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FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA

INSTITUT CANADIEN DE RECHERCHES EN GÉNIE FORESTIER

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July 1978

# Problems in Salvaging Timber Affected by the Spruce Budworm

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# Problems in Salvaging Timber Affected by the Spruce Budworm

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Ce rapport technique est disponible en français

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## Foreword

This report starts from the assumption that there has been a budworm infestation severe enough to cause tree mortality and that a salvage operation has been decided upon. Its purpose is to alert the forest manager and logger to the effect this infestation will have on the forest and the harvesting operation and how its effect changes with passage of time since the outbreak.

Because mortality is usually progressive, the true cost penalty may be buried in the overall average of a cut which includes green trees, those just dead and those dead 1, 2 or more years in varying percentages. The loss and cost data supplied for this report by the cooperating companies were based on relatively small samples and rough estimates and are recognized as being less than adequate for budgeting and planning. The data are used only to warn the operator of where he might run into machine-capacity bottlenecks and to caution the manager to set up an accounting cost system to inform him when salvage is no longer economical.

At both the logging and mill levels, early salvage may cause some organizational disruptions and operating inconveniences but only minor additional costs. With the passage of time, costs increase rapidly until after 3 to 5 years they will usually become prohibitive. There are very real benefits to be gained from preparing the logging plan and road network into sensitive forest areas in advance of the budworm attack. This action should be considered seriously by companies and governments when plans for road building or other assistance are being negotiated. There may be reluctance to make actual expenditures to provide for an event that might not happen. However, a plan which may be put into action quickly may save a year which could otherwise be lost in planning, purchasing, preparation and negotiation.

The excess cost from a budworm infestation does not stop when the wood is delivered to the plant gate. Peeler and saw logs can be downgraded to pulpwood; fibre in the sapwood rot is lost in the debarking operation; extra bleach and chemical pulp may be required to maintain paper quality. A detailed study (8), made available to FERIC, using 100% 6-year-old hemlock looper-killed wood showed a newsprint manufacturing cost increase of 23% of the wood content value over and above any additional operation and financing costs incurred in the woodlands. A cost penalty of this magnitude must be a recognized factor when the decision to salvage or not to salvage is being made.

## Summary

The objectives of this study are to:

(i) Provide the logging manager who is faced with a severe spruce budworm infestation with a picture of the effect this will have on the forest and how this effect will change with time.

(ii) Alert the manager to the effect this will have on the logging plan, productivity and cost of manual and mechanized harvesting.

(iii) Summarize the identified cost-affected areas to provide a check list as an aid to companies or government agencies to determine the total cost penalty for salvaging specific budworm-affected timber stands.

Thirteen companies were visited and a literature review was made to determine the effects on methods, productivity, costs and associated problems of harvesting spruce budworm-infested timber in the provinces of Quebec, New Brunswick, Nova Scotia, Newfoundland and the state of Maine.

In all these areas, the spruce-balsam fir softwood forests were infested by the budworm and some stands were attacked by other primary insects. Tree mortality was most serious in western Quebec, southern New Brunswick, Cape Breton Island and the west coast of Newfoundland.

A budworm-infested stand of timber may contain varying combinations of trees that are green (normal), trees having different degrees of defoliation, trees that have reached mortality and those which have been dead for 1, 2 or more years. Very rarely does the stand contain trees of uniform condition. Generally, infested stands consist of mature to over-mature balsam fir and may contain a high percentage of cull and rot not related to the latest budworm infestation. In addition, secondary insect and fungus damage rapidly reaches a point where the timber may no longer be suitable for the intended final product. In particular, sap rot progresses more rapidly with increasing forest moisture (most severe with mortalities below 10%) and with age since death and may affect in the order of 20% of the wood volume by the fourth and fifth year after mortality. Even though this wood can be harvested and delivered to the mill, most of this fibre vol-

ume may be lost in the subsequent debarking and processing operations.

Unless the outbreak is successfully controlled, such as by aerial spraying of insecticides, there is usually a period of about 7 years to salvage the forest after infestation. First, there is a warning if budworm outbreaks are seen in neighbouring forests particularly to the west. After infestation, 4 years of defoliation may be followed by mortality and salvage harvesting may be carried out for a further 3 years (including the year of mortality) for balsam fir and for 5 years in the case of spruce. Whether salvaging is practical will depend on the end product, the time since mortality, means of transportation and period and method of storage between harvesting and manufacturing.

Before mortality, additional harvesting costs are limited to those incurred because of changes in the logging plan. After mortality, dead trees become lighter, brittle and, when handled roughly, have a tendency to break and thus reduce the yield per hectare and the productivity of most of the harvesting stages. Disruption of the logging plan may include construction of new roads, the relocation of camps, the moving of equipment and the displacement of personnel. The value of the money tied up prematurely in temporarily abandoned roads and camps must not be overlooked. While harvesting and tree-length transportation costs usually increase, cost reductions can also occur with the transportation of lighter shortwood loads, if the new operations are closer to the mill or if a live-in camp can be changed to a commuter camp.

For a limited sample, on conventional tree-length operations in western Quebec, loss due to breakage represented 3.0% of the total volume harvested from a stand having 10 to 20% mortality with trees dead for 1 to 2 years even though a special crew to recover broken wood at the landing was employed. An on-site count showed that approximately 50% of the tops were broken before slashing. A similar test on 22,000 trees from a stand having 20 to 40% mortality and trees dead 2 to 3 years had a volume loss of 4.0%. More than 80% of these volume losses were in balsam fir.

For mechanized harvesting (in trees dead 2 to 3 years) productivity may be reduced 5 to 10% due to breakage, which occurred in 12% of trees in a small sample tested in 1977. When felling is followed by tree-length skidding, trucking and slashing stages, their productivity is also reduced by similar or increasing amounts because of the missing broken tops.

Trucking costs of shortwood, if paid for by weight, are likely to be reduced by 10 to 20% for equivalent hauling distances as the budworm-infested wood dries and gets lighter.

It is suspected that river-driven wood previously infested with borers (*Monochamus* spp.) is more subject to sinkage and such losses may increase.

In summary, harvesting costs will increase and productivity will decrease for a period of 2 to 3 years for balsam fir following mortality (4 to 5 years for spruce) after which it may no longer be possible to use the wood. Because of the variety of conditions which occur, however, decisions must be made based on the specific facts of each case as determined from regular monitoring for deterioration in the stands concerned.

Detailed productivity and cost figures relating to pre- and post-budworm-infestation logging were not available. Data obtained were related to specific cases and from studies of very limited size. At best, they provide an order of magnitude of the problem which may be expected.

Before mortality, the traditional harvesting equipment of the company can continue to be used. With increasing time since mortality, the 8-foot cut-and-bunch with pulpwood transporter appears to be the most efficient logging system. This method has the added benefit of providing a quality control inspection at the stump which also rejects the cull from non-related rot from further handling. It also eliminates further handling breakage and ensures that all the wood paid for is delivered to the road.

Somewhat of a surprise, there was no evidence to indicate that the budworm infestation caused an increase in industrial accidents or forest fires in recent years. The potential for both was well recognized and additional precautions were taken.

Salvage of budworm-affected trees may result in a higher percentage of balsam fir in wood deliveries. This can have an adverse effect on the manufacturing processing system capacity (because of its lower density) and on the final product quality.

In extreme cases, additional costs may be incurred to obtain other wood to maintain the necessary species mix.

Budworm-killed wood cannot be used to produce good quality lumber because of holes made by wood borers and developing sap rot.

Realistic utilization standards need to be established for deciding whether a tree should be salvaged for a given market. It is important that both the industry and governments recognize that while a stand may be worth salvaging, this may not be true of every tree, particularly when the end use possibilities are limited.

During the course of this survey, areas of high tree mortality from the hemlock looper and other causes were also encountered. Information on the salvage operations in these stands has been included as there are many similarities but also some important differences when compared with a stand after severe budworm infestation.

# 1. INTRODUCTION

The principal objective of the study was to identify the problems associated with harvesting timber affected by the spruce budworm (*Choristoneura fumiferana* (Clemens) ), henceforth referred to as the "budworm", from the point of view of logging methods, productivity and costs.

Sub-objectives were to report on the effect of the budworm infestation on:

i) Control measures as they affect stumpage, weighing, piece rates, production control and mill inputs.
ii) Safety experience in relation to status of the forest and operating methods.
iii) Forest fire hazard in relation to status of the forest and operating methods.
iv) Logging and its interface with:
  a) forest management
  b) wood-using industries

A review of the literature yielded very little information on problems related to the salvaging of budworm-affected timber; however, some information was available on the rate of deterioration of balsam fir (*Abies balsamea* (L.) Mill.), henceforth referred to as fir, killed by the budworm (6, 12).

Thirteen pulp and paper company operations were visited in the provinces of Quebec, New Brunswick, Nova Scotia and Newfoundland, and in the state of Maine (Fig. 1):

Quebec
- Canadian International Paper Co., Maniwaki
- James Maclaren Co. Ltd., Masson and Mont-Laurier

New Brunswick
- Consolidated-Bathurst Ltd., Bathurst
- Fraser Companies Ltd., Edmundston and Plaster Rock
- MacMillan Rothesay Ltd., Saint John
- Miramichi Timber Resources Ltd., Newcastle
- New Brunswick International Paper Co., Dalhousie

Nova Scotia
- Nova Scotia Forest Industries Ltd., Port Hawkesbury
- Scott Maritimes Ltd., Abercrombie Point, New Glasgow

Newfoundland
- Bowaters Newfoundland Limited, Corner Brook
- Price (Nfld.) Pulp and Paper Limited, Grand Falls

Maine
- Great Northern Paper Co., Millinocket
- Scott Paper Company, Jackman

Pertinent information was also gathered from woodlot owners and forest protection representatives of Quebec, New Brunswick and Nova Scotia.

# 2. THE SPRUCE BUDWORM INFESTATION

## 2.1 Description of outbreaks[1]

The spruce budworm is a native insect that periodically reaches outbreak proportions over vast forest areas. Outbreaks do not follow a regular cycle, and intervals between outbreaks for a given region can vary from 30 to over 80 years. The usual consequence of a budworm outbreak is the death of spruce-fir stands over vast regions. Mature and over-mature stands are most vulnerable.

The Task Force for Evaluation of Budworm Control Alternatives (5) in New Brunswick recognized that the main hosts of the budworm are balsam fir (most vulnerable) and the three eastern spruces, red (*Picea rubens*, Sarg.), white (*Picea glauca* Moench) Voss.) and, to a lesser extent, black (*Picea mariana* (Mill.) BSP.). Prevailing wind patterns contribute to the direction of dispersal of the infestation which, for eastern Canada, is generally from the west to the east.

At epidemic levels, defoliation resulting from budworm feeding causes reduced

[1] Most of this section is drawn from Blais (7) and the New Brunswick Task Force report (5).

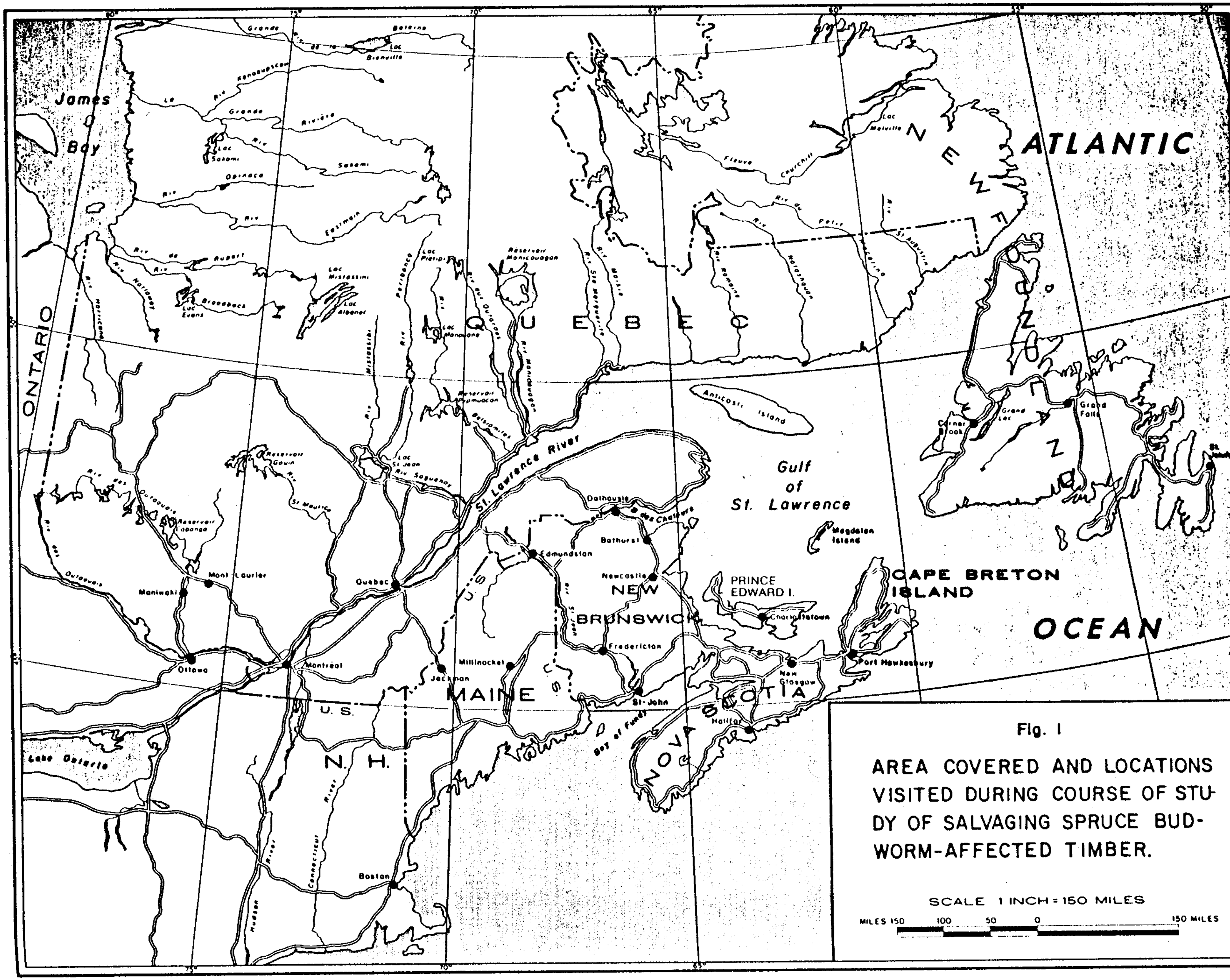


Fig. 1

AREA COVERED AND LOCATIONS VISITED DURING COURSE OF STUDY OF SALVAGING SPRUCE BUDWORM-AFFECTED TIMBER.

SCALE 1 INCH = 150 MILES

MILES 150 100 50 0 150 MILES

growth and, if repeated over several years, causes death of host trees and stands. The preference of the budworm larvae for current year foliage imparts a time lag to tree and stand mortality. Since fir and spruce trees retain a portion of each year's needles for 8 years, or longer, it takes several years of defoliation of the current foliage to weaken a tree to the point of death. In areas where no protective spraying has been undertaken, 8 successive years of defoliation (involving more than 75% of the current foliage) generally result in death of 60-80% of the fir and red spruce trees in the affected stands (5). Mortality will be more rapid if more severe defoliation occurs.

The pattern of outbreaks is not uniform either in terms of the general population level or its geographic distribution. Because of variations in climate and forest conditions, outbreaks never extend to the limit of available host tree distribution under natural conditions.

An infested forest may (and usually does) contain green trees, trees that have experienced varying degrees of defoliation, and trees that are dead. The severity of the infestation may increase or decrease from one year to the next. Thus budworm infestation is not necessarily terminal, and an affected forest stand may recover.

## 2.2 Magnitude and degree of infestation by area visited

The logging chances[1] visited presented a wide range of stand conditions. Some stands were infested by the budworm, others by the tussock moth [*Orgyia leucostigma* (J.E. Smith)], eastern hemlock looper [*Lambdina fiscellaria* (Guen.)], and larch sawfly [*Pristiphora erichsonii* (Htg.)], and in one isolated case, trees being harvested had been killed by sulphur dioxide emanating from a metal concentrating plant. More details on the areas presently affected, on the volumes being salvaged and on relevant logging factors are presented in this section.

[1] Specific areas to be harvested.

### 2.2.1 Quebec

Increased budworm populations were apparent in 1967 in the Grand'Mère and Lower Gatineau regions (1). By 1970, populations increased considerably and the insect reached outbreak proportions in western, central and eastern Quebec, covering an area of 2 million hectares (5 million acres). By 1975, 35 million hectares (87 million acres) were infested with mortality in over 3 million hectares (7 million acres).

The operations visited were carried out by two pulp and paper companies in mixedwood and softwood stands of the Great Lakes — St. Lawrence forest region. Spruce and balsam fir were the main species harvested. Stands were mature and over-mature.

The visited area had been severely hit in past years by the budworm outbreak. In 1977, mortality[1] of balsam fir reached 45-50% of its volume; in some stands, all balsam fir trees were dead. Spruce did not suffer from the infestation. All fir in the visited areas was infested to various intensity levels. The softwood content was approximately 50% fir, 40% spruce and 10% pine. It was evident that some dead trees had been attacked by bark beetles and wood borers.

The volume of wood harvested by the visited companies was approximately 1,400,000 $m^3$ (500,000 cunits) annually, of which 45%, or 600,000 $m^3$ (225,000 cunits) was from budworm-infested forests. The salvage operation began in 1972 and will continue until 1978, and probably 1979, if the quality of wood permits.

### 2.2.2 New Brunswick

The province of New Brunswick has suffered from the budworm infestation for the past 25 years and continuous efforts have been made towards its control. In fact, an average of some 17% of the forest area of the province (approximately 1.2 million hectares (3 million acres) ) was sprayed each year (with the exception of 1959) from 1952 to 1976 costing a total of $95,000,000 (5).

[1] Mortality refers to the areas harvested.

Budworm host species volume harvested during the period was 120,000,000 $m^3$ (43,000,000 cunits).

The current budworm outbreak began in the north and northwestern part of the province in the early 1950's, with near collapse of that population in 1960 but with higher population levels persisting in central New Brunswick. From 1969 to 1975, the outbreak spread, as a result of both local population build-up and adult dispersal, until it covered virtually the entire host forest in the province. Although average population declined from 1974 to 1975 and 1975 to 1976, the area of infestation remained essentially province-wide.

In the western part of the province, approximately 10 to 30% of spruce and fir trees were attacked at various intensity levels. Approximately 10% of the fir volume was dead with 75% of the dead trees showing sap rot signs. This area was sprayed in 1975, 1976 and 1977. Approximately 1,100,000 $m^3$ (400,000 cunits) are logged annually in this region.

In the southern part, most spruce and balsam fir trees were defoliated at various intensity levels. Softwood and mixedwood stands were both severely affected and an estimate of the volume of dead or dying fir was 75% and spruce 50%. The observed stands displayed sap rot signs and had been dead for 3 to 5 years. In this area, approximately 660,000 $m^3$ (250,000 cunits) of softwood are produced annually. The amount of mortality in the mixed stands and in an area which had received insecticide spray protection was unexpectedly high.

In northern and eastern New Brunswick, defoliation was generally light. Softwoods made up about 70% of the stands and the balance was in hardwoods. This area suffered a budworm epidemic in 1916-20, again in the early 1950's, and most recently beginning in the early 1970's. In addition, 83,000 hectares (200,000 acres) in one area were hit by prolonged rain and freezing temperatures during January 1956, which built up ice on trees and, when high winds followed, caused extensive damage, mostly in top breakage. Another part of the area contains trees killed by sulphur dioxide originating from a metal concentrating plant (2). The annual softwood volume cut was approximately 2,000,000 $m^3$ (700,000 cunits).

### 2.2.3 Nova Scotia

The budworm has been an integral part of the forest in Nova Scotia, and particularly Cape Breton Island, for perhaps thousands of years. Evidence of its presence dates back 250 years (4).

On the Mainland, the budworm infestation remained negligible until 1968; beginning in 1969, it became active with severe defoliation and mortality (1972) in the northern part of the province along the Bay of Fundy and the Northumberland Strait.

In the summer of 1973, the budworm moths migrated to northern Cape Breton Island. The population built up and moderate to severe defoliation was apparent in 1974. Most of the Island suffered severe defoliation in 1975 and 1976, with first signs of mortality in 1976.

a) *Mainland Nova Scotia*

The infestation started in 1969, heavy mortality occurred in 1972 and the salvage operation began in 1974. Species composition was approximately 50% fir and the balance was mainly red spruce.

Defoliation was also caused by another insect, the white-marked tussock moth, (9). This was first reported in 1974, and expanded in 1976 to an area of 345,000 hectares (850,000 acres). Moderate and severe defoliation was reported, with some mortality of balsam fir.

Two other insects of major concern are the eastern hemlock looper, and the larch sawfly.

b) *Cape Breton Island*

The softwood content on the Highlands is 90% fir and 10% spruce. The forest stands are generally over-mature and the average age is approximately 60 to 65 years.

A 1976 provincial survey on Crown lands indicated that a total area of

95,000 hectares (235,000 acres) on the Highlands, with a gross merchantable volume of 7,600,000 $m^3$ (2,700,000 cunits), was 25% to 100% defoliated (4). This included an area of 57,000 hectares (140,000 acres), 50% and more defoliated, containing a volume of 5,000,000 $m^3$ (1,800,000 cunits).

Total pulpwood production on the Highlands was 200,000 $m^3$ (70,000 cunits) in 1975, 280,000 $m^3$ (100,000 cunits) in 1976 and 400,000 $m^3$ (140,000 cunits) in 1977.

Construction assistance was provided by the provincial government in 1977 for logging roads. This was equivalent to 50% of the road construction costs or about $0.45/$m^3$ ($1.25/cunit) of wood harvested. The subsidy was restricted to roads built on the Highlands of Cape Breton Island.

On the Lowlands, the infestation was reported not as severe as on the Highlands because of the higher percentage of spruce.

### 2.2.4 Newfoundland

Two major insect outbreaks have occurred in Newfoundland since 1966: they are the eastern hemlock looper and the spruce budworm.

The last hemlock looper outbreak occurred in 1966. Dry and warm weather led to rapid expansion of the population, which reached a peak in 1969. Approximately 800,000 hectares (2,000,000 acres) of fir forest have been defoliated since the outbreak started in 1966 (3). Areas in western and central Newfoundland were sprayed with insecticide in 1968 and 1969.

The outbreak began to decline in 1970 and by 1972 defoliation was negligible. Estimates in 1971 indicated that about 10,000,000 $m^3$ (3,500,000 cunits) of merchantable balsam fir trees were killed during the outbreak.

The budworm outbreak began in 1971, and by 1972 was the largest and most severe ever recorded on the Island. In 1972, defoliation was evident over an estimated 400,000 hectares (1,000,000 acres) of fir and spruce forests from St. George, on the west coast, to as far east as Badger. About 360,000 hectares (900,000 acres) were in the moderate to severe defoliation class. In 1976, the total infested area was 2,600,000 hectares (6,300,000 acres) with 1,200,000 hectares (3,000,000 acres) in the moderate and severe defoliation stages, and approximately 200,000 hectares (490,000 acres) with tree mortality (see Fig. 2) (3).

The volume distribution by softwood species is approximately 50% spruce and 50% fir.

During the hemlock looper outbreak, most of the trees severely infested were killed, leaving a pure dead forest the second year after infestation. The conditions after mortality were such that bark would peel off the trees the first year, permitting rapid drying of the trees and delaying apparent sap rot attack until the third and fourth years. During the fifth and sixth years, sap rot increased and windfall occurred (see Fig. 3).

While more than 2,200,000 $m^3$ (800,000 cunits) of wood killed by the hemlock looper were salvaged over 5 to 6 years, three times this amount could not be harvested and used before it was lost to decay. Because of the extent of the infestation, cutting operations were carried out mainly in the best stands.

A major access road construction program has been under way since 1976 with DREE's[1] assistance. The terms of agreement specify that wood has to be infested by budworm and salvaged over a period of 5 years.

Aerial spraying was conducted on an experimental basis in 1976 and the cost was shared equally by Industry, and Provincial and Federal Governments.

Salvage operations in the budworm infested areas are under way at an annual rate of 450,000 $m^3$ (160,000 cunits). The total annual cut is 2,200,000 $m^3$ (800,000 cunits).

### 2.2.5 Maine

In Maine, the budworm has been of serious concern for the past 3 years

[1] Department of Regional Economic Expansion

(since early 1975), and a spray program has been under way since then. In 1976, 1,400,000 hectares (3,500,000 acres) were sprayed at a total cost of $8.5 million. In 1977, the program was expected to cost $3.5 million for a tentative sprayed area of 380,000 hectares (930,000 acres). The spraying program was shared by Industry and governments (state and federal).

Surveys were conducted with the use of helicopters, coloured infra-red photographs and maps. From these surveys, volumes and areas of severe infestation were identified in order to direct or concentrate harvesting in critical areas. The expenses involved in the surveys to locate the budworm damage were estimated at $30,000 per year. The surveys were applicable to an annual cut of approximately 1,400,000 m³ (500,000 cunits).

Spruce and balsam fir distribution throughout the forest varied from site to site. Fir content varied from 40 to 75% and spruce from 25 to 60%.

Mortality occurred approximately 3 years after signs of defoliation. Salvage operations, on a very limited basis (approximately 20,000 to 30,000 m³ (8,000 to 12,000 cunits) ), were undertaken in stands which had some trees dead for 1 year.

# 3. THE INFESTED FOREST

## 3.1 The infested stand

The spruce-fir forest in eastern Canada is mostly an unevenaged over-mature forest which, even without a budworm attack, presents a problem because of the cull which adversely affects logging productivity, unit costs and eventually the yield in manufacturing plants.

The budworm-infested stand of timber contains a combination of trees that are green (normal), trees having varying degrees of defoliation, trees that have reached mortality and those that have been dead for 1, 2 or more years. Very rarely is the stand one that contains trees of uniform condition. The stand is mature to over-mature with a possible high percentage of cull or rot, much of which existed before the present budworm infestation. Following mortality, trees dry, decrease in weight, become brittle and, if handled roughly, have a tendency to break. It is not possible to define in a precise manner the status of deterioration of a tree in relation to the elapsed time since mortality in the many conditions encountered in budworm-infested forests (see fig. 4).

A wide range of conditions affects the trees that die and their rate of deterioration following mortality; for example, geographic location, prior exposure to budworm and other insects such as the balsam woolly aphid [*Adelges piceae* (Ratz)], duration of periods without frost, average temperatures, the amount of precipitation and rates of defoliation. A slower rate of wood fibre deterioration occurs in stands experiencing rapid defoliation and total stand mortality. The opinion has been expressed that this condition results from much improved air circulation around the trees.

Definitions of *defoliation* and *mortality* which might be useful in assessing a stand are given below:

*Defoliation*

1) Light: in which 0-25 per cent of new foliage has been destroyed.
2) Moderate: in which 26-75 per cent of new foliage has been destroyed.
3) Severe: in which 76-100 per cent of new foliage has been destroyed.

*Mortality (Dead but Salvageable)*

One company uses the following definition: to be a dead tree, all of the following requirements must be met: (see Figs. 5 and 6)

i) There must be no green foliage.
ii) The tree must be standing.
iii) The tree must have at least 2/3 of its estimated original total height.
iv) The twig branching pattern remains intact.

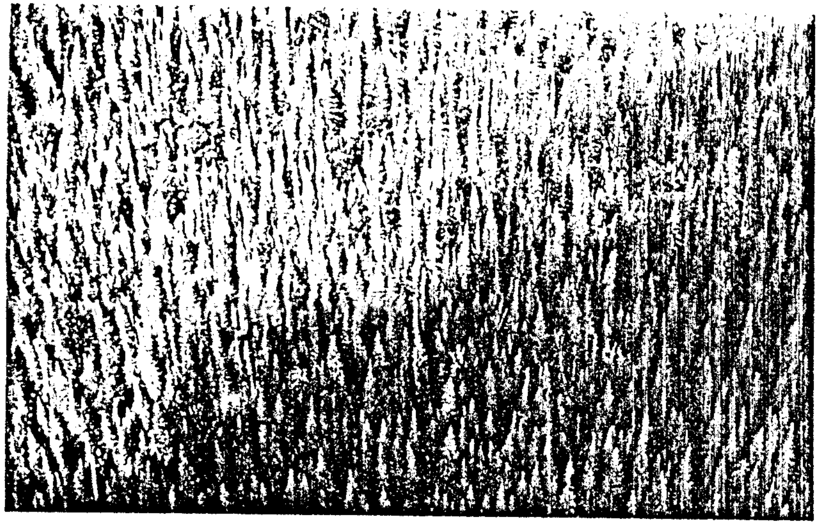

Fig. 2. Forest severely infested by spruce budworm, Newfoundland.

Fig. 3. Hemlock looper-killed wood, Newfoundland.

Fig. 4. Varying degree of infestation.

Fig. 5. Budworm-killed trees.

v) The cambium is dead, in a sample taken at breast-height. (The cambium is dead when it is brown and sticks to the wood of the tree-trunk).

However, there exists no criterion to determine whether a stand is dead or not. At one point, the percentage of dead trees in a stand may preclude logging, but the stand will be, in part, alive.

## 3.2 Secondary insect attack

Bark beetles and wood borers will attack dying or recently killed trees. They will enter through the bark provided moisture is still present. Bark beetles enter through the bark leaving tell-tale holes and proceed to lodge themselves in the cambium layer making small canal-like impressions on the woody part of the tree trunk. These small crevices alone have no effect on wood quality insofar as the wood product industry is concerned.

Most wood borer damage is caused by the sawyer beetle (*Monochamus* spp.) (11). The larvae (grubs) of sawyer beetles riddle dying or recently dead trees with large elliptical wormholes, which facilitate the entrance of stain and decay fungi (10). Larval mines penetrate to depths from 100 to 150 mm (4 to 6 inches) (see Fig. 7).

## 3.3 Fungus attack and rot

Spores of fungi present in the air find their way into trees through exposed wood or holes made by insects, and cause rot to develop.

Moisture in wood is also a prerequisite for the advent of fungi. Fire-killed standing trees without bark are usually dry, and therefore without bark beetles, borers or fungi.

The degree of decomposition at any given time will depend on the elapsed time since mortality, climatic conditions experienced and the conditions surrounding mortality initially.

When harvesting any over-mature stand of trees, there will be normal cull from rot whether or not there has been a budworm infestation. There will also be rot, particularly troublesome in sawlogs, which extends from the top down the inside of the trunk. This comes from leader or top killing causing multiple forking of tree tops and may have been the result of previous budworm infestations. There will also be sap rot or ring rot which may be found, eventually, in any tree that has died, such as wood recovered from windfall, insect attack mortality; and so forth.

The sap rot is the one related to the recent budworm infestation. As this rot progresses, it reaches the stage when the infected wood becomes so soft that it is removed if subjected to the abrasion of a debarking process. Serious fibre volume losses will then occur (see Figs. 8 and 9). Since this rot is on the outer circumference, the loss for any given stick may represent 10 to above 25% of its total volume.

A study (12) was conducted in New Brunswick in 1955 to determine the nature and rate of fungus deterioration in balsam fir killed by spruce budworm. This showed that in the stand where 50 to 100% mortality occurred, incipient decay (reddish-brown discoloration) penetrated the sap wood to an average depth of 10 mm (0.4 inch) within 1 year of death. The average depth of deterioration (incipient and advanced decay) increased to 18 mm (0.7 inch) in trees dead 3 to 4 years, but did not exceed 18 mm (0.7 inch) in trees sampled 4 to 7 years after death. Table 1 shows the rate of deterioration with respect to the number of years since death.

In balsam fir stands suffering less than 10% mortality, the development of advanced decay was more rapid than in stands with 50 to 100% mortality. (See Table 1. The advanced sap rot volume based on the total stand was the same (1.5%) after 1-2 years when mortality was 10% as after 2-3 years when the mortality was 50%.)

Heavier mortality exposed trees to direct sunlight and to air currents and they consequently dried more rapidly, as

## Table 1. Rate of fungus deterioration in balsam fir killed by the spruce budworm in northwestern New Brunswick (12)

| Number of years since death | % of merchantable volume showing: | | Average radial penetration of: | |
|---|---|---|---|---|
| | Incipient decay | Advanced* decay | Incipient and advanced decay (in.) | Advanced decay (in.) |
| | Mortality of 50 to 100% | | | |
| 0-1 | 17 | | 0.4 | |
| 1-2 | 22 | | 0.5 | |
| 2-3 | 29 | 3 | 0.6 | 0.1 |
| 3-4 | 23 | 14 | 0.7 | 0.2 |
| 4-5 | 16 | 27 | 0.7 | 0.3 |
| 5-6 | 14 | 27 | 0.7 | 0.4 |
| 6-7 | 17 | 22 | 0.7 | 0.3 |
| | Mortality less than 10% | | | |
| 0-1 | 18 | 5 | 0.4 | 0.1 |
| 1-2 | 11 | 15 | 0.6 | 0.3 |

* Advanced decay is equivalent to soft rot or unfirm wood.

evidenced by the presence of split and hanging bark. Higher moisture conditions in the light mortality stand probably increased the deterioration rate there.

These observations were confirmed by a survey (3) of deterioration of balsam fir damaged by hemlock looper in stands where most of the trees were killed. Incipient sap rot penetration was 7 mm (0.29 inch) in trees dead for 1 year and reached 19 mm (0.74 inch) in trees dead for 6 years. Advanced sap rot first occurred in the fourth year after death and increased to 9 mm (0.35 inch) by the sixth year.

Another study undertaken in Ontario (6) showed that the merchantable volume of balsam fir occupied by sap rot was 0% 1 year after death, 23.1% the second year, 33.1% the third year and 44.6% the fourth year.

## 3.4 The acceptable tree

Forest stands, after severe budworm infestation, usually include green trees, those just dead and those dead for 1, 2 or more years. It is important to establish standards recognized by industry and government for the tree that will be acceptable for the manufacturing end use. Otherwise unnecessary expenses are incurred harvesting, processing and transporting trees which must later be rejected.

What is acceptable for one end product may not be acceptable for another, and the alternative end use may not always be available at any particular location. The period of acceptability for manufacturing is not the same for fir and spruce that have died as the result of budworm defoliation.

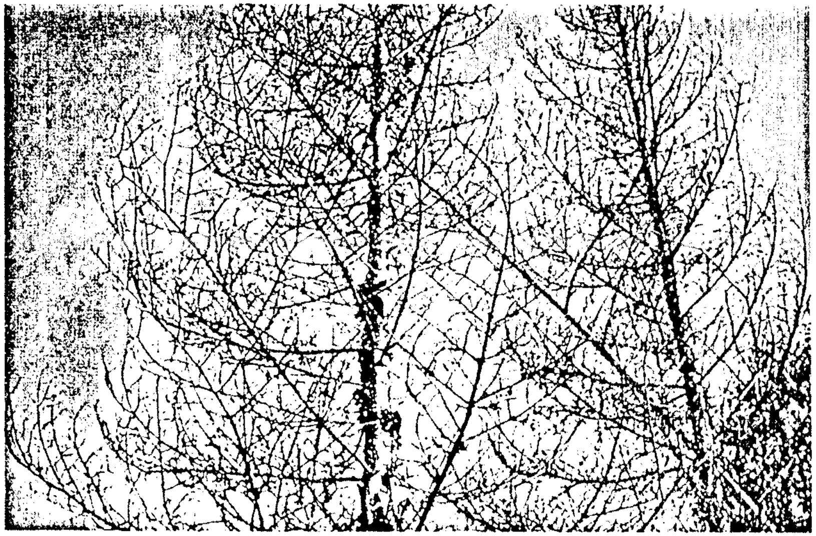

Fig. 6. Tops of dead trees.

Fig. 7. A tree attacked by wood borers.

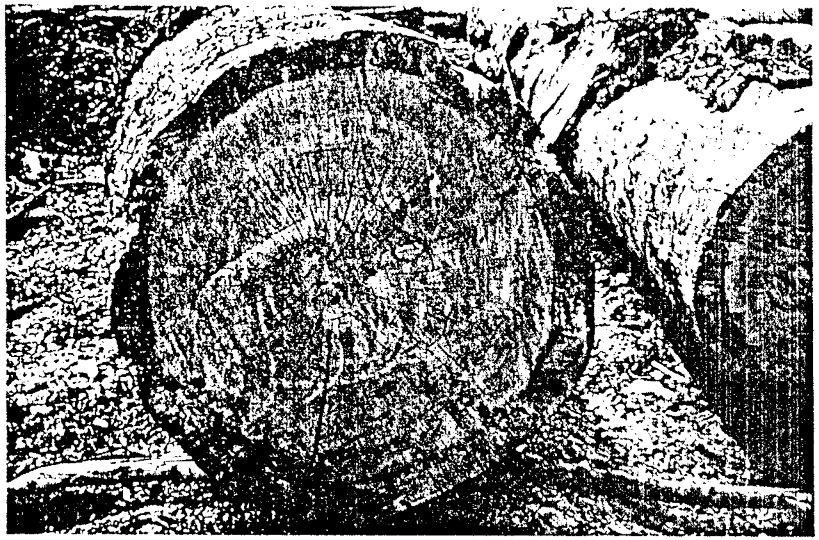

Fig. 8. Sap rot found in dead trees.

Fig. 9. Incipient decay in a dead balsam fir tree.

Depending on the final product, spruce may be salvaged up to 2 years longer than fir. Thus, both government utilization standards and the industry logging plan must be defined and adjusted to the lccal conditions to encourage the maximum amount of economic salvage logging. These standards to decide whether or not to harvest for a particular market must be applied to the individual trees as opposed to the complete stand.

Generally, budworm populations move from west to east so that there may be a warning period of 1 or 2 years before an infestation. Following infestation, defoliation will generally go on for about 4 years before mortality occurs, although some have taken as little as 2 years. The period available for salvage after mortality is by no means clearly defined, but there does seem to be a consensus that in the case of pulpwood, 2 years minimum, or 3 at the most, are available for balsam fir and 5 years in the case of spruce. Fig. 10 illustrates the probable effect of a budworm epidemic on the forest.

The elapsed storage time between harvesting and manufacturing, and the transportation methods used, are factors to consider when deciding whether a stand should be harvested or not. The activity of insects and fungi will be halted if wood is submerged in water, but not if wood is trucked and continues to be exposed to the air in dry land inventory piles.

The downgrading of logs and loss of yield at plants processing dead wood is of major economic importance. A log unsuitable for veneer because of sawyer beetle holes or incipient sap rot may still be acceptable in a pulp mill at some penalty in product yield and quality.

It is not the purpose of this report to analyze the consequences of the use of budworm-affected trees for the different manufacturing purposes; primarily veneer, lumber and pulp. It is vitally important, however, to define precisely what is acceptable wood quality for each use before making a logging plan.

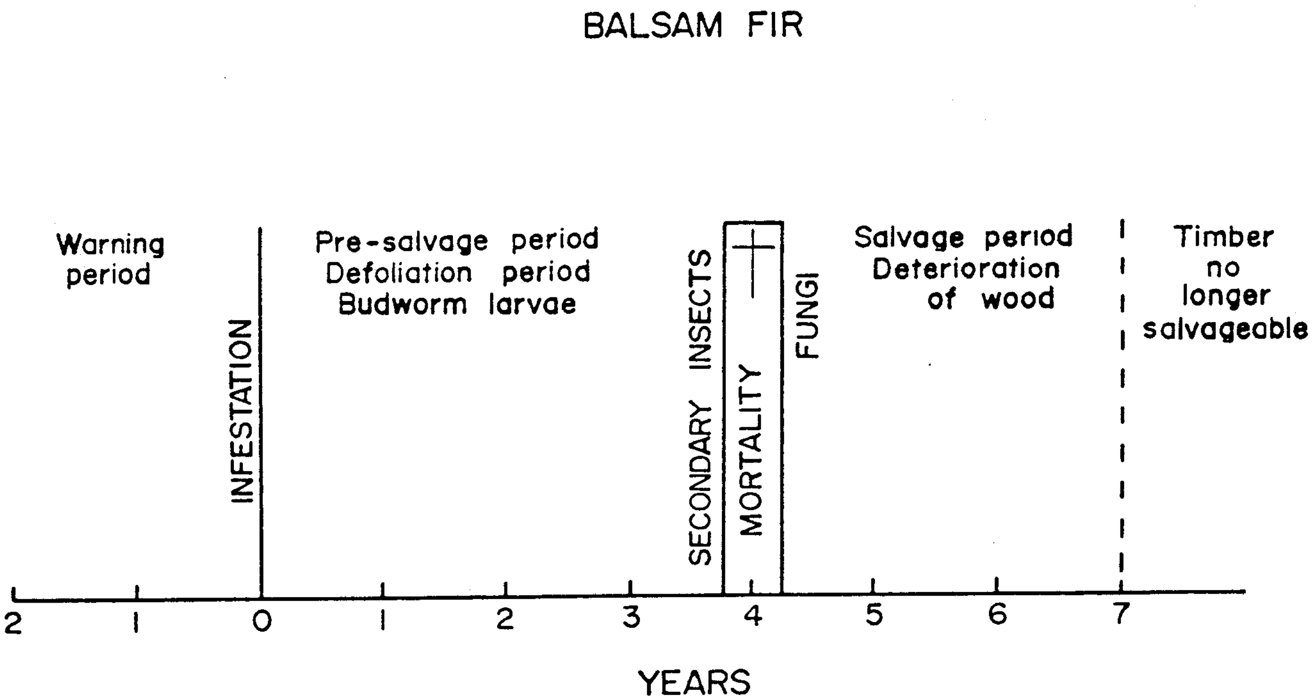


Fig. 10. Evolution of spruce budworm infestations in a balsam-fir forest stand and the relationship to the pre-salvage and salvage harvesting periods.

# 4. HARVESTING THE INFESTED FOREST

## 4.1 Confronting the infestation

### 4.1.1 The anticipated infestation

It is sometimes possible to anticipate a budworm attack, and also to prepare for it by providing the necessary road system into areas containing mature and over-mature balsam fir. Timber that has been harvested cannot be infested and should the budworm get to it first, a road sytem will be available for a pre-salvage operation to remove the infested timber quickly before mortality sets in. The benefits that result from such a plan are offset by added costs for roads, for the moving of camps and equipment, and from money tied up prematurely in temporarily abandoned roads, camps and facilites.

### 4.1.2 The actual infestation

Confronted with a forest stand that has been infested by the budworm, the operator must decide whether or not it is acceptable for harvesting. Recognized standards do not exist at present for doing so. His decision will be based on:

(a) The chronological status (see Fig. 10, page 13) of infestation with particular attention to when mortality, if it is present, began.

(b) The final product to be manufactured.

(c) The elapsed time and method of storage between harvesting and manufacturing.

(d) The volume of infested wood to be produced relative to the total deliveries to the mill.

(e) The logging and delivery methods to be used.

(f) The costs for harvesting and delivering the wood.

Finally, the capital investment required for harvesting a given area will have to be weighed against the volume it will be possible to log before the wood reaches a degree of deterioration that renders it unacceptable.

Assuming a decision to harvest the stand has been made, the operation may be pre-salvage or salvage depending on whether the trees are partially defoliated or dead.

## 4.2 Effect of disruption to logging plan

If logging plans anticipate or coincide with budworm infestations, a pre-salvage or salvage operation simply follows the plan. Often, however, pre-salvage or salvage operations will require changes to the operating plan and increases or even short-term decreases in costs may result. It must also be recognized that an operation may start off as pre-salvage with minor effects on the harvesting operation itself. As trees die and deteriorate with time, it changes into a salvage operation with increased tree breakage and wood quality deterioration, and decreased operating productivity.

A pre-salvage or salvage operation in a virgin forest requires the building of roads, a camp, and other logging facilities. An operation already in progress may be moved with its equipment and portable buildings while the roads, buildings and installations such as airports, and river and communication facilities for the original location are temporarily abandoned. This will cost money; the amount will depend on the specific conditions which apply to each case. Furthermore, deterioration of the unused facilities will eventually lead to added costs.

A decrease in costs may occur if the relocation is to an area already serviced by roads or permits cheaper road building in the area to be logged.

An indirect cost can occur if the new operation cannot supply enough peeler or sawlogs (often because of quality deterioration), or if the species mix includes too much balsam fir. Then the needed logs or species may have to be obtained from another source at a possible added expense.

Depending upon the location of the salvage operation relative to the suspended one, personnel costs may increase or decrease. Costs will increase if the woods-workers' living habits are disrupted, if travelling distance is increased substantially or becomes more difficult and particularly if this leads to an adverse effect on daily production. On the other hand, conditions may become more favourable decreasing the costs, if for example, the original camp can be replaced by a commuter operation. A camp subsidizes, at considerable expense, the man's living requirements whereas in the commuter operation, the man lives at home where he normally prefers to be.

A very important factor is the additional capital required within the short period of time available to carry out any salvage program. These added capital requirements, even if they are depreciated over the salvage period, result in increased working capital which is an added corporate burden.

In the areas visited, relocation of operations necessitated the construction of new logging roads and modifications to the regular road construction program. In Nova Scotia and Newfoundland, major road construction programs were under way in order to provide access to heavily infested areas. These program costs were shared by Industry and Governments. During the hemlock looper outbreak in Newfoundland, roads valued at approximately $1,000,000 were temporarily abandoned to relocate the operations for the salvage of 2,200,000 $m^3$ (800,000 cunits).

New camps had to be set up in Quebec, the Cape Breton Highlands and in Newfoundland. In Newfoundland, approximately $700,000 was spent on the relocation of camps for the salvage of 850,000 to 1,100,000 $m^3$ (300,000 to 400,000 cunits); this amount was depreciated over the 3- to 5-year salvage period. For each camp moved (180 men), the additional relocation expense was approximately $100,000.

The relocation of operations from the Nova Scotia Mainland to the Cape Breton Highlands resulted in an added cost of approximately $0.35/$m^3$ ($1.00/cunit) for moving the camps and equipment, the transportation of personnel and the more expensive operation of the camps. The purchase and setting up of additional camp facilities (if required) were not included in this figure.

## 4.3 Harvesting and scaling

### 4.3.1 Establishing the volume

The logging engineer must first establish the volume and quality of the infested wood scheduled for cutting. Secondly, he must obtain from the buyer of the wood, if the option exists, the volume he is able or prepared to accept. The infested wood can only be some percentage of a total mill supply. The critical factor is whether, and for how long, a manufacturer is able to use it. This will depend on when mortality occurred, the degree of deterioration and the time that will elapse until the wood is harvested and used.

### 4.3.2 Logging from stump to main road

It was not possible to obtain adequate figures to show the effects on productivity and unit costs of harvesting budworm-affected wood. Rough estimates and data from limited samples have been included in this report as they demonstrate the order of size which can be expected.

Fig. 11 shows the alternatives that the logger will encounter when harvesting budworm-affected timber and is included to clarify the remarks that follow.

Wood may be felled manually with a power saw, or mechanically with a machine. In both cases, it may or may not be partially or fully processed, then skidded or transported to a landing. These methods may be in each case applied to an infested but pre-mortality forest, or to a post-mortality forest.

"Pre-mortality" and "post-mortality" are defined as follows:

— A pre-mortality stand may contain green and infested trees having various degrees of defoliation. There are no dead trees.

— A post-mortality stand will contain some dead trees and might contain up to 100% trees that are dead.

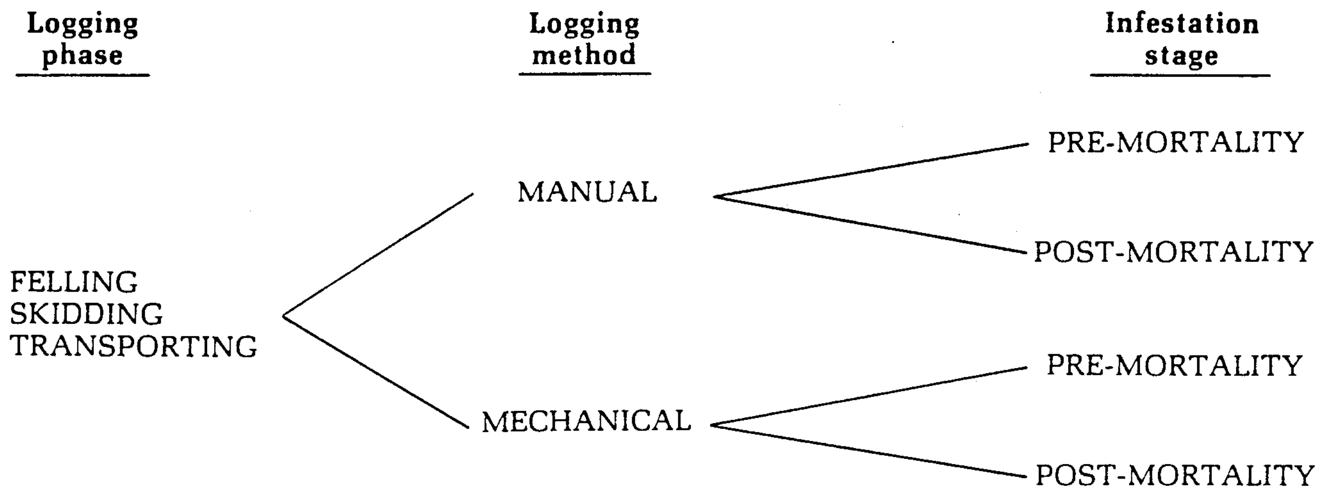


Fig. 11. Harvesting alternatives for a budworm-infested forest

**4.3.2.1 Pre-mortality — manual felling and skidding**

Cutters experienced few problems felling pre-mortality trees with the one small exception of hang-ups with trees in an advanced stage of defoliation. These trees are lighter and do occasionally hang-up. Productivity and earnings are not affected. Manual slashing to 1.2 or 2.4 m (4 or 8 ft) is normal with the possible advantage of the wood being lighter to handle.

**4.3.2.2. Pre-mortality — mechanical harvesting**

As with the manual method, there are no particular problems except that the closer a tree approaches mortality, the more likely it is to break off near the top if handled roughly.

**4.3.2.3 Post-mortality — manual felling and skidding**

Dead trees become light and brittle and they may become infested with secondary insects and fungi. Harvesting this timber may result, unless precuations are taken, in delivering a high percentage of cull wood to a manufacturing plant. Particularly important is the sap rot that should usually be expected and guarded against during the third year of mortality. Sap rot will be lost when the wood is barked and this wood may not be suitable at all for peeler logs or lumber.

The main manual logging methods used are: i) the cut and bunch of 8-foot wood forwarded to roadside and ii) the cut and skid of tree-length wood to roadside.

*a) Cut and bunch of 8-foot wood*

This method was used in New Brunswick, Nova Scotia and Newfoundland in stands infested to varying intensity levels.

In southern New Brunswick, cutting operations were taking place in heavily infested forests. Trees being cut had already been dead for 2 to 3 years (longer in some cases) and had dried out. Sap rot signs were already apparent in logs. No abnormal cutting problems were noted with this method here or during the visits to Nova Scotia or Newfoundland.

The method offers advantages, although it is labour intensive. The "cut and bunch" felling and bucking operations involve a single cutter. The felling phase is the most practical gentle method available, and breakage of trees is kept to a minimum. There is a problem, although not a major one, of dry, light trees hanging up. When delimbing, dry, brittle branches may be a potential cause of eye injuries, but this suspicion was not confirmed. In the bucking phase, the cutter's instructions normally are not to include sticks that are total culls in the piles to be hauled. The buyer, in keeping with the applicable scaling regulations, will not pay for them. Each 8-foot stick therefore is subject to a quality control inspection and total cull sticks are eliminated at the outset from the log handling and transportation system. If the cull factor reaches a level obliging a cutter to handle more wood to net his normal daily quota, then an increase in rates may be expected. (Note: cull not related to the most recent budworm infestation is also eliminated at the stump).

The wood is assembled into small bunches in the cutting strip by the cutter, loaded onto a pulpwood transporter and off-loaded onto a truck trailer or downpiled at roadside. The wood is then scaled for payment of the men and machines involved in this stump-to-main-road operation. The latter ensures that all wood paid for has reached the truck road and that unusable cull has been left in the woods. The 8-foot wood handled by the transporter loader, because it is short and free of the worst cull, will not usually break and losses from this source will normally not occur.

According to the cutters involved, there are no objections to cutting in these types of stands. The dry wood weighs 20 to 25% less than green wood and where aerial spraying had taken place, the absence of biting insects made the working conditions more pleasant. Disadvantages mentioned included delimbing problems with large dry spruce branches (but not with balsam fir), a higher than normal amount of dust from the trees which caused throat irritation, and an increase in the number of flat tires on the forwarders.

b) *Tree-length cut and skid to roadside*

This method, which consists of felling and delimbing trees with a power saw and transporting them to roadside with a conventional skidder, was used in all areas visited.

In western Quebec, this method was carried out in softwood and mixedwood stands in which nearly all balsam fir trees had been dead for more than a year. Tree top breakage occurred during felling, skidding and slashing. Top breakage resulted in fibre loss on the cutting site and at the landing (see Figs. 12 and 13). A special crew was hired to recover the broken sticks on the landing at a cost of approximately \$0.20 per $m^3$ (\$0.50/cunit) applied to the total cut. An on-site count showed that approximately 50% of tops were broken before slashing, and this percentage may increase in winter. After loading, broken tops and short logs remain at the landing site as the loader cannot reach them. The number of broken trees delivered to the landing has more than doubled compared to normal operations.

In 1976, from a sample of 7,500 trees, the percentage of wood loss due to breakage was estimated at 2.6% of the volume of all trees logged. Ten to 20% of the trees had been dead 1 to 2 years. The percentage breakdown by activity is estimated as follows:

| Activity | Percentage Volume Loss (1976) |
|---|---|
| Felling | 2.1 |
| Skidding | 0.6 |
| Slashing or loading (landing) | 0.4 |
| Sub-total | 3.1 |
| Recovered (stump to landing) | - 0.5 |
| Total | 2.6 |

In 1977, similar tests were conducted on a sample of 22,000 trees. Test counts and measurements showed that 7% of the trees broke, for a volume loss of 4.0%. The scalers made deductions amounting to

0.8% of the volume. The loss distribution was 0.8% of the volume before scaling and 3.2% in delivery losses after the scaling. The tree sample was an "as harvested" mix from a stand which included 20 to 40% of trees that had been dead 2 to 3 years. More than 80% of the volume loss was in balsam fir.

Trees were scaled at the butt end and cutters were paid accordingly. Because of the method of payment, the broken trees were a net loss (3.2%) to the company. In some cases, the psychological effect the poor appearance of the stand has had on the cutters has led to pressure to have the stand classified for the "poor quality" payment scale. Their rates may then be 5 to 10% higher than normal.

In New Brunswick, no salvage was under way during visits, except for a small percentage of dead trees (10% of balsam fir volume). Top breakage during skidding was the major problem encountered with these dead trees. The volume loss was estimated at 2 to 3% of the total stand cut in the limited areas which showed this mortality.

On the Mainland of Nova Scotia, according to industry representatives, the salvage operations carried out for 2 years following mortality did not present logging problems. When cutting trees or stands dead for more than 2 years, serious breakage occurred. Cutters claimed that, when cutting in pure stands of dead balsam fir, their production was reduced by approximately 25% due to trees breaking into two or three pieces. The volume cut under these conditions was limited. It was felt that salvaging after mortality might be done for 3 years in balsam fir and 5 years in spruce.

On the Cape Breton Highlands, no variations in productivity and costs were found. The mortality first occurred in 1976 and trees had just started to dry.

In Newfoundland, this tree length cut and skid method was the main one used. In some cases, it was followed by manual bucking into 4-foot and loading on pallets at roadside. The major problems encountered when salvaging hemlock looper-killed wood were due to serious breakage and windfall 4 years after mortality, which resulted in a production loss ranging from 20 to 25%. As the cutting rates were on the basis of tree length paid by the cord, an upward rate adjustment had to be made up to as high as $0.50/m³ ($1.50/cunit) to compensate for the cutters' reduced productivity for a given amount of work.

In Maine, it was reported that top or tree breakage was more frequent in trees dead for 2 years. From the salvage operations undertaken, no changes in cost and productivity had been identified.

In summary, in post-mortality stands, the conventional cut and skid tree-length to roadside method has the same problem as the manual cut and bunch at the felling stage with tree hang-ups and some breakage. Delimbing, in both cases, causes little problem except with large dead spruce branches. Extra breakage losses are incurred, however, in the skidding operation and this amount will increase with the percentage of stand mortality and the time since tree death. The longer the salvage period, the more gentle the harvesting operation should be if volume breakage losses are to be minimized.

#### 4.3.2.4 Post-mortality — mechanical harvesting

As stated previously, mortality causes trees to become increasingly brittle with time. Mechanical felling or processing, which are rough operations, will cause some trees to break into more than two pieces, depending on the degree of brittleness. One of two alternatives then occurs. First, the piece that has broken off is left in the stump area and there is a volume loss or, second, the machine operator will attempt to recover the broken piece if warranted by its size, causing a productivity loss. Obviously, in both cases, there will be a cost increase, which, due to the variable conditions met, is extremely difficult to quantify. Further

Fig. 12. Broken tops remaining on the cutting site after initial skidding.

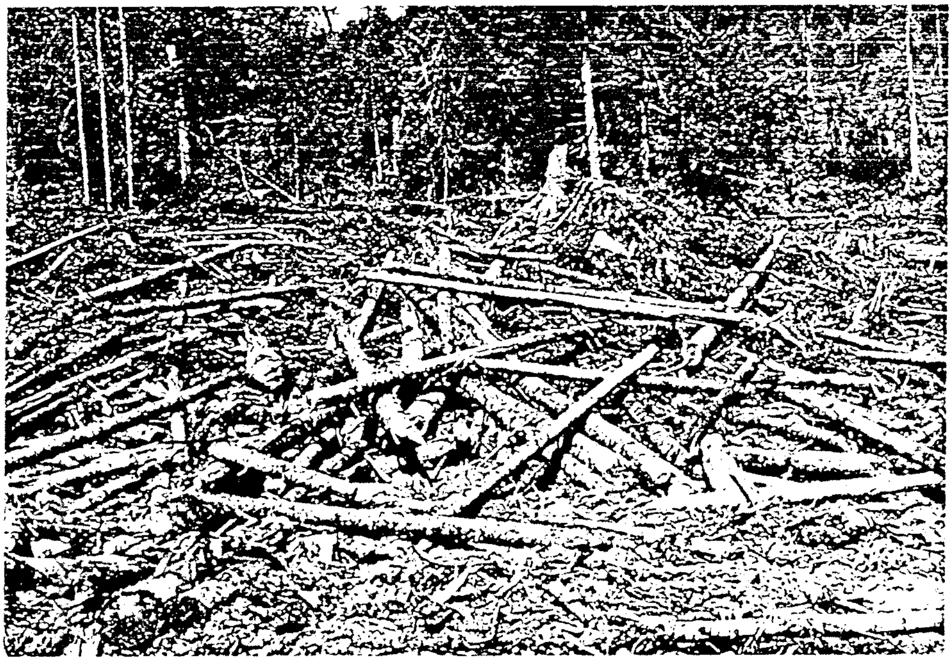

Fig. 13. Broken tops remaining on landing after trucking.

losses will be experienced during the skidding operation and more will occur on the landing when the wood is slashed or loaded on trucks.

The two main systems used for salvage logging were: a) mechanized short-wood logging, which generally led to less breakage and loss; and b) mechanized long-wood operations, which were generally more destructive to brittle, budworm-affected wood.

*a) Mechanized processing of 8-foot wood at the stump*

In western Quebec, Koehring shortwood harvesters were operating in mixedwood stands having light budworm damage and where a few balsam fir trees were dead. When harvesting in dead fir, nearly all trees broke when being felled or delimbed. Also, to reduce breakage, removing the underbrush with a tree in the felling head must be avoided. Broken tops were generally salvaged by the machine but at a loss in production estimated at more than 2.8 $m^3$ (1 cunit) per shift. The production cost increased approximately $0.50 per $m^3$ ($1.50/cunit). It was also mentioned that, due to dry branches, delimbing knives need to be kept sharp. The average number of trees to make a load, due to breakage, increased by 10 to 15% in dead balsam fir.

In northern New Brunswick, supervision responsible for the logging operations reported no decrease in productivity or added costs as a result of operating in wood infested by budworm, as defoliation of trees was generally light.

On the Highlands of Nova Scotia, two systems are used to produce 8-foot logs at the stump. In one system, trees are felled with a feller-buncher (wheel- or track-mounted), delimbed and processed into 8-foot bolts at the stump with a Kockums processor, and then forwarded to roadside. In the second system, trees are processed with the Koehring shortwood harvester.

No variations in productivity and costs were found as the mortality first occurred in 1976 and some trees had just started to dry.

*b) Mechanized long-wood systems*

In the operations visited in western Quebec, trees were felled with a feller-buncher (Forano BJ-20) in a mixedwood stand where balsam fir was moderately attacked, but not dead. Trees were then forwarded by a grapple skidder and debranched by a Logma delimber.

With this system, if trees are felled in a severely attacked stand, the top breakage will be higher than with the conventional cut and skid method. Breakage occurs in the felling area, during skidding, at the landing and when delimbing.

Tests conducted on a sample of 1,700 trees in the summer of 1977 showed that breakage occurred in 12% of the trees and this represented a loss of 6.7% of the total volume. In the harvesting operation, 3.1% loss of total volume occurred before scaling, and was borne by the reduced crew and machine productivity to that point. Scaling failed to detect 3.6% total volume loss which would show as an eventual yield loss in paid-for deliveries. (Note that stumpage fees would not be paid for losses before scaling but would be paid for losses undetected in scaling.)

On the Highlands of Nova Scotia, no particular problems were noted; however, breakage and sap rot are expected to become a serious concern for coming cutting seasons. Breakage will make salvaging more costly when mechanical equipment is used.

In Maine, salvage operations were undertaken on a limited scale, 22,000 $m^3$ (8,000 cunits) in 1975, and trees harvested were not all dead or had been dead for only 1 year. The major difference noted was that mechanical harvesting was done in younger stands (smaller wood) that would have not otherwise been cut. No added costs were noted.

The productivity and cost penalties for salvaging budworm-killed timber cannot be defined in a single set of figures. They are dependent upon the harvesting method used, the percentage of dead trees and the time since mortality. As these latter two variables are time dependent, the productivity and cost penalties normally increase with each year the salvage operation continues.

In general, there are few adverse effects with any system when harvesting pre-salvage or just-dead stands. With increased time since mortality, the more gentle the harvesting and transportation methods used, the better the possibility for minimizing the breakage losses. Each handling of tree lengths between the standing tree and the cut-to-length and loading stages increases the breakage and productivity losses.

#### 4.3.3 Slashing

With the tree-length-to-roadside systems, trees are slashed either at roadside or at a central landing into 4-foot or 8-foot bolts and 16-foot sawlogs. Depending on the deterioration of the trees, further breakage is likely to occur and production correspondingly reduced when trees are taken by the loader and fed into the slasher.

On the Mainland of Nova Scotia, one contractor reported that his slashing production was reduced by approximately 25% in balsam fir dead for more than 2 years. The volume produced under these conditions was very limited.

In Newfoundland, slashing production was reduced by 10 to 15% because of tree breakage in hemlock looper-killed wood 4 years after mortality.

#### 4.3.4 Transportation of wood

##### 4.3.4.1 Weight of wood

As a tree weakens from a budworm attack, its wood becomes drier, lighter and more brittle. A cubic metre of green wood, which would normally weigh about 950 kg (4,400 pounds/cord)[1] may be reduced to 640 kg (3,000 pounds/cord). The budworm-infested forest results in so many different combinations of conditions that specific stands would have correspondingly different weights per cubic metre. The figures given above should be treated accordingly.

The magnitude of the weight reduction and its variability were demonstrated by a limited sample in Nova Scotia. The average weight per cubic metre dropped from 900 kg (4,300 pounds/cord) to the range 680 to 770 kg (3,200 to 3,700 pounds/cord). Indications were that this same general weight drop and its variation could be expected in budworm killed wood from the Cape Breton Highlands.

In Maine, where trees harvested were not all dead, or had been dead for only 1 year, the weight of wood appeared to be 20% lighter.

##### 4.3.4.2 Truck transportation

*a) Trucking shortwood*

If a logging operation in progress is moved to a pre-salvage or salvage operation, distances for deliveries may change. The latter may be favourable or unfavourable from the point of view of costs. During the course of the study, the authors learned of one case where a trucking distance was decreased by 65 km (40 miles) when an operation in green wood was transferred to a salvage operation. If, for example, trucking costs are \$0.04/m³-km (\$0.20/cunit-mile) then in this particular case there was a saving for transportation of \$2.80/m³ (\$8.00/cunit). Another specific case encountered involved an increase in distance of 32 km (20 miles) and a possible cost increase of \$1.40 per m³ (\$4.00/cunit) on the same basis; however, this cost difference is for green wood. When wood gets lighter, the trucking cost on a m³-km (cunit-mile) basis is subject to some reduction.

A trucker is normally paid for hauling wood either by volume or by weight.

If a trucker is paid by volume but his loads are limited by weight regulations covering public highways, he will be able

[1] One cord equivalent to 78 cubic feet

to increase the volume of lighter budworm-killed wood and thus become more productive. On the other hand, if his loads are limited by regulations governing vehicle and load dimensions, he will not be able to take full advantage of the reduced weight of budworm-killed wood. On private roads, neither weight nor dimensions are usually as restrictive, and the trucker can overcome the problem of light budworm-killed wood by increasing his load volume.

Trucking budworm-killed wood by weight creates a dilemma. Sometimes it is not possible to put a light wood payload on a truck within the limitations imposed by public highway regulations. If the buyer uses the same rate as for green wood, the trucker will receive less per truck load than the man hauling green wood even though he will be delivering the same amount, or even more, fibre. If he uses a higher rate, he will be paying more money for inferior wood. Adding to the problem is the variation in the weight of wood. One company has attempted a solution by setting a minimum weight to be paid per truck load.

On the Mainland of Nova Scotia, trucking of wood was paid for by the ton. The trucker had to increase the wood volume on his truck to maintain his payload. Thus, the trucking cost per cord to the mill decreased as wood became lighter. For example, costs were reduced by approximately \$0.70/m³ (\$2.00/cunit) for a distance of 80 kilometers (50 miles) and \$1.00/m³ (\$3.00/cunit) for 160 km (100 miles). The difference in trucking costs does not take into account the change in quality of wood for manufacturing purposes.

b) *Tree-length transportation*

Tree-length haul over short distances was affected as loads were smaller than normal due to the volume loss in broken tops. In Newfoundland, it was reported that the average truck load decreased from 22 (8) to as low as 17 cubic metres (6 cunits) when hauling hemlock looper-killed wood, dead 5 to 6 years.

In Maine, where trucking was carried out over a long distance (exceeding 56 km (35 miles) ) with butt and top loading, the average weight per load was reported to be reduced by as much as 20% with the same volume transported. This difference affected truckers who were paid by weight.

#### 4.3.4.3 Water transportation

If budworm-affected wood is put in water and driven, it is subject to all the normal conditions of this means of transportation such as sinkage, hang-ups along waterways, wintering in holding grounds and relatively long periods between harvesting and its use in manufacturing.

When driven, budworm-affected wood in the defoliation or pre-mortality stage should not vary much in its behavior from normal wood.

Secondary insects are arrested by cold below approximately 10°C (50°F) and, because of the lack of oxygen, killed by water.

If budworm-affected wood infested by borers is driven, the small tunnels in the wood due to the borers will admit water, cause the sticks to float at a lower level and presumably cause some increase in sinkage. Information to quantify and substantiate this is not available.

Fungi in the wood will, with few exceptions, do little damage while wood is in the water. Any time logs are out of water and suitable temperatures exist, the fungi will be active in decomposing the wood. The length of time usually involved in driving increases the exposure period to decomposition and is a disadvantage when budworm-killed wood must be salvaged.

## 4.4 Forest yield per hectare

In the salvage of budworm-killed timber, the yield per hectare is generally lower than in a normal harvesting operation.

- First, the yield is reduced in direct relation to the breakage of trees that occurs and a possible cull factor increase.

- Secondly, better quality stands are harvested first in order to salvage as much wood as possible, and often poor quality stands are not salvaged because they are more expensive to harvest and less productive.

For these reasons, it is likely that more roads will have to be built for the same volume of wood harvested. However, when cutting the best areas, the average volume per hectare will frequently be larger than normal, thus making a partial compensation.

A discussion with two woodlot owners revealed that they lost 10% of their volume per hectare due to breakage and rot in trees dead for more than 2 years.

## 4.5 Industrial safety

FERIC was particularly concerned with logger safety when harvesting budworm infested stands. Somewhat unexpectedly, there is no evidence that there is an increase in the number of logging employee accidents traceable to the spruce budworm until deterioration has progressed to the point where windfall becomes pronounced. When this occurred in the Newfoundland salvage operation of trees dead 4 to 5 years after the hemlock looper outbreak, the accident rate was said to have increased in the windfalls from falls when walking and from eye injuries.

The possibility of an increased incidence of eye injuries was mentioned elsewhere during the visits. Records at one company showed 63 over a 5-year period but no effort had been made to relate these to budworm affected trees. Despite the lack of firm evidence, extra safety precautions should be taken because of the potentially serious nature of this type of accident.

## 4.6 Forest fire hazard

This section deals with the incidence, type and suppression of forest fires as a result of budworm infestations and is the result of discussions with representatives of forest protection organizations.

### 4.6.1 Incidence of fires

i) It is unlikely that members of the public will venture into budworm-killed forested areas; it may be deduced that this source of fire occurrence has therefore been very much reduced. (Although the figures are subject to change, in one representative area and for a 6-year period, 74% of forest fires were caused by people other than woodsworkers.)

ii) In any given area, lightning will strike topographic features with equal frequency. Assuming that dry dead trees will catch fire more easily, more fires from lightning can be expected in budworm-affected stands as compared with similar stands of green trees.

iii) There has been no recognized increase of forest fires due to men logging with chain saws or mechanical equipment. Technological advances and improvements in logging equipment have been positive factors here.

iv) A prevalent opinion holds that budworm-killed trees constitute a high forest fire hazard. This is not substantiated by experience.

v) It may be that past experience reflects good fortune, but forest protection representatives confirm that so far little blame may be assigned to the budworm for any increase in the number of forest fires in recent years.

### 4.6.2 Type of fires

i) Normal crown fires will not be found in budworm-killed forests, and the tendency for fires to spread or jump to neighboring areas is therefore decreased.

ii) Ground fires of high heat, because of the dry fuel, will occur. More fuel remains on the ground when compared to a 4-foot or 8-foot cut-and-pile operation.

### 4.6.3 Suppression of fires

i) Added difficulty with windfalls which usually increase with time since mortality will be experienced in the construction of trails for fire fighters.

This would be translated into lower productivity and higher costs but precise figures are not available.

ii) Spending large sums of money to fight fires in a dead forest may be questionable. Depending on the degree of wood deterioration, a wiser course may be, if a fire does occur, to take a "prescribed burning" approach and control it at the lowest possible cost until finally extinguished.

## 4.7 Quality and end use of timber

The yield of spruce when used for manufacturing pulp is superior to that of fir; a decrease in the yield of wood will increase the cost of the finished product. There is a cost disadvantage, therefore, if a logging organization producing spruce is moved to pre-salvage or salvage balsam fir. The monetary penalty of such a change may become very important when mill equipment capacity is being used to its maximum and potential sales are lost.

On the operations visited, the normal rot and cull were substantially higher in fir than in spruce. (The stands being harvested were generally overmature.) This is a serious disadvantage for sawmilling and reduces the yield in any manufacturing process. The recent budworm outbreak was not the cause of this rot. However, especially the centre rot extending from the top down the trunk may have been caused by a previous non-fatal budworm attack that had resulted in breakage in the top branches allowing fungus entry at that point.

The sap rot seen during the visits was limited, due to the current budworm epidemics being in their initial stages or, where used, to aerial spraying maintaining trees alive.

Budworm-killed wood will not produce good quality lumber because of developing sap rot and holes made by wood borers.

The degree of deterioration of trees, with respect to the number of years after mortality, has a serious effect on the end-product or the utilization of these trees.

While it is not the main purpose of this report to deal with the manufacturing aspects of using budworm-affected wood, it was the good fortune of the authors to obtain a report, the content of which it is felt will make a useful contribution (8).

The report is a result of the 1966 hemlock looper outbreak in Newfoundland. It was estimated that 14,000,000 $m^3$ (5,000,000 cunits) of balsam fir were killed. The value of the dead wood as a newsprint pulp was of great concern to the pulp and paper industry in that province.

Because there is similarity between trees killed by the hemlock looper and the spruce budworm and both result in sap rot, the results for pulping would not differ very much for the two insects. It was reported, however, that the hemlock looper in Newfoundland killed trees quickly and generally speaking a high percentage of each stand. This left the stands well ventilated and deterioration, it was reported, would not be so rapid as in a stand killed by spruce budworm where fewer trees are killed in any one stand, where ventilation is poorer, moisture is retained, and trees deteriorate faster.

The following extract from the report on the economic value of decayed wood is pertinent.

"The use of Hemlock Looper killed wood to produce newsprint would result in a cost increase per ton. The increase would be due to higher wood costs as a result of handling and yield losses and higher manufacturing costs incurred from bleaching, extra power for shive removal, and the use of extra chemical pulp to maintain strength. The increase in cost would depend on the extent of decay and/or the number of years dead." The increased cost per ton of newsprint as a result of using 100% killed wood dead six years is shown by the table on page 26, and estimated at a total cost per ton equivalent to 23% of the cost of the wood content. "This does not include increased logging costs. An increase in cost of this order would certainly make most mills in Canada non-competitive and hence could not be tolerated. The increase in cost as a result of using trees

**Table 2. The increased cost per ton of newsprint as a result of using 100% killed wood dead 6 years (8)**

| | Chemical pulp | Groundwood pulp |
|---|---|---|
| Cost per cord of wood — July 1974 | 100% | 100% |
| Increase in cost of killed wood due to: | | |
| — Wood loss on barking over and above normal wood | 11% | 11% |
| — Chipping loss | 1% | — |
| — Yield loss | 2% | — |
| Total | 114% | 111% |
| Total cost per ton of paper from wood cost increase for 25% sulphite, and 75% groundwood at 1.15 cord/ton newsprint | | 14% |
| Increase in manufacturing due to: | | |
| — Bleach | | 3% |
| — Extra refining for shive reduction | | — |
| — Increase in chemical pulp content from 25% to 35% | | 6% |
| Total cost per ton increase[1] | | 23% |

[1] Expressed as a % of the cost of wood (Delivered cost of wood = 100%)

dead three years or less would be substantially lower and probably in the order of $1.00/ton. (2% of the cost of wood in the furnish.) The extra costs would be mainly for bleach."

It is difficult to conceive a situation where 100% of the wood entering a papermill would be the result of budworm or other mortality. The foregoing figures must therefore be considered in the context of actual practice where a mix consisting of normal green wood and budworm-defoliated and budworm-killed wood make up a mill supply. However, while the cost penalty per ton of product will be lower, the same total dollar losses will still be there for an equivalent amount of this wood.

# 5. CONCLUSIONS AND RECOMMENDATIONS

## 5.1 The infested forest

The forest products industry is reaching or has reached, in some cases, the end of an era. The forest resource of the past appeared to be unlimited, and was not completely developed. The need for forest management was not given a high priority. Today, in some parts of the area studied, a substantial network of public and private roads exists and industry's wood requirements are in balance with, or exceed, the perpetual yield of the forest on which they depend. Where a problem exists or is foreseen, more intensive forest management and better utilization of the forest resource will be necessary. An agent that has contributed to making this more evident is the spruce budworm.

All spruce-fir forests of eastern Canada and the state of Maine are infested with the budworm to varying degrees. The most seriously affected areas visited were western Quebec, southern New Brunswick, Cape Breton Island in Nova Scotia, and Newfoundland.

Tussock moth, hemlock looper and larch sawfly in more limited quantities were also found.

It is difficult to assess the effect the forest undergoing a budworm epidemic will have on harvesting. Individual trees may be green, some defoliated to varying degrees and others may be dead for varying numbers of years. All of the latter may be present in heterogeneous fashion, and no two areas will be exactly alike. Compounding the problem will be the possibility that the forest may from one year to the next recover or get progressively worse depending on such unforeseeable factors as climatic conditions. At the present time, the most used means to preserve the timber inventory and reduce timber losses due to budworm is aerial spraying of insecticides.

Most of the balsam fir stands seen were overmature and the presence of rot or cull was high as may be expected in any overmature tree.

## 5.2 Wood deterioration

Bark beetles and wood borers will attack dying or recently killed trees, provided moisture is still present. Fungus spores will follow both these insects into the dead tree and the developing fungi will cause deterioration resulting in rot.

The development of sap rot is more rapid in stands suffering less than 10% mortality. In stands suffering 50 to 100% mortality, sap rot signs appear, generally, between the second and third year after mortality in 3% of the total wood volume. This percentage increased to 14% between the third and fourth year, and to 27% between the fourth and fifth year. Following this period, no change was noted. The maximum penetration of decay (incipient and advanced decay) was reported to be 18 mm (0.7 inch) in trees dead more than 3 years.

## 5.3 Salvage operation period

Generally speaking, there is a 7-year period to salvage a forest following infestation by the budworm unless the infestation can be successfully controlled by, for example, aerial spraying of insecticides. First, the spruce budworm may be seen in neighboring forests; 4 years of defoliation will follow to mortality and salvage may be carried out for 3 years, including the year of mortality. The salvage period may, however, be shorter or longer. Each case must be judged on regular monitoring data obtained. The end product, transportation means, the elapsed time between harvesting and manufacturing, and how the logs are stored prior to use will all have a bearing on the length of the practical post-mortality salvage period. Wood and yield losses can be reduced if it is possible to "hot log" from the stump directly into the manufacturing process.

## 5.4 Harvesting the infested forest

### 5.4.1 Operational planning and disruption

Disrupting operational plans affects costs in a large number of ways. Costs may be incurred in the construction of new roads, the relocation of camps, the moving of equipment and the displacement of personnel. These costs vary for each particular operation.

Added capital expenses in the order of \$0.70 to \$1.40 per $m^3$ (\$2.00 to \$4.00/cunit) may be required for the construction of access roads to infested areas and for camp relocation. These will increase the required working capital for the operation. Added operating expenses in the order of \$0.10 to \$0.20/$m^3$ (\$0.25 to \$0.50/cunit) may also be expected. Lower costs for lodging employees can actually occur if the relocation permits the camp operation to be converted into a commuter one.

### 5.4.2 Harvesting and transportation costs

There are costs involved for harvesting and transportation which might increase or decrease. Usually, there are no changes in costs prior to mortality. After mortality, sap rot develops, dead trees become light, brittle and, when handled roughly, have a tendency to break resulting in wood losses, reduced productivity and higher costs.

When harvesting budworm-affected wood, particular attention must be paid to tree breakage, in order to avoid wood losses and lower productivity. The productivity of any operation based on handling or processing tree-length (felling, skidding, trucking, slashing) is reduced if the average length of the trees is shortened by breakage.

Because the post-mortality stand usually contains both green and dead trees, the excess cost and wood loss burden from the latter tends to get averaged over the whole cut. For example, for a limited sample which had been harvested mechanically from a stand having 20 to 40% mortality and trees dead 2 to 3 years, the breakage loss averaged 6.7% for all trees. If related to the approximate 30% dead trees only, the loss was about 22% of the trees actually killed by the budworm. Measurements made on a sample harvested by the more gentle conventional manual cut-and-skid method and in a similarly affected and aged stand reduced these breakage losses to 4.0% of the total stand or about 12% of the dead trees.

Some of these breakage losses are detected in the scaling operation. The division of the 6.7% loss in the mechanical operation reported above was as follows:

- 3.1% deducted by scaling and absorbed as reduced stand yield, and man and machine productivity up to that point in the harvesting process. As no stumpage is paid on this it is also a government revenue loss.
- 3.6% not detected by scaling. This shows up as wood paid for but not delivered to the manufacturing process.

Usually, for balsam fir, costs will increase and productivity will decrease for a period of 2 to 3 years following mortality (it will be up to 5 years for spruce) after which it may no longer be economically possible to use the wood.

Except for possible losses from developing sap rot, there are minimal added costs when using the cut and bunch 8-foot logging method. In the tree-length cut and skid to roadside method, breakage might result in an added 2 to 4% of wood cost to roadside, or $0.20 to $0.35/m$^3$ ($0.50 to $1.00/cunit). Recovery of broken tops may add $0.20/m$^3$ ($0.50/cunit) on the total wood volume produced from the infested area. In those cases where cutting rates are increased because of decreased productivity due to deterioration of the trees, wood costs to roadside can be further increased by 5 to 10%, or from $0.35 to $0.70/m$^3$ ($1.00 to $2.00/cunit).

For mechanical harvesting, productivity may be reduced by 5 to 10% due to breakage, which may be as high as 7% of the stand merchantable volume. Wood harvesting costs will be increased accordingly.

Mechanical slashing production may be reduced by 10 to 15% because of the shortened trees and the need for more careful handling. Costs are increased accordingly.

When preparing a salvage logging plan, it is important to make certain that there is enough equipment for the scheduled production. Skidder, loader and, therefore, slasher productivity depends largely on the average length of the trees. As more and more trees are shortened by breakage, the productivity of the following operation is correspondingly reduced. More equipment is, therefore, needed to produce a given amount of wood.

Trucking costs, if paid for by weight, are likely to be reduced by 10 to 20% for equivalent hauling distances. On the other hand, if paid for by volume, trucking costs of tree-length over short distances will increase as volume transported per load gets smaller (shortened broken trees). No changes in costs are likely to occur in trucking shortwood by volume. Due to large fluctuations in weight per cord of wood from infested stands, it is recommended that those defining weight regulations on public roads be informed of these variations and that temporary adjustments to these regulations be considered.

It is suspected that river-driven wood infested by borers will become water-logged more quickly and sinkage losses may increase.

In summary, although it was not possible to obtain detailed productivity and cost figures related to specific degrees of infestation and mortality, Fig. 14 indicates what may be expected. It is recommended that specific detailed case studies be undertaken within each company to evaluate productivity and cost differences for salvaging budworm-killed timber.

## 5.5 Harvesting method

A logging system that appears to be efficient for salvaging operations is the 8-foot-cut-and-bunch with pulpwood transporter. This system provides at the stump a quality control inspection for each stick of wood, eliminates losses through breakage and ensures that the cull sticks are removed at the earliest stage in the production system.

## 5.6 Industrial safety

From the industrial safety point of view, there is no evidence of an increase in the number of employee accidents on logging operations traceable to the budworm. However, it is suspected that there may be a higher incidence of eye injuries and adequate precautions should be taken.

## 5.7 Forest fire hazard

Prevalent opinion is that forest fire hazard is higher in budworm-killed trees, but there is so far no factual evidence to substantiate this.

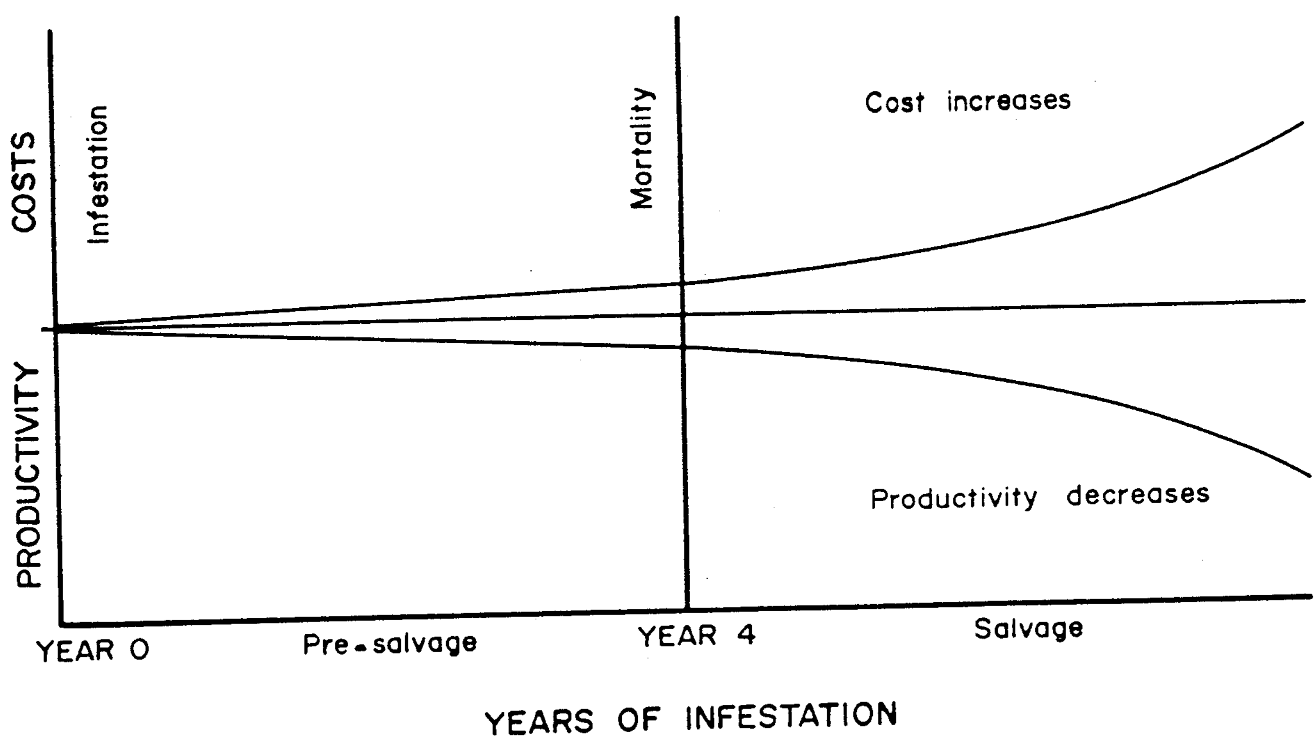


Fig. 14. Trends in costs and productivity with time in salvaging budworm-affected wood

## 5.8 Utilization

Pre-salvage and salvage of budworm-affected wood may result in a higher percentage of balsam fir in wood deliveries. The latter, because of its lower density, would result in reduced yield and an increase in manufacturing costs for pulping.

Dead trees are light, brittle and may be infested with secondary insects and fungi. Unless precautions are taken, harvesting this timber may result in delivering to a manufacturing plant a high percentage of cull. Particularly important is the sap rot that should usually be expected and guarded against during the third year of mortality.

Sap rot will result in wood losses at the manufacturing plant, particularly during debarking. One study evaluated such losses at 11% of delivered wood costs. The same study shows that with 100% of the trees dead 6 years due to the hemlock looper, the cost per ton of newsprint increased by 23% of the cost of the wood content (excluding increased logging costs).

It is extremely doubtful that any manufacturing plant would have an input of 100% budworm-infested wood at one time. As with the harvesting operation, while the total extra cost burden remains, there is a tendency for it to be masked in an average spread over all the production made from a mix of green, dying and dead trees. It is very difficult for an accounting system to clearly identify the added cost from using the inferior wood quality.

Because of holes made by wood borers and developing sap rot, budworm-killed wood cannot be used to produce good quality lumber.

It is important that those concerned in industry and government establish standards in each case for deciding whether a tree, as opposed to a stand, should be salvaged for a given market or not.

## 5.9 Cost burden check list

The true cost of a severe budworm infestation can be spread over many places in the salvage logging and manufacturing operations. The amount and the distribution will depend on the local conditions. The following check list may be a useful aid to the logging and corporate managers.

**Pre-logging**

- Shared cost — for budworm control
  — identification of infested areas.
- Added capital for new roads, camps, equipment and facilities.
- Added operating costs of camp made operational in advance of overall logging plan.
- Cost of capital tied up in temporarily abandoned roads, camps and facilities.
- Repair costs to temporarily abandoned facilities when they eventually have to be used.

**Harvesting and transportation**

- Tree breakage loss (increases with time since mortality).
- Cost of broken tree salvage operation.
- Productivity decrease, particularly in operations dependent on average tree length.
- Increased rates to compensate for reduced productivity or unpleasant working conditions.
- Increased sinkage loss with river-driven wood that has suffered from secondary infestation from wood borers.
- Potential shortwood transportation cost decrease (per ton of fibre) if costs based on delivered weight.

**Value lost from reduced wood quality**

- Peeler and sawlogs downgraded to pulpwood because of sap rot and/or wood borer damage.
- Extra cost of providing suitable logs for sawmill and peeler operations because of insufficient supply of suitable logs.

**Delivery and debarking loss**

- Overstated delivery because of broken wood not deducted during scaling.
- Loss of fibre during debarking operation from erosion of softened sap rot portion and from greater log end chipping and breakage.

**Excess pulp and paper manufacturing cost**

— Reduced digester yield if species mix changed to a higher percentage of lower density balsam fir.

— Increased refining power required for shive removal.

— Increased chemical pulp content in the paper to compensate for the lower strength groundwood from dry and dead wood.

— Increased bleach to maintain brightness specifications.

In addition, there may be added costs in the future as the timber supply may have to be brought from longer distances and because of reduced growth rate from trees defoliated but not killed.

Because the budworm-infested wood is harvested along with the green trees in the stand and is usually supplied to the manufacturing process with green trees from other stands, accounting systems have not been set up to clearly identify the cost penalty associated with the budworm damage. Also, much of the added cost can occur after the scaling and delivery to the mill. To maintain economic viability, it is important that this be looked at as a corporate and not just a logging problem.

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