bi-monthly research notes

A selection of notes on current research conducted by the Canadian Forestry Service and published under the authority of the Minister of the Department of Fisheries and the Environment. A French edition is published under the title of Revue bimestrielle de recherches.

ENTOMOLOGY

Egg-sampling for Western Spruce Budworm on Douglas-fir.— Western spruce budworm, *Choristoneura occidentalis* Freeman, is a major pest of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) in some British Columbia forests. Infestations occur periodically, and successive years of heavy defoliation will weaken and even kill the trees. Thus reliable sampling surveys are important to measure and record annual population fluctuations.

Limited resources dictate that simple, inexpensive sampling methods be developed. The egg stage of the budworm is a good one to sample because 1) it precedes the destructive period of the budworm (older larvae) by up to 9 months, giving ample time for the planning of future survey and control operations, 2) egg masses are deposited on needles, which are relatively easy to collect and examine in a quantitative manner, and 3) this stage is a stable one, enabling handling over many weeks without significant change.

Methods already investigated for sampling spruce budworm eggs involve a choice of branches, or parts of branches, from different locations within the crown. McKnight (USDA Forest Serv. Res. Note RM-122, 1968) found that the density of egg masses per 100 $in.^2$ (645 $cm.^2$) of foliage on a midcrown, 24-in. (61cm) branch-tip sample gave an estimate similar to that found with conventional half-branch samples. Carolin and Coulter (USDA Forest Serv. Res. Pap. PNW-149, 1972) developed a technique using the latter but did not test the reliability of smaller branch sizes.

In the current study, smaller part-branches collected from three crown levels were compared with half-branch samples to determine if the former could be used to reduce both collection and examination costs for the purpose of comparing year-to-year population levels. Samples were collected from Gingerbread Creek in the Lillooet River valley, about 24 km northwest of Pemberton, where populations of western spruce budworm had risen to outbreak levels. In October 1970, 20 trees averaging 20 cm dbh and 17 m in height were selected in each of four defoliation categories — from a stand of 60-year-old Douglas-fir on a southwest aspect at elevation 760 m.

These categories were as follows: nil or trace (some defoliation may be detectable on new foliage); light (noticeable defoliation, but only on new growth; no significant top defoliation); medium (upper quarter of crown partially defoliated); moderately heavy (upper quarter to half of crown 50% or more defoliated, obvious defoliation over remainder of tree; trees defoliated to point where there was virtually no foliage on entire tree were excluded from sample).

Two whole branches were taken from each of the upper, middle, and lower crown levels; hatched-egg masses, subsampled so as to record separately those from the 10-in. (25-cm) and 18-in. (46-cm) apical portions and a longitudinal half of each branch, were removed and counted by two successive examiners. The numbers of masses per 1,000 $in.^2$ (6 452 cm^2) and per kg (fresh weight) of foliage were determined; foliage area was calculated by assuming the branch tips and half branches to be triangular, and multiplying the length by half the width at the widest point. Only branches with little for no defoliation were selected, or the measurement was made after discarding heavily defoliated tip portions. Fresh foliage weight included all parts of the sample branch-tips but omitted the primary branch axis of the longitudinal half branches.

The data were compared by analysis of variance, repeated measures design (Winer, Statistical principals in experimental design, McGraw-Hill, New York, 1971). Since the populations were asymmetrically distributed and showed heterogeneity of variance, the data were transformed. A logarithmic transformation, $\log_e$ [(count + 1) per 1,000 $in.^2$ or per kg], stabilized the variance better than a square root transformation.

The results indicated no differences in numbers of egg masses per 1,000 $in.^2$ or per kg among the four defoliation classes used; therefore, defoliation level was not considered further in the analysis. There were significant between-tree, between-crown-level and between-sample-branch size differences in transformed egg mass counts (Table 1). Comparison by the Newman-Keuls test of the transformed means averaged across defoliation classes (Table 1) (Miller, Simultaneous statistical inference, McGraw-Hill, New York, 1966) showed no significant differences in the numbers of egg masses per unit of sample within different crown levels using the 10-in. (25-cm) sample size. The other two sample-branch sizes also yielded results similar to each other, except that the 18-in. (46-cm) samples from the lower crown contained significantly fewer eggs than mid- and uppercrown samples, and longitudinal half-branch samples (area basis only) had significantly larger numbers at midcrown than at the other two levels.

The results from different sample-branch sizes within each crown level were compared, and they showed that all three sample branches differed significantly from one another at the lower and middle crown levels but, at the upper crown level, only the 10-in. (25-cm) sample size differed from the others.

The foregoing suggests that no single type of sample alone could provide an absolute estimate of total populations on the tree. For year-to-year-trend comparisons, such an estimate is not necessary, but the same type of sample must be taken each year. A sample somewhat representative of the whole population is an asset, and it is important to minimize sampling effort without sacrificing reliability.

TABLE 1

Log-transformed mean numbers of western spruce budworm egg masses per 1 000 g and 1,000 $in.^2$ (6 452 cm^2) of Douglas-fir foliage, Pemberton, 1970 (data transformed $\log_e$ [(count + 1) per 1,000 $in.^2$ and per 1 kg] comparing sample-branch sizes and crown levels by the Newman-Keuls Test). (Two means within each row or column followed by the same letter are not significantly different at the .05 level.)

	Branch size					
	Per 1 000 g of foliage			Per 1,000 $in.^2$ of foliage		
Crown level	Longitudinal ½ branch	18" branch tip	10" branch tip	Longitudinal ½ branch	18" branch tip	10" branch tip
Upper	2.027cd	1.585bd	-0.059a	0.758cd	0.395bd	-1.458a
Middle	2.731c	1.646b	-0.395a	1.406	0.454b	-1.786a
Lower	2.095c	0.590	-0.227a	0.468c	-0.924	-1.903a

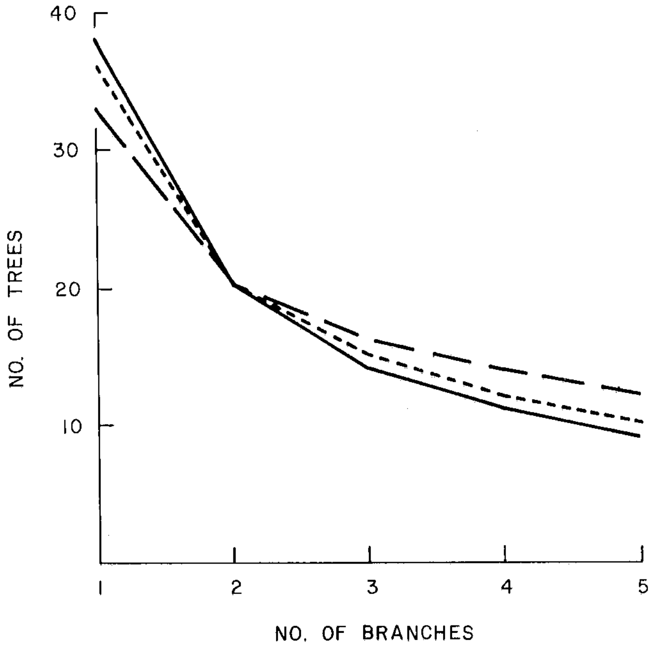

Figure 1. Tree-branch combinations with the same standard error of the mean egg masses per 1 000 g (transformed $\log_e$[(count + 1) per kg] as 20-tree, 2-branch samples).
10-in. (25-cm) sample branch ————————
18-in. (46-cm) sample branch — — — — —
longitudinal half sample branch - - - - - - - - - - - -

The 10-in. (25-cm) branch tips provide good sample branch sizes, as they yield comparable results at all crown levels. However, they are subject to zero counts at low population levels and to severe defoliation, which is usually worse at the ends of branches. An 18-in. (46-cm) branch sample from either of the upper two crown levels is probably better; it is representative of at least the upper two-thirds of the crown. The longitudinal half branch is generally to be avoided, as it usually requires climbing or felling trees; the line-throwing gun branch sampler (Collis and Harris, Can. J. Forest Res. 3:149-154, 1973) is not efficient in clipping off branches at their bases. Also, as Carolin and Coulter (1972) point out, the greatest effort in such sampling is examining foliage, which is greatest on whole or half branches.

Similar factors affect the choice of crown level. Lower-crown samples can be the largest and most time-consuming units to examine, compounding the disadvantages of the half branch. Samples from the upper crown or midcrown can be utilized if the line-gun sampler is used. A midcrown sample is suggested because it yields numbers intermediate between those from upper and lower crown levels and is usually practical to sample, being reachable by pole pruners in the case of small trees, or by the line-gun sampler.

The number of sample trees and branches examined is usually limited by available time and manpower. The sample combination used is a survey manager's decision, depending upon the mechanics of sampling and the men and equipment available. With the line-gun and sampler method of retrieving branches from the upper crown, it is efficient to take more branches from fewer trees. The data show that a sample with reliability comparable to that of past years' samples, two 18-in. (46-cm) branches from each of 20 trees at a sample point, could be reduced to around 15 trees if three branches per tree were taken, or to 10 trees if five were taken (Fig. 1).

In this study, only data from 1 year were examined, when populations were high and still increasing. More confidence in the design would be achieved by testing new data at different times in the development of an infestation.

Dr. R.R. Davidson, of the University of Victoria Mathematics Department, and D.W. Whitney, formerly of the Pacific Forest Research Centre Biometrics Unit, provided statistical advice and services; the former scientist's work was under a statistical consultation contract with the Centre.—J.W.E. Harris, Pacific Forest Research Centre, Victoria, B.C.

SILVICULTURE

Root Forms in Habitats with Heavy Shrub Competition.—Most mature forests in the central and northern interior of British Columbia are composed of white spruce (*Picea glauca* [Moench] Voss) and alpine fir (*Abies lasiocarpa* [Hook.] Nutt.) in varying proportions. The forest inventory of British Columbia shows that this complex covers 52 000 km² (13 million acres), or 7.5% of the total of 710 000 km² (175 million acres) of productive forest land.

On dry sites, the origin of the white spruce-alpine fir forests can be traced to fires and subsequent lodgepole pine or aspen cover under which spruce and fir regenerated. On wet sites, the uneven-aged, understocked character of the forest and absence of charcoal in the soil suggest that these forests have approached the final (climax) stage of their succession. A dense layer of shrubs is usually present and regeneration of spruce and infilling of open spaces is practically nonexistent.

Root system morphology of white spruce and its relationship with soil texture and soil moisture in northern Alberta were described by Wagg (Can. Dep. For. Rural Dev. Publ. 1195, 1967). This note has been written because, on wet sites, in stands with heavy shrub competition, up to 40% of the root system forms of white spruce did not fall into the described categories.

The data were obtained from 1962 to 1973, during studies of root growth and its influence on survival of spruce seedlings in the Crooked River area of the Prince George Forest District of British Columbia. About 300 root systems of juvenile spruce, almost equally distributed on dry, moist, and wet sites, were hydraulically excavated, and root systems of about 60 mature, wind-thrown trees were plotted after the soil was cleaned from the roots. The ages of a few of the largest primary

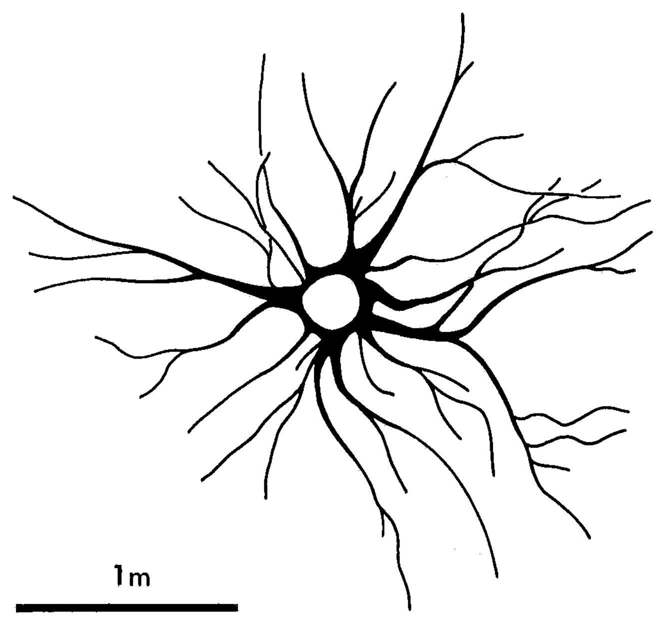

Figure 1. Root pattern on dry sites with no shrub competition. The tree originated on mineral soil. The root system forms a simple shallow disk. The roots are straight and well branched and radiate in all directions. Grafting is rare.