Large Larvae (3rd through 6th Instar)*

Objectives:

1. Provide a measure of expected damage.
2. Identify candidate stands for spraying, including "last minute" removal of marginal population spray blocks for initial or second pesticide application.
3. Time direct control properly.
4. Time placement of pheromone traps.

Time of Year:

Sampling may be carried out anytime after larvae are established in the buds or new shoots. It is essential that date of collection and budworm phenology be recorded (See #4 below for help in determining budworm phenology).

When timing of control programs is a primary goal, aerial and ground reconnaissance are usually conducted. In New Brunswick, aerial reconnaissance is based on conducting flights at tree top level over spray blocks and observing shoot flushing on balsam fir. Ground reconnaissance is based on as many blocks as possible, in as many phenologically-different locations as possible. Ground and aerial observations are compared before a decision is made on a block by block (or partial block) basis for opening for treatment. Ground reconnaissance at development plots assess larval development (refer to life history section, p. 18 and section on determining budworm development, p. 45), shoot development (refer to Auger Index, p 46-47) and feeding location of larvae (ie., feeding in mined needles, inside buds, silked outside buds, in flowers or inside flushing shoots). In addition, in New Brunswick, timing of pesticide applications is based on differing criteria of whether the spray blocks are predominantly red/black spruce or balsam fir, and the type of pesticides used (eg., fenitrothion (a contact insecticide) vs B.t. (a biological insecticide which must be ingested)). For more details about timing spray programs, see Carter and Lavigne (1990, 1991, 1992).

* In New Brunswick, spring-emerged 2nd instar larvae are included here. L2s and L3s are typically used, at least in New Brunswick, in the monitoring efforts leading up to the appropriate time for applying pesticides. Once 100% emergence has occurred, L2s are part of the "pre-spray" population counts which are correlated with subsequent damage for a comparison of spray blocks and control areas (L. Hartling, pers. comm.).

Equipment Needed:

Extension pole pruners with basket or clamp attachments, tarpaulin on which to drop branch when clamp attachment is used, tape measure, data sheets.

Note: Use of basket or clamp attachments in sampling branches for large larvae is important. Up to the fourth instar, losses of $<6\%$ of larvae through dropping from foliage when disturbed occur. Losses can rise to 30% for sixth instar larvae (DeBoo, 1974).

Procedure:

1. For **intensive sampling** programs (e.g., preparation of life tables), branches should be taken from each crown zone of sample trees. As a starting point, one whole-branch sample is taken from each crown zone (lower, middle, and upper) of dominant and codominant trees. Morris (1955) computed the number of samples for a required accuracy for whole branches from the four crown zones of balsam fir in moderate to high densities. [Note: Sanders (1980) comments that this sampling scheme is quite feasible in moderate or high density populations where the number of samples required for a given precision is not too great. However, at low population densities the required number becomes so large that obtaining samples from each crown zone is impractical. In order to maximize the amount of information obtained, Miller (1964) proposed the use of a single branch from the mid-crown zone of each sample tree.]

2. For **extensive surveys**, 45 cm (18 inch) branch tips are taken (Atwood, 1944). The number of buds should be recorded whenever possible in order to later analyze data as per insects/bud and insects/branch.

   Variance-mean relationships for whole-branch samples (intensive surveys) and 45 cm branch tips (extensive surveys) of balsam fir are presented in Tables 10 and 11. The number of trees sampled per plot and per block is dictated not only by statistical design, but also by operational logistics, including accessability of spray areas and the number of full-time and seasonal staff available. [For examples of sampling protocol and intensities in New Brunswick, see Carter and Lavigne (1990, 1991, and 1992)].

Table 10. Tentative estimates of variance-mean relationships for third-fourth instar larvae per whole mid-crown balsam fir branch tip [Miller, (unpubl.), as presented by Sanders, (1980)].

Mean	Variance	Required Number of Branches
1	1.8	45
2	5	31
4	14	22
6	25	17
8	40	16
10	54	14
15	100	11
20	150	9
30	280	8
40	400	6
50	600	6
>50		

Table 11. Tentative estimates of variance-mean relationships for third/fourth instar larvae per m^2 of balsam fir branch surface [Miller, (unpubl.), as presented by Sanders, (1980)].

Mean	Variance	Required Number of Branches
4	15.5	24
6	24.0	17
8	36.0	14
10	42.0	10
20	150	9
40	375	6
>50		

3. **Estimate foliage area.** Branches (L x W) are measured (see options for determining area of foliage under egg survey section, page 6). Branch measurements should be recorded on data sheets.

4. **Determine budworm development.** Allen *et al* (1984) suggest that five 18-inch midcrown tips be collected with pole pruners from each of 5 to 10 dominant or codominant trees per plot. The required number of trees sampled in low populations may be higher because a minimum of 25 larvae, and preferably from 100 to 200, from both spruce and fir are needed to determine development. Sampling should be repeated every 2 to 3 days until the target stage of development is reached.

   Development is usually predicted and/or determined in one of 5 ways:

   a. **Head capsule width:** Titus (1977) and McGugan (1954) have presented ranges of head capsule measurements for various larval instars (see Table 1).

   b. **Body length:** Titus (1977) has presented body lengths that correspond to various larval instars (Table 1).

c. **Bud phenology:** Bud phenology as defined by Auger's bud classification system (Figure 2) can be used to derive a bud development index (Table 12). A sample of 25-50 shoots per plot is recommended to accomplish the latter. The index is a useful way to anticipate damage by comparing bud development to that of the insect (Table 13). When the insect is developing faster than the buds/shoots, a lower infestation level is required to cause a specific amount of damage compared to a higher population developing slower than the buds/shoots. Thus, the larval density vs current defoliation relationship produces a different damage curve under these two circumstances.

Table 12. Example of calculation for Auger's bud development index (from Dorais and Kettela, 1982).

	Bud Class Number					
	I	II	III	IV	V	Total
Number of shoots (25 to 50 per plot)	0	5	5	40	1	51

Bud Development Index = $\frac{\#\text{ in Class I} + 2(\#\text{ in Class II}) + 3(\#\text{ in Class III}) + 4(\#\text{ in Class IV}) + 5(\#\text{ in Class V})}{\text{Total \# of Buds}}$

Sample index calculation:

1. $(1 \times 0) + (2 \times 5) + (3 \times 5) + (4 \times 40) + (5 \times 1) = 190$
2. $190/51 = 3.7$

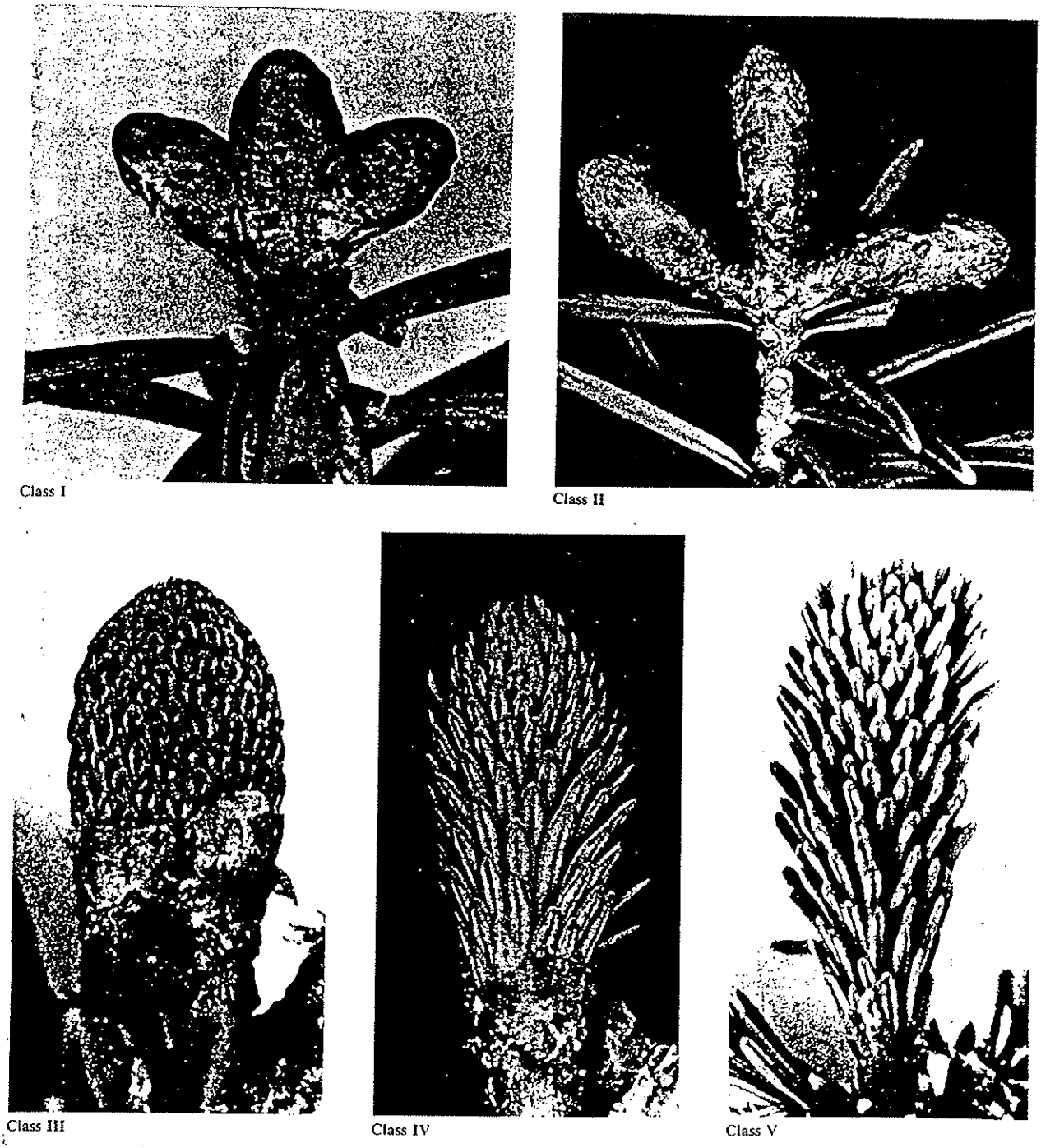

Figure 2. Auger's balsam fir bud classification system (from Schmitt *et al*, 1984).

Table 13. Computation example for spruce budworm development index based on degree days above threshold of 5° C (Dorais and Kettela, 1982).

A. Numerical Assignment	Budworm Development	Number in Sample
1	100% of larvae in hibernation	0
2	peak L2	0
3	peak L3	25
4	peak L4	50
5	peak L5	25
6	peak L6	0
7	peak pupae	0
8	100% adult emergence	0
B. Index $= \frac{(25 \times 3) + (50 \times 4) + (25 \times 5)}{100} = 4.0$		
C. Development Index	Budworm Development	Degree-days Above 5°C
1.0	100% hibernation	45
2.0	peak L2	100
3.0	peak L3	170
4.0	peak L4	240
5.0	peak L5	330
6.0	peak L6	440
7.0	peak pupae	550
8.0	100% adults	-

d. **Degree days:** Degree day accumulations above 42 degrees F (Table 1) are used to predict budworm development. Sometimes a developmental index is assigned, which utilizes knowledge of the relationship between temperature and budworm growth (Table 13, Section C). BioSIM model developed by Regniere and Cooke (in press) is a tool that can be used to predict development of the insect. The model is based on degree day units, and takes into consideration the altitude, latitude, and longitude. This model enables predictions of development for a precise area.

e. **Location of larvae:** Information on the location of larvae may also help to establish the general stage of development. For example, small and wandering caterpillars are usually L2s that have recently emerged from overwintering sites. Budworm that are found mining needles and buds or feeding in staminate flowers are usually L2s or L3s, and L4 through L6 larvae are usually found on current year's foliage.

5. **Examine the foliage for larvae.** Foliage may be examined visually for larvae, or larvae may be extracted by various mechanical and chemical techniques (see a and b below) and then counted.

   a. **Drum technique:** 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 10 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.

b. **Beating:** For rapid, extensive surveys to provide indices of population density the beating technique has been used commonly throughout Canada. A standard technique for budworm sampling has been agreed upon for eastern Canada. At each sampling location two samples are taken, one from each side of the tree, from 10 trees. Each sample consists of the number of larvae falling onto a cloth tray 3 ft x 3 ft (ca 1 m^2) when the foliage in a volume of 1 yd^2 (ca 1 m^3) above the tray is jarred.

Beating is most suitable for pre-outbreak surveys of large larval populations. Although tree beating samples are used primarily for quantitative studies, Miller *et al* (1968) were able to show that, when they are taken over wide areas, they provide a population index that compares favorably with other, more intensive methods of sampling.

6. **Classify the infestation.** Density of large larvae may be expressed as number of budworm per 18-inch (45 cm) branch tip, or as number per whole branch or per 100 ft^2.

Interpretation: A sufficient number of trees is sampled to determine the category into which the budworm population level falls. Note that the tables presented here for balsam fir and spruce include cumulative number of larvae and pupae per sample unit (Tables 14-15).

Table 14. Classification of the number of budworm larvae per branch into low, medium, or high population density. A sample unit is two 45 cm tip per tree from balsam fir.

No. of Sample Units	Low	Medium	High
1	-	-	33 or more
2	1 or less	15- 17	50 or more
3	5 or less	20- 33	66 or more
4	10 or less	24- 50	83 or more
5	14 or less	28- 66	100 or more
6	18 or less	32- 83	117 or more
7	22 or less	37-100	133 or more
8	27 or less	41-117	150 or more
9	31 or less	45-133	167 or more
10	35 or less	49-150	184 or more

Table 15. Classification of the number of budworm larvae per branch into low, medium, or high population density. A sample unit is four 45 cm tip per tree from balsam fir.

No of Sample Units	Low	High
1	-	10 or more
2	-	13 or more
3	3 or less	17 or more
4	6 or less	20 or more
5	10 or less	24 or more
6	13 or less	27 or more
7	17 or less	30 or more
8	20 or less	34 or more
9	24 or less	37 or more
10	27 or less	41 or more

Data Sheets: Data sheets on page 53, used for data about large larvae are similar to those used for 2nd instar larvae.

Comments:

1. Larval sampling becomes more difficult once the insect inhabits expanding buds, staminate flowers, or current year's foliage (Allen *et al*, 1984).

2. Comparison of densities from year to year can be made only if budworm phenology at time of sampling is identical or if appropriate adjustments have been made (Sanders, 1980).

3. Budworm larvae, like those of many tortricids, are apt to move if disturbed. Sampling during these stages must be done with care.

4. As larvae mature, the probability of their dropping when disturbed increases. Therefore, basket attachments on pole pruners should be used for sampling fifth and sixth instars.

5. Determining numbers of large instar larvae gives the best estimate of the population density of the stage that is responsible for the tree damage.

6. Surveys of large larvae provide an assessment of post-spray mortality [eg., see Abbot (1925), Allen *et al* (1984), Kemp *et al* (1979), and Simmons and Chen (1974, 1975)].

SPRUCE BUDWORM SURVEY

MAP AREA _____

FIR SPRUCE POINT NO._____

Collectors:_____

Date: _____ Year: _____ Town: _____

Location:_____

Stage: Early larval___ Late larval___ Pupal___ Egg___Overwintering larval___ Adult_____

PRE-SPRAY_____ POST-SPRAY _____ DEVELOPMENT_____ PARASITE_____

No. Units Searched _____ Total No. of Egg Masses or Larvae_____

EGG MASS OR OVERWINTERING LARVAL SURVEY

Branch #	Length	Width	Sq. Ft.	#Larvae or Egg Masses	#/Sq. Foot	#/100 Sq. Ft.

Egg Mass No. Old _____ Par._____ D.O.C. _____