branches should be sampled per plot, depending on the mean to variance ratio (Table 3). Before processing branches to count second instar larvae, calculate branch area as described for the egg mass survey.

A sodium hydroxide (NaOH) wash (Miller and McDougall 1968, Miller and others 1971, Miller and Kettela 1972) or a forced emergence (Miller 1958), sometimes followed by a NaOH wash in intensive surveys, are two methods used widely by to extract second instar budworm from their hibernaculae.

> Sodium hydroxide wash: Washes can be conducted any time from September though April of the next year. Clip each branch into small pieces and place all in a paper bag labeled by plot, tree and branch number. If prolonged storage is necessary the foliage should be kept at 0 °C. Wash each sample in a 10 L plastic pail and leave overnight in a warm room to thaw. Add 90 g of sodium hydroxide per pail and fill pail to the 9 L mark with 50 °C water to make a 1% solution of NaOH. Keep foliage submerged with a weighted screen top. Let soak for 5 h, stirring every hour. Strain the liquid content of each pail through two sieves, one with a 0.8 mm mesh and a second with a 0.25 mm mesh. Place a wire basket in a tub (90 wide by 150 long by 9 cm deep, with a corrugated bottom and drain), and pour the remaining contents of the pail into the wire basket removing any larvae stuck to the sides of the pail. Wash foliage in the wire basket thoroughly and then discard. At

this point, branches should be completely bare. Pour contents of the tub through both sieves and wash into a collecting jar. Pour contents of collecting jar, removing any larvae stuck to the sides of the jar, into a 5 L separating funnel. Add hexane to the funnel, creating a 3 mm layer on top of the aqueous solution. Shake this mixture vigorously to obtain thorough mixing and allow 5 minutes to settle. Approximately 99% of the larvae will settle at the hexane-water interface. Draw off plant debris that has settled at the bottom of the funnel, and draw off the hexane-water fraction into 400 ml beakers to be vacuum filtered. If there is much plant debris in this fraction, process only 100 ml at a time. Fit a Buchner funnel to the separating filter using a molded rubber diaphragm (Filtervac) and connect a filter pump. Pour debris onto a piece of grided (to be seen under microscope), wetted filter paper. 'Washed' budworm larvae have black heads and very light colored bodies. This technique requires 5 h soaking time and 30 min per branch for preparation and examination. Miller and others (1971) found the cost of this technique to be substantially higher than the beat method for large budworm larvae but only a third of the cost of counting egg masses.

Forced emergence: Diapause must be complete before this technique can be used. This usually occurs in early March in eastern Canada, however, samples can be collected earlier and stored until diapause requirements have been met. The enclosed box or paper cone methods can be used.

Any sealed, darkened container with a transparent, clear collecting vial would make an adequate emergence cage for the enclosed box method. Fill each container with foliage but do not pack tightly. Orient box so that the collecting vial is pointed upward, facing a bank of lights that serve to attract larvae to this vial. Count and remove the larvae in the collecting vials periodically during the emergence period. A modification of this technique is used in PQ. A 45-cm branch tip is placed in a small polystyrene ice bucket with a closed top. The bucket is painted black to reduce light transmission. A transparent vial is fitted into the bottom of each bucket, and all buckets are placed on a wire fence with the vials facing the light. Vials are checked for 10 d, after which time budworms have become third and fourth instars. Branches are then removed from the buckets, and the number of larvae remaining in the bucket are counted. Alternatively, branch tips can be left in the bucket (with no clear vial) until most larvae are either third or fourth instar, and then the foliage can be removed and beaten (as for large larvae below) to dislodge all larvae.

The paper cone method involves wrapping branches with paper towel and hanging each branch separately by the proximal end, suspending all samples by a string under a strong light. Collect larvae as they crawl up

the paper and string. Some larvae will drop off the branch, so to collect these larvae place a piece of paper below each branch. Ring the edge of each sheet of paper with Tanglefoot (The Tanglefoot Co., Grand Rapids, MI) to prevent escape. The string is also ringed with Tanglefoot approximately 30 cm up from the branch. Spray branches with water periodically to prevent drying. This method is messier (due to Tanglefoot), and requires more time and space, than the box method. Information on relationships between the density of overwintering second instar budworm and the population level of large larvae, or of defoliation potential, can be found in Miller and others (1971) and Miller and Kettela (1972).

Surveys for large larvae: To determine how many samples are needed for the large larvae survey, see either Table 4, 5, or 6 (original publication) depending on the chosen survey method or method of expressing budworm population levels. Sampling should coincide with the predicted peak of the third through sixth instar stages. Collect a 45-cm branch tip or a whole branch for extensive or intensive surveys, respectively. For extensive surveys, remove one branch tip from the mid-crown of each sample tree. For intensive surveys, remove one whole branch from each crown level of each sample tree if population levels appear moderate to high. If populations appear low, remove one whole branch from the mid-crown of each sample tree. If trees have been sprayed with insecticides, then remove branches from both the upwind and downwind sides of the tree.

In the laboratory, count the number of current shoots to determine the potential number of feeding sites. Examine visually the foliage for presence of large larvae, otherwise, larvae can be extracted from foliage by a drum or a beating technique. Third and fourth instars are usually found in buds or staminate flowers but fifth and sixth instars can be found anywhere on the branch, including the bag where the branch was stored.

To sample fifth and sixth instars in the field, use either a basket attachment below the cutting head of the pole pruners, or a tarp below the branch being lowered from the sample tree. Populations are classified as either low or high based on the cumulative counts of budworm from 45-cm branch tips (Table 7). The drum technique, a method to separate larvae from foliage, is summarized as follows:

*4.7 Drums*

The drum technique evolved from earlier attempts to speed up larval counting by extracting larvae from samples by various mechanical and chemical techniques (DeBoo et al. 1973).

The equipment now used in many parts of eastern Canada consists essentially of the following six parts (Martineau and Benoit 1973):

(1) a galvanized steel drum, 60 cm (24 in.) deep and 48 cm (18.) in diameter

(2) a perforated cap (for 16 oz (ca 500 ml) screw top widemouth glass jar) welded close to the bottom end to fit a 5 cm (2 in.) hole, and a handle fixed near the point of balance on the opposite side of the drum

(3) a removable rectangular iron screen tray 59 x 45 cm (23.2 x 18 in.), made of mesh 1.25 cm (0.5 in.) framed with a welded steel rod .63 cm (0.25 in.) in diameter

(4) a 16 oz (ca 500 ml) collecting jar

(5) a paint brush (7 cm wide)

(6) a folding wooden stand built so as to keep the drum at the required angle and height when in operation, and fitting inside the drum during transportation.

The separation of the insect material from the foliage by the drum technique is done in three steps: (1) beating of the branch sample vigorously against the screen table and the side of the drum (30 strokes in all), (2) brushing down the screen and the inside of the drum to direct larvae into the jar, and (3) removing the jar for examination of contents.

The beating technique is used to obtain indices of population density for extensive surveys. Beat with a stick 1 $m^3$ of foliage at ground level from two sides of each of 10 trees (20 samples total), counting the number of larvae falling onto a 1-$m^2$ cloth tray situated below the 'beat' area. For larval densities of less or greater than 5 per cubic meter, refer to Table 8 in the original publication to determine the number of additional samples needed. If densities are less than 1 larva per cubic meter then sample until one larva is found.

Surveys for pupae: Sample during the predicted peak pupal stage of the population or shortly after adult emergence. Collect either a 45-cm branch tip or a whole branch for extensive and intensive surveys, respectively. The sampling intensity and method of branch examination is the same as the large larval survey. The drum technique may also be used in extensive surveys, but this technique damages some pupae and is not recommended if pupae are to be reared to adults. Populations are classified as either low or high based on

the cumulative counts of pupae from 2-10 45-cm branch tips per sample tree (Table 9).

Surveys for adults: Light, Malaise, and pheromone traps are used to develop population indices for budworm moths. Light traps can be used to forecast population trends for a period of years in the same location and can also be used to indicate moth invasions into new areas. Miller and others (1979) found that catches of female moths in light traps suspended in the forest canopy, coupled with density estimates of resident female pupae, can be used as a crude estimate of budworm egg mass densities over a broad area. This method is considerably cheaper than egg mass surveys. As of 1980, Malaise and pheromone traps were not in operational use as tools to determine budworm population levels.

Surveys to estimate defoliation: Budworm defoliation can be determined by aerial, ground with binocular, Fettes and Dorais-Hardy assessments. Aerial assessments can be made from aircraft with reasonable accuracy by trained observers (Waters and others 1958). Use binoculars from <50 m on the ground to determine the percentage of new growth remaining in the upper two-fifths of the live crown. Rate trees as excellent (>75% new growth remains), very good (50-75%), good (25-50%), poor (<25%), very poor (only if some new shoots are found on entire crown) or nil (0%).

The Fettes method (Fettes 1950) involves obtaining branches from the mid-crown of balsam fir and then visually estimating the percentage of needles removed from each current-year shoot on the branch (Fig. 2 in original publication). Estimates are averaged to provide a defoliation level for the whole branch. The Dorais-Hardy method is used for branches that were so defoliated that normal bud development was prevented. This method accounts for damage to buds and foliage, however, they are not cut from the tree as in the Fettes method. Instead they are labeled and defoliation levels assessed both before and after an insecticide treatment. Before treatment, record the presence of terminal buds on the three terminal shoots of the branch (Fig. 3 in the original publication). Also, estimate defoliation, based on the Fettes method, for each of the three terminal shoots, and then record the average of the three estimates. Because a new year of growth has been added in the time between the before and after treatment estimates of defoliation, the new set of buds must be evaluated for presence as well as the same shoots evaluated earlier (bottom of Fig. 3 in the original publication). An index can be calculated from this data that indicates recovery potential. However, the Dorais-Hardy method does not account for the production of adventitious buds, which may be produced by heavily defoliated trees.

Hazard mapping: A method of assessing hazard is described in Prebble (1975). Determination of hazard is based on four criteria: egg mass counts, current defoliation, previous damage, and recovery; the last 3 of which can be

estimated when conducting the egg survey. Each criterion is then assigned a numerical value and each value is added to determine hazard levels (Table 10). Most reliance is placed on the egg mass counts because they predict the severity of defoliation and damage for the following year. If egg mass density in a given area is 0 (nil), 1-99 (light), 100-239 (moderate), 240-399 (severe) or >400 (extreme) eggs per square foot, then assign the appropriate hazard value (Table 10).

Defoliation is assessed during the ground survey but can also be estimated during aerial surveys, or a combination of both techniques. Estimate defoliation using the Fettes method (Table 10). Assign a nil (0%), light (1-25%), moderate (25-65%), and severe (>65%) rating as appropriate.

Examine the defoliation of each age class of foliage and assess the health of the crown of each tree sampled for egg masses to estimate previous damage. Assign a nil (no apparent damage), light (defoliation evident on 1-year old shoots), moderate (defoliation evident on 1- and 2-year-old shoots and crown appearing thin) or severe (crown noticeably thin and grayish with >60 cm of bare top) hazard value.

Trees weakened by budworm attack vary in their ability to recover. Assign a nil (no current shoots), poor (a small crop of current shoots), fair (moderate crop of current shoots) and good rating (current foliage crop apparently normal) to each tree sampled as appropriate to define recovery.

Once the hazard value has been determined for each of the four criteria above, add each value to determine overall hazard levels. Assign a low (0-7), moderate (8-10), severe (11-14) and extreme(>15) rating as appropriate. These data can then be plotted on appropriate maps to help identify the areas in most need of control measures.

Quebec uses a similar method of hazard determination except that only the current year egg mass survey data and a 4-yr defoliation history are used to determine hazard levels that would provide justification of control measures.

**Note:** Please refer to original publications for more details regarding these survey methods.

**References:**

Fettes, J. J. 1950. Investigations of sampling techniques for population studies of the spruce budworm on balsam fir in Ontario. Annual Rep. 1949. Sault Ste. Marie: *Canadian Forest Service, Forest Insect Lab*; 11 p.

Miller, C. A. 1958. The measurement of spruce budworm populations and mortality during the first and second larval instars. *Canadian Journal of Zoology* 36: 409-422.

Miller, C. A.; McDougall, G. A. 1968. A new sampling technique for spruce budworm larvae. Res. Note 24. Ottawa: *Canadian Forest Service, Rural Development*; 30-31.

Miller, C. A.; Kettela, E. G.; McDougall, G. A. 1971. A sampling technique for overwintering spruce budworm and its applicability to population surveys. Inf. Rep. M-X-25. Fredericton, NB: *Canadian Forest Service*; 4 p.

Miller, C. A.; Kettela, E. G. 1972. An additional note on sampling overwintering spruce budworm larvae. Inf. Rep. M-X-34. Fredericton, NB: *Canadian Forest Service*; 6 p.

Miller, C. A.; Greenbank, D. O.; Kettela, E. G. 1979. Possible use of canopy light traps in predicting spruce budworm egg-mass counts. Res. Notes 35. Ottawa: *Canadian Forest Service*; 29-30.

Prebble, M. L. 1975. Aerial control of forest insects in Canada. Ottawa: *Canadian Forest Service*; 330 p.

Waters, W. E.; Heller, R. C.; Bean, J. L. 1958. Aerial appraisal of damage by the spruce budworm. *Journal of Forestry* 56: 269-276.

**Tables:**

Table 1. Sequential sampling of spruce budworm eggs. Sample unit is one mid-crown branch per tree from balsam fir.

| No. of sample units | Balsam fir | |
|---|---|---|
| | Population category | |
| | Low | High |
| | (Cumulative egg-masses per 100 ft.2 (~10 m2)) | |
| 1 | --- | 313 or more |
| 2 | 138 or less | 469 |
| 3 | 293 | 624 |
| 4 | 448 | 779 |

Table 3. Tentative estimates of variance-mean relationships for overwintering second-instar larvae on mid-crown branches of balsam fir, and required sample size for 20% precision.

| Mean | Variance | Required no. of branches |
|---|---|---|
| 2 | 2.3 | 14 |
| 4 | 5.4 | 8 |
| 6 | 10.5 | 7 |
| 8 | 17.1 | 7 |
| 10 | 25.0 | 6 |
| >10 | --- | 5 |

Table 7. Sequential sampling of spruce budworm larvae developed for New Brunswick. Sample unit is one 45 cm tip per tree from fir, and one from spruce.

| Number of sample units | Balsam fir | | Red spruce | |
|---|---|---|---|---|
| | Population category | | Population category | |
| | Low | High | Low | High |
| | (Cumulative larvae) | | (Cumulative larvae) | |
| 1 | --- | 28 or more | --- | 34 or more |
| 2 | --- | 36 | --- | 47 |
| 3 | 2 or less | 43 | 3 or less | 60 |
| 4 | 9 | 50 | 7 | 74 |
| 5 | 16 | 58 | 11 | 87 |

Table 9. Sequential sampling of spruce budworm pupae developed in New Brunswick. Sample unit is two 45 cm tips per tree from balsam fir, and four from red spruce (*Picea rubens* Sarg.).

| Number of sample units | Balsam fir | | Red spruce | |
|---|---|---|---|---|
| | Population category | | Population category | |
| | Low | High | Low | High |
| | (Cumulative pupae) | | (Cumulative pupae) | |
| 1 | --- | 33 or more | --- | 9 or more |
| 2 | 1 or less | 50 | 1 or less | 12 |
| 3 | 5 | 66 | 4 | 15 |
| 4 | 10 | 83 | 8 | 19 |
| 5 | 14 | 100 | 11 | 23 |

Table 10. Hazard values assigned to tree condition and budworm abundance, New Brunswick (from Prebble [1975]).

| Category | Hazard value | Category | Hazard value |
|---|---|---|---|
| Current defoliation | | Recovery | |
| Nil | 0 | Good | -3 |
| Light | 1 | Fair | -2 |
| Moderate | 2 | Poor | -1 |
| Severe | 3 | Nil | 0 |
| Extreme | --- | --- | --- |
| Previous damage | | Egg-mass density | |
| Nil | 0 | Nil | 0 |
| Light | 3 | Light | 1 |
| Moderate | 6 | Moderate | 2 |
| Severe | 9 | Severe | 3 |
| | | Extreme | 4 |