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Service
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ISSN 0228-9989

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canadian forestry service research notes

A Paper-cup Container for the Bioassay of Nuclear Polyhedrosis
on Foliage

Evaluating Effects of Western Spruce Budworm on Douglas-fir
Volume Growth

Maximum Possible Salvage of Budworm-killed Stands in New-
foundland and Some Economic Consequences

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VOL. 2, NO. 4, OCTOBER-DECEMBER 1982

Canada

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A selection of notes on current research conducted by the Canadian Forestry Service and published under the authority of the Minister, Environment Canada. A French edition is published under the title of *Revue de recherches du Service canadien des forêts*. It is the editorial policy of this publication that the names of members of review boards considering manuscripts for publication shall not be disclosed. Manuscripts submitted for review will be accepted for consideration only on this basis.

ENTOMOLOGY

A Paper-cup Container for the Bioassay of Nuclear Polyhedrosis Virus on Foliage.—Little progress has been made in the improvement of techniques to bioassay foliage to detect nuclear polyhedrosis viruses affecting various forest insect pests. Usually, field-collected foliage and insect larvae used in a bioassay are placed in glass lantern globes atop water-filled jars. Similar procedures have been employed to determine the pathogenicity of baculoviruses, where foliage contaminated with a particular nuclear polyhedrosis virus is fed to host insect larvae (Cunningham and Entwistle in *Microbial Control of Pests and Plant Diseases 1970-1980*, Academic Press, 1981; Biever and Hostetter, *J. Invertebr. Pathol.* 18:81-84, 1971). A more recent method is to triturate samples of foliage and bark in water, spread on synthetic diet, and feed the treated diet to *Lymantria dispar* larvae to assess the extent of baculovirus contamination on red oak, *Quercus rubra* L., and red maple, *Acer rubrum* L. (Podgwaite et al., *Environ. Entomol.* 8:528-536, 1979). However, because of the complexity of this technique and the need to determine the presence of small quantities of virus persisting on the foliage, the use of bulk foliage bioassays is still justified. The use of lantern globes for this purpose is labor-intensive and requires large quantities of sterile glassware. This paper describes an inexpensive, convenient container that eliminates many problems associated with the use of lantern globes.

The container is constructed by inserting a 255-mL waxed paper cup into a 199-mL waxed paper cup (Fig. 1). This arrangement produces a cavity (reservoir) capable of holding 40 mL of water. A small piece of branch sample is inserted through a hole made in the base of the 255-mL cup so that the stem protrudes into the water reservoir and the foliage will stay fresh for up to 2 wk. A 15-cm square of cheesecloth secured in place by an elastic band covers the cup. Sample identification can be recorded directly on the large cup.

This container has several advantages over the use of glass lantern globes. The paper cups are inexpensive and fairly free of contaminants, unlike laboratory glassware. The water reservoir is easily refilled by lifting the larger

cup out of the smaller one, leaving the foliage and insects undisturbed. At termination of the experiment, the smaller cups can be salvaged, dried, and reused; the larger cups can be discarded along with the foliage and insects.

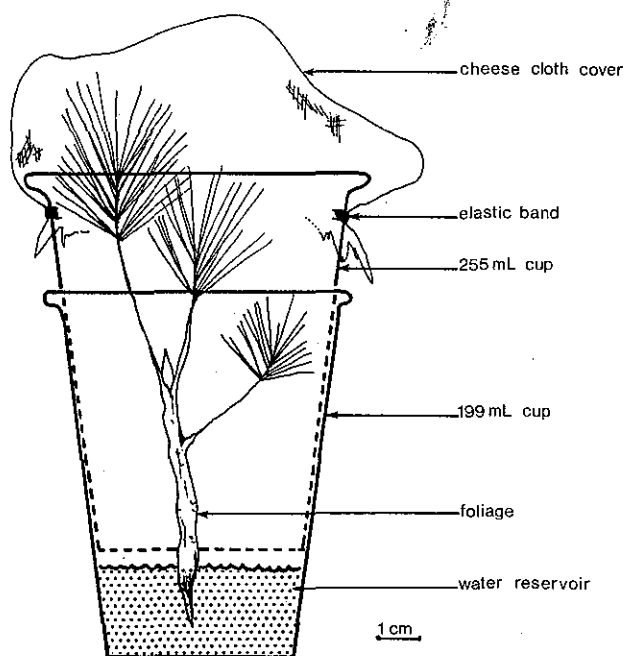


Figure 1. Schematic diagram of the paper-cup container as it has been used in the bioassay of coniferous foliage.

This would eliminate tedious cleaning and decontamination procedures.

These containers have been successfully used in this laboratory to bioassay coniferous foliage for the presence of baculoviruses affecting *Orgyia pseudotsugata*, *Choristoneura fumiferana*, *Neodiprion sertifer*, and *N. lecontei*. The paper-cup containers have also been employed to rear *N. sertifer*, *N. lecontei*, *N. pratti banksianae*, *Banasa dimidiata*, and *Podisus sericeiventris* on host foliage and have proved to be superior to lantern globes and jars in their handling and versatility.—W.J. Kaupp, Forest Pest Management Institute, Sault Ste. Marie, Ont.

Evaluating Effects of Western Spruce Budworm on Douglas-fir Volume Growth.—Accurate prediction of wood production is an essential component of effective forest management. Prediction is complex when pest effects must be taken into account. This presentation describes results of research into methods of extrapolating pest impact studies on a plot scale to provide impact estimates at the stand level and ultimately at the scale of a timber supply area.

At the research plot level, an accurate method of estimating tree growth losses caused by western spruce budworm feeding has been described (Thomson and Van Sickle, *Can. J. Forest Res.* 10:176–182, 1980) in which bole growth is determined from a series of discs at different heights. From these data, the annual growth of the bole can be reconstructed. The consequences suffered by a Douglas-fir tree subjected to four budworm outbreaks in its 90-yr life cycle are illustrated in Figure 1a. The discontinuities in the bole are the effects of dieback and the interruption of height growth. The narrow rings are reduced radial growth, resulting from budworm attack. The bole deformities are smoothed over in the tree, but we do not attempt to recreate this condition in our system.

The stem analysis method permits (i) the estimation of potential growth based on pre- and post-outbreak growth rates (Fig. 1b); (ii) the evaluation of the effects of controlling outbreaks (Fig. 1c); or (iii) the examination of one outbreak in isolation (Fig. 1d). In addition, effects of height and radial growth losses can be evaluated independently.

The detailed stem analysis procedures can give an accurate estimate of actual volume; however, in the absence of such detailed data, bole volume is generally estimated from a volume equation in which volume is expressed as a function of other, more easily measured variables such as height and d.b.h. For example, the B.C. Ministry of Forests published equation (1) to estimate Douglas-fir volume (Anon 1976):

$$\begin{aligned} \log V &= -4.319071 + 1.813820 \log D + 1.042420 \log H, & \text{age} \leq 120 \\ \log V &= -4.348375 + 1.692440 \log D + 1.181970 \log H, & \text{age} > 120 \end{aligned} \quad (1)$$

where V = tree volume (m^3)
 D = d.b.h. (cm)
 H = height (m)

This volume equation is a representation of average bole form. Form of budworm-attacked trees would be different from that of unattacked trees as height is decreasing as a result of dieback, while the radius is increasing, albeit at a reduced rate. As a measure of this change in form, annual bole volumes obtained by the stem analysis procedures indicated above (actual volume) were compared with volumes estimated from equation (1) for corresponding height and diameter values. The ratio of actual:potential volume as a function of age, for the tree illustrated in Fig. 1, is shown in Fig. 2.

Equation (1) estimates the actual volume very well, as indicated by the volume ratio close to 1.0, until the time of the first outbreak, when the ratio departs from unity. After the first outbreak, the ratio recovers toward unity. Subsequent outbreaks occur, which further increase the ratio, until the actual volume exceeds the potential volume by more than 30% in this tree.

When the volume of the potential tree (Fig. 1b) is compared to that estimated by equation (1), a much better fit at all ages is found (Fig. 2). Applicability of equation (1) to the actual and potential volume growth was studied in 42 budworm-attacked trees. In general, the fit of equation (1) is much better for the potential than for the actual tree, although there were some exceptions. However, the stem analysis method includes allowances for dieback effects based only on a preliminary analysis of our data set. When we have fully analyzed the dieback and recovery patterns, we hope to more accurately define the relationship of volume ratio to outbreak incidence.

At the present time, our results indicate two important points:

- (a) Impact estimates based on volume equations must allow for modification of the equations in budworm-

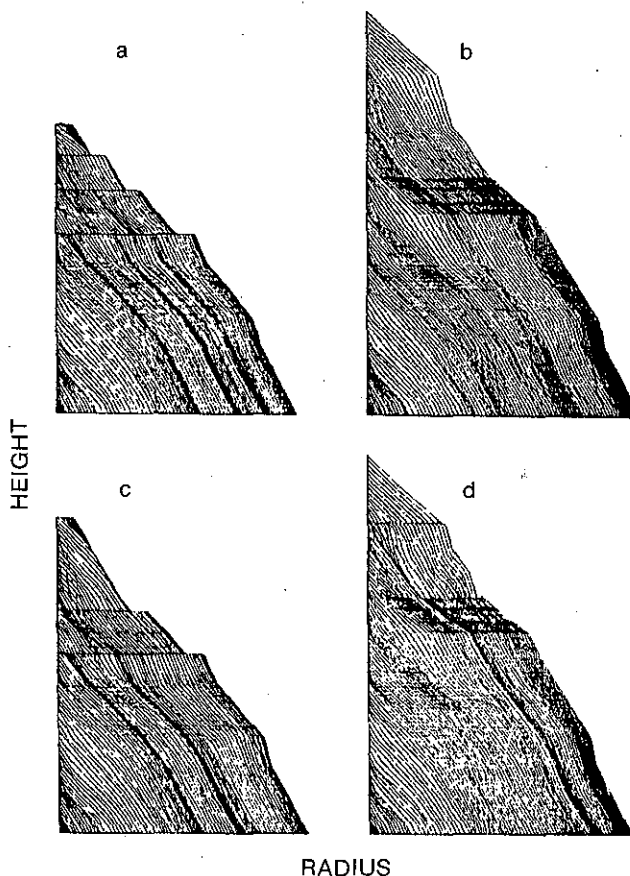


Figure 1. Computer-drawn representation of annual bole outline of: (a) actual tree showing four outbreaks; (b) potential tree (no outbreaks); (c) tree with one outbreak controlled; and (d) tree with one outbreak studied in isolation. The radial scale is greatly exaggerated for clarity.

attacked stands or a correction factor must be applied to the estimate in unattacked stands.

- (b) A detailed study of dieback and height-growth recovery patterns is a prerequisite for the estimation of the effect of budworm on form and volume and for the development of fully satisfactory potential growth estimates.

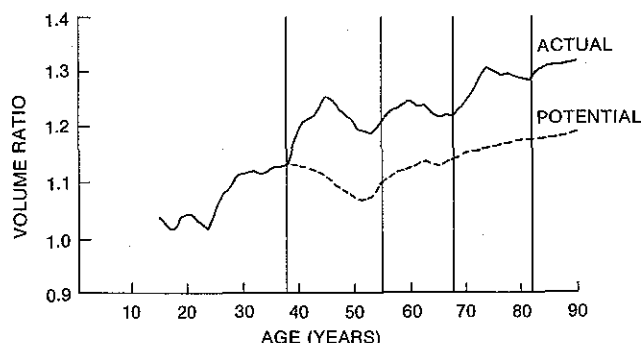


Figure 2. Ratio of observed volume, obtained by stem analysis, to volume expected from the B.C. Ministry of Forests equation, for each year of a tree's growth from age 15. The four vertical lines indicate the start of an outbreak.

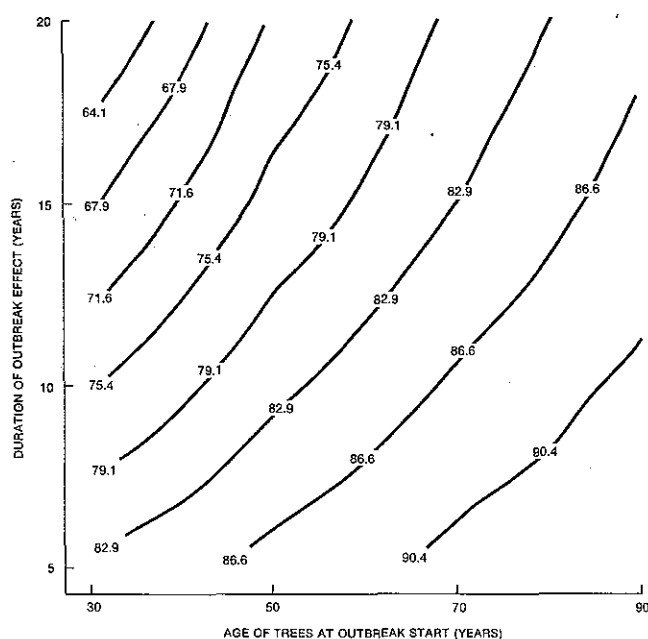


Figure 3. The contour lines represent stand volume at rotation as a percent of potential stand volume for a hypothetical stand subjected to varying levels and timings of defoliation in a stand model. The intersection of stand age and expected duration of outbreak effect (including the recovery period) is located and the estimate of expected percent potential volume read off.

A system for presenting results of such analyses in a manner easily usable by forest managers has been developed and is illustrated in Fig. 3 for a hypothetical stand. Stand volume, as a percentage of the potential stand volume at rotation, is shown in relation to stand age at the start of a single outbreak and duration of the outbreak. The period of outbreak effect includes both active defoliation and recovery periods. These values might be used as correction factors applied to an estimate of volume for unattacked stands. A set of such figures can be constructed for merchantable volume and other management-related information, as well as percent potential volume, for a wide range of situations. The forest manager could then select the figures appropriate to his particular situation and cross-index the age of the stand with an estimate of expected duration of outbreak effects to obtain loss estimates. The expected duration of effect can be obtained from pest survey records or from stem sectioning or core sampling studies.—A.J. Thomson, R.I. Alfaro, and G.A. Van Sickle, Pacific Forest Research Centre, Victoria, B.C.

FOREST PRODUCTS AND UTILIZATION

Maximum Possible Salvage of Budworm-killed Stands in Newfoundland and Some Economic Consequences.—The forests of Newfoundland, composed mainly of balsam fir (*Abies balsamea* [L.] Mill.) and black spruce (*Picea mariana* [Mill.] B.S.P.), support a pulp and paper industry using 2.2 million m³ and a sawmilling industry using 0.1 million m³ annually (Munro, pages 80-99 in Hudak and Raske, editors, Nfld. Forest Res. Cent. Inf. Rep. N-X-205, 1981). The present outbreak of the spruce budworm (*Choristoneura fumiferana* [Clem.]) has caused significant damage to these forests. Even after several years of salvage operations and destruction of some budworm-killed stands by fire, the total volume of existing softwood stands containing tree mortality of more than 10% was estimated at 31.7 million m³ in 1981, or about 18% of the fir-spruce inventory of the Island (Raske et al., Nfld Forest Res. Cent. Inf. Rep. N-X-211, 1982). The volume of stands with all degrees of mortality was 31.9 million m³. Most of these stands are considered in need of salvage and contain 16.0 million m³ of dead trees and 2.8 million m³ of dying trees (> 80% defoliated) (Raske et al. 1982). It is estimated that 2.5 million m³ of the dying trees will be dead before they can be salvaged, thereby increasing the dead tree component of the stands to 18.5 million m³. It is impractical to cut only dead trees, therefore the whole stand must be harvested in a salvage operation. In this report, we attempt to determine the proportion of the 31.7 million m³ damaged stand volume that can be salvaged before decay is too advanced and to indicate the magnitude of the economic impact of the unsalvaged stands.

TABLE 1

Estimated standing volume (millions m³) of timber killed and damaged by the spruce budworm in Newfoundland and estimated salvaged and salvageable volumes to 1987

Year	Estimated standing volume of balsam fir damaged by the spruce budworm			Volume removed by salvage	Not salvageable volume dead more than 5 yr	Salvageable volume remaining**	% of dead volume not salvageable†	% of stand volume (31.7) not salvaged
	Total	Dead	Dying					
1981	31.7	16.0	2.8	1.3*	4.3	26.0	23	96
1982	30.4	16.8	1.1	1.3*	4.9	24.1	26	91
1983	29.1	16.8	0.3	1.3*	6.1	21.6	33	87
1984	27.7	16.6	0	1.3*	7.9	18.5	43	83
1985	26.4	15.9	0	1.3*	9.6	15.5	52	79
1986	25.1	15.3	0	1.3*	12.8	11.0	69	75
1987	23.8	14.6	0	1.3*	13.5	8.9	73	71

*Half of this (660 000 m³) is dead timber (dead 5 yr or less)

**Includes trees living, dying, and dead 5 yr or less

†Volume of wood in column 6 divided by the estimated total spruce budworm mortality — 18.5 million m³ (see text, paragraph 2)

Assumptions made in estimating the possible salvageable volume were as follows: 1) The total wood requirement of the three paper mills in Newfoundland will remain at 2.2 million m³ annually. 2) A maximum of 60% of the requirement (1.3 million m³) may be fir. 3) All harvesting of balsam fir will be confined to damaged stands, i.e. salvage. 4) The maximum acceptable portion of dead balsam fir in pulp mixtures will be 50% of the fir requirement; the rest will be living but damaged fir. 5) Trees will be salvaged up to 5 yr after death. 6) The quantity of wood dead for 1, 2, 3, 4, and 5 yr will be salvaged in the same ratio as it exists in the year of salvage; i.e., salvage operations will not be concentrated in any 1-yr-since-death class. 7) The dying volume will have died by the end of 1983. 8) Stocking of all damaged stands will continue to be sufficient for economical salvage till 1987. 9) The salvage of damaged stands by the sawmilling industry will be negligible.

Most of the fir and spruce stands killed by the spruce budworm in Newfoundland will not be salvaged, at projected levels of utilization, before they will have deteriorated (Table 1). Even modifying the assumptions does not alter the general conclusion that the budworm has damaged more stands than can be utilized. Estimated stand volume not salvaged by 1987 was 22.4 million m³, consisting of 13.5 million m³ unusable, decayed trees and 8.9 million m³ of salvageable trees. This 22.4 million m³ is 71% of the original stand volume of 31.7 million m³ damaged by the budworm. The salvageable volume of 8.9 million m³ remaining in 1987 will likely be uneconomical to harvest because it will be scattered among the 13.5 million m³ of dead volume. Therefore, it is probable that the previously mentioned 22.4 million m³ will be lost to the wood industry.

The economic impact of this loss of 22.4 million m³ to Newfoundland is difficult to estimate, but future wood deficits are expected (Munro 1981). To give an indication

of the magnitude of the economic losses, an example has been calculated that assumes a wood deficit for 10 yr totaling half of the wood remaining in 1987 ($22.4 \div 2 = 11.2$ million m³). Currently, pulp and paper mills in Newfoundland generate annual provincial benefits equivalent to about \$70/m³. This figure comprises salaries for logging and processing employment, provincial taxes, and timber revenues. When this figure is applied to the assumed wood deficits of 11.2 million m³, the resulting economic losses are \$784 million for a 10-yr period. (Figures are in Canadian dollars, May, 1982).

Other possible economic loss factors are increased costs of salvage logging, relocating logging operations, need to procure wood from greater distances, reforestation of killed immature stands, increased stand rotation, loss of previous investments of silvicultural treatments in killed stands, loss of wood increment on damaged trees, reduced growth on recovered trees, and revising forest management plans. A comprehensive economic analysis of the various losses is needed to assess the total economic impact of the spruce budworm outbreak in Newfoundland.—A.G. Raske and W.J. Sutton, Newfoundland Forest Research Centre, St. John's, Nfld.

ERRATUM

On page 21, column 2, line 22 in vol. 2, no. 3 (July-September 1982) the figure 1.0 cm should read 0.1 cm.

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